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VOL-I





DETAILED PROJECT REPORT (DPR) FOR

REJUVENATION OF

SUTLEJ RIVER

THROUGH FORESTRY INTERVENTIONS

Himalayan Forest Research Institute, Shimla



APPROACHES AND FORESTRY INTERVENTIONS

VOLUME –I

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ACKNOWLEDGEMENTS

In the preparation of DPR, a holistic (multi-disciplinary, multi-stakeholders, and multi-scale) and participatory planning and assessment process was adopted. Thus, the extensive and consultative process involved a wide range of policy and decision-making agencies/ organizations, user agencies, professionals, beneficiaries, individuals, etc. All through the extensive and consultative process, varied stakeholders made significant contribution. Hence, HFRI team would like to acknowledge and thank the following organizations and individuals for their valuable resource inputs, contributions, support, advice, guidance, and suggestions in bringing forward the DPR in the present form:

Ministry of Environment, Forest and Climate Change, Govt of India, New Delhi

Sh. Bhupender Yadav, Hon'ble Minister for Environment, Forest and Climate Change; Dr. Harsh Vardhan, Former Hon'ble Minister for Environment, Forest and Climate Change; Sh. Ashwani Kumar Choubey, Hon'ble Minister of State for Environment, Forest and Climate Change; Sh. Gajendra Singh Shekhawat, Hon'ble Minister Jal Shakti, Sh. Rameshwar Prasad Gupta, IAS, Secretary; Sh. Sidhhantha Das, IFS (Retd.), Former DGF and Special Secretary; Sh. Subhash Chandra (Add. Charge), IFS, DGF and Special Secretary; Sh. Sisir Kumar Ratho, ADGF (FC), Sh. Soumitra Dasgupta, Additional Director General of Forest (WL & DBT), Sh. Saibal Dasgupta, IFS, Former ADG (FC); Mrs. B.V. Uma Devi, IFS, Addl. Secretary; Sh. Ravi Agrawal, O/o AS (RA), Addl. Secretary; Sh. Praveen Garg, IAS, Sepecial Secreatary & Financial Advisor; Sh. Rohit Tiwari, Forest Policy (FP), Wildlife (WL)O/o IGF(RT); Sh. Suneesh Buxy, Externally Aided Projects (EAP), Forest Protection (FPD), Survey & Utilization O/o IGF; Sh. Anjan Kumar Mohanty, Forest Conservation (FC)O/o IGF(AKM)

National Afforestation & Eco-Development Board Ministry of Environment and Forests Government of India, New Delhi

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Kumar, IFS, DFO; Sh. Satinder Singh, DFO; Sh. Harbhajan Singh, DFO; Sh. Kanwar Deep Singh, DFO; Sh. Amit Chauhan, IFS, DFO; Sh. R.U. Vidhya sagri, IFS, DFO; Dr. Sanjeev Tewari, DFO; Sh. Jarnail Singh, DFO; Sh. Naresh Mahajan, DFO; ; Sh. Santosh Chand, DFO; Dr. Anshul Qayum, DCF; Sh. Manish Kumar, DCF and all concerned DFOs and Frontline Staff.

PAU Ludhiana: Dr. Sanjeev Chauhan, Prof & Head Forestry and Natural Resource, PAU Ludhiana; Dr. Harmeet Singh, Prof. (Forestry) PAU Ludhiana.

ICFRE Regional Institutes – Shri R.S.C. Jayaraj, Director, RFRI; Sh. M.P. Singh, IFS, Director, IWST; Sh. D. Jayaprasad, Director, IFB; Sh. Mana Ram Baloch, Director, AFRI; Dr. G. Rajeshwar Rao, ARS, Director, TFRI; Dr. C. Kunhikannan, IFS, Director, IFGTB; Dr. Nitin Kulkarni, Director, IFP; Dr. Dinesh Kumar, Scientist, FRI; Dr. Manisha Thapliyal, Scientist, FRI; Dr. Ombir Singh, Former Scientist, FRI

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National Institute of Technology – Dr. Chandra Prakash; Municipal Corporation/ Council – Sh. Ashok, Sh. Chaman Lal, Sh. Naresh Kumar, Sh. T.S. Thakur, Sh. Shashi Bhushan, Sh. Phushpraj Katraya, Sh. Virender Sharma, Sh. B. R. Negi; Nagar Panchayat – Er. Arun Kumar, Sh. Satish Thakur, Sh. Jivan Lal, Sh. Karan Singh, Ms. Lalita Devi, Sh. Bhim Singh; District Panchayat Office- Harbans Singh; Veterinary Department- Dr. Bhuvnesh Thakur; District Tourism Dev. Office- Nitesh Kumar Koundal; Department of Mining – Sh. Rajeev Kumar; Department of Public Relations – Sh. Prem Thakur, Sh. Anil Guleria, Sh. G.D. Rana, Sh. Devender Bansal, Sh. Inder Thakur, Sh. Naresh Vaidya; Tourism Development – Sh. Partap Negi; AFCONS - Er. Sanjeev Kumar; Sh. Vijay Kumar Dhiman; Hiamalayan Niti Abhiyan- Sh. Kulbhushan Upmanyu

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Media (Electronic and Print)

Electronic Media – Doordarshan, DD News, All India Radio (AIR), ETV, News 18 Himachal, Khabrein Abhi Tak, Divya Himachal,

Print - Dainik Savera, Apka Faisla, Himachal Dastak, Bharat, Amar Ujala, Dainik Jagran, Punjab Kesari, The Tribune, Khabrein Abhi Tak and Aapka Faisla.

EXECUTIVE SUMMARY

1. River Ecosystems Human Well Being and Sustainable Development

Man has been interacting with environment ever since he first walked on Earth. A good climate, clean water, fertile soil, etc. are aspects of the physical environment that enable humans to live and thrive. Humans need to interact with the environment to obtain food, water, fuel, medicines, building materials and many other things for survival. Freshwater ecosystems such as lakes, ponds, Rivers, groundwater, flood plains, wetlands and springs has been vital for sustaining life and establishing civilization throughout history of mankind. Natural ecosystems are the planet's lifesupport systems not only for the human being but for all other forms of life. Among natural resources, freshwater is most essential for human health and is one of the important renewable natural resource. Water is paradoxical by its nature. It is an abundant global resource at over 1,400 million km^3; but, it is also a scarce commodity with just 0.001% being readily available for human consumption with huge geographical variations even of that small fraction (PWC, 2012). Globally, the availability of water per person has declined markedly in recent decades.

Advances in Science and Technology have significantly transformed ecosystems which depend on fundamental environmental cycles (i.e., water, carbon, nitrogen, and other nutrients), which have been modified by human activities in the past century or so. Consequently, freshwater resources too have been greatly affected by the anthropogenic activities. Natural water bodies such as lakes, Rivers, streams and groundwater need to contain water of good quality because they are the only natural water sources on which life depends.

Sustainable development requires man to recognize his place within the ecosystem considering the longterm impacts of his actions on the ecosystems (Hardi and Zdan, 1997). A minimum necessary condition for sustainability is the maintenance of the 'Natural Capital' on natural assets at or above the current level (Constanza and Daly, 1992). At the Sustainable Development Summit in September 2015, UN Member States adopted the 2030 Agenda for Sustainable Development, which includes a set of 17 Sustainable Development Goals (SDGs) so as to end poverty, fight inequality and injustice, and tackle climate change by 2030 (UNDP, 2015). The agenda on Sustainable Development Goals (SDGs) emphatically recognized that maintenance of natural ecosystem or natural capital is pivotal for the human wellbeing and sustainable development.

2. Rivers

Healthy, self-sustaining River systems provide important ecological and social goods and services upon which human life depends (Postel and Richter, 2003). Rivers are systems in dynamic equilibrium and balance the water flow and sediment transport. When Riverscapes are altered under naturally dynamic hydrologic conditions, the River readjusts itself with respect to dimension, profile and pattern to reach its former balance or equilibrium (Couture, 2008).

A River is an extremely complex ecosystem which carries out fundamental processes in order to maintain environmental equilibrium, benefiting both the natural ecosystem and the human world. Rivers are often referred to as ecological highways and might well be seen as 'Green Highways'

linking up a succession of natural zones. Even where human actions and presence is marked, the River and its ecotone are still vital areas, used both by plants and animals for movement and reproduction. The most obvious characteristics of streams and Rivers are that they flow, which distinguishes these *Lotic* (i.e., Flowing water) system from L*entic* (i.e., Standing or still) water system like lakes and ponds (Dooge, 2009). Streams, Rivers and their floodplains are amongst the most fascinating, complex and dynamic ecosystems on earth as their water exhibit high degree of connectivity between systems longitudinally, laterally, and vertically (Amoros and Bornette, 2002). Five unifying characteristics have been described in the context of Rivers *viz*., unidirectional flow, a state of continuous physical change, a high degree of spatial and temporal heterogeneity at all scales, high variability between lotic systems, and specialized biota to live with flow conditions (Velde *et al.,* 2004).

3. Sutlej River Conservation Significance

a) The Sutlej River is the most extensive River in the Indus River Basin, and is considered to be its main stem. It is a transboundary River which flows through the nations of India, China and Pakistan, and lifeline for millions of people who live along its course and depend on it for their daily needs. The River has been the source of physical and spiritual sustenance of Indian civilization for millennia. The Sutlej River is one of the five tributaries of the Indus River System and referred as one of the three Eastern Rivers under the Indus Water Treaty (1960). The total catchment area of Sutlej Riverscape in India is 48,321.62 km^2. In India, the catchment falls in one Union Territory i.e., UT of Ladakh (1,172.22 km^2) and three States of the country viz., Himachal Pradesh (20,181.94 km^2), Punjab (26,887.45 km^2) and Haryana and (80.01 km^2). The Sutlej River hosts a large number of National Wetlands of Importance and Important Bird Areas, besides other important Protected Areas (i.e., Pin Valley National Park, Kibber, Chhitkul, Lippa Asrang, Majathal and Ropar Wildlife Sanctuaries, Nangal Wetlands and Gobind Sagar Reservoir and Cold Desert Biosphere Reserve). The River contributes immensely to the Indian economy as the country's agriculture sector is heavily dependent on the fertile plains of SutlejRiver and its tributaries. The River is endowed with enormous hydropotential with major HEPs including Kashang, Baspa, Karchham, Wangtoo, Nathpa- Jhakri, Rampur HEP, Kol Dam and Bhakhra Dam, etc.

b) Snowpeaked Himalayan Mountains and various natural ecosystems along the Sutlej Riverand its tributaries, besides wide ranging religious, cultural and historic values, have enormous potential for recreation and tourism industry. The Sutlej River Basin in India is spread over parts of Spiti, Kinnaur, Kullu, Shimla, Solan, Hamirpur, Mandi, Bilaspur and Una regions of Himachal Pradesh and its western most part falls mainly in the Roopnagar, Nawashahr, Ludhiana, Jalandhar, Moga, and Ferozpur regions of Punjab. Thus, Sutlej Riverhas significant geographical, ecological, environmental, religious, cultural, spiritual and economic significance in India with these values transcending the boundaries of the Basin. In spite of the religious and cultural preeminence of Sutlej River in the Indian ethos since times immemorial, testifying to its centrality to Indian civilization and conservation significance, diversion of water, reduced water flow, extreme pollution pressure, excessive use of water and enhanced floods continued down the ages and the river remained neglected for a long time. Conservation Significance also

becomes important as Sutlej River Basin is endowed with varied agricultural andhorticultural practices, irrigation projects and further the local communities dependent upon the forest resources around the River.

4. Sutlej Riverscape Application of Remote Sensing and GIS for Spatial Analysis

Sutlej River is one of the major and perennial tributaries of the Indus River system. The main stem of Sutlej River stretches about 605 km. in India. The surrounding forests, agriculture and human activities collectively exert enormous influence on the River, its flow and numerous associated ecological characteristics and processes. Vegetation cover in general and forest cover in particular, are vital and serve as indicators for the quality and functioning of the Riverine environment or Riverscape. Thus, the present task on the preparation of DPR for Forestry Interventions on Sutlej River required a better insight and understanding not only of Sutlej River and its tributaries, but also of the surrounding lands and expanding human footprints.

Geographic Information System (GIS) is an information system working with geographically referenced spatial and nonspatial data for planning, monitoring and effective implementation of the management plans. The role of GIS is invaluable for optimal land use planning and making integrated development plans. A GIS database is a structured collection of digital spatial and nonspatial data that describes map features, spatial relationship and character of features. They may be linked to GIS through common identifier or other mechanisms. GIS has two distinct utilization capabilities, the first pertaining to querying and obtaining information and the second pertaining to integrated analytical modelling. However, both of these capabilities depend upon the GIS database for queried results through a GIS package having the capability of handling both spatial and nonspatial databases.

5. Sutlej River Rejuvenation and Conservation Initiatives

Various initiatives have been carried out by the Forests, other concerned Departments, R&D organizations and NGOs in the past; and continually putting their efforts currently for the conservation of Sutlej River Basin. Some of them have been briefly description of given below.

Forests play an important role in reducing sediment flux, which is major cause of siltation in the River. Keeping in view of the fact, State Government has mandated that HEPs should include investment in the Catchment Area Treatment (CAT) Plan. The activities envisaged under CAT Plan such as afforestation, Pasture Management, check dams and trenching were based on thorough field evaluation and consultations. To address various environmental issues arising out of construction of HEPs, Himachal Pradesh Forest Department has formulated Comprehensive Catchment Area Treatment Plans (CCATPs) for all the four major River Basins viz., Beas, Sutlej, Ravi and Chenab in the State. These CCATPs emphasized on the integrated approach for the treatment upto watershed level and also beneficial for socioeconomic and upliftment of the local communities through livelihood support.

A series of plantation programmes have been launched by the Government of India with the purpose of increasing forest cover and regenerating degraded forests. There is massive funding

for these programmes coming directly to the Forest Department and other concerned Departments for carrying out the plantation activities.

In agrarian States of Punjab and Haryana is depleting water levels, resulting in high input costs of crops. With water level going as deep as 200 m in some pockets of Punjab, farmers have to rely on tube wells, raising the input cost substantially. This problem has been addressed by engaging community through Self Help Groups, Farmers' Club and Producer Organisations. In this initiative, NABARD covered approximately 3,300 villages out of approximately 12,000 villages in Punjab under its water conservation and management initiatives, and created awareness at village and block levels on new innovations in Water conservation.

In 2009, Nokia India CSR team in collaboration with WWFIndia and the Department of Forests and Wildlife Preservation of Punjab Government initiated the 'River Watch Project', a programme for the biomonitoring of freshwater biodiversity in the Sutlej, Beas and Ravi Rivers in Punjab, which covers the Harike Wetland, a biodiversity hotspot. Since its inception in 2010, the 'River Watch Project' has recorded 9 mammals, 200 avian species, 7 turtle species and 26 fish species in this wetland of conservation importance. The wetland is designated as Ramsar Site.

Himalayan Research Group (HRG), Shimla has carried out significant work in 2014-15 for empowering mountain women and other local communities by reducing forest dependency by supplying cost effective solar energy application for domestic water heating in Mool Koti village of Shimla district.

The Environment Appraisal Committee (EAC) of Ministry of Environment and Forest (MoEF), Government of India (GoI), in its Minutes of 47th EAC Meeting on River Valley Project No. 2011 9J12011/6/2011IA.I, has directed the Department of Energy (DoE), Government of Himachal Pradesh (GoHP) to conduct Cumulative Environmental Impact Assessment (CEIA) Study of HEPs in Sutlej River Basin, Himachal Pradesh. Biological Environment (i.e., Terrestrial Flora) and Socio Economic Environment Assessment were carried out by Himalayan Forest Research Institute, Shimla.

Himachal Pradesh State Disaster Management Authority and Desert Development Project **(**DDP) of Kinnaur and Lahaul–Spiti districts have shown their presence by taking immediate action on impact of disasters such as floods, landslides, earthquake, avalanches and moraine management. Sometimes the roads in the state remain cutoff for months due to the occurrence of landslides, formation of lakes and submergence of roads. There are many instances when the districts of Kinnaur and Lahaul Spiti remained cutoff from rest of the State for months. The connectivity is also broken due to avalanches and snowstorms hindering the transport to the affected border areas. Lack of connectivity would also cause secondary effects such as nonavailability of essential supplies and hoarding by the rich and hardship to the poor.

Keeping in view deterioration in the water quality of Sutlej River, the Government of Punjab (GoP) initiated action in 2008 to identify the sources of its pollution in coordination with Punjab Pollution Control Board (PPCB). Ludhiana City falls within the catchment area of Sutlej River,

and is contributing significantly to the water pollution of Sutlej River through Buddha *Nallah*, which passes through the heart of Ludhiana city. As of now, out of 65 towns, which are discharging their wastewater into Sutlej River, a total of 101 Sewage Treatment Plants (STPs) need to be installed out of which 59 STPs have already been installed, 8 are under installation and remaining 34 are under various stages of planning for establishment.

6. Current Task for Preparation of DPR on Forestry Interventions in Sutlej River

Isolationist approaches to River management till recent times constrained the development of new scientifically based comprehensive approaches for River development and management. It is only in recent decades that hydrological, geomorphologic and biological researches have been integrated to establish a new understanding for the dynamic River systems. Recent approaches to River management emphasize the Riverine landscape or 'Riverscape' perspective as running waters are open ecosystems. The Riverscape approach integrates Rivers with their surrounding landscapes.

The DPR preparation involves recognizing the diversity, complexity and intricacies of forest ecosystems and pivotal multiple functions performed by them and their interconnectedness with highly dynamic River ecosystem and to adopt a holistic approach for the improvement and management of Riverine ecosystem in the entire River basin through forestry interventions. The holistic approach emphasizes appropriate Forestry Interventions by the way of protection, habitat management, afforestation, catchment treatment i.e., Soil and Moisture Conservation works, ecological restoration of vital Riparian forest buffer, bioremediation, improved livelihoods of forest dependent communities and forest dwellers and alternate income generation activities through regulated tourism and community awareness.

The NITI Aayog directed concerned Central Ministries (MoRD, MoEF&CC, MoA, MoDWS, MoH&UA, MoPR) and Chief Secretaries/Administrators of all States to initiate pilot projects for revitalization of Rivers by appropriate convergence of schemes and active involvement of various stakeholders. In response to this and following the pursuit of Forestry Interventions on Ganga River by NMCG, the MoEF&CC assigned a major task on the preparation of DPRs on Forestry Interventions for rejuvenation of 13 major Indian Rivers (i.e., tributaries of Indus – Jhelum, Chenab, Ravi, Beas and Sutlej; Yamuna, Luni, Narmada, Godavari, Mahanadi, Krishna, Cauvery and Brahmaputra) belonging to nine River Systems to the Indian Council of Forestry Research and Education (ICFRE), Dehradun, An Autonomous Organization under its control. The ICFRE is an umbrella organization responsible for carrying out forestry Research, Education and Extension activities in the country and an apex body in the National Forestry Research System. The Council has a pan India presence with its nine Research Institutes and five Centres located in different biogeographic zones of the country. Each Institute has been mandated the task of research, education and extension in the States under their jurisdiction. The Himalayan Forest Research Institute (HFRI), Shimla, one of the institutes of ICFRE has been entrusted the task to prepare DPRs of five tributaries of the Indus River Basin. The present DPR specifically deals with the Sutlej River, a major tributary of the Indus River. The ICFRE has allowed HFRI a time frame of 18 months to prepare the DPR envisaging that proposed Forestry Interventions will

immensely facilitate the major goals of accomplishing *Aviral Dhara* (i.e., uninterrupted flow), *Nirmal Dhara* (i.e., clean flow) and ecological regeneration of aquatic and terrestrial life/ biota.

7. Preparation of DPR Aim and Objectives

The proposed Implementation Plan aims to contribute towards restoration of Sutlej River by way of ensuring *Aviral Dhara* and *Nirmal Dhara,* besides maintenance of ecological and geological integrities. Based on extensive consultative process carried out as a part of this DPR, the following shared vision emerged for the Implementation Plan.

Vision: Conservation and sustainable use of biodiversity of Sutlej River ecosystem is fundamental to ecologically sustainable development. Biodiversity is an integral part of human lives and livelihoods and constitute resources upon which families, communities, nations and future generation depend.

The following objectives were envisaged for achieving the main aim of Forestry Interventions.

1. To review and assess the existing situation of River Basin, past River management and implications and lessons learned
2. To identify and involve stakeholders and build consensus for design and development of strategies and approaches
3. To assess ongoing forestry activities of the states engaged in the River management programme (s)
4. To assess potential and possibilities for regeneration, improvement, and restoration of forest catchments
5. To assess the conditions of Riparian forests and potential of biological filters
6. To examine the possibility of allied and other income generation activities
7. To assess the potential of cultivation of medicinal plants, restoration of conservation areas and identify appropriate species and suitable sites
8. To identify research and monitoring needs and develop a strategy for future research and monitoring
9. To formulate strategies, develop approaches, and plan activities for project implementation

8. Sutlej Riverscape Environment, Development Programmes, Conservation Issues and Implications

The implementation of DPR project in field would be done by the HP and Punjab Forest Departments. For this purpose, a need was envisaged to constitute a State Level Committee headed by the PCCF, while Nodal Officer as the Member Secretary to initiate, regulate and monitor the flow of funds from the State Forest Departments (SFDs) to concerned Circles/ Divisions/ Division Level Committee. This Committee will have representations from the Line Departments, Civil Society, Eco-Task Force, NYKS, etc. The Committee will study and approve the APOs submitted by Division Level Committees and in association with the SDFA, would arrange for release of funds required for the project. The Division Level Committee would be headed by the Conservator of Forests of the respective Circle while, concerned DFO, would be the Member Secretary. The Division Level Committee would also have adequate representations

from the Line Departments, Civil Society, Eco-Task Force, NYKS, etc. at the Local/ Division level. The involvement of Civil Society should be informal as well as formal. In the case of latter, proper and defined institutional mechanism must be drawn up before hand and explained in the respective State DPR. The Committee should have representation by people from different walks of life. Activities related to DPR project should be peoplecentric and must generate employment for roping in the masses. All out efforts must be made to coordinate with the various Departments/Agencies engaged with the Indus River DPR Project for a holistic approach and its successful outcome. There should not be any overlapping of ongoing State activities/Schemes with those of the DPR Project. The approved project proposals of the States are to be forwarded by the PCCF of the concerned State and submitted to HFRI and ICFRE.

9. Preparation of DPR -The Approach

The Sutlej River originates in Tibet and flows through Himachal Pradesh and in the plains of Punjab. It meets with Beas River at Harike and finally confluence with Chenab River in Pakistan. The states, Himachal Pradesh and Punjab were involved in the extensive consultative process, planning and assessment. The project Launch Workshop and sequential Consultative Meetings were organized in HP and Punjab included policy and decision makers, representatives of State Forest Department and various Line Agencies i.e., Agriculture, Horticulture, Animal Husbandry, Mining, Irrigation, Hydroelectric Projects (HEPs); State/National Level Scientific or Specialized Organizations i.e., Soil and Water Conservation, Hydrology, Forestry, Wildlife, Environmental Management, Central Water Commission, Groundwater, Remote Sensing and GIS; Universities; Civil Society; and Non-Governmental Organizations besides conservationists and field practitioners. The well planned consultative process and feedback from various stakeholders have been the key step in the formulation of strategies and preparation of present DPR. Constant persuasion, guidance and support at all stages by the Hon'ble Union Minister of Environment Forest and Climate Change, Hon'ble Forest Ministers of HP and Punjab, senior officials of the MoEF&CC, ICFRE and SFDs were instrumental throughout the process of planning and finalization of the DPR.

a) Consultative Process

The preparatory phase for DPR included review of literature, primary and secondary data collection and analysis, Expert consultations and receiving inputs from the wide ranging stakeholders. Accordingly, extensive and intensive consultations at the National and State levels were organized. The Himachal Pradesh and Punjab forming part of the Sutlej Riverscape, the State Forest Departments of these States were instrumental in planning and organization of State Level Consultations. The entire process of consultative process was facilitated by the HFRI. Consultations and feedbacks from various stakeholders have been the key step in the preparation of present DPR and proposed strategies and actions for its implementation The assignment envisaged stakeholder consultations at the National and State levels at the time of launch of entrusted task and also after the preparation of draft DPR. Accordingly, prominent consultations for the preparation of DPR held at the National and State levels, while a broadbased list of Central/ State Government Ministries, Departments, Agencies, Organizations, besides Civil

Society and NGOs that were consulted and their representatives also participated in the various Meetings.

b) Sutlej Riverscape, Spatial Analysis, Geospatial Modelling, and Prioritization of Suitable Areas for Proposed Forestry Interventions

The present task on DPR for Forestry Interventions on Sutlej River required a better insight and understanding not only of the River and tributaries themselves, but also of the surrounding lands and expanding human prints. Thus, remote sensing and geospatial modelling were used in identification of prioritized and suitable sites for forest plantations.GIS was used to generate different layers within the Riverscape like land use pattern, soil erosion rates, and slope of the topography.

c) Development of Plantation and Treatment Models

The multidisciplinary expertise available at HFRI was used in developing potential plantation and treatment models for the proposed forestry and other conservation interventions in major three type of landscape components visualized in the Sutlej Riverscape. These were: (i) Natural, (ii) Agriculture, and (iii) Urban Landscapes. The purpose of various models planned in the Natural Landscapes is primarily protection, ecorestoration and conservation. Details of potential models were sent to the concerned States for selection and to recommend appropriate modifications, if necessary based on local knowledge, expertise, and experience.

In this multilevel plantation of trees, herbs, shrubs, grasses and important Medicinal and Aromatic Plants (MAPs) may be included. More and more temperate medicinal plants should be grown in the nurseries of concerned department and it should be on the priority list to plant Medicinal and Aromatic Plants (MAPs) in Himachal Pradesh. While selecting species for planting, ability of plants to tolerate the temperature and other factors of that area should also be considered. In the upper areas of Himalaya, the species which are planted should be useful in conserving soil and also provide the shade for wild animals in the River in hot days. Grasses and other ground cover must be kept intact during plantation and other activities. It is important to ensure the planting stock needs and the quality with the help of research nurseries and other quantity planting stock production units of the State Forest Research Institutes/ Research Wings of the SFDs. Grasses Plantation activities for monsoon should be planned carefully, so that, these activities are in harmony with the overall project for which DPR is prepared. In the threetier models of plantation, emphasis has been given to indigenous species of fodder, fruits, medicinal and other values which would include bamboo, grass, shrub, Medicinal and Aromatic Plants (MAPs), tree and horticulture species.

d) Design of Field Data Formats and Software for Sutlej River Project

HFRI has modified for the field data collections and adopted five formats earlier developed and prescribed in the context of Ganga by FRI, Dehradun. Five elaborate formats were meant for the collection of primary field data. Various efforts have been taken for the collection of correct

information and data in a uniform template for HP and Punjab which comes under the DPR project. The data formats were very useful for preparing the DPR. Details of these five data formats, types of information required, and the procedure to collect desired information were shared with stakeholders, particularly the forest officials and frontline staff during the consultative process and specific training sessions organized. Adequate soft and hard copies of formats were made and widely distributed to forest officials and other stakeholders during the consultative process. Duly filled formats from various stakeholders, collected, processed and analyzed through the software developed for this purpose.

(e) Riverscape Environment Secondary Information Collation, and Synthesis

An understanding of overall Riverscape environment under consideration from the perspective of its physical, biological and socioeconomic environments was considered vital for Proposed Forestry Interventions, Sutlej rejuvenation, biodiversity conservation, involvement of local communities and institutions in these efforts, sustainable livelihoods and awareness. Much of the information on the physical and social environment of the Sutlej River Basin and the Riverscape in particular are widely available in existing literature.

Climate, topography, geological substrate, land cover and human disturbances along the River course control overall environment of the Riverscape. An understanding of the overall environment of the Riverscape from the perspective of River restoration, Forestry Interventions, biodiversity conservation, community engagement, awareness, livelihoods and sustainable development is the prerequisite. Much of the information on the biological subenvironment (i.e., biodiversity, forests, alpine pastures, wetlands, floodplain, wildlife and their habitats, threatened species, protected areas, conservation initiatives, etc). was collected from the MoEF&CC, ICFRE, FSI, FRI, HFRI, WII, GBPNIHESD, WWF India, State Department(s) – Forest, Agriculture, Animal Husbandry, Fisheries, Science and Technology, Environment, Medicinal Plants, etc., and State Level Universities. Information thus, obtained from Departments/ Agencies or collected from respective websites were optimally used for the synthesis of an insight on the biological subenvironment of the Riverscape. Hence, a large number of studies and reports were referred in the synthesis. The demographic and other socioeconomic information was either obtained from the State Government's websites or downloaded from the primary web source of *censusindia.gov.in.*

(f) Reconnaissance for Planning Pilot Trials on Bioremediation

The HFRI availed offerings of an Expert on Biofilters and Bioremediation so as to signify capacity remedy fashions and websites for the purpose. A reconnaissance was made to potential field sites in districts of Himachal Pradesh and Punjab for the purpose.

10. Organization of DPR

The present DPR is prepared in two Volumes. Volume I deals with the main DPR while the Volume II contains summaries of HP and Punjab along the course of the Sutlej River. Volume I has two parts (i.e. Part I and Part II). Part I has altogether four Chapters dealing with the existing

situation of the Sutlej Riverscape while Part II with three Chapters deals with the proposed plans. Chapter 1 'Introduction highlights the complexity and dynamic nature of Rivers and its linkages with forests, other lands, and human wellbeing, past and present River management, evolving concepts and holistic approach of Basin management and Riverscape, current task on Forestry Interventions, logical framework, and the organization of the DPR. Chapter 2 highlights the existing environment (i.e., physical, biological, and socioeconomic) in the broader context of Sutlej River Basin, in particular the Riverscape under consideration along the course of Sutlej River. This Chapter emphasizes the details of biodiversity in terms of diverse forests, grasslands, wetlands, and associated threatened species besides the physical and the socioeconomic environment. Chapter 3 describes the Riverscape, i.e., the planning and assessment area for DPR and the approach adopted. Chapter 4 deals with the details of various Central and State Governmentlevel Agencies and Organizations that are directly responsible for the policy and decision making, overseeing and implementation of various activities relevant to water resources, environment, forest management, biodiversity conservation, River management, etc. This Chapter critically examines the existing policies, conventions, treaties and laws pertaining to the themes of the DPR, identifies gaps, imperatives and future needs from the perspective of various users and those who either influence/impact or are responsible for the management of water resources. Chapter 4 also provides an insight into various Civil Society Organizations, *Nehru Yuva Kendra Sangathan* (NYKS) and Eco-Task Force that can either undertake activities relevant to Forestry Interventions or assist and facilitates in various supporting activities. Chapter 5 under Part II describes the goals and objectives of forestry interventions and the adopted strategies for implementation. This is followed by Chapter 6 which specifically narrates institutional arrangements and mechanisms for project implementation besides aspects of sustainability. The Chapter 7 provides details on the overall project budget, cost tables and the schedule of operations. The Chapter 8 describes the potential benefits of Proposed Forestry Interventions. References are provided at the end. As already stated, Volume II incorporates details of States, summaries of Himachal Pradesh and Punjab relevant to the Sutlej Riverscape that have been included for implementation during the Phase1 and PhaseII of the Project.

11. Legislations and Policies in Context of River Conservation

The Sutlej River flows through Himachal Pradesh and Punjab before flowing into Pakistan. Thus, it is not just an interstate River, but also a transboundary River whose waters are shared between India and Pakistan (IWT, 1960). Himachal Pradesh, the biggest collective threat to the Sutlej River Basin is from anthropogenic activities and natural disturbances. Other threats include illegal sand and boulder extraction and related activities including operation of stone crushing units, road construction, illegal waste and untreated effluents dumping, etc. Real estate and tourism related construction activities have also started to prove disastrous to Basin as floodplains are getting exploited by these sectors increasing flood risk.In the State of Punjab, the issues related to over extraction of water for the purpose of irrigation, commercial and industrial purpose as well as dumping of industrial waste into the River. Most importantly, the Sutlej River Basin has already started witnessing climate change related impacts including glacial melt and increasing threat of Glacial Lake Outburst Floods (GLOFs). Therefore, the law and institutions need to gear itself to the realities of climate change. India’s law on natural resources have

focused on meeting mostly the developmental needs of the nation to a large extent and meeting local aspirations to a very limited extent. This needs to be changed by focusing on both the sustainability of resources and vulnerability of the resources. The institutional mechanism and legal system must focus on the risk facing the River systems and the dependent communities in view of receding glaciers and hotter climate.

These issues have been dealt with law and policy Chapter, presenting issue wise relevant legislative, policy and institutional framework in order to achieve the ultimate purpose of the present DPR to restore Sutlej River.

12. Institutions and Implementing Agencies Central/ State Governments and Civil Society

The preceding chapters and the forgoing sections have given ample idea about the wide array of Government and NonGovernmental Agencies at the Centre and State levels besides diverse stakeholders and the Civil Society those are involved with the prominent disciplines/ sectors of forest management, wildlife conservation, environmental management, water resource management, River development and restoration of Rivers in the country. The Chapter on the Sutlej Riverscape and its environment has appropriately highlighted the intricacies of the physical, biological and socioeconomic subenvironments in the context of River besides numerous sectors and agencies directly connected and responsible for the maintenance of uninterrupted eflows and clean water of Sutlej River. In general, the Union Ministry of Jal Shakti and the Ministry of Environment, Forest and Climate Change at the Centre are the two prominent Ministries those are directly concerned with the Rivers, its environment, and much desirable restoration process. From the perspective of proposed forestry interventions, details of the Implementing Agencies at the National and State levels are much desirable. Hence, the following section provides details on the MoEF&CC as the Nodal Agency for overseeing and steering the programme implementation; the ICFRE, Dehradun and its institute i.e., the HFRI, Shimla as the National Partner Organization for capacity development and monitoring; and the pivotal role of the HP and Punjab Forest Departments, Implementing Agencies.

The Civil Society represents the collective group of individuals, NonGovernmental Organizations and Institutions in a society that mark interests and will of citizens, and also referred as the ‘Third Sector’ of the society, distinct from the Government and Corporate. Since, the SutlejRiver flows through cities and towns and the River and its tributaries throughout their journey from origin to confluence are surrounded by densely populated human habitations. The Civil Society can play vital role in creation of mass awareness, protection of River and River resources, and allied activities. Likewise, numerous Organizations and Institutions (i.e., Civil Society Organizations) can be of utmost importance and they can be involved in awareness campaigns, cleaning drives for River and surrounding lands, protection and monitoring, and also implementation of Proposed Forestry Interventions.

13. River Ecosystem and Conservation Need for Research, Monitoring, and Knowledge Management Centre

Broadly, two types of monitoring have been envisaged during the project execution phase; (a) Monitoring of project performance in terms of project goals/ objectives, activities, targets, outputs, outcomes and impact; and (b) Ecological and socioeconomic monitoring in terrestrial as well as aquatic ecosystems.

Research and monitoring activities are vital to develop the information base, setting goals and objectives and evolving strategies besides facilitating policy and decision making. It is evident from the foregoing description on the physical, biological and socioeconomic environment in the context of Sutlej River and its Riverscape, a large number of interrelated variables and factors from the origin to mouth of the River come into play. The subject of River ecology and management is therefore multifaceted, intricate and elaborate. Considering the complex and dynamic nature of River ecosystem, and the fact that the vast area is covered within the Riverscape and much of the area is in difficult terrain and inaccessible, it is essential to adopt various concurrent monitoring mechanisms and relevant tools for carrying out envisaged monitoring activities. Thus, concurrent monitoring mechanisms include: (a) IT enabled monitoring, (b) RS and GIS based monitoring, (c) Online monitoring through Web Portal, (d) On ground monitoring, and (e) Participatory monitoring. In recent times, increasingly mobile app based monitoring on real time basis in a much more transparent manner is possible. Thus, it is proposed to incorporate IT/ Mobile app based monitoring. Since large, difficult and inaccessible areas form the major part of the River Basin/ Riverscape, optimal use of RS and GIS technologies, particularly for monitoring glaciers; sedimentation in reservoirs; and changes in channel morphology, land use and land cover, snow cover, forest cover, wetlands, cropping pattern, etc.

Over the years, HFRI has developed as a Knowledge Management Centre in the field of high altitude (i.e., Himalayan and TransHimalayan regions) Ecology and conservation of diverse temperate forest ecosystems and privilege to have essential ingredients: (a) Professionals and expertise, (b) state of the art laboratories and other physical infrastructure, and (c) Processes and innovative technologies. Since its establishment, HFRI has made significant contributions towards the development of suitable nursery techniques, propagation of native plant species and ecorestoration of mined areas and cold desert and having long experience in dealing with cumulative environmental impact assessments of Himalayan Rivers and welllaid infrastructure has been proposed to undertake the major responsibility as the National Level Partner Organization for effective implementation of this priority project on River restoration (i.e., forestry and conservation interventions aiming for A*viral Dhara* and N*irmal Dhara*, ecological integrity and restoration of River health), liaisoning with Central Nodal Ministry and Implementing Agencies at the State level, concurrent research and development, science and technology based backstopping, capacity development, monitoring, and evaluation.

For this purpose, the HFRI would need to establish a Project Facilitation Unit (PFU), headed by the Nodal Officer (NO) of the project at a senior level (Scientist – G or CCF level officer). He/ she will be supported by River Coordinator (RC)/Senior Project Scientist/DCF, one Junior

Project Scientist, two Project Associates (one each for Forestry Research/ Communication and Conservation Education/ Ecosystem Monitoring/ Forestry Training), one Project Manager for IT and National River Database/ Administration/ Procurement/ Finance and Audit), one Office Assistant, and one MTS.

14. DPR Vision, Goal, Objectives, Components, Activities, and Logical Framework

In the broad sense, the proposed Implementation Plan aims to contribute towards clean Sutlej River, besides maintenance of ecological and geological integrities. Based on extensive consultative process carried out as a part of this DPR, the following shared vision emerged for the Implementation Plan.

Vision: Conservation and sustainable use of biodiversity of Sutlej River ecosystem is fundamental to ecologically sustainable development. Biodiversity is part of human lives and livelihood and constitute resources upon which families, communities, Nations and future generation depend.

Mission: River network empowers and unites people and communities to protect and restore Rivers and other waters that sustain all life. DPR envisions a future with clean and ample water for people and nature, where local caretakers are well-equipped, effective and courageous champions for Rivers. Further, it envisages that everyone should have access to affordable, clean water and healthy Rivers. The mission is to accomplish the above shared vision by adopting multipronged strategy and pursue of five specific strategic priorities: (a) Address Rivers of environmental degradation and arrest biodiversity loss, (b) Adopt integrated, innovative and nature based solutions, (c) Enhance resilience and adaptation, (d) build alliances and foster synergies, and (e) Opt for the right influential models and interventions so as to achieve reduced pressure on biodiversity, restore degraded ecosystems, promote sustainable use of biological and water resources, enhance capacities, mainstream biodiversity, augment policy and law support, and facilitate science based efficient decision making.

Goals: To manage human and ecological needs and advocate conservation goals within the context of human health, economic and other community needs, and their connection to ecosystem, healthy Rivers and clean water and to develop a comprehensive understanding of entire River System.

In view of the above and in accordance with the National and Global Level priorities, commitments, agendas, strategies, and approaches, the Implementation Plan on Proposed Forestry Interventions seeks to address the following focal areas or goals in an integrated manner:

(a) Riverscape Management: Aiming a holistic Riverine landscape (Riverscape) approach for sustainable management of Sutlej River, its banks, or its Riparian areas, within its fluvial system.

(b) *Aviral Dhara, Nirmal Dhara*, Ecological Rejuvenation and Biodiversity Conservation: These aims to address the Rivers and stressors of River ecosystem and promote sustainable use by balancing ecological requirements with the needs of sustainable livelihoods.

(c) Improved Ecosystem Services and Sustainable Livelihoods: This goal aims to specifically seek enhanced ecosystem services so as to maintain sustainable livelihoods.

(d) Effective Implementation, Knowledge Management and Innovative Approaches: This goal aims to ensure effective implementation of the project, knowledge management, development of innovative approaches (i.e., nursery techniques, afforestation, bio-filters and bioremediation), and adoption of appropriate modern technologies.

The Logical Framework Approach has been adopted for the formulation of DPR. It is important tool thinking for relating inputs to the implementation of activities, activities to the production of outputs, outputs to the achievement of a defined purpose, and purpose to a high level goal or impact. The LFA summary is a living document consulted and altered through the project's lifecycle based on the new information, monitoring and lesson learnt; besides, it facilitates efficient communication mechanism between decision makers, practitioners and other stakeholders involved in the project.

15. Strategies

The understanding on the Riverscape environment has amply revealed that the Riverscape is a mosaic of varied land uses and it includes the: (a) Natural ecosystems, (b) Rural system predominated by agro-ecosystems, and (c) Built-up urban environment represented by cities and towns. Each of these broad land use category represents significant area of the Riverscape with unique conditions and situation, and varied use patterns, ownerships and management needs. Hereafter, three broad land use categories within the Riverscape are being referred as the 'Natural', 'Agriculture', and 'Urban' Landscapes. These three landscapes immensely influence the intricate and vibrant nature of Sutlej River ecosystem, especially the environmental flow, water quality, and aquatic biota besides terrestrial biodiversity in surrounding lands, and the various ecological and fluvial processes of the *Lotic* System. Hence, in view of the prominence of three types of Landscape elements within the Riverscape, a multipronged strategy for Proposed Forestry Interventions addressing specific requirements of each of the Land Use type/ Landscape category has been planned for the execution as a part of the implementation plan during the Phase I (i.e., 5years duration). The Phase I will be followed by Phase II (i.e., Maintenance Phase). As a part of the broader strategy, zoning within the Riverscape is visualized keeping in view three distinct Landscape categories and specific targeted Forestry Interventions those are being planned in each of the zone.

A. Zoning and Lower Order Zone Plans

Three broad and distinct Landscape types or 'Three Zones' have been deciphered within the Riverscape for the purpose of Proposed Forestry Interventions. The following section presents an elaborate account of specific Forestry Interventions in each of the zone or represents the self-contained 'Lower Order Zone Plan' for the Natural, Agriculture and Urban Landscapes, respectively within the Riverscape.

Natural Landscapes

Total 33 models in three types of Landscapes (Natural Landscapes, Agriculture Landscapes and Urban Landscapes) have been finalized and incorporated in the present DPR. Altogether, 16 models are selected for Natural Landscape in the hilly region of Himachal Pradesh and these are numbered from SL/HP/NL/01 to SL/HP/NL/16. While 05 models for Natural Landscapes in Shivalik and alluvial plains of Punjab, numbered from SL/PB/NL/01 to SL/PB/NL/05 have been included. Details of these models in Natural Landscapes relevant to hills and alluvial plains along with incorporated abbreviations are summarized in chapter 5.

Agriculture Landscape

The Second Lower Order zone *i.e.*, the Agriculture Landscape largely in the rural environment constitutes the matrix of the Riverscape. The activities in this zone mainly seek enhanced agricultural production. Within the Sutlej Riverscape, in terms of extent the Agriculture Landscapes was widely distributed i.e., firstly, along the altitudinal gradient in Himachal Pradesh secondly, in the vast expanse of alluvial plains of Punjab along the Sutlej Riverscape. The primary activity in this zone is agriculture and horticulture production. A wide range of agricultural and horticultural crops are being undertaken by farmers on their private lands. The purpose of this Lower Order Zone (i.e., Agriculture Landscape) is to enhance productivity of agricultural lands by appropriate soil and moisture conservation measures and planting of economical and important fruit trees so as to support the overall conservation values and other expected ecological functions and ecosystem services. Two models for the Agriculture Landscapes in Himachal Pradesh are proposed. These are: (a) Model SL/HP/AL/01, and (b) Model SL/HP/AL/02 relevant to boundary plantations and Block plantation, respectively. In alluvial plains of Punjab, two models (SL/PB/AL/01 and SL/PB/AL/02) specifically designed for plantations along the boundaries of crop fields and plantations in blocks, respectively have been proposed.

Urban Landscape

Proposed Forestry Interventions in the Third Lower Order Zone i.e., the Urban Landscapes. The built up environment represented by the Land Use and Land Cover category of ‘Settlement’ of the Riverscape. This category of Land Use and Land Cover was widely distributed throughout the Riverscape, predominantly all along the main channel and its tributaries and formed the Third Lower Order Zone referred as the ‘Urban Landscape (UL)’. Under this Lower Order Zone, altogether 4 models (SL/HP/UL/01 to SL/HP/UL/04) focusing on Bioremediation and Bio-filtration, Riverfront development, plantations in Institutional and Industrial Estates and Eco-Park development, have been proposed in the mountainous tract of Himachal Pradesh. Within the alluvial plains of Punjab, 4 models *viz*., Bioremediation and Biofiltration (SL/PB/UL/01), Riverfront development (SL/PB/UL/02), Institutional and Industrial Estate plantations (SL/PB/UL/03), Eco-Park development (SL/PB/UL/04) are proposed in Urban Landscape.

B. Theme Plans

In addition to Forestry Interventions and specific treatment models included for Three Lower Order Zone plans, additional 'Conservation Activities' and 'Supporting Activities' those are

common to two or all the three zones are referred as important themes have been proposed. Theme based activities or 'Theme Plans' are grouped under the name of: (i) 'Conservation Interventions' such as (a) Soil and Water Conservation, (b) Riparian Wildlife Management, and (c) Wetland Management (i.e., Natural and Artificial), and (ii) 'Supporting Activities' such as (a) Policy Interventions, (b) Concurrent Action Research, (c) Capacity Building, (d) Awareness, (e) Participatory Monitoring, and (g) Evaluation. These Theme based activities (i.e., Conservation Interventions and Supporting Activities) have been planned at the State and local field levels HP and Punjab.

16. Project Implementation Components, Partnership Arrangements, and Management

The Project envisages the following four Components for implementation.

Component 1: Implementation of Forestry Interventions in HP and Punjab of Sutlej Riverscape

Implementation of Forestry Interventions in Riverscape areas of concerned states is deal with the course of main stem of Sutlej River and all its tributaries in hilly State as well as in Punjab plains. The Component 1 includes three subcomponents i.e., (i) Proposed 'Forestry Interventions' in Natural Landscape (NL), Agriculture Landscape (AL) and Urban Landscape (UL) adopting appropriate plantation treatment models; (ii) Conservation Interventions; and (iii) Supporting Activities. Besides proposed extensive plantations in three types of Landscapes within the Riverscape, the significant inputs under the subcomponents on Conservation Interventions by way of Soil and Water Conservation, Riparian and Riverine Wildlife Management, and Wetland Management have been envisaged.

For the overall success of project on Forestry Interventions, it is important that the HP and Punjab the participating States, will carry out 'Supporting Activities' referred as 'Themes' at the State and Local levels. These activities include: (a) Policy Level Interventions; (b) Concurrent Research and Development; (c) Participatory Monitoring; (d) Capacity Development; (e) Awareness; and (f) Evaluation.

Further, in order to ensure effective implementation, coordination and monitoring of the statewide project activities, support for the establishment and smooth running of the State Level Project Management Units (SPMUs) in Himachal Pradesh and Punjab is also provisioned as a part of this Component.

Component 2: Strengthening Knowledge Management and Capacity Development for Forestry Interventions and Conservation of Riverscape

In the management of River ecosystem, there is an evident paradigm shift from River development to River conservation and then River restoration. Obviously, India lacks desired experience in Restoration of Rivers as relatively it is a new discipline for the country. However, efforts are on in this direction. For successful River conservation and restoration, holistic strategies should be adopted in policy and planning for better understanding of forest River linkages and their intricacies, and successful River conservation needs. Moreover, in the

emerging scenario of transparency in public policy, and essential requirements of comprehensive environmental impact assessment, and integrated planning for conservation of water resources, there are several expectations from multidisciplinary sciences. These expectations can vary based on the political climate, objectives of different (and often competing) Government Agencies, spatial and temporal scales of River resources and resultant complexity of the issues. The Best Available Science in River management and restoration should be based on six broad criteria i.e., (a) Relevance, (b) Inclusiveness, (c) Objectivity, (d) Transparency and openness, (e) Timeliness, and (f) Peer review. In view of the above stated facts, the component two of the Project aims to incorporate science into policy, planning and management for informed decision making that can facilitate positive outcomes of concerted efforts towards sustainable management of Rivers and River restoration in particular in India.

Himalayan Forest Research Institute (HFRI), Panthaghati, Shimla has taken a lead in the preparation of present DPR adopting a multistep holistic approach based on exhaustive consultations and stakeholder participation while following a scientific planning process using RS and GIS based geospatial analysis for the Riverscape, multidisciplinary review on the Riverscape environment, and extensive field data collection by the concerned SFDs in the data formats prescribed by the institute. The HFRI is a reputed and well known established learning Centre in the fields of Natural Resource Management and Forestry, particularly relevant to the Himalayan environment; those have direct relevance to the River ecosystems. Thus, it is of utmost importance that HFRI is not only involved as a National Level Partner Organization for facilitating monitoring, evaluation, and capacity development as proposed in the present DPR, but also be entrusted the responsibility of major task to serve as the Knowledge Management/ Learning Center, and to undertake concurrent research related activities essential for conservation and restoration of the Himalayan Rivers. The Institute also plays a pivotal role in building desired National capacity for demonstrating the strong linkages between diverse forests in the Himalaya and River ecosystems.

The Component 2 will seek to support improved knowledge by strengthening the Knowledge Management Centre and Capacity Building on learning and experience required for conservation of Himalayan Riverscapes within the country by offering best practices for Forestry Interventions and various activities like conservation measures as envisaged in the DPR.

Component 3: Scaling Up, Replication of Successful Models in Additional Sites and Maintenance Phase

The present implementation plan of DPR focuses on implementation in whole catchment area in Himachal Pradesh on the selected watershed areas, particularly once the River descends in the plains in Punjab. The Component 3 plans to support the scaling up and replication of planned efforts in additional sites / tributaries of Sutlej River besides primarily, supporting the maintenance phase of various types of plantations raised in later years (3^{rd}, 4^{th} and 5^{th} years) of the Phase I – Implementation Phase.

Component 4: National Coordination for Forestry Interventions and Riverscape Conservations

River management and restoration programmes require National Level Coordination for Proposed Forestry Interventions and various conservation efforts among the participating States or located along the course Sutlej River and its tributaries because major Indian River Systems involve two or more States as the Basin of the River and its tributaries is spread over multiple States. Therefore, Ministry of Jal Shakti (MoJS) is the Central Nodal Ministry for all aspects of management of water resources including River development and restoration of Rivers, but several other Ministries are also involved for specific components/needs.

Thus, for National level coordination, an appropriate mechanism is vital for Forestry Interventions and River restoration at the level of Central Nodal Ministry. The Component 4, therefore, visualizes activities for: (a) Establishment of the River Decision Support and Management Information System (RDS & MIS); (b) Facilitating activities relevant to policy and legal interventions, Riverscape level coordination, monitoring and impact evaluation; and (c) Administering the implementation of major project on Forestry Interventions. In order to accomplish this, the Component 4 specifically envisages the establishment of a Project Management Unit (PMU) at the Nodal Ministry level. The PMU at the Nodal Ministry would handle the programme implementation, coordination among participatory States, partner organizations at the National and State level besides extending support for the finances required for the project execution.

17. Implementation, Project Overseeing and Fund Flow Mechanism

In order to ensure effective execution of the project involving multiple agencies across the HP and Punjab of Riverscape, an efficient implementation mechanism is desirable. Thus, the project visualizes setting of two Project Steering Committees (PSCs), one at the National level in the Central Nodal Ministry i.e., National Programme Steering Committee (NPSC), while other at the state level in each of concerned States i.e., State Programme Steering Committee (SPSC).

(i) National Level Programme Steering Committee (NPSC)

The National Level Programme Steering Committee (NPSC) will be chaired by the Secretary of the concerned Central Nodal Ministry and the Member Secretary would be the National Project Director (NPD). The NPSC is expected to have multiple members represented by senior officials of the MoEF&CC; Ministries of Jal Shakti, Agriculture, AYUSH, Youth Affairs and Sports, Tribal Development, Rural Development, Urban Development, Panchayati Raj, and Tourism; PCCFs and HoFFs of concerned States or their representatives; Nodal Officer of the National Partner Organisation (HFRI); and one representative each from ITBP and Eco-Task Force. Thus, the NPSC is expected to have about 20 members or so. The NPSC shall meet at least once in a year at appropriate time for considering and approving the APOs submitted by the concerned SFDs. The funds against the approved APOs of the States shall be transferred by the NPMU to respective SFDs. The National level PFU will follow its own mechanism of governance and if required will have its Monitoring and Steering Committee for overseeing the project.

(ii) State Level Programme Steering Committee (SPSC):

As similar to National level NPSC, each concerned SFD will also have the State level SPSC. The existing framework of the State Forest Development Agency (SFDA) at the State level or any other similar/ equivalent agency will be used for transferring of funds at the State level and funds will be released on the approval of the SPSCs. Only after approval of SPSC, the matching funds will be transferred to SPMU for further allocation to concerned Divisions as per the respective APOs, dully approved by the SPSC. At the Circle/ District level, a Circle Project Implementation Committee (CPIC) will be constituted under the Chairpersonship of the Conservator of Forests (CF) with concerned DFO as the Member Secretary so as to ensure a transparent and accountable mechanism for implementation of activities as proposed in present DPR. Various works related to Proposed Forestry Interventions in the Riverscape could be implemented in close association and involvement of the village *Panchayat*/*JFMC* level setup. SPMU is proposed to perform in each of the implementing States. The SPMUs shall be responsible for all the directions, operations, and control of Forestry Interventions at the State level through SPSC. The SPSC shall be chaired the Principle Secretary Forests/ PCCF and HoFF while at the State level Project Executive Director (PED) shall be the Member Secretary. The SPSC shall have equal level representative of various Line Agencies/ Departments, Civil Society, NGOs, Eco-Task Force, ITBP, etc. The SPSC shall meet atleast twice a year at appropriate times for approving the APOs submitted by Divisions and steering the project implementation activities across the State.

(iii) Implementation at District/ Division Level

The District Level Implementing Committee (DIC) shall be constituted for programme execution having the CF as the Chairperson and the concerned DCF/ DFO as the Member Secretary along with the representation of District Level Line Agencies/ Departments as well as the Civil Society. A Civil Society Organisation at the Division/ District level shall be involved for programme execution at the field level. The concerned DFO as the Member Secretary who is also the Chief Executive Officer of this FDA wherever in existence and functional shall submit APOs for Forestry Interventions as envisaged in the project in consultations with the representatives of Line Departments, NGOs, Eco-Task Force, and other Civil Societies. Upon approval of the APO by the NPSC, the funds shall be transferred against the APO to an account separately maintained by the respective SFDs for implementation of the project envisaged in the present DPR. Likewise, separate accounts shall be opened by each of the DFOs at the Division level. Financial expenses, creation and management of assets, incurring overhead expenditures, etc. shall be as per the provisions of GFR2015 and/ or any rules/ guidelines framed by the Central Government and State Governments in this regard from time to time.

(iv) Execution at Field Level:

Once the APO submitted by the Division has been approved and works have been allotted, the respective work shall be executed with active involvement of JFMCs and/ or other CSOs in the area. In case the works are entrusted to JFMCs/ CSOs for execution, the cashbook and account so maintained by them in turn shall be submitted to the concerned DFO who will ensure that the works have been done in accordance with the physical and financial parameters prescribed. The concerned Range Officers will be responsible for the implementation of the project activities as

per the approved document/APO pertaining to their ranges with the assistance of field staff, namely Deputy Range Officers and Forest Guards.

18. Project Budget

The total financial outlay for Phase I and Phase II for Detailed Project Report (DPR) of Sutlej River through Forestry Intervention is Rs. **996** Crore. The projected financial outlay of the Phase 1 on Project Implementation of five years duration is Rs. **824.64** Crore. The projected budget outlay of Phase II in Sub Component C.2 (i.e., Maintenance cost of A.3 B and D component) of five year duration is Rs. **42.20** Crore. As mentioned above, the project includes four broad based components. Accordingly, financial cost of each of these four components is summarized below.

Project Outlay: Component and Activity Wise

The Principal Component-A: Implementation of Forestry Interventions in Sutlej Riverscape

An amount of Rs 851.84 Crore, which is 85.53 % of the overall project budget, is provisioned for principal component A. which include Rs. 525.17 Crores for component A.1, Rs. 197.51 Crores for component A.2 and whereas, Rs. 93.03 & 36.13 crore is provisioned for Maintenance cost of A.1 and A.2 and Scaling up and Replication of successful Models of Forestry Interventions (5% of A.1 and A.2) Sub-component C.1 and C.2 respectively.

Component -A: the **Sub-component (A.1)** on plantations and various treatment models in three types of Landscapes within the Riverscape is the largest in terms of its spread, extent and quantum of funds provisioned. Rs. 851.84 crore is provisioned for Forestry Interventions in three Landscapes, which is 85.53% of total budget outlay of the project. Amongst three Landscapes, the more emphasis is on Natural Landscapes, thus a sum of Rs. 324.03 Crores has been provisioned for proposed Afforestation/Reforestation activities in Natural Landscapes in Sutlej Riverscape. The projected budget outlay for proposed plantations in Natural Landscapes accounts for 38.04% of the principal component- A. The projected budget outlays for Eco-Task Force, Agriculture and Urban Landscapes are of the tune of Rs. 44.86 Crores, Rs. 47.68 Crore and Rs. 108.60 Crore or 5.27%, 5.60% and 12.75%, respectively of the envisaged cost of the Principal component- A.

The second Sub-component on 'Conservation Interventions' (A.2) includes three major types of interventions/ activities. These are: (a) Soil and Moisture Conservation Measures, (b) Riverine and Riparian Wildlife Management, and (c) Wetland Management. Rs 197.51 Crores are provisioned for this sub component, which is 19.83 % of total budget outlay. Of this, the budget outlay for SMC is Rs. 144.38 Crore, which is 16.95 % allocation of the funds provisioned for Component -A. Budget outlay provisioned for Riverine and Riparian Wildlife Management and Wetland Management is 53.13 Crore, which is 6.24 % of total budget of component- A.

The third Sub-component (A.3) pertaining to 'Supporting Activities' is to be executed by State/Level IAs. This Sub-component includes eight broad based activities viz., (a) Policy level interventions, (b) Participatory monitoring, (c) Adaptive research, (d) Capacity development, (e) Awareness, (f) Project management, (g) Evaluation, and (h) Contingency and other expenses. A budget of 46.61 Crore or 5.47 % of the component- A or 4.68% of total budget proposed to

Himachal Pradesh and Punjab has been provisioned for carrying out various supporting activities for five-year period.

The Component-B: 'Strengthening Knowledge Management and enhancement of National capacity for Forest Hydrology, Forestry Interventions, and conservation and restoration of Rivers would require a sum of Rs. 29.52 Crore or 2.96% of the overall project outlay. The highest budget amounting Rs. 10.24 Crore has been provisioned for cost of PFU, while budget of Rs.10.07 Crore has been provisioned for Research and Development, while Rs. 2.68 Crores, Rs. 4.32 Crore, Rs. 5.76 Crore, Rs. 1.54 Crore, Rs. 1.06 Crore and Rs. 2.26 have been envisaged for policy level interventions, capacity development, Scientific exchange, awareness, Monitoring and Evaluation, respectively.

The Component – C on the Phase II of the project of five years duration for maintenance of plantations raised during Phase I of the project has also been planned. The Phase II would also include limited activities related to replication of efforts in additional tributaries/areas and scaling up of the planned effort. A sum of Rs. 42.20 Crore or 4.24 % of the total project financial outlay has been envisaged specifically for the Sub-Component – C.2 on 'Maintenance Phase' of A.3, B and D.

The Component – D pertains to project management at the National level which would include the establishment of National Project Management Unit (NPMU) at the Central Nodal Ministry with the responsibility to oversee, steer and manage this priority project. A sum of Rs. 25.82 Crore, representing 2.59 % of the overall budget over a period of five-year during the Phase I has been provisioned. Thus, it is clear that the major portion of project budget outlay is meant for field level activities incorporating Proposed Forestry Interventions, Conservation Interventions and Supporting Activities to be implemented in Himachal Pradesh and Punjab.

A total of 24 Territorial Forest Divisions and 8 Wildlife Divisions in Sutlej Riverscape will carry out proposed activities relevant to Forestry Interventions within the Riverscape. A total of 27,016 ha area of three Landscapes, 2000 ha of ETF, 542 ha area of Riverine and Riparian Wildlife Management and Wetland Management and 7,50,828 m^3 extent of Soil and Moisture Conservation in Sutlej Riverscape is envisioned to be treated under the various Forestry Interventions.Project Schedule

Initially, the project implementation during Phase-I has been planned for duration of five years by respective States and concerned SFDs as the Implementing Agencies. A provision for inbuilt, Results Based Monitoring has been made for continuous monitoring, organizational learning and adaptive management. The Phase II after five years implementation would deal with maintenance phase of plantations raised during the phase I, scaling up of the activities and covering of the left over tributaries.

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LIST OF ACRONYMS & ABBREVIATIONS

ABS	Access and Benefit Sharing
ACFs	Assistant Conservator of Forests
AR	Afforestation and Reforestation
AFOLU	Agriculture, Forestry and Other Land Use
AGB	Above Ground Biomass
AIG	Alternate Income Generation
AL	Agriculture Landscape
APCCF	Additional Principal Chief Conservator of Forests
APOs	Annual Plan of Operations
BBMB	Bhakra Beas Management Board
BCRLIP	Biodiversity Conservation and Rural Livelihood Improvement Project
BGB	Below Ground Biomass
BMB	Bhakra Management Board
BMC	Biodiversity Management Committee
BOD	Biological Oxygen Demand
BPL	Below the Poverty Line
BSI	Botanical Survey of India
BSL	Beas Sutlej Link
BVP	Bharat VikasParishad
CAMPA	Compensatory Afforestation Fund Management and Planning Authority
CAPFs	Central Armed Police Force
CAT	Catchment Area Treatment
CBD	Convention on Biological Diversity
CBOs	Community Based Organizations
CCF	Chief Conservator of Forest
CCs	Completion Certificates

CDM	Clean Development Mechanism
CETF	Composite Eco-Task Force
CETP	Common Effluent Treatment Plants
CF	Conservator of Forest
CGWB	Central Ground Water Board
CI	Conservation Interventions
CIA	Cumulative Impact Assessment
CIFOR	Center for international Forestry Research
CIFRI	Central Inland Fisheries Research Institute
CITES	Convention on Control of International Trade in Endangered Species
CIWSA	Centre of Inland Waters in South Asia
CMS	Convention on Migratory Species
CN	Curve Number
CPIC	Circle Project Implementation Committee
CPSEs	Central Public Sector Enterprises
CRS	Cut Root Stock
CS	Carbon Sequestration
CSD	Commission on Sustainable Development
CSOs	Civil Society Organization
CSP	Carbon Sequestration Potential
CSS	Centrally Sponsored Schemes
CTE	Consent to Establish
CTO	Consent to Operate
CV	Coefficient of Variation
CWC	Central Water Commission
DEM	Digital Elevation Model
DFID	Department for International Development

DFO	Divisional Forest Officers
DIC	District Level Implementing Committee
DLT	Drainage line treatment
DoLR	Department of Land Resources
DOM	Dead Organic Matter
DoRD	Department of Rural Development
DPR	Detailed Project Report
DRDO	District Public Relation Office
DRO	Deputy Range Officer
DSRO	Direct Surface Runoff
EAC	Expert Appraisal Committee
EAPs	Externally Aided Projects
ECs	Eco-development Committees
EFs	Environmental flows
EIA	Environment Impact Assessment
EPA	Environmental Protection Agency
ESCAP	Economic and Social Council for Asia and Pacific
ESZ	Eco Sensitive Zones
ET	Evapo-transpiration
ETF	Eco-Task Force
FAO	Food and Agriculture Organization
FCS	Forest Carbon Stock
FDA	Forest Development Agency
FFGs	Functional Feeding Groups
FG	Forest Guard
FPC	Flood Pulse Concept
FREEP	Funded Forestry Research, Education and Extension Project

FRI	Forest Research Institute
FRL	Full reservoir level
FSC	Forest Carbon Stock
FSI	Forest Survey of India
FYM	Farm Yard Manure
GEF	Global Environmental Facility
GHGs	Greenhouse Gases
GIM	Green India Mission
GIS	Geographic Information System
GIZ	German Developmental Agency
GLOF	Glacier Lake Outburst Flood
GoHP	Government of Himachal Pradesh
GoI	Government of India
GOM	Government of Maharashtra
GoP	Government of Punjab
GPs	Gram Panchayats
GPCC	Global Programme Climate Change
GPG	Good Practices Guidance
GPS	Global Positioning System
HAW	High altitude wetlands
HCC	Hyporheic Corridor Concept
HDBP	High Density Block Plantation
HEPs	Hydro Electric Projects
HFL	High Flood Level
HFT	Himalayan Frontal Thrust
HIMCOSTE	Himachal Pradesh Council for Science, Technology and Environment
HKH	Hindu Kush Himalaya

HoFF	Head of Forestry Force
HP	Himachal Pradesh
HPC	High Powered Committee
HPPCL	Himachal Pradesh Power Corporation Ltd.
HPPWD	Himachal Pradesh Public Works Department
HPSCCC	Himachal Pradesh State Center on Climate Change
IAFs	Indian Armed Forces
IARI	*Indian Agriculture Research Institute*
IAs	Implementing Agencies
IAS	Invasive alien species
IBAs	Important Bird Areas
IBO	Indus Basin Organization
ICAR	Indian Council of Agriculture Research
ICFRE	Indian Council for Forestry Research and Education
ICMOD	International Centre for Integrated Mountain Development
IDA	International Development Agency
IDWH	Integrated Development of Wildlife Habitats
IFS	Indian Forest Service
IGB	Indus, Ganga and Brahmaputra
IHC	Indian Himalayan Cryosphere
IHCAP	Indian Himalayas Climate Adaptation Programme
IHR	Indian Himalayan Region
IIRS	Indian Institute of Remote Sensing
IISWC	Indian Institute of Soil and Water Conservation
IIT	Indian Institute of Technology
IP	Implementation Plan
IPCC	Intergovernmental Panel on Climate Change

IPH	Irrigation and Public Health
ISFR	India State of Forest Report
ISRO	Indian Space Research Organisation
ITBP	Indo Tibetan Border Police
IUCN	International Union for Conservation of Nature
IWA	Integrated Water Association
IWMI	International Water Management Institute
IWMP	Integrated Watershed Management Programme
IWT	Indus Tsangpo Thrust
IWT	Indus Water Treaty
J&K	Jammu and Kashmir
JFM	Joint Forest Management
JFMCs	Joint Forest Management Committees
JICA	Japan International Cooperation Agency
KBA	Key Biodiversity Areas
KVK	KrishiVigyan Kendra
LC	Least Concern
LFA	Logical Framework Analysis
LULC	Land use and land cover categories
LULUCF	Land use land use change and forestry
MAPs	Medicinal and Aromatic Plants
MBF	Main Boundary Fault
MBs	Measurement Books
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MDF	Moderately Dense Forest
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act

MHWDP	Mid Himalayan Watershed Development Project
MINARS	Monitoring of National Aquatic Resources
MK	Mann Kendall
MMDR Act	Mines and Minerals Development and Regulation Act
MoD	Ministry of Defense
MoEF&CC	Ministry of Environment, Forest and Climate Change
MoHA	Ministry of Home Affairs
MoPR	*Ministry of Panchayati Raj*
MoRD	Ministry of Rural Development
MoU	Memorandum of Understanding
MoUD	Ministry of Urban Development
MoWR	Ministry of Water Resources
MoWR, RD&GR Ganga	Ministry of Water Resources, River Development and Rejuvenation of
MoYA&S	Ministry of Youth affairs and Sports
MTS	MutliTasking Staff
NAEB	National Afforestation and Ecodevelopment Board
NAP	National Afforestation Project
NAPCC	Nation action Plan on Climate Change
NBA	National Biodiversity Authority
NBAP	National Biodiversity Action Plan
NBFGR	National Bureau of Fish and Genetic Resources
NBM	National Bamboo Mission
NCF	National Conservation Foundation
NDC	Nationally Determined Contribution
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index

NGO	NonGovernmental Organizations
NGRBA	National Ganga River Basin Authority
NGT	Nation Green Tribunal
NHB	*National Horticulture Board*
NIH	National Institute of Hydrology
NIR	Near Infrared
NITI	National Institution for Transforming India
NJHEP	Nathpa Jhakri Hydroelectric Project
NL	Natural Landscape
NMCG	National Mission for Clean Ganga
NMEEE	National Mission for Enhanced Energy Efficiency
NMGI	National Mission for a Green India
NMPB	National Medicinal Plants Board
NMSA	National Mission for Sustainable Agriculture
NMSH	National Mission on Sustainable Habitat
NMSHE	National Mission for Sustaining the Himalayan Ecosystem
NMSKCC	National Mission on Strategic Knowledge for Climate Change
NO	Nodal Officer
NPMU	National Project Management Unit
NPO	National Partner Organization
NPSC	National Programme Steering Committee
NR	National Report
NRCAF	National Research Center for Agroforestry
NRCD	*National River Conservation Directorate*
NRSC	National Remote Sensing Centre
NSM	National Solar Mission
NSS	National Service Scheme

NTFPs	Non Timber Forest Products
NWM	National Water Mission
NWRC	National Water Resources Council
NYKS	*Nehru Yuva Kendra Sangathan*
OF	Open Forest
OM	Office Memorandum
PAs	Protected Areas
PBP	Peripheral and Boundary Plantation
PBR	Peoples' Biodiversity Register
PC	Project Coordinator
PCCF	Principal Chief Conservator of Forest
PD	Project Director
PE	Project Elephant
PED	Project Executive Director
PEO	Project Executive Officer
PESA	Panchayats Extension to the Scheduled Areas
PFs	Protected Forests
PFU	Project Facilitation Unit
PLM	Programme Logic Model
PMU	Project Management Unit
PPCB	Punjab Pollution Control Board
PPM	Parts per million
PSP	Permanent sample plot
PT	Project Tiger
PWSSB	Punjab Water Supply and Sewerage Board
RBM	Results Based Monitoring
RC	River Coordinator

RCC	Reinforced Cement Concrete
RCC	River Continuum Concept
RCC	Reinforced Cement Concrete
RDS& MIS	River Decision Support and Management Information System
REDD Plus	Reducing emissions from deforestation and forest degradation
RET	Rare, Endemic and Threatened
RF	Recharge Factor
RFA	Recorded Forest Area
RFO	Range Forest Officer
RFs	Reserved Forests
RGR	Reviving Green Revolution
ROs	Range Officers
RRC	River Rejuvenation Committee
RS	Remote Sensing
RTDSS	Real Time Decision Support System
SAARC	South Asian Association for Regional Cooperation
SAC	Space Application Centre
SACEP	South Asia Cooperative Environment Programme
SAP	Sutlej Action Plan
SCS–CN	Soil Conservation Services and Curve Number
SDC	Serial Discontinuity Concept
SDGs	Sustainable Development Goals
SDI	Standardized Discharge Indices
SEAC	State Expert Appraisal Committee
SEIAA	State Level Impact Assessment Authority
SFD	State Forest Department
SFDA	State Forest Development Agency

SFM	Sustainable Forest Management
SFS	State Forest Service
SHPs	Small Hydropower Projects
SJVN	Sutlej Jal Vidyut Nigam
SLEM	Sustainable Land and Ecosystem Management
SMC	Soil and Moisture Conservation
SMEs	Small and Micro Enterprises
SMS	Subject Matter Specialists
SOI	*Survey of India*
SOM	Soil Organic Matter
SPCB	State Pollution Control Boards
SPMUs	State level Project Management Units
SPSC	State Programme Steering Committee
STD	South Tibetan Detachment
SWIR	Short Wave Infrared
SWOT	Strength Weakness Opportunity& Threats
TD	Timber Distribution
TK	Traditional Knowledge
TOFs	Trees Outside Forests
TOFs	Trees Outside Forests
UAVs	Unmanned Aerial Vehicles
UC	Utilization Certificate
UDFs	Undemarcated Forests
UFs	Unclassed Forests
UL	Urban Landscape
UN	United Nations
UNCBD	United Nations Convention on Biological Diversity

UNCCD	United Nations Convention on Combat of Desertification
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
US	United States
USAID	United States Agency for International Development
VAM	Vesicular Arbuscular Mycorrhizae
VAM	Vesicular ArbuscularMycorrhizae
VBSs	Vegetated Buffer Strips
VCS	Verified Carbon Standard
VDF	Very Dense Forest
VFDCs	Village Forest Development Committees
VFDSs	Village Forest Development Societies
VFPCs	Village Forest Protection Committees
VSS	Van Sanrakshan Samiti
WGMS	World Glacier Monitoring Service
WIHG	Wadia Institute of Himalayan Geology
WII	Wildlife Institute of India
WLS	Wild Life Sanctuary
WMO	World Meteorological Organization
WMS	Web Map Service
WRIS	Water Resources Information System
WRR	Water Resource Regions
ZSI	Zoological Survey of India

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CHAPTER-1

INTRODUCTION

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1.1 Natural Capital – Human Well Being and Sustainable Development

Since the origin of humans on the Earth, they have been continuously interacting with the environment. To nurture life on the Earth, pleasant climate, clean water, fertile soil, etc. are essentials aspects of the natural ecosystem because of these physical conditions; humans can live and thrive on the Earth for generations. Humans are inter-depended upon the environment to obtain food, water, fuel, medicines, building materials, and many other things for their survival and well-being. Freshwater ecosystems such as lakes, ponds, rivers, groundwater, flood plains, wetlands, and springs have been vital for sustaining life and establishing civilization throughout the history of humankind. Natural ecosystems are the planet's life-support systems not only for the human being but for all other forms of life. Among natural resources, fresh water is essential for human health and is one of the significant renewable natural resources. Water, by its very nature, is ambiguous. While water is one of the abundant globally available resources covering 1,400 million km^3, despite that, this scarce commodity only 0.001% is readily available for human consumption, along with substantial geographical variations (PWC, 2012). Globally, during recent decades availability of this scarce commodity per person has been declined rapidly.

Advances in science and technology have significantly transformed ecosystems that depend on fundamental environmental cycles (water, carbon, nitrogen, and other nutrients), which have been modified by human activities in the past century or so. Consequently, freshwater resources have been greatly affected by anthropogenic activities. Natural water bodies such as lakes, rivers, streams, and groundwater need to contain water of good quality because they are the only natural water sources on which life depends.

Sustainable development requires man to recognize his place within the ecosystem, considering the longterm impacts of his actions on the ecosystems (Hardi and Zdan, 1997). A minimum necessary condition for sustainability is the maintenance of the 'natural capital' on natural assets at or above the current level (Constanza, and Daly, 1992). At the Sustainable Development Summit in September 2015, UN Member States adopted the 2030 Agenda for Sustainable Development, which includes a set of 17 Sustainable Development Goals (SDGs) to end poverty, fight inequality and injustice, and tackle climate change by 2030 (UNDP, 2015). The plan on SDGs emphatically recognized that maintenance of the natural ecosystem or natural capital is pivotal for human wellbeing and sustainable development.

1.2 Rivers – Complex and Dynamic Ecosystems

Healthy, self-sustaining River systems provide essential ecological and social goods and services upon which human life depends (Postel and Richter, 2003). Rivers are systems in dynamic equilibrium and balance the water flow and sediment transport. When River channels altered

under naturally dynamic hydrologic conditions, the River readjusts itself for dimension, profile, and pattern to reach its former balance or equilibrium (Couture, 2008).

A River is an extremely complex ecosystem which carries out fundamental processes to maintain environmental equilibrium, benefiting both the natural ecosystem and the human world. Rivers are often referred to as ecological highways and might well be seen as 'green highways' linking up a succession of natural zones. Even where human actions and presence is marked, the River and its ecotone are still vital areas, used both by plants and animals for movement and reproduction (UNESCO). The most apparent characteristics of streams and rivers are that they flow, which distinguishes these *lotic* (flowing water) systems from *lentic* (standing or still) water systems like lakes and ponds (Dooge, 2009). Streams, rivers, and their floodplains are amongst the most fascinating, complex, and dynamic ecosystems on Earth as their water exhibit a high degree of connectivity between systems longitudinally, laterally, and vertically (Amoros and Bornette, 2002). Five unifying characteristics have been described in the context of rivers *viz*., unidirectional flow, a state of continuous physical change, a high degree of spatial and temporal heterogeneity at all scales, high variability between lotic systems, and specialized biota to live with flow conditions (Velde *et al.*,2004).

1.3 River Ecosystems – Human Use and Disturbance

Water is the principal element to sustain life on Earth. Since time immemorial, humans depend much on Earth's ecosystems, especially on freshwater systems, and thus, human settlements primarily found along with freshwater systems. In recent decades, human actions have severely impacted the environmental flow of the rivers, fragmented the River ecosystems and polluted the rivers. The threats to freshwater ecosystems due to social activities include clearance of forests and their conversion to farmlands, the growth of cities, the building of roads, and surface mining, etc. In particular, HydroElectric Projects (HEPs) have severely imperiled the natural streams and rivers by reducing River flow downstream. Physical barriers (dams, reservoirs, barrages, etc.) have significantly impacted the various River ecosystems.

Humans have altered River ecosystems in multiple ways that are likely to influence annual rates of ecosystem productivity and metabolism (Finlay, 2011). Human alterations of terrestrial landscapes by agriculture and urbanization have substantially modified cycles of water, sediments, and reactive elements in watersheds (Falkowski *et al.*, 2000; Tilman *et al.*, 2001; Foley *et al.*, 2005). Eutrophication, hydrological change, and degradation of habitat and environmental conditions associated with human actions severely threaten the integrity of freshwater ecosystems (Carpenter *et al.*, 1998; Dudgeon *et al.*, 2006). By virtue of their strong connections to surrounding landscapes, disturbances are rapidly conveyed throughout fluvial systems, making streams and rivers among the most highly modified ecosystems by humans (Poff *et al.*, 1997; Gleick, 2003; Allan, 2004; Dudgeon *et al.*, 2006). HEPs physical barriers are just one of the human disturbances in the context of rivers.

Deforestation is one of the most pressing environmental issues that the world is currently facing (Kumari *et al.*, 2019). It is the conversion of forested land to nonforested land by humans and started with the growth of agriculture, but was exacerbated during the 19th century when British commercial forestry operations destroyed Indian forests. The main reasons attributed to the reduction in forest cover are shifting cultivation, rotational felling, other biotic pressures, diversion of forest lands for developmental activities, etc. Continuous illegitimate cutting of trees leaves impacted on the microclimatic conditions, hydrological cycle, soil quality, biodiversity, etc. These conditions lead to making the country more vulnerable to any uneventful happening (Kumari *et al.*, 2019). The increasing demands on water resources by India's burgeoning population and diminishing quality of existing water resources because of pollution and the additional requirements of serving the country's spiraling industrial and agricultural growth have led to a situation where the consumption of water is rapidly increasing. At the same time, the supply of freshwater remains more or less constant (Dhawan, 2017).

The regional climate change has a significant influence on the hydrological characteristics of a watershed, which can substantially alter the runoff volume and timing in the basin (Ma *et al.*, 2009). In the future, climate change has been expected to change regional hydrologic conditions and subsequently impact local water resources in terms of both quantity and quality (Gleick, 1989; Jyrkama and Sykes, 2007). Studies also indicate that streamflow may rise drastically in the monsoon season, but will decrease in non-monsoon season due to the projected future climate change (Narsimlu, 2013).

According to Karr *et al.* (1986), species distribution and abundances of River ecosystems are affected by alterations in the principal drivers (i.e., energy source, physical habitat, flow regime, water quality, and biotic interactions), which might be used as substitutes to evaluate the ecosystem integrity (Poff *et al.*, 2007). Human disturbances impact the ecological security of watersheds by decreasing the integrity of River ecosystems, where the processes involved are complex at both temporal and spatial scales (Stein *et al.*, 2002). Compared with many terrestrial and marine ecosystems, the biodiversity of River ecosystems is highly threatened or has already diminished due to the growing need for water resources, and the impacts of climatic warming and land-use changes (Nel *et al.*, 2009; Li *et al.*, 2016). The sustainability of River ecosystems stands to be further affected by increasing human threats (Vörösmarty *et al.*, 2010).

1.4 The Rivers – Past, Present and Future

River Streams in the past have served different communities as well springs of food, water, power, sinks for squander item and objects of creative and supernatural intrigue. Notwithstanding high worth and respects for rivers, the people have been misusing this regular asset of high importance for shifted cultural needs particularly since, the mechanical upset (Johnson et al., 1995; GBEA et al., 2002; Srivastava, 2007; Addy et al., 2016). By that process most of the world's rivers are heavily influenced by human disruption. In the mid-1900's, many studies were conducted under the auspices of lake biology, which focused on the history of

biodiversity, but in the mid-1900s, accentuation moved towards portraying and estimating natural creation and vitality of rivers. However in the 1960s, analysts began using critical research in the river to look for connections between biotic and abiotic signals. It has long been the case that the physical and natural ideas of the dissemination of communications have been consolidated into a way of integrating everything that sees lotic frameworks as between subordinate blends of the sea-going and earthly scenes. There are at present two essential theories of how lotic frameworks work i.e., the waterway continuum idea with its conclusions and the flood-beat idea. The principal idea expresses that forested waterway frameworks have a longitudinal structure that outcomes from an angle of physical powers that change typically along the length of stream. These physical powers produce a continuum of morphological and hydrological highlights from headwaters to the mouth. The flood-beat idea mirrors that the most significant hydrologic highlight of enormous waterways is the yearly flood beat, which expands the stream onto the floodplains. The flood-beat idea acquaints a sidelong measurement with the elements of lotic frameworks and therefore, broadens center past the principle channel (Johnson et al., 1995).

The 21st century witnessed the construction of dams, the diversion of water through a wide canal network or river connections, affecting the rivers environment and leading to changes in river course. In addition, draining of wetland, over fish harvesting, deforestation, industrial waste, invasion of exotic and alien species have been found to change larger and even more powerful rivers. The creation of physical barriers and the transformation of rivers have often been carried out with an emphasis at the best, without the knowledge of the potential and negative impacts.

It is clear that's, freshwater science, governance and management have entered an era where human society needs to analyze impacts and act across local and global scales (Vörösmarty *et al.*, 2015). There is much more to be done to meet human demands for water, food and energy, yet also protect biodiversity and other valuable assets of freshwater ecosystems at the same time. This will require adequate recognition of the environment as a user of water and overcoming the barrier effects of dams to maintain or restore connectivity. It will also need a significant shift in investment to tackle pollution at its source, eliminating point source inputs and reducing diffuse pollution though more targeted Riparian protection. A more integrated and systematic approach is needed, that embraces the social and economic dimensions of these problems and not just the biophysical aspects. This is likely to require changes in governance, drawing on experiences in water-stressed systems from around the world (Grafton *et al.*, 2012). Ultimately, the conservation of River ecosystems depends on how well these issues are understood and addressed, as well as on solutions that allow them to coexist with multiple problems.

Recognizing the degradation and impaired ecological functioning of major rivers, the scientific community, River resource managers and several national governments have started planning about conservation of rivers by adopting a holistic perspective (Barrow, 1998; Brunner and Urenje, 2012; Basu, 2018). These planings include River basin or catchment management, riverscape and ecosystem management, linking upstream and downstream, source to sea

approach etc. In recent years, even the concept of River health and providing an impetus to scientific and evidence-based River management is gaining popularity.

1.5 Scientific Basis of River Management

River management is one of the most prominent areas of applied water resources science, which is gaining popularity in recent years. Traditionally, several methods have been developed to characterize river ecosystem structure and incorporated it into environmental assessment protocols. Despite the growing demand, however, much less progress has been made to develop and standardize methods to measure ecosystem functioning, or to incorporate them into the assessment of river ecological status (Palmer and Febria, 2012). While researchers recognize the importance of river ecosystem functioning, water authorities remain in general reluctant to measure River ecosystem processes. The main reasons for reluctance are the widespread consideration of being too expensive, difficult to perform or interpret, or simply that these measurements yield results not directly applicable to River management (Schiller *et al.*, 2017). Fortunately, sufficient scientific knowledge exists today to provide suitable and efficient functional measures for River restoration (Cote *et al.*, 2009; Hartmann *et al.*, 2013; ICPDR, 2015; Seliger and Zeiringer, 2018).

There are some challenges for scientific understanding in river restoration. These include: how physical complexity supports biogeochemical function, stream metabolism, and stream ecosystem productivity, characterizing response curves of different river components, understanding sediment dynamics and increasing appreciation of the importance of incorporating climate change considerations and resiliency into restoration planning (Wohl *et al.*, 2015). Riverine complexity has become one of the notable prospects of River science. Physically complex rivers have many refuges that can play a significant role in the ecological process governing *lotic* systems, thereby making the structural variety of habitats vital to the existence of well-balanced aquatic communities (Jungwirth *et al.*, 1993). Anthropogenic distribution of hydrogeomorphic complexity, through changes in channel structure (e.g., levees) and the natural flow regime disrupts and diminishes ecosystem functions (Neill and Thorp, 2011). River corridor is identified as the area that provides the physical space required by the River to express its energy and meander without causing it to dig down. Further, the environment of River refers to the relationships that living organisms have with each other and with their environment, the ecosystem. The river cannot be defined as just the water inside it, and also water is not only one component of the River ecosystem.

Enormous work on riverine basin/system management has been done across the world by the scientific community that is mainly focused around restoration and conservation of the river. Earlier before the twentieth century, river management mostly revolved only around the fisheries sector. However, with the advancement in technology and other scientific fields along with evolving policies, different objectives of river management have been achieved (Loucks and Cosgrove, 2015). Earlier, due to isolationist scientific approaches for the management of River

degradation, it only attempted to tackle the symptoms rather than focusing on the causative factors for the same. These attempts only concentrated on shorter stretches of River, narrow range of River forms, habitats or species. With the progression in scientific achievements, the scientific community engaged in River conservation has come to truly understand and appreciate the role of importance of River habitats and ecological environment in association with land, freshwater and oceans. Further, it has been realized by all concerned that even small scale Conservation Interventions are unlikely to be able to respond to the growing challenges. A comprehensive strategy following a systems-based approach, recognizing physical, biological, ecological, socioeconomic, political and cultural aspects of the River and human systems that are intricately interconnected has been required to understand the River ecosystem due to its complex and dynamic nature (Bock *et al.*, 2018).

The newer science of River management calls for integration and involvement of allied multidisciplinary disciplines *viz*., geomorphology, hydrology, climatology, landscape ecology and planning, hydraulic engineering, forestry, and aquatic and terrestrial ecology besides social sciences (Cai *et al.*, 2014). In brief, it can be stated that River conservation and restoration efforts require a holistic approach that includes various stakeholders from various government, non-government organizations along with Civil Society Organizations (CSOs) and local communities living in and around a River. These efforts now recognize the physical, biological and socio-economic sub-environments of a River (King *et al.*, 2003; Villela, 2017). The Potamology (the study of rivers) pays more considerable attention to fluvial processes, which is associated with rivers and streams and the deposits and landforms created by them. Along with that, it is also emphasized that ecological processes and the riverine landscape perspective as rivers are open ecosystems (Thorp *et al.*, 2008).

Environmental rehabilitation of River systems inevitably requires an ecosystem-based approach involving solutions supported by the public. The challenge is to combine ecological and socioeconomic sustainability (Velde *et al.*, 2006). For Scientific management of rivers, the following objectives need to be looked into:

a. Prevent soil erosion and land degradation

b. Improve land capability and moisture regime

c. Rehabilitate the degraded forest areas, slopes and landslide-prone areas

d. Promote land use to match the land capability

e. Improve the pasture land

f. Plant wild fruit species and create water resources for wildlife

g. Seek people’s participation in planning and implementation

Upgraded skills in planning and execution of land development in the early 20th century were mostly motivated by the interest of the fishery sector. However, over time, a growing influence

of evolving policies and the full range of techniques available has made it possible to achieve different objectives of River management. Increasingly, it has been realized by all concerned that adhoc or piecemeal, small scale Conservation Interventions are unlikely to be able to respond to the growing challenges. The complex and dynamic nature of River ecosystems requires a comprehensive strategy following a systems-based approach, recognizing physical, biological, ecological, socioeconomic, political and cultural aspects of the River and human systems that are intricately interconnected (UNESCO, 2016).

1.5.1 River Ecology

The River ecology deals with the relationships that living organisms have with each other and with their physical environment (the ecosystem). An ecosystem is the sum of interactions between plants, animals and microorganisms and between them and nonliving physical and chemical components in a particular natural environment. River ecosystems have: (a) flowing mostly unidirectional water, (b) a state of continuous physical change, (c) a high degree of spatial and temporal heterogeneity at all scales (micro-habitats), (d) variability between lotic systems is quite high, and (e) *biota* is specialized to live with flow condition (Giller and Malmqvist, 1998).

The origin and development of human civilization are closely related to rivers. Former may be the reason why the word 'River' evokes positive emotions and associations of things pure, clean and calm. At the same time, being so close to human activities, rivers are subject to various and quite often negative impacts. For most people, a River means water flowing from the mountains to the sea. However, flowing water is only one (essential) component of the living body called 'River.' Instead, the rivers have four dimensions – length, width, height (depth) and time. (Mihov and Hristov, 2011). Most problems of river management are the combined result of land-use changes, development of water resources (dams, reservoirs, barrages, canals, etc.), industrial expansion and urbanization that not only altered the pattern of runoff but also influenced the quality of River discharge, and the size, distribution and load of sediment transported (Calow and Petts, 1994).

1.5.2 River – Ecological Concepts and Connectivity

The ecological system as a part of natural functioning remove carbon dioxide and suspended particles from the air, purify running and ground water, control flooding and other natural disasters and maintain or improve biological diversity. These ecological functions work on a connected framework of high quality land compromised of control hub interconnected by corridor for the movement of species, energy and matter across the landscape covering particular ecological system. Road development, Industrialization, Deforestation and urban sprawl are threats to the framework of connectivity in Ecological system. (EPAs, 2008).

Ecological connectivity refers to the spatial and temporal extent to which living organisms and associated ecosystems services, processes and functions can move between different habitat patches (Huber *et al.*, 2018). The ecological connectivity in the context of a River is of paramount importance for environmental integrity and long term viability of a River ecosystem. The concept of ecological connectivity is related to the functional aspect of the actual connections among the different elements of the complex and dynamic River, from energy to matter, for instance, nutrient cycles, movement of floral and faunal populations and genetic exchange. Maintaining ecological connectivity protects the entire environmental system. Several well-known concepts of running water ecology have evolved, which deal with dimensions of riverine systems, *viz.*, the idea of ecological connectivity, the flood pulse concept, extended Serial Discontinuity Concept (SDC), and the ecotone concept. A theoretical concept, namely SDC, was developed that views immurement as significant disturbances of longitudinal resource gradients along with River courses (Ward and Stanford, 1995). According to the SDC, dams result in upstream-downstream shifts in biotic and abiotic patterns and processes; the direction and extent of the displacement depend on the variable of interest and are a function of dam position along the River continuum. The River Continuum Concept (RCC) was proposed to explain the longitudinal variation of benthic macroinvertebrate communities in fresh water catchments. (Gurubagh, *et al.*,1997). Further, it hypothesizes that as stream size grows and the composition of available organic matter alter, the Functional Feeding Groups (FFGs) will also change to signify the increase in habitat diversity and the alter in food availability (Vannote *et al*., 1980).

The FloodPulse Concept (FPC) was derived on large floodplain rivers in temperate and tropical areas that caused investigators to consider the role of seasonal flooding in *lotic* systems (Junk *et al.*, 1989). The Hyporheic Corridor Concept (HCC) added to riverine ecology the pattern and importance of groundwater interactions in understanding biological patterns (Stanford and Ward, 1993). Persistence is a vital concept for evaluating what happens to a species and community when connectivity is lost and which connection is crucial to maintain them. More researches on species persistence, behavioral ecology, community structure and likely implications of climate change are primarily needed to advance the knowledge on the vital discipline of the River connectivity (Rudnick *et al.*, 2012).

As such, all the above-stated concepts evolved over the past 34 decades focus on the longitudinal distribution of geophysical features and aquatic organisms along a River, a tradition that has been central in River research. Thus, increasingly, riverine landscapes are viewed as expansive systems whose functional and structural elements are determined by the River and its flow regime, yielding a complexly interconnected system consisting of the River and its surroundings. The balance between destruction, formation/rejuvenation and developmental processes contributes to the constancy and stability of the total system. It is viewed as one of the primary traits of the ecological integrity of Riverine Landscapes.

1.5.3 Riverscapes

Rivers are increasingly investigated from a landscape perspective, both as 'landscapes' in their own right and as 'ecosystems' (Hynes, 1975; Wiens, 1989; Allan *et al.*, 1997; Ward, 1998; Fausch *et al.*, 2002; Robinson *et al.*, 2002; Allan, 2004). Increasingly, riverine landscapes are viewed as 'riverscapes,' and it was Leopold and Marchand (1968) who used the concept of 'riverscape' (or riverine landscape) as early as in the 1960s to describe broadscale physical, biological and aesthetic nature of rivers. The study of water in the landscape is a new and rapidly expanding field. Rivers make riverscapes (even if the rivers are frozen) and riverscapes then determine the rivers except for the ever-increasing human impact. The development of River and riverscape, their ecology, the effect of social activities (such as water abstractions, flood control and management for recreational use) and water resources are described both in principle and using case histories (Haslam, 2008). A landscape approach is particularly important in natural resource management as humans have altered landscapes at multiple scales. Landscape ecology provides a perspective for integrating ecological processes and spatial complexity (Fausch *et al.*, 2002). Landscape ecology places particular emphasis on spatial heterogeneity, connectivity, and scale, all of which have received considerable attention in running waters (Allan, 1995 and 2004). Thus, in recent decades, a landscape perspective of streams and rivers ('riverscape') has emerged (Malard *et al.*, 2000; Sullivan *et al.*, 2007).

The diverse habitats within stream corridor in the riverscape viewpoint is recognized as a single, integrated ecological unit operating across spatial scales. Though, there is plenty of evidence that the present concept is appropriate in understanding the physical trends of stream corridors, still significantly less attention has focused on its ecological developments. Some most influential variables that play significant roles are channel slope, drainage area, and instream habitat conditions. Therefore, it is suggested that a holistic approach should be adopted to assessing and managing the mosaic of patches in the riverscape that has significant conservation potential.

While the riverscape concept may be applied across multiple spatial scales; it recognizes a stream, its floodplain (i.e., area of land regularly covered with water as a result of stream flooding), and Riparian area (i.e., land adjacent to the stream that directly affects the flow; includes woodland, vegetation, and floodplain) as an integrated ecological unit (Wiens, 2002). This view builds on documented connections between streams and their Riparian zones (Vannote *et al.*, 1980; Amoros and Roux, 1988; Naiman and De´camps, 1997), and subsequently explores the importance of physical disturbance (Resh *et al.*, 1988; Junk *et al.*, 1989; Poff, 1992; Giller, 1996; Poff *et al.*, 1997), interhabitat coupling (McDade *et al.*, 1990; Gregory *et al.*, 1991; White, 1993; Johnson *et al.*, 2000; Covich *et al.*, 2004), and nonuniform patchiness (Amoros and Bornette, 2002; Ward *et al.*, 2002) to the structure and function of stream ecosystems. Riverscapes are interactive, open systems, characterized by high levels of natural disturbance and interconnected ecotones (Ward, 1989; Ward and Wiens, 2001). Channel geomorphology, hydrological flows, and connectivity shape spatial and temporal riverscape patterns (Wiens,

2002) and exchanges of particulate and dissolved organic matter, energy, and biota (Hansen and di Castri, 1992; Tockner *et al.*, 1999; Ward *et al.*, 2002) across ecotones link various riverscape patches. These exchanges are multidirectional, creating foodweb dynamics that spatially connect distinct spots within the riverscape. The importance of terrestrial to aquatic transfers of organic material and biota has been well documented (Wipfli, 1997; Nakano *et al.*, 1999; Baxter *et al.*, 2005), and the reciprocal energy transfers from aquatic to terrestrial systems are attracting increasing attention (BenDavid *et al.*, 1998; Nakano and Murakami, 2001; Baxter *et al.*, 2005). Much of the current understanding of species habitat relationships within the riverscape comes from researches that independently address instream, floodplain, and Riparianbiotic links. Many investigations focus on instream habitat characteristics that support benthic macroinvertebrates and fish communities (Gorman and Karr, 1978; Karr, 1981; Kerans and Karr, 1994; DeShon, 1995; Deacon and Mize, 1997; Inoue and Nunokawa, 2002). Floodplains are explored primarily in terms of habitat diversity, biocomplexity, and hydrological connectivity (Copp, 1989; Ward *et al.*, 1999; Amoros and Bornette, 2002). The importance of Riparian buffers to instream ecosystems is also widely studied (Jones *et al.*, 1999; Boothroyd *et al.*, 2004; Zaimes *et al.*, 2004), as are influences of the extent and quality of Riparian vegetation on bird communities (Maloney *et al.*, 1999; Ammon, 2000; Inman *et al.*, 2002; Tucker *et al.*, 2003; Warkentin *et al.*, 2003; Miller *et al.*, 2004).

However, the riverscape concept encourages viewing biological communities and connections to their riverine habitats considered as a single ecological unit. The present idea requires a broader understanding of species– habitat relationships; habitat loss, fragmentation, and degradation; and the range of reciprocal connections between the channel and its surrounding Riparian zone. Thus, the riverscape level planning and assessments are being considered vital for the restoration of degraded River systems.

1.5.4 River Ecological Integrity

The term ‘Ecological integrity’, also defined as ‘River health’ or ‘Ecological condition,’ is frequently used in monitoring studies of water resources as a measure of the global condition of aquatic ecosystems. However, the first attempt to define the ‘health’ of aquatic ecosystems have not reached consensus. Karr (1992) uses three expressions interchangeably, given the similitude of the components. Nevertheless, Suter (1993) insists that ‘health’ is an inappropriate metaphor in an ecological context since it is a property only observable in organisms. Campbell (2000) agrees with Suter that the use of these concepts is useless and that operational definitions of these terms are necessary (ecological integrity and ecosystem health).

Consequently, Campbell concluded that ecological integrity is an ecosystem property that reaches the highest level when its structure is complete and when all processes inside it work perfectly. Schofield and Davies (1996), following Karr and Dudley (1981), and Angermeier and Karr (1994), defined ecological integrity as the ability of aquatic ecosystems to support and

maintain key environmental processes and an adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the same region. Edwards and Ryder (1990) recently used the expression 'Harmonic community' in a similar context to describe the goal of restoration of the ecological integrity of North American lakes. The health of an ecosystem has been defined not only in terms of system organization, vigor, and resilience, but also by the absence of environmental stress (Rapport *et al.*, 1998). Karr *et al.* (1986) point out that a healthy ecological system has a high capacity to resist the disturbances imposed by the natural environmental phenomenon and many alterations induced by society, therefore requiring a low external intervention. However, nowadays, it is almost impossible to find an area utterly unaltered by human activities. The term 'minimally' disturbed becoming more appropriate to describe the expected conditions in sites that exhibit high biological integrity. EPA (1998) agrees with this concept of integrity, considering that it represents a system that is balanced, adaptable and that reflects the natural evolutionary processes. It means that, despite the large group of definitions and designations used for the term ecological integrity (River health or environmental condition), it will be convenient that all these concepts converge into a unique one, that can be translated as being the natural state of the ecosystems where the changes that can arise are due to the evolutionary dynamics without human influence (Cortes and Oliveira, 2006).

1.5.5 River Restoration

Riverine ecosystems are remarkably resilient in their ability to recover from physical and chemical disturbances. Because running water ecosystems are so intimately attached to physical, chemical, and biological processes that occur throughout the catchment, restoration is a complex and challenging task (Gore and Shields, 1995). River restoration refers to a large variety of ecological, physical, spatial and management measures and practices aiming at restoring the natural state and functioning of the river system in support of biodiversity, recreation, flood management and landscape development. By restoring natural conditions, River restoration improves the resilience of the river systems and provides the framework for the sustainable multifunctional use of estuaries, rivers and streams. River restoration is an integral part of sustainable water management (UNESCO, 2016). Complete restoration of large rivers impacted by humans is unlikely, but partial rehabilitation may be possible (Gore and Shields, 1995).

All over the world, restoration of rivers is a central issue in the 21st Century (Chan, 2010). While the governments have always been traditionally entrusted with the responsibility of managing rivers increasingly, involvement of a wide range of stakeholders including policy makers, practitioners, scientists and nongovernmental organizations, as well as all citizens groups is needed to bring a better result. River restoration should involve cooperation between States and neighboring countries sharing the same river basin, and cooperation between government and all stakeholders. All stakeholders need to start taking proactive actions, even sacrifices, to manage, protect, conserve and restore rivers so that their resources can be sustained for future use. By actively drawing these various stakeholders into the process of River restoration, visions can be

shared and tuned towards each other. This makes for different interests to be met, and increases support for restoration efforts. Internationally, countries need to negotiate and use rivers as the basis for peace rather than conflict (Chan, 2010).

River restoration embraces a great variety of measures having common emphasis on natural functions of rivers, which may have been lost or degraded by human interventions. Broadly, 'River restoration' aims at any activity that focuses on improving the health of River, including improving ecosystem functions and any of the related ecosystem services. River restoration is done to mitigate the negative effects of the anthropological disturbances. The development of floodplains and wetlands helps to retain and slowly release water discharge from water bodies, facilitates groundwater recharge, provides seasonal aquatic habitats, supports corridors of native Riparian forests and creates shaded Riverine and terrestrial habitats.

Ecological restoration has grown rapidly and now encompasses not only classic ecological theory but also utilitarian concerns, such as preparedness for climate change and provisioning of ecosystem services (Palmer *et al.*, 2014). Restoration ecology is largely based on the theory that habitat heterogeneity promotes biodiversity (King and Hobbs, 2006; McCoy and Bell, 1991; Tews *et al.*, 2004).

1.6 Rivers – Concerns for Conservation

Rivers are dynamic ecosystems, and change is an essential characteristic of healthy riverine ecosystems (Karr, 1999). This dynamism is again based on the hydrological regime, and its interaction with the physical environment of the river. Anthropogenic environmental influences for the sake of development or fundamental need to improve the human wellbeing, in the recent past have resulted in degradation of the health of the river. The degradation of the River ecosystem has been accelerated by the economic and technological advancements. Increased population pressure have resulted in high density habitations, increased industrial development, intensive agricultural practices and consequently reshaping of the riverscape.

Human activities deeply affect the global water cycle, modifying the amount of water and the seasonality of flood and drought periods, both essential components of River health. Today, about 15% of the world's total runoff (40,000 km^3 /yr) is retained in 45,000 large dams, greater than 15 m in height (Nilsson *et al.*, 2005), and a further 10% is abstracted (Vörösmarty and Sahagian, 2000). As a result of these manipulations and subsequent irrigation, up to 6% of the water is evaporated (Dynesius and Nilsson, 1994). A total of 52% of the surface area connected by large River systems (discharge over 350 m^3s^1) is heavily modified. The heavy impact on the global water cycle is associated with the decline in freshwater biodiversity (Sabater, 2008). The alterations of the hydrologic regime directly affect the availability of water, which is the essential environment for many riverine species and an important force shaping habitats both in the channel and on the floodplain (Elosegi and Sabater, 2013). Direct or indirect effects on the hydrologic regime will become all the more critical and will aggravate the situation with the

increase in global population (i.e., upto 8.9 billion people in the world by 2050 (Cohen, 2003), together with the associated rising demand for water (Gleick, 2003).

The frequency, timing and magnitude of floods and droughts in most of the rivers have increased due to the change in global environment, which have detrimental consequences for organisms adapted for a particular ecosystem and the natural water regime. In the most extreme cases, abusive water abstraction dries out entire River sections wiping out the ecosystem services they provide and the biodiversity they harbor (Trenberth, 2008; Arnell, 2016). Humans have also brought profound changes upon the physical structures of River channels, impeding and diverting their flow and impairing their life supporting architecture (Elosegi and Sabater, 2013). Natural River channels are complex and dynamic, and River species are depend upon these characteristics for survival (Sabater and Elosegi, 2014). The technological capacity of humans has paved the way to huge investments of damming, building levees, channelizing, of otherwise controlling channel form and mobility. Many rivers today are the simple versions of the complex and dynamic ecosystems they once were, and biodiversity and ecosystem functioning are consequently profoundly compromised (Sabater and Elosegi, 2014).

Pollution an epidemic threat to rivers can sometimes be caused by natural substances when they appear in too high concentrations. This is the case of nutrients, essential elements for primary producers such as algae and other plants, but that in too high concentrations produce fouling of water, lack of oxygen, and declines in biodiversity (Stevenson, 2011). Anthropogenic activities have caused an enormous increase in the amount of nutrients circulating worldwide, either through diffuse sources such as agricultural fertilizers, or through point or end of pipe sources such as urban wastewater (Heathwaite, 2010). Other pollutants are more insidious, as they are novel substances, synthesized by humans for various purposes, but which nevertheless end up in rivers (Heathwaite, 2010; Elosegi and Sabater, 2013). Pharmaceutical drugs, pesticides and other substances with potentially powerful biological effects are frequently detected together with their degradation products. These socalled emerging pollutants pose a large challenge to science and environmental management, as very little is known on their action mechanisms in the biota, on their mobility and biomagnifications capabilities, nor on their interactions in complex mixtures (Petrovic *et al.,* 2002). Depending on their chemical characteristics, many pollutants remain dissolved or are stored in the sediments. Others are more volatile, and cross entire watersheds to areas far from where they were initially released (Nizzetto *et al.*, 2010). The pollutants volatilize in warm regions and are deposited in colder localities (Elosegi and Sabater, 2013).

The effect of these aggravators may create on organisms and environments rely upon their concentration, timing and extent (Stevenson and Sabater, 2010). There is a pecking order of stressors as per their concentration, recurrence and scale, and their properties range from transient to irreversible. A few stressors work at small spatial scales, for example, an abundance of nutrients or contaminants. The sequential levels at which stressors influence life forms and their environment are likewise distinct. Small stresses, for example, lethal pulses can create consequences on life form physiology or in public structure, yet a large portion of these will

probably be transient. Largescale stressors will rather deliver more tenacious consequences for organisms, whose reactions will dynamically convey from people to populaces, areas and lastly to ecosystems. Though, most environments are exposed at the same time several stressors in the so-called multiple stress circumstances. Waterways offer excellent natural examples of biological systems threatened by different stressors. The order of the monarchy and the complexity that illustrate the River systems made communication between the oppressors extremely difficult. The impacts might be synergistic, and should be further intensified by changes in the worldwide water framework driven by environmental change, with likely impeding ramifications for River biological system structure and working (Milly *et al.,* 2008; Ormerod *et al.*, 2010; Smol, 2010; Ferguson and Maxwell, 2012; Stendera *et al.*, 2012).

The above mentioned threats are not fully comprehensive, it should be emphasized that it affects biodiversity and water safety. Complete analysis by Vörösmarty *et al.* (2010) on anthropological access to water and the dangers of ecosystems around the world, produce amazing interactions. Those are areas where people are most endangered and species are at risk. Some of the threats to River conservation are mentioned below:

i) Insufficient Supply: Global demand for clean and fresh water is set to outstrip supply in near future owing to, exponential population growth during this century if current usage rates continue. Many water systems around the world have now been overexploited, and some have already dried up. Shortages of water resources have affected millions in Sao Paulo, Brazil, and forced to residents for evacuating their homes following a drought, while the US State of California entering its fourth year of drought. During recent years, The City of Cape Town, South Africa planned on 'Zero Day,' where taps are expected to be turned off. About one-half of the world's population lives in regions where groundwater is used faster than refilled (Gleeson *et al*., 2012). The study has estimated that, by 2030, the population's demand for water will exceed by 40%.

ii) Pollution: Pollution is amongst the most significant threats to the majority of rivers. The reduction in River water quality is a clear indicator of the decline in the environmental health of a River basin. Agriculture, industrial processes, untreated waste and degraded lands are leading causes of pollution in freshwater systems. Pollutants in the form of sewage, pesticides and heavy metals pose serious health hazards to human beings and aquatic life. Impaired water quality threatens freshwater species, affects fisheries to coasts, increases water treatment costs and poses risks to human health (Walter and Matt, 2020).

iii) Vulnerability: Climate change is a big concern all over the world. Due to climate change, frequency of occurence of droughts and floods has increased substantially affecting fresh water systems. Not only lack of availability of freshwater but also, there are more disasters in the form of droughts, floods, cyclones and many others natural calamaties. It is not only affecting human population but also, the animals because like human, animals also need fresh water. The communities those are heavily depend on the healthy fresh water ecosystems have become vulnerable under present scenario of climate change. Burning of Amazon Rainforest, Fire in

Australia, frequent Floods in Assam, Cyclone in West Bengal & Odisha and reduction in the size of Himalayan Glaciers are the recent examples of impact of climate change on ecosystems (Pletterbauer *et al.*, 2018).

Today, rivers are among the most diverse and threatened ecosystems in the world, and their preservation is vital to sustainable development. Their Preservation and Management practice should take into account the structure and functioning of the elements (usually species), as well as their natural environment. Therefore, effective River conservation must go beyond protecting species to protect the entire ecosystem. River conservation must meet the legitimate aspirations of the anthropogenic populations to provide clean and easily accessible water, without compromising the water needs of ecosystems and nature. Therefore, it is vital to take into consideration the landscape that incorporates processes that take place in Riparian rivers and inland connections and the river network (Sabater and Elosegi, 2014).

1.7 Indian River System

Rivers, particularly large river systems, constitute one of the most important, essential and vital life support systems that have sustained civilizations for more than 5,000 years and are projected to be a critical determinant for the sustainability of humanity (Sinha *et al.*, 2013). Large River systems are the most important continental geomorphic systems and have vast and longlived deltas. Further, large rivers and their valleys have long timeperiod alluvial stratigraphic records revealing their development on varied time scales from century to tens of millions of years (Tondon and Sinha, 2007). Based on the stated criterion, nearly 38 large rivers have been recognized across the globe and their locations are Fig. 1.1. However, most large rivers face a pandemic deterioration due to increasing human impact resulting into degradation of River ecosystems, serious threats to biodiversity and water security.

India owing to strategic location on the confluence of different biogeographic realms is endowed with the rich and unique diversity of natural resources; mighty rivers are one of them. India is privileged to have four large River systems *viz.*, Indus, Ganga, Brahmaputra and Godavari (FAO – AQUASTAT, 2011, Balasubramanian, 2007). The rivers of India have been broadly categorized into the following four groups:

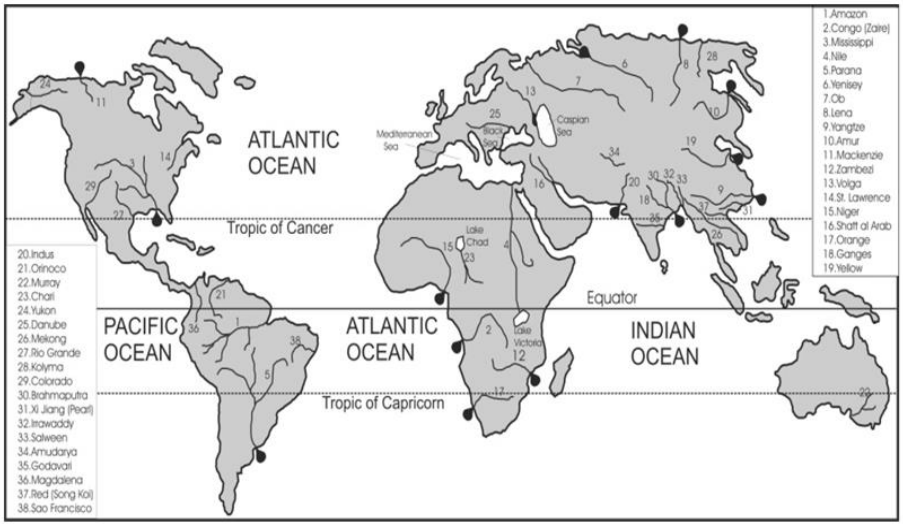


Fig. 1.1 Major Rivers of the World; Numbers Correspond to the River Names as Listed
(Source- Tondon and Sinha, 2007)

i) Himalayan Rivers: Himalayan rivers are fed by melt of snow and glaciers and flow throughout the year. During the monsoon season, these rivers assume alarming proportions as they carry enormous sediment and cause frequent floods. The Indus, Ganga and Brahmaputra along with their tributaries form the most important River systems.

ii) Peninsular Rivers: The Kaveri, the Godawari, the Krishna, the Mahanadi, the Narmada and the Tapti along with their tributaries are known as the Peninsular rivers. The rivers of southern India can be grouped into west flowing rivers and the east –flowing rivers. The rivers *viz*., Narmada, Tapti, Sharavathi, Kali, Nethravathi and the Periyar are some of the west flowing short and swift rivers having their source in the rugged topography of the Western Ghats. The important east flowing rivers of Peninsular India are the Mahanadi, Godhavari, Krishna and Cauvery apart from many others like the Damodar, Brhamani, Palar, Pennar, Vaigai and 'Thamara bharai' (Balasubramanian, 2007).

iii) Coastal Rivers: The Coastal Rivers are comparatively small in size and numerous in numbers, with nearly 600 flowing on the west coast itself (SANDRP, 2014). Example of some of the main west flowing rivers are Sabarmati, Mahi, Bharathpuzha and Periyar.

iv) Inland Rivers: Rather than calling it Inland river, it can be called as inland drainage (SANDRP, 2014).An inland drainage is the drainage (rivers and streams) which do not empty into any ocean or sea, but meet a lake, an inland sea or disappear in desert. Luni and Banas are two major examples of inland drainage. Both the rivers rise in Rajasthan, enter Gujarat and end their journey in the Rann of Kachchh. Many small rivers from north Gujarat also empty into the Little Rann of Kachchh. Another example of important inland Riverof Punjab is GhaggarHakra River.It's a River system in northwestern India and eastern Pakistan, which falls into the Ottu

reservoir in Haryana. The rivers in this system are Ghaggar, Kaushalya, Markanda (Haryana), Sarsuti, Tangri and Chautang.

1.7.1 River Basin

The river basin is defined as portion of the land through which the primary stream of a main river and feeder streams flow. It is the primary hydrologic unit for planning and improvement of water assets of a nation. In other words river basin is a catchment area, catchment basin, drainage area, water basin and drainage basin. Drainage basin is area of land where precipitation collects and drains off into a common outlet, such as into River, bay or other body of water. The drainage basin includes all the surface water from rain runoff, snow/glacial melt and nearby streams that run down slope towards a shared outlet, as well as the groundwater underneath the earth surface.

On the basis of area drained, the river basins of India have been classified into three categories: (i) Large river basins having catchment area of >20,000 km^2; (ii) Medium river basins having catchment area between 2,000 km^2 to 20,000 km^2 and (iii) Minor River basins having catchment area <2,000 km^2 (Rao, 1979). Accordingly, the Indian geographic extent has been divided into 113 river basins including 14 large, 44 medium and 55 minor basins. Concerned Government agencies *viz.*, Central Water Commission (CWC), Central Ground Water Board (CGWB), Government of India Web Portal, and River India – Water Resources Information System (India WRIS) by CWC and National Remote Sensing Centre (NRSC) have described varied number of basins due the fact that various agencies have either bifurcated larger basins into smaller one or clubbed smaller ones as single entity. However, 14 are large River basins while remaining 99 basins have been grouped into 6 River units. The spatial distribution of River basins is presented in Fig. 1.2 (CWC, 2017).

1.7.2 Hindu Kush Himalaya – A Global Asset and a Major Source of Fresh Water Supply

The Hindu Kush Himalaya (HKH), is the inception of 10 significant River basins and incorporates over 4.2 million km^2 area (Bajracharya and Shreshtha, 2011; Bajracharya *et al*., 2015) (Fig.1.2). The HKH zone and Tien Shan Mountains together possess the biggest territory of permanent ice cover outside the North and South Poles. Therefore, the HKH is being alluded as the 'Third Pole' of the world. The earthbound and oceanic biological systems in the HKH are home for rich and unique biodiversity. The HKH harbors the world's most elevated peaks and home for several mountain peaks >6,000 m. The area continues to support the livelihood of 240 million individuals living in its fluctuated mountain ranges and slopes (Sharma *et al*., 2019). About 1.9 billion individuals living in 10 river basins having origin in the HKH region also gets different advantages from its assets, including the 240 million individuals living in the mountains and slopes of the HKH (Table 1.1). With regards to the Indian subcontinent, the Indus, Ganga and Brahmaputra (IGB) river systems frameworks south of the HKH Reaches, accomplish unique importance from the of history, folklore, culture, economy and biology points of view (Eriksson *et al*., 2009). The Indus River System is the longest river in Asia among the 10

significant river systems in the HKH region (Fig. 1.3 and 1.4), and its basin is shared by China (Tibet), India, Pakistan and Afghanistan. It establishes the second largest drainage with 11,16,350 km^2 area. The Indus Stream and its feeders have immense importance for India and Pakistan.

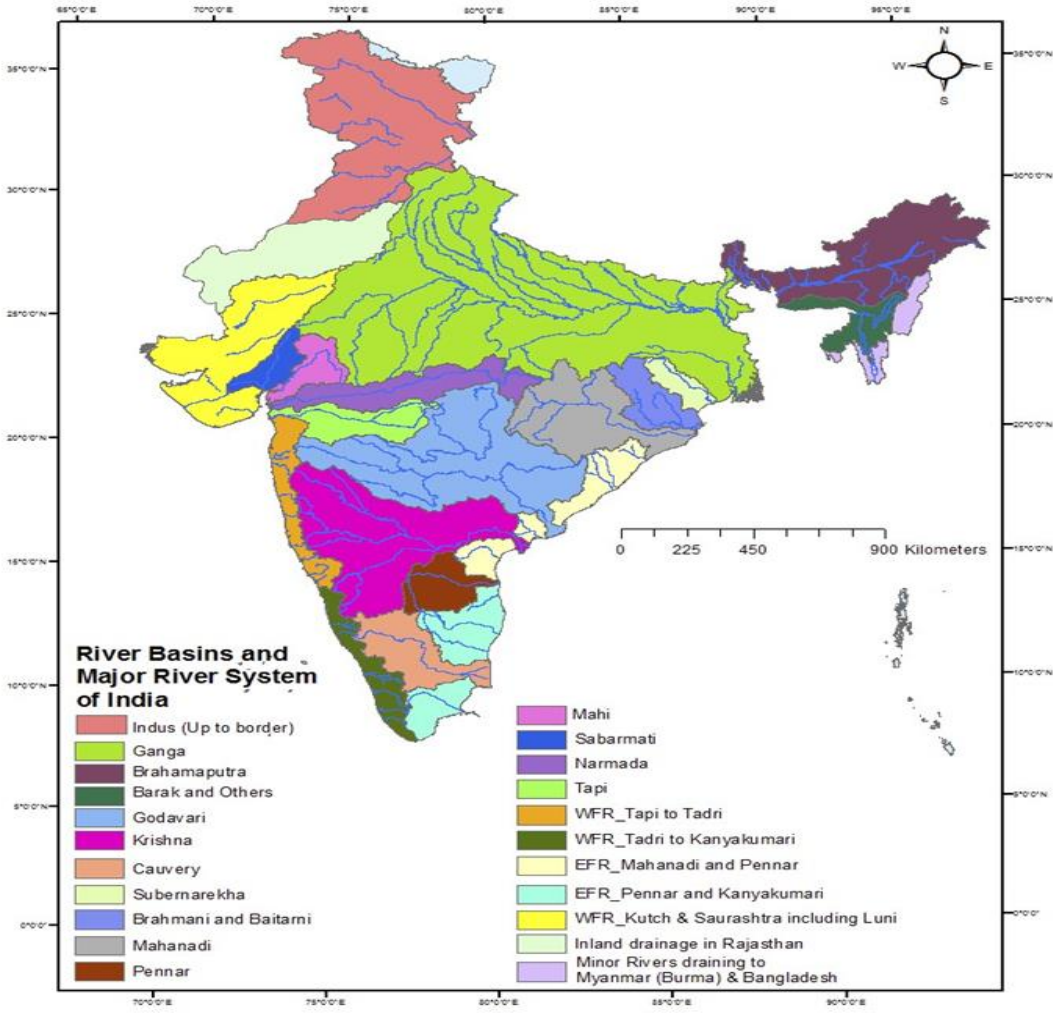


Fig. 1.2 River Basins and Major River Systems of India

(Source: CWC, 2017)

Table 1.1 Area and Population of the Major River Basins Originating in the HKH

River Basin	Area (km^2)	Population in 2010 (million)	Population in 2015 (million)
Amu Darya	6,45,870	27.1	30.18
Brahmaputra	5,28,083	64.63	68.07
Ganges	10,01,090	539.43	580.09

Indus	11,16,350	244.31	268.42
Irrawaddy	4,26,393	40.18	42.87
Mekong	8,41,337	74.58	77.31
Salween	3,63,898	18.19	17.88
Tarim	9,29,254	10.65	11.37
Yangtze	20,66,050	600.92	604.94
Yellow River	10,73,440	192.86	198.02
Total	**89,91,765**	**1,812.95**	**1,899.14**

(Source: Sharma *et al.*, 2019)

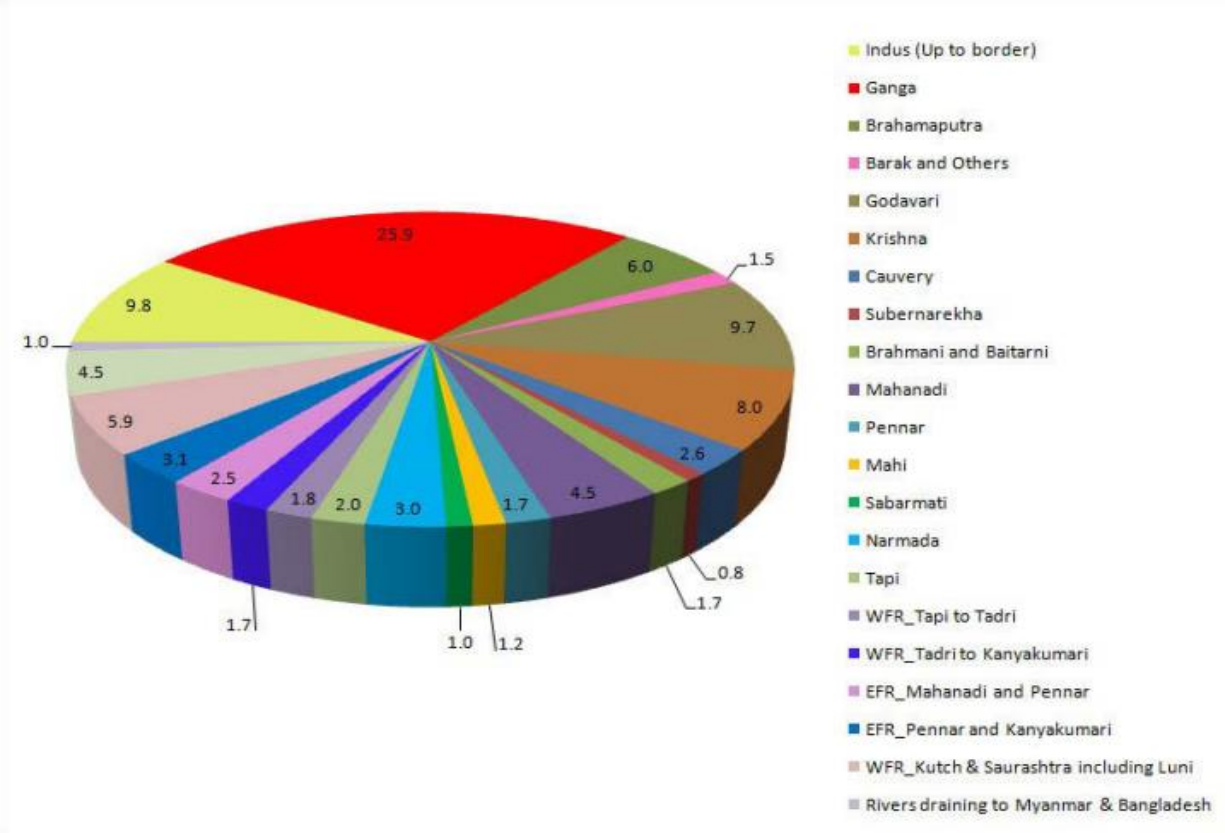


Fig. 1.3 Percentage of Geographical Area in Each Basin

(Source: CWC, 2017)

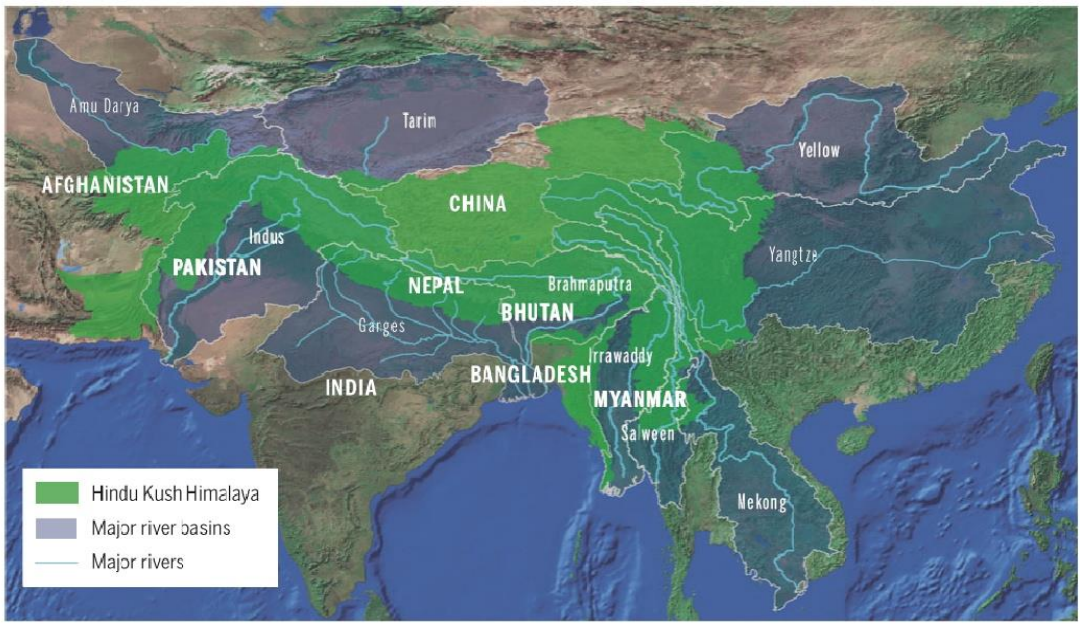


Fig. 1.4 Ten Major River Basins of Hindu Kush Himalaya

(Source: Sharma *et al.*, 2019)

1.7.3 Indus river systems

The transboundary Indus River basin with the 20approx. Area of 1.12 million km^2 is located in four countries, of which the largest part is distributed in Pakistan (47%), and substantial upstream parts in India (39%), China (8%) and Afghanistan (6%) (FAO – AQUASTAT, 2011). In India, the basin spreads over the Ladakh and Jammu and Kashmir Union Territories, Himachal Pradesh, Punjab, Rajasthan, Haryana and Chandigarh UT. Ladakh and J&K UTs share the highest extent of basin area, being 1, 93,762 km^2 (60%), followed by Himachal Pradesh (51,356 km^2 or 16%) and Punjab (50,304 km^2 or 15.96%). Rajasthan and Haryana States contribute 5% and 3% extent of the basin, respectively, Chandigarh UT has a minuscule extent of 114 km^2 or just 0.04% of the total basin area. The geographical extent of the basin is between latitude N 29°08’ to 36°59’ and longitude E 72°28’ to 79°39’ with a maximum length and width of 756 km and 560 km, respectively. The basin is bounded by the Himalaya on the east, by the Karakoram and Haramosh Ranges on the north, by Sulaiman and Kirther Ranges on the west, and by the Arabian Sea on the south (IndiaWRIS, 2012). The Indus catchment area is unique in the sense that it contains seven of the world’s highest peaks after Mt. Everest including K2 (8,600 m), Nanga Parbat (8,100 m) and Rakaposhi (7,800 m) and the world’s highest motorable passes *viz.*, Umling La (5,882.6 m) and Khardung La (5,358.3m). Nearly 55% area of the Indus River Basin within India lies above 3,000 m elevation (IndiaWRIS, 2012). The land use/ land cover mapping undertaken in the Indian part of Indus basin by IndiaWRIS revealed that agriculture land accounts to 35.8% of the total area while diverse forests covered 15.09% area. Snow and glaciers covered 12.46% area. Wastelands occupied as high as 28.53% area of the

basin within India. Grasslands and water bodies represented 4.19% and 1.85% area, respectively while built up land covered just 2.09% area.

1.8 Indus Water Treaty

With partition in 1947 and subsequent emergence of the two independent political entities, India and Pakistan, the sharing of Indus waters resulted in a dispute and became an international issue. After years of discussion and negotiations between the Governments of India and Pakistan carried out under the auspices of the World Bank resulted in the Indus Water Treaty (IWT), signed in the year 1960 (Muhammed, 2005). The Indus Waters Treaty is one of the most liberal water distribution agreements between the two countries. The Government of India and the Government of Pakistan, being equally desirous of attaining the most complete and satisfactory utilization of the waters of the Indus River System and recognizing the need, therefore, of fixing and delimiting, in a spirit of goodwill and friendship, the rights and obligations of each in relation to the other concerning the use of these waters and of making provision for the settlement, in a cooperative spirit, of all such questions as may hereafter arise in regard to the interpretation or application of the provisions agreed upon herein, have resolved to conclude a Treaty in furtherance of these objectives, and for this purpose have named as their plenipotentiaries.

Under this treaty, Indus River (Fig. 1.5) and its five prominent tributaries (Fig. 1.6) flowingfrom India to Pakistan were grouped as Eastern Rivers and Western Rivers. According to IWT (1960), the eastern rivers (the Ravi, the Beas and the Sutlej) are assigned for the unrestricted use of India and water of the three western rivers (the Indus, the Jhelum and the Chenab) is assigned for the unrestricted use by Pakistan.

1.9 Sutlej River Statement of Significance

The Sutlej River is the most extensive River in the Indus River Basin, and is considered to be its main stem. The Sutlej River is a transboundary River which flows through the nations of India, China and Pakistan. It is also a lifeline for millions of people who live along its course and depend on it for their daily needs. The River has been the source of physical and spiritual sustenance of Indian civilization for millennia.

The Sutlej River is one of the five tributaries of the Indus River System and referred as one of the three eastern rivers under the Indus Water Treaty (1960). The total geographical area of Sutlej River Basin up to Bhakra dam is about 56,980 km^2, of which about 37,153 km^2 lies in Tibet and the remaining 19,827 km^2 area lies in the Indian Territory. The River basin in India is spread over two States, namely Himachal Pradesh and Punjab. The Sutlej Basin in India is spread over parts of Spiti, Kinnaur, Kullu, Shimla, Solan, Hamirpur, Mandi, Bilaspur and Una regions of Himachal Pradesh and its western most part falls mainly in the Roopnagar, Nawashahr, Ludhiana, Jalandhar, Moga, and Ferozpur regions of Punjab.

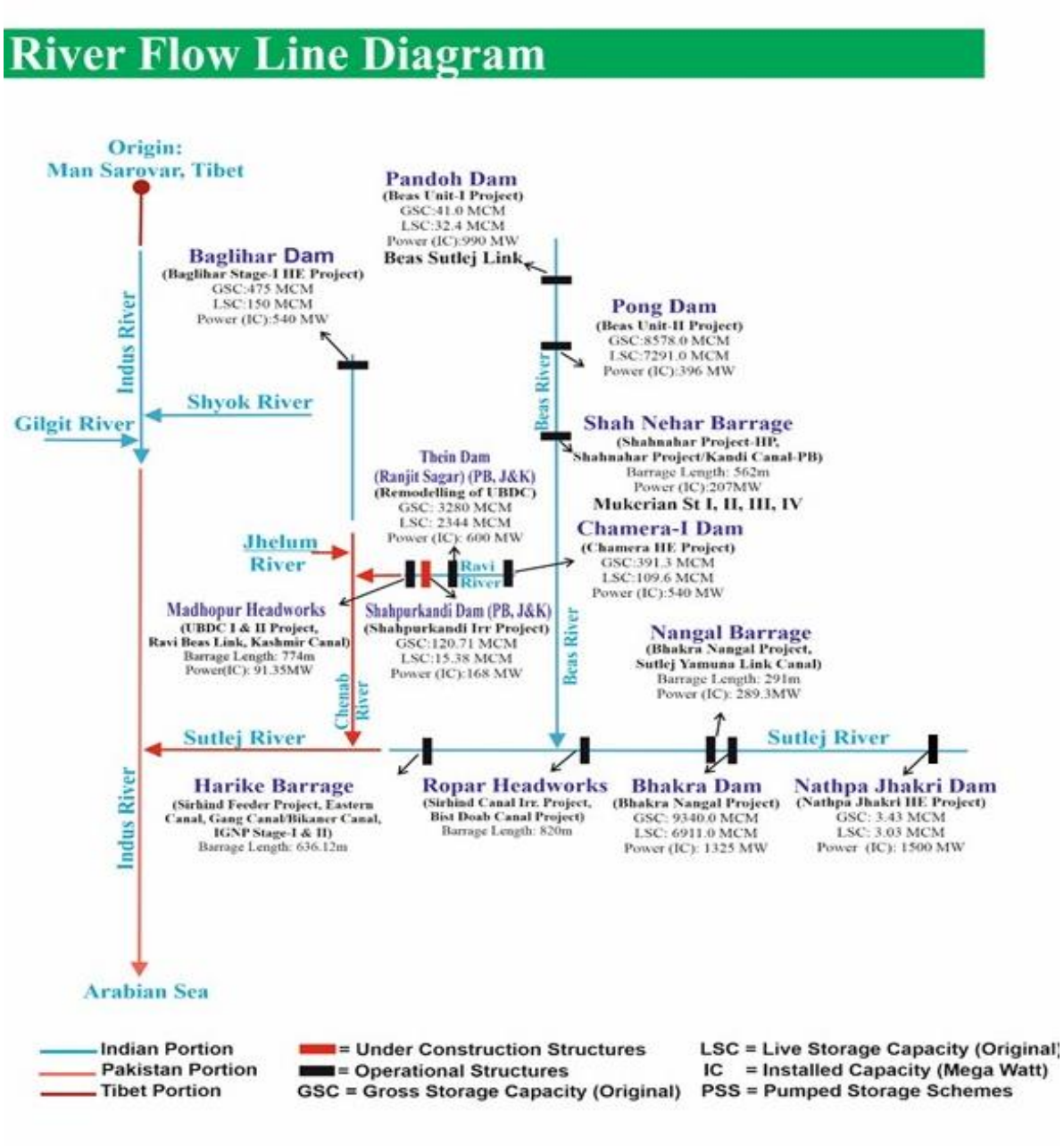


Fig. 1.5 Indus River Flow Diagram

(Source: IndiaWRIS, 2012)



Fig. 1.6 Indus River and Its Tributaries

Sutlej River Ecosystem- Statement of Significance

Sutlej River has significant geographical, ecological, environmental, religious, cultural, spiritual and economic significance in India with these values transcending the boundaries of the basin. The significance of the Sutlej River basin has been described below.

Ecological Significance

The Sutlej River originates from China in Western Tibet, the Kailash Mountain Range and near the source of the Indus, Ganga and Brahmaputra Rivers. The river is 1,536 km long and has a catchment area of 75,369 km2 (of which 70% is in India). It flows into Pakistan (Punjab) near Ferozepur and eventually joins the Chenab River close to Panjnad barrage. The Sutlej River has eight major tributaries (all except Rohi Nullah join Sutlej River in India). River Sutlej is the most important tributary of the Indus River System so far India is concerned and its basin spreads over 48,321.62 km^2. It is characterized by rugged topography with high ranges and peaks covered with glaciers, and massive ice and snowfields. The altitudinal variation in the basin ranges from 325 - 6,619 m. The Sutlej River and its northern and eastern tributaries are glacial or snow fed

perennial whereas the southern tributaries are seasonal. Along its upper course in Himachal Pradesh, the river is fed by numerous important tributaries like, Spiti, Ropa, Taiti, Kashang, Mulgaon, Yula, Wanger, Throng and the Rupi on the right bank, whereas the Tirung, Gayathing, Baspa, Duling, Nogli Khad and the Soldang are the left bank tributaries.

Due to variation in climatic conditions and a wide range in the altitudinal gradient, different mountain ranges within the basin are home to diverse forests (i.e., Sub-Tropical to Temperate), Sub-alpine and Alpine forests. They are host to a variety of Rare, Endemic and Threatened floral and faunal species. It represents two bio-geographic zones: (i) The Himalaya, and (ii) The Semi-arid region of the Punjab plains. Freshwater reservoirs found in Himachal Pradesh are Nako Lake, Tani Jubbal Lake, Kol Dam and Gobindsagar Lake. Across the Sutlej River Basin in Punjab, Nangal Wetland, Ropar Wetland and Harike Wetland are situated. Several Important Bird Areas (IBAs), Pin Valley National Park besides other 10 important protected areas situated in Sutlej Basin. A Sutlej basin is rich in avifaunal biodiversity and there are total of 390 species of birds. In the Sutlej sub-basin in Himachal Pradesh, some of the IBAs harbour critically endangered Western Tragopan and the vulnerable Cheer Pheasant.

The Sutlej sub-basin in Himachal Pradesh is also known to support around 51 species of cold water fish including exotic trout, snow trout and several species of hill stream fishes (HPSSCAP, 2012).Wildlife sanctuaries situated in Sutlej Basin are (a) Kibber Wildlife Sanctuary , (b) Lippa Asrang Wildlife Sanctuary, (c) Rakchham Chitkul Wildlife Sanctuary, (d) Rupi Bhawa Wildlife Sanctuary, (e) Daranghati Wild life Snactuary, (f)Shikari Devi, (f) Majathal Wildlife Snactuary (g)Gobindsagar Wild life Sanctuary (g) Nangal Wildlife sanctuary, (h) Abohar Wild life Sanctuary, (i)Harike Wild life Sanctuary. These Wildlife sanctuaries are home to rare animals like ibex, snow leopard, blue sheep and birds like snow cock, bearded eagle griffons, etc. The wide altitudinal ranges and varied topography of Sutlej River Basin has resulted in making the two States a very rich repository of wild fauna and flora.

Economic Significance

The river has historically been important to the survival of many cultures of the region. The Sutlej along with the Beas is the most important supplier of water resources to Punjab and Himachal, forming the backbone of agriculture and food production in these two States. The river is especially critical since rainfall is not sufficient to benefit agriculture, especially in the plains. Irrigation canals feeding from these rivers have proved to be a boon during the green revolution era. The extensive irrigation and dam projects provide the basis for Punjab's good production of crops such as cotton, sugarcane and wheat. There are several major HEPs constructed across the Sutlej-the important ones being the Bhakra Dam, Karcham Wangtoo, Nathpa Jhakri and Kol Dam, which generate electricity for heavy industries and provide the much needed electricity in urban centers of the region. River Sutlej has a number of tributaries of which few tributaries supports significant aquatic biodiversity. Historical survey reports of the State Fisheries Department for the streams of river Sutlej i.e. upstream of Bilaspur, estimated presence of 51 species belonging to 9 families of cold water fishes including exotic trout, snow

trout and several species of hill stream fishes. Mostly these species were unique due to sub–temperate climate and the zoo-geographic affiliation to the Himalayan region. The fishing activities provided full time direct and indirect vocation to over 5000 fishermen families mainly uprooted due to the completion of these river valley projects. The sustained fishery activities clearly demonstrated the potential of providing viable jobs through fishing and other fishery related activities.

Cultural Significance

The Sutlej River Basin supports a substantial human population belonging to numerous ethnic groups in the States of Himachal Pradesh and Punjab. Mythological, cultural, religious, historical, natural, ecological, scientific and economic values provided by the river basin contributes significantly to the nation's development as also the prosperity of the people in the region.

Besides, the Sutlej River and its basin are also important from cultural/historical point of view. There are large numbers of prominent historical / cultural sites include Ropar (Rupnagar), Tattapani, Vyas caves and Sri Naina Deviji temple. Tattapani in Mandi district is supposed to be the tenacity place of Jamadagni Rishi. Tattapani hot sulphur spring is a famous tourist place. Pilgrims take a holy dip at Tattapani hot spring on the banks of Sutlej on the occasion of Makar Sakranti. Shri Naina Deviji temple is one of the most prominent places of worship in Himachal Pradesh, located in district Bilaspur. Vyas caves lies on the left bank of Sutlej, near Bilaspur. Here the author of the epic Mahabharta, Rishi Vyas is presumed to have stayed in his days of performing penance. Ropar (Rupnagar) is a town lies on the Sutlej river near the Head of the Great Sirhind Canal. The Ropar area has been site of a centre of the ancient Indus civilization. Temple is situated on triangular hill known as 'Naina Dhar Hill' and surrounded by the landmarks of Bhakhra Dam, Anandpur Sahib (famous Sikh Gurudwara), and the Gobind Sagar lake created by the Bhakhra Dam. Temple is the one of the famous 51 Shakti Peeths of Hindu's having mythological linkage with lord Shiva and Guru Gobind Singh ji. A special fair is organized during Chaitra, Shravan and Ashvin navratras which attracts millions of pilgrims from far flung areas in the country. In addition, Lavi fair now designated as the 'International Lavi Trade fair' has been held in the upper reaches of Sutlej, mainly in Shimla and Kinnaur districts. The rich cultural, social and economic history is celebrated with fan fare during this fair. Further, Nalwari fair in March and Sazo festival in January are celebrated every year. Both these fairs/festivals are deeply associated with Sutlej River as people take bath in the river on the stated occasions.

In spite of the religious and cultural preeminence of Sutlej River in the Indian ethos since times immemorial, testifying to its centrality to Indian civilization and conservation significance, diversion of water, reduced water flow, extreme pollution pressure, excessive use of water and enhanced floods continued down the ages and the River remained neglected for a long time. The River basin is endowed with varied horticultural practices along with agriculture in both aspects.

1.6.4 Sutlej River Basin Uniqueness

Sutlej River along with its tributaries is known as the 'Power House of Himalaya'. The Government of India and State Government of Himachal Pradesh have identified the Sutlej River as one of the main sources of Hydro-electric Projects (HEPs). The total hydropower potential of Sutlej River Basin as estimated is 9,728.25 MW, out of which 5,515.75 MW is being harnessed through projects that are either under operation or in construction stages (SJVNL, 2005). Some of the major HEPs constructed on the River Basin are Bhakra Dam (1,325 MW), KarchamWangtoo (1,000 MW), NathpaJhakri (1,500 MW), Rampur (412MW) and Kol Dam (800 MW). The Sutlej River Basin is also known for variations in its biodiversity due to the extreme elevation variation. The upper reaches (i.e., Spiti and and upper parts of Kinnaur) of Sutlej River Basin which are cold desert regions have sparse vegetation. The major forest types in this cold desert area are the Dry Alpine Scrubs especially between 3600 - 5500 m amsl, and are famous for the diversity of the high altitude medicinal herbs and shrubs. Major flora in the Sutlej River Basin includes tree species such as *Picea smithiana, Juniperus polycarpos, Populus ciliata, Salix viminalis, Alnus nitida, Cedrus deodara, Pinus roxburghii, Lyonia ovalifolia, Senegalia catechu, Phyllanthus emblica, Pinus wallichiana, Pinus gerardiana, Berberis* spp., *Corydalis* spp., *Geranium* spp., *Astragalus* spp., *Cotoneaster* spp., *Sinopodophyllum hexandrum* (Mayapple), *Aconitum heterophyllum* (Aconite), *Saussurea obvallata* (Brahma Kamal), *Gentiana algida, Artemisia* spp., *Oxytropis microphylla, Cremanthodium ellisii, Carissa opaca, Dodonaea viscosa, Indigofera heterantha, Rhamnus virgata,* etc. There are also the variations in fauna of the Sutlej River Basin. The fauna of the Upper Sutlej River Basin is of special concern as most of the prominent wild animal species are reported in this part. Some of the prominent faunal species are Snow leopard, Himalayan black bear, Wooly hair wolf, Brown bear, etc. that are reported from this region while the major herbivores in the region are Ibex, Blue sheep, Yaak, Ghoral, etc. Similarly, in the Lower Sutlej River Basin, Leopard, Jungle cat, Wild boar, Bengal Fox, and Indian Porcupine are the major fauna. Sutlej River Basin has only one National Park i.e., Pin Valley National Park and six Wildlife Sanctuaries in Himachal Pradesh. Gobind Sagar Reservoir is one of the major reservoirs on Sutlej River which is consistently maintaining highest per hectare fish production level in the country with annual production of over 1,400 MT worth Rs. 8 Crore. The Sutlej River harbours both cold water as well as warm water fishes. The cold water fishes include *Tor* spp., *Schizothorax* spp., *Barillius* spp., *Bangana* spp., *Garra* spp., *Schistura* spp., *Triplophysa* spp., etc. are the indigenous fishes important in terms of food, sport and ornamental value. Punjab is also having Wetlands of International Importance which includes Ropar and Harike Wetlands which have been declared as Ramsar Sites. The River Basin also supports livelihood of the local communities in terms of irrigation and drinking water supply as well as the belt is very fertile with production of agricultural and horticultural crops.

1.10 Sutlej River Basin Problems and Need for Scientific Management

The river is one of the major natural resources that play important role in supporting and sustaining human life, maintains aquatic and terrestrial biodiversity by establishing longitudinal, vertical and horizontal linkages. Therefore, it is imperative that the quality as well as quantity of water in the river must be sustained by protecting from all forms of pollution and unscientific exploitation. The main stem of River has been over exploited for sequential HEPs for power generation in the Kinnaur, Shimla, Kullu and Bilaspur districts. Dams constructed on the river are affecting the catchment and the river ecology drastically. In the plain areas, Sutlej River is being generally polluted by disposal of untreated sewage, unabated disposal of municipal solid waste, unauthorized dumping of construction and demolition wastes and pollution from minor/major establishments. There is no proper treatment facility for municipal solid waste being generated from households and other activities and the same is dumped in open along the bank of Sutlej River. This is also contributing to the pollution of River. Construction of new buildings and establishments in the recent past has generated lot of wastes and demolition material finds its way into the river and contributes to its degradation. The Sutlej River Basin is quite diverse and complex, which covers the parts of two countries and provides livelihoods and sustenance to the people inhabiting the River catchment. For the better planning and management of Sutlej River Basin, long term national and regional collaboration framework on scientific lines is urgently required so that quality and quantity of water in Sutlej River is maintained.

Therefore, there is an urgent need of scientific management of Sutlej River for ecological regeneration of terrestrial and aquatic biota that ensures improvement in the quality and quantity of the water in the river, which ultimately leads to enhanced ecosystem services and improved livelihoods.

1.11 River Conservation Initiatives

The Ganga and Indus Basins in India supporting the livelihood of nearly 370 million Indians are two of the world's ten most endangered River systems. Rivers in India have been altered and depleted drastically in spite they are inextricably intertwined with culture and spiritual heritage. However, the current state of rivers cannot be held responsible entirely on the growth of human population or the development of the society over time. Irrigation development from prehistoric time coupled with intensification of agriculture with the advent of technologies, deforestation and urbanization, especially in the past century or so are the factors responsible for the current sorry state of most rivers including Sutlej River. The Government did recognize the conservation significance of rivers and freshwater resources while realizing the growing demands on these precious natural resources as early as the 1980s when a separate Union Ministry of Environment and Forests (MoEF) was created. Even much before this, the Wildlife (Protection) Act, 1972 was enacted by the Government of India (GoI) which provided equal emphasis on all natural ecosystems (terrestrial, aquatic, and coastal and marine). This Act extended legal support for protection and conservation of wildlife and wildlife habitats. Accordingly, a large number of

protected areas (national parks and wildlife sanctuaries) were established. A large number of PAs that focus specifically on freshwater resources (glaciers, rivers, estuaries, lakes, swamps, floodplains, etc.) were designated as either national parks or wildlife sanctuaries so as to ensure effective conservation of such ecosystems and habitats and their associated biota. Despite increasing concerns about the urgent nationwide need to revitalize Indian Rivers to sustain ecosystem functions and provide livelihood security, efforts towards River conservation in past has been extempore, fragmentary, often ineffective often ineffective slow or even halfhearted.

1.11.1 National Water Resources Council and National Water Policy

The Central Government has in place an overarching policy on utilization and conservation of water resources of the country in the form of a 'National Water Policy'. The National Water Resources Council (NWRC) was constituted under the Chairmanship of Hon'ble Prime Minister. The NWRC Council adopted the National Water Policy in September 1987. The National Water Board was constituted in September, 1990 with the Secretary, Ministry of Water Resources as Chairman and Chief Secretaries of all the States/UTs, Secretaries of concerned Union Ministries and Chairman, Central Water Commission as Members, in order to review the progress of implementation of the stipulations of the National Water Policy for reporting to the NWRC and also to initiate effective measures for systematic development of the country's water resources.

The NWRC adopted the revised 'National Water Policy2002' and passed a resolution to this effect in its 5th Meeting held on 1 April, 2002 at New Delhi. Thereafter, the National Water Board considered the further revised Draft National Water Policy (NWP) 2012, as recommended by the Drafting Committee on 7 June, 2012 and the same was again circulated amongst all the States and Central Ministries/ Departments concerned for comments. The Council adopted the NWP, 2012 on 28 December, 2012. The NWP, 2012 was released on 8 April, 2013 during the India Water Week, 2013.

The policy had laid down the hierarchy of use of water resources drinking water, irrigation, hydropower, navigation and industrial/other uses. The NWP lists outs the guiding principles for implementation of laws relating to sustainable utilization and conservation of water resources and also identifies that it must not be simply considered as a scarce resource but also a sustainer of life and ecology. Therefore, water needs to be managed as a community resource held, by the state, under 'public trust doctrine' to achieve food security, livelihood, and equitable and sustainable development for all. The Policy also recognizes the need for encompassing issues relating to climate change while planning and appraising any activity which involves utilization of water. These overarching principles, especially relating to community participation as well as climate adaption become critical when formulating and implementing a restoration scheme for the Sutlej River.

1.11.2 Bhakra Beas Management Board

A proposal to construct a storage reservoir on the Sutlej River was first time originated in November, 1908 much before the partition of the country. However, a detailed and comprehensive project for a high dam at Bhakra was prepared in 1919. During 19191951, the subject of harnessing water of Sutlej and construction of Bhakra dam remained active into consideration firstly, under the British India and subsequently after partition by the Government of India and the Government of Punjab; and during this period various consultations with different governments, US Bureau of Reclamation and US Irrigation Service, surveys and investigations, and planning for project proposal(s) took place. The fullfledged construction activity started only after April, 1952 and after untiring efforts of day and night for almost a decade, the Bhakra dam was ready. Bhakra Reservoir, which is also known as Gobind Sagar, one of the oldest built dams in India, was commissioned on 22 October, 1963. It has controlled devastating floods and the accrued benefits of irrigation and power have brought prosperity to north India. Bhakra Reservoir has a designed dead storage of 2,431.81 Mm^3 and live storage of 7,436.03 Mm^3; i.e. a total storage capacity of 9,867.84 Mm^3. The waterspread area of the Bhakra Reservoir extends over 168.35 km^2 at full reservoir level (515.11 m) and its head touches a point about 12.87 km above Slapper village near Kasol (CBIP, 1990).

The Bhakra Reservoir is fed by the flows consisting of contribution from rain and snowmelt. Singh and Kumar (1997) have studied precipitation distribution for several Himalayan Basins and found that the maximum contribution to annual rainfall (42-60%) is received during the monsoon season, whereas the minimum (5-10%) is received in the postmonsoon season. Consequently, the reservoir attains its maximum water level just after the monsoon season. The water level of the reservoir gradually reduces due to various types of use and reaches lower levels before the onset of the next monsoon. The Sutlej River transports heavy amounts of sediment, which is detrimental to the life of the reservoir (Jain *et al.*, 2002). The silt contribution in this basin is largely due to deforestation, overgrazing in the pasture lands, unscientific agricultural practices, farming at elevated terraces, etc. (BBMB, 1997). This region is also highly prone to landslides and slips which may be one of the major sources of sediment in this River. The natural factors that also attribute to high levels of sediment transport from the study region are steep topographic gradient, poor structural characteristics of soils; clay rich rocks such as Spiti shales and schists; and the widespread existence of limestone deposits (Sharma *et al.*, 1991).

On reorganization of the erstwhile State of Punjab on 01 November, 1966, 'Bhakra Management Board' (BMB) was constituted under the Sec, 79 of Punjab Reorganisation Act, 1966 on 1 October, 1967 for operation and maintenance of the Bhakra Nangal Project. Following signing of the Indus Waters Treaty in 1960 between India and Pakistan, and completion of the Beas Project in 1976, the Beas Project was transferred to BBMB, which was renamed as the Bhakra Beas Management Board (BBMB). BBMB is headed by a full time Chairman and two full time

Members, who head the Irrigation and Power wings of BBMB. They are supported by six Chief Engineers who head the respective offices in the Irrigation Wing and the Power Wing. The water regulated by BBMB is distributed among Punjab, Haryana and Rajasthan, with smaller shares for water supply to Chandigarh and Delhi. While water issues will not be completely solved by the implementation of Real Time Decision Support System (RTDSS), better quality information and tools will assist the representatives of the State Agencies to have more complete and accurate knowledge of the system and its functioning, and be empowered for more judicious decision making. Functions of BBMB includes: (a) administration, operation & maintenance of BhakraNangal Project, Beas Project UnitI (Beas Sutlej Link Project) and Beas Project Unit II (Pong Dam) in Northern India; (b) regulation of supply of water from Sutlej, Ravi and Beas to the States of Punjab, Haryana and Rajasthan; (c) regulation and supply of power generated from BhakraNangal and Beas Projects; (d) providing and performing engineering and related technical and consultancy services in the various fields of hydroelectric power projects and irrigation projects.

1.11.3 Sutlej Jal Vidyut Nigam (SJVN)

SJVN Limited, a Mini Ratna, CategoryI and Schedule –'A' Central Public Sector Enterprises (CPSEs) under the administrative control of the Ministry of Power, Government of India, was incorporated on May 24, 1988 as a joint venture of the Government of India (GOI) and the Government of Himachal Pradesh (GoHP).

Beginning with a single Project and single State operation (i.e., India's largest 1,500 MW Nathpa Jhakri Hydro Power Station in Himachal Pradesh), the Company has commissioned five projects totaling 2,015.2 MW of installed capacity including wind and solar power. SJVN is presently implementing power projects in Himachal Pradesh, Uttarakhand, Bihar, Maharashtra and Gujarat in India besides neighboring countries *viz.*, Nepal and Bhutan.

1.11.4 Sutlej Action Plan (SAP)

The Sutlej River flows in Himachal Pradesh and Punjab. In Himachal Pradesh a Comprehensive Environmental Imact Assessment (CEIA) study has been carried out by ICFRE/HFRI and detailed report submitted to MoEF&CC for acceptance and implementation. The Sutlej River in Punjab has been used as a source of irrigation, drinking purpose especially in southern Punjab and various activities including industrial purposes. The Sutlej and Beas Rivers have played a significant role in the socio-economic and industrial development in Himachal Pradesh and Punjab. Keeping in view the deterioration in the water quality of Sutlej River, the State Government of Punjab (GoP) initiated action in 2008 to identify the sources of its pollution in coordination with Punjab Pollution Control Board (PPCB). Ludhiana City lies within the catchment area of Sutlej River and is contributing significantly to the water pollution of Sutlej River, through Buddha *Nallah,* which passes through the heart of Ludhiana City. Accordingly, Ludhiana City was declared as critically polluted areas by the Ministry of Environment and

Forests vide office memorandum J11013/5/2010IA II (I) dated 13/1/2010, thereby imposing restrictions on setting up of new / expansion of existing projects attracting the provisions of EIA Notification, 2006. The GoP, Department of Local Government vide notification no. 14/89/20183LG1/2065 dated 26.10.2018 has constituted a Task Force under the chairmanship of Satguru Uday Singhji of Namdhari Sampardhai for execution of the programme/ interventions for tackling pollution in Buddha *Nallah* approved by the Government under Mission Clean Sutlej River to prepare and implement a comprehensive action plan to clean Sutlej River for (i) creating awareness about the adverse impact of water pollution, (ii) identifying the sources of water pollution, (iii) setting up facilities for treating the pollutants, (iv) ensuring effective operations of the facilities, (v) ensuring effective monitoring of the quality of water, and (vi) mitigating adverse impact on health of the people in the surrounding areas. As part of the Sutlej Action Plan, the government has identified 42 places, including around 30 major towns, where there is utmost need of installing Sewage Treatment Plants (STPs) as waste is being released into Sutlej directly from here. It is also identified that there is need to upgrade Common Effluent Treatment Plants (CEPTs) at Ludhiana and Jalandhar as industry is releasing industrial untreated water into river. Implementation of Sutlej Action Plan (SAP) would bring significant changes in quality of Sutlej Water.

1.11.5 River Rejuvenation Committee (RRC)

Central Monitoring Committee has been constituted by the National Green Tribunal (NGT) to prepare and implement a National Plan to make over of more than 350 river stretches across the nation over contamination free as it has caused a serious threat to safety and sustainance of whole ecosystem. A bench headed by National Green Tribunal (NGT) Chairperson Justice Adarsh Kumar Goel said the advisory group would contain a delegate of NITI Aayog; secretaries of Ministry of Water Resources, Ministry of Urban Development and Ministry of Environment Forest & Climate Change; the Director General of National Mission for Clean Ganga and the Central Pollution Control Board Chairman. The Central Monitoring Committee will likewise facilitate with the River Rejuvenation Committees of the states and supervise the execution of the action plans, considering the timetables, budgetary system and different components. The River Rejuvenation Committee was constituted by the Hon'ble NGT, Principal Bench at Delhi. The RRC constituted as four member committee comprising Director Environment, Director Urban Development, Director Industries, and Member Secretary, State Pollution Control Boards of Himachal Pradesh and Punjab. The RRC shall prepare action plans of all the polluted River stretches extending inside the Himachal Pradesh and Punjab and to make contaminated river water fit for at least bathing purposes according to standard water quality measures recommended by State Pollution Control Board (SPCB).

1.11.6 National Action Plan on Climate Change and Eight Missions

Climate change is one of the most critical global challenges of present times and recent events have emphatically demonstrated the growing vulnerability to climate change. National Action Plan on Climate Change (NAPCC) 2008 of the Government of India aims at creating awareness among the representatives of the public, different agencies of the government, scientists, industry and the community as a whole, on the threat posed by climate change and the steps proposed at the level of India to counter these changes. The action plan outlines a number of steps to simultaneously advance India's development and climate changerelated objectives. The National Action Plan on Climate Change (NAPCC) encompasses a range of measures. It focuses on eight missions, which are as follows: (i) National Solar Mission NSM, (ii) National Mission for Enhanced Energy Efficiency NMEEE, (iii) National Mission on Sustainable Habitat NMSH, (iv) National Water Mission NWM, (v) National Mission for Sustaining the Himalayan Ecosystem NMSHE, (vi) National Mission for a Green India NMGI, (vii) National Mission for Sustainable Agriculture NMSA, and (viii) National Mission on Strategic Knowledge for Climate Change NMSKCC. The activities undertaken as a part of different national missions would definitely contribute directly or indirectly towards the conservation of freshwater resources, particularly to the conservation of rivers and efficient flow of rivers.

1.12 Present Task – Forestry Interventions for Sutlej River

The forests perform multiple functions, provide multiple uses and multiple values and, they are strongly linked with freshwater resources including, rivers and hydrology. The present task also emphasizes why ‘Forestry Interventions’ on scientific basis are pertinent for River conservation besides describes various ecosystems services offered by the River. It also underlines the emerging global perspective on strong linkages between forests and water, specifically in the context of Sutlej River restoration.

1.12.1 Forests – Multiple Functions, Uses and Values

Importance of forests is indispensable as they are the lungs of the planet. Humanity is strongly intertwined with diverse forests as they provide various ecosystem services. Forests cover a third of all land on the Earth, providing vital organic infrastructure for some of the planet's densest, most diverse collections of life. Since time memorial, human have been using timber, fuelwood, fodder, fiber, edible products, medicinal and aromatic plants, etc. from different forests and also living within or in vicinity for subsistence and livelihood. Forests are repository of biodiversity and support countless species as well over 1.6 billion human livelihoods (IUCN, 2017). Forest provides habitat for wildlife, form catchment of streams and rivers and harbour a variety of wetlands. Besides, freshwater resources to humanity, forests also offer watershed protection, prevent soil erosion and mitigate climate change, besides helping in the formation of soil and enrichment of soil minerals. Forests have been the source of inspiration, recreation, adventure tourism and education while forest grove’s have sacred and spiritual values. Forests immensely

help in sequestration of carbon and its storage, thereby, playing an important role in global carbon cycling and climate change mitigation. Forests also play vital role in protection from natural hazards *viz*., avalanches, floods, cyclonic storms and tsunamis. Forests ameliorate local environment and influence all variables of microclimate.

Trees serve as natural sponges, collecting and filtering rainfall and releasing it slowly into streams and rivers, and are the most effective land cover for maintenance of water quality. The ability of forests to aid in the filtration of water provides benefits to human health and the health of an ecosystem. Forest cover has been directly linked to the function of water purification and biofilters by filtering sediments and other pollutants from the water in the soil before it reaches a water source, such as a stream, lake or River. Having a buffer of forestland by streams and riverbanks contributes much more than just filtering the water. It helps prevent erosion of sediment into the water, recharges the water table by allowing water to enter the ground and even the shade of trees play an important role in the lives of certain fishes, especially the freshwater ones like the trout. In spite, enormous benefits and values forests provide, they have been always been overexploited. Thus, most forests are in the state of degradation and deterioration and are not unable to sustain the ecosystem services (Hughes, 2008). Sustainable management of forests requires continuous efforts, financial resources, engagement and participation of forest dependent communities besides support of appropriate laws, policies and political will (FAO, 2010).

1.12.2 Riparian Forest Buffers as 'Biological Filters' – Ecological Machinery for Self Purification and Bioremediation in River Ecosystems

The term 'Riparian' connotes to the sum total of biotic communities and the environment on the shores of streams, rivers, ponds, lakes and some other wetlands; and 'Riparian forest' refers to the vegetation directly adjoining to the rivers. Properly applied on a landscape level, Riparian and upland forest buffers can enhance and diversify farm income opportunities, improve the environment and create wildlife habitat. By developing an understanding of the interactions between a Riparian buffer (i.e., trees, shrubs, grasses, etc.), the stream, and the adjacent upland area, (Shultz *et al.*, 2004). Riparian forest buffers are combinations of trees, shrubs, grasses, forbs and bioengineered structures adjacent to, or within, a stream channel designed to mitigate the impact of land use on the stream. Riparian forests are one of the biospheres most complex ecological systems but also one the most important for maintaining the vitality of the landscape and its rivers (Welsch, 1991; Lowrance *et al.*, 1985; Wenger, 1999). Buffers have high levels of soil moisture, experience frequent flooding, and are populated by plant and animal communities that are adapted to life along the water. The boundary between the buffer and adjoining uplands is gradual and may not be well defined (Klapproth, 2009). Riparian buffers protect the quality of the water, intercept nonpoint source pollutants carried by surface water runoff, and remove the excess nitrogen, phosphorus and other substances that can pollute water bodies, stabilize stream banks, and minimize erosion, decrease the frequency and intensity of flooding and low stream

flows, prevent sedimentation of waterways, and through shading reduce swings in stream temperatures and prevent elevated temperatures harmful to aquatic life. Riparian vegetation removes metals, nutrients, and other chemicals from runoff via plant uptake and by facilitating bacterial degradation of the pollutants (Castelle and Johnson, 2000). Although narrow buffers can generally remove sediment in runoff, wide buffers are needed for effective nutrient removal (Dabney *et al.*, 2006). The removal of nitrogen, a major pollutant of many watersheds, from runoff occurs almost exclusively in watersaturated zones where abundant organic matter is present and the bacteria present in those watersheds uses nitrogen as an energy source, converting it to gas. Some plant roots also absorb nitrogen in groundwater and use it for growth and development. Buffers here act as a nitrogen sink when it is taken up by trees and stored in their biomass.

Riparian buffer zones are performing a wide range of ecological functions along with economic and social values to people. These functions include, (a) Trapping/ removing sediment from runoff, (b) Stabilizing stream banks and reducing channel erosion, (c) Trapping/ removing phosphorus, nitrogen and other nutrients that can lead to eutrophication of aquatic ecosystems, (d) Trapping / removing other contaminants, such as pesticides, (e) Storing flood waters, thereby decreasing damage to property, (f) Maintaining habitats for fish and other aquatic organisms by moderating water temperatures and providing woody debris, (g) Providing habitat for wildlife, (h) Improving the aesthetics of stream corridors, and (i) Offering recreational and educational opportunities (Malanson, 1993; Schueler, 1995; Wenger, 1999; Shultz *et al.*, 2004). The Riparian buffers, directly affect and are also directly impacted by the aquatic environment.

1.12.3 Forest Ecosystems – Fragmentation and Degradation

The history of human existence and civilization is strongly linked with forests and people all over the world depend on forests for various goods and services provided by the forests. Forests are home to 300 million people around the world. Historically, the coming up of civilizations across the planet made abundant use of the forest resources. Forests were heavily grazed by livestock and burnt in the mountainous tracts, particularly in the River basins for promoting pastoralism or expansion of agriculture which promote soil erosion. In past two centuries or so, forests were heavily worked, cleared and extensive commercial plantations were raised to meet the growing demands of timber and other forests based industries. Forests were also severely impacted by the development of linear infrastructure (road and rail network) and other developmental activities like the establishment of multipurpose hydroelectric projects, industries, new townships etc.

The process of forest fragmentation due to human activities such as logging or conversion of forests into agricultural areas and suburbanization has been identified as the most important factor contributing to the decline and loss of species diversity worldwide (Noss and Cooperrider, 1994). Simply defined, forest fragmentation refers to any process that result in the conversion of

formerly continuous forest into patches of forest separated by nonforested lands. The definitions of fragmentation are as diverse as the subject itself. For instance, a definition which uses habitat as the qualifier is 'the splitting or isolating of patches of similar habitat, typically forest cover, but including other types of habitat' (Lenore, 2003). Habitat can be fragmented naturally or from forest management activities, such as clearcut or logging. In another example, the definition is empirically linked to population growth, 'fragmentation is a complex phenomenon resulting from dynamic interactions between the Natural Landscape and society's everincreasing demands on the land, creating a mosaic of natural and humanmodified environments' (Laurance, 2000). The consequences of fragmentation include habitat loss for some floral and faunal species, habitat creation for others, decrease connectivity of the remaining vegetation, decreased patch size, increased distance between patches and an increase in edge at the expense of interior habitat (Reed *et al.*, 1996; Midha and Mathur, 2010). There is a general consensus that fragmentation has a strong negative impact on biodiversity within forests. Fragmentation of the forest leads to degradation. Forest degradation is a process leading to a 'temporary or permanent deterioration in the density or structure of vegetation cover or its species composition'. It is a change in forest attributes that leads to a lower productive capacity caused by an increase in disturbances by human activities for domestic, industrial and infrastructural development. Forest degradation is the changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services.

The long history of forest management besides high human disturbances, particularly in higher reaches or upstream forested tract along the streams and River courses has severely impaired not only the functioning of forest ecosystems by way of forest fragmentation and degradation but also induced soil erosion, and impacted environmental flow and biota in terrestrial and aquatic ecosystems. Forest degradation on account of uncontrolled livestock grazing, recurrence of forest fires and invasion of alien species results into decline of capacity of forest ecosystems to provide important goods and services to people and nature.

1.12.4 Forests and Water Strong Linkages

The intricate relationship between forests and water has been of great interest to the natural resource professionals and policy makers. The relationship between forests and water is complex that deserves to be accorded a high priority (Calder *et al*., 2007). Forests are, in all circumstances, necessary good for the water environment they increase rainfall, increase runoff, regulate flows, reduce erosion, reduce floods, sterilize water supplies and improve water quality (Calder, 2004). The most sustainable and best quality freshwater sources in the world originate in forest ecosystems. The biological, chemical, and physical characteristics of forest soils are particularly well suited to delivering high quality water to streams, moderating stream hydrology, and providing diverse aquatic habitats. Conversion of forests to grow crops, pastures, or lawns almost always results in deterioration of water quality (Neary *et al.*, 2009). The availability and quality of water in many regions of the world are more and more threatened by

overuse, misuse and pollution, and it is increasingly recognized that both are strongly influenced by forests. Moreover, climate change is altering forest's role in regulating water flows and influencing the availability of water resources (Bergkamp *et al.,* 2003). Therefore, the relationship between forests and water is a critical issue that must be accorded high priority.

Often, interactions between forests and water are of a transboundary nature and that requires collaboration at the interNational Level. Thus, forest and water interaction need to be recognized and considered in the broader landscape context and an integrated approach should be applied at the local, national and interNational Levels. The International Year of Freshwater 2003 and the third World Water Forum (Kyoto, Japan, 2003) helped drive the incorporation of this understanding of biophysical interactions between forests and water into policies. In recognition of the crucial relationship between forests and water, there has been increasing international actions to address forestwater interactions since the 3rd World Water Forum and Shiga Declaration in 2002 and a Five Year Action Plan emerged from the discussions and recommendations of the Forests and Water Agenda. This plan calls for the tangible integration in science, policy, economics and forest practices related to forestswater interactions (Forests and Water agenda, 2014). The Sustainable Development Goals (SDGs) related to water (SDG 6) and land (SDG 15) explicitly acknowledge the linkages between forests and water.

1.12.5 From 'Isolationist' to 'Holistic' Approaches to River Conservation

The foregoing narration illustrates that for a long time mainly isolationist approaches were adopted for researches on rivers, their management and conservation. The much desired holistic River basin approach or the concept of riverscape was thus ignored, resulting in little success of River conservation initiatives and programmes. The dynamic nature of rivers, their complexities, intricacies and interconnectedness and entirety from the perspective of ecological integrity, connectivity, water flow, and livelihood and biodiversity conservation also have been overlooked (Molle *et al.,* 2007).

One of the envisaged major activities for restoration of Sutlej is 'forestry interventions' so as to enhance the productivity and diversity of the forests in headwater areas and all along the River and its tributaries. The availability and quality of water in the Sutlej have been increasingly threatened by over use, misuse and pollution, and both are strongly influenced by the extent and condition of forests in the upstream and downstream areas. More so, looming climate change is also likely to alter the role of forests in regulating the water flows and influencing the availability of water resources (Bergkamp *et al.,* 2003; Calder *et al.,* 2007). These strong linkages between forests and water urgently seek high priority attention by adopting holistic approach through forestry interventions.

1.12.6 Current Task – DPR Preparation on Forestry Interventions for Rejuvenation of Sutlej River

Isolationist approaches to River management till recent times constrained the development of new scientifically based comprehensive approaches for River development and management. It is only in recent decades that hydrological, geomorphologic and biological researches have been integrated to establish a new understanding for the dynamic River systems. Recent approaches to River management emphasize the riverine landscape or 'Riverscape' perspective as running waters are open ecosystems (Eros and Lowe, 2019). The riverscape approach integrates rivers with their surrounding landscapes.

In contrast to specific species focused management and evaluation, the current emphasis is on ecosystem management which focuses on key processes that enable Riverfloodplain systems to maintain, repair and regenerate themselves to a certain state. The ecosystem approach seeks an insight through interdisciplinary researches at all stages of the planning, implementation and evaluation process. 'Forestry Interventions' on a scientific basis are pertinent for River conservation, specifically River restoration and overall sound ecological health of River ecosystem. The proposed DPR aims to adopt a holistic approach of River basin management for restoration through multistakeholder consultative process. The existing scientific knowledge, past experiences, landuse changes and their effects and varied expertise available will be utilized for developing the framework, strategies and activities of the DPR. The concept of River ecology, spatial analysis of Riverscape through application of Remote Sensing and Geographical Information System for delineation of sites and collection of primary and secondary data analysis, identification and selection of critical areas for treatment, approaches for soil conservation, developing plantations models relevant to Sutlej Riverscape and prioritization of forestry intervention sites will also be used for the preparation of DPR.

Realizing the current plight of all major Indian rivers, the Government of India, NITI Aayog prepared a programme for action. The Department of Rural Development prepared an action plan to launch a major mission on revitalization of Rivers. Accordingly, the NITI Aayog directed concerned central ministries and Chief Secretaries/Administrators of all States and UTs to initiate pilot projects for revitalization of rivers by appropriate convergence of schemes and active involvement of various stakeholders. In response to this, the MoEF&CC through the National Afforestation and Eco-Development Board (NAEB), which was set up in August 1992, and is responsible for promoting afforestation,tree planting, ecological restoration and eco-development activities in the country, with special attention to the degraded forest areas and lands adjoining the forest areas, national parks, sanctuaries and other protected areas as well as the ecologically fragile areas like the Western Himalayas, Aravallis, Western Ghats, etc., assigned a major task on the preparation of DPR(s) on Forestry Interventions for rejuvenation of 13 major Indian Rivers (tributaries of Indus – Jhelum, Chenab, Ravi, Beas and Sutlej; Yamuna, Luni, Narmada, Godavari, Mahanadi, Krishna, Cauvery and Brahmaputra) to the ICFRE, Dehra Dun, an autonomous organisation under its control. The ICFRE with its umbrella organisation

spread across each region of the country, responsible for carrying out forestry research, education and extension activities is an apex body in the national forestry research system with mandated task of research, education and extension in the States/UTs under their jurisdiction. Thus, HFRI Shimla, has been entrusted the task to prepare DPR(s) of five tributaries of the Indus River, falling in their mandated jurisdiction. The present DPR specifically deals with the Sutlej River, a major tributary of the Indus River. The ICFRE has allowed HFRI a time frame of 12 months to prepare the DPR envisaging that proposed forestry interventions will immensely facilitate the major goals of accomplishing *Aviral Dhara* (uninterrupted flow), *Nirmal Dhara* (clean flow) and ecological regeneration of aquatic and terrestrial life/ biota.

1.12.7 Himalayan Forest Research Institute (HFRI) – A Knowledge Management Centre

Himalayan Forest Research Institute (HFRI), Shimla, is one of the nine institutes under the umbrella of ICFRE. Initially, HFRI, Shimla was established as the High Level Conifer Regeneration Research Centre during 1977, with specific objective to carry out researches on problems associated with natural regeneration of Silver Fir and Spruce. In 1998, the Government of India appreciating the environmental problems of Temperate Forests Ecosystems and high altitude ecology in the Himalayan States, particularly Himachal Pradesh and Jammu & Kashmir (now Ladakh and J&K UTs) decided to develop this Centre to a fullfledged research institute at the time of reorganization of forestry research in ICFRE. The Institute has been mandated to carry out forestry research, education and extension activities in State and UTs in western Himalayan region with a focus on ecorehabilitation of cold desert, regeneration of coniferous and broadleaved forests, insect pest management in temperate forests, and popularization of agroforestry. HFRI is well equipped with state of the art laboratories and other facilities in its own campus at Panthaghati, Shimla. The Institute has established six experimental field research stations, model nursery and model village in different parts of Himachal Pradesh, J&K and Ladakh UTs. The institute has a team of multidisciplinary scientists working in five divisions and supported by technical staff. Since its establishment, HFRI has made significant contributions towards the development of suitable nursery techniques, propagation of native plant species and ecorestoration of mined areas and cold deserts. Over the years, HFRI has developed as a knowledge management center in the field of high altitude ecology (Himalayan and TransHimalayan regions) and conservation of diverse temperate forest ecosystems and privilege to have essential ingredients: (a) Professionals and expertise, (b) State of the art laboratories and other physical infrastructure, and (c) Processes and innovative technologies (HFRI, 2020)

1.12.8 Project Development Phase and Preparation of DPR – The Approach

HFRI has followed the broad framework of DPR as adopted earlier in the context of forestry interventions for rejuvenation of River Ganga as per the direction of MoEF&CC and ICFRE. Vast field based experience, existing scientific knowledge available at the Institute have been

optimally utilized for planning, assessment and development of suitable approach and strategies in the case of the DPR preparation. The Sutlej River originates from the Tibetan plateau, enters the state of Himachal Pradesh and flows in the plains of Punjab before its confluence with Beas River at Harike Pattan. In short, concerned two States (Himachal Pradesh and Punjab) were involved in the extensive consultative process, planning and assessment. The project launch workshop and sequential consultative meetings organized in two States included policy and decision makers, representatives of SFDs and various line agencies, State/National Level scientific or specialized organizations, Universities, Civil Society and NGOs, besides expertise from conservationists. The well planned consultative process and feedback obtained from various stakeholders during the various consultative meetings played a vital role in the formulation of strategies and preparation of the present DPR.

1.12.9 Logical Framework Approach

Managing a River Basin or River ecosystem or a Riverscape is a challenging task due to conflicting needs such as drinking water and industrial supply, irrigation, power generation, waste dumping, navigation, sand mining, fish harvest, water sports and recreation, and flood mitigation besides the development of the basin in terms of water resources, urbanization and wetland protection (Bong and Putuhena, 2008; Puranik and Dhadwad, 2015). Conservation of these systems requires consideration of interacting and often competing ecological and social factors and values (Hand *et al.*, 2018). Hence, Riverscape level planning and conservation requires integration of physical, biological and socioeconomic subenvironments of River ecosystem adopting participatory approaches and active involvement of stakeholders.

Over the years, various international agencies working in the development sector have evolved various approaches *viz.*, Logical Framework Approach (LFA), Programme Logic Model (PLM) and ResultsBased Management (RBM) those offer analytical tool for systematic and logical approach for designing projects with inbuilt mechanism for distinct performance review or evaluation so as to enhance the efficiency of such developmental projects and to ensure accomplishment of desired outcomes and goals (Framst, 1995; Cummings, 1997; Puranik and Dhadwad, 2015; Örtengren, 2016). Cummings (1997) has described role and use of LFA, PLM and RBM and pointed out their similarities and differences. The LFA developed in late 1960s has been under continuous development and has been adopted by major agencies for monitoring. LFA is an extensive, participatory and integral method that delivers a wellstructured plan with clearly measurable objectives and welldefined, relevant activities and indicators (Örtengren, 2016).It facilitates efficient communication mechanism between decision makers, practitioners and other stakeholders involved in the project. This approach facilitates the planning, monitoring and management of ‘Change Processes’ so that they can achieve positive and sustainable results. Considering the recognition of LFA as one of the most efficient tools for designing, implementation, monitoring and evaluating developmental projects, this approach has been used in the process of preparation of present DPR.

1.12.10 Aims, Objectives and expected outcome of the Project

Recognizing the diversity, complexity and intricacies of forest ecosystems and pivotal multiple functions performed by them and their interconnectedness with highly dynamic River ecosystems, the HFRI has embarked on the task to adopt a holistic approach of River basin management for the restoration of Sutlej River and to prepare a Detailed Project Report (DPR) with the following vision, objectives and outcomes:

i) Vision: Conservation and sustainable use of biodiversity of Sutlej River ecosystem is fundamental to ecologically sustainable development in its catchment. Biodiversity is an integral part of human lives & livelihoods and constitute resources upon which families, communities, nations and future generation depend and in Sutlej basin need to be conserved and sustainably utilized for the welfare of human beings.

ii) Objectives:

a. To review and assess the existing situation of Sutlej River Basin, past River management and implications, and lessons learned.

b. To identify and involve stakeholders and build consensus for design and development of strategies and approaches.

c. To assess ongoing forestry activities by the Himachal Pradesh and Punjab engaged in the River management programme(s).

d. To assess potential and possibilities for regeneration, improvement, and restoration of forest catchment.

e. To examine the possibility of allied and other income generation activities.

f. To assess the potential of cultivation of medicinal and aromatic plants and restoration of conservation areas and identify appropriate species and suitable sites.

g. To identify research and monitoring needs and develop a strategy for future research and monitoring.

h. To formulate strategies, develop approaches and plan activities for project implementation.

iii) Expected Outcomes: Proposed Forestry Interventions involving extensive plantation activities in three Landscapes (Natural, Agriculture and Urban) within the Sutlej Riverscape besides execution of planned Conservation Interventions and Supporting Activities. Likely potential benefits of proposed interventions in terms of increased availability of water; enhanced eflow; reduced soil erosion and sedimentation; augmented forest cover; and improved water quality, terrestrial and aquatic biota, ecosystem services and rural livelihoods besides significant contribution towards climate change mitigation by way of sequestration and storage of carbon. It is pertinent to mention here that the plantations produce range of direct and indirect environmental benefits, which when taken into account, would lead to much higher benefits.

1.13 Organization of DPR

The present DPR is prepared in two volumes. Volume I deal with the main DPR while the Volume II contains summaries of two States located along the course of the Sutlej River. Chapter 1 of VolI 'Introduction' highlights the complexity and dynamic nature of rivers and its linkages with forests, other lands, and human wellbeing, past and present River management, evolving concepts and holistic approach of basin management and Riverscape, current task on forestry interventions, logical framework, and the organization of the DPR. Chapter 2 highlights the existing environment (physical, biological, and socioeconomic subenvironments) in the broader context of Sutlej River Basin, in particular the riverscape under consideration along the course of SutlejRiver. This Chapter emphasizes the details of biodiversity in terms of diverse forests, grasslands, wetlands, and associated threatened species besides the physical and the socioeconomic environment. Chapter 3 describes the Riverscape, i.e., the planning and assessment area for DPR and the approach adopted. Chapter 4 deals with the details of various central and state governmentlevel agencies and organizations that are directly responsible for the policy and decision making, overseeing and implementation of various activities relevant to water resources, environment, forest management, biodiversity conservation, River management, etc. This Chapter critically examines the existing policies, conventions, treaties and laws pertaining to the themes of the DPR, identifies gaps, imperatives and future needs from the perspective of various users and those who either influence/impact or are responsible for the management of water resources. Chapter 4 also provides an insight into various civil society organizations *viz*., *Nehru Yuva Kendra Sangathan* (NYKS) and Indian Armed Forces (Eco-Task Force), Central Armed Police Forces (IndoTibetan Border Police) those can either undertake activities relevant to forestry interventions or assist and facilitate in various supporting activities. Chapter 5 describes the goals and objectives of forestry interventions and the adopted strategies for implementation. This is followed by Chapter 6 which specifically narrates institutional arrangements and mechanisms for project implementation besides aspects of sustainability. The Chapter 7 provides details on the overall project budget, cost tables and the schedule of operations. The last Chapter provides an insight on potential benefits of proposed forestry interventions. References are provided at the end. As already stated, Volume II incorporates details of State summaries concerning the States of Himachal Pradesh and Punjab of the Sutlej Riverscape that have been included for implementation during the Phase-I and Phase- II of the Project.

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CHAPTER-2

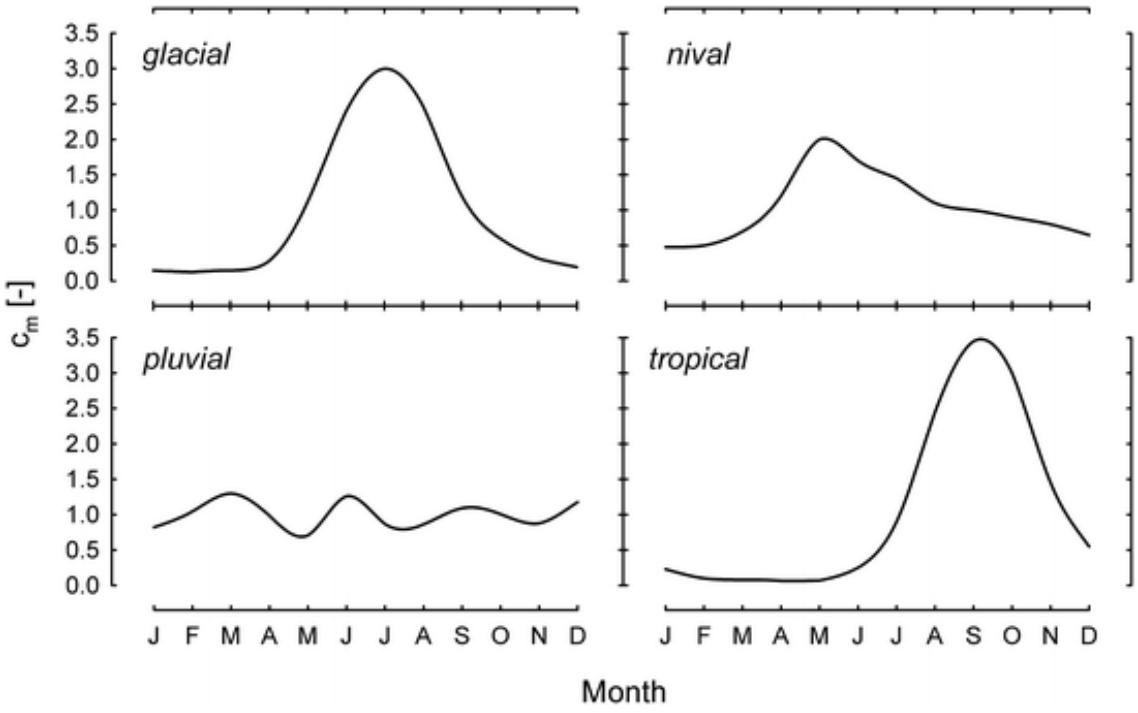
SUTLEJ RIVERSCAPE AND ITS ENVIRONMENT

2.1 River Environment

'River is more than just the water inside it and water being only one component of the River ecosystem'. The overall environment of an intricate River ecosystem comprises of the; (i) physical, (ii) biological, and (iii) socio-economic sub-environments. Further, the interactions between these subenvironments i.e., between plants, animals, microorganisms and their natural environment having nonliving physical and chemical components, etc., together contribute to River Ecology. Water flow is the main factor that makes River ecology different from other water ecosystems. This is known as a lotic (i.e., flowing water) system and this flow or hydrology is the central driving force of River ecology. In other words "The water runs the River" (Zeiringer *et al.*, 2018).

In terms of geomorphic context which refers to the geomorphic setting of a River reach, is defined as a length of River with consistent valley and channel geometry (Ellen, 2018). Geomorphology represents the configuration of the earth's surface, the distribution of the land, water, etc., and is largely determined by topography and geology. Thus, geomorphology in turn dictates how water flows across the landscape or, in other words, the hydrology.

High altitude rivers, particularly Himalayan Rivers receive water mainly from glacial melt during summer with distinct diurnal melting peaks following air temperature warm up (i.e., glacial regime) (Fig. 2.1). At lower elevations snow melting in spring causes seasonal peaks (i.e., nival regime) while periods of high flow and floods due to rainfall can occur at any time of the year (i.e., pluvial regime). Tropical rivers are characterized by distinct flow cycles related to dry and wet seasons. The tropical regime is similar to the pluvial regime, i.e., drought in the dry season and abundant rainfall in the wet season. Depending on the local conditions and position within the catchment, observed flow may represent a mixture of hydrological regimes. Flow regimes are very important to understand the key functions and processes of Riverine ecosystems (Zeiringer *et al.*, 2018).



(Source: Adopted from Zeiringer *et al.,* 2018)

Fig 2. 1 Simple Hydrological Regimes

Flow can be affected by sudden water input from snowmelt, rain and groundwater. Water flow can alter the shape of riverbeds through erosion and sedimentation, creating a variety of changing habitats (McCabe, 2011). Floods and high flows carve and shape River channels and valleys and deposit sediments to create wide, flat floodplains, thereby changing the geomorphology. Living systems in a River are comprised of wide ranging plants, invertebrates and vertebrates that interact with nonliving systems. Four types of connectivity *viz.,* longitudinal (i.e., connectivity throughout the River length), lateral (i.e., connectivity of River to floodplain), vertical (i.e., connectivity to the underlying groundwater and aquifers) and temporal (connectivity of River overtime) in a River help to develop understanding of the complex nature of a River ecosystem (McDonough, 2011; Scott *et al.,* 2018). These four types of connectivity are of paramount importance as they ensure natural processes to continue to occur in a River. These types of connectivity also ensure flow of energy and nutrients between and within aquatic and terrestrial environments. In view of these intricacies and interrelationships, an understanding of longitudinal changes from the River's source to its mouth, vertical interactions, lateral exchange processes and temporal changes and patterns in the overall environment of the River itself and its surrounding lands are vital for evolving an effective scientific basis to River management (Loucks and van Beek, 2017).

River systems are under ever increasing pressure through the growing demands of water abstraction and hydroelectric power generation, and suffer recurrent disturbance through diffuse and point source pollutants, drought, flooding and channel modification. The environmental management of rivers is required to mitigate the effects of these pressures which requires a holistic understanding of how River systems are structured and function, and of how these systems have been altered by anthropogenic activities (IWA). The MoEF&CC, GoI has decided to adopt the River basin approach for restoration of the Sutlej River and its management under the proposed forestry interventions and for this reason, much of the available information/ literature either relates to the entire Sutlej River Basin spread over three countries (i.e., India, Pakistan and China) or in the context of the largest part of the basin which lies within India itself, and is spread over its northwestern Indian States of Himachal Pradesh, Punjab, Haryana andUnion Territory of Ladakh.

The present attempts have been made to examine the above subenvironments in the context of the Sutlej River Basin and, in particular, the Sutlej Riverscape selected for the purpose of its proposed forestry interventions. However, on the basis of consensus emerging in the exhaustive consultations with various stakeholders, a Riverscape covering an area of 24,110.83 km^2 falling in Himachal Pradesh and Punjab has been delineated for the purpose of proposed forestry interventions. Area coverage of Sutlej Riverscape and Sutlej River Basin within India has been shown in Table 2.1. The following sections attempt to depict the physical, biological and socioeconomic subenvironments of the Riverscape based on the collation and synthesis of secondary information and planning and assessment exercises carried out as part of the present task of preparation of the DPR. Therefore, information and insight on the physical and socioeconomic environment was adequately reviewed, summarized and presented while efforts to link the insight thus developed effectively with the vital part of the biological environment from the forestry, wildlife and biodiversity perspectives has been emphasized in the following sections.

Table 2. 1 Area coverage under the Sutlej River Basin and the Sutlej Riverscape

Sr.No.	Consideration Unit	Area Covered (km^2)	Coverage Area (States/UT)
1.	Sutlej River Basin (India)	48,321.62	Union Territory of Ladakh, Himachal Pradesh, Punjab and Haryana
2.	Sutlej Riverscape	24,110.83	Himachal Pradesh and Punjab

(Source: Microwatershed Atlas of India; SLUSI)

The drainage area of the Sutlej River Basin within India lies in one Union Territory i.e., UT of Ladakh and three states i.e., Himachal Pradesh, Punjab and Haryana located along the River course of Sutlej River from its origin to confluence. The State wise distribution of the Riverscape is presented in Table 2.2.

Table 2. 2 State wise Distribution of the Riverscape Area of Sutlej River

Sr. No.	State	Geographical Area of the State (km^2)	Extent in the Riverescape (km^2)	Representative Area of the States (%)	Representative Area of the Riverescape
1.	Himachal Pradesh	55,673.00	20,154.61	36.20	83.59
2.	Punjab	50,362.00	3,956.22	7.86	16.41
Sutlej Riverscape (Total)		**1,06,035.00**	**24,110.83**	**22.74**	**100.00**

2.1.1 Area Coverage under Sutlej River Basin and Sutlej Riverscape

Nearly 84% of the area of Sutlej Riverscape is located in Himachal Pradesh (i.e., upstream of Bhakra Dam right up to Shipki La on main Sutlej River Basin and up to KunzumLa in Spiti Subbasin). Sutlej River Riverscape is considered to be the most active and covers 36.20% of the total geographical area of Himachal Pradesh. The elevation of the Basin varies between 540 m to 6,680 m amsl. Along its course within the State, the River passes through Lahaul & Spiti, Kinnaur, Shimla, Kullu, Mandi, Solan and Bilaspur districts. The Sutlej River has a length of about 1629 km and flows through hilly and plain areas of Tibet (China), India and Pakistan. According to Khan *et al*., (2013) total catchment area of Sutlej River Basin is about 1,06,728.23 km^2, out of which 46,200.21 km^2 (43.29%) area is shared by China, 31,437.28 km^2 (29.45%) lies in India and 29,090.75 km^2 (27.26%) falls in Pakistan. The upper tracts of the Sutlej Basin are under permanent snow cover and its snow fed tributaries carry significant volume of water, which fluctuates seasonally. It covers the Nari Khorsam province of Tibet, China and that of Himachal Pradesh, India. The geographical limits of the Sutlej River Basin upto Bharka Dam lie between Latitudes 30° to 33° N and Longitudes 76° to 83° E. The catchment area upto Bhakra Dam is about 56,875 km^2, out of which about 36,000 km^2 is in Tibet and 20,875 km^2 in India (Kumar, 2015). The Basin represents some remarkable physical features, in the loftiest mountain ranges of the world radiating from the Pamir Knot and later in an easterly direction constitutes a massive mountain wall extending over 2,500 km with a varying width of 250 to 300 km. The Sutlej River is bounded in the east by the water divide of the Giri Khad (a tributary of Yamuna River) and on the west by that of the Beas River. The catchment area of Sutlej River Basin comprises of 6 Agro-Ecological zones (ICFRE, 2014).

2.1.2 Area Coverage of Sutlej River in Himachal Pradesh

Sutlej River Drainage Area

The Sutlej River after flowing through varied topography finally drains into the Indus River in Pakistan. The River's total length is around 635 km with delineated Riverscape area is being

about 24,110 km^2. Enroute, Sutlej River is fed by numerous glaciers, lakes, rivers and streams. It also receives water from many *Khad*s i.e., Nogli, Ghanvi, Kurpan, Macchad, Ropa, besides numerous other seasonal streams. Erosion, silt and road widening in Sutlej Valley is much higher as compared to its neighbouring streams.

In the upper catchment of the River (i.e., temperate and cold arid zones of Himachal Pradesh), the water received via precipitation is either stored in ice and snow during winter or infiltrates into the groundwater and is released into rivers during summer. Thus, topographically and climatologically, the upper catchment area can be divided into four following categories as per DHI, 2006.

(a) Tibetan Plateau: The Sutlej River enters India near Shipki La after traversing a length of about 320 km in the Tibetan Province of Nari Khorsam. The region receives no local rainfall and the precipitation is entirely in the form of snow. During summers, the snow melt results in deep channel formation on the almost barren landscape. This cold desert region is characterised with scanty or almost no vegetation.

(b) Spiti Valley: Spiti River is the largest tributary of the Sutlej River and meets the River at Namgia (Khab), about 14 km upstream of Pooh. The characteristics of this catchment area are identical to that of the Tibetan Plateau, but with a little more scrubby vegetation. Rainfall is scarce in this area and precipitation is in the form of snow during the long winter season. An altitude variation in the catchment area drained by Spiti River is between 3,048 to 4,570 m.

(c) Khab to Nathpa Dam Site: The catchment area is bounded by moderately high hills with elevation ranging from 1,525 to 3,048 m amsl. The region too receives little rainfall, but snow fall remains very heavy. The River flow is mainly due to snow melt, which follows more or less a regular pattern. The area has steep to very steep slopes with little soil cover. Due to the absence of rain, cold arid conditions prevail and the forests are seen only around Ribba, Purbani, Reckong Peo, Kalpa, Baspa Valley and Kilba. The pine forests near KarchamWangtu give way to Chilgoza (*Pinus gerardiana*) plantations in the higher altitudes.

(d) Nathpa Dam Site to Bhakra Dam: The catchment in its upper zone is characterised by steep dry cliffs on the southern aspects while on the northern aspects there are good temperate forests. In its lower zone, it is flanked by the sub-tropical Shivalik foot hills near Bhakra Dam (296 m). Rainfall in the region is moderate to heavy during the monsoon. The area is forested with dense temperate forests in the upper valleys and scattered subtropical scrubs in the lower zone. There is extensive agricultural and horticultural development in several locations, mainly along the River and on flatter hill slopes. In the lower area, Rampur to Bhakra, the average slope of the River is very steep, with heavier rains and silt loads. The forest cover is sparse with denudation of vegetation as a result of overgrazing.

2.1.3 Area Coverage under Sutlej River in Punjab

Sutlej River is the easternmost and longest River of Punjab, India. It enters into Punjab near Nangal, moves on to the plains at Ropar, Enroute passing through the districts of Ludhiana, Jalandhar, Kapurthala, Nawanshahr, Mohali, Amritsar and Firozpur and finally reaches Harike Lake, a prominent weltland also a Ramsar Site before crossing into Pakistan. Its total length is 440 km in Punjab and it is here that it receives a large amount of effluents from various industries (i.e., fertilizer, brewery, paper and pulp mills, cardboard, pipes and tubes, slaughter houses, etc.) and city sewage via 'Budha *Nallah* and East Bein' which degrades the water quality of the Sutlej River (Sharma *et al.,* 2017). Average discharge of Sutlej River in the state of Punjab as measured at Ropar is approximately 500 m^3/sec. The total catchment area of Sutlej River in Punjab is approximately 20,303 km^2.

2.2 Sutlej–Head Streams, Main Stem, Tributaries, Confluence Points and its Delta

Sutlej rises from beyond Indian borders in the southern slopes of the Kailash Mountain near Manasarovar Lake from Rakshastal Lake, as Longcchen Khabab River (in Tibet) and is a principal River of Indus River. Sutlej River Basin, is located in the western and northwestern Himalayan region.



Plate 2. 1 Confluence of Spiti with Sutlej at Khab

Headwater streams, which form the hydrologic connectivity, are the smaller tributaries that carry water from the upper reaches of the watershed to the main channel of the River. Hydrologic connectivity is the watermediated transport of matter, energy and organisms within or between elements of the hydrological cycle. Headwater streams compose over two thirds of total stream length in typical River drainage and directly connect the upland and Riparian Landscape to the rest of the stream ecosystem (Mary *et al.,* 2007). Based on the estimation of stream orders the Sutlej River Basin falls under 7^{th} order. Drainage pattern of stream network in the Basin is mainly observed as the dendritic type. Sutlej River is the principal and easternmost tributary of the Indus River System, which successively crosses three mighty mountain ranges i.e., Zanskar, Great Himalaya, and the Lesser Himalaya i.e., the Dhauladhar Range. The availability of a Perennial River due to permanent glaciers makes this River Basin unique from the other basins. Under the Indus Water Treaty (IWT) which was signed in 1960s between India and Pakistan, the waters of the Sutlej River are allocated to India, and are mostly diverted to irrigation canals in India. It enters Himachal Pradesh at Shipki La and flows in the southwesterly direction. The upper tracts of the Sutlej River Valley are under the permanent snow, providing continuous water flow. Along its journey, it is joined by various tributaries (Fig. 2.2) and the first major tributary of Sutlej River within Indian Territory is the Spiti River which joins it at Khab. The other right bank tributaries include Ropa, Kashang, Sorang, Ganwai, Kashang, Kurpan, Mulgaon, Yula, Wanger, Throng and Rupi. The major left bank tributaries of Sutlej River are Gayathing, Baspa, Dubling, Panwai, Nogli, Tidong and Soldang (ICFRE, 2014).



Plate 2. 2 General view of Sutlej River at Kinnaur

Sutlej River cuts a gorge in Naina Devi Dhar, where the famous Bhakra Dam has been constructed, before entering the Punjab plain (Sarma, 2019). After entering the plains at Rupnagar (Ropar), it turns westwards and is joined by the Beas River at Harike Pattan. A big dam across this gorge near Bhakra village has been constructed which has created a huge reservoir called the Gobind Sagar Lake Reservoir in Una and Bilaspur Districts of Himachal Pradesh with 56 km length and nearly 3 km width (SERHP). It meets the Beas River in Firozpur district of Punjab. Continuing wests to outhwest, the Sutlej River enters Punjab province, Pakistan. It joins with the Chenab River, forming the Panjnad River, which finally flows into the Indus River. The Indus River then flows through a gorge and the plain region of Sindh (Pakistan), forming a large delta region, finally flowing in the Arabian Sea. Evidence suggests that the Indus Valley Civilization also flourished on the banks of Sutlej River. Today, Sutlej River plays a key role in the economy of northern India.



(Source: Adopted from ICFRE, 2014)

Fig 2. 2 Tributaries of Sutlej River in Upper Sutlej River Basin

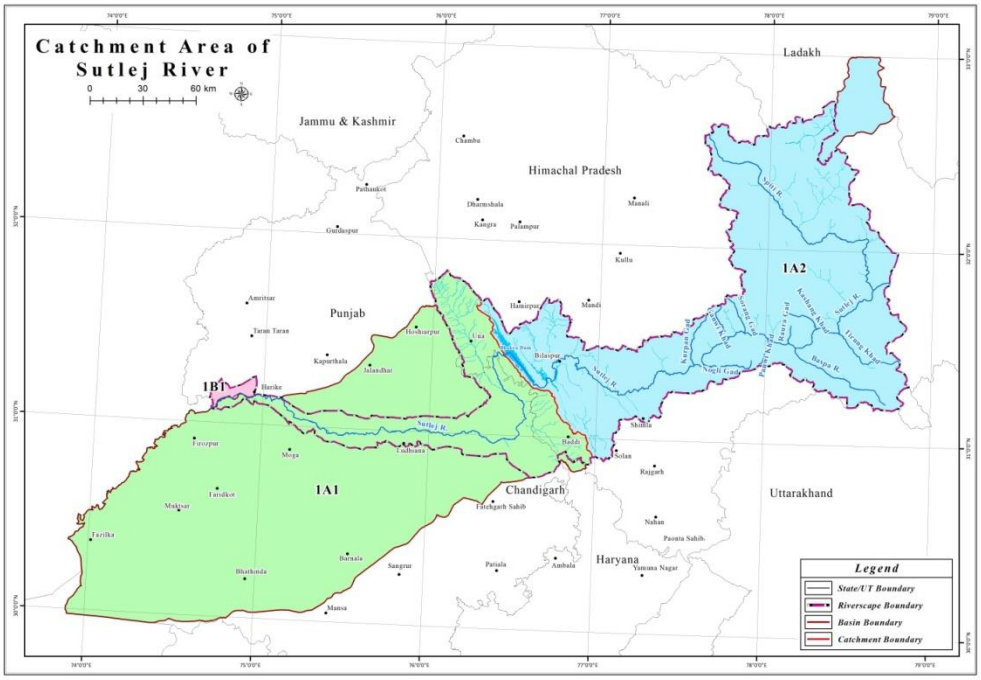


Fig 2. 3 Sutlej Riverscape, its Catchment and Major Tributaries

The delineated area known as the Riverscape is situated between Latitudes 30° 44' 19" to 32° 56' 42" N and Longitudes 74° 39' 26" to 78° 50' 31" E respectively and covers a geographical area of 24,110.83 km^2. The length of the Sutlej River main stem and its major tributaries are given in Table 2.3 and Fig 2.3.

Table 2. 3 Length of Sutlej River Main Stem and its Major Tributaries

Sr. No.	River Name	State	River Length (km)
Sutlej Main Stem			
1.	Sutlej River	Himachal Pradesh	350.58
2.	Sutlej River	Punjab	284.44
Total length			**635.02**
Major Tributaries			
1.	Spiti River	Himachal Pradesh	185.58
2.	Tirung Khad	Himachal Pradesh	45.98
3.	Kashang Khad	Himachal Pradesh	22.23
4.	Baspa River	Himachal Pradesh	67.74
5.	Raura Khad	Himachal Pradesh	11.23
6.	Panwi Khad	Himachal Pradesh	16.59

7.	Bhaba/Wanger	Himachal Pradesh	35.0
8.	Sorang Khad	Himachal Pradesh	26.0
9.	Ganwi Khad	Himachal Pradesh	24.28
10.	Sorang Khad	Himachal Pradesh	23.67
11.	Nogli Khad	Himachal Pradesh	37.36
12.	Kurpan Khad	Himachal Pradesh	35.32
13.	Machhada Khad	Himachal Pradesh	23.0
14.	Baihna Khad	Himachal Pradesh	15.0
15.	Ali Khad	Himachal Pradesh	26.0
16.	Gambhar Khad	Himachal Pradesh	20.0
17.	Seer Khad	Himachal Pradesh	58.0
18	Swan Khad	Himachal Pradesh & Punjab	72.0
Total Length of Tributaries			**744.98**
Total Length of Sutlej Main Stem and Tributaries			**1,380**

2.2.1 Important Tributaries of Sutlej River

There are a large number of tributaries of the Sutlej River which are small and big. Prominent tributaries of the Sutlej River are: Spiti River, Titang *Khad*, Tingoo *Khad*, Ropa *Khad*, Tagla *Khad*, Koirnag *Khad*, Tidong *Khad*, Kashang *Khad*, Pangi *Khad*, Tangling *Khad*, Shyang *Khad*, Runga *Khad*, Baspa *Khad*, Roura *Khad*, Panwi *Khad*, Wanger *Khad*, Salring *Khad*, Soldan *Khad*, Chanda *Khad*, Sornag *Khad*, Kut *Khad*, Sallan *Khad*, Dharli *Khad*, Ghanvi *Khad*, Manglad *Khad*, Sechi *Khad*, Nogli *Khad*, Kurpan *Khad*, Machhada *Khad*, Ani *Khad*, Kingal *Khad*, Dhurmna *Khad*, Pandoa *Khad*, Chaainra *Khad*, Nauti*Khad*, Annun *Khad*, Manwal *Khad*, Suin *Khad*, Deoli *Khad*, Seer *Khad*, Lunkhar *Khad*, Gambhar *Khad* and Gambhrola *Khad* and Swan *Khad*.

Brief description of the main Indian tributaries of Sutlej River from origin to the confluence point at Harike is presented below.

i) Spiti River: The Spiti River rises from Kunzum Range on northern slopes of the Himalaya and drains through the famous Pin Valley National Park. It joins the Sutlej River at Khab in Kinnaur district after traveling a distance of about 150 km. Spiti River and its major tributaries (i.e., Tegpo and Kabzian) pass through huge mountains on either side. Its other tributaries are Lingti on the left bank and Pin River on the right bank. The main settlements along the River are Hansi and Dhankar Gompa (Chauhan *et al.*, 2016).



Plate 2. 3 General view of Spiti River

a) **Right Bank Tributaries of Spiti River** are Gyundi *Nallah*, RatangRiver, Parahio River and Yang Cho Lake. Gyundi *Nallah* with its main source being Sumto Kona Glacier joins the Spiti River near to Hal and Morang village. There are two *Nallah*s which join it as tributaries namely Gyundi *Nallah*or Shiya *Nallah* (on the left bank) and Kuligo *Nallah* (on the right bank). RatangRiver originates from the Shigri Parvat near to Khamengar Range in Spiti Block and is sourced from the Sumto Yoma and other nearby glaciers. The major tributaries of this River are Sanugba, Chhachhumi and Tarakh *Nallah*s. River Parahio, a glacier fed River is the major tributary of Spiti River with its origin near the boundary of Kullu district and Nichar block of Shimla district. Pin River is the major right bank tributary while Debsa *Khad* and Killing *Khad* are the left bank tributaries and Maro *Nallah*, a stream flows northward from the Yang Cho Lake and joins with Spiti River near Mane(Chauhan *et al.,* 2016).

b) **Left bank tributaries of the Spiti River** include, Kabjima *Nallah*, Takling *Nallah*, Puri Lungpa *Nallah*, River Lingti and River Parechu. Kabjima *Nallah* originates at the intersection of Lahaul and Spiti's block boundary and joins the Spiti River at an initial stage nearby Losar, being sourced from the permanent glacial bodies. Takling *Nallah* another tributary of Spiti River joins it on its left bank near Latarse village. Major tributaries of Takling *Nallah* are Kigar *Nallah* and Tokro *Nallah* joining it on the left bank. Puri Lungpa *Nallah* joins the River near to Sumling Gompa with its main supply from Dumla *Nallah* joining it on the right bank. LingtiRiver is the

major tributary of the Spiti River, feeding mainly from the Lagma glacier. Sheru River Tokpo originates from Lagma glacier and joins the Lingti River on the left bank. Other left bank tributaries of Lingti are Kebri Tokpo *Nallah*, Zingiu Tokpo *Nallah* and Tuti Tokpo *Nallah*. The major tributaries that join it on the right bank are the Sharma Lungpa *Nallah*, Aksinma Tokpo *Nallah*, Tiphu Tokpo *Nallah* and Korse Tokpo *Nallah*. Sourced from glaciers, Parechu Riveroriginates in India and flows in the Tibetan part before reentering into the India border and joining Spiti River at Samdoh. In 2005, the flash flood incident was occurred due to breach of artificial lake that resulted into enormous loss of property and life (Chauhan *et al.,* 2016).

ii) Tidong/ Tirung *Khad*: Tidong *Khad* originates at an elevation of 6,000m amsl in the Zanskar Range of Trans Himalaya and joins the Sutlej River above Rispa village in Kinnaur. The major tributaries on right bank of this *Khad* are Lamber *Khad,* Gara *Khad* and Dua *Khad*, all of which are snowfed and thus perennial (Chauhan *et al.,* 2016).

iii) Kashang Khad: The Kashang *Khad,* which is a right bank tributary of Sutlej River, originates at the foothills of Chikim and Mukim Dhar that divides the Kalpa and Nichar blocks. The Rogle *Khad* on the left bank tributary drains the water from Sankarishul Glacier. The River flows for 18 km from its origin before falling down a vertical height, as Kasang falls and joins the Sutlej River on left bank near village Powari. The major settlements on the bank of Kashang *Khad* are Shangidor, Dunang and Grama Dogri (HFRI, 2008).



Plate 2. 4 General view of Kashang Khad

iv) Baspa River: The 70 km long Baspa River is an important tributary of the Sutlej River in its upper course, considered as the second largest tributary of Sutlej River. This River rises in IndoTibetan border and it supposedly demarking the catchment of the Sutlej and Bhagirathi River. The River starts in the Baspa hills and joins Sutlej River near the left bank of Karcham at the lower end of Kinner Kailash. The Singan *Khad* and Hurba *Khad* join Baspa River at Batseri village; Rokti *Khad* joins at Sangla while Baturi *Khad* joins at Chunang village. On the right bank Nagasti *Khad* meets the Baspa River at Nagasti village and Shailpya *Khad* meets the Baspa River at Chitkul village while Mangsa Garang *Khad* joins the Baspa River at Mastarang. The major settlements on the bank of Baspa River are Chitkul, Nagasti, Mastarang, Rakchham, Batseri, Sangla and Chunang (Chauhan *et al.* 2016).



Plate 2. 5 General view of Baspa River

v) Roura *Khad*: Roura *Khad* originates from the snowcapped mountains at an elevation of 4,500 m amsl, and is joined by a number of *Nallahs* upto its confluence with Sutlej River near Chowling village in KinnaurDistrict. The total length of the River is about 12 km with a catchment area of about 95.63 km^2 (HPSFD, 2011).

vi) Panwi *Khad*: Panwi *Khad* is also known as Shatul *Khad*, which originates near the high peaks of a mountain called Chhayunda Dhar of the Himalaya. Due to the vicinity of the village Pannwi, it is also known as the Panwi *Khad*. It flows for about 17 km in the Kinnaur District and meet Sutlej River just above the Wangtoo village. Panwi and Joktarang are the two major settlements on the bank (Chauhan *et al.,* 2016).

vii) Bhaba/ Wanger *Khad*: The Wanger *Khad* originates from Shrikhand mountainscape and its catchment lies within the Nichar block. It joins the Sutlej River near Rarang above Wangtoo village. This *Khad* has a larger catchment with an eastern tributary even as far away as the Taiti valley of Lippa–Asrang in Kinnaur. The Surcho *Khad* joins the Wanger *Khad* at Shango on the left bank while Kangrang *Khad* is the left bank tributary of the River (Chauhan *et al.,* 2016).

viii) Sorang *Khad*: The Sorang *Khad* originates from the Kokshane (5,625m amsl) peakand is fed mainly by the Zangasu glacier. The main left bank tributaries of this *Khad* are Tal *Nallah* and

Kumrang *Nallah*. It flows for about 26 km in a southernly direction before joining Sutlej River on its right bank, near Nigulsari (Chauhan *et al.,* 2016).

ix) Nanti/Ghanvi *Khad*: Ghanwi *Khad* originates from the Srikhand Mahadev glacier. At its place of origin, it is known as Nanti *Khad* and further downward to it is called Ganwi *Khad*, with reference to the nearby villages. This tributary of Sutlej River joins it on the right bank near Jeori. The left bank tributaries are Daduwa *Khad* and Ghartr *Khad* while the right bank tributaries are Sagori, Kapni and Saran *Khad*. The major settlements on the bank of this *Khad* are Nanti, Phancha, Badain, Dhar and Ganwi. This perennial snow fed *Khad* originates at an elevation of 4,600 m amsl and flows mostly in southwesterly to westerly direction before it joins Sutlej River at an elevation of 1,350 m amsl (Chauhan *et al.,* 2016).

x) Sechi *Khad*: Sechi *Khad* is a tributary of Sutlej River and joins it on right bank opposite to Jhakri. It is a perennial *Khad* which emanates at an elevation of 4,000 m amsl and flows mostly in southeasterly direction before it joins Sutlej River at an elevation of 1,030 m amsl (ICFRE, 2014).

xi) Nogli *Khad*: Nogli *Khad* joins Sutlej River near Rampur Bushahar at Nogli. At its origin place it is also known as Sageti *Khad*. The Nogli *Khad* comes to exist where the Suket *Khad* and Devpani *Khad* meet (Chauhan *et al.,* 2016). Major settlements on the bank of this *Khad* are Sharnal, Sari, Taklech and Nogli.



Plate 2. 6 Confluence of Nogli Khad with Sutlej

xii) Kurpan *Khad*: It originates from the snowcapped peaks near the boundary of Banjar and Rampur blocks and is called the Umli *Khad*. After the confluence with Dewar *Khad*, Umli *Khad* is named as Kurpan *Khad*. In this stretch below 1,075 m amsl, Kurpan *Khad* watershed is either barren rocky land or covered with cultivated terraces and settlements. Its tributary is Nager *Khad* that joins it on the left bank near to the Nager village. The major settlements on the bank are Badar, Bagipul and Bhadu *Khad*. Between 2,200 to 3,200 m amsl the catchment is covered with dense vegetation. Its catchment above 3,200 m amsl is barren rocky land. In the headwater region, three snowfed streams join together above 3,700 m amsl and feed the Umli *Khad* channel.

xiii) Machhada *Khad*: The spring fed and snow fed Machhad *Khad* originates from Maral Kanda peak at an elevation of 3,732 m amsl and flows 23 km towards northwest and drains into Sutlej at 870 m amsl. Most parts of its catchment on its left bank are covered with dense forests. In the initial stretch, Machhad *Khad* flows as Seri *Khad*, then as Gatera *Khad* after it receives water from Sungt Nali. Further downstream, in the region downstream of the confluence with Dhuni *Nallah*, it flows as Machhad *Khad* and after its confluence with Dogar *Khad* at 1,250 m amsl it flows for a 6 km stretch as Machhad *Khad* (ICFRE, 2014).

xiv) Baihna *Khad*: The Khudhi *Khad* and Kunir *Khad* converge in Shawad village to from the Baihna *Khad* which joins the Sutlej River near Phirnu village. Ani *Khad* is its major tributary that joins the Baina *Khad* at Rorha. The Baihna *Khad* also demarcates the natural boundary between Kullu and Mandi districts of Himachal Pradesh. Shawad, Nagan, Bari, Haripur and Phirnuare the major settlements on the bank of Baihna *Khad* (Chauhan *et al.*, 2016).

xv) Ali *Khad*: The Ali *Khad* originates from Shimla district and joins the left bank of Sutlej River at Korwarni near Bilaspur after passing through Bahadurpur Dhar covering a total length of about 26 km. The catchment of this *Khad* falls in the Kunihar and Bilaspur blocks. The Ali *Khad* joins Gobind Sagar near Korwarni and Ghagas is the main settlement on the bank of this *Khad* (Lal, 2016; Chauhan *et al.*, 2016).

xvi) River Gambhar: Gambhar River originates from district Solan, Shimla and is having its catchments in five blocks in Solan and Bilaspur districts. The Dabar River and Kuthar River on the left bank are the main tributaries of Gambhar with Jayalang, Padog and Neri being the major settlements on its banks (Lal, 2016).

xvii) Seer *Khad*: The Seer *Khad* originates near Awah Devi in Mandi district and it travels about 58 km with two main tributaries being Sukkar *Khad* and Saryali *Khad*. It travels through the Bilaspur district and joins the right bank of Sutlej River at a place called Jyor (Lal, 2016).

xviii) Swan/Soan *Khad*: The Swan River is a rain fed seasonal River which arises from the Southern slopes of the Shivalik Range also known as Solasinghi Range in the tract to the east of the Beas River gap across the southern periphery of the Kangra Valley. Its gradient is not very steep and the slopes of the Swan catchment vary from gentle to steep. In the summer the

discharge drops drastically, while it carry huge water during monsoon. Swan River is 85 km long, out of which 65 km is in Una district, Himachal Pradesh and the remaining 20 km is in Punjab (Venu and Rishi, 2010).

2.3 Physical Environment

The term 'Environment' simply means 'Surroundings' (Environs) which include the abiotic (Nonliving) and biotic (Living) components of the environmental systems. The concept of environment in case of individual, object, element or system includes various entities ranging from the physical to biophysical and from the natural to the social environments. Clear understanding of the interactions and interrelationships between different parts of the environment is necessary for the effective ecosystem management.

The physical environment in context of the Himalayan River like Sutlej is complex as its geological framework is formed due to consequences of the continental drift i.e., tectonic movements and it has been immensely influenced by the geodynamic processes and evolution; glacial, fluvial and denudation processes; driving variables *viz*., glaciers, snow cover, rainfall, temperature and overall climatic conditions.

Climate, geology and soils affect the availability of surface water and groundwater resources. Climatic factors largely determine the amount of available precipitation in the basin while geology and soil factors determine the proportion of precipitation which runs off the land as surface water to that which infiltrates the soil and percolates through underline materials to become the groundwater. Geology and soils also determine the surface drainage characteristics, the vulnerability of aquifers to contamination and the limits of groundwater development.

The Sutlej Riverscape represents two major physiographic divisions: (a) the Himalayan Mountainous Zone in the State of Himachal Pradesh, and (b) the Indo Gangetic Plains in Punjab. These two prominent physiographic and geomorphological divisions have a direct bearing on the characteristics of Sutlej River Basin, its Riverscape and the River Hydrology in particular. Noticeably, the physical environment of the Sutlej Riverscape is fascinating owing to the natural grandeur of Himalayan Mountains and vastness of the alluvial plains; incessantly evolving evolutionary and environmental processes; and expanding human imprint by way of developmental projects and intensification of agriculture. Thus, it is of paramount importance to first develop an insight on the physical environment in the context of Sutlej Riverscape, specifically with regard to above mentioned two prominent physiographic and geological formations that have experienced continuous change since their creation.

Sutlej River traverses a course of 350.5 km area in Himachal Pradesh and considered as a largest River among the other four rivers (i.e., Beas, Ravi, Yamuna and Chenab). The River leaves Himachal Pradesh downstream of Bhakhra Dam, which is the second highest dam (225.55 m) in India. The Bhakra Dam is also Asia's second highest gravity dam. The length of the River in Punjab is 284.4 km. Thus, the total length of Sutlej River in India is 635.0 km before it finally

drains into the Chenab River in Pakistan. On account of varying geographical features, the Sutlej River Basin topographically is divided into two parts, i.e., the Upper Sutlej Basin and Lower Sutlej River Basin. Beyond the Nathpa village in Kinnaur district, Sutlej River is considered to be the Upper Sutlej River Basin, while the southwestern part of the Nathpa village to Bilaspur, it is known as the Lower Sutlej River Basin in Himachal Pradesh.

2.3.1 Himalayan Mountains in Himachal Pradesh

Geologically, Himalaya is the youngest folded mountains, supposedly still undergoing the mountain building process, and represents multifaceted subparallel structural units produced by the northward thrust of the Indian tectonic plate beneath the Central Asian plate (Saxena, 1970). The Himalaya is representative of the recent–most epoch in the orogenic history of the earth causing uplift of Archaean to Mesozoic accumulations in the geosyncline (about 2560 million years ago) (Wadia, 1961; Dewey and Bird, 1970; Powell and Conagan, 1973; Dewey *et al.*, 1989; Thakur, 2001). Singh (1971) divided the Himalaya on the basis of geological and geomorphological characteristics into the following three physiographic division's *viz*., (a) Shivaliks, (b) *Himanchal* and (c) *Himadri*, extending almost uninterrupted throughout its length. These are briefly described as below:

(a) Shivalik or Outer Himalaya (Sub Himalaya): The Shivalik Range or the sub Himalaya forms the foothills of the Himalayan Range with an average height of 900 to 1,200 m amsl and width from 8 km to 80 km. This is essentially composed of Shivalik sediments derived from the erosion of the Himalaya, basically newer and River borne deposits brought down by the rivers (i.e., Indus, Ganga, Brahmaputra and others) coming from the Himalaya and represents the recent phase of the Himalayan orogeny.

(b) Himanchal or Lesser Himalaya: The *Himanchal* with an average height of 3,900 to 4,500 m amsl and width varying from 32 to 80 km forms the central chain and composed mainly of highly compressed altered rocks from Algonkian or PreCambrian to Eocene in age. These low grade sediments are thrust over the Shivaliks along the MBT. Prominent ranges of the middle Himalaya include the Nag Tibba, Dhauladhar, Pir Panjal and Mahabharat.

(c) Himadri or the Great Himalaya (High Himalaya): The Great or Inner Himalaya rises above 6,060 m and includes peaks like the Everest, K2, Kangchenjunga, Dhaulagiri, Nanga Parbat, etc. It forms the backbone of the Himalayan Orogeny and encompasses the areas with the highest topographical relief. Himadri Range is a granitic core flanked by metamorphosed sediments. As the highest zone, it consists of a huge line of snowy peaks with an average height exceeding 6,100 m amsl and the width of this zone being about 24 km. Along with the Karakoram Range, Himadri has the credit of having the world's 14 highest peaks. To the north of Greater Himalaya stretch out several ranges such as the Zanskar, Ladakh, and the Kailash (Saxena, 1970; Khawas, 2008).

The Himachal Himalayan region corresponding to the Himachal Pradesh is situated between Latitudes 30°22´40´´ to 33°12´40´´ N and Longitudes 75°45´55´´ to 79°04´20´´ E located in the northern part of India. It is bordered by Punjab in the west and Haryana in the southwest; China in the east and Uttarakhand in the southeast; and Jammu and Kashmir and Ladakh UTs in the north. The Himachal Himalayan region owing to distinct ranges; variations in their evolutionary origin and wide altitudinal gradient; corresponding to geology, rock and soil types; and varied climatic conditions; largely influenced by glacial, glacio-fluvial and fluvial processes and sediments displays a wide range of geomorphic features, ecological characteristics and rich ethnic groups (Michael *et al.,* 2006). The region forms the catchment of four major Himalayan Rivers, *viz*., Chenab, Ravi, Beas, and Sutlej all feeding to the mighty Indus River System. Glaciers, snowcapped peaks, headstreams and their tributaries, lakes and waterfalls in the Himachal Himalayan region along with diverse forests in the Outer, Lesser, and Great Himalaya and Trans Himalaya play a crucial role in the River ecology. A large number of International, National and State Level Government Organizations/ Agencies have been carrying out long term researches on varied aspects of the Himalayan Mountains *viz*., their formation and structure, geological characterization, tectonic movements, seismicity, glaciers, snow cover, glacial hazards, hydrology, surface and groundwater resources i.e., springs and aquifers, erosion and sedimentation, environmental flow, water quality, pollution, climate change, irrigation and hydroelectric projects, vulnerability, etc., and have made significant contributions to the relevant literature. A voluminous literature highlighting past trends on above themes is available and optimally used to provide a brief synthesis and insight in the context of management of the Sutlej Riverscape and proposed forestry interventions for restoration of an important River like Sutlej.

d) Sutlej Alluvial Plains

An alluvial plain is a largely flat landform created by the deposition of sediment over a long period of time by one or more rivers coming from highland regions, from which alluvial soil forms. A floodplain is part of the process, being the smaller area over which the rivers flood at a particular period of time, whereas the alluvial plain is the larger area representing the region over which the floodplains have shifted over geological time.

As the highlands erode due to weathering and water flow, the sediment from the hills is transported to the lower plain. Various creeks will carry the water further to a River, lake, bay, or ocean. As the sediments are deposited during flood conditions in the floodplain of a creek, the elevation of the floodplain will be raised. As this reduces the channel floodwater capacity, the creek will, over time, seek new, lower paths, forming a meander (i.e., a curving sinuous path). The leftover higher locations, typically natural levees at the margins of the flood channel, will themselves be eroded by lateral stream erosion and from local rainfall and possibly wind transport if the climate is arid and does not support soil holding grasses. These processes, over geologic time, will form the plain, a region with little relief (local changes in elevation), yet with a constant but small slope.

e) Malwa Plains

Malwa plains are the alluvial plains region in Central Punjab. It lies between the Ghaggar and Sutlej Rivers south of the Bist Doab (plain). The plains are bordered by the Siwalik (Shivalik) Range to the northeast and range in elevation from 300 m amsl in the northeast to 200 m amsl in the southwest. The terrain is slightly undulating, and there are occasional sand dunes and sand ridges in the southern part of the plains bordering the Great Indian (Thar) Desert. A few perennial rivers, including the Ghaggar, Patiali, Dangri, and Markanda cross the plains, which are marked by former River channels. Scattered tropical dry deciduous forests, mostly of teak and dhak, are found. In addition, Eucalyptus and Poplar trees have been planted along roads and canals.

Agriculture dominates the economy of the plains; crops include cereals, pulses (legumes), cotton, sugarcane, and oilseeds. The region produces a surplus in food grains, particularly wheat. Small scale industries manufacture machine tools, footwear, sewing machines and parts, plastic goods, and water pipes and fittings. Tractors, dry-cell batteries, polyester films, nylon, and automobile tires and tubes are produced on a large scale. The region has a network of roads and railways connecting Ludhiana, Chandigarh, Abohar, Bhatinda, and Maler Kotla, the important towns.

The Malwa Plains are named for the Malloi peoples (Malavas) who ruled the Punjab in the 4th Century BCE and offered stiff resistance to Alexander the Great. The Guptas supplanted the Malavas in the 4th Century CE.

In the Malwa Tract, similar physiographic changes took place but in a different context. There was a discontinuous chain of sand dunes south of the Sutlej River flood plain. There are different viewpoints with regard to the origin of these sand dunes. Some thought they were made by sand carried by the winds from the sandy bed of the Sutlej River, while others are of the opinion that they were deposited by the River itself when it was following an easterly course along these sand dunes which formed linear belts. The flood plains are formed of new alluvium deposited by the rivers during the rainy season every year. Generally, they are separated from the upland plains by low scraps, at places even by steep cliffs. These flood plains along the rivers are linear tracts having a width not more than 10 to 15 km. The flood plains are formed of new alluvium deposited by the rivers during the rainy season every year. Generally, they are separated from the upland plains by low scraps, at places even by steep cliffs. These flood plains along the rivers are linear tracts having a width not more than 10 to 15km (Gosal, Physical Geography of the Punjab).The upland plains are essentially inter fluvial tracts. From the Sutlej River to the Indus River the Punjab plain gradually slopes westward resulting in the westward shift of the rivers' courses. All these plains are made of old alluvium originally deposited by the major rivers descending from the Himalaya. The plains look flat and featureless for the most part. They generally slope from the northeast to the southwest, the elevation decreasing by about four meter to a kilometer in the upper parts, and by less than a metre to a kilometre in the lower parts.

2.3.2 Glaciers and Snow Cover

There are five major perennial rivers i.e., Chenab, Ravi, Beas, Sutlej and Yamuna of northern India which flow through the Himachal Himalaya, having their origin either in the glaciated terrains in or outside the State. Three rivers i.e., Chenab, Ravi and Beas originate from the high mountains in Himachal Himalaya while two other rivers i.e., Sutlej and Yamuna have their origin outside the State/Country (GoHP, 2012). Almost all the Himalayan rivers receive most of its annual flow (30% to 50%) from snow and glacier melt run off (Agarwal *et al.*, 1983) and their River flow dynamics is greatly influenced by the seasonal and monsoonal precipitation as well as by snow and glacial melt (Immerzeel *et al.*, 2000; Dutta *et al.*, 2012).

Sutlej River is the largest River of Himachal Pradesh and 3rd largest in the Himalaya with great variation in its physical characteristics. The availability of a perennial River due to permanent glacier makes this River basin unique from the other basin. The topography of upper Sutlej River Basin is very favorable for the Hydropower Development. This Basin is also rich in the herbal plants and rare Chilgoza Pine. This River Basin has maximum glacial area that covers 37.87% area, followed by Forest areas, 24.96%, Barren areas, 20.16% and Agricultural land, 10.95% (Chauhan *et al.*, 2016). Upper Basin has more than above 4000 m elevations that increases the velocity of the River and sometime become the reason of flash flood. The lower basin has 1000 3000 m elevation and surrounding Gobindsagar Lake has 600m elevation. The overall Sutlej River Basin is rich in the developmental activities especially of hydropower development (Chauhan *et al.*, 2016; Muhammad *et al.*, 2019).

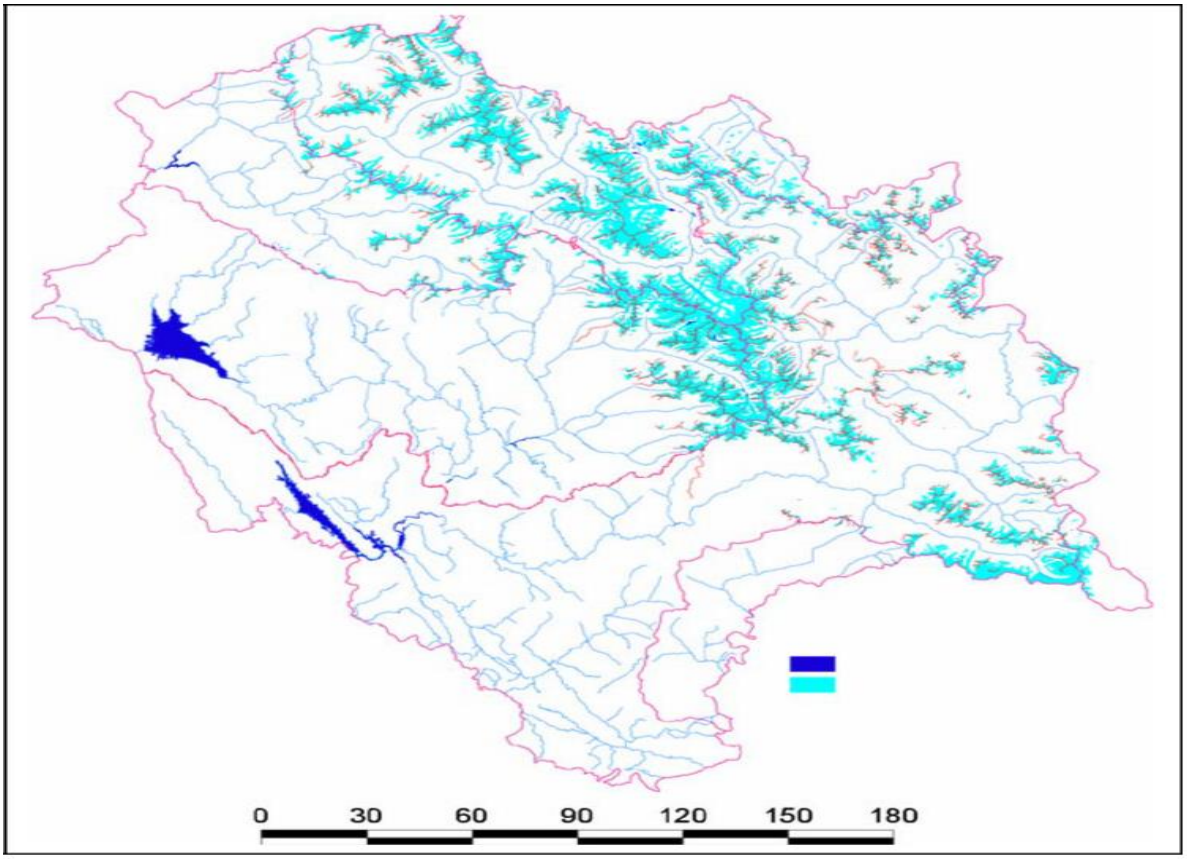
a) Glaciers

Glaciers often called “Rivers of Ice,” are a huge mass of ice that moves slowly over land. Glaciers begin forming in places where more snow piles up each year than melts. Pulled by gravity, a glacier moves slowly down a valley. Glaciers fall into two groups i.e., (a) alpine glaciers and (b) ice sheets.

Alpine glaciers also called valley glaciers or mountain glaciers form on mountain sides and move downward through valleys, sometimes creating or deepening valleys by pushing dirt, soil, and other materials out of their way. Alpine glaciers are found in high mountains of every continent except Australia (although many in New Zealand). Ice sheets, unlike alpine glaciers, are not limited to mountainous areas and form broad domes and spread out from their centers in all directions. As ice sheets spread, they cover everything around them with a thick blanket of ice, including valleys, plains, and even entire mountains. The largest ice sheets, called continental glaciers, spread over vast areas.

Presently, glacier ice covers about 15 million km^2 or 10% of earth's land area, but holds roughly 77% of its freshwater (Srivastava, 2012). The Hindu Kush Himalayan region has the largest concentration of snow and glaciers outside the Polar Regions and has been referred to as the Third Pole (Dyhrenfurth, 1955; Dyurgerov and Meier, 1997; Raina and Srivastava, 2008; Raina,

2009; Bajracharya and Shrestha, 2011; Bhambri 2011). Various studies and estimates on glaciers in Himachal Pradesh have been prepared. One of the recent studies for Himachal Pradesh carried out in 2004 has documented that there were 2,554 glaciers in the State (Fig. 2.4), covering an area of 4,160 km^2 (Campbell, 2005). The study also provided River Basin wise breakup on number of glaciers, their areal extent, and ice reserves in them. Accordingly, the highest number of glaciers, being 945 was reported in the Sutlej River Basin, followed by 681, 358, and 198 glaciers in Chenab, Beas, and Ravi River Basins, respectively. In addition, 372 glaciers were reported in sub basins of other rivers flowing through the State. The maximum glacier area (1,704.70 km^2) or 40.97% glacier area of the State was represented by Chenab River Basin, followed by Sutlej River Basin having an aerial extent of 1,217.70 km^2 or little over 29% of the total glacier area within the State while the Ravi River basin had glacier area to the extent of 235.21 km^2 or 5.6% of overall glacier area within the State.



(Source: Adopted from Campbell, 2005)

Fig 2. 4 Glaciers Cover Map of Himachal Pradesh

The largest glacier in Sutlej River Basin, occupies an area of 63.79 km^2 and ice reserve of 11.04 km^3, which lies in the extreme south eastern corner of the state border. Randhawa and Sharma (2014) have reported presence of total 334 glaciers and 1987 snow fields in the entire Sutlej

River Basin covering an area of 2,697 km^2 using remote sensing techniques. Glaciers are very sensitive to the ongoing climate change and are thus, recognized as indicators for regional climate change (IPCC, 2007) and changes in the glaciers may have a significant impact on the quantity and timing of water availability (Rabatel *et al.,* 2013). Thus, the monitoring of glaciers and snow cover is important to assess the overall reservoir health (Bhambri and Bolch, 2009; Bhambri *et al.,* 2011).

Srivastava (2003) reported that Sutlej River Basin has 926 glaciers covering an area of 1,252 km^2. According to Bajracharya *et al.* (2019), Sutlej River Basin including Trans Boundary Drainage Catchment with China, has basin area of 1,05,735 km^2 having 2,108 number of glaciers having a glacial area of 1,315 km^2, having estimated Ice reserve of 82.89 km^3. Glaciers are vital to mankind as they control the global hydrological cycle, maintain the global sea levels and perennially supply freshwater to the rivers (Bahuguna *et al.,* 2014). The Sutlej River Basin has total of 2,026 glaciers of different sizes totalling 1426 km^2. According to Prasad *et al.* (2019) study of extreme case model, GFDLCM3, to assess the impact of climate change on Sutlej River glaciers by 2090, observed that smaller glaciers will melt faster. Those having area of less than 1 km^2 will experience about 62% loss by 2050, according to new findings. Sutlej River is among dozens of basins in the Himalayan region that have thousands of glaciers many of which are receding while some are not. Almost half of the annual flow of the Sutlej River comes from snow and ice melt and it feeds up to 80% of the inflow into the Bhakra Dam in Himachal Pradesh. Changing climatic patterns are affecting the health of glaciers in the Himalayan region. A new study has warned that as many as 55% of glaciers in the Sutlej Basin may disappear by 2050 and 97% by 2090 under extreme climate change scenario (Prasad *et al.,* 2019). This could also adversely hit availability of water for irrigation and power projects including the Bhakra Dam. The analysis showed that the total glacier stored water in the Sutlej River Basin was 69 km^3. About 56% of the total volume is stored in large glaciers (over 5 km^2) covering an area of 517 km^2. The largest glacier spreading over 66.8 km^2 and containing 6.5 gigaton (Gt.) of ice is located in Tibet (Prasad *et al.,* 2019). However, most of the glaciers contain less than 0.1 Gt. of ice. The basin has already lost 21% or 16.4 Gt. of glacier volume between 1984 and 2013. Water reserves held by glaciers are likely to be affected in future due to climate change. The rise in near surface air temperature in the North Western Himalaya by 0.65ºC during 1991–2015 is already higher than the mean global rise of 0.47ºC (Sharma, 2019). The future rise in temperature has been projected under different scenarios, depending on how much emissions occur in the present century.

b) Snow

Snow is a type of precipitation in the form of crystalline ice, consisting of a magnitude of snowflakes that fall from clouds. Snow is composed of small ice particles and the process of precipitation is referred as snowfall. The density of snow when it is fresh is 3050 kg/m^3, however, when it becomes 'Firm' then the density is higher in the range of 400830 kg/m^3. Snow

becomes glacial ice when density is 830910 kg/m^3 (HPSCCC, 2019). Over 30% of the Earth's land surface is seasonally covered by snow (NIH, 2000). Snow and ice play an important interactive role in the Earth's radiation balance, because snow has a higher albedo than any other natural surface (Foster and Chang, 1993). The snow cover in the Himalaya occurs and exists depending on the terrain and the climatic conditions of the region. The snow cover has been categorized into three types i.e., (a) Temporary snow cover, (b) Seasonal snow cover, and (c) Permanent snow fields and glaciers. Snow cover that stays for a few days and then melts away has been termed as 'Temporary Snow Cover' which usually occurs at lower altitude during winter and even sometimes at higher altitudes during summer. Snow cover that is formed over weeks or months by consecutive snowfalls and which melts away gradually during the following summer has been termed as the 'Seasonal snowpack/cover'. Above a certain altitude and in certain situation, some amount of snow is carried over to the next winter season without melting during summer, and this turns into 'Firm' and ultimately ice, adding to the permanent snow fields and glaciers (NIH, 2000). The seasonal snowpack contributes to the water resources during the lean summer months, and thus, very important for the flow of rivers during summer season. The Himalaya, often referred to as the water towers of Asia, are the cradle of a large number of streams and mighty rivers, which ensure all the year round availability of water even in summer or lean period due to the melting of seasonal snow pack (Immerzeel and Bierkens, 2012).

c) Snow Cover

The Himalayan Mountains account for almost 70% of nonpolar glaciers. In winter season, most of the high altitude areas in this region experience snowfall to form permanent snow fields (Kulkarni *et al.,* 2002). The freshwater from melting of this snow is important for local drinking water supplies (Woodwell, 2004; Meissner and Reller, 2005) flood control, and agricultural purposes (Keller *et al.,* 2000; Pimentel *et al.,* 2004; Deems *et al.,* 2006; Armstrong and Brun, 2008). The snow melt affects water management through annual runoff, recharge and water supplies. Snow melt being the dominant source of many rivers, is considered to be the lifeline of millions of people, downstream in the summer season. The Sutlej River originating from the Tibetan Plateau at an elevation >4,500 m amsl in the southern slopes of Mount Kailash and flows generally west and southwest entering India in Himachal Pradesh. In the Tibetan Plateau, the entire Basin is characterized by a cold desert winter climate which, therefore, leads to a very low flow in the River until it joins its major tributary, Spiti, near Namgia in Kinnaur district of Himachal Pradesh. The Spiti River catchment in the winter months experiences extensive snowfall due to westerly weather disturbances and, therefore, contributes to the Sutlej River flow in spring months (Singh and Kumar, 1997).

Snow cover is the second largest component of the cryosphere and covers approximately 40–50% of the earth's land surface during Northern Hemisphere winter (Rathore *et al.,* 2018). Snow cover measurements are difficult and estimates are not reliable, cheap or easy because of hostile conditions. Conventional methods have limitations in the monitoring of snow covered areas in

the Himalayan basin because of inaccessibility. Remote Sensing (RS) has been used to provide information characterizing the snow cover of a basin and the information obtained through it has been integrated into snowmelt run off models (Bahadur and Prasar, 1998; Bahadur, 2004). Snow by virtue of high reflectivity is one of the objects on the surface of earth which is readily detected or identified any visible or near infrared remotely sensed image. Fresh snow has a very high reflectivity in the visible wavelengths and decreases as the snow ages. During the past two decades or so, remote sensing due to the availability of large number of satellites in the space at a time, improved sensors and high spatial resolution have opened up new avenues for efficient monitoring of snow cover in the large number of basins in the Himalaya (NIH, 2000). Monitoring of snow cover is vital for the purpose of understanding hydrological regimes and climatic patterns.

The Sutlej River Basin in India covers an area of about 22,305 km. The elevation ranges from 500 to 7,000 m amsl. Due to the large differences in the elevation range and seasonal temperatures, the snow line goes down to an elevation of 2,000 m amsl during winter and reaches up to 5,000 m amsl at the end of the summer. However, the permanent snow line is observed to be 5,400 m amsl in this part of the Himalayan region (BBMB, 1988). Thus, about 65% of the Sutlej River Basin area is covered with snow during winter and about 12% of the Basin (2,700 km^2) is covered with permanent snowfields and glaciers (Singh and Bengtsson, 2004; Shukla *et al.,* 2017). The snow cover area in the Sutlej River Basin for the months of March/April and September/October usually indicates the maximum and minimum snow covered area. Based on the 08 years data (1986-1993) about 65% (14,498 km^2) of the basin was under snow by the end of March/April, which reduced to 20.3% (4,528 km^2) after the snow melt indicated that about 9970 km^2 becomes snow free during melt season (ICFRE, 2014).

The maximum snow cover during 1997 to 2000 was reported to vary from 55% to 67%. Peak values of the total discharge in July and August are essentially due to the combining snowmelt and glacier melt with monsoon rainfall in the lower elevations. Snowmelt is the source of freshwater required for drinking, domestic, agricultural, hydropower and industrial sectors especially in middle and high latitudes.

Minimum flow is obtained in winter season when the base flow contribution sustains the River flow. Spring seasonal inflow anomalies are strongly reported to be correlated with large scale precipitation and diurnal temperature range in the preceding winter over the western Himalaya as well as the adjoining northern and central Indian plains. Upper Sutlej River catchment snowmelt contributes 80-90% of the mean annual discharge in tributary catchment, while glacial melts account for 10-20% of their annual budget (ICFRE, 2014). The middle Sutlej River catchment sustains high snow and glacier melts derived discharge throughout the ablation period (May September).

The Himachal Pradesh State Center on Climate Change (HPSCCC), Shimla and the Space Application Centre (SAC), ISRO, Ahmedabad assessed the spatial distribution of seasonal snow

cover in different River basins within Himachal Pradesh during 2017-18 and 2018-19 using satellite data and provided month-wise insight on temporal changes (HPSCCC, 2019).

The Sutlej River Basin, with the basins of its main tributaries, *viz.*, Baspa, Spiti and Pin show similar trends of having maximum area under snow in the month of October 2018-19 than 2017-18. On analyzing the satellite data for the month of October 2018-19 total spatial area of snow was found to be enhanced by about 185.2% over the area under snow in 2017 18. Likewise, the month of November showed an increase of about 75% in comparison to 2017-18, the surface area has increased from 3,177.8 km^2 (2017-18) to 5,569.59 km^2 (2018-19). The months of December and January months showed a decrease of 0.95% and 0.05 % in 2018-19. In February 2018-19 an increase of about 14.9% has been observed in the total area (10,940 km^2) under snow in Sutlej River Basin in comparison to the 2017-18 which was 9,516.5 km^2 in the same month. Likewise, in March the surface area has increased from 9,022.51 km^2 in 2017-18 to 10,662.87 km^2 in 2018-19 reflecting an overall increase of about 18% (Table 2.4).

Table2.4 Monitoring of Area under Snow in Sutlej River Basin during 2017-18 and 2018-19

Sr. No.	Observation Month	Area Under Snow Cover (Monthly Average) (km^2) (2017-18)	Area Under Snow Cover (Monthly Average) (km^2) 2018-19	Area Under Snow Cover (% change)
1	October	1,480.3	4,222.4	185.2
2	November	3,177.8	5,569.59	75.2
3	December	7,177.0	7,108.75	0.95
4	January	8,583.2	8,578.08	0.05
5	February	9,516.5	10,940.7	14.9
6	March	9,022.51	10,662.87	18.1

(Source: Adopted from HPSCCC, 2019)

d) Aquifers and Springs

An aquifer is an underground layer of permeable rock or sand that collects, holds, and conducts water (Rosen, 2015) and the water in the aquifer is called groundwater. Many aquifers are like reservoirs because they store water useful to human and aquatic ecosystems. The materials act like underground sponges allowing water to flow very slowly through it and this groundwater may naturally emerge from the aquifer as a spring. When aquifer water table reaches the surface, groundwater can be released as surface water into streams, lakes or rivers and wetlands may also form where groundwater reaches the ground level. Aquifers vary in size, from narrow to wide, and may have varying thickness. People drill wells or put submersible pumps into the aquifer to pump groundwater to the surface to use for drinking or irrigation. Aquifers are important source of water and most of the water pumped from aquifers is used for irrigation. Springs are the places where aquifer water flows to the surface and a pool and often a stream are formed by

springs. Most springs are often formed along faults. Most aquifers do not support aquatic ecosystems as there is no light underground and hence photosynthesis by plants cannot occur. However, excess nitrates, particularly from agricultural lands where fertilizers or manure containing nitrates are used, may seep into the aquifer as the water pollutant (Rosen, 2015). The State wise distribution of aquifers in Himachal Pradesh and Punjab has been given in Table 2.5.

Table 2. 5 Distribution of Principal Aquifer Systems in Himachal Pradesh and Punjab

Sr. No.	State / Rock Type	Himachal Pradesh		Punjab	
		Aquifer Area (km^2)	%	Aquifer Area (km^2)	%
1	Alluvium	1803	3.3	48446	98.5
2	Laterite	0	0	0	0
3	Basalt	0	0	0	0
4	Sandstone	10514	19.26	738	1.5
5	Shale	2932	5.37	0	0
6	Limestone	6407	11.73	0	0
7	Granite	2719	4.98	0	0
8	Schist	17926	32.83	0	0
9	Quartzite	4638	8.49	0	0
10	Charnockite	0	0	0	0
11	Khondalite	0	0	0	0
12	BGC	3534	6.47	0	0
13	Gnesis	4063	7.44	0	0
14	Intrusives	61	0.11	0	0
15	Unclassified	0	0	0	0
Total Area		54597	100	49184	100

Source: Adopted from CGWB, 2012

Springs are the main source of water for millions of people and their livestock in the Indian Himalayan Region (IHR) as both rural and urban community in Himalayan Mountains depend on springs for drinking, domestic and agricultural water needs. As per a rough estimate, there are 5 million springs across India, out of which nearly 3 millions are in the IHR alone (NITI Aayog, 2018). There is increasing evidence and growing concern that springs are drying up or their discharge is reducing throughout the Himalaya. Erratic rainfall, variable snowfall, seismic activity, ecological degradation due to change in land use and infrastructural development coupled with climate change are impacting mountain springs. Despite the key role played by mountain springs, particularly in the remote areas of the Himalaya, water production has declined in most springs indicating a dangerous sign that aquifers are depleting in the mountainous states where rural population is almost entirely dependent on springs for drinking

water. Besides water quality has also deteriorated under changing land use, improper sanitation and pollutants from agricultural lands.

In Himachal Pradesh, the traditional groundwater resources i.e., springs, *Khuls*, *Baories*, *Khaties* and ponds play a significant role. However, there is an imbalance between the supply and consumption of water, particularly by the poor and weaker section of the societies resulting into decline and deterioration of traditional sources of water. The State Council for Science Technology and Environment, Himachal Pradesh has carried out a pilot survey in 169 *Panchayats* of seven districts in the State on traditional water resources (Bhardwaj, 2014). The survey revealed that there are 10,512 traditional sources of water in the State for rural habitations. The study also showed that only 30.4% sources are in good working condition and recharging properly throughout the year, but a larger proportion (69.6%) of traditional water resources are not in proper working condition and likely to go dry in near future.

In recent years, there has been upsurge of studies and initiatives to address spring management in India, realizing the seriousness of the emerging crisis around springs. Recently, the report of the NITI Aayog's Working Group on the 'Inventory and Revival of Springs in the Himalaya for Water Security' recommended launching a National Programme on Regeneration of Spring in the Himalayan Region (NITI Aayog, 2018). The Working Group made specific recommendations for systematic mapping of springs across the Himalaya, creation of web enabled database/ portal, synergies between R&D Institutions/ Universities and community based NGOs to provide assistance for scientific assessments besides implementing plans for revival of springs, capacity development of young professionals and community based resource persons (Para Hydrologists), policy interventions and addressing cross cutting issues. The Group also stressed for developing springshed management plans and protocols in addition to assessing hydrological and social impacts.

e) Glacial Hazards

The Sutlej River Basin is the largest River Basin in Himachal Pradesh in terms of spatial extension. A total of 40 lakes have been identified in this basin with an area of 136.46 km^2 (Rana *et al.,* 2006). Most of the lakes are reported to be small in size with area less than 0.06 km^2. The aerial extent of the lakes varied from 0.017 to 0.058 km^2 in the basin of which about 35 lakes are directly associated with glaciers (Rana *et al.,* 2006). An inventory of all the moraine dammed lakes and the water bodies was prepared in the Sutlej River Basin Using IRS LISS III Resourcesat 2 satellite data for the period September and October 2012 and 2013 (HPCCC, 2014) with spatial resolution of 23.5m. A total of 391 moraine dammed lakes /water bodies was observed from the satellite data. Although, most of these lakes are of small dimensions with area less than 5 ha (276) there are few larger lakes with area between 5 to 10 ha (75).

Flooding refers to the inundation of an area by unexpected rise of water by dam failure or/and extreme rainfall duration and intensity. Glacial Lake Outburst Floods (GLOF) will likely become

a more serious issue in the mountainous region due to the gradual retreat of glaciers and increased melt rates. Increased rainfall intensity and runoff resulting from climate change are likely to increase the risk of floods. It is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems which not only damages the lives, natural resources and environment, but also causes loss to economy and health. Flood risk maps provide useful information about places that may be at risk from flooding and show more direct and stronger impression of spatial distribution of the flood risk. These maps offer a cost effective solution for planning, management and mitigation strategies in flood prone areas. In HP, the District of Kinnaur has higher levels of vulnerability than the surrounding regions and is threatened by numerous potential GLOFs originating in both Indian and Chinese sectors of the upper Sutlej River Basin (Gupta and Sah, 2008; HPCCC, 2014; Allen *et al.*, 2016).

The most effective approach to flood risk management is through the development of flood risk management strategies by incorporating the elements of prevention, protection, preparedness, emergency response and recovery. Traditional methods of flood risk mapping are based on ground surveys and aerial observations, but when the phenomenon is widespread, such methods are time consuming and expensive. Digital Elevation Model (DEM) and various parameters extracted from it also have major role to play in hazard mapping, especially flood risk mapping (Sugumaran, 2000). The possible combination of DEM and other maps of area using an overlay operation method within the Geographical Information System (GIS) platform can lead to derivation and the understanding of spatial association between various parameters which could be used to predict flood risk zones. Another form of flooding is flash flooding which is principally associated with hydrologically small regions and the duration of this phenomenon is short, but cause extensive damage. Flash flood in Sutlej valley has caused damage of about Rs 1,466.26 crore and 895.8 crore during 2000 and 2005 respectively (GoHP, 2000 and 2005). The formation of landslide dammed lakes in high altitude zones such as Parachoo in the upper catchment of Spiti River Basin in Tibet caused tremendous threat to the life and property located in the downstream areas. The left bank of Sutlej River in the downstream reaches near Rampur is more vulnerable to flooding by virtue of its low topography. Flood vulnerability of the left bank was best exemplified during the 2005, flood events. The quantum of floods damage is bound to increase due to indiscriminate development and settlement in the flood risk areas. In order to keep minimum environmental degradation due to developmental activities, it is essential to identify the vulnerable areas which are at risk of flood hazards.

f) Vulnerability

Vulnerability is defined as the susceptibility of human and environmental systems that are likely to experience harm or damage from the exposure to stresses and from the absence of capacity to adapt (IPCC 2001; Adger 2006; Emrich and Cutter, 2011). Despite the advances in scientific research and literature, the measurement and classification of vulnerability are highly uncertain (Kates *et al.*, 2001; Kasperson *et al.*, 2003; Adger, 2006; Eakin and Luers, 2006).

Increasing intensity and frequency of rainfall coupled with gradual retreating of glaciers in Himalayan regions is likely to increase the risk of floods. A better understanding of risk zones which are vulnerable to flood disasters can be evolved from the detailed studies on slope, geomorphology and land use/land cover patterns. Information of these parameters is an important input for the identification of vulnerable areas.

Kumar (2015) divided Sutlej River Basin of Himachal Pradesh into five risk zones i.e., very low, low, moderate, high and very high which helped to differentiate between areas that are at risk of different intensities of flood (Table 2.6). The study found that the very high flood risk zone covers only 3.25% of total area, while the very low risk zone covers 13.63%. The area falls within the very high and high risk constitutes 9.52% of total basin area. Domain of moderate risk covers an area of 30.66%. But, the maximum area of River basin i.e., 46.19% is constituted by low risk zone (Table 2. 6).

Table 2. 6 Flood Risk Zone of Sutlej River Basin in Himachal Pradesh

Domain of Risk	Area in km^2	Percentage
Very High	661.5	3.25
High	1276	6.27
Moderate	6241.5	30.66
Low	9400.5	46.19
Very Low	2774.5	13.63
Total	**20354**	**100**

(Source: Adopted from Kumar, 2015)

Geological, topographical, and climatic conditions and also human disturbance factors such as deforestation, extension of road network, blasting carried out for road cutting and construction of dams or reservoirs, housing, terracing, forest fires and water intensive agriculture practices on steep slopes result in landslides. The region has also experienced major cloudbursts in recent decades. A cloudburst is an extreme amount of precipitation, sometimes accompanied with hail and thunderstorms. It usually lasts for minutes and causes huge sudden flash flood.

i) Vulnerability to Landslides

The term ‘Landslide’ describes a wide variety of ground processes that results in the downward and outward movement of slope forming materials, including rock, soil, artificial filling, or combination of all these (Joshi, 2010). The materials may move by way of falling, toppling, sliding, spreading or flowing. In the mountainous areas, landslides after earthquake are the second most destructive natural hazards. The economic as well as loss of life due to landslides were considerably increased in the last century, and most of the landslides are due to global climate change, such as, El Niño and human activities (Runqiu and Weile, 2011). Precipitation

has played a very important role to affect the mass movement and landslide. Topographic variance (434– 6,448 m asml) influences precipitation pattern in the study region. Annual isohyets varied from 100-1,400 mm (Singh and Jain, 2002). Rainfall decreased in this basin from the lesser to the Greater Himalaya (Singh and Kumar, 1997). The upper Sutlej River Basin was divided into two broad climatic zones i.e., (i) sub humid temperate zone extending between Nathpa and Morang; and (ii) semiarid to arid temperate zone (cold desert) extending from Morang to upstream (Gupta *et al.,* 2003). The upper zone of the Basin falls in a semiarid to arid temperate zone, which receives most of the precipitation in the form of snowfall. The middle zone of the Sutlej Basin falls under the sub humid temperate to humid region. Most of the precipitation occurred in the form of rainfall. Here, rainfall pattern varied from 300 to 1,400 mm. Thus, it is clear that maximum occurrence of rainfall was found in the middle and lower zones. Total 112 landslides were identified out of which 19 were large (>0.198 km^2), and 93 small. Highest numbers of landslides (i.e., 91) were observed in the middle zone of the Sutlej River Basin, while 15 were observed in the upper zone. On the other hand, the lowest numbers of landslides were recorded in the lower zones. Steep slopes, high relief, number of structural discontinuities and underlying geology were combined with anthropogenic activities which decrease the stability of slope (Gupta *et al.,* 1993). Steep and vertical slopes have high degree of landslides. The middle zone i.e., Reckong Peo to Rampur, has the highest damaged area (12.13 km^2) having average vulnerability score was 5, under the landslide parameter; also having the highest number of HEPs (23) as compared to other two zones i.e., upper and lower zone. About 3.12 km^2 area was affected due to landslides in the upper zone i.e., from Spiti to Reckong Peo, where its vulnerability score stood to be 2. The least area was affected in the lower zone i.e., from Rampur to Koldam (0.91 km^2) having a vulnerability score of 2.6 (Kuniyal *et al.,* 2019).

ii) Vulnerability to Floods

The Sutlej River Basin has witnessed several flash floods along the tributaries of the Sutlej River. It was 1993, 1995, 1997, 2000, 2005 and 2007 when most of the disastrous floods were experienced in the Sutlej River (Gupta and Saha, 2008a). During flash floods, unusual high discharge was observed. Water level in a River could rise up to 15 to 20m from normal River level and its discharge may go up to 10-12 times more than a normal discharge (Gupta and Saha, 2008b).

During the period of 12 years (1991 to 2003), nearly 36 major cloudbursts and flash floods have been recorded. An unprecedented cloudburst and flash flood of August 11, 1997 in the catchment area of Sutlej River caused extensive damage. The Sutlej River was blocked near Wangtoo and a 5 km long and 2 km wide lake was formed in a matter of hours.

Punjab is vulnerable to 21 types of hazards out of 33 identified by the High Powered Committee (HPC) of Government of India into 5 Subgroups. Apart from the identified hazard by HPC the State has high impact of groundwater and surface water pollution, depletion of groundwater level and cancer epidemic which needs to be addressed as a hazard.

A major part of geographical area of the State is prone to floods although substantial part has been protected through flood control measures. The water table is rising in south western districts of the State due to limited or non extraction of groundwater because of blackish/saline quality, which makes it unfit for domestic, irrigation and other purposes which causes water logging.

Punjab has experienced drought due to inadequate rains in monsoon in recent past. The State experienced drought in 1978, 1979, 1985, 1987, 2002 and 2004, both in rural and urban areas. In 1987, a major drought was experienced in the State but in 2002, the intensity of the drought has made the situation much more acute and has broken the back of the farming community (ENVIS, Punjab).

iii) Vulnerability to Earthquakes

Earthquakes are serious menace in the Shivaliks and *Kandi* region (i.e., transitional zone between the Shivalik and the plain), along the River courses, streams and *Nallah* and in the south western arid and hot region. In seismic zoning map, most of the area of Punjab lies in Zone III and IV. However, northern boundary of Punjab with Himachal Pradesh is in close proximity to Zone V. According to the Building Material and Technology Promotion Council, 1997, 48.6% area of the State is vulnerable to Intensity VIII and 45.6% area to Intensity VII. (SDMP, Punjab)
The Himalayan region is topographically fragile due to tectonic activity which is still in mountain building process (Molnar and England, 1990). In Himachal Pradesh, Kuniyal *et al.* (2019) showed that all the three zones of the Sutlej River Basin i.e., the upper zone from Spiti to Reckong Peo, the middle zone from Reckong Peo to Rampur and lower zone from Rampur to Koldam have the presence of tectonic elements and all of these tectonic elements have high degree of risks and vulnerability. Faults have been recorded in the upper and middle zone as Main Central Thrust (MCT); separates the Greater Himalaya from the Lesser Himalaya and faults were also found in the lower zone as the Main Boundary Fault (MBF); separates the Shivalik formations of the Sub-Himalaya from the older rocks of the Lesser Himalaya lying to their north. Sediment flux is largely affected due to stronger earthquakes with greater magnitudes of >M7 (Hovius *et al.,* 2011) despite, seismically active mountain belts have shown link between earthquakes, landslides and fluvial sediment transport (Meunier *et al.,* 2008; Dadson *et al.,* 2003).

Various anthropogenic activities like deforestation, road construction i.e., highway expansion and removal of slope toes at road cuts, mining, cultivation on steep slopes, building of tunnels of HEPs are also responsible for increased number of landslides, accelerated soil erosion and high concentration of sediments in the Himalayan Rivers (Burnard *et al.,* 2001). Highest affected area under the landslides was observed under the middle zone (12.13 km^2) and lowest affected area

(0.91 km^2) was recorded in the lower zone. All the observed landslides (121) were found along the Sutlej River (i.e., Kol Dam to Khab) has increased the sediment load into the Sutlej River.

iv) Vulnerability due to Dams and HEPs

According to Kuniyal *et al.* (2019), Sutlej River Basin has 38 hydroelectric projects under different phases and categories of development. Eight numbers of projects were commissioned, 6 projects under construction, 15 pending for environmental clearances and 9 under various stages of investigations. The middle zone of Sutlej River Basin i.e., from Reckong Peo to Rampur was found to be affected most by different categories of HEPs. Anthropogenic pressure was high in this zone, which was more subjected to a greater loss in terms of changing River morphology, frequent mass movement, forests, agriculture, assets and property losses and limited livelihood options. The middle zone (i.e., from Reckong Peo to Rampur) had 23 projects, which is followed by the upper zone (i.e., from Spiti to Reckong Peo) with 10 projects and the lower zone (from Rampur to Kol dam) with 5 projects. The density of hydropower projects was found to be high in the middle zone, which is having high vulnerability and risks of land degradation (Kuniyal *et al.,* 2019). The brief about the main Hydro Electric Projects on Sutlej River are as follows:

Bhakra Dam: The Bhakra Dam is one of the highest straight gravity dams in the world, second tallest in India (225.55m) constructed on the Sutlej River near the upstream of Bhakra village in Bilaspur district of Himachal Pradesh. The dam has created a huge reservoir of water, called the Gobind Sagar Lake, having a gross storage capacity of 9,867.84 Mm^3, with a water spread area of 168.35 km^2 at Full Reservoir Level (FRL). The reservoir has a live storage capacity of 7,436.03 Mm^3 for irrigation and power generation. The dead storage capacity is 2,431.81 Mm^3 (BMB, 1970). The average annual inflow into the reservoir is 17,890 Mm^3 (Asthana, 2007). A large part, about 16,835 ha, of the then princely state of Bilaspur immersed in Gobind Sagar Lake, also resulted in displacement of > 36,000 people (Raj, 1960; Singh *et al.,* 2002). The Nangal dam has been constructed about 13 km downstream of the Bhakra dam which serves as an auxiliary dam and act as a balancing reservoir for taking care of the daily fluctuations from the Bhakra dam. The Bhakra Nangal Multipurpose Dams were one of the first River valley projects undertaken in post-independent India and completed in the early 1970s. The dam canal network also provides direct surface irrigation water to several districts of Himachal Pradesh, Punjab, Haryana, and Rajasthan covering an area of about 3.54 mha (Bhatia *et al.,* 2007).



Plate 2. 7 General view of Bhakhra Dam

Kol Dam: Kol Dam HEP commonly called Koldam is an embankment dam built at Barmana, in Bilaspur district of Himachal Pradesh. The reservoir level of Kol dam had area of submergence corresponding to 1,302 ha extending up to about 40 km upstream of dam axis. Kol Dam HEP has affected many of the families who have been displaced to different places. These families are now residing at different places like resettlement colonies of Kangoo (Mandi), Mundkhar (Solan), Sunni (Shimla), Jamthal and Chamyon (Bilaspur). The HEP has resulted in loss of land holding per family in affected sampled areas i.e., cultivated land, loss in grazing lands, and decrease in crop area. Similar findings were given by Chand *et al.* (2016).



Plate 2. 8 A view of Kol Dam

Nathpa Jhakri: The 1500 MW Nathpa Jhakri Hydroelectric Project (NJHEP) is a run of the River project on the Sutlej River with a dam near village Nathpa in district Kinnaur and an underground power house near village Jhakri in district Shimla. According to a study conducted by Katoch *et al.* (2014), on impacts of Nathpa Jhakri project in Kinnaur and Shimla districts of HP, they observed that after project implementation, cultivated and uncultivated areas had decreased by 5.82% and 42.78%, respectively. The occupational structure showed that due to dislocation, agriculture is decreased from 43.3% to 20%, the private business has increased from 13.3% to 30%, shop owner have increased from 20% to 26.7% and the government jobs have decreased from 16.7% to 13.3% (Katoch *et al.*, 2014).



Plate 2. 9 A View of Nathpa Jhakri Dam

Rampur Hydro Electric Project: Rampur HEP is a 412MW hydroelectric power plant commissioned on 2013 on the Sutlej River in the Himachal Pradesh state of India. It is located downstream of the existing 1,500MW Nathpa Jhakri Hydro Electric Power Project (NJHEP).

Karcham Wangtoo: Commissioned on 13 September, 2011, the Karcham Wangtoo plant is located on Sutlej River in Kinnaur district of Himachal Pradesh, with a generating capacity of 1,091 MW. Its diversion dam is located at village Karcham and the powerhouse is located near village Wangtoo.

2.3.3 Hydrology Surface and Groundwater Resources, Sedimentation, Environmental Flows and Water Quality

The flow in the Sutlej River is complex and derived from a contribution of rain, snow and glaciers. The contribution of River flow from rain, snow and glaciers varies from place to place and with season of the year. Various hydrological aspects of the Sutlej River from the perspective of availability of surface and groundwater resources, its use for agriculture by way of irrigation and groundwater exploitation, power generation, creation of dams, reservoirs and hydroelectric projects, River fragmentation (i.e., barriers water storage in dams, reservoirs and diversion of water by tunnels and canals), pollution i.e., dumping into the River of waste and

sewage and water quality, River flows, all through the River course and River basin have been important aspects of study by various organizations. A large amount of literature is thus, available on these aspects of hydrology which is not only important from the viewpoint of requirements of River management but also of direct relevance to Sutlej River i.e. forestry interventions.

a) Surface Water

A significant portion of the discharge from the Sutlej River comes from the Himalayan mountain system, primarily glaciers, snowmelt and rainfall and runoff during the monsoon season. Most of the water reserves are in the form of ice that rest in the upper part of the basin located within the districts of Lahaul and Spiti, Kinnaur and Shimla, where, most of the area is inaccessible due to hilly terrain and unstable geology. Snowmelt dominated stream flow of the western Himalayan Rivers is an important water resource during the dry premonsoon spring months to meet the irrigation and hydropower needs in the northern India. It is observed that on an average about 65% area of the Sutlej River basin is covered with snow in the month of March- April, which reduces to about 20% in the month of September- October. The average snow and glacier runoff contribution in the annual flow of Sutlej River at Bhakra is estimated to be about 61%. The total catchment area within the mountains is 47,480 km^2, with the Lahaul and Spiti and Kinnaur district tributaries accounting for 5,875 km^2 and 5,157 km^2, respectively. The Bhakra Reservoir is the lifeline for water supply in three major States in Northern India including India's "Bread Basket" the Punjab State. The current total inflow to the Bhakra Dam comprises the Sutlej River flow (65–80%) and the flow diverted from a tributary of the Sutlej i.e. the Beas River (via the Beas Sutlej Link (BSL), 20–35%). Melting snow and ice provides the water supply to much of the Himalayan region during the dry months before the summer monsoon. Snowmelt is most important in the western Himalaya where melt water comprises up to about 70% of the annual discharge of the Indus River and its tributaries (Kattelmann, 1993; Archer, 2003). More than 50% of the annual flow of the Sutlej River is contributed by snow and ice melt (Singh and Jain, 2002 and 2003). The annual and seasonal Standardized Discharge Indices (SDI) has been derived in order to preserve uniformity and facilitate comparison between flows of Sutlej River at different sites. MannKendall (MK) test, a nonparametric test method, has been applied to detect trend in annual and seasonal SDI for periods 1970–2010. The results of annual and seasonal trend analysis have revealed decreasing trends in SDI at all the gauging sites. The trend in annual SDI is statistically significant (95% confidence level) at Rampur (0.04 cumec/year) and insignificant at Kasol (0.02 cumec/year) and Sunni (0.01 cumec/year), respectively. The study of annual decadal change in SDI at all the sites showed that reduction in River discharge has occurred in the decade of 2001–2010 (Singh *et al.,* 2014).

b) River Slope

The Sutlej River rises as Langchen Khabab in the lakes of Mansarover and Rakastal in the Tibetan Plateau from the southern slopes of Mount Kailash at an elevation of about 4,570 m amsl

and forms one of the principal rivers of the Indus River System. Major portion of the Sutlej River catchment comprises of steep to very steep high hills of Great Himalaya, which are covered with snow most of the year. The rainfall zone varies from 750-1,000 mm to more than 2000 mm. The lower elevation area has steep to very steep high hills of the Lesser Himalaya. The forest types found are dry alpine and moist alpine with lowest rainfall range (<700 mm). The slope supports forest type such as Subalpine, Himalayan moist temperate, Subtropical pine and Subtropical broadleaved (ICFRE, 2014).

c) Annual Flow of Sutlej River at Bhakra

The stream flow of the Sutlej River consists of the contribution from rain, snow and glaciers and the respective contribution to stream flow of each component varies with time throughout the year. Generally, the snowmelt contribution starts from March and lasts until June and July and increases continuously and exceeds the rainfall component. Thus, in the pre monsoon season (April to June), a major part of the stream flow is generated from seasonal snow. During the monsoon season (July to September), flow is governed mainly by monsoon rains which result in discharges and floods in the lower part of the basin. The seasonal snow gets accumulated on glaciers during the winter season and by the end of May and June, thereafter, glaciers start contributing to stream flow. Glaciers contribute to their maximum in the months of July and August. Minimum stream flow is observed during winter because no melting takes place due to low temperatures (Singh and Jain, 2002). Also according to Sharma *et al.* (1991) about 80% of the annual flow of the Sutlej River System from basins in the High Himalaya i.e., from Tibet, Spiti, and Kinnaur, occurs between May and September, and is primarily due to snow melt.

Singh and Jain (2002) described the monthly distribution of stream flow at Bhakra Dam from October, 1986 to September, 1996 (10 years) (Table 2.7) and observed that about 83% of the total annual flow is observed during the pre-monsoon and monsoon seasons, because a high contribution from all the sources of runoff is produced in these two seasons. In the other two quarters, flow is only 17% of the total annual flows.

Table 2. 7 Quarterly Distribution of the Annual Flows of Sutlej River at Bhakra Dam

Sr. No.	Season	Period	Average Runoff (mm)	Contribution to annual flow (%)
1	Pre Monsoon	April to June	150.9	26.8
2	Monsoon	July to September	317.4	56.4
3	Post Monsoon	October to December	55.0	9.9
4	Winter	January to March	38.1	6.9
Total			**561.4**	**100**

(Source: Adopted from Singh and Jain, 2002)

Total inflow data of Sutlej River in Bhakra Reservior has also been analyzed for the period from April, 2017 to March, 2018 and same trends were observed. The pre monsoon and monsoon

season inflow found to be 72.73% of the total inflow, while in winter season, the annual inflow was found to be only 11.11% (Table 2.8).

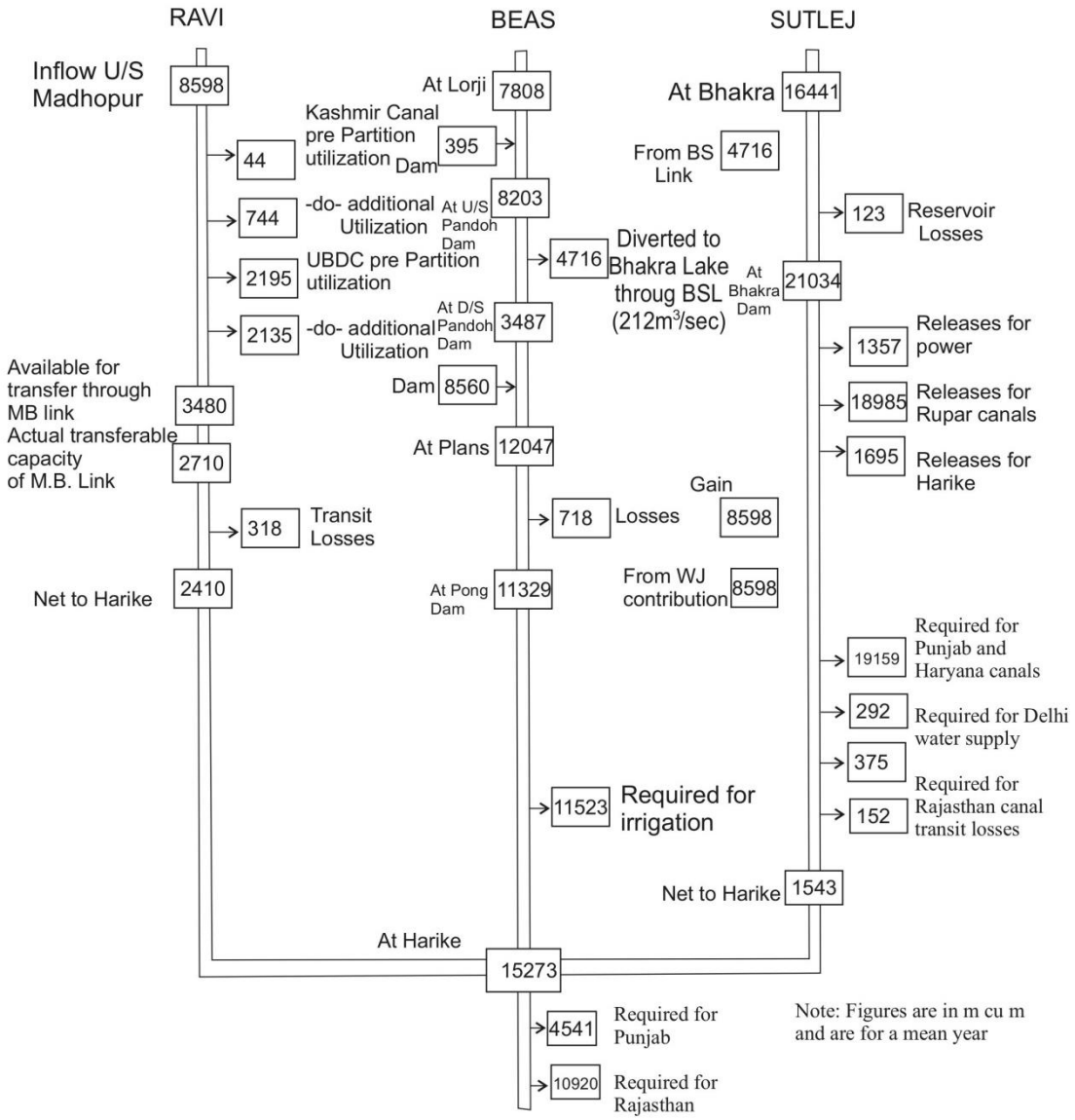
Table 2.8 Quarterly Distribution of the Annual inflows of Sutlej River at Bhakra Dam

Sr. No.	Season	Period	Inflow (Cusec)	Inflow (km^3)	Contribution to Annual inflow (%)
1	Pre Monsoon	April to June	143833.00	4.07	43.60
2	Monsoon	July to September	96107.00	2.72	29.13
3	Post Monsoon	October to December	53300.00	1.51	16.16
4	Winter	January to March	36680.00	1.04	11.11
Total				**9.34**	**100.00**

(Source: BBMB, 2018)

d) Annual Flows of the Sutlej River and Water Balance (Beas-Sutlej Link)

The Beas-Sutlej link comprising a diversion dam at Pandoh across the Beas River near Pandoh was created to transfer 4,727 million m^3 of water to Bhakra Reservoir on the Sutlej River through tunnels and open channels (Rao and Ramasheshan, 1985). Likewise, water from the Ravi River is being transferred by a diversion at Madhopur Headworks through the Madhopur-Beas Link (Max. capacity: 283 cumecs) to the Beas River. The interconnected surface water budget system of the Beas, Sutlej, and Ravi Rivers was shown diagrammatically by Lamba and Prem (1975) and adopted by Rao and Ramasheshan (1985). The same diagrammatic sketch showing the inflows of the three rivers and their interconnections has been incorporated in the present DPR for the purpose of clarity and better insight on three interlinked rivers (Fig. 2.5).



(Source: Adopted from Lamba and Prem, 1975)

Fig 2. 5 Interconnected Surface Water Budget System of Beas, Sutlej and Ravi Rivers

e) Water Use and River Fragmentation

The Sutlej River and its tributaries have been used for irrigation since ancient times. The waters of the Sutlej River are allocated to India under the Indus Water Treaty (1960) and India has the full right to use the flows of Sutlej River. In Himachal Pradesh, which has underdeveloped irrigation facilities, almost all of the agricultural activities are rainfed. Post-independence, agriculture expansion in the country for food self-sufficiency, and efforts to boost activities

under the programme of 'Green Revolution' resulted in the loss of forests and other natural vegetation besides reclamation of swamps and marshes. The physical barriers by way of dams, barrages and other manmade structures block or constrict the River, thereby interrupting the flow of water, sediments and aquatic species. In the region of Punjab, at Ropar Headworks there is extensive canal system through which most of the water of River is diverted to irrigation canals for irrigation purposes in addition to the water supply from Gobind Sagar Lake to the States of Punjab, Haryana and Rajasthan.

Short term economic benefits of such physical barriers can be reasonably estimated while the longterm, basin wide environmental losses in terms of River stability, soil fertility and water quality, ecological balance, flood events and health effects are difficult to predict (UNEP, 2008). The River fragmentation by such manmade structures not only interrupts or changes the flow rate that causes physical imbalance in the River, the other alterations in sediment load and seepage inflow/ outflow could also be easily upset.

f) Groundwater Availability

The River flows are comprised of glacier melt, snowmelt, rainfall and runoff. Outside the Polar Regions, the Upper Indus River Basin contains the greatest area of perennial glacial ice in the world (22 000 km^2); the area of winter snow cover is an order of magnitude greater. The glaciers serve as natural storage reservoirs that provide perennial supplies to the Indus River and some of its tributaries (WCD, 2000). The groundwater availability in Himachal Pradesh and Punjab are briefly described as below.

g) Groundwater in Himachal Pradesh

The groundwater availability of the Himalayan region is essentially controlled by geological setting, distribution of rain, snow and porosity of rocks constituting aquifers. Therefore, hydrogeology mapping of the area has been carried out. Geologically, the study area constitutes the rocks of Proterozoic Era to the Quaternary Period. Groundwater occurs mostly in the fractured bedrock under unconfined and semi confined conditions and ooze out in the form of springs areas of Sutlej Riverscape. Springs are the main ground water structures that provide water for domestic and irrigation uses in major rural and urban centers. Springs are locally called *Dhara* or *Chasma or Bowries. Bowries* area type dug well, or another structure constructed in the hill slopes to tap the seepage water. The ground water in most of the locations around Sutlej River was found to be suitable for drinking and irrigation purposes. Springs in Sutlej River catchments are both perennial and seasonal with varying discharges (ICFRE, 2014).

Groundwater in Punjab

Various workers have studied the ground water quality in various districts of Punjab, India (Chopra and Krishan, 2014; Kumar *et al.,* 2017; Sharma *et al.,* 2017; Kaur *et al.,* 2017). In a study conducted by Kaur *et al.* (2017) in Malwa region of Punjab, India, it was found that

groundwater quality in all the 24 locations spread across the districts of Faridkot, Muktsar, Bathinda, Mansa and Bar *Nallah*; found to be highly contaminated. The majority of water samples were found to be beyond desirable limits as prescribed by WHO standards and Indian standards for drinking water. Samples from almost all the locations were classified as hard and contained high TDS which indicate its unsuitability for drinking. Another study conducted by Chopra and Krishan (2014) revealed that groundwater in areas lying south of Sutlej is affected by native salinity and alkalinity problems. Groundwater quality problem is more acute in south and southwestern part. On the other hand, groundwater quality is found to be fresh/fit for irrigation in large parts of the State comprising of districts Ropar, SAS Nagar, Fatehgarh Sahib, Patiala, Ludhiana, Northern part of Moga, north and eastern part of Ferozepur districts. However, groundwater between the depth range of 45 to 60 m is found to be unfit for irrigation in districts of Muktsar, Faridkot, Bathinda, Mansa, and part of Sangrur due to high salinity and or alkalinity.

h) Environmental Flow

Environmental Flows (EFs) describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems. Environmental flow management provides the water flows needed to sustain freshwater and estuarine ecosystems in coexistence with agriculture, industry, and cities. The goal of environmental flow management is to restore and maintain the socially valued benefits of healthy, resilient freshwater ecosystems through participatory decision making informed by sound science. Groundwater and floodplain management are integral to environmental flow management (Brisbane Declaration, 2007).

Increasing demands and withdrawals of water are responsible for large reductions in natural flows of many rivers in many parts of the world. Since flowing water is one of the important determinants of the health of a River, a large reduction of flows can cause many adverse impacts, including degrading River ecosystems. Current attention on EFs has emerged because some researchers believe that the dams and diversions constructed to regulate rivers for direct societal needs have significantly and mostly adversely impacted the rivers with loss of ecosystem services; although there are contrary views to this as well. However, besides the dams and diversions, many other changes in the catchment affect the flow regime of a River (Jain, 2015).

The EFs are water that is left in a River ecosystem or released into it for the specific purpose of managing the condition of that ecosystem. The Sutlej River between Nathpa and Jhakri has low biological productivity with no fishery practiced. Therefore, only survival habitat may be required in the reach for which 10% of mean flow may be specified as per this method. In the case of Nathpa Jhakri reach, Coefficient of Variation (CV) of flow is expected to be high as CV of seasonal and annual rainfall is found to be high. However, BFI (i.e., proportion of total flow that is base flow) is also expected to be high due to snow melt contribution to base flow. DHI Institute Water and Environment in its study on managed River flow for Rampur HEP has

performed hydrodynamic practice analysis to obtain velocity profile of Sutlej River between Nathpa and Bael so as to determine most favorable flow condition for flushing of sediments, dilution for BOD load and for growth of aquatic life. The different scenarios were simulated for different flow releases varying from 1 cumec to 10 cumec as well as zero release and 1500 cumec release. A more appropriate term for environmental flow or minimum flow is the managed flow as in addition to discharge, so as to prescribe other hydraulic variables,(i.e., velocity of flow, flow variability, depth of flow, submerged width of River bed, etc.) also, which are important for aquatic habitat, silt flushing, water quality, aesthetic River condition, etc. (Kumar, 2007).

Sutlej River flow is augmented by flow from tributaries joining the River downstream of the dam, plus a base flow contribution to the River from groundwater. Nevertheless, there may be critical reaches in which altered flows are not able to sustain the riverbed and Riparian ecosystems that existed prior to implementation of the project. In this context, Kumar *et al.* (2007) analyzed the hydrological, hydraulic and ecological data to assess the EFs in the Nathpa Jhakri reach of Sutlej River. The organization DHI (2006) assessed both the direct and the indirect impacts of restricted water flow in the Sutlej River, particularly during the lean season, on the riverine system, the health and hygiene of the downstream population, irrigation practice in the downstream and on aesthetics of the River.

i) Erosion Processes

Sutlej River in general is characterized by a very high silt load coming from snow melts from Tibet and cold desert areas of Spiti Valley. The average annual sediment load in the Spiti, a major tributary of Sutlej River was estimated at 7.66 million tons while that for Sutlej River was estimated to be 7.30 million tones. These estimations were carried out on the basis of suspended sediment sampling done by the Himachal Pradesh State Pollution Control Board at several gauging stations in the Sutlej River System. The annual sediment transport for the River Spiti has been reported at 7.84 million tones and correspondingly 7 million tones for Sutlej River. Snowmelt and the related erosion processes (i.e., rapid mass wasting in combination with glacier runoff) are the major sediment sources. The local developmental activities like construction of roads, hydroelectric projects, residential areas, tourism also contribute in soil erosion and are of great importance for estimating erosion potential of the area. The density of the silt deposits is influenced by the particle size distribution and is time dependent. At the upper Sutlej River region, the bed material is heterogeneous as a result of heavy floods which break up the 'Erosion Pavement' of coarse bed material exposing a finer substratum. Catastrophic input from rapid mass wasting process also leads to heterogeneous nature of bed material. Both factors result in a rapid increase in bed load transport by the Sutlej River that is reduced only when the riverbed adapts to the new situation. Sutlej River on its course of travel flows through terrain having very little as well as loose vegetation. Such terrain does not hold soil tightly and hence, enhances the

rate of erosion. Most of the loose soil is flushed into the River. This makes River high in suspended solid and hence, turbid water for larger part of the year.

j) Sediment Transport

The Sutlej River is known for its high sediment loads, and the current mean annual suspended sediment load is in the order of 7,00,000 tonnes per year (IHA, 2007). Sometime the bed load and suspended loads leads to flash floods and other disastrous activities in 2005, a flash flood caused by an artificial lake breach increased silt load up to over 25,000 ppm because of the destabilisation of River banks. Twenty days after the flood, the silt load was 5,000 ppm, which is the limit for power generation. As a result, the power plant had to be shut down for several weeks.



Plate 2. 10 Silt in Sutlej River

k) Sediment Transport along the Sutlej River Basin

The maximum discharge was observed to be 1,156 cumec on 15 June, 2007 in Sutlej River and 2,684 cumec on 26 July, 2007 in Spiti River. The average annual suspended sediment transported at Powari was computed as 31.69 million tonnes. The R2 value of 0.91 indicates a very good relationship between discharge and sediment load carried by the River. The maximum sediment concentration in the Baspa River Basin is of 22,983 mg/l, reported for the discharge of 137 cumec on 30 July, 2008. The maximum discharge at Baltarang (Karcham Wangtoo HP) of

1,663 cumec was recorded on 7 August, 2010 with a silt content of 21537 ppm. The maximum discharge at Nathpa Jhakri is about 1,553 cumec on 4 August, 2006 had the silt content of 4,080 ppm, while the maximum silt content of 17,720 ppm was observed on 11 September, 2009 for a discharge of 588 cumec (ICFRE, 2014).

l) Sediment Budget

Rivers are dynamical systems with alternating patterns of sedimentation and erosion. Both sedimentation and erosion may have negative consequences from a perspective of River management. A sediment budget is a most valuable tool for taking measures in River management that deal with sediment dynamics effectively. Drawing up a sediment budget is time consuming and complicated, but very rewarding in that it strongly increases our understanding of the functional behaviour of a River system and the human impact thereon. A watershed sediment budget is one that identifies the magnitude of sediment sources and sinks in a watershed relative to watershed output (Reid and Trustrum, 2002). High mountain regions like the Himalaya are characterized by a high rate of denudation (Shroder, 1993) with River systems like the Ganges Brahmaputra and the Indus acting as the export mechanisms for sediments. The large quantity of sediment produced and transported downstream creates a number of major water resources management problems such as siltation of reservoirs, damage to turbines, reduction in quality of water supplies, and transport of chemical pollutants (Johnson *et al.*, 1998). Sediments budgets are a useful and powerful conceptual framework for examining the relationships between sources, sinks, fluvial transport and sediment yield, and investigating how these relationships are affected by changes in land use, climate, seismicity and isostatic adjustment (Wasson, 2002). Reid and Dunne (1996) have defined sediment budget on account of the sources and disposition as it travels from its point of origin to its eventual exit from the drainage basin.

m) Water Quality of Sutlej River

Most of the rivers in India have their cultural and religious significance and hence, are revered and worshiped. Despite this, the quality and quantity of water in most of the rivers have deteriorated with passage of time due to anthropogenic pressure, urbanization and rapid pace of industrialization (Sharma and Walia, 2016; Kumar *et al.*, 2017; Solanki and Khera, 2019). Inadequate freshwater supply and inappropriate management of freshwater resources have further aggravated the situation (Shankhwar *et al.*, 2015; Ingole *et al.*, 2015). The entire course of main channel and its tributaries are under great influence of densely populated human habitations, townships, tourism destinations, and expanding agriculture and horticulture. Thus, the Sutlej River and its tributaries are heavily burdened by waste and untreated disposal of sewage and effluents from townships, and pollutants from Agriculture Landscapes. The issue of water quality has become much more severe in recent years rather than the issues of quantity and access of water. Thus, the assessment of the status of water quality of natural water bodies and rivers is of utmost importance from the perspective of drinking water, other uses and public

health. The State Pollution Control Board (SPCB) is the primary agency responsible for monitoring the water quality in a State as the monitoring is a prerequisite to ascertain the impact on water quality and planning of type and extent of pollution control measures required to mitigate the situation.

i) Water Quality of Sutlej River in Himachal Pradesh

Himachal Pradesh regularly monitors status of natural water bodies for water quality through Himachal Pradesh State Pollution Control Board (HPSPCB). The CPCB under the National Program Monitoring of National Aquatic Resources (MINARS) has sponsored the water quality monitoring of major rivers of the State. The samples are collected quarterly i.e., in the months of March, June, September and December. Water samples from 38 location across the Sutlej River and its tributaries were analyzed under CEIA, Sutlej 2014 and overall quality in the entire stretch between the first and last sampling points on the main Sutlej River (i.e., from upstream of Khab to Kol dam) were well within the prescribed limit for drinking water (ICFRE, 2014) with some exceptions. The total dissolved solids, conductivity during lean season and the total coliforms, few nutrients and heavy metal mercury in pre monsoon was recorded above the acceptable limits near Wangtoo intake site. DO, total coliform, Mercury during lean and winter recorded high in Nathpa dam sites. Ghanvi recorded high BOD, total coliform and occurrence of mercury during lean season. Total coliform in *Pandoa* location were also observed to be higher. The DO observed was higher than the normal limits which is expected due to high flow rates and velocity. The changes in marginal high values of DO, BOD, COD and total coliforms may be due to runoff generated from snow melt, concentration of organic matter and due to sediments (or due to landslide). The total coliform is attributed to organic waste merging in the water in the sites recorded. TDS in one location of Himachal Pradesh namely Nogli *Khad* after confluence to Sutlej River in pre-monsoon recorded high. TC was recorded higher from the permissible limits of CPCB for class A of water quality in few locations (i.e., Karcham Wangtoo outlet, of Sutlej tributaries) (ICFRE, 2014).

ii) Water Quality of Sutlej in Plains of Punjab

Sutlej River, the largest River of Punjab, after flowing through mountains of Himachal Pradesh enters Punjab near Nangal and enters the plains at Ropar. At Ropar, there is a Head Works for canal system to provide irrigation to large parts of the State. The River flow quite slowly downstream headwork's due to broad bed width and meager flow and major part of River water has been diverted to the irrigation canals. Sutlej River finally reaches Harike Pattan where it meets Beas River. During the monsoon period, the areas on both sides of River are prone to floods. The River leaves Punjab plains near Ferozepur and enters Pakistan after flowing through Ludhiana, Jalandhar, Kapurthala and Firozpur districts of Punjab. Sutlej River is a major source of water supply for irrigation, and the water is also being used by the people for drinking, washing, bathing, etc. In the region of Punjab, Sutlej River receives a large amount of effluents

from various industries (fertilizer, brewery, paper and pulp mills, cardboard, pipes and tubes, slaughter house, etc.) and city sewage via 'Budha *Nallah* and East Bein' which degrades the water quality of the River. Punjab Pollution Control Board regularly monitors the water quality of Sutlej River. A number of studies have been carried out regarding pollution of Sutlej River in Punjab (Jindal and Sharma, 2011; Mahajan and Bali, 2012; Chauhan and Sagar, 2013; Sharma *et al.,* 2018). In a study on comparing various physico-chemical parameters of the water of Sutlej River with National and International Standards (ISI 1973; ICMR 1975; WHO 2011). Sharma *et al.* (2018) found that most of the parameters analyzed were within the permissible limits of drinking water standards at Ropar Headworks and at a site before confluence with East Bein. Whereas, the site downstream of Buddha *Nallah* and at Harike before confluence with Beas River, the values of DO, total alkalinity, phosphate and BOD were found to be above the permissible limits.

2.3.4 The Climate

The Sutlej River Basin has great variation in its climate. The climate of basin varies from hot and sub-humid tropical in the southern part and while the glacier and alpine are seen in the eastern and northern part of the basin. The cold desert i.e., Spiti area has two seasons, summer from March to September and winter thereafter. The Sutlej catchment experienced the three seasons (i.e., summer, rainy, and winter), downstream of upper Kinnaur (Chauhan *et al.*, 2016). In the basin, the summer season starts from April to June with an average temperature varies from 20°C to 38°C. The rainy season starts from July to September, followed by a relatively warm October. The winter season starts from November to February with the average temperature varies from 0°C to 15°C. Snowfall is common in alpine tracts (above 2,200 m i.e., in the higher and Trans Himalayan region).

The Sutlej River Basin in Punjab encompasses a more than 60% area of the State. An analysis of the water balance in the context of climate change for this River Basin indicates that as the temperatures rise by 1.7^{o}C to 2.0^{o}C by 2021-2050s, changes in evapotranspiration are likely to be minimal, it being comparatively higher in the October to February period. An overall increase in rainfall of about 32% is expected with respect to the present average annual rainfall ranging between 960 mm sub mountain region and 460 mm in the plains. The western parts of the basin, may receive up to 50% more precipitation by the end of the century compared to the current climatological baseline. This also means that the water logging conditions in the southwestern region of the state may intensify. Projections indicate increase in heavy precipitation events of the order of 100mm/day and 150mm/day level for the entire River Basin. Smaller increases are projected to occur in the central region of the Basin, and some regions could see the numbers of such days double from about 3 per year to 6 per year. Mountainous regions are less affected. With increase in heavy precipitation events, likelihood of increase in flash floods can be anticipated. An increase in annual average surface runoff (i.e., 1.6 times more than the annual precipitation) is projected with largest increase projected during the southwest monsoon period. Higher runoffs can be attributed to more precipitation falling on saturated soils.

a) Climate of Punjab

The geography and subtropical latitudinal location of Punjab lead to large variations in temperature from month to month. Even though only limited regions experience temperatures below 0°C, ground frost is commonly found in the majority of Punjab during the winter season. The temperature rises gradually with high humidity and overcast skies. However, the rise in temperature is steep when the sky is clear and humidity is low.

The maximum temperatures usually occur in mid-May and June. The temperature remains above 40°C in the entire region during this period. Ludhiana recorded the highest maximum temperature at 46.1°C with Patiala and Amritsar recording 45.5°C. The maximum temperature during the summer in Ludhiana remains above 41°C for a duration of one and a half months. These areas experience the lowest temperatures in January. The sun rays are oblique during these months and the cold winds control the temperature at daytime.

Punjab experiences its minimum temperature from December to February. The lowest temperature was recorded at Amritsar (0.2°C) and Ludhiana stood second with 0.5°C. The minimum temperature of the region remains below 5°C for almost two months during the winter season. The highest minimum temperature of these regions in June is more than the daytime maximum temperatures experienced in January and February. Ludhiana experiences minimum temperatures above 27°C for more than two months. The annual average temperature in the entire state is approximately 21°C. Further, the mean monthly temperature range varies between 25 °C in July to approximately 9°C in November. Punjab experiences three main seasons. They are: (a) Hot season (mid-April to June); (b) Rainy season (July to September); and (c) Cold season (December to February).

Apart from these three, the state experiences transitional seasons like: Pre-summer season (March to mid-April): This is the period of transition between winter and summer. Post-monsoon season (September to November): This is the period of transition between monsoon and winter seasons.

1. Summer Season: Punjab starts experiencing mild hot temperatures in February. However, the actual summer season commences in mid-April. The area experiences pressure variations during the summer months. The atmospheric pressure of the region remains around 987 millibar during February and it reaches 970 millibar in June.

2. Rainy Season: The monsoon brings joy to the agricultural sector as farmers become very busy. Punjab's rainy season begins in first week of July as monsoon currents generated in the Bay of Bengal bring rain to the region.

3. Winter Season: Temperature variation is minimal in January. The mean night and day temperatures fall to 5°C and 12°C, respectively.

b) Climate in Himachal Pradesh

Rainfall determines the cropping season of a region. Precipitation in the North-Western Himalaya is controlled by two atmospheric circulation systems i.e.,(i) the Indian summer monsoon draws moisture from the Bay of Bengal in the southeast and lasts from June to September. Rainfall magnitudes vary considerably within short distances as a result of convective, localized monsoonal storms (Barros *et al.,* 2006);(ii), the Northern Hemisphere westerlies supply moisture during December to March, derived from the Mediterranean, Black, and Caspian Sea (Gadgil, 2003; Lang and Barros, 2004).The winter westerly precipitation is coupled to mid/ upper tropospheric, synoptic scale low pressure systems, known as Western Disturbances, and is thought to be of stratiform type, i.e., less intense, more prolonged, and encompassing a larger area, than the commonly convective monsoonal rainfall (Putkonen, 2004; Dimri, 2006). The River basin receives most of its rain during the monsoon season, which starts in June/ July. From mid-July to mid-September, the Indian monsoon accounts for intense rainfall focused at elevations of 900±400 m and 2100±300 m especially at the southern Himalayan front (Bookhagen and Burbank, 2006). The higher Himalaya acts as an orographic barrier that inhibits most monsoonal moisture to migrate northward into the orogen and therefore creates a steep orographic rainfall gradient. Rainfall decreases from >2,000 mm at the front to <200 mm in the interior of the orogeny, over a horizontal distance of <100 (Wulf *et al.,* 2010). The present average annual rainfall ranges between 960 mm in sub-mountain region and 460 mm in the plains.

2.4 Biological Environment

Man is an integral part of a natural ecosystem whether it is forest, grassland, wetland or marine ecosystem. Since time immemorial, nature and humanity have always had an intricate and symbiotic relationship as natural ecosystems are the planet's life support system not only for human wellbeing but also for all other forms of life *viz*., plants, animals, and microorganisms. Natural ecosystems provide varied goods and services to humankind. Enhanced human imprint, particularly in the last century and increase in human disturbance by way of conversion of natural ecosystems, livestock grazing, forest fires, over harvests of natural resources, introduction of invasive and alien species, and incompatible land use in surrounds of delicate ecosystems has caused habitat fragmentation, decline of biodiversity, reduced ecosystem services, and even impairment of natural functioning of complex and dynamic ecosystems. It has been lately realized that the maintenance of 'Natural Capital' is essential for the human wellbeing and to accomplish varied goals of sustainable development. Decline in freshwater ecosystems and looming water crisis in a considerable part of the world has attained the significance as one of the global challenges that is strongly linked with other challenges faced by the humanity.

The biological environment in the context of a *lotic* system like River or the Riverscape includes terrestrial, aquatic, coastal and deltaic ecosystems all along the Sutlej River and its tributaries and their catchment. The biological environment from the point of view of the Sutlej Riverscape

is thereby, constituted by diverse forests, alpine pastures, grasslands, and wetlands in the Himachal Himalaya and the Punjab plains. The following section attempts to provide an insight on the biological environment based on a synthesis of widely scattered information on varied aspects natural ecosystems and associated flora and fauna.

2.4.1 Biogeographic Representation

The Sutlej Riverscape along with the States of Himachal Pradesh and Punjab represents three biogeographic zones: (i) 1-Trans Himalaya; (ii) 2 -Himalaya; and (iii) 4 -Semi Arid. These three biogeographic zones are further represented by five biotic provinces, *viz.*, (a) 1A-Ladakh Mountains; (b) 1B- Tibetan Plateau; (c) 2A- Northwestern Himalaya; (d) 2B -Western Himalaya and (e) 4A-Punjab Plains (Rodgers and Panwar, 1988). These three biogeographic zones and five biotic provinces cover a wide range of natural ecosystems and associated rare, endangered and threatened flora and fauna. The biogeographic zone 2 Himalaya with four biotic provinces are represented in the mountainous State of Himachal Pradesh while Punjab falls in one biogeographic province of a single zone i.e., 4AThe Punjab Plains of the Semi-Arid zone.

1A Ladakh Mountains Biotic Province: The Trans-Himalayan Zone is the least protected of all the biogeographic Zones in India. Out of an estimated land area of 1,84,823 km^2, Ladakh UT and Lahaul and Spiti district of Himachal Pradesh, two biotic provinces *viz.*,1A Ladakh Mountains cover 1,09,754km^2 area. Pin Valley National Park in Himachal Pradesh represents the 1ALadakh Mountains Biotic Province (Rodgers and Panwar, 1988).

1B Tibetan Plateau Biotic Province: High altitude (4,500 to 6,000 m amsl) cold and arid plateau of Tibet is represented in this biotic province. Much of this has internal brackish drainage, but it does fed the major Indus, Sutlej, Brahmaputra and Yangtze River Systems. Despite, huge extent, there are very few established protected areas. In India, the Trans-Himalayan Biogeographic Zone, Ladakh UT and Lahaul and Spiti district in Himachal Pradesh represents this biotic province. The Kibber Wildlife Sanctuary (2,220.12 km^2) is also located in 1B Tibetan Plateau Biotic Province.

2ANorth Western Himalaya Biotic Province: The Himalayan Mountain Ranges covering an area of about 2, 36,300 km^2 in India spread across five States i.e., Uttarakhand, Himachal Pradesh, Sikkim, West Bengal, and Arunachal Pradesh and one Union Territory i.e., Jammu and Kashmir. The value of Himalayan Mountains in terms of their natural resources, particularly the fresh water resources is much greater than the extent of the area implies. A significant portion of the country's population besides human populations in Nepal, Bhutan, Bangladesh, Myanmar, China, and Pakistan depend on water for various uses. The Himachal Pradesh embodies the full range of Himalayan ecosystem from the arid cold desert of the Trans-Himalaya (Zone 1) across the main Himalayan Range (Zone 2) to the semiarid foothills (Zone 4). The State has representation of two biotic provinces (2ANorth Western Himalaya and 2BWestern Himalaya). These two provinces are divided by the Sutlej River which acts as a barrier for species like the Himalayan Ibex (Rodgers and Panwar, 1988).

The 2A Northwestern Himalayan biotic province characterized by high snowcapped peaks, considerable chunk of glaciers, steep slopes, unconsolidated soils, intense rainfall and represented by the Great Himalaya, Lesser or Middle Himalaya, and the Outer Himalaya or Shivaliks. Varied landforms, notable altitudinal gradient, and harsh climatic conditions make the environment in this zone of extreme fragility. Despite human pressure and impact of developmental activities, like i.e., linking of rivers and diversion of water, HEPs, widening of road network, and ever increasing tourism etc., the biotic province harbors a large number of endangered faunal species namely, snow leopard, bears, wolves, tahr, bharal, musk deer, etc. The biotic province is represented by a wide range of galliforms and other avifauna. The biotic province harbors broad leaved tropical, subtropical, temperate, subalpine forests and alpine vegetation dominated by conifers, oaks, spruce, fur, *Rhododendron* spp., etc. along the altitudinal gradient. The biotic province is rich in lichens, bryophytes, orchids, bamboos, grasses, medicinal and aromatic herbs, and shrubs. The Sutlej Riverscape in this biotic province includes Bandli, Lippa Asrang, Shikari Devi and Rupi Bhaba Wildlife Sanctuaries.

2B Western Himalaya Biotic Province: This biotic province covers Himalayan region from the Sutlej River to the Gandak River in Nepal. In general, the Western Himalaya biotic province is drier and experiences harsher winters. The biotic province includes the eastern part of Himachal Pradesh and the larger part in Uttarakhand i.e., Garhwal and Kumaon Himalaya. The Nanda Devi, Garhwal Himalaya is the prominent peak in this province. Important PAs in this province are: (a) Himachal Pradesh – Shimla Catchment WLS, Chail WLS, Shri Naina Devi Conservation Reserve, Churhdhar WLS, Majathal WLS, and Rakchham Chitkul WLS, (b) Uttarakhand Nanda Devi National Park, Valley of Flowers National Park, Kedarnath Musk Deer Sanctuary, Gobind Pashu Vihar National Park, Gangotri National Park, Askot WLSand Binsar WLS. The Sutlej riverscape in this biotic province has three wild life sanctuaries (i.e., Majathal, Daranghati and Rakchham Chitkul). Besides, two Conservation Reserves (i.e., Shri Naina Devi and Darlaghat) are also present.

4A Punjab Plains Biotic Province: According to Rodgers and Panwar (1988), the entire state of Punjab lies in a single biotic province i.e., 4AThe Punjab Plains of the Semi-Arid Biogeographic Zone. Climatically, much of the Punjab should be in the Arid Desert Biogeographic Zone (<400 mm rainfall), but the great extent of irrigation by Himalayan Rivers i.e., Ravi, Beas and Sutlej has removed virtually all true desert elements. Thus, the State is placed in the SemiArid Indus drainage area. The entire biotic province can be recognized in three regions viz., (a) North Shivalik Hill system, (b) Indus Alluvial Plains, and (c) Fragmented region of wetlands natural and artificial. The Shivalik forests still has important faunal species like Sambar, Wild pig, Barking deer, etc. The alluvial plains have fragmented relict populations of Nilgai which together with Wild pig cause considerable crop damage. The wetlands have an important migratory water fall avifauna. The Harike Barrage at the confluence of Beas and Sutlej Rivers forms an important wetland site and is one of the Ramsar Sites. In this biotic province, Sutlej Riverscape includes the prominent PA i.e., Harike Lake Wildlife Sanctuary.

2.4.2 Forest Diversity

The Sutlej River Basin of Himachal Pradesh falls under Western Himalaya, which harbours a rich regional flora due to its diverse topography, wide altitudinal range and location at the intersection of several biogeographical units. The vegetation is represented by lower and upper western Himalayan temperate forests, dry temperate coniferous forests, subalpine forests and scrubs, alpine pastures, dwarf Juniper scrubs, and dry alpine scrubs.

i) Major Forest Type Groups of Himachal Pradesh

The Sutlej River Basin of Himachal Pradesh falls under Western Himalaya, which harbours a rich regional flora due to its diverse topography, wide altitudinal range and location at the intersection of several biogeographical units (Chawla *et al.,* 2012). The valleys of tributaries of Sutlej River presents large altitudinal gradient and thus supports diverse forest types with large area under alpine meadows at higher elevations. The upper zone of the Basin falls in Greater Himalaya Range that lies just north of the Chandrabhaga River in Lahaul Spiti region. The Spiti valley situated beyond the Kunzum Pass (4591 m) falls in Trans Himalayan Zone, has a cold desert climate and supports sub-Alpine and Alpine vegetation (Samant *et al.,* 2012). However, in some areas along River margins and glacial moraines, it is of moist alpine type, dominated by grasses, shrubs and few plantations of *Salix* and *Populus* near human habitations. The vegetation around the areas of Losar and Hansa are semiarid and the vegetation of the regions can be divided into temperate type (2400– 3500 m) and alpine type (above 3500 m). Kinnaur district falls both Greater and Trans Himalayan regions has three almost parallel mountain ranges. They are Zanskar, Great Himalaya and Dhaula Dhar with their peaks varying between 5180 to 6770 m amsl and covered with snow throughout the year (ICFRE, 2014).

The forests groups in Sutlej River Basin comprise of 24 forest types falling in seven major groups as per classification of Champion and Seth (1968) with the total forest cover area of 2550.90 km^2. These forest types are as follows as per ICFRE, 2014:

- **A.** Tropical Dry Deciduous Forests
- **B.** Subtropical Pine Forests
- **C.** Himalayan Moist Temperate Forests
- **D.** Himalayan Dry Temperate Forests
- **E.** Sub alpine Forests
- **F.** Moist Alpine Scrubs
- **G.** Dry Alpine Scrubs

A. Tropical Dry Deciduous Forests

(a) Northern Dry Mixed Deciduous Forests (5B/C2)

These types of forests are found in Bilaspur, Kullu, Mandi, Shimla, and Una districts. This forest type is well developed in the drier parts of the Shivalik and in the exposed slopes of the lower Himalayan foothills. The forest is open and comprised of poor quality trees of different deciduous species *viz., Senegalia catechu, Anogeissus latifolia, Lannea coromandelica, Aegle marmelos, Mallotus philippensis, Phyllanthus emblica* etc. The average annual rainfall varies from 100 to 150 cm. The soil is deficient, shallow and at times severely eroded. Biotic pressure is very heavy.

(b) Dry Deciduous Scrubs (5/DS1)

These are found in Bilaspur, Kullu, Mandi, Shimla, Solan and Una districts. Low broken soil cover supports shrub growth. The main tree species found in the form of scrubs are *Senegalia catechu, Butea monosperma, Lannea coromandelica,* etc., and the shrubs include *Nyctanthes arbortristis, Dodonaea viscosa, Woodfordia fruticosa, Maesa indica, Murraya* spp.etc. Some bamboos are often present. Many of the shrubs are distasteful to cattle (*Holarrhena antidysenterica, Dodonaea viscosa*) or thorny (*Randia tetrasperma* and *Carissa oppaca*), thin grass occurs throughout.

(b) *Euphorbia* Scrubs (5/DS3)

This forest type is found in Bilaspur district of Himachal Pradesh. Fleshy *Euphorbia royleana,* are the most important constituent species. The thorny *Acacia* spp. and their associates also occur but are usually stunted. Soil is bare, with thin cover of grasses.

(c) Khair Sissu Forests (5/1S2)

This forest type is found in Bilaspur and Solan districts. These are dry deciduous forests and found along the riverine tracts of the Shivalik hills or Outer Himalaya, conspicuously occur on fresh sandy and gravelly alluvium of River bed. Sissoo (*Dalbergia sissoo*) and Khair (*Senegalia catechu*) are the main species. The upper layers of the soil under this forest are almost entirely devoid of humus and are highly porous, unstable and get washed away at any time.

(d) Dry Bamboo Brakes (5/E9)

This forest type is found in Bilaspur, and Una districts. Only one bamboo species, *Dendrocalamus strictus,* occurs and forms relatively low, but often dense brakes. These forests occur mainly on dry hillsides, but also on alluvium with rainfall of 900 mm. The soil is dry most of the year and often shallow and stony as well. Biotic factors certainly influence the occurrence of this bamboo species associated with soil conditions.

B. Subtropical Pine Forests

(a) Lower or Shivalik Chir Pine Forests (9/C1a)

This forest type is found in Bilaspur, Kullu, Mandi, Shimla and Una districts. Chir Pine (*Pinus roxburghii*) stands singly or in groups with scattered lower deciduous tree storey, is more numerous in typically on steep dry slopes below 1,000m on the Shivalik conglomerates and sandstones, depressions and cool aspects. The tract experiences a very hot and dry summer with usually a fairly continuous low scrub growth of the xerophytic shrubs.

(b) Upper or Himalayan Chir Pine Forests (9/C1b)

These are more or less pure forests of Chir Pine (*Pinus roxburghii)* found at an elevation of about 1,800 m in the Lesser Himalayan hills, overlapping the tropical deciduous forest at the lower elevations notably on the Shivalik hills, and giving way to the temperate broadleaved or coniferous forests. The other main tree species found are *Engelhardtia spicata, Lyonia ovalifolia, Myrica esculenta, Pyrus pashia, Quercus oblongata, Sapindus murkorossi, Rhododendron arboretum*, etc. These are very well developed over rocks that are rich in quartz, *viz.,* quartzite, sandstone and granite. This forest type is found in Bilaspur, Kullu, Mandi, Shimla & Solan districts.

(c) Himalayan Subtropical Scrubs (9/DS1)

Over considerable areas in the Shivalik Chir zone, extending up to the Himalayan Chir forests and down into the mixed deciduous forests, these scrub forests have developed owing to excessively dry and shallow soil. *Justicia adhatoda, Berberis lycium, Leptodermis lanceolata, Murraya koenigii, M. paniculata, Carissa oppaca, Dodonaea viscosa, Rosa moschata, Zanthoxylum armatum Rubus ellipticus, Woodfordia fruiticosa, Rhus parviflora,* etc. are common shrub species in this forest type. This forest type is found in Bilaspur, Mandi, Shimla and Solan districts.

C) Himalayan Moist Temperate Forests

(a) Oak Scrubs (12/C1/DS1)

The severe lopping, felling, etc. of the *Quercus oblongata* has lead the species to the form of scrubs. This forest type is found in Kullu, Mandi, Shimla and Solan districts nearby settlements.

(b) Moist Deodar Forests (12/C1c)

These are almost pure forests of Deodar (*Cedrus deodara*) found between 1,700 to 2,500 m amsl extending appreciably lower on cool aspects and much higher even up to 3000m amsl or more on sunny ridges. However, they avoid the outer ranges and regions of high rainfall and extend into much drier climate. The main associated species are *Pinus wallichiana, Picea smithiana, Cornus macrophylla, Taxus wallichiana, Quercus oblongata, Rhododendron arboreum, Clematis montana, Hedera nepalensis, Jasmium officinale, Parthenocissus semicordata, Rubia cordifolia, Berberis lycium, Deutzia staminea, Indigofera heterantha, Desmodium elegans, Lonicera*

angustifolia, *Rosa macrophylla*,etc. This forest type is found in Bilaspur, Kinnaur, Kullu, Mandi, Shimla, and Solan districts.

(c) Western Mixed Coniferous (Spruce, Blue Pine, Silver Fir) Forests(12/C1d)

These forests are the most attractive in the Himalaya with a varying mixture of coniferous trees often of very fine growth of Spruce (*Picea smithiana*), Silver Fir (*Abies pindrow*), Blue Pine (*Pinus wallichiana*) and Deodar (*Cedrus deodara*), and varying inter mixture of evergreen and deciduous broadleaved trees like *Quercus* spp. at altitudes between 2,400 to 3,000 m amsl or more. The main species are *Abies pindrow, Cedrus deodara, Picea smithiana, Pinus wallichiana* and other associated species are *Acer acuminatum, A. caesium, Cornus macrophylla, Corylus jacquemontii, Euonymus pendulus, Juglans regia, Rhododendron arboretum* and *Taxus wallichiana. Berberis aristata, B. lycium, Cotoneaster microphyllus, Deutzia corymbosa, Ribes* spp., *Sorbaria tomentosa, Drepanostachyum falcatum, T. spathiflorus* and *Viburnum nervosum* etc. are common shrubs in the understory. This forest type is found in Kinnaur, Kullu, Mandi& Shimla districts of the Sutlej River Basins.

(d) Low Level Blue Pine (*P. wallichiana*) Forests (12/C1f)

Pinus wallichiana is the colonizer of vacant sites. More or less Kail forest occurs in the Ban Oak, Moru Oak and mixed coniferous zone as a separate type. The other tree species found in the forests are *Acer cappadocicum, Cedrus deodara, Viburnum mullaha, Rhododendron arboretum, Taxus wallichiana* and *Picea smithiana,* etc. Undergrowth is represented by *Berberis* spp., *Cotoneaster* spp., *Rabdosia rugosa, Sarcococca saligna* etc. This forest type is found in Kinnaur, Kullu, Mandi and Shimla districts.

(e) Oak Scrub (12/C2/DS1)

Practically all the oak forests are subjected to heavy grazing and in the absence of special protection measures, equally heavy lopping is found. At the lower elevations *Pyrus pashia* often survives perhaps owing to its thorniness, *Quercus floribunda* tends to be lopped to main stem and stands in columnar form till it is killed so that most of the scrub is *Quercus oblongata* and *Quercus semecarpifolia.* This forest type is found in Kullu district.

(f) Himalayan Temperate Secondary Scrubs (12/C1/DS2)

This forest type is usually found throughout the temperate forests on burnt and degraded areas especially in southern aspects. These are irregular, but often dense and extensive low scrub secondary forests with small sized trees and shrubs indicating heavy biotic pressure. The major shrub species found are *Plectranthus rugosus, Berberis* spp., *Rubus biflorus, Indigofera heterantha, Prinsepia utilis, Desmodium elegans, Sorbaria tomentosa, Rosa* spp., *Lonicera* spp. etc.This forest type is found in Kullu, Mandi and Shimla districts.

(g) Kharsu Oak Forests (*Quercus semecarpifolia*) (12/C2a)

The Kharsu Oak (*Quercus semecarpifolia*) forests occupy the highest elevation amongst the three main Western Himalayan Oaks with the altitude ranges from 2,500 to 3,500 m amsl along the outer and moister ranges particularly on southern aspects and scarp slopes. These forests are under an intense biotic pressure particularly near human habitations. Major associated species are *Picea smithiana, Pinus wallichiana, Rhododendron arboreum, Prunus cornuta, Betula utilis, Sorbus foliolosa, Cotoneaster bacillaris, Ribes glaciale, Rosa macrophylla, R. sericea, Rhododendron campanulatum, R. anthopogon, Viburnum grandiflorum, Ilex dipyrena,* etc. This forest type is found in Kullu, Mandi and Shimla districts.

(h) West Himalayan Upper Oak/Fir Forests (12/C2b)

These occur between 2,600 to 3,000m amsl. Both coniferous (Fir/Spruce) and broadleaved (Kharsu Oak) species are intricately mixed together and looks like a two storied forest. The tract in which this forest occurs receives very heavy snowfall including hailstorms during the winter months, summers are warm and dry. The main tree species are *Abies pindrow*, *Pinus wallichiana*, *Quercus semecarpifolia*, *Taxus wallichiana* and *Betula utilis*. Undergrowth constitutes spreading shrubs like *Rosa macrophylla, Rosa sericea, Rubus foliosus, Thamnocalamus spathiflorus, Viburnum grandiflorum,* etc. Herbs belonging to species of *Ainsliaea* spp., *Fragaria* spp., *Galium* spp., *Valeriana* spp., etc. This forest type is mainly found in Kullu and Shimla districts.

D) Himalayan Dry Temperate Forests

(a) Dry Broadleaved and Coniferous (*Quercus ilex; P. gerardiana*) Forests(13(i)/C1)

These are the open forests occurring between 2,000 to 2,440 m amsl having Pine mixed with evergreen Oaks and a few other xerophytic trees and shrubs which together form a fairly complete cover on sheltered sites and cool aspects leaving much of the soil exposed. The rainfall varies from about 660 to 900 mm, summers are mild, but winters are very severe. Cold dry winds lash the entire tract. The major species are *Pinus gerardiana, Quercus ilex, Cedrus deodara, Celtis australis,* etc. Such forest type is found in Kinnaur district.

(b) Neoza Pine (*P. gerardiana*) Forests(13(i)/C2a)

This type consists of pure *Pinus gerardiana* crops*;* mainly occur in the arid zone with rainfall less than 500 mm on the steep slopes and north exposures. Main species are *Pinus gerardiana* and *Cedrus deodara.* Collection of the pine seed, i.e. '*Chilgoza'*, is frequently done from *Pinus gerardiana*. This forest type is found in Kinnaur district.

(c) Dry Deodar Forests(13(i)/C2b)

This type is mainly found 2,100 - 3,250 m amsl where the rainfall rarely exceeds 1,000 mm. These are pure coniferous forest where the broadleaved trees are confined to moister ravines etc.

The main species under this type are *Cedrus deodara, Pinus wallichiana* and *Picea smithiana,* etc. This forest type is found in Kinnaur and Shimla districts of the River Basin.

E. Subalpine Forests

(a) West Himalayan Sub-Alpine Birch/Fir Forests (14/C1b)

It consists of an irregular forest type consisting predominantly of Fir (*Abies spectabilis, A. pindrow*), Birch (*Betula utilis*) and *Rhododendron campanulatum* in varying proportions. In the moist zone *Quercus semecarpifolia* may extend into this type. This forest type is found in Kinnaur, Kullu, Mandi and Shimla districts of the River Basin.

F. Moist Alpine Scrubs

(a) Rhododendron Scrub Forests (15/C1)

These are low evergreen forests of *Rhododendron* species with some stunted Birch (*Betula utilis*) and other deciduous trees primarily at an elevation of 3000 m amsl in the Higher Himalaya and sporadically in areas of higher elevation in the Lesser Himalaya. The growth habit of the *Rhododendron* is well adapted to stand snow pressure and even sliding snow. A thick layer of black humus is typically present and soil is generally wet. This forest type is found in Kinnaur, Kullu and Shimla districts of the River Basin.

(b) Dwarf Rhododendron Scrubs (15/E1)

The type is found in very cold regions, also in rocks in glacier ice. Dense *Rhododendron* spp. thickets occur between 3,350 to 4,600m amsl at upper limit, dominant at 4,600 4,900m amsl and ascending upto 5,500m amsl on dry southern slopes. These scrubs are the result of sporadic growth of dwarfed *Rhododendron* spp. occurring near the snowline all over the Great Himalaya. The average precipitation varies from 250 mm to 2000 mm mostly as snow and the major species found are *Lonicera obovata, Rhododendron anthopogon, R. campanulatum, R. lepidotum* and *Sorbus foliolosa*. This forest type is found in Kullu and Shimla districts of the River Basin.

G. Dry Alpine Scrubs

(a) Dry Alpine Scrubs (16/C1)

These forests are xerophytic in nature and occur in the dry zone of the Higher and Trans-Himalaya where dwarf shrubs predominate. Rainfall is very low and snow accounts for much of the total annual precipitation from mid-October to May hence a very short growing season is available leading to the stunted growth. Soil is poor in humus. The dry scrub forest is well developed along the streams formed by snowmelt water. *Salix* spp., *Myricaria* spp., *Hippophae* spp. and *Juniperus* spp. are quite common species in these alpine scrubs. This forest type is found in Kinnaur and Lahaul Spiti districts.

(b) Dwarf Juniper Scrubs(16/E1)

These occur on very dry sites exposed to intense insolation during the short growing season. The annual precipitation is up to 250 mm with dry sandy and loose soil. Main species are *Juniperus indica, Juniperus communis*, etc. 3,000 to 4,200m amsl. This forest type is found in Kullu, Lahaul and Spiti, Kinnaur and Shimla districts.

ii) Forest Types of Punjab

In Punjab only two types of forests are found which are as follows:

A. Tropical Dry Deciduous Forests

B. Subtropical Pine Forests

(A) Tropical Dry Deciduous Forests

(a) Northern Dry Mixed Deciduous Forests (5B/C2)

These forests are found in the districts of Faridkot, Amritsar, Bhatinda, Mansa, Sangrur, Patiala, Rupnagar, Ludhiana, Jalandhar, Kapurthala, Firozpur, Gurdaspur and Hoshiarpur. *Anogeissus latifolia* is the characteristic species of this forest. The main species are *Senegalia catechu, Anogeissus latifolia, Lannea coromandelica, Aegle marmelos, Mitragyna parvifolia, Flacourtia indica, Mallotus philippensis, Dendrocalamus strictus, Bauhinia vahlii* etc.

(b) Dry Deciduous Scrubs (5/DS1)

These are found in the districts of Gurdaspur, Amritsar, Bhatinda, Rupnagar, Hoshiarpur and Jalandhar. This forest type is characterized by a low broken soil cover of shrubby growth 3 to 6 m high including some tree species reduced to similar conditions. This is found throughout the Dry Deciduous zone in Punjab. The main species are *Nyctanthes arbortristis, Dodonaea viscosa, Woodfordia fruticosa, Carissa opaca, Clerodendrum* spp., *Murraya koenigii, M. paniculata, Maesa indica, Ziziphus* spp., etc.

(c) Dry Bamboo Brakes (5/E9)

This type is found in Hoshiarpur district. Only one species, *Dendrocalamus strictus*, occurs and forms relatively low but often dense brakes. Sometimes there is practically no overwood. They are found mainly on hillsides but also on alluvium with rainfall of 900 mm or more. The soil is dry and often shallow and stony as well. The main species are *Dendrocalamus strictus, Anogeissus latifolia, Lannea coromandelica*, etc.

(d) Khair Sissoo Forests (5/1S2)

This type is found in Rupnagar and Hoshiarpur districts. *Dalbergia sissoo* dominates these forests. The canopy is light but usually fairly complete and 18 to 25m high. *Senegalia catechu* is usually but not always present. There is an ample water supply at a moderate depth though the upper soil may be very porous hot and dry during the summer. The soil is unstable. The main species are *Dalbergia sissoo, Acacia farnesiana, Saccharum spontaneum, Erianthus munja, Phragmites* spp. etc.

(B) Subtropical Pine Forests

(a) Outer or Siwalik Chir Pine Forests (9/C1a)

This forest type is found in Gurdaspur and Hoshiarpur districts. The main species are*Pinus roxburghii, Terminalia chebula, Mallotus philippensis, Pyrus pashia, Syzygium venosum, Albizia chinensis, Phyllanthus emblica, Senegalia catechu, Murraya koenigii, Woodfordia fruticose,* etc.

2.4.3 Forest Cover and Change

The Forest Survey of India (FSI) has been undertaking the biennial assessment of forests and tree resources in different biogeographic zones, States and UTs of the country since 1987. Changes in forest cover between the two consecutive assessment periods allow appreciation of the actual change on the ground during the intervening period. The real changes on the ground can be on account of diversion of forest lands for non-forestry uses, plantation activities, harvesting of short rotation plantations, silviculture based fellings, shifting cultivation, clearances in encroached areas and conservation measures (FRI, 2016). In addition to the vital information on forest cover that provides an insight on the aerial extent of country's forests, the FSI also provides crucial information on growing stock which is the measure of substance of its tree wealth. In recent years, FSI has also started providing valuable information on the Tree Outside Forests (TOFs), the Tree Resources outside RFAs. The inventory of TOFs is carried out in both rural and urban areas of the randomly selected districts. Further, FSI has started estimating the Carbon stock in the Indian forests based on the methodology of 'Good Practices Guidance (GPG)' provided by the Intergovernmental Panel on Climate Change (IPCC). More recently, FSI has also started collecting information on Bamboo Resource of India. An insight on forest cover, TOFs, growing stock, Carbon stock, spatial pattern of forest cover and fragmentation and forest changes in two States represented within the Sutlej Riverscape is provided below based on the information published by FSI in its biennial ISFRs.

Due to large differences in altitude and precipitation in Sutlej River Basin, the vegetation types in this region range from Tropical to Trans Himalayan region. In the lower regions, the vegetation type is tropical with high temperature and receives a large amount of rainfall. The prevailing forest types in this part are mainly Sal (*Shorea robusta*) and mixed deciduous. On the southern slopes of the Himalaya, the temperature is low, reaching even zero degrees during winter. Temperate forests consist of temperate mixed deciduous coniferous forests, blue pine forests, deodar forests and oak forests. At higher altitudes climate changes into Trans Himalayan, being very dry and the temperature often below zero during winter. Because of these low temperatures and very small amount of precipitation, most of this region is barren (Cold desert).

(a) Forest Cover

According to the ISFR–2019 (FSI, 2019), India had a Recorded Forest Area (RFA) of 7, 67,419km^2 representing 23.34 % of the country's geographical area. This RFA included 57%, 29%, and 15% proportion under the legally defined Reserved Forests (RFs), Protected Forests

(PFs), and Unclassed Forests (UFs), respectively (Table 2.10). The values of RFAs in Himachal Pradesh and Punjab located along the course of the Sutlej River were 37,033 km^2 and 3,084 km^2, respectively. Himachal Pradesh has nearly 67% area as the recorded forest area while the agriculture dominated State of Punjab had a meagre recorded forest area of just 6.12% of its geographical area. The proportion of reserved forest in both the states was substantially low as bulk RFA was in the legal category of protected forests. Himachal Pradesh with it's nearly 67% RFA contributes 1.13% of the country's RFA while the Punjab contributes a minuscule proportion of country's RFA. The factual information provided in Table 2.10 amply revealed that the Himachal Pradesh wherein the Sutlej River not only enter from China, but also have catchment of some of its major tributaries still has considerable RFA. However, the bulk RFA is under the relatively lower category of PFs. The situation of forests in terms of overall RFA as well as their lower legal categories (PFs and UFs) in the Punjab alluvial plains is dismaying in proportion to the larger size of this State. The factual insight about the current forest cover and the historical information on the considerable loss of forests in these two States in the past century warrants intensive forestry interventions in the Riverscape by way of plantations as well as strict protection to the existing limited extent of forests.

Table 2. 9 Recorded Forest Areas (RFAs) in India, Himachal Pradesh and Punjab Represented in the Sutlej Riverscape

Sr. No.	India/State	Geographical Area(km^2)	Reserved Forests(km^2)	Protected Forests(km^2)	Unclassed Forests(km^2)	Forest recorded Area (km^2)	Country/ State Geographical Area (%)	% of India Forest Area
1	**All India**	32,87,469	4,34,853	2,18,924	1,13,642	7,67,419	23.34	100
2	**Himachal Pradesh**	55,673	1,898	33,130	2,005	37,033	66.52	4.82
3	**Punjab**	50,362	44	1,137	1,903	3,084	6.12	0.40
Total(23)		**1,06,035**	**1,942**	**34,267**	**3,908**	**40,117**	**37.83**	**5.22**

(Source: FSI, 2019)

Further, the close scrutiny of information on forest cover on canopy density provided by the FSI in its ISFR – 2019 in two Himachal Pradesh and Punjab provided almost similar impression (Table 2.10). Notably, out of total forest areal extent of 17,283 km^2 in H.P. and Punjab, a small area (3,121 km^2) or 18.06% was under the category of Very Dense Forests (with >70% canopy density) while as much as much 36.08% forests were under the category were under Open Forests. The Moderately Dense Forests (MDFs) with >40% and <70% canopy density constituted 45.87% of total forests in these States. The lowest proportion of VDFs in both the States and a meager extent of just 8 km^2 of VDFs in Punjab justify improvement of forests by way of protection, massive plantation and interventions like assisted natural regeneration and gap planting (Table 2.11).

Table 2. 10 Forest Cover in India, Himachal Pradesh and Punjab Represented in the Sutlej Riverscape

Sr. No.	India/ State	Geographical Area (km^2)	VDF (km^2)	MDF (km^2)	OF (km^2)	Total Forest (km^2)	Percent Geographical area (%)	Tree Cover (km^2)	Total Forest (km^2)	Scrub (km^2)
1	All India	3,287,469	99,278	3,08,472	3,04,499	7,12,249	21.67	95,027	8,07,276	46,297
2	Himachal Pradesh	55,673	3,113	7,126	5,195	15,434	27.72	829	16,263	315
3	Punjab	50,362	8	801	1,040	1,849	3.67	1,592	3,441	33
Total(23)		**1,06,035**	**3,121**	**7,927**	**6,235**	**17,283**	**16.30**	**2,421**	**19,704**	**348**

(Source: FSI, 2019)

(b) Tree Cover and Tree Outside Forests (TOFs)

Tree cover in small tree patches i.e., <1 ha in extent, outside the recorded forest area and usually those found in village woodlots, orchards, homesteads, urban areas, industrial plantations, and compact blocks along roads, canals, railway lines, etc., which has immense value as it provides multiple benefits. Owing to mapping limitations, isolated small tree patches (<1 ha) are excluded from 'Forest Cover', however, their contribution is captured in the form of tree cover. The entire country as per the ISFR2019 had Tree Cover Outside RFAs to the extent of 95,027 km^2 while Himachal Pradesh and Punjab along the Sutlej River course together had 2,421 km^2Tree Cover Outside RFAs (Table 2.11). Punjab, which was deficient in the actual forest cover, had greater areal extent of 1,592 km^2 than the Himachal Pradesh having 829 km^2 of tree cover.

(C) Growing Stock

The ISFR2019 by FSI (2019) provided the insight on the growing stock in the RFA. The growing stock for the whole country was computed to the extent of 4,273.47 million m^3 while the growing stock in TOFs was 1,642.29 million m^3 (Table 2.12). Collectively, diverse forests in Himachal Pradesh and Punjab had the growing stock in RFAs to the tune of 358.19 million m^3 and this constituted 8.38% growing stock of the country in RFA. Two States (Himachal Pradesh and Punjab) contributed just 2.66% growing stock of the country in TOFs. Incidentally, both States included in the Riverscape were poor contributors to the growing stock in RFA as well as TOFs of the country

Table 2.11 Growing Stock in India, Himachal Pradesh and Punjab Represented in the Sutlej Riverscape

Sr. No.	India/ State	Geographical Area (km^2)	Forest Recorded Area (km^2)	% of India's Forest Area	Country/ States' Geographical Area (%)	Growing Stock in RFA M m^3	Growing stock in TOF M m^3
1	**All India**	3,287,469	7,67,419	100	23.34	4,273.47	1,642.29
2	**Himachal Pradesh**	55,673	37,033	4.82	66.52	347.07	25.19
3	**Punjab**	50,362	3,084	0.40	6.12	11.12	18.56
Total (23)		**1,06,035**	**40,117**	**5.22**	**37.83**	**358.19**	**43.75**

(Source: FSI, 2019)

Above revelations with regard to the extent of RFA, legal categories of forests, forest cover, representation of canopy density classes, and contribution to the growing stock of RFA and TOFs of the country by two Himachal Pradesh and Punjab noticeably explained that the overall situation of forests in two catchment States is notably not very sound. These observations provide ample clues that there is enormous scope not only to enhance the forest extent in two States along the River course, but also to improve the quality of forests and the resultant contribution to the growing stock.

(e) Spatial Pattern of Forest Cover and Fragmentation in Different Patch Size

Anthropological distribution depends on forests for their survival, from the air they breathe to the wood they use. Besides providing habitats for animals and livelihoods for humans, forest also offer watershed protection, prevent soil erosion and mitigate climate change. Yet, despite human dependence on forests, mankind is still allowing them to disappear. A substantial chunk of forests has been cleared for expansion of agriculture. Forest lands are being diverted for non-forest uses and various developmental projects. These multiples uses, long history of management, and changes in land use owing to developmental works have resulted into fragmentation of natural as well as manmade forests. Lowrence (2000) has defined fragmentation as simultaneous reduction of forest area, increase in forest edge and subdivision of large forest area into smaller noncontiguous fragments or forest patches. The process of forest fragmentation has produced a mosaic of natural and managed ecosystems in the human dominated landscapes (Roy *et al.*, 2013; Midha and Mathur, 2010).

The Fragmentation may be defined as the breaking of large contiguous, forested areas into smaller pieces of forest; typically these pieces are separated by roads, agriculture, utility corridors, subdivision, or other human development. The Landscape Ecology examines spatial variation in fragmentation by way of assessing the spatial patterns or landscape structure, composition and dynamics by way of patch characteristics i.e., patch number, size,

shape, abundance and forest matrix that characterize forest fragmentation and impact of human activities on forests and other natural ecosystems. Forest fragmentation not only disrupts the contiguity, but also results into the loss of biodiversity and associated ecosystem processes and services Non forest patches tend to multiply and expand until eventually the forest is reduced to scattered, disconnected forest islands. The surrounding non forest land sand land uses seriously threaten the health, function and value of the remaining forest. When a forest becomes isolated, the movement of plants and animals is inhibited, which restricts breeding and gene flow resulting in long term population decline. Fragmentation is a threat to natural resilience, and connectivity of forest habitats may be a key component to forest adaptation and response to climate change.

(f) Forest Cover Changes in Two States

The spatiotemporal changes in forest cover between two consecutive assessment periods reflect the change on the ground during the intervening period and provide an insight on the forest dynamics in human dominated Landscapes. A comparison of total forest cover and forest canopy density classes in two consecutive assessment periods (2017 and 2019) in the case of entire country and two Himachal Pradesh and Punjab relevant to the Sutlej Riverscape provided noteworthy observations (Table 2.13). Accordingly, the country as well as two States registered slight increase in respective forest cover in 2017 than the previous biennial assessment. The extent of Very Dense Forests (VDFs) increased in two year period from 98,158 km^2 to 99,278 km^2 in the case of entire country. Likewise, the Himachal Pradesh showed an increase in the extent of VDFs from 3,110 km^2 to 3,113 km^2. However, Punjab haven't showed any change in VDFs i.e., 8 km^2. Similarly, in case of MDFs, the country again showed gain (from 3,08,318 km^2 to 3,08,472 km^2) while Himachal Pradesh relevant to the Sutlej Riverscape recorded slight gain in MDFs over two year intervening period. While, Punjab show very little decline in MDF. The extent of Open Forests was enhanced in the case of whole country as well as the State of Punjab while in contrast; Himachal Pradesh registered a slight decline in the extent of open forest in 2017 in comparison to the previous biennial assessment (Table 2.14).

Table 2.12 Comparison in Forest Cover and Canopy Density Classes in India, Himachal Pradesh and Punjab Between two Consecutive Assessments of 2017 and 2019

Sr. No.	India/ State	Geographical Area km^2	2017 Assessment				2019 Assessment			
			Total Forest Cover km^2	VDF km^2	MDF km^2	OF km^2	Total Forest Cover km^2	VDF km^2	MDF km^2	OF km^2
1	All India	32,87,469	7,08,273	98,158	3,08,318	3,01,797	7,12,249	99,278	3,08,472	3,04,499
2	Himachal Pradesh	55,673	15,100	3,110	6,705	5,285	15,434	3,113	7,126	5,195
3	Punjab	50,362	1,837	8	806	1,023	1849	8	801	1040
Total (23)		**1, 06, 035**	**16,937**	**3,118**	**7,511**	**6,308**	**17,283**	**3,121**	**7,927**	**6,235**

(Source: FSI, 2017 and 2019)

Undoubtedly, the country as well as two Himachal Pradesh and Punjab showed gradual increase in forest cover in past 32 years. However, such increase in forest cover has to be seen with caution in connotation with the valuable insight on various forest canopy density classes, growing stock, spatial patterns of forest cover, patch characterization, and the pace of fragmentation, particularly loss of smaller forest patches at a very fast pace. The forgoing description on changes in forest cover, the condition of the growing stock and the alarming rate of forest fragmentation warrants extensive as well as intensive forestry interventions so as to ensure healthy forests, efficient catchments, and sustainability of river ecosystems.

2.4.4 Carbon Stock in Forest

Climate change has emerged as the leading environmental issue of the present century and has become a global concern. Climate change and its implications not only pose enormous challenges for natural ecosystems but also likely to severely influence the quality of human life. Among natural ecosystems, forests have important role to play in climate change mitigation as forests and climate change are intricately connected. On the one hand, forests regulates the climate, rain, groundwater, and soil while on the other hand climate influences the spatiotemporal patterns of forests, their diversity, associated floral and faunal life, productivity, and even the ecosystem services they offer to humankind. Forests are both, the source as well as sink of carbon. They sequester the carbon as well as store more carbon than any other terrestrial ecosystem. Carbon sequestration by forests has been recognized as a major contributor towards the climate change mitigation. The 'Good Practices Guidance (GPG)' developed by the Intergovernmental Panel on Climate Change (IPCC) is the universally accepted source book for concepts, definitions, various pools, methods, default values, various required equations, etc. for preparing account of Forest Carbon Stock (FCS). The total carbon which is stocked in the forests has been divided into five pools by GPG (FSI, 2019). The living portion of carbon in biomass is in two pools *viz.*, the Above Ground Biomass (ABG) and the Below Ground Biomass (BGB) and they are major stores of significant amount of carbon. The Dead Organic Matter (DOM) is also categorized into two pools *viz*., the 'Dead Wood' and 'Litter'. The fifth pool is Soil Organic Matter (SOM) which also contains substantial amount of Organic Carbon. Since, FSI has a huge repository of past data on forest growing stock as well as continue to carry out biennial assessment of forest cover in the country, State and UTs, and forest types; FSI is in a position to provide an insight on carbon stock in India's forests and changes. The ISFR – 2019 has provided updated valuable information on State-wise carbon stock in different carbon pools. This valued information provided by FSI (2019) is used below to summarize the current situation of carbon stock in different pools into two States relevant to the Sutlej Riverscape.

The forest carbon stock for the country has been estimated to be 7,124.6 MT (FSI, 2019). An increase of 42.6 MT of carbon stock has been recorded in comparison to the estimates of previous assessment. The annual increase of carbon stock is estimated 21.3 million tonnes which is 78.1 million tonnes of CO_2 equivalent. Soil organic carbon is the largest pool of forest carbon

accounting for (56.19 %) followed by AGB (31.67 %), BGB (9.84 %), Litter (1.80 %) and dead wood (0.50 %). On comparing the changes between the present and previous assessment, the largest increase has been observed in soil organic carbon followed by AGB and dead wood. (Table 2.15). The forest carbon stock in Himachal Pradesh as per the ISFR2019 was 252.36 MT of the country's total forest carbon stock. Like in the case of entire country SOM was the largest pool in the mountainous State, followed by AGB, BGB, Litter and Dead Wood. The values of per hectare stock in different pools ranged from 44.89 t ha^1 (SOM) to 0.14 t ha^1 (Dead Wood). The forest carbon stock in the Punjab recorded in 2019 was 133.44 MT. The AGB contributed 110.04 MT while the SOM contributed 106.3 MT of carbon. The value of per hectare stock was higher in Himachal Pradesh, being 252.36 than Punjab which registered the value of 133.44 per hectare stock (Table 2.16) (FSI, 2019).

Table 2. 13 Forest Carbon Stock in Different Carbon Pools (values in '000 t) in India, Himachal Pradesh and Punjab along the Course of Sutlej River (Values in parentheses are of per ha of a stock in tonnes)

State	Forest Cover (km^2)	AGB (MT)	BGB (MT)	Dead Wood (MT)	Litter (MT)	SOM (MT)	Total (MT)
All India	7,12,249	22,56,533 (31.68)	7,00,824 (9.84)	35,842 (0.50)	1,27,902 (1.80)	40,03,575 (56.21)	71,24,676 (100.03)
Himachal Pradesh	15,434	1,10,045 (71.30)	30,745 (19.92)	2,559 (1.66)	2,711 (1.76)	1,06,300 (68.87)	2,52,360 (163.51)
Punjab	1849	3,529 (19.09)	1,367 (7.40)	25 (0.14)	125 (0.67)	8,298 (44.89)	13,344 (72.18)

(Source: FSI, 2019)

2.4.5 Wetlands

Wetlands have been recognized as one of the world's most important environmental assets, existing in all continents and latitudes (IUCN, 2017). They are important features in the landscape, and are the most productive ecosystems in the world, comparable to rain forests and coral reefs (HIMCOSTE, 2018). Wetlands provide a wide array of useful and appreciable ecosystem services, and are essential to human wellbeing, climate mitigation and adaptation as they are the Earth's greatest natural carbon stores (Ramsar, 2018). Wetlands have been recognized as the 'Biological Supermarkets' as they offer immense food that attracts wide range of faunal species for completion of their life cycle (Randhawa, 2014). Wetlands are the ecosystems infused with aquatic, semiaquatic as well as terrestrial characteristics. As the name suggests, they are characterized by the presence of water, unique soils and vegetation (hydrophytes) adapted to wet conditions. Wetlands cover about the 6% of the total land surface. Cowardin *et al.* (1979) provided first widely used classification on wetland systems based on their hydrological, ecological and geological characteristics and categorized them into lacustarine (lakes), riverine (i.e., along rivers and streams), palustarine (i.e., marshes, swamps and bogs), marine (i.e., coastal wetlands), and estuarine (i.e., including deltas, tidal marshes, and

mangrove swamps). Varied definitions of wetlands exist. Broadly, wetlands are land areas saturated with water, either permanently or seasonally, and thus characterize a distinct ecosystem. Wetlands can be natural or manmade. These include estuaries, deltas, bogs, streams, ponds, reservoirs, etc. However, as per the recent Wetland (Conservation and Management) Rule, 2017 notified by the MOEF&CC on 26.09.2017, the revised definition notably 'does not included River channels, paddy fields, human made water bodies/tanks specifically for drinking water purpose and structures specifically constructed for agriculture, salt production, recreation and irrigation purpose.

In India, various attempts have been made to prepare the inventory of wetlands and assess the areal extent (Woistencroft *et al.*, 1989; WWF and AWB, 1993; Garg *et al.*, 1998). However, these earlier assessments were marred by problem of inadequate understanding of the definition and characteristics of wetlands (Gopal and Sah, 1995). The National Wetland Atlas prepared by the Space Application Centre (SAC), ISRO is the latest scientific inventory on wetlands of the entire country, identified and mapped on 1:50,000 scale (SAC, 2011). A total of 2,01,503 wetlands were mapped in the country. In addition, 5,55,557 wetlands with area <2.25 ha which is smaller than minimum measurable unit were identified as point features (Bassi *et al.*, 2014). Thus, India has about 7,57,060 wetlands covering total area of 15.3 million ha, accounting for nearly 4.7% of the country's geographical area.

Himachal Pradesh encompasses a wide variety of wetlands, spread in various ecological zones which are the source of livelihood besides having enormous values of biodiversity, aesthetic, recreational and tourism. Altogether, 641 inland wetlands (natural 67; manmade170; wetlands <2.25 ha471) covering an area of 984.96 km^2 (Table 2.17).

Table 2. 14 Diversity of Wetlands in Himachal Pradesh and Punjab Relevant to the Sutlej Riverscape

Sr. No.	Wetland Category	Himachal Pradesh			Punjab		
		Number of Wetlands	Wetland Area (ha)	% of Wetland Area	Number of Wetlands	Wetland Area (ha)	% of Wetland Area
A	**Inland Wetlands – Natural**						
1	Lakes/ Ponds	8	52	0.05	200	1,934	2.24
2	Oxbow Lakes/ Cutoff Meanders				11	373	0.43
3	High Altitude Wetlands	42	387	0.39			
4	Riverine Wetlands				9	306	0.35
5	Waterlogged	10	47	0.05	43	2,032	2.36
6	River/ Stream	67	55,558	56.41	1.51	59,864	69.38
B	**Inland Wetlands – Manmade**						
7	Reservoir/ Barrages	13	41,817	42.46	31	11,858	13.74
8	Tanks/ Ponds	27	134	0.14	878	3,526	4.09
9	Waterlogged	3	30	0.03	58	1,341	1.55
C	**Total Inland**	**170**	**98,025**	**99.25**	**1,381**	**81,234**	**94.15**

Sr. No.	Wetland Category	Himachal Pradesh			Punjab		
		Number of Wetlands	Wetland Area (ha)	% of Wetland Area	Number of Wetlands	Wetland Area (ha)	% of Wetland Area
	Wetlands						
D	**Wetlands (<2.25 ha)**	**471**	**471**	**0.48**	**5,049**	**5,049**	**5.85**
E	**Grand Total**	**641**	**98,496**	**100**	**6,430**	**86,383**	**100**

(Source: SAC, 2010a and b)

It is evident from Table 2.17 that amongst diverse natural and manmade wetlands in Himalayan State, wetlands in the categories of rivers/ streams, reservoirs/ barrages, and high altitude wetlands were prominent covering nearly 99.26% of the total wetland area in the State. Obviously, four prominent rivers (i.e., Chenab, Ravi, Beas and Sutlej) and their tributaries those originate/ flow through the State contributed the maximum number as well as area amongst various natural wetlands. The reservoirs/ barrages created on different rivers or their tributaries constituted the second largest category of wetlands (i.e., manmade). In addition, the other prominent category was of high altitude wetlands. The 'High Altitude Wetlands – HAW' is a generic term to describe 'Areas of swamp, peat land or water bodies located at an altitude higher than 3,000 m amsl whether they are natural or artificial, permanent or temporary with water that is static, brackish or saline' (Panigrahy *et al.*, 2012). The high altitude wetlands represented 0.39% area of all wetlands in the State. Prominent high altitude lakes are Chandertal Lake (4,000 m), Brighu Lake (4,200 m), Surajtal Lake (4,833 m), Nako Lake (3,635 m), Manimahesh (4,190 m), Seruvalsar or Sirolsar Lake (3,100 m), Ghadasaru Lake (3,470 m), Mahakali (4,080m), Lamadal (3,960 m), etc. The wetland category of rivers/ streams represented the maximum area of wetlands in the State, being 56.41% while reservoirs/ barrages covered 42.46% area of total wetlands. There are few barrages made on Beas and Sutlej Rivers. The barrage at Sundernagar situated at 845 m on Beas River. Among reservoirs, the Gobind Sagar is the prominent reservoir and wetland on the Sutlej River. In addition, the Wetland Atlas for Himachal Pradesh also mapped 471 wetlands <2.25 ha in size as point feature (Table 2.17).

The Punjab also harbours a wide variety of natural and manmade wetlands. Amongst diverse wetlands mapped in Punjab, the wetland category of River/ stream was the most prominent, covering 59,864 ha area that represented 69.38% of the total wetland area mapped in the State (Table 2.17). The second largest category of wetlands in terms of areal extent was reservoirs/ barrages covering 11,858 ha area, representing 13.74% area of the total wetland area recorded in the Punjab State. Smaller wetlands, mainly tanks <2.25 ha in size represented 5.85% area of the overall wetland extent in the State. Most of the wetlands in Punjab are located on major rivers and they are the main source of water for irrigation and hydropower generation and have large canal network. These wetlands attract large number of migratory birds. The prominent wetlands of the State are Harike Lake, Kanjli Wetland, Nangal Lake, Ranjit Sagar Wetland and Ropar Wetland. Harike Lake Wetland falls in three districts *viz*., Amritsar, Kapurthala, and Ferozepur, constructed at the confluence of Beas-Sutlej Rivers.

In the context of Sutlej Riverscape, the Nako Lake, Gobindsagar Lake, Tani Jubbar Lake and, Karali Lake are prominent wetlands in Himachal Pradesh and Harike and Ropar Wetlands in Punjab of greater ecological, cultural and recreational importance. Brief description in case of these prominent wetlands is provided below:

(a) Nako Lake: Nako Lake is an oval shaped high altitude lake in the Pooh subdivision of the Kinnaur district in Nako village at an altitude of 3,662 m amsl which freezes during winters (Wikipedia, 2018). It forms part of the boundary of Nako village and seems that the village is half buried in the lake's border. The lake is surrounded by willow and poplar trees. Principal vegetative around Nako Lake is *Populus*, *Salix*, *Berberis* spp., *Lonicera* spp., and *Rosa* spp, etc. The herbaceous species of the surrounding areas are species of *Anaphalis*, *Anemone*, *Artemisia*, *Aster*, *Astragalus* spp., *Bupleurum*, *Epilobium* spp., *Erigeron* spp., *Gentiana* spp., *Potentilla* spp., *Primula* spp., *Ranunculus* spp., *Saxifraga* spp., *Sedum* spp., *Silene* spp., *Thalictrum* spp., and several members of Brassicaceae and Poaceae. The Lake is also important from cultural point of view as near the Lake there are four Buddhist temples, where near this place there is a foot like impression ascribed to the Saint *Padmasambhava*. Thus, It is a sacred place for the



Plate 2. 11 A view of Nako Lake

people of various regions where followers come from as far places as Ladakh and Spiti Valley. There is a waterfall nearby which has snow water falling like a River of milk. Legend says that it is a heavenly realm of fairies. In one of the caves, one can still able to see the live footprints of these fairies or other demigods. However, Nako is facing anthropogenic threats like the solid waste left behind by visiting tourists and also from construction activities on all sides of the lake and the sewage from the village entering into the Lake.

(b) Tani Jubbar Lake: The Tani Jubbar Lake is a small wetland placed among the scenic surroundings of snow covered mountains of Shimla district. It is the home for many kinds of birds. The dominant species in the area are *Cedrus deodara, Pinus wallichiana, Quercus semecarpifolia, Abies pindrow, Picea smithiana, Berberis* spp., *Cotoneaster* spp., *Rubus* spp., *Apluda* spp., *Decoytis glomerata, Chrysopogon gryllus, Arundinella* spp., *Senecip* spp., *Artimisia* spp., *Viola* spp., *Valeriana* spp., *etc*.

(c) Karali Lake: Karali Lake is one of the famous lakes in Shimla district. It is a small water body located on the Chhota Shali hillock just on the other side of Shali peak. Major flora of the lake is *Cedrus deodara, Pinus wallichiana, Quercus semecarpifolia, Abies pindrow, Picea smithiana, Rubus*spp.,*Cotoneaster* spp., *Apluda* spp., *Themeda* spp., *Euphorbia royaleana, Berberis* spp.,*Chrysopogon* spp., *Rosa* spp., *Lonicera* spp., *Cotoneaster* spp., *etc.*

(d) Gobind Sagar Lake: Gobind Sagar Lake is a reservoir, situated in Bilaspur and Una districts of Himachal Pradesh that is formed by back water of the Bhakra Dam. The reservoir is on the Sutlej River and is named in honour of Guru Gobind Singh, the tenth Sikh Guru. One of the world's highest gravity dams, the Bhakra dam rises nearly 225.5 m above its lowest foundations. Gobind Sagar is an important reservoir for more than one reason. i.e., (a)The Bhakra Nangal project was launched at the dawn of country's independence, signifying the beginning of an era of large developmental projects in India and the project was considered as an icon of the young nation's pride, aptly described by Jawaharlal Nehru as one of the 'Temples of Modern India'(Nehru, 1958a); (b)Secondly, the reservoir, by virtue of its location at high latitude, transcending the limits of the tropics and cold water influx from the Beas River system, simulates some sub-temperature environment that interests the limnologists, and (c)It provides a unique opportunity for the fishery biologists to study the behavior of the exotic silver carp in an Indian reservoir. Gobind Sagar has attracted the attention of a number of Scientists including limnologists, fishery biologists, technologists and general fishery managers. The principal species found around the reserviour are *Senegalia catehu, Albizia lebbeck, Arundo donax, Aegle marmelos, Anogeissus latifolia, Pinus roxburghii, Feronia limonia, Flacourtia indica, Dendrocalamus strictus, Ficuspalmata, Diospyros montana, Bauhinia variegata, Teminalia* spp., *Grewia optiva, Polygala* spp., *Brachiaria* spp., *Murraya koenigii, Vitex negundo, Withania somnifera, Woodfordia floribunda* and *Ziziphus oenoplia, Polygonum* spp., *Carex* spp., *Scirpus* spp., *etc*. The reservoir was studied by The All India Coordinated Project on Reservoir Fisheries from 1971 to 1985 (Sugunan, 1995). Gobind Sagar reservoir, one of the largest manmade lakes of India, was created by a 255 m high, straight gravity dam at Bhakra (Latitude 31° 25' N and Longitude 76° 25'E) on the Sutlej River. Construction of Bhakra Nangal Dam was initiated in 1948 and the reservoir was formed in 1963. Important tributaries (*Khads*), such as Lunkhar Khad, Sir Khad, Gambhar Khad and Ali Khad enter the Reservoir directly (Sugunan, 1995). Gobind Sagar reservoir covers 16,867 ha at the FRL of 514 m amsl and 5,063 ha at the minimum water level. The reservoir has been designed to hold 9,621 million m^3 of water, when full and 2, 431 million m^3 at DSL. However, due to silt accumulation, the capacity has declined to 7,118

and 1,973 million m^3, respectively (Table 2.18).



Plate 2. 12 A view of Gobind Sagar lake

The total catchment area of the reservoir is 56, 980 km^2. Gobind Sagar is a 96.56 km long, 6 km wide reservoir with an irregular shoreline, as indicated by the high shoreline development index of 12.86. (Sugunan, 1995). The reservoir provides warm, mixed and cool lacustrine conditions for its biota. It has 3 distinct zones, *viz*., Lunkhar khad zone, lentic zone and lotic zone, covering 26.0%, 42.0% and 32.0% of the area, respectively. At Dehar, the edge of the lotic zone, the water from Beas River enters into Sutlej River. (Fig.2.6). Discharge through the outflowing channels varies from 1.21 million ha m in the year 1974–75 to 2.35 million ha m during 1978–79, causing a level fluctuation of 67.96 m. The two power plants at the base of the Bhakra Dam reservoir are the Ganguwal and Kotla power houses, have a total installed capacity of 1204 MW of power. The irrigation canals originating from Gobind Sagar support a command area of >4 million ha of agricultural land making it one of the largest multipurpose river valley projects in the world.

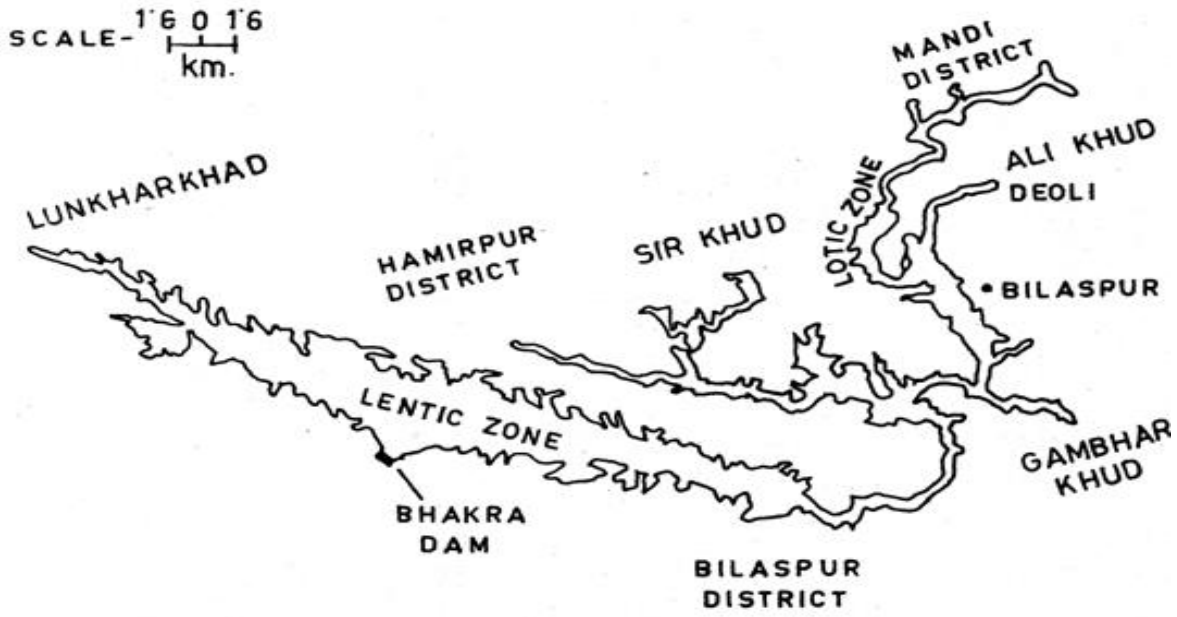


Fig 2. 6 Gobind Sagar Reservoirs, Himachal Pradesh

(Source: Sugunan, 1995)

Primary Productivity and Flora and Fauna of Wetland:

Gobind Sagar being located at the highest latitude among the reservoirs studied in India, receives the least amount of incident solar radiation (172 X 10^4 cal m^2 yr^1). The rate of energy fixation by primary producers is, however, higher, obtaining better energy conversion (0.68°) rate than in the reservoirs closer to the equator (0.20% to 0.49%). The gross primary production observed for seven years has an average range of 316.86 to 1 088 mg C m^3 day^1. The net production for the same period is 186.6 to 670.28 mg C m^3 day^1 (Sugunan, 1995).

The annual average plankton biomass which ranges from 2.1 to 16 ml m^2, increases from September onwards, reaching the maximum in December and February. Zooplankton dominates only in September and October, while in other months the phytoplanktons dominates. Lentic sector is the most productive sector of the reservoir with planktonic biomass ranging from 0.75 to 6.32 ml m^3 (1975 to 1983). Ceratium is the dominant planktonic alga, the abundance of which varies in different zones (Sugunan, 1995).The benthic macrofauna of the reservoir is not very rich both in qualitative and quantitative terms, the density varying from 345 individuals' m^2 in the lotic to 677 in the Lunkhar Khad sector. Oligochaetes (58.8%), Culicids (22.4%), Chironomids (12.6%) and Molluscs (3.0%) form the benthic community. (Sugunan, 1995).The Fish Fauna of the Gobindsagar reservoir comprises of 51 species belonging to 9 families, which include the Brown Trout *Salmo truta*, Snow trouts, *Schizothorax* spp., and several species of hill stream fishes (Anonymous, 1989). The species spectrum of the reservoir is distinct due to the sub-temperate climate and the zoogeographic affiliations with the Himalayan region. Prior to the

construction of the dam, the cold water of the upper reaches of the Sutlej River used to sustain 30 species of fish, of which *Tor putitora, Labeo dero, Labeo dyocheilus, Schizothorax* spp. and *Aorichthys seenghala* were the dominant ones.

(e) Nangal Wetland: Nangal wetland is one of the four wetlands of national importance identified in Punjab, and has been included in the National Directory of Wetlands by the MoEF&CC, GoI in January, 2008 because of its avian diversity and spreads over an area of approx. 400 ha. The wetland is an artificial lake on Sutlej River that is created due to the erection of barrage for diverting the water of Sutlej River into irrigation canals. Nangal Lake is situated on the foothills of Shivalik ranges in Ropar district of Punjab. The beautiful lake is formed due to construction of Nangal barrage on Sutlej River that is about 13 km downstream of Bhakhra dam and it forms a 6 km long artificial lake popularly called Nangal Lake. The name Nangal came after the name of Nangal Nikku, a small village. It is located at a distance of about 100 km from Chandigarh. The wetland is situated at Latitude 31°23' N and Longitude 76°22' E and has an average elevation of about 326 m amsl.

Recently, in the list of 'Ramsar Wetlands of International Importance' published on 2 February 2020, Nangal Wetland has been notified into Wetland of International Importance or Ramsar site. Nangal Wildlife Sanctuary is now categorised under Wetland of International Importance on dated 26/09/2019 covering an area of 116 ha (Ramsar, 2020). Before, Nangal Wetland was declared as a Wildlife Sanctuary in 2009 by the Punjab Government; it was notified as a protected forest by the Punjab Government in 1964, spreading over an area of 289.69 ha covering six villages of Tehsil Anandpur Sahib (PEC). The wetland is surrounded by beautiful hills and is a heaven for bird lovers and numerous migratory birds can be seen here.The influx of birds, both local and migratory, in this boarder area of Punjab and Himachal Pradesh has been on the rise for the past many years. Beside the resident birds, including the Red jungle fowl, Large Indian parakeet, Indian cuckoo, Bank myna, Wood shrike, Yelloweyed babbler and Crested bunting, one can watch a large number of birds from faroff hills roosting and feeding in the area. Nangal Wetland Sanctuary is an important habitat for some threatened species like the Scaly anteater and the Python. Phytoplanktonic study is very important because they act as primary producers, food for variety of aquatic organisms and an efficient bioindicator for water quality. Large population of phytoplankton is thriving in this wetland which enhances its productivity.

Brraich and Kaur (2015) studied 49 genera belonging to three major classes i.e., dominated by Chlorophyceae (21 genera), followed by Bacillariophyceae (19 genera) and Cyanophyceae (13 genera) which were reported. The range, mean and standard deviation for all 3 classes of phytoplankton were recorded. The most abundant genera include *Navicula* spp., *Cymbella* spp., *Pinnularia* spp., *Gomphonema* spp., *Meridion* spp., *Fragillaria* spp., *Tabellaria* spp., *Spyrogyra* spp. and *Oedogonium* spp. The maximum and minimum species richness (Menhinick Index R2) was found to be 0.05 for Chlorophyceae and 0.04 for Cyanophyceae. Maximum and minimum Species diversity (ShannonWeiner H') were found 2.94 for Chlorophyceae and 2.15 for

Bacillariophyceae. Maximum species evenness was recorded for Cyanophyceae and minimum for Bacillariophyceae. Further, current wetland is an important source of freshwater for Punjab, Haryana and Rajasthan. Nangal Lake is habitat for most of migratory and resident birds, insects, reptiles, amphibians and water plants and hence, it plays significant role in the conservation of biodiversity.

Besides, Nangal wetland is also a holy place to take bath during important days like Amavasya and Baisakhi. The wetland is a must visit for nature lovers, environmentalists, birds watchers, scientists and general public for educational and recreational purposes. Beside the importance, part of the Nangal Wetland is facing some threats and needs attention. The major threats in Nangal wetland is that of the soil erosion. Hills around Nangal Lake are prone to soil erosion due to sparse vegetative cover and excessive grazing. Second major problem is the agriculture runoff from fields which is contributing to water pollution. It also receives waste water from the villages and other sources situated along the River. The fertilizer/pesticide run off from agricultural fields on both side of the wetland also contributes to its pollution load. Mining of sand and stone boulders is also one of the threats in and around the Nangal Lake. This cause further degradation of topography and destructions of the overall ecosystem. Weed infestation around the wetland is also one of major concern and *Lantana camara* and *Parthenium* spp. have invaded the natural vegetation. It also receives the treated wastewater from STP Nangal and STP BBMB, Nangal. Illegal collection of wood or forest resources like *Saccharum* spp. and *Arundo* spp. grasses is also one of the threats to the Nangal Wetland.

(f) Ropar Wetland: Ropar Wetland was created in 1952. It is a manmade freshwater riverine as well as Lacustrine Wetland. It came into existence with the impoundment of water by constructing a barrage on the Sutlej River near Ropar town by building a head regulator to store and diverts water for beneficial uses of irrigation through canals, drinking and industrial water supply. It was declared as Wetland of International Importance in 1990, and consist of an area of 4,100 ha (Ramsar, 2020). It is situated at Latitude 30°58’31.02’ N and Longitude 76°30’76.33’E. This important ecological zone is located in the Shivalik foothills of the Lesser Himalaya. Shallow water features exist along both the sides of the River located within the wetland area. Climatically this area is sub-moist or humid and comparatively less hot region of Punjab with mean annual rainfall of 1,518 mm. Brraich and Akhter (2019) reveals the diversity, abundance and composition of zooplankton in Ropar wetland. A total of 17 genera of zooplankton population were recorded and categorized into 5 different groups, i.e., Protozoa, Rotifera, Cladocera, Copepoda and Ostracoda at all the sites (S1, S2, S3 and S4) from October 2015 to September 2017. Among these, Protozoa and Rotifera were the dominant groups consisting of 6 genera each. Of all the seasons, summer season depicted the highest density of zooplankton at all the sites and lowest diversity during monsoon season. The total area covered by the wetland is 1,365 ha, which includes 800 ha area of the River and the reservoir, 30 ha of forest area named as Sadabarat Forest (Evergreen) and 30 ha under marshy plants, which serves as an important habitat for some rare and threatened species of the Shivalik foothills. It is also an important

staging and resting ground for migratory waterfowl (Ladhar, 2005). Around 55 species of fishes and 318 species of birds have been reported from this wetland area (PSCOST, 2015). Ropar wetland also serves as an important habitat for Pangolin, Sambar and Hog deer and for some threatened species in the Shivalik foothills like Scaly ant eater, Phython, etc. The reservoir formed with the construction of barrage over Sutlej River serves in recharging ground water and is an important source of water for distant areas through Sirhind and Bist Doab canals. It helps in protection from floods and also in improvement of water quality. Due to its tremendous recreational value, a number of bird watchers and nature lovers visit the area. The major threats in the Ropar Wetland are siltation and Industrial Pollution. Ropar Wetland is facing severe problems of siltation from the adjoining barren and dried hills which need immediate treatment and greening; otherwise it may lead to shrinkage of wetland area. Secondly, Fertilizer plant at Nangal and Thermal Power Plant at Ropar are mainly responsible for water quality degradation of this ecosystem. Inflow of chemical pollutants like agrochemical residues run off, industrial effluents and sewage from adjoining towns in the upper reaches like Nangal, Naya Nangal, Anandpur Sahib and Kiratpur Sahib, need assessment and control measures.



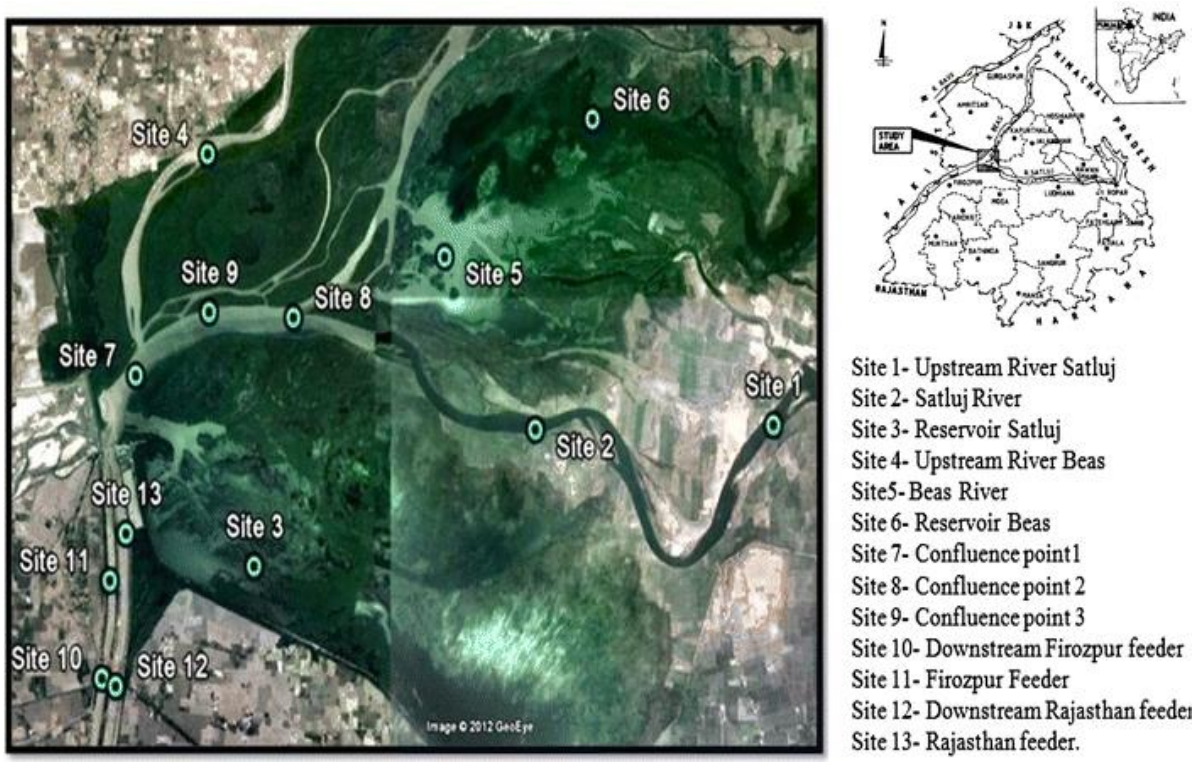
Plate 2. 13 A view of Ropar Wetland

(g) Harike Wetland: Harike Wetland is the largest freshwater wetland of the country, covering an area of about 4,100 ha and was declared Wetland of International Importance on 23/03/1990 (Ramsar, 2020). The Govt. of Punjab had earlier declared Harike Wetland as a Wildlife Sanctuary in 1982. Harike Wetland encompasses four districts *viz*. Amritsar, Firozpur,

Kapurthala and Jalandhar of Punjab, between Latitudes 31°06′ and 31°12′N and Longitudes 74°55′ and 75°05′E. It is about 12 km long and 11 km in width (Mabwoga *et al.*, 2010). As per Islam and Rahmani (2004), the lake covers an area of about 14.8 km^2 in the open water and reported that about 33 islands are scattered throughout the lake. Due to the formation of barrage at the confluence of Sutlej and Beas River at Harike Pattan, the present wetland came into existence in 1952, with an aim of storing and providing irrigation and drinking water to parts of southern Punjab, and to the adjoining state of Rajasthan. The wetland is having high ecological value as it supports rare, vulnerable and endangered floral and faunal species and attracts large populations of avifauna during the winters (Kaur *et al.*, 2017). The Wetland was declared as wildlife sanctuary in 1982 and further, in 1990 it was designated as Ramsar site and included in the list of Wetlands of International Importance under the Ramsar Convention (Ramsar Convention Secretariat, 2006). Later, in the year 2000, it came under 'Wildlife Protection Act, 1972' and fishing was totally banned. Over the years, the wetland has been facing a threat from a developing economy with increasing pressure on the resources (Chopra *et al.*,2001; Jain *et al.*, 2008). The wetland is getting degraded due to intense siltation, weed invasion, agricultural runoff and pollution brought in by Sutlej and Beas River (via Buddha *Nallah*, Chitti Bein, Kala Sanghian drain and Kali Bein (Dhillon *et al.*, 1996; Ladhar, 2002; Kaur *et al.*, 1999). The impact of the polluted water has spread to a wide area of southern Punjab and Rajasthan, through the Harike waterworks.



Plate 2. 14 A view of Hari ka Pattan wetland



(Source: Kour *et al.*, 2017)

Fig 2. 7 Different Sites within Harike Wetland and Feeder Areas

Harike Wetland is divided into two major parts, i.e., Wetland area and Feeder area. Wetland area comprises two rivers, i.e., Sutlej and Beas, reservoirs for both the rivers, i.e., Sutlej Reservoir (contains maximum water from Sutlej River) and Beas Reservoir (contains maximum water from Beas River), and confluence point of both the rivers (Fig. 2.7). Feeder area comprises two feeders called Rajasthan Feeder and Firozpur Feeder which supply water to Rajasthan and southern part of Punjab. Harike Wetland is a very rich wetland in term of fish species diversity. Harike Wetland due to its uniqueness i.e., confluence of two major rivers (Beas and Sutlej) of Indus River system, represents fish fauna of both the rivers and provides suitable environmental conditions for breeding, feeding and nesting (Kaur *et al.*, 2017). The polluted water and declining water table in Harike Wetland is affecting water quality, biodiversity and fish growth (Jain *et al.*, 2008; Brraich and Jangu, 2013, 2015). Presence of fishes in an aquatic habitat is a good indicator of the health and status of that ecosystem. Contemporary freshwater fish diversity has seen a constant decline in recent years due to destruction of habitat on account of various natural and anthropogenic factors (Dudgeon *et al.*, 2006). The diversity of 116 fish species were recorded from reorganized Punjab by Johal and Tandon (1981), but after a long gap only 26 and 16 species were reported from Harike Wetland by Ladhar *et al.* (1994), (Dhillon and Kaur, 1996), respectively. Fishery resources of Harike Wetland has decreased sharply on an average of 57% during the period of 1999 to 2005 and Sutlej River too showed similar decreasing trend of 52.79% during the same tenure. Ladhar *et al.* (1994) reported 26 species of commercial

importance fishes from this wetland. Dhillon *et al.* (1996) identified 16 fish species, and Dua and Chander (1999) have reported 61 fish species at Harike wetland. Brraich *et al.* (2003) identified three new fish species from Harike wetland which were not earlier documented by any worker i.e. *Nandus nandus*, *Lepidocephalichthys guntea* and *Monopterus cuchia*. Moza and Mishra (2008) studied fish composition of Harike wetland and along with that they reported a total of 55 fish species from Harike wetland. In addition to this, some researcher also added that accumulation of polluted water and declining water table in Harike wetland is affecting its water quality, biodiversity and fish growth (Jain *et al.*, 2008; Brraich and Jangu, 2013, 2015). Further, Datta *et al.* (2017) documented *Wallago attu*, *Labeo rohita* and *Channa marulius* as comprises the highest percentage of catch among catfish, carp and murrel group of fishes, respectively. Recently, Kaur *et al.* (2019) studied freshness quality of three major commercial fish species i.e. *Wallago attu*, *Labeo rohita* and *Channa marulius* from current wetland and reported species wise; *C. marulius* ranked most fresh followed by *L. rohita*, while *W. attu* scored least freshness rank. The wetland retains rich biodiversity and plays a vital role in maintaining the precious hydrological balance in the catchment area with its high Biodiversity Index of indigenous and migratory fauna (Kaur *et al.*, 2019). The Wetland, although recognized as an area of International importance for waterfowl conservation, faces many serious problems. Keeping in view the present land use, water spread, turbidity and aquatic vegetation, the threats to the Harike wetland were identified as being due to increase in the level of siltation and weed infestation. Water Hyacinth (*Eichhornia crassipes*) is the main weed that has invaded the Harike Wetland.

The area under the plant doubles every 6–15 days, depending on the nutrient status of water. In the Harike Lake, silt is another major issue that should be addressed here. Silt had started depositing near the barrage at the beginning of 1985. Siltation has reduced the erstwhile lake to shallow wetland now. A major amount of silt is deposited in the monsoon season when heavy rains wash down the soil from hill slopes and fields in the catchment area of the two rivers. Islam and Rahmani (2004) reported fisheries, grazing, incidental poaching, water pollution by pesticides and solid waste, and tourism as major threats to the avifauna diversity and ecological integrity of the wetland. The Harike Lake Bird Sanctuary is one of the prominent Wetlands, the Important Bird Area, and the Ramsar Site. The Lake is surrounded by agricultural land and is main source of water for the Indira Gandhi (Rajasthan) canal providing water to a larger western arid part of the Rajasthan State.The embankments have been planted with *Dalbergia sissoo*, *Acacia nilotica*, *Ziziphus* spp., *Ficus* spp., *Prosopis* spp etc. The Lake is an important staging and wintering area for migratory waterfowl. A study conducted by the Bombay Natural History Society (1980-85) recorded 167 species of resident and migratory birds. The updated list by Harvey (2002) included 358 species, including some very old records such as the Little Bustard (*Tetrax tetrax*) that was not seen in India for the past five decades or more. The open water zone is very important for Near Threatened Darter (*Anhinga melanogaster*). Because of congregation of this threatened species and other birds, Harike Wetland as the Ramsar Site qualifies A4i criteria, i.e., the site is known to or thought to hold, on a regular basis, ≥1% of a biogeographic

population of a congregatory water bird species. Sinha (1997) reported 16 mammalian species from this IBA site including the Smooth Indian Otter (*Lutra perspicillata*), Fresh Water Turtles and a large number of species.

The forgoing description on wetlands in Himachal Pradesh and Punjab along the course of Sutlej River have amply revealed that most wetlands are small (<2.25 ha) or in the categories of natural inland wetlands – rivers/streams or the wetlands created due to manmade reservoirs/ barrages. Like most wetlands in India and elsewhere, wetlands in above two States and within the Sutlej Riverscape are facing enormous anthropogenic pressures as they are surrounded by densely populated townships or other urban areas. Most high altitude wetlands in Himachal Pradesh are fragile and threatened by geological processes, climate change and ever increasing tourism pressure. The manmade wetlands created due to reservoirs/ barrages face challenges owing to high rate of sedimentation, pollutants from surroundings agricultural lands and waste from towns and cities besides issues of excessive fishing, livestock grazing in draw down areas and unchecked increase in tourism activities.

2.4.6 Terrestrial and Aquatic Weeds

Weeds are unwanted plants in a particular situation or a plant in the wrong place that have been considered enemies of the farmers since the dawn of agriculture. Their struggle against them to save their precious crop still continues. These weeds cause drastic loss to the productivity and resultant loss to country's economy. Over the past 4-5 decades, the concept of invasive alien species and threats by them has received special attention globally. Alien species are nonnative or exotic organisms that occur outside their natural adapted ranges and dispersal potential. However, some of these alien species become invasive when they are introduced deliberately or unintentionally outside their natural habitats into new areas where they express the capability to establish, invade and out compete native species (Raghubanshi *et al.*, 2005). Invasive Alien Species (IAS) have devastating impacts on native biota, causing decline or even extinction of native species, and negatively affecting ecosystems as they reproduce rapidly, outcompete native species for food, water and space, and has been recognized as one of the main causes for global biodiversity loss. Invasive species are the second largest threat to biodiversity after habitat loss. Invasive species impact native ecosystems by way of habitat modification, out compete native species, predation of native species and herbivore on native plants, bring pathogens, and hybridize with natives, leading to loss of genetic diversity. About 40% of the species in the Indian flora are alien, of which 25% are invasive. Proliferation of invasive alien species is caused due to higher level of disturbances (i.e., livestock grazing, forest/ grassland fires, lopping, excessive openings, etc.).

The Himachal Pradesh has been gifted with plenty of land that cannot be put under frequent cultivation. Such lands are under orchards, pastures, grasslands, forests and wasteland ecosystem. Since, most of these lands do not receive frequent cultivation and intensive care of the owners, the obnoxious invasive alien species or weeds like *Lantana camara, Ageratum*

houstonianum, *Parthenium hysterophorus*, *Chromolaena adenophorum*, and *Urtica dioica* have invaded most of these areas (Angiras, 2014). These invasive species are difficult to control and have spread like a wild fire across the entire State because of the favorable climatic conditions; ability to propagate by seeds, stems and roots; faster dissemination by wind, water, birds, other animals, machinery, transport systems, and even human (Angiras, 2014 and Rana *et al.*, 2015; Badiyala *et al.*, 2015). Angiras (2014) have provided a detailed account on diversity and management of invasive species under noncropland hill ecosystem. Rana *et al.* (2015) provided an insight on major weeds in the non-cropped lands of Himachal Pradesh while Badiyala *et al.*, (2015) have given a descriptive account of major weeds of cropped lands of Himachal Pradesh. Varshney *et al.* (2008) provided an insight on the current status of aquatic weeds and their management in India. Accordingly, *Eichhornia crassipes*, *Ipomoea aquatica*, *Typhha angustata*, etc. are prominent aquatic weeds and are of primary concern. Lot of work has been done to control and manage weeds in agricultural areas and there has been considerable success in checking the menace. However, most control measures require either manual uprooting or use of chemicals/ weedicides those can be practiced by farmers in smaller crop fields but such methods cannot be recommended for natural ecosystems and protected areas as chemicals/ weedicides may have adverse impact on wide range of biota as well as influence quality of freshwater resources, particularly, wetlands and River ecosystems. It is always desirable to prevent invasion of alien species as either appropriate control measures are not available or they are expensive, cumbersome, and even risky as they may allow invasion of other species. Sporadic efforts have been made to control and manage terrestrial weeds in forests, grasslands, and wetlands with little success. Much needs to be done in the field of management of invasive alien species and it calls for well-coordinated, concerted, and long term efforts to mitigate menace of invasive species.

2.4.7 Wildlife

The foregoing section on the physical and biological sub-environments in the context of Sutlej River, its tributaries and surrounding lands from the origin of the River in Himachal Pradesh to its confluence with Beas River in Alluvial Plains of Punjab have highlighted the diversity of geological formations, landforms, forests, grasslands, alpine pastures, wetlands, etc. The role played by the vast altitudinal range and extremities of climatic conditions in maintaining such diversity was also understood. Varied physical and biological systems influenced by long history of management and human influence also offer an array of faunal species representing different natural ecosystems in the terrestrial and aquatic environments. The following section provides an insight on the diversity of wild fauna in varied ecosystems.

a) Terrestrial Ecosystem

In context of the Sutlej Riverscape, Himachal Pradesh and vast lands in Punjab Plains are two relevant geological formations. They are home to a wide range of rich and unique wild fauna including mammals, birds, reptiles, amphibians, fishes, and exceptionally diverse invertebrates. Prominent mammalian species of the Sutlej Riverscape are Snow Leopard (*Panthera uncia*),

Himalayan Ibex (*Capra sibirica hemalayanus*), Himalayan Brown Bear (*Ursus arctos*), Himalayan Black Bear (*Ursus thibetanus*), Common Leopard (*Panthera pardus*), Indian Wolf (*Canis lupus*), Himalayan Tahr (*Hemitragus jemlahicus*), Blue Sheep (Bharal) (*Pseudois nayur*), Serow (*Naemorhedus sumantraensis*), Himalayan Musk Deer (*Moschus chrysogaster*), Goral (*Naemorhedus goral*), Sambar (*Rusa unicolor*), Barking Deer (*Muntiacus muntjac*), Wild Pig (*Sus scrofa*), etc. The Himachal Pradesh and Punjab in the Sutlej Riverscape harbours nearly 60% of the country's avifauna. Voluminous literature in the form of published and unpublished documents represented by faunal checklists, peer reviewed papers, and survey/ research reports are available focusing different regions, taxonomic groups and taxa. Considering the importance and relevance to the DPR, diversity of terrestrial and aquatic fauna is described below for each of the physiographic region under consideration, i.e., the Himachal Pradesh, and the Punjab Plains.

i) Himachal Pradesh

The fauna of the Himachal Pradesh constitutes a different assemblage sandwiched between the tropical forests of the alluvial Punjab Plains and the Palaearctic Steppe of the Tibetan Plateau (Gaston *et al.*, 1983). The Himachal Pradesh has representation of the Ladakh Mountains north western and western Himalayan biotic provinces and the mountainous region as a whole is geologically young, tectonically active and environmentally sensitive. The steep slopes, unconsolidated soil and ill planned developmental activities make it all more fragile. The exploitation level of natural resources in the State is especially high where rapid conversion of protective ecosystems into productive and urban industrial ecosystems has become major cause of environmental concern. As a result, a large number of faunal species have become rare and many of them are endangered in the State. In spite of high human pressure and disturbances, the State harbours considerable faunal diversity associated with wide range of ecosystems –i.e., forests, grasslands, alpine pastures, and wetlands including rivers; protected areas; agroecosystems; and even the urban environment.

Snow Leopard– A Flagship Species

The higher reaches (>3,600 m) or above the tree line in Lahaul and Spiti, Kinnaur, Chamba, Kangra, Mandi, Shimla and Kullu districts form the habitat of the iconic, elusive and culturally treasured cat, a flagship species of the Himalayan Mountains i.e., the Snow Leopard (*Panthera uncia*) also known as the 'Ghosts of the Mountain'. Nearly 27,000 km^2 area in the higher reaches is the potential Snow Leopard landscape in Himachal Pradesh. The Nature Conservation Foundation (NCF) in collaboration with the Himachal Pradesh Forest Department has been carrying out a collaborative project since 2016 to estimate the population of Snow Leopard and its wild prey population(s) using camera traps and field level assessments based on direct sightings and indirect evidences. The NCF in its preliminary findings based on camera trapping studies has identified seven landscapes within the larger project area having the confirmed presence of snow leopard. These are Bhaga, Chandra, Miyar Thirot, Tabo, Upper Spiti and Pin Valley landscapes in Lahaul and Spiti district, and Kinnaur landscape in Kinnaur district. Based

on preliminary analysis, a minimum population of 44 snow leopards across the seven landscape sites was estimated (Suryawanshi *et al.*, 2019). Thus, it is evident that Snow Leopard occur in very low densities in the Trans-Himalayan region of Himachal Pradesh State. The Upper Spiti landscape recorded the highest number of snow leopard, followed by Upper Kinnaur and Pin Valley landscapes. The northeastern part of the Great Himalayan National Park and upper reaches of Parbati sub-watershed are also potential sites. Poaching for skin and retaliatory killing to reduce livestock loss are the two major concerns for the conservation of endangered Snow Leopard. These high mountainous regions are also home to unique high altitude fauna that includes the Himalayan Tahr (*Hemitragus jemlahicus*), Bharal (*Pseudois nayur*), Argali (*Ovis ammon*), and Ibex (*Capra sibirica*).

Mammals – Diversity, Status, Distribution and Threats

HPFD (2005) has provided a brief account on diversity of mammalian species, their status, distribution and threats. Accordingly, Himachal Pradesh has a rich assemblage of 74 species of mammals (excluding Chiropterans) belonging to eight Orders and 21 Families/ subfamilies. Out of these, 17 species were unconfirmed although they were most likely to occur. RSET (2019) has compiled information on mammals in the Beas River Basin exclusively for the mountainous part of Himachal Pradesh based on secondary sources including published papers, Forest Working Plans and Wildlife Management Plans and reported 40 mammalian species in the mountainous part of the Beas Basin. Family Bovidae is the largest family represented by six species while Viverridae is represented by four species, and families *viz*., Felidae, Muridae, Mustelidae, Cervidae and Cercoitecidae each represented by three species. The conservation status of the mammalian species was reported on the basis of their listings by different agencies *viz*., the IUCN Red List of Threatened Species (2015) and different Schedules notified under the Wildlife (Protection) Act, 1972. Accordingly, nine species of mammals belonged to the Schedule-I of WPA, 1972; 14 species were Schedule-II and rest of the species were either included under the Schedule III, IV or V. Six species have restricted distribution inhabiting higher elevations of the basin. According to the IUCN Red List (2015), 11 species are listed under different threat categories of which two species are under endangered category *viz*., *Panthera uncia* and *Moschus chrysogaster*, 4 are under vulnerable category viz., *Panthera pardus*, *Capricornis sumatraensis*, *Rusa unicolor* and *Ursus thibetanus* while 5 species are listed as Near Threatened category. Rest of the 29 species of mammals reported from the basin is under Least Concern (LC) category. Among these threatened species, Snow Leopard, Musk Deer, Serow, and Himalayan Tahr are confined to upper reaches of the Sutlej River Basin.

Other Prominent Carnivores

Carnivores are represented by species belonging to Families Felidae, Viverridae, Herpestidae, Hyaenidae, Canidae, Ursidae and Mustelidae.

Felids

Species of Common Leopard (*Panthera pardus*), Snow Leopard (*Panthera uncia*), Leopard Cat (*Felis bengalensis*), Fishing Cat (*Felis viverrina*), Jungle Cat (*Felis chaus*) and The Eurasian Lynx (*Lynx lynx*) occur in the State. Common leopard is common throughout the State and occurs up to 4,000 m amsl in a wide variety of habitats. This carnivore is highly versatile and can survive in poor quality habitats and on small wild prey or domestic animals. In many parts of the State, this is a 'Problem Species' as increased incidence of livestock loss and human attacks are frequently reported. Payments of compensation to livestock loss, tackling public backlash, controlling poaching and illegal trade in leopard skins, reducing retaliatory killings by people, capture of cubs and adults which eventually spend rest of their lives in refuge or captivity are major management problems. Leopard cat occurs in forested habitats and sometimes near cultivated areas or human habitations. Presence of water characterizes its habitat and is usually encountered in the lower elevations in the State (1,500 -3,000 m amsl). However, the status of this species is not known. Fishing cat and Jungle cat are also reported to occur widely in the State in areas <1,500 m elevation range. While the former is largely found around aquatic habitats, the latter is found in wide variety of habitats including scrub and near to habitations. The status of both these species in this State is also not known. Eurasian lynx is a rare species found in parts of Spiti, but its status too not known. Habitat loss is the major conservation threat to these cats.

Viverids

Three species of viverids (civets) *viz*., Small Indian Civet (*Viverricula indica*), Common Palm Civet (*Paradoxus hermaphroditus*) and Himalayan Palm Civet (*Paguma larvata*) are reported to occur in the State. While the Small Indian Civet and Common Palm Civet occur below 1,500 m elevation range, the Himalayan Palm Civet occurs between 1,500 to 3,000m amsl.

Herpestids

Common Mongoose (*Herpestes edwardsi*) and Small Indian Mongoose (*Herpestes auropunctatus*) occur below 1,500 and 1,000 m amslelevation ranges, respectively. No information is available on the conservation status of these viverids and threats to them.

Hyaenid

Striped Hyaena (*Hyaena hyaena*) is reported to occur in the plain areas of the State adjoining Punjab but there is no available information on them.

Canidae

Five species of Canids (Dogs) *viz*., Himalayan Wolf (*Canis himalayensis*), Jackal (*Canis aureus*), Red Fox (*Vulpes vulpes*), Indian Fox (*Vulpes bengalensis*) and Dhole or Indian Wild Dog (*Cuon alpinus*) are reported to occur in the State (HPFD, 2005).

Himalayan wolf is reported to occur in the Trans-Himalayan region of the State i.e., Lahaul and Spiti district, however information on their status is not available. It is being threatened by retaliatory killings due to the wolf human conflict. Jackal is commonly encountered (<1,500 m amsl) throughout the state including degraded areas and near human habitations. Red fox is fairly common in the subalpine and alpine regions of the Great Himalaya and the Trans-Himalayan regions (3,000 - 5,000 m amsl). Indian fox is reported to occur only in the lower areas of the State, particularly areas adjoining Punjab. The dhole or Indian wild dog is likely to be present in the Trans-Himalayan region, but its presence is yet to be confirmed. No information is available on the conservation status of these species.

Ursids

Himachal Pradesh has two species of bears *viz*., Asiatic black bear (*Ursus thibetanus*) and Himalayan brown bear (*Ursus arctos isabellinus*). Black bear occurs in forested habitats (1,200 m to 3,300 m amsl) throughout the State, largely due to its ability to use plantations, orchards, scrub lands, cultivated areas and even villages to move between forested an area which has resulted in conflict with people. Black bear is reported to be present in and around several protected areas as is the Himalayan brown bear. Black bear is seriously threatened due to poaching for its gall bladder and skin. Brown bear is threatened due to retaliatory killings by shepherds to avoid livestock loss due to their predation. Populations of black and brown bears are under severe threat in the region.

Mustelids

Nine species of Mustelids are reported to occur in the State; eurasian otter (*Lutra lutra*), smooth-coated otter (*Lutra perspicillata*), smallclawed otter (*Anonyx cinerea*), beech or stone marten (*Martes foina*), Himalayan yellowthroated marten (*Martes flavigula*), Himalayan weasel (*Mustela sibirica*), stoat or ermine (*Mustela erminea*), pale weasel (*Mustela altaica*) and yellowbellied weasel (*Mustela kathiah*). Of these, two species, the smooth-coated otter and small-clawed otter are locally extinct in the State as there are no reports on the presence in the recent past.

The eurasian otter is reported to occur in all the major River systems (<3,000 m amsl) of the State but there is no information on the conservation status of this species. The stone or beech marten usually inhabit the temperate and subalpine zones (1,500 to 3,600 m amsl) and are threatened due to poaching for fur and to reduce predation on poultry. The Himalayan yellow-throated marten occurs between 1,200 m and 3,200 m in the Temperate and Subalpine zones and also in the Shivaliks (600 m to 1,200 m). It predates on small herbivores, birds including pheasants and sometimes ungulates such as musk deer, tahr and goral. This species is relatively more easily sighted when compared with the stone or beech marten. There is no information on the conservation status of both the species.

Weasels occur in a variety of habitats between 1,500 and 4,500 m amsl in the State. Himalayan weasel is rare as sightings are very few with exception of areas such as Kugti WLS, where it appears to be fairly common. The stoat or ermine occurs in a variety of habitats but prefers rivers banks, streams, edges of lakes and ponds. The pale weasel prefers to live in sparse forest and predominantly open landscape and preys on *pika, voles* and other animals. Very little information is available about this species. The Yellowbellied weasel is among the least studied species and not much is known about it. However, weasels are threatened due to poaching for fur.

Wild Ungulates

Seven species of caprids are reported to occur in Himachal Pradesh. They are: Tibetan Argali (*Ovis ammon*), Bharal or Blue Sheep (*Pseudois nayaur*), Asiatic ibex (*Capra ibex*), Himalayan Tahr (*Hemitragus jemlahicus*), Serow (*Nemorhaedus sumatraensis*) and Goral (*Nemorhaedus goral*). Bharal or Blue Sheep is a commonly encountered in the TransHimalaya and some alpine regions of the Greater Himalaya between 3,500 and 5,500 m amsl, more commonly in Spiti and upper catchment of Parbati valley. Some of the PAs known for holding populations of Blue Sheep include GHNP, Kibber, Tundah, Sechu Tuan, Lippa Asrang, and Sangla WLSs. Major threats are competition with livestock, habitat degradation /loss and poaching. The Asiatic Ibex is distributed in most of Lahaul and Spiti and upper catchments of Beas and Parbati between 3,500 and 5,500 m amsl. Some of the PAs holding populations of Ibex include Pin Valley NP, Kugti, Tundah and Sechu Tuan WLSs. Himalayan Tahr is distributed in isolated pockets along a narrow strip (2,200 to 4,400 m amsl) all along the southern side of the Great Himalaya. Some of the PAs known to hold tahr populations are GHNP, Kanawar, Tundah, Sangla, Dharangati, Rupi Bhabha and Talra WLSs. Serow occurs in low densities along a narrow strip (2,000 m to 'treeline') in the Great Himalaya. Some of the PAs that are reported to have serow are, GHNP, Kalatop Khajjiar, Tundah, Sangla, Dharangati, Rupi Bhabha and Talra WLSs. Goral is commonly encountered in a variety of habitats throughout the State below 4,000 m. Some of the PAs known to hold goral populations are: GHNP, Majhatal, Chail, Simbalbara, Dharangati WLS, Rupi Bhabha, Talra, Churdhar and Sangla WLSs.

Other Prominent Mammals

Sambar (*Rusa unicolor*) is reported to be fairly common in most of the densely forested habitats in the lower and middle altitude zones of the State. Muntjac or Barking Deer (*Muntiacus muntjac*) is commonly encountered below 2,700 m in most parts of the State. However, there is no information on the status and distribution of this species in this State and Habitat degradation, habitat loss and poaching are the major threats. Himalayan Musk Deer (*Moschus chrysogaster*), is distributed in isolated pockets all along the southern side of the Great Himalaya between 2,500 m and 'treeline'. This species has been persecuted for centuries for its 'Musk'. Some of the PAs in this State known to have Musk Deer include the GHNP, Kugti, Tundah, Sechu Tuan, Lippa Asrang, Sangla, Dharangati, Rupi Bhabha and Talra WLSs. The Indian Wild Pig (*Sus scrofa*) is

reported to be fairly common in areas <2,700 m in most parts of the State. There are reports of crop damage by wild pigs in some parts of the State leading to wildlife human conflict. Two species of primate's, Rhesus Macaque (*Macaca mulatta*) and Common Langur (*Presbytis entellus*) occur in the State. Rhesus Macaque is commonly encountered throughout the State and occurs in a variety of habitats upto 3,000 m. The species is recognized as a problem species in most parts of the State, particularly the State capital Shimla and its surrounds as they raid orchards or crop fields and even attack human beings. Common langur is commonly encountered in forested areas and may occur even in subalpine zone upto 3,700 m. Rhesus Macaque – human conflict is emerging as a serious problem. The Himachal Pradesh Forest Department has undertaken a state wide program to capture and sterilize monkeys so as to control the population. However, there appears to be little success as monkeys are fed at almost all religious places.

Avifauna and Galliformes

Himachal Pradesh is bestowed with rich avifaunal diversity due to the representation of four major biotic provinces within the State. The Himachal Pradesh Bird Checklist includes 657 bird species from 18 Orders and 88 Families. This is 51% of the bird species reported from India and includes 53 threatened and near threatened species as per the IUCN. Among them: Critically Endangered4, Endangered5, Vulnerable19, Near Threatened24 and Data Deficient1 (HPFD, 2018). Pheasants along with other Galliformes (such as partridges and quails) represent a unique group of birds marked by relatively large body size and attractive plumage patterns. In Asia, which is native to the majority of these pheasants, the wild populations seem to have suffered constant removal from sport hunting by rulers, and for meat and the beautiful plumage to fulfil economic and social needs of local people. Burgeoning human population leading to large scale conversion of wildlife habitats (including those of pheasants) into human habitations and indiscriminate removal of wild populations have created a situation, wherein the once abundant and widely distributed pheasant species are now found in isolated pockets, survived by small population size. The State of Himachal Pradesh is rich in pheasants (7 species) and over 12 other species of Galliformes. Of these pheasants, the Western Tragopan (*Tragopan melanocephalus*) and Cheer Pheasant (*Catreus wallichii*) are among the most vulnerable bird species (according to IUCN Red Data List). These birds are known to be patchily distributed, with small surviving populations. Interestingly, pheasants are representative of the forest ecosystem, with strong association with ground vegetation shrub and herb layers. They are among the most popular wildlife in the State. The Himalayan Monal (*Lophophorus impejanus*) has once been 'The State Bird' and Western Tragopan, the present State bird is found in folklore, described as 'The king of all birds'. They are also known to play a significant role as a prey base for mammalian and avian predators. Other pheasants are, Kaleej (*Lophura leucomelana*), Red Jungle fowl (*Gallus gallus murghi*), and The Indian Peafowl (*Pavo cristatus*). Given the 'Flagship' stature of this group, it would be logical to assume that conservation initiatives for these species would also help survival of other forest wildlife. However, scientific support for several of these species is grossly inadequate to be able to effect efficient conservation actions for the wildlife in the State.

Herpetofauna

Herpetofauna comprise of amphibians that include frogs, toads, newts, salamanders, etc. and reptiles which include snakes, lizards, turtles, terrapins, tortoises, etc. Sharma and Sidhu (2016) reported diversity of amphibians and reptiles of Himachal Pradesh and listed 16 species of amphibians, 55 species of reptiles. The IUCN Red List (2017) has kept the Indian Rock Python (*Python molurus*), Spotted Pond Turtle (*Geoclemys hamiltonii*) and Gangetic SoftShell Turtle (*Nilssonia gangetica*) under vulnerable category. Eleven species were under the Least Concern category and rest of the species is yet to be evaluated for their status. Altogether, seven species of turtles *viz.*, Spotted Pond Turtle (*Geoclemys hamiltonii*), Indian Black Turtle (*Melanochelys trijuga*), Gangetic Softshell Turtle (*Nilssonia gangetica*), Brown Roofed Turtle (*Pangshura smithii*), Indian Tent Turtle (*Pangshura tentoria*), Indian Flapshelled Turtle (*Lissemys punctata*), and North Indian Flapshell (*Lissemys punctata andersoni*) were included in the list of reptilians. Eight species of amphibians reported by RSET (2019) belonged to 4 families, which comprises of toads and frogs and Bufonidae was the largest family with 3 species.

Invertebrates

The comprehensive insight on invertebrates in the context of Sutlej River and two Himachal Pradesh and Punjab is relatively poor except survey and taxonomic records maintained by the ZSI. Moreover, the existing information is fragmentary, old or specific to select stretches or regions of the States. Chandra (2012) has provided broad base information on insect fauna of States and UTs in India. The phylum Arthropoda alone constitute about 80% of the total number of faunal species described so far globally. The most successful group, 'Insecta' accounts for about 66% species in 39 orders of all animals. The insect order Coleoptera represents about 38% of the insect species (Zhang, 2011). According to Chandra (2012), Himachal Pradesh is represented by as many as 2,356 species of insects constituting 3.7% of insect diversity while Punjab harbours 1,116 species of insects representing 1.75% of known insect diversity in the country. In Himachal Pradesh, the order Lepidoptera (butterflies and moths) is represented by 570 species while in the case of Punjab, 340 species of butterfliers and moths have been described. RSET (2019) has attempted to describe the diversity of butterflies in the mountainous landscape and forest cover of Himachal Pradesh based upon the data compiled from secondary sources, Forest Working Plans, Management Plans of Protected Areas, and published literature by Uniyal and Mathur, (1998), Uniyal (2007), Bhardwaj and Uniyal (2009), Chandel *et al.* (2014). Accordingly, a total of 150 species of butterflies sub-basin wise were listed and they were grouped under 7 families with species richness in different sub-basins ranged from 76 to 137. Majority of the species were common in distribution in all sub-basins while a few of them were restricted to upper reaches (Red Apollo *Parnassius charltonius*, Common Blue Apollo *Parnassius hardwickei*, Painted Lady *Vanessa cardui*, Mountain Argus *Erebia shallada*) and Lower Reaches (Spangle *Papilio protenor*, Tawny Mime *Chilasa agestor*, Psyche *Leptosia nina nina*, Common Jezebel *Delias eucharis*, Pale Hedge Blue *Udara dilecta*, Purple Hedge

Blue *Heliophorus epicles*, Common Baron *Euthalia aconthea*, Common Jester *Symbrenthia hippoclus*, Common Bush brown *Mycalesis perseus*, etc). Likewise, other taxa in Sutlej River Basin, the richness of butterflies decreased along the elevational gradient. Thus, the sub-basins in the lower reaches harboured relatively high butterfly richness.

ii) Punjab

Punjab has made an unparalleled progress in the agriculture since the advent of the Green Revolution in the mid-sixties, resultant the State is densely populated and intensively cultivated. Nearly 84% of the State's geographical area is under agriculture with a cropping intensity of 183%. Only a meager area i.e., 5.7% of the geographical area is under forest that too mainly confined to north-eastern part of Shivalik hills. Owing to the expansion of agriculture and conversion/ reclamation of natural areas (forests, grasslands and wetlands), and creation of several large dams and barrages have resulted into the great loss to natural biodiversity. In the context of Sutlej Riverscape, there are hardly any known or substantial forest and grassland areas left in the alluvial plains of Punjab. Several manmade and natural wetlands exist in the riverscape. Thus, from the perspective of wildlife, aquatic ecosystems and associated aquatic fauna, the State attains higher importance. The forgoing section on wetlands and associated avifauna has already provided much desired insight on resident and migratory birds. Bir forests i.e., dry tropical riverine forests and dry mixed deciduous forests, are found around wetlands. An insight on Harike Ramsar wetland site has already been provided along with its avifauna. Punjab Plains used to have abundant populations of Antelope (blackbuck and nilgai) but today the populations of these antelopes have suffered. The threatened fauna of Punjab includes the Indus River Dolphin (*Platanista gangetica* minor), White-Backed Vulture (*Gyps bengalensis*), Sarus Crane (*Grus antigone*), Indian Rock Python (*Python molurus*) and Indian Roofed Turtle (*Pangshura tecta*).

b) Aquatic Ecosystem

The Sutlej River with its numerous tributaries and diverse wetlands in the Himalayan State of Himachal Pradesh and the alluvial plains of Punjab constitute rich and unique aquatic ecosystems and they are home to a wide variety of aquatic plants, fishes, reptiles (crocodilians), amphibians, and aquatic mammals (e.g., otter and the Indus River dolphin).

i) Fish Fauna

Fish fauna represent nearly half of all known vertebrate species and are an important resource worldwide especially as food. Nearly, 22,000 species of fishes have been recorded in the world of which about 11% are found in Indian waters (Jagtap, 2013). Out of the 2,200 species so far listed, 73 (3.32%) belong to the cold freshwater regime, 544 (24.73%) to the warm freshwaters domain, 143 (6.50%) to the brackish waters, and 1,440 (65.45%) to the marine ecosystem. Roughly, 40 families of freshwater i.e., warm freshwater species, fishes out of 450 families recorded globally are represented in India. About 25 of these families contain commercially

important species (Jagtap, 2013). According to Hilborn *et al.* (2003), 544 endemic species in warm water have been reported. Cyprinidae is one of the largest families and is well represented in India species ranging from few millimeters in length (minnows) to more than a meter (major carps). Cyprinidae accounts for nearly 24.12% freshwater fishes in India. Owing to substantial variation in altitude from 210 m (at Harike) to 6,500 m and a vast network of rivers/ streams along with a large number of natural and manmade wetlands, the two States (Himachal Pradesh and Punjab) relevant to the Sutlej River constitute important zone for fish fauna.

Different workers have either provided insight on the diversity and status of fish fauna state-wise or specific to different stretches/ River zones based on biotic status *viz*., (a) the crenon zone area near the source of River with lower oxygen level and colder temperatures, (b) the rhithron zone – the upstream area of the River characterized by faster and turbulent flowing speeds, cooler temperatures and higher oxygen level, and (c) the potamon zone – the downstream area of the River having slower water flowing speeds, warmer temperatures with lower oxygen level. Seghal (1974) has provided an account on fisheries survey of Himachal Pradesh and some adjacent areas with reference to trout, mahseer and allied species. Later, Sharma and Tandon (1990) have provided an account of fish and fisheries of Himachal Pradesh. Johal *et al.* (2002) described the fish diversity in the streams of lower Middle Western Himalaya. Dhanze and Dhanze (2004) provided an updated insight on fish diversity of Himachal Pradesh. The Sutlej River harbors both cold water as well as warm water fishes. The cold water fishes *viz*., Tor, *Schizothorax*, *Barillius*, Bangana, Garra, Schistura, *Triplophysa* spp. were the indigenous fishes important in terms of food, sport and ornamental value.

According to Jagtap (2013), the rivers/ streams of Himachal Pradesh falls under two categories *viz*., general waters and trout waters with estimated length of 600 km and 2,400 km, respectively and reported 61 species of fishes belonging to 13 families, and their familywise representation was: Notopteridae (02), Cyprinidae (36), Cobitidae (05), Siluridae (02), Bagridae (04), and Amblycipitidae, Sisoridae, Schilbeidae, Belonidae, Muglidae, Channidae, Anabantidae, and Mastocembelidae by one species each. The major fishes available in various rivers/ streams were Trout, Mahseer, *Nemacheilus* spp., *Barilus* spp., *Schizothoracides*, *Crossocheilus* spp., *Glyptothorax* spp., etc.

Sugunan (1995) reported that the Gobind Sagar Reservoir was designed to hold 9,621 million m^3 of water when it is full. However, due to silt accumulation, the capacity has declined to 7,118 million m^3. Commissioning of Beas-Sutlej Link (BSL) project in 1978 added a new dimension to hydrographic cycle of the waterbody. Blending of the cold water of Beas River with warmer Sutlej River water in the reservoir led to unique pattern in the thermal and oxygen regimes and other processes which influence the life and production cycle of organisms. Ichthyofauna of the Gobind Sagar Reservoir comprises 51 species belonging to 9 families, including the Brown Trout (*Salmo truta*), Snow Trout (*Schizothorax* spp.), and several other species of hill stream fishes. Prior to the construction of dam, the cold water of the upper reaches of the River Sutlej

use to sustain 30 species of fish. In 196162, the reservoir was stocked by *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*. The emergence of silver carb in 1979 marked the beginning of a radical change in the catch structure and the fish has established an overriding dominance over all other species. The fish catch in the reservoir from 200708 to 201617 ranged from 1147.28 t to 1144.88 t per year with an average catch value of 1326.44 t per annum. The fish yield ranged from 48.5 kg/ha to 149.22 kg/ha during 20072017(DoF, HP, 2018).

Dua and Parkash (2009) studied the distribution and abundance of fish populations in Harike wetland, and reported 61 fish species belonging to 35 genera and 17 families with maximum number of species (27) was recorded for family Cyprinidae. Study compared fish fauna in Harike with Beas and Sutlej Rivers and observed that these two rivers provide less diverse habitats than the Harike Wetland. Hence, Harike is a rich wetland in term of fish species diversity. Kaur *et al.* (2017) assessed the fish composition and biodiversity indices at Harike Wetland and reported 37 fish species belonging to 14 families and 25 genera. They also reported that Harike wetland is excessively eutrophic and the portion fed by Beas River water is mildly eutrophic, but eutrophication has not yet been seen in the middle portion of the reservoir and the downstream areas. Further, they concluded that despite of different natural and anthropogenic disturbances, the Wetland continuous to support a good number of fish species which needs to be conserved. Fishing by *'Chatti Jal'* and rope loop type takes away juvenile fishery brooders from the system and affects the natural recruitment. The study recommended: (a) massive afforestation programme along foothills of Shivalik Himalaya so as to check soil erosion, (b) establishment of sewage treatment plants along Kali/ West Bein to diminish organic load, and (c) removal of water hyacinth from Kali Bein.

ii) Herpetofauna

In case of potamone (downstream area) zone of the Sutlej River, information on herpetofauna is available for Harike wetland only. Seven species of turtles *viz*., Brown roofed turtle (*Pangshura smithii*), Indian roofed turtle (*Pangshura tecta*), Crowned River turtle (*Hardella thurjii*), Spotted pond turtle (*Geoclemys hamiltonii*), Indian flapshelled turtle (*Lissemys punctata*), Indian softshell turtle (*Nilssonia gangetica*), Narrow headed softshell turtle (*Chitra indica*), four species of snakes, and six taxa of amphibians have been reported (PSCST, 2008). In spite of the fact that natural ecosystems particularly rivers and other wetlands are under serious threat of human pressure and developmental activities, there was hardly any evidence to ascertain the current status of these threatened species, except the taxonomic surveys or explorations.

iii) Aquatic Mammals

From the perspective of ecological integrity, health of Sutlej River, and conservation of Sutlej Riverscape, acquires great significance. Aquatic mammalian species i.e., the otters have been recognized as an emblematic or flagship species for conservation of fluvial ecosystems or as the ambassadors of the aquatic bodies (Norris and Michalski, 2009; Khan, 2015; Gupta *et al.*, 2016).

The amphibious lifestyle of otters allows them to disperse over wide areas of Riverine Landscapes and use diverse habitats and influence the ecological processes of the River flood plain. These mammalians carnivores belonging to the family Mustelidae exist at the apex of the aquatic food chain and have been recognized as indicators of a healthy aquatic ecosystem. Historically, three species of otters i.e., Smooth-coated otter (*Luterogale perspicillata*), Oriental small-clawed otter (*Aonyx cinereus*), and Eurasian (*Lutra lutra*) were widely distributed in the Indian Himalayan region (Hussain, 1999; Hussain and de Silva, 2008; Hussain *et al.*, 2008; Khan *et al.*, 2014; Mishra *et al*., 2006; Khan, 2015). However, they have been severely impacted by wide scale human disturbances and largescale changes in land use of their natural habitat. Despite all species of otters face growing threats, few studies have been undertaken to assess the distribution, population dynamics, habitat use and overall current status of these threatened species.

The alluvial plains of Punjab with a wide network of River systems has water-stressed semiarid environment. Once, the distribution of smooth-coated otter (*Luterogale perspicillata*) locally called Ludhar was widespread in Punjab (Singh, 1991). Currently, like other regions of the country and other species of otters, the population of Smoothcoated otter is severely fragmented. Accordingly, Khan (2015) reported the findings of the population assessment carried out during 201012 on the basis of direct and indirect signs besides the questioner survey and interviews of locals. He confirmed the occurrence of Smooth-coated otters along select stretches of Beas, Sutlej and Ravi Rivers and the Harike Wetland. Further, the study confirmed the occurrence of otters in the upper reaches of Sutlej River between Nangal barrage and Ropar barrage whereas the upstream of River Beas till Dhunda Pattan. However, the species requires urgent measures for its protection and conservation in human dominated landscapes of Punjab.

Further, the Government of Punjab alarmed by decline of 7 freshwater turtle species in the State has decided to enforce wildlife laws for effective protection of nesting sites of seven turtle species in Harike Wildlife Sanctuary. The government has planned to involve ex-poachers and people from the Riparian community in the turtle watch program as tour guides so as to pave a way for the transformation of the local community besides involving them in protection of turtle nesting sites and safe release of hatchlings into the River. The Department has also reintroduced the Gharial (*Gavialis gangeticus*), that is critically endangered. The last documented record of Gharial in Punjab was of 1930s and after that no one has reported this species in waters of Punjab. Hence, the Department decided to reintroduce the species in waters of the Beas and Sutlej River in a phased manner to promote ecotourism (MoEF&CC, 2020). The Gharial recovery action plan is considered a successful effort aiming at restoring a species verging on the brink of extinction.

2.4.8 Conservation Initiatives and Challenges

The life support systems (i.e., forests, grasslands, and wetlands) of Himachal Pradesh and the alluvial plains of Punjab are now under great stress due to the impact of modern civilization,

economic development and growth in human and livestock population. Both States were part of the larger Punjab prior to the country's independence, partition and bifurcation of two sovereign countries in 1947. Later, the State of Punjab, India was reorganized to carve out the present three Indian States (i.e., Punjab, Haryana, and Himachal Pradesh) and one Chandigarh UT. Both States have longer historical perspective of management of their natural resources prior to the independence of the country as well as their subsequent reorganization. Further, both States on the account of physical, biological, and sociocultural sub-environments exhibit uniqueness and varied peculiarities and challenges for conservation of their natural resources.

In Himachal Pradesh, nearly 90% of the population lives in rural areas. Most of the villages are situated on steep slopes and are either adjacent to or enclosed by forests. Thus, forests are deeply integrated with the livelihood of the local people. They depend on forests for timber, for the construction of the houses, firewood, agriculture implements, fodders and a variety of other products and services, including medicinal and aromatic herbs. A larger proportion of the rural population is still using fuelwood for cooking and heating. Almost 90% of the forests of the State apart from protected areas and forest areas taken up for regenerations and plantations are open to grazing. Cultivation of green fodder in the agriculture fields is virtually do not exist. Much of the human population in higher reaches keeps substantial population of sheep and goat and they still practice transhumance seasonal migration to subalpine forests and alpine pastures every year in summer. Local people have recorded rights for constructional timber. Substantial yield from the forest annually goes in Timber Distribution (TD) Rights. The menace of encroachment of the forest areas particularly in the undemarcated protected forests is alarming as these adjoin private forests. The fate of village common lands vested with the government is similar. The forests fires are of a recurring nature and cause lot of damage to forests and wildlife. The increasing demand of land for agriculture and horticulture, lead to the clearance of the forest tracts, especially in the years after independence under Grow 'More Food' campaign and later, when the big landed estates were abolished and the scheme for 'Allotment of Land to the Landless' was launched in the mid1970s also resulted in substantial loss of forests. Expansion of horticulture and large requirement of wood based packing crates for fruits during 1970s to 1990s brought extra burden on forests. Further, the mountainous stretches were maneuverer mainly for power generation by creation of sequential HEPs.

Likewise, the pressure on forests and other natural ecosystems in Punjab after the independence of the country was not different than Himachal Pradesh as it increased several folds because of policies favouring the expansion of agriculture, increased food production, construction of large dams and vast network of canals besides rapid development of agro-based industrial and food processing units. In 1987, Punjab had only 943 km^2 area under forest cover which has now increased to 1,849 km^2 in 2019 (FSI, 2019).

As such, both the above States have initiated much earlier a wide range of conservation programmes and initiated measures to protect the forests along other natural ecosystems so as to

safeguard the interests of varied terrestrial and aquatic wildlife. However, like most world countries and other parts within the country, the awakening towards the protection of environment and conservation of natural ecosystems and wildlife in particular started late in 1960s. Since 1960s, the GoI, has enacted different laws pertaining to the environment, forests, wildlife, and forest dwellers; formulated numerous National Level policies and launched countrywide programmes, projects, and schemes besides several other initiatives so as to protect the environment and conserve the country's natural heritage. Likewise, the State governments also initiated several priority actions for conservation of scarce natural resources of their respective State.

The Wildlife (Protection) Act, 1972 enacted by the GoI was the first unified legislation of the country for the protection of wildlife and their habitats by setting aside Protected Areas (PAs) for conservation of diverse flora and fauna in their natural environment. The establishment of PAs was recognized as the foremost step towards protection and conservation of natural ecosystems, and their associated flora and fauna alongside genetic resources so they can continue to provide varied ecosystem services to humanity. Rodgers and Panwar (1988) not only provided the biogeographic basis for appreciating the country's unique and spectacular wildlife resources in different biogeographic zones and biotic provinces but also carried out a comprehensive review of PAs at that time so as to identify gaps and make recommendations for the planning and establishment of Protected Area Network in the country.

The above two States under consideration in the present DPR in the context of Sutlej River have altogether 55 PAs including 05 National Parks, 40 Wildlife Sanctuaries, 07 Conservation Reserve, and 03 Community Reserves, 8,787.88 km^2 area representing 8.28% and 0.26% geographical area of two States and the country as a whole, respectively (Table 2.18). The forgoing description has described that the two States are represented by three biogeographic zones and five biotic provinces. The Himachal Pradesh is represented by four biotic provinces and harbours 35 protected areas including 01 Biosphere Reserve, 05 National Parks, 28 Wildlife Sanctuaries, and 03 Conservation Reserves covering 8,406.55 km^2 representing 15.09% geographical area of the State. Thus, the State of Himachal Pradesh has three times more per cent area of its geographical area covered under PAs than the national average of just about 5%. However, in the contrast the State of Punjab, altogether 20 PAs (i.e., 13 Wildlife Sanctuaries, 04 Conservation Reserves, and 03 Community Reserves) covered a meager area of 381.33 km^2 and just represented 0.75% geographical area under PA network (Table 2.19). Comparing the status of PAs in different biotic provinces in two States, it was observed that Himachal Pradesh has nearly 41.22% area of the Trans-Himalaya biogeographic zone and 22.2% area of the Himalaya biogeographic zone. The State had representation of 17.23% area of the country's Northwest Himalaya biotic province. The Punjab represented a very small proportion (0.31%) of the Punjab plain biotic province. The average size of PAs in Himachal Pradesh was 240.18 km^2 while the average size of the PA in Punjab was just 19.0 km^2.

Out of above PA Network in two States, the Sutlej Riverscape included one National Park that is Pin Valley NP and six Wildlife Sanctuaries within Himachal Pradesh. Pin Valley National Park included 675 km^2 PA areas while one WLS (Kibber) falling in Tibetan Plateau included 2,220.12 km^2 areas while two WLSs falling in North-Western province namely Lippa Asrang and Rupi Bhabha WLSs collectively included an area of 534 $km^{2.}$ Similarly, Daranghati, Majathal and Rakchham Chitkul WLSs falling in Western Himalaya Province collectively covered an area of 506.36 km^2 and harbour a wide range of diverse forests from conifers to alpine pastures and several associated threatened floral and faunal species. This PA complex is not only rich in biodiversity but forms an important catchment tract for one of major tributary the Baspa River. Further, in the Punjab Plains, Harike Lake Wildlife Sanctuary at the confluence of Beas River with Sutlej River as a Ramsar Site and the only habitat for the Indus River Dolphin in India are obviously of the highest conservation priority and require utmost attention and care in managing these unique and environmentally sensitive PA sites. Other major PA areas in Punjab the Ropar Wetland Conservation Reserve and Nangal WLS as designated Ramsar Sites are also environmentally important as bird watching areas.

Table 2.15 Protected Area Network in Himachal Pradesh and Punjab Showing Biogeographic Representation

Biozone	Province	Province	Name of PA	PA Area	Total Area
Himachal Pradesh					
01A	**Ladakh**	**6,502**	Pin Valley NP	675.00	**675.00**
01B	**Tibetan Plateau**	**7,325**	Chandratal WLS	38.56	**2,258.68 (30.84%)**
			Kibber WLS	2,220.12	
02A	**Northwest Himalaya**	**27,785**	Great Himalayan NP	754.40	**4,787.46 (17.23%)**
			Inderkilla NP	104.00	
			Khirganga NP	710.00	
			Bandli WLS	32.11	
			Gamgul Siyabehi WLS	108.40	
			Kais WLS	12.61	
			KalatopKhajjiar WLS	17.17	
			Kanawar WLS	107.29	
			Khokhan WLS	14.94	
			Kugati WLS	405.49	
			Lippa Asrang WLS	31.00	
			Manali WLS	29.00	
			Nargu WLS	132.37	
			Pong Dam Lake WLS	207.59	
			Rupi Bhabha WLS	503.00	
			Sainj WLS	90.00	
			Sechu Tuan Nala WLS	390.29	
			Shikari Devi WLS	29.94	
			Thirthan WLS	61.00	

Biozone	Province	Province	Name of PA	PA Area	Total Area
			Tundah WLS	64.00	
02B	Western Himalaya	14,061	Chail WLS	16.00	685.41 (4.87%)
			Churdhar WLS	55.52	
			Darlaghat CR	0.67	
			Daranghati WLS	171.50	
			Majathal WLS	30.86	
			Renuka ji WLS	4.00	
			Rakchham Chitkul	304.00	
			Shilli Conservation	1.49	
			Shimla Catchment WLS	10.00	
			Shri Naina Devi	17.01	
			Simbalbara NP	27.88	
			Talra WLS	46.48	
Punjab					
04A	Punjab Plains	1,20,903	Abohar WLS	186.50	381.33 (0.31%)
			Beas River Conservation	Not	
			Bir Aishvan WLS	2.64	
			Bir Bhadson WLS	10.23	
			Bir Bunerheri WLS	6.62	
			Bir Dosanjh	5.18	
			Bir Gurdialpura WLS	6.20	
			Bir Mehaswala WLS	1.23	
			Bir Motibagh WLS	6.54	
			Harike Lake WLS	86.00	
			Jhajjhar Bacholi WLS	1.16	
			Kathlaur KushlianWLS	7.58	
			Keshopur Chham	3.40	
			Lalwan Community	12.67	
			Nangal WLS	2.90	
			Rakh Sarai Amanat Khan	4.95	
			Ranjit Sagar Conservation	18.65	
			Ropar Wetland	2.11	
			Siswan Community	12.95	
			Takhni – Rehampur WLS	3.82	

(Source: National Wildlife Database, WII, 2019)

Key features of the PAs included within the Sutlej Riverscape are described below in brief:

India well known for having wide variety of plants and rich ethnic diversity is considered as one of the Mega biodiversity Centre in the world and one of the gems to this jewel is Indian Himalayan Region (IHR) embracing diverse habitats which provide varied ecological niches and microclimates not only for plants but also for human beings. The IHR is rich store house of biodiversity which is readily utilized by the rural communities of the region as source of

medicine, food (wild edible), fodder, fuel, timber, making agriculture tools, religious and various other purposes. The region is inhabited by number of ethnic groups, which have been dependent on the wild plant resources of the region. Use of wild plants as a food source is an integral part of the culture of indigenous people that dwell in the tribal areas. Wild edible plants form an important source as a supplement or substitute food in time of scarcity for tribal communities. They play a major role in meeting the nutritional requirement of the tribal population in remote parts of the country (Samant and Dhar, 1997). Like other regions of the IHR, Cold Desert Biosphere Reserve (CDBR) is also rich in medicinal, aromatic and edible plant wealth. The tribal communities residing in CDBR also utilise wild edible plants as food and depend on this resource to meet their food needs for sustenance. The harsh climatic conditions and lengthy freezing winters prevalent in cold arid zones enforced tribal people to search for edible plants. Utilization of wild edible plants as food source by tribal communities residing in CDBR is more significant for them as they do not have yearlong easy access as well as normal availability and supply of other regular food resources in comparison to rural people residing in other regions.

The Cold Desert Biosphere Reserve (CDBR) which is the sixteenth Biosphere Reserve of India lies in Trans Himalayan region of India and located in Northern part of the Himachal Pradesh. It covers about 7,770 km^2 area and extends between Latitudes 32° 59' to 31° 44'N and Longitudes 77° 21' to 78° 34' E providing unique representation of biophysical and sociocultural values of Trans Himalayan cold desert ecosystem. Both Lahaul valley and Spiti valley are part of CDBR. Spiti valley forms the major part of Cold Desert Biosphere Reserve and in addition to this it includes the parts of Chandertal, Baralacha Pass, Bharatpur and Sarchu areas of Lahaul Forest Division. The core zone of the CDBR includes Pin Valley National Park, and Kibber and Chandertal Wildlife Sanctuaries. These three areas are well known for Trans Himalayan biodiversity in the valley. The vegetation comprises of alpine mesophytes, Oasitic and desert plant species (Samant *et al*., 2012). A total of 91 species of edible plants (trees 01 sp.; shrubs 11 spp. & herbs 79 spp.) belonging to 64 genera in 31 families were recorded (Sharma*et al.,* 2018).Among families, Polygonaceae and Asteraceae were found to be dominant, represented by maximum species (11 spp., each), followed by Apiaceae (08 spp.). Among the genera, *Allium* (06 spp.), *Ribes* (04 spp.), *Chenopodium, Hippophae* and *Rheum* (03 spp.) were the species rich genera. The present study revealed that maximum wild edibles (89 spp.) were found between altitudinal zone, 3000 to 4000 m, followed by 56 species found between 4000 to 5000 m zone. Some notable wild edible plants of the altitudinal zone 3000 to 4000 m were *Arabis tibetica*, *Bupleurum candolii*, *Capparis spinosa*, *Humulus lupulus*, *Mentha longifolia*, *Plantago himalaica*, *Rumex acetosa*, etc. The notable wild edible plants of altitudinal zone 4000 to 5000 m were *Allium carolianum*, *Bergenia stracheyi*, *Nepeta longibracteata*, *Oxyria digyna*, *Rhodiola heterodonta*, *Thymus linearis*, etc.

In total, 354 species of medicinal plants belonging to 208 genera and 76 families were recorded. Of these, 27 species were trees, 40 shrubs, 284 herbs and 3 ferns. The families Asteraceae (54 spp.), Polygonaceae (21 spp.), Rosaceae and Lamiaceae (20 spp. each), Fabaceae (19 spp.),

Ranunculaceae (18 spp.) and Apiaceae (16 spp.) and genera *Artemisia* (11), *Polygonum* (10), *Astragalus* and *Nepeta* (7 each) and *Saussurea* and *Thalictrum* (6 each), were rich in medicinal plants.The indigenous uses of 124 species were based on secondary information. A total of 196 common species was reported. Amongst the medicinal plants, *Aconitum heterophyllum, A. violaceum, Angelica glauca, Allium carolianum, A. victorialis, Arnebia euchroma, Betula utilis, Bergenia stracheyi, Bunium persicum, Carum carvi, Corylus jacquemontii, Dactylorhiza hatagirea, Dioscorea deltoidea, Ephedra gerardiana, Gentianella moorcroftiana, Hippophae rhamnoides, H. salicifolia, Hypericum perforatum, Hyssopus officinalis, Hyoscyamus niger, Inula racemosa, Juglans regia, Juniperus polycarpos, Jurinella macrocephala, sinopodophyllum hexandrum, Picrorhiza kurrooa, Rheum australe, R. webbianum, Rhododendron anthopogon, Saussurea costus, S. gossypiphora* and *Taraxacum officinale* were most preferred for indigenous use and trade purposes. Thirteen species were identified as critically endangered, 27 as endangered, 40 as vulnerable, 81 species as near threatened and 193 as of least concern. The species identified as critically endangered, endangered and vulnerable have been prioritized for conservation. Of these species, 68 face habitat degradation, 10 overexploitation and 81 both habitat degradation and overexploitation. Amongst the prioritized species for conservation, critically endangered, endangered and vulnerable categories species *viz., Aconitum heterophyllum, A. violaceum, Angelica glauca, Allium humile, A. victorialis, Dactylorhiza hatagirea, Dioscorea deltoidea, Hippophae rhamnoides, H. salicifolia, Hypericum perforatum, Hyoscyamus niger, Jurinella macrocephala, Ephedra gerardiana, Sinopodophyllum hexandrum, Picrorhiza kurrooa, Rheum australe, R. webbianum* and some of near threatened species *viz.,Bunium persicum, Carum carvi* and the cultivated species *Inula racemosa, Saussurea costus* were recommended for commercial cultivation in the Lahaul valley based on their market potential(Singh *et al*., 2009; Sharma *et al*., 2017). In the following chapter only two major core zones (Pin Valley National Park and Kibber WLS) of the CDBR along with other protected areas are described below.

(a) Pin Valley National Park

Pin Valley National Park located in the Lahaul and Spiti district of Himachal Pradesh was established in 1987. Total area of the Park is about 1,150 km^2 (Core Area675 km^2) and is located in the coarse and rocky Spiti region of Himachal Pradesh. The Park is a region of hills, cliffs and mountainous crevices, interspersed with grassy lower slopes. The cold desert region is adjoined to the Great Himalayan National Park in the southwest and Rupi Bhabha Wildlife Sanctuary in the south. The mountains are snow-covered and largely devoid of vegetation, which is restricted to sheltered strips along channels formed by the melting snow. The Park has a rich flora and fauna, including the Snow Leopard, Ibex, Red fox, Marten, Weasel, Pika, Himalayan snow cock, *Chukor*, Golden eagle, Griffon, Snow partridge, Chough and Raven. The Park has rich plant diversity with numerous medicinal and aromatic herbs. There are about 17 villages situated on the periphery of the park with a total population of about 1,600 people. The Pin River arises from the glaciers of the Pin-Parvati pass that are located at a height of 4,802 m. and it flows down to

meet the Spiti River, a large tributary of the Sutlej River, at Lingti village. There are 12 perennial streams, and numerous springs and glaciers. Nevertheless, the area is relatively dry and forms part of the cold desert of India where the annual average precipitation is 177 mm with heavy snow during winters. The vegetation is roughly demarcated into three main zones the Dry Temperate Zone (3,276 to 4,200 m) the Alpine Zone (4,200 to 4,800 m) and the Zone of Perpetual Snow above 4,800 m. Dominant plants of Pin Valley National Park is *Salix* spp., *Myricaria* spp., *Betula utilis*, *Juniperus polycarpos*, *Populus*, *Aconitum rotundifolium, Arnebia euchroma*, *Ephedra gerardiana*, *Ferula jaeschkeana*, *Hyoscymus niger*, *Gentiana tubiflora*, *Gentianopsis detonsa, Gentiana leucomelaena, Gentianopsis paludosa, Geum elatum*, *Picris hieracioides, Polygonum tortuosum* etc. Dominant mammals are: Tibetan gazelle, Wooly hare, Snow Leopard, Himalayan ibex, Red fox, Wolf, Bharal, Himalayan marmot, Indian porcupine, Blue sheep, Himalayan black bear, Himalayan brown bear, Mouse hare, Indian wolf, etc. while the important birds include Himalayan snow cock, *Chukor*, Golden eagle, Griffon, Cough, Raven, Blue rock pigeon, Snow pigeon, Yellow billed and Red billed choughs, Kestrels, Tibet snow finch, Bearded vulture, etc.

(b) Kibber Wildlife Sanctuary

Kibber WLS was established in the Spiti Region (Lahaul and Spiti district) of Himachal Pradesh in 1992 for conservation of Trans-Himalayan wildlife. It is located on the bank of Spiti River and it is India's only cold desert wildlife sanctuary. Kibber village is situated on the periphery of the sanctuary and area of WLS spreads over 1400 km^2; it is connected by roads to Kibber, Langza and Lhalung villages. As rationalization of boundaries of Kibber Wildlife Sanctuary notified on 7 June, 2013 an additional area of 867 km^2 was included and 46.88 km^2 area was excluded along with village Kibbri from earlier notified area of 1,400.00 km^2 of Kibber Wildlife Sanctuary. The Sanctuary is a mountainous cold desert, where altitudes range between 3,600 to 6,700 m amsl and the temperatures range between 23°C and 3°C in winter and between 1°C and 28°C during summers. The vegetation of this area has been broadly classified as dry alpine steppe. Kumar (2020) in Kibber Wildlife Sanctuary recorded a total of 116 Herbs, shrubs and Grass species *viz., Aconogonum tortuosum, Allium carolinianum, Allium consanguineum, Alyssum desertorum, Androsace delavayi*, *Arabidopsis himalaica*, *Aconitum* sp., *Arnebia euchroma*, *Artemisia gmelinii* , *Artemisia salsoloides, Artemisia santolinifolia, Artemisia* spp., *Askellia flexuosa*, *Aster flaccidus, Astragalus candolleanus, Astragalus* spp., *Astragalus nivalis, Astragalus rhizanthus*, *Berginia stracheyi*, *Biebersteinia odora*, *Bistorta affinis*, *Calamogrostis* spp., *Caragana versicolor*, *Carex* spp., *Carum carvi*, *Chenopodium* spp., *Christolea crassifolia, Christolea himalayensis*, *Corydalis crassifolia*, *Corydalis filiformis*, *Corydalis thyrsiflora* , *Cousinia thomsonii* , *Dracocephalum heterophyllum, Dracocephalum stamineum, Elsholtzia eriostachya, Elymus nutans, Ephedra gerardiana, Erigeron multiradiata* , *Erigeron poncinsii* , *Eriophyton rhomboideum* , *Eritrichium canum, Euphorbia tibetica, Festuca* spp., *Gagea lutea* , *Gentiana moorcroftiana* , *Gentiana tianschanica* , *Geranium lambertii* , *Geranium himalayense* , *Geranium wallichianum, Marmoritis nivalis, Heracleum pinnatum,Heracleum thomsonii* ,

Kobresia royleana , *Kobresia schoenoides*, *Krascheninnikovia ceratoides*, *Lactuca tatarica*, *Leontopodium himalayanum*, *Lepidium apetalum*, *Lindelofia longiflora*, *Lindelofia stylosa*, *Lonicera semenovii*, *Lonicera spinosa*, *Myosotis alpestris*, *Myricaria germanica*, *Myricaria prostrata*, *Nepeta eriostachya* , *Nepeta longibracteata*, *Nepeta podostachys* , *Nepeta* spp., *Oxytropis cachemiriana*, *Oxytropis lapponica*, *Oxytropis microphylla*, *Oxytropis mollis*, *Oxytropis* spp., *Oxytropis tatarica*, *Paraquilegia microphylla* , *Pedicularis bicornuta* , *Pedicularis longifolia* , *Physochlaina praealta* , *Plantago depressa* , *Plantago* spp. , *Polygonum cognatum* , *Potentilla arbuscula*, *Potentilla argyrophylla* , *Potentilla bifurca* , *Potentilla desertorum* , *Potentilla multifida*, *Potentilla nivea*, *Potentilla* spp., *Rhamnus prostrata*, *Rheum spiciforme*, *Rheum tibeticum*, *Rhodiola crenulata*, *Rhodiola heterodonta*, *Rhodiola tibetica* , *Rhodiola wallichiana* , *Ribes orientalis* , *Rosularia alpestris* , *Salsola collina*, *Saussurea glacialis*, *Saussurea taraxicifolia*, *Saussurea nana* , *Scrophularia dentata* , *Silene gonosperma* , *Silene rechingeri*, *Stipa capillata*, *Stipa* spp., *Tanacetum nubigenum* , *Taraxacum officinale* , *Thalictrum cultratum* , *Thalictrum foetidum* , *Thermopsis inflata* , *Thymus linearis* , *Tragopogon gracilis* , *Urtica hyperborea*, *Waldheimia glabra* were recorded belonging to 65 genus and 28 families *viz.*, Amaranthaceae, Amaryllidaceae, Apiaceae, Asteraceae, Biebersteiniaceae, Boraginaceae, Brassicaceae, Caryophyllaceae, Crassulaceae, Euphorbiaceae, Fabaceae, Gentianaceae, Geraniaceae, Grossulariaceae, Lamiaceae, Liliaceae, Orobanchaceae, Papaveraceae, Plantaginaceae, Poaceae , Polygonaceae, Primulaceae, Primulaceae, Rosaceae, Saxifragaceae, Scrophulariaceae, Solanaceae, Urticaceae for woody and non woody vegetation in 12 sampling study sites. A Total of 5 numbers of species viz., *Arnebia euchroma*, *Berginia stracheyi*, *Ephedra gerardiana*, *Physochlaena praealta* and *Rhodiola heterodonta* was found threatened out of 116 species recorded in Kibber Wild Life Sanctuary. Kibber Wildlife Sanctuary is a home for rare animals too like snow leopard, ibex, blue sheep and birds like snow cock and the bearded eagle griffons. Snow leopards prefer to inhabit steep cliff areas rocky outcrops and ravines. These habitats provide them with camouflage they need to ambush unsuspecting prey. Large mammalian fauna of the area includes bharal (*Pseudois nayaur*), relatively few ibex (*Capra ibex*), and their predators, namely the snow leopard and the wolf. Other fauna includes the red fox (*Vulpes vulpes*), pale weasel (*Mustela altaica*), stone marten (*Martes foina*) and the Himalayan mouse hare (*Ocho tonas*). Nearly 45 species of birds were identified, including several species typical of this alpine habitat (Lyngdoh and Habib, 2019), such as chukar (*Alectoris chukar*), and Tibetan snowcock (*Tetraogallus tibetanis*).

(c) Lippa Asrang Wildlife Sanctuaries

This high altitude Sanctuary lies in Kinnaur district covering an area of 31 km^2. Much of this high altitude Sanctuary is a plateau of barren cold desert landscape. Lippa Asrang is one of the few sanctuaries in India where feral yak (*Bos grunniens*) have been reported. The studies on phyto-diversity of Lippa-Asrang Wildlife Sanctuary in District Kinnaur, Himachal Pradesh (Man, 2013) resulted into the findings that 247 taxa belonging to 153 genera and 52 families, out of which 243 species were angiosperms and 4 gymnosperms. Out of 243 species of angiosperms

207 species were dicots and 36 were monocots. *Saussurea* was most dominant genus followed by *Potentilla*, *Gentiana* and *Silene* with maximum number of species. A total of 93 plants species have also been identified as important medicinal plants. The enumeration also includes 25 species of medicinal plants from 21 genera belonging to 16 families under different threat categories. Mammals reportedly include the Asiatic black bear (*Ursus thibetanus)*, Himalayan brown bear (*Ursus arctos*), Musk deer (*Moschus chrysogaster*), Goral (*Nemorhaedus goral*), Ibex (*Capra sibirica*), Blue sheep (*Pseudois nayaur*) and Yak (*Bos grunniens*) (Singh *et al.*, 1990). This Sanctuary is away from human habitations represents undisturbed alpine habitat and thus has very few visitors in its barren, cold desert plateau habitat. Grazing of livestock takes place, which is unsustainable due to the fragile ecosystem. Otherwise, little can be said without data regarding conservation issues.

(d) Rupi Bhaba Wildlife Sanctuary

Rupi Bhaba Sanctuary is located near Rampur Bushahr in the district of Kinnaur in Himachal Pradesh, located between an altitude of 909 to 5,650 m, it lies on the left bank of the Sutlej River covering an area of 503 km^2. The sanctuary lies adjacent to the Great Himalayan and Pin Valley National Parks. Major flora of this WLS is Kharsu Oak (*Quercus semecarpifolia*), Chirpine (*Pinus roxburghii*) and Deodar (*Cedrus deodara*) forests. The Sanctuary is covered with lush green forests, and the undulating terrain shelters a large number of Indian faunal species. Major fauna of Rupi Bhaba Wildlife Sanctuary is snow leopard, Himalayan brown bear, Himalayan black bear, Himalayan tahr, fox, Musk deer, Blue sheep, Goral, Yellowbilled chough, Nutcracker, Blackthroated jay, Streaked laughing thrush, Whitecapped redstart, Orangeflanked bush robin, Wren, black tit, Wall creeper, Crested black tit, Wagtail and Western tragopan.

(e) Daranghati Wildlife Sanctuary

The Daranghati Sanctuary is located in Shimla district of Himachal Pradesh. The Sanctuary is composed of two segments, with villages and cultivated areas in between. The two units of the Sanctuary lie on either side of the Dhauladhar Range that forms part of the Lesser Himalaya. One part of the Sanctuary to the north forms the southern catchment area of the Manglad Gad, with three main streams, including the Wajadi Gad, Gharat Gad and Manglad Gad. The second part of the Sanctuary to the south encompasses the southern catchment area of the Nogli Gad with main streams flowing northwards including Bankdari *Nallah*, Rigir Gad and Setlu *Nallah*. Manglad and Nogli Khad from the eastern tributaries of the Sutlej River. Daranghati, once a former hunting reserve of the Raja of Bushahr State, now show signs of degradation, but remains particularly important for pheasants, notably the Western Tragopan (*Tragopan melanocephalus*). It also supports a variety of Himalayan ungulates (Pandey 1990; Singh *et al.*, 1990). Pandey (1995) notes five main forest types: (1) Moist Cedar *Cedrus deodara* forest (1,900 to 3,000m) (2) Western Mixed Coniferous Forest on northern and eastern slopes above 2,000 m, comprising Blue Pine (*Pinus wallichiana*), Silver Fir (*Abies pindrow*) and Spruce (*Picea smithiana*), with Cedar on welldrained sites, (3) Moist Temperate Deciduous forests, (4) Kharsu Oak forest with

common associates *Taxus wallichiana*, *Pyrus*spp., and *Prunus*spp., and (5) West Himalayan subalpine forest, with Silver Fir and some *Quercus semecarpifolia*, above 3,000m. It has undisturbed forest areas. Monal, Tragopan, Koklas and Kaleej are the pheasants found here. Detailed studies on birds of this site have not been conducted. Based on secondary information, Singh *et al.* (1990) prepared a short list of birds of this Sanctuary and used the Western Tragopan (*Tragopan melanocephalus*) as a species of conservation interest. Gaston *et al.* (1981a, b), found no evidence of Cheer Pheasant (*Catreus wallichii)*, although the species used to occur in this area (WynterBlyth 1951). Himalayan or Impeyan monal (*Lophophorus impejanus)*, Koklass Pheasant (*Pucrasia macrolopha)* and Kaleej pheasant (*Lophura leucomelanos)* are also found here. This site is selected as an IBA based on the presence of the globally threatened Western Tragopan. Pandey (1995) estimated a density of 1.5 birds per km^2 in winter habitat. It was estimated that both parts of Daranghati WLS and the surrounding areas may support a population of 150 to 250 birds. This could be one of the most important sites for this globally threatened bird, listed as Vulnerable. It is also listed as restricted range in the Western Himalaya Endemic Bird Area (Stattersfield *et al.*, 1998). Daranghati WLS has almost all the representative mammals of the temperate forest and subalpine zone of Himachal Pradesh while the leopard (*Panthera pardus*) is the major carnivore. Asiatic black bear (*Ursus thibetanus)* is the largest carnivore of the Sanctuary, mainly found above 3,000 m in summer and much lower during winters. Himalayan Brown bear (*Ursus arctos)* is also found in the alpine and subalpine regions. Smaller carnivores include Red fox (*Vulpes vulpes)*, Himalayan weasel (*Mustela sibirica)*, Yellowthroated marten (*Martes flavigula)*, Himalayan palm civet (*Paguma larvata)* and Jungle cat (*Felis chaus)*. Wild ungulates Musk deer (*Moschus chrysogaster)*, Barking deer (*Muntiacus muntjak)*, Goral (*Nemorhaedus goral)*, Serow (*N. sumatraensis)* and Himalayan tahr (*Hemitragus jemlahicus)*, Ibex (*Capra ibex*) and Bharal (*Pseudois nayaur)* are reported on higher elevations. Not much is known about the reptile and amphibian fauna. Like most of the sanctuaries in Himachal Pradesh, Daranghati WLS has a large human population residing in and around the Sanctuary with two villages existing inside the Sanctuary and the peripheral areas have 26 villages. These villagers have rights of fuelwood and minor forest produce collection, and livestock grazing. Besides, nomadic Gujjars have the grazing permits too. There is a need to link both parts of the Sanctuary and further enlarge the area so ecologically viable area could be provided for the protection of Western Tragopan (Pandey 1990, 1995). Regular monitoring of bird populations has also been recommended.

(f) Majathal Wildlife Sanctuary

Majathal Wildlife Sanctuary, located in Shimla and Solan districts, is part of the catchment area of the Sutlej River. It is bounded to the north by the Sutlej River, and to the south by a mountain ridge enclosing an area of 30.86 km^2. The Sanctuary comprises a short section of the southern slopes of the Sutlej Valley, with steep terrain. Places of religious interest include the Harsingh Temple (Singh *et al.*, 1990). The temple attracts thousands of pilgrims. The Sanctuary may be one of the most important sites in Himachal Pradesh for Cheer pheasant (*Catreus wallichii*), and

the only site present within the Sutlej River catchment. Seven species of Galliformes have been reported from this area (Mishra, 1996). Chir pine (*Pinus roxburghii*) and Ban oak (*Quercus oblongata*) forests, and subtropical *Euphorbia* scrubs are the major vegetation types (Mishra, 1996). The slopes are sparsely forested with Chirpine and Ban oak, and mostly dominated by grassy tracts, often extending continuously from the ridgetops down to about 1,000 m (Garson, 1983). Mishra (1996) during his studies on the goral enumerated 106 species of birds, including the globally threatened cheer pheasant, the Kaleej pheasant (*Lophura leucomelana*) and Koklass (*Pucrasia macrolopha*). Shah *et al.* (2002) have worked on the Black Francolin (*Francolinus francolinus*), a common Galliform in the Sanctuary. The mammalian fauna includes Leopard (*Panthera pardus*), which is the top predator. Asiatic black bear (*Ursus thibetanus*), Golden jackal (*Canis aureus*), Common palm civet (*Paradoxurus hermaphrodites*), Himalayan palm civet (*Paguma larvata*), Yellowthroated marten (*Martes flavigula*), and Jungle cat (*Felis chausmoru oak*) are other carnivores. Sambar (*Cervus unicolor*), Barking deer (*Muntiacus muntjak*), Goral (*Nemorhaedus goral*) and Wild boar (*Sus scrofa*) represent the ungulates. According to Mishra (1996), 17 settlements with a population of about 650 inhabitants are present inside the Sanctuary. They have rights to cultivate, graze livestock, and collect fodder, timber, fuelwood and minor forest produce. Crop damage by ungulates and livestock killing by Leopard and Black bear create resentment against the Sanctuary among the villagers. Besides the local people, nomads also come during winter from the higher reaches to graze their livestock, which exerts further pressure on the limited resources of the Sanctuary. Graziers start forest fires to get better grass for livestock. The State Government has started a project to provide drinking water to 100 villages in the western part of the Sanctuary. One of the major threats is the establishment of a cement manufacturing plant just outside the Sanctuary. Mishra (1996) found 39 gun license holders, and many unlicensed guns. Ungulates and pheasants are their major targets, as they provide good meat for the table.

(g) Rakchham Chitkul WLS

Rakchham Chitkul (Sangla Valley) WLS located in the catchment area of the Baspa Valley, is situated in the arid zone of the middle Himalaya, having an area of 304 km^2. Gobind Wildlife Sanctuary of Uttarakhand is adjacent to its southern boundary, and a little beyond the eastern boundary of the Sangla Sanctuary lies the Tibetan plateau (Singh *et al.*, 1990). The high altitude areas of this Sanctuary are less accessible and therefore, less disturbed. Thick forests of Deodar (*Cedrus deodara*), and broadleaved species are found from 2,000 m upwards. Beside this, Fir-Spruce, Mixed Forest with Birch-Fir prevails and fill the tree cue. The flora and fauna is, therefore, quite unique and is known for its vast alpine pastures. Five major forest types are seen in this Sanctuary: Dry Alpine Scrub, Dry Temperate Coniferous Forest, Dry Broadleaf and Coniferous Forest, Upper West Himalayan Temperate Forests, and Lower Western Himalayan Temperate Forests. This classification is based on Champion and Seth (1968). The forest clad hill slopes are very steep, punctuated with rock outcropping bearing no vegetation at all. Such habitats alternate with a vast number of hill streams (*nallahs*), which descend to meet the main

valleys of Shong, Barua, Rukti and Batseri *nallahs*. The precipitous hill slopes in these remote valleys make them difficult for humans to approach but are suitable for wildlife. The higher reaches are snowbound for most parts of the year, and four glaciers are located within the Sanctuary. The alpine area of this WLS has a rich repository of medicinal and aromatic herbs. The important herbs are Dhup (*Jurinea macrocephella*), Karu (*Gentiana kurroo*), Patish (*Aconitum heterophyllum*), Banafsha (*Viola canescens*), Kutki (*Picrorhiza kurroa*), Brahmkamal (*Saussurea obvallata*) and Hathpanja (*Dactylorhiza hatagirea*). Several herbs found in the alpine pastures of this Sanctuary are of great importance in Ayurvedic medicine.

Kapoor and Verma (2013) assessed the plant diversity study in the Rakchham Chitkul Wild life Sanctuary and reported 322 plant species belonging to 70 families and 162 genera. The dominant families were Asteraceae, Rosaceae, Ranunculaceae, Ploygenaceae and Lamiaceae. Out of the total 322 species, 127 plant species of medicinal importance were recorded from the Sanctuary.

Most abundant plant species found in different areas of the sanctuary are *Potentilla atrosanguinea*, *Salvia nubicola*, *Spiraea canescens*, *Rosa macrophylla*, *Sibbaldia parviflora*, *Potentilla nepalensis*, *Juniperus communis*, *Juniperus indica*, *Trigonella emodi*, *Polygonum alatum*, *Lonicera parviflora*, *Potentilla multifida*, *Cassiope fastigiata*, *Salix fragilis*, *Thymus linearis*, *Swertia pupurascens*, *Lonicera angustifolia*, *Lonicera hypoleuca*, *Cedrus deodara*, *Abies pindrow*, *Berberis* spp., *Rabdosia rugosa*, *Plantago depressa*, *Picea smithiana*, *Impatiens urticifolia*, *Salvia lanata*, *Androsacerotundifolia*, *Bistorta affinis*, *Anaphalis nubigena* and *Arenaria festucoides*.

Out of the 127 medicinal plants species 23 species *Viz.,Aconitum heterophyllum*, *Aconitum violaceum*, *Angelica glauca*, *Bergenia stracheyi*, *Betula utilis*, *Dactylorhiza hatageria*, *Dioscorea deltiodea*, *Heracleum lanatum*, *Hippophae rhamnoides*, *Juniper polycarpos*, *Jurinea dolomiaea*, *Meconopsis aculeate*, *Picrorhiza kurrooa*, *Sinopodophyllum hexandrum*, *Polygonatum cirrhifolium*, *Polygonatum verticillatum*, *Rheum webbianum*, *Rhodiola heterodonata*, *Rhododendron anthopogan*, *Rhododendron campanulatum*, *Rhododendron lepidotum*, *Saussurea obvallata* and *Taxus wallichiana* fall in the category of threatened plants.

Highly endangered species of pheasants, including the Western Tragopan (*Tragopan melanocephalus*) are found in this Sanctuary. Other pheasants are Himalayan Monal (*Lophophorus impejanus*), Koklass (*Pucrasia macrolopha*) and Kaleej pheasant (*Lophura leucomelana*). The main large mammals found in this sanctuary are Snow Leopard (*Panthera uncia*), Musk Deer (*Moschus chrysogaster*), Bharal (*Pseudois nayaur*), Himalayan Tahr (*Hemitragus jemlahicus*), and Asiatic Black Bear (*Ursus thibetanus*) at high altitudes, bordering alpine and subalpine regions. At lower elevations, Goral (*Nemorhaedus goral*), Serow (*Nemorhaedus sumatraensis*), Leopard (*Panthera pardus*), and Common Langur (*Semnopithecus entellus*) are found. During recent years, the WLS which is in the extreme western part of Kinnaur district, has become open to outside influences, and has seen a great deal of commercialization, especially in the main valley. The construction of the Baspa I HEP has

changed the face of the valley forever, which has brought in roads, equipment of building construction, engineers and infrastructure. In addition to being employed in the hydroelectric projects, the villagers have started growing apple and other fruits as commercial crops. Agriculture, however, continues to be the major occupation of the local residents. The conditions of people living in upper Baspa Valley, including the villages of Chitkul, Mastrang, and others, are in direct contrast to those of the Baspa Valley. People in these remote villages have clung to their oldage customs and traditions. In the past, after snowfall, hunting of wild animals had been their major occupation. The musk deer used to be ruthlessly hunted for its musk pod, which fetched them a good price in the market towns of Rampur, Shimla and Amritsar (Bird Life International, 2020). Even today, the local people say that the musk deer of Chitkul forests produces the best quality and quantity of musk in the whole Himalayan region. Most of the people are non-vegetarian and hunt for meat during the harsh time during winters. Barking deer or muntjac, which once had a good population, has now become almost extinct because of persecution for meat. The pheasant too are hunted for meat while the monal pheasant has been traditionally hunted for its crest feathers, which the villagers wear on their caps, as a status symbol for Kinnaur.

(h) Shri Naina Devi Conservation Reserve

Shri Naina Devi Conservation Reserve is in Bilaspur district of Himachal Pradesh with an area of 17.01 km^2.As the Sanctuary is located in the Lower Shivaliks, floral and faunal affinities are close to Dry Deciduous Forests of the northern plains (Singh *et al.*, 1990).The forests correspond to the northern Dry Mixed Deciduous Forests (3,000 ha) and Chir pine (1,550 ha), along with some dry bamboo brakes. Commercial plantations of Chir and *Acacia* spp. have been established in an area of 1,427 ha between 1979 and 1984 along with the introduction of *Eucalyptus* spp., (Singh *et al.*, 1990). The avifauna is poorly recorded, but Singh *et al.* (1990) provided a preliminary list of 15 bird species. As the forest is still intact in places, and the large wetland attracts numerous waterfowl, further surveys would yield at least ten times more species than the present record. Thus, more research is required to find out the total number of waterfowl and species-wise abundance and populations. Almost all the representative large mammalian species of subtropical forests of the Outer Himalaya are found.

(i) Abohar Wildlife Sanctuary

This nature reserve Abohar Wildlife Sanctuary is located about 15 km from Abohar and sprawls over an area of 186.5 km^2 in the Fazilka district of Punjab. The Sanctuary was initially established temporarily in 1975 and later in 2000, it was established as a sanctuary under the Wildlife (Protection) Act, 1972. The Sanctuary is home to rich biodiversity indigenous to the area. The dominant flora includes *Acacia nilotica*, *Azadirachata indica*, *Albizia lebbeck*, *Acacia tortilis*, *Dalbergia sissoo*, *Prosopis cineraria*, *Melia azedarach* and *Prosopis juliflora*. The

Sanctuary spreads over thirteen villages that are home to the Bishnoi community. A unique initiative has been started by the *Bishnoi* community which has shown concern and taken up the responsibility to protect the Blackbuck, the State Animal of Punjab, considered to be sacred by the *Bishnois*. The community also protects the Blue bull popularly known as Nilgai. The initiative taken by the community has been successful and number of black bucks has been gone up to 4,728. According to a recent survey, the number of blue bulls has also gone up to 6,011 (Bishnoi, 2020). The flora in the Abohar Wildlife Sanctuary is classified under the tropical dry mixed deciduous forests. Apart from the Blackbuck and Nilgai, the Sanctuary is also home to several other animals like Porcupines and Wild boars which can be spotted easily in the sanctuary. The *Bishnois* protect the animals in the Sanctuary from poaching and hunting.

(j) Jhajjar Bacholi (Bachauli) Wildlife Sanctuary

This Sanctuary is situated 15 km from Anandpur Sahib City in the forest area of district Rupnagar. It has an area of 116.00 ha. This area was first declared as Wildlife Sanctuary in 1998 and final notification was issued in December, 2003. Sambar, Barking Deer, Hare, Jackal, Python, Cobra, Rat Snake and Leopard etc. are found in the sanctuary. Important Plants of the Sanctuary are *Mangifera indica*, *Phyllanthus emblica*, *Terminalia arjuna*, *Ficus bengalensis*, *Dendrocalamous strictus*, *Butea monosperma*, *Eucalyptus hybrid*, *Senegalia catechu*, *Acacia nilotica*, *Prosopis juliflora*, *Azadirachata indica*, *Ficus religiosa*, *Holoptelia integrifolia*, *Dalbergia sissoo*, *Albizia lebbeck* and *Leucaena leucocephala*.

(k) Ropar Wetland Conservation Reserve

The Ropar Lake that lies in the Hoshiarpur Chandigarh sub-montane plain region was created in 1952 with the construction of the Bist-Doab canal which receives water from its head works on the Sutlej River near Ropar town. It is essentially a reservoir surrounded by marshy margins dominated by large stands of *Phragmites* spp. A few shallow waterbodies along both sides of the River are located within the wetland area. The area has been declared as a reserved forest, and is under the control of the Punjab Government. The wetland experiences semiarid monsoon type climate with average annual rainfall of approximately 1,000 mm. Under the National Wetlands Programme of the MoEF&CC, GoI, the Ropar Wetland has been selected for inclusion in the list of Wetlands of National Importance during 2002; it has also been declared as a Ramsar Site. The edge of the wetland is characterized by thorny bushes, reeds, grasses, sedges, trees and the Water Hyacinth (*Eichhornia crassipes*) has invaded the wetland. About 154 species of birds have been identified till now (Bird-Life International, 2020). It serves as an important staging ground for a number of migratory birds, but detailed studies are lacking. As the lake is surrounded by agricultural fields and human habitations, large mammals are absent, except for Wild Boar (*Sus scrofa*) and Nilgai (*Boselaphus tragocamelus*), both of which cause destruction to crops. Sambar (*Cervus unicolor*), Hog Deer (*Axis porcinus*) and Smooth Indian Otter (*Lutra perspicillata*) are reported to be present, but the report needs confirmation (BirdLife International, 2020). Thirty five species of fish are found, many among them are of commercial value. Major pollution threat

to the wetland comes from the fly ash from the nearby thermal plant. The wetland is severely degraded and very little suitable habitat left for the birds. It is in immediate need of restoration. This reserve has great potential to be developed as an excellent bird watching area. Since this wetland is an important source of fisheries, it is significant from the economic point of view of the State. Ever since the inclusion of Ropar Wetland as a Wetland of National Importance, the Punjab State Council for Science and Technology has taken some initiatives to improve the wetland to make it more suitable for birds and tourists. However, these measures are not enough. A holistic management plan, based on scientific research, is required to make this wetland truly a Ramsar Site important both for waterfowl and for the State's economy.

(l) Harike Wildlife Sanctuary

Harike, also known as HarikePattan, is situated at the confluence of the Beas and Sutlej Rivers. The Sanctuary ecosystem, covering an area of 4,100 ha, was created following the construction of the Harike barrage across the Sutlej River, which is internationally recognized Ramsar Site. During winters, thousands of migratory birds arrive from the high Himalaya, Europe and Siberia, making it the best time of the year to visit. Some of the regular visitors sighted in the Sanctuary include the large Cormorant, Purple Moorhen, Bar-headed Geese, White-winged Tern, Tufted Duck and White-eyed Pochard. The birds commonly found in the Sanctuary areYellow eyed Pigeon, Tufted Duck, Yellow Clowned Woodpecker, Watercock and White Rumped Vulture. The wetlands are also home to several species of Turtles, Snakes and Fish. The rare Indus River Dolphin can also be seen. Apart from that Smooth Indian Otter, Jungle Cat, Jackal, Indian Wild Boar and Common Mongoose also occurs in the Sanctuary.

2.5 The Socio-economic Environment

Humans have exploited potentially renewable natural resources to the fullest for their own prosperity and as a result they suffer by the syndrome of resource degradation. Human's interference with natural processes is such that his activities have resulted in a very high and unsustainable rate of depletion of natural resources. Humans has not only altered the natural ecosystems for his requirement, but also changed own environment. Unplanned development and, changing social structure, culture and consumption patterns have immensely influenced the overall natural environment (Gliksn, 1971). The resource degradation is one of the most important aspects of the current global environmental crisis, and it is a formidable obstacle to the achievement of a sustainable human economy. It has been lately realized that the 'Natural Capital' is key to achieve various goals of sustainable development. 'Human Environment' represents the space which surrounds human movement, work, habitation, rest and interaction – towns and villages, settlement influence areas, the rural and the accessible virgin landscape (Glikson, 1971). This environment is generally defined as a set of biological and physical facts in space, as modified by man. Human ecologists are attempting to understand the various linkages between humans and the natural ecosystems that sustain them (Bates, 1997).



Plate 2. 15 A view of Key Monastry

Riverine landscapes (Riverscape) are interconnected freshwater habitats that are commonly associated with diverse ecological, socioeconomic, and cultural systems (Hand *et al.*, 2018). Riverscape are landscape scale pattern of connected River and stream habitats having diverse ecological and socioeconomic settings. Socioecological interactions among diverse stakeholders and often their competing demands complicate natural resource conservation and management of Riverscape. The water of the Indus River originates in Chinese Tibet and the Himalayan Mountains in Pakistan and Ladakh UT. The River flow through the arid land of Punjab and in Sind culminated in the Arabian Sea at Karachi. Since the turn of 1900 AD, the Indus River and its Principal Rivers have developed as major source of life in the northern region of India, with arrangements of dams and canal building for inundating Landscapes throughout its travel. At present, this River system is serving water to 1,10,000 km^2 of area, which is the largest for any River system in the world (Yadav, 2015). Partition of India in 1947 gave birth, not only two nations eventually, but also a number of troubles and conflicting interests, along with mutual hostility. Most evidently, India and Pakistan came into existence as independent nationals as a result of partition. As a division of water resources of the Indus River and its principal rivers under the Indus Water Treaty, 1960, there have been various implications.



Plate 2. 16 General view of Cold desert landscape

2.5.1 Historical Perspective – Creation of Forest Reserves, Timber extraction, Commercialization of Forests and Deforestation

The archaeological knowledge pertaining to the Sutlej River has been traced back to pre-British period, but the information regarding this period regarding land use and agriculture is scanty. Hence, from the early British compilations one can put together a broad picture of 'Traditional' land use and social structure. The mountain region above Punjab fell under British control as well. The new rulers moved quickly to establish the elaborate administrative structure which was already in place in other British regions of India. Soon they demonstrated that there are many potential links between hills and lowlands, and integrated hill life with broader north Indian region more fully than ever before. The traditional village life and resource use in the Himalayan Mountains was relatively self-sufficient local system of subsistence. As an agro-ecological system, forests, grazing lands and croplands were integrated. Throughout most of its history, this system had important ties to two dimensions of the outside world politically powerful overlords and urban market linked with trade routes and both of them were controlled by different social groups. In the past, rural people in Himachal Pradesh had very limited arable lands. The most important non-agriculture use of land in upper Sutlej River Basin was pastoralism. Villagers kept larger flocks of sheep and goat and since long followed the migratory transhumant system. The upper Sutlej River region maintained geography of sacred places and most villages in hills had

temples to ancient local gods and goddesses (*Devtas* and *Devis*). Temple groves of the sacred deodar tree were under the care of the *Devtas*, protected against cutting.. A regional network of markets, fairs and trade routes (Lavi Fair, Rampur) linked the Kinnaur and Spiti area with far-flung locations, both in the north Indian lowlands and the northern reaches of the Himalayan Mountains. Currumooddeen (1815) has reported details of trade between Bushair and China. He reported that Chinese trade node called Gartok, though named as a town, but does not contain a single permanent structure. Along with describing the trade route, the study also talks about the movement of trade articles. Frazer (1820) was the first to write admiringly about Kinnaurese during the Gorkhaii invasion. He gave social and religious account of the society. Though he observed that Kinnauri language is different from Tibetan and Hindi, he could not make any significant study of it.

The rising power of various Empires in lowland gradually reduced the mountain region to a status of dependency (Singh, 1991). Several of the Pre-Mughal Muslim conquerors of the north Indian lowlands invaded the outer hills for plunder. Immediately after the British conquest, large extent of deodar trees were felled by contractors for new commercial markets in lowland Punjab and beyond, resulting severe damage to forest in the middle elevation belt (Stebbing, 1921). Soon under the Forestry Law of 1855, the first of its kind in British India, the haphazard approach of forest felling by private contractors was replaced by the governmental timber operations from 1864 onwards (Trevor, 1920; Samler, 1935). The Forest Law was refined in 1878 and by mid1880s, and the category of reserved forests were made largely free of local rights, and a complete list of records was a prerequisite. Since this was not possible, few forests were declared as RFs while some areas were listed as Protected Forests (PFs). Even PFs included two classes: Demarcated Forests, in which rights were more extensive and a higher priority, and Under-marketed Forests, incorporating all other forests and wastelands not recorded in the land revenue settlement. Commercial timber trade placed increasing pressure on forests and resulted into gradual encroachment by Punjabi contractors and the arrival of the outside labourers.



Plate 2. 17 Forest resource dependency of local communities

The most challenging and complex issue in forests was grazing rights and the process of recognizing the grazing rights and demarcation of forests. Under colonial rule, the forests of Bushahr State (Rampur) were taken over by the British under lease in 1864 (the forests of Chamba state were also taken on lease in 1850). Mr. A.L. Mclntyre (Deputy Conservator) and Mr. C.S. Hart (Deputy Conservator) on their note on Bashar Forest reported that the Bashahr Forest situated in the Sutlej River valley began to be worked for deodar timber for export to the plains about 1850 (PSG, 1995). In 1851, the Governor General, Lord Dalhousie appointed Captain Longden to carry out a survey of the forests of the western Himalayan region. He carried out the survey during 1852-53 and submitted his report. His recommendation for the establishment of a timber agency at Sialkot and Ropar was accepted by the Governor General. Later, he was appointed as an agent of that agency in 1854. Between that year and 1864 great havoc was made in the most accessible of them by traders, and arrangements made by the Superintendent, Hill states, Simla, for their protection under the Raja's control having failed, they were in 1864, at the request of the Raja, leased to the British Government. To start with the latter paid the Raja for the trees it cut, but in 1877 a revised lease stipulating for the payment to him of a fixed yearly rental, *viz;* Rupess 10,000 was executed. This revised lease, which is still in force, made over the control of all the Bashahr forests, including those situated in the valleys of the Pabar and Giri rivers, tributaries of the Jumna, in perpetuity to the Brtish Government, but it is stipulated for free supplies of forest produce required by the State and inhabitants of Bushahr. Since its execution the forests have been managed by the Forest Department on the same lines as

forests in British Territory. In Sutlej River valley the important forest blocks have all been demarcated and surveyed, and records of rights to be exercised in them were prepared by Mr. Minniken between 1884 and 1900. The settlement report was sanctioned by Government in 1903. At that time deodar was the only timber product worth exporting. From these point of view two divisions has been established. These are;

a) The forests situated in the eastern half of the Sutlej River valley i.e., east of Wangtu Bridge, where the summer rainfall is very small, whilst the winter snowfall is very heavy.

b) Forests situated in the western part of the Sutlej River valley and in the Pabar and Giri valleys where the summer rainfall is considerable, whilst the winter rain or snowfall is moderate.

Since 1891, all the demarcated forests in the valley of the Sutlej River Basin have been managed under a Forest Working Plan, which prescribes the forests to be felled and the number of trees to be cut in such forests. The working plan aims at establishing such a rate of felling of the remaining old deodars as will admit of their replacement by trees of younger growth by the time the supply of old trees is exhausted. Therefore, if at all, terms like 'Forest Management' and 'Scientific Conservation and Exploitation of Forests' have any relevance, it is primarily in the context of overexploitation of forests by the British. Obviously, the British were less interested in the development and conservation of the forests, than in extracting the most from them in a very systematic manner. The result was that overexploitation of forest resulted into the thinning of the green cover. Captain Longden also visited the Sutlej River Valley and found that the state of affairs of the forests was not so bad in the inner valleys of Shimla Hills, because the forest contractors, who used to supply timber to the British Government, ruthlessly exploited only the accessible forests near the natural watercourses.



Plate 2. 18 Forest resource dependency of local people

There are certain ancient deodar trees and groves in the interiors of upper Himalayan region that are related intimately to many of the autochthonous gods and goddesses. The miraculous and legendary origin of deities may be found in innumerable folk traditions and the eulogies of these deities. There is no documented history of forests of this region. However, various myths, legends and traditions are associated with innumerable demonic deities and forest spirits, about which we have already spoken. The Sacred Groves are a continuation of those ancient traditions. Although, the British Forest Officers admired those Sacred Groves, because 'The natives of the hills venerate the groves surrounding their temples, and religiously conserve them,' they were deeply envious of their richness, for 'whilst to the state, the wood is of the greatest importance for houses and bridge building'. Almost all traditional houses in the region are largely made of deodar wood and one may still find some of the old traditional houses entirely made of wood from ground to the roof, as at Kafaur and Chitkul villages in district Kinnaur. All these wooden dwellings are the rich repositories of the traditional popular woodcarvings.

The British officials introduced hunting and fishing when new generation guns gave sport to hunters with great fire power. Certain forests were reserved for shooting by the hill rulers and British Officers. The forest near Ghanahatti in Dhami State was reserved for the Viceroy of India. A list of animals and birds regarded by local inhabitants as sacred, such as monkeys, apes and peafowl was prohibited (Gazetteer of the Simla District, 1904). After the formation of Himachal Pradesh, many of the rules were replaced by new shooting rules introduced under the Indian Forest Act, 1927 and the Punjab Wild Birds and Animals Protection Act, 1933 to deal with the forest and non-forest areas separately. The protection and preservation of wild life was further strengthened in 1957 when a Wild life Wing was created in the Forest Department

(Himachal Forest Centenary (1861-1961). Shooting was prohibited during the closed season and a breach of rules was heavily fined. In short, forests in upper reaches River Basin had long history of management of forests as they have been shaped by foresters, local people and their livestock for several centuries. The colonial era's major changes were commercial logging, introduction of fruit orchards, and slow expansion subsistence cropping. Undoubtedly, no serious reduction of flora occurred in the colonial century. However, during the phase of post-independence of the country, large scale fellings and enhanced human disturbances greatly influenced the condition of forests in the upper River Basin as the independent governments at the Centre/ State made a commitment to rapid economic and social development.

In Himachal Pradesh, the first priority was transport infrastructure to overcome the severe inaccessibility of the mountains (Verma and Pratap, 1992). Once the transport infrastructure was improved, the government pursued its second major priority of expansion of agriculture market. The area under fruit crops marked exponential rise from 1948 to 1988 while apple crop was 80% contributor (Verma and Pratap, 1992). Subsequently, the new trend of growing vegetables for urban markets within the State, and farther away in the cities of Punjab and Haryana, and even Delhi commenced. The new tourisms activities boomed in the 1970s also provided markets for fruits and vegetables. The environmental impact of the new horticulture was also complex. Heavy logging of the high forests became a major extension of the ecological impact of the market economy, throughout the upper Basin. Finally, from the 1960s onwards a major cropping change evolved, from the variety of traditional grains to mostly rice, wheat and maize. Yet another pressure on forests was built-up in the form of collection of Non Timber Forest Products (NTFPs), particularly medicinal and aromatic herbs and morel mushrooms. This was a different management challenge after the issue of grazing rights, for administrators as well as local people. Since the early forest settlements placed no restrictions on anyone's collecting the herbs, except in the protected areas. Until the 1960s, there was no significant commercial market for the major herbs, and no one anticipated that this would become a much larger organized market In view of the above stated long history of management of forests, other natural ecosystems and in the process of rapid development, particularly after the country's independence and State's reorganization, the rural population in the hills has evidently left its local institutions far too weak and fragmented.

The situation of forests in Punjab, in the past and in the present time was quite different in comparison to upper Sutlej River Basin. The State had a small extent of forests as it experiences the arid to semiarid climatic conditions and natural forests were sparsely distributed. All through, the forests in human dominated landscapes experienced traditional resource dependence and they were heavily exploited. The post-independence of the country, the thrust of the Central and State Governments was on expansion of agriculture, construction of reservoirs/ barrages/ canals for irrigation and establishment of HEPs for power generation, and grow more food programme under the ambitious programme of the Green Revolution. These activities not only neglected the scant and remnant forests in the State, but also the forestry sector including

wildlife. Further, grasslands and wetlands were reclaimed for expansion of agriculture. Moreover, pollutants from agriculture and associated industries severely impacted the quality of water in all major rivers of the State and their tributaries. In the process, there was heavy toll of forests and wildlife including aquatic fauna. In 1960s and on other occasions, the GoI launched different schemes of plantation/ afforestation including the Social Forestry Programme to meet the growing demands of fuel wood, fodder, etc. and also to expand the forest covers in the hills/ plains. However, most of these efforts were project/ scheme based or *adhoc* in nature that too with mixed success and definitely not adequate to compensate what was lost by way of clear fellings and other allied activities of forestry. Cumulatively, largescale deforestation and other human disturbances (i.e., collection of fuel wood and fodder, livestock grazing, forest fires, and harvest of NTFPs, etc.) impacted the River environment downstream.

2.5.2 Land and People

Himachal Pradesh and Punjab along the course of Sutlej River owing to enormous diversity of natural resources (i.e., forests, grasslands, alpine pastures and wetlands including rivers) and wide range of opportunities in different sectors *viz*., agriculture, horticulture, medicinal and aromatic plants (MAPs), fisheries, food processing, pilgrimage, road network and highways, mining sand/ boulder, hydropower projects, industries, nature adventure and tourism always worked as magnetic force to attract people from far flung areas. Thus, both States concerned with the Sutlej Riverscape are populous. Details on land and land use in two States and their people are provided below.

a) Land and Land Use

Collectively, two States along the course of Sutlej River cover 24,110 km^2 areas and represent 4.39% geographical area of the country (Table 2.30). By and large, Himachal Pradesh and Punjab are near equal in their respective geographical area. However, one State is totally mountainous with high hills while the other State is in plains. Hence, both States are contrast in terms of topography and altitudinal gradient. Himachal Pradesh represents 1.7% geographical area of the country while Punjab represents only 1.53% area of the country. In terms of land use categories *viz*., forests, net area sown, permanent pastures and other grazing lands, and area not available for cultivation, both States exhibit contrasting situation. The extent of forest as land use category in Himachal Pradesh represented 24.21% area while in Punjab it was just 5.86%. Punjab is largely agriculture dominated State having the higher value of net area sown of 82.83% of the geographical extent while net area sown in Himachal Pradesh accounted 11.9%. The extent of permanent pastures and other grazing lands was much higher (32.89%) than Punjab (0.14%). A larger proportion of geographical extent (24.82%) in Himachal Pradesh was not available for cultivation while the value of land use category on area not available for cultivation was 10.25%. Thus, it is clearly evident that the upper Sutlej River Basin is rich in forests and permanent pastures and other grazing lands while the lower Sutlej River Basin in alluvial plains distinctly had relatively meager area of these two land use categories.

Table 2. 16 Land Use Pattern in Himachal Pradesh and Punjab

Land Use					
Sr.No.	**Land Use**	**Himachal Pradesh**		**Punjab**	
		Area (km^2)	**Per cent Geographical Area of**	**Area (km^2)**	**Per cent Geographical Area of Country/ State**
1	Total Geographical Area	55,673	1.7	50,360	1.53
2	Reporting Area for Land Utilization	45,490	100.00	50,330	100.00
3	Forests	11,010	24.21	2,950	5.86
4	Not Available for Cultivation	11,290	24.82	5,160	10.25
5	Permanent Pastures and other Grazing Lands	14,960	32.89	70	0.14
6	Land Under Miscellaneous Tree Crops and Groves	650	1.43	50	0.10
7	Culturable Wasteland	1,380	3.03	30	0.06
8	Fallow Lands other than Current	150	0.33	0	0.00
9	Current Fallows	640	1.41	370	0.74
10	Net Area Sown	5,410	11.90	41,690	82.83

(Source: Statistical Abstract of Himachal Pradesh and Punjab, 2018-19)

2.5.3 Human Settlement and Demography

As per the Census 2011, human population of Himachal Pradesh and Punjab (Table 2.31) was 34.60 million, representing 7.08% of the country's population. Punjab had a population of 27.74 million while Himachal Pradesh had population 6.86 million (Table 2.31). While Himachal Pradesh and Punjab were near equal in the geographical extent, the human population in Punjab was nearly four times higher. In case of Himachal Pradesh, the bulk population was rural contributing nearly 90% of the total population while in case of Punjab, 62.5% human population was rural and 38.1% urban. The proportions of urban and rural populations in case of Punjab were closer to the average of all India. The values of average population density are 123 persons/ km^2 for Himachal Pradesh and 551 persons/ km^2in Punjab. The average population density in Himachal Pradesh was nearly one third of the average population density of the country. The population density of Punjab was more than four times than the Himachal Pradesh. The decadal growth (2001-2011) of human population in Himachal Pradesh and Punjab was 12.94% and 13.89%, respectively against the value of 17.69% registered for the entire country. The livestock population in Himachal Pradesh and Punjab as per the 19th Livestock Census of 2012 ranged from 4.84 million to 8.11 million, respectively against the country's total livestock population of 512 million. Owing to the mountainous State, Himachal Pradesh having 11 hill districts out of total 12 districts and two tribal districts. Punjab neither had hill district nor the tribal district (Census, 2011). Altogether, Punjab has 20 districts as per the Census of 2011 against 640 districts in the country.

Table 2. 17 Comparison of Demography of Himachal Pradesh and Punjab in the Sutlej Riverscape

Sr. No.	Variable	All India	Himachal Pradesh	Punjab
1	Geographical Area (km^2)	32,87,263	55,673	50,362
2	Population (As per 2011 Census million)	1,210.8	6.86	27.74
3	Urban (million)	377.11 (31.1%)	0.68 (9.91%)	10.39 (38.1%)
4	Rural (million)	830 (68.58%)	6.17 (89.9%)	17.34 (62.5%)
5	Average Population Density (per km^2)	382	123	551
6	Livestock Population (As per 19 Livestock Census in 2012; Values in million)	512.0	4.84	8.11
7	No. of Districts (As per Census 2011)	640	12	22
8	No. of Hill Districts		11	
9	No. of Tribal Districts		2	
10	Sex Ratio	940	972	895
11	Literacy (%)	74.04	82.80	75.8
12	Poverty Line (Per capita/ month as per 201112) Rural	972	708	830
13	Poverty Line (Per capita/ month as per 201112) Urban	1,457	888.3	960.8

(Source: Statistical Abstract of Himachal Pradesh and Punjab, 2018-19)

(a) Sex Ratio, Literacy Rate and Poverty Line: The values of sex ratio in two States ranged from 895 in Punjab to 972 in Himachal Pradesh against the sex ratio of 940 in the country indicating that the proportion of female population in Punjab was lower than the all India as well as Himachal Pradesh. Himachal Pradesh has higher rate of literacy, being 82.80% while Punjab had lower literacy rate of 75.8%. Both States had higher literacy rate than the country's average value of literacy. As per the estimates of the poverty line for 2011-12, the monthly per capita consumption expenditure in India for rural areas was of Rs. 972 while the monthly per capita expenditure in urban areas was Rs. 1,407. Against these values of poverty line, the values of poverty line in Himachal Pradesh were lower than Punjab. The monthly per capita expenditure in rural areas of Punjab was Rs. 830 which was higher against the country's average value of rural poverty line i.e., Rs. 816 per capita monthly expenditure. The value of estimated poverty line in urban areas of Himachal Pradesh was Rs. 883.30 monthly per capita expenditure.

(b) Culture and Religion: Culture refers to the cumulative deposit of knowledge, traditions, beliefs, values, experience, attitudes, meanings, hierarchies, religion, notion of time, spatial relations, concepts of the universe, and material objects and possessions acquired by the group of people in the course of generations through individual and group striving (Porter and Samovar, 1994; Kumar, 2017). Culture of a place is exhibited by different aspects *viz*., people and lifestyle, language, religion, art and craft, music and dance, fairs and festivals, and cuisines. The Himachal Pradesh and Punjab exhibit two distinct, rich, unique and vibrant cultures along the course of Sutlej River.

Himachal Pradesh, a mountainous Himalayan State known as *Dev Bhumi* until recent past was one of the few Indian States that had remained largely untouched by external customs and exposures, mainly owing to its difficult terrain. However, with the technological advancements, efficient road transport and communication systems, and linkages with markets in far-flung areas, the State has changed rapidly. The State has three well defined ecocultural zones *viz*., (a) The tribal belt dominated by Buddhism and Tibeto-Burmes language of the Himalayan group, (b) The middle belt adjoining the tribal areas, inhabited by communities following terrace cultivation, horticulture, and some elements of pastoralism, and (c) The lower and sub-montane areas inhabited by communities practicing settled cultivation and animal husbandry. The inhabitants of the latter two belts are mainly *Pahari* language speakers whereas in the first belt, only the *Gaddis, Pangwalas, Gujjars*, and some minor communities like *Swangla* speak *Pahari* language while rest speak a language akin to the Himalayan group of Tibeto-Burmes. Although the population is predominantly Hindu, the State also has small populations of Christians, Muslims, Sikhs and Buddhists. The State is a multi-religional, multilingual, and multicultural due to migrations and settlements.

Earlier, as the Frazer (1820) was the first to admiringly write about Kinnaurese, after that Sanskritayan (1956) discussed about people of the area and gave an account of inhabitants in his travelogue. Negi (1972) provided tribe-wise profile of Kinnaureses people while Kapoor (1972) discussed in detail about the sociocultural and religious attributes of them. First household level analysis of socioeconomic condition of Kinnaur was done by the Tribal Development Department (1980), Shimla. The analysis has been done for agriculture and allied activities, artisans, hamlets and road transport as well as for communication. Nag (1981) in his study on racial composition of the tribes has given religious account. He classified Kinnaur into three distinct religious regions; (a) Religions with the dominance of Indo-Aryan stocks have Hinduism, (b) People of Tibetan blood in upper area practice Buddhism, and (c) Central Kinnaur is influenced by both the religions. Singh (1977), in his short article has given an informative account of MAPs of Kinnaur and its potentials. He highlights that apart from being suitable for horticulture, the agro-climatic conditions of the district are highly suitable for cash crops and offseason vegetables. He also brings out importance of *Chilgoza* pine, a wild tree whose nuts have value as cash crop. This has the advantage of not competing for land with other crops.

Being a Himalayan mountainous State and in general characterized by inaccessibility, fragility, marginality and diversity in a vast geographical extent and highly variable geo-climatic situation coupled with wide array of environmental risks, people of the State have adopted unique ways of living in harmony with nature's gift of natural resources. The culture of Himachal Pradesh has remained traditional and its ethnicity and originality have been retained to a great extent. The beauty of culture in the State lies in its simplicity. Culture is not only exuberant in the physical attires of the *Himachalis*, but also in their festival celebrations, musical melodies, rhythmic dance and simple lifestyle (Kumari and Punam, 2016).

Large proportion of the population does not belong to the aboriginal stock. Occasional waves of migration of considerable magnitude have taken place at different times. New settlers matrimonial alignments with the natives in the beginning of 9th century and continued for centuries (Nangia *et al.*, 1999). Institution of *Devta* (God) is the major religious establishment and generally each village has a *Devta* while some *Devtas* have jurisdiction over several villages. People go to neighboring *Devta* at every occasion, at the beginning or closer of sowing, the harvesting time or any other auspicious occasion such as festival, marriage, birth and construction, etc. Numerous fairs and festivals exhibit their collective expression of the traditional and cultural values. Society is very closely knitted and, on such occasions, all strata of society be it old and young, man and woman, and boys and girls in large number. They wear colourful dresses, caps and costumes. The portraits of *devtas* are made of wood and metal and are kept in village temple. However, they are frequently brought out from temple at the time of festivals and other public ceremonies. People seek guidance and blessing of *Devta* on all occasions of important events in their life. Himachal Pradesh has been recognized a land of dance and music. The dance and music of the State is mainly religion oriented where gods are invoked by singing and dancing during festivals. According to the belief, dancing when done with body and soul gets a person connected with the almighty. The local fairs and festivals have their unique attraction (Kumari and Punam, 2016, Nangia *et al.*, 1999). The State is well known for its various handicrafts *viz*., carpets, shawls, caps, paintings, woodwork, metal wear, leather works, etc. and worth appreciating. Pashmina shawl is one of the products in high demand. The rich culture and tradition of the State are reflected in its cuisine that encompasses a wide range of delicacies with a plethora of aroma and taste. However, traditional feast known as *Dham* is being prepared in *Himachali* style and served on special occasions such as marriages, local festivals and other important events. Dham forms an integral part of *Himachali* traditions (Tanwar *et al.*, 2018). The State harbours numerous historical and old temples.

Punjab has a cultural and ethnic background going back to the Indus Valley Civilization, which existed from 2,800-1,800 B.C., and was remarkable for its ordered cities and advance sanitation, excellent roads and uniquely structured society. Thus, Punjab has one of the oldest and richest cultures of the world. Its diversity and uniqueness is evident in the Punjabi poetry, philosophy, spirituality, education, artistry, music, cuisine, science, technology, military warfare, architecture, traditions, values and history.

The culture of Punjab is unmatched and has its own unique fragrance and it is a land of dynamic people, portrays vitality and liveliness, which is amply reflected in the traditional culture. People of Punjab exhibit compassion and high spiritedness in their lifestyle and Punjabis are known for their strong determination. There is artistry in every aspect of life in Punjab and an aura of embellishment dominates the place. The century-old culture in Punjab is renowned for its tolerance, progressiveness and logical approach to life as well. The culture of Punjab has undergone significant phases of evolution. Different phases can be broadly classified into three categories. The ‘Ancient Punjab’ had a rich baked-brick urban architecture. During the ‘Middle

Age', the State experienced several foreign invasions. Greek, Persian, Mongol and Afghan invasions had significant influence on the Cultural Landscape of the State. During this phase, the birth and growth of Sikhism occurred, giving a new dimension to the Punjabi culture. The rich and fertile land of the Punjab was meeting ground of different people and races.

Its people descended from various stocks and consist of heterogeneous racial elements. Today, people from Punjab (prominently Sikhs) are distributed all over the world and as a result the traditional Punjabi culture has been expanded and strengthened in the western world as well. Punjab is inhabited by people of diverse sociocultural dominations. They are basically of Indo-Aryan ethnic origin and belong to South Asia. Numerous invaders including British have invaded, settled and ruled the region, giving the State a unique culture. Punjab, being a multi religional State has prominence of Sikhism and Hinduism religions while other religions like Islam, Christianity, Jainism and Buddhism also flourish, though relatively low in proportion. Punjabis celebrate several religious and seasonal festivals *viz*., Dussehra, Diwali, Lohri, Holi, Baisakhi, and several others. In addition, there are numerous anniversary celebrations as well in honor of 10 religious Gurus or leaders of Sikhism and various saints. Punjab is a land of legends, myths, folklore, and the Sufi philosophical and material culture which are carried forth by its continuing relevance to the present communities. Sikh identity arouses an image of potentially powerful, economic, political and cultural force. The Punjabi culture is renowned for variety of reasons as it reflects exclusiveness and liveliness of the people. The scope, history, sophistication and complexity of the culture are vast. Undoubtedly, the culture of Punjab is one of the distinctive cultures found anywhere around the globe. The people of the State are friendly, hospitable, hardworking and relish living.

History has not been kind to the people of Punjab. The brutal division of the State during partition led to both carnage and to one of the biggest mass population movements during the 20^{th}century. Amidst the riots, butchery and devastation, Punjabis of all religious persuasions suddenly found that they had to create new identities. Punjab has seen the extreme transformation due to shattering partition which ensued in many cultured changes.

People are regarded as born hosts and popular for having palate for eating. The philosophy of life for most of the Punjabis is to eat, drink and make merry. Punjab is known for being one of the greatest producer of rich and tasty food and the State bequeath the *Dhabha* culture, a way side eating joint (Kaur, 2013). The folk heritage of the Punjab reflects its thousand years of history. The State has a very rich tradition of romantic dances, particularly the folk once. The vitality of people is vigorously displayed in their folk dances. Dances are typically performed at the time of celebrations such as crop harvest (Baisakhi), weddings, festivals, fairs, etc. The State had a rich tradition of arts and crafts and the richness of the land is reflected in its handicraft. The fascinating art works include mud work (i.e., mud plaster on house walls in rural areas), metal work, phulkari – an intricate needle and embroidery work, basketry, cotton flat woven rugs (*duries*), wood work, weaving, etc. and they provide enormous opportunities for varied markets

(Kaur, 2013). Punjab is one of the prime destinations for pilgrimage in India as the State has a large number of holy shrines of equal religious significance. Apart from the world's largest Gurdwara – The Golden Temple and predominance of Sikh religious places, one can also visit a host of mosque dating back to the mughal times, temples and churches. In addition, the State is famous for the Anandpur City, a Riverfront town on the Bank of Sutlej River as it is famous for Gurdwara Anandpur Sahib and Hola Mohala Festival. Every year, millions of Sikh followers visit here during this festival and Sikh worrier show their battle activities in the festival. Another, two famous places around Sutlej Riverscape are Kiratpur Canal and Patalpuri Gurdwara where Sikh peoples criminated the ashes.

(c) People, Occupation and Resource Dependence: Himachal Pradesh is the only State in the country whose 89.96% population lives in rural areas (Census, 2011). Traditionally, forests and pastures formed an important components of the village economy's resource base, boundaries between villages evolved to demarcate their access. Economic activities of the people living in rural areas can be divided into two broad categories i.e., subsistence and commercial. Prominent activities in the former category are agriculture and pastoralism. The major activities falling in the second category includes extraction of MAPs and collection of mushrooms besides involvement of local people in wide range of occupations *viz*., trade and commerce, construction activities, transportation, small businesses shops, professionals like carpenter, tailor, etc. and a small proportion of people in the service class. Agriculture is the main occupation of the people of Himachal Pradesh, and has an important place in the economy of the State. Dependency on the agriculture and horticulture is imminent as it provides direct employment to about 62% of total workers of the State. Agriculture happens to be the premier source of State income. About 10% of the total State income comes from the agriculture and its allied sectors. The average land holding size is about one ha. According to the Agricultural Census (2010-11), 87.95% of the total holdings were of small and marginal farmers while 11.71% of holdings were owned by semi-medium and medium farmers and only 0.3% holdings were owned by large farmers. In comparison to the mountainous State, the economy of Punjab was characterized by a productive, increasingly commercial agriculture, a diversity of small and medium scale industries, and the highest per capita income in the nation. Wheat and cotton are the principal crops. Livestock and poultry are also raised in large numbers. Industries with the largest number of workers include cotton, woolen and silk textiles, metal products and machinery, food and beverages, and transport equipment and parts. Other industries include hosiery, bicycles sewing machines and sporting goods.

Unlike Punjab, wherein the people's primary dependence for subsistence and commercial activities is on agriculture, the dependence of people in Himachal Pradesh, particularly, Middle Himalaya and the Greater Himalaya continue to be on diverse forests along the altitudinal gradient for a variety of purposes including timber, fuelwood, fodder, livestock grazing, collection of MAPs, etc. In fact, forests and livestock occupations provide much desired

insurance against natural calamities and occasional failures of agriculture/ horticulture crops due to erratic patterns of climate.



Plate 2. 19 Anthropogenic Pressure on Forests

(d) Livestock: Himachal Pradesh and Punjab along the Sutlej River account for nearly 2.52% country's livestock. The livestock sector in the State of Himachal Pradesh contributes around 28 to 30% of total agricultural produce. The sector has registered a high growth in gross value distribution as compared to the overall agriculture sector (Kumar *et al.*, 2012). The livestock population, though almost static, has witnessed increase in the population of buffalo and goats over time. According to 2012 livestock Census, the State had altogether 4.48 million livestock including 2.14 million cattle, 0.71 million buffalo, 0.80 million sheep, 1.11 million goats, 0.01million horses and ponies, 0.02 million mules, and 2,921 yak, and other animals. Sheep rearing is one of the main occupations of the people in Himachal Pradesh. Rampur Bushari and Gaddi breeds are famous for indigenous carpet wool production. 37% of agricultural families rear sheep. 38% sheep in the State are crossbred (GoHP, 2017). Average decline in sheep population over last 15 years is to the extent of 1.67% per year. Migratory system is much prevalent as greater than 90% of State sheep and around 70% goat population is reared under this system. Several tribal communities are involved in migratory sheep husbandry (Sankhyan and Thakur, 2019). The majority of flocks now have goats and sheep in equal proportion but two to three decades earlier sheep use to be in majority. The migratory herds have been classified under

three categories: (a) Small flocks consisting 100 to 200 animals, (b) Medium flocks having 200-350 animals, and (c) The large flocks with >350 animals. Migratory herds traverse through different forests along the altitudinal gradient so as to optimally utilize alpine pastures for grazing during summer. Sankhyan and Thakur (2019) concluded that the migratory system is the cornerstone of sheep farming in the State that is being practiced for long time and will remain as an integral part of the agro-economy of hill farming system. Nearly, 70% sheep population is migratory. In spite of various constraints, the migratory system is still sustainable owing to the fact that it is a very low input system which effectively counter balances its constraints and makes it a profitable venture. Sheep in the State produces about 3.08 million kg of wool, contributing about 8.2% of the country's wool production (Siril *et al.*, 2014).

As per the Livestock Census 2012, Punjab had 8.1 million total livestock including 2.42 million cattle, 5.16 million buffalo, 0.12 million sheep, 0.32 million goat and other animals. Livestock sector plays an important role in Punjab agriculture as evident from its contribution to the total agricultural GDP recorded at 36% during 2016-17 (Singh and Kaur, 2018). According to Singh and Kumar (2018) the growth rate of Livestock Sector in last five year period has been observed to be 5.05% as compared to only 0.46% in crop sector. The State is producing 11.28 MT of milk production of the country. The Punjab is leading milk producing State in the country. Tanwar and Verma (2016) assessed feed and fodder availability in Punjab *vis-à-vis* livestock population and reported the total annual availability of feed and fodder in the State to the extent of 24.24 MT against the requirement of 14.94 MT, thereby excess of around 62.18% per annum. They estimated availability of green fodder to the extent 3.31 MT on dry matter basis. They suggested that excess fodder may be transported to the deficit area of the State as well as in other parts of the country by forming feed blocks.



Plate 2. 20 Livestock Pressure on Forest

(e) Agriculture and Allied Activities: Agriculture is the largest occupation and source of livelihood to most people in Himachal Pradesh and Punjab. In Himachal Pradesh, agriculture is the source of livelihood for nearly 67% of the total population and cultivation is mainly done on terraces as per the topography of the State. The cultivation in hills is subjected to soil erosion since crop cultivation is usually on 5% to over 30% slopes and nearly, 81% agriculture is rainfed. The size of land holdings up to 1 ha covers 61.5% farming community (GoHP, 2012). The small and marginal farmers put together account for 82.1% and cover an area of 43%. The medium farmers with holdings ranging from 2 ha to 10 ha cover an area of 47.2%. The agriculture workforce is nearly 35% of total population of which 63.25% are cultivators. The ratio of agriculture laborer's to total workers forms only 2.66%. Agriculture in the State though made significant progress yet faces enormous challenges. Major challenges include: (a) Land fragmentation and small size of land holdings leading to un-remunerative agriculture; (b) Hill agriculture is seriously constrained unless it is backed up by a scientifically designed strategic policy framework; (c) The society is undergoing changes in economic transitional phase as the joint family systems are becoming nuclear families and consequently working hands in agriculture are severely reduced; and (d) Vagaries of weather.

With the provision of irrigation in some of the districts, there is a clear-cut shift in the cropping pattern. Major shift is from cereal crops to vegetable crops. Multiple cropping has also been introduced in irrigated area. The replacing crops are generally cash crops and have become a predominant factor in small farm management to earn cash in order to meet their input requirements and needs of the family money. However, this trend in certain situation is detrimental to meet the enhanced demands for cereal crops. Increasingly, there has been a heavy reliance on higher energy inputs in the form of tractors, diesel and electric pump sets and threshers. The State recorded the substantial increase nearly by four times in the number of tractors from 1987 to 1997. There has been a widespread use of various chemicals in agriculture including fertilizers (NPK), pesticides, fungicides, herbicides and weedicides. The use of fertilizers has substantially increased from 34,852 MT in 1997-98 to 46,808 MT in 2003-04. In comparison to fertilizers, the use of Farm Yard Manure has been progressively decreasing as nuclear families are hardly engaged in rearing cattle or domestic animals.

There has been a sharp rise in the use of pesticides, particularly in vegetable crops. In recent times, various agriculture and horticulture crops face a serious threat from proliferation of invasive alien species and also by crop depredation due to increasing populations of wild pig and monkeys. In addition, the agriculture faces problems of market access, and inadequacy of soil and water conservation programmes. The hill agriculture has undergone a big transformation in past five decades or so and conspicuous changes have occurred in cropping patterns, fruit orchards have replaced traditional cereal farming and cultivation of cash crops gained lot of significance (GoHP, 2012). The bullock cultivation is replaced by the use of tractors for cultivation. Use of fertilizers and other chemicals has gone very high. Several old crops and traditional/ local varieties have been replaced. New crops are being adopted to diversify crop cultivation. Mixed cropping is fading away. Farmers have become conscious about using the available water resources of which earlier they were ignorant. Definitely, there has been evident erosion in agrobiodiversity. The State has been bestowed with conducive environment for cultivation of large variety of horticulture crops *viz*., fruits, vegetables, ornamental plants and herbs in prevailing wide range of agro-climatic conditions within the State. Presently, more than 30 fruit species are being grown. Prominent once are apple, apricot, peach, pear, plum, almond, walnut, pecannut, mandarin, sweet orange, mango, guava, papaya, litchi, kiwi, olive, and strawberry. Various fruit crops grown during 2017-18 in the State covered 2,30,852 ha, out of this apple with maximum extent of 1,12,634 ha was distinctly prominent and provided total production of 4,46,574 t (GoHP, 2018). Kumarsain, Kinnaur and Spiti are one of the major producers of Apple crop.

Like Himachal Pradesh, the State of Punjab has also made unparalleled progress in the agriculture since the advent of green revolution in the mid60s with traditional agriculture progressively giving way to modern and commercial agriculture. Presently, 82% of the geographical area of the State is under cultivation and cropping intensity is around 191% with

over 99% of the cultivable area with under assured irrigation. The State has 41,370 km^2 areas as net sown in 2015-16. The production food grain in the State increased from 3.16 MT in 1960-61 to 28.39 MT in 2015-16 as a result of introduction of High Yielding Varieties and new technologies to the hardworking and receptive farmers with the support of the government policies. The State known as 'Granary of India' has played key role in transforming India from grain importing nation to self-reliant and export surplus nation. The State has highest yield of rice, being 4.41t/ha while the yield in case of wheat has been 5.04 t/ha. The State contributed 46.4% of wheat and 29% of rice to central pool during the year 2016-17. The stunning rise of food grain production from 11.92 MT in 1980-81 to 29.44 MT in 2013-14 was attributed to intensive use of farm chemicals. The consumption of chemical fertilizers (NPK) was increased from 0.76 MT to 1.71 MT in 2013-14. Enhanced use of nitrogenous fertilizers and relative under use of other fertilizers and micronutrients has led to imbalance in micronutrients in soils of the State. It is also worth mentioning here that 85% of water consumption in the State is accounted by the agriculture sector. Canals provide about 27% irrigation while tubewells contribute 73% irrigation. The number of tubewells has increased considerably in past decades. The groundwater is being over exploited to meet the increasing demand of water for irrigation. The present groundwater development in the State is 170% with groundwater in 80% geographical area of the State is over exploited. Farm mechanization has played a key role to bring a significant improvement in agriculture productivity in the State. Against the National average of one tractor per 62 ha net cultivated area in the country, Punjab has one tractor for every 8.17 ha of net cultivated land in the State. Farm mechanization in the State has reached at a saturation point. Punjab produced nearly 20 MT of rice straw and 17 MT of wheat straw annually and farmers practice open field burning of straw after combine harvesting. This straw burning has been recognized as a major pollutant of air impacting the neighboring regions. Undoubtedly, the State has immensely helped the country in bringing the self-reliance in food grain production and made significant contribution to the Country's/ State's economy. However, from the perspective of rivers, excessive groundwater abstraction and decline of water quality due to chemical pollutants are important concerns.

(f) Growing Tourism and Pressure on Forests: Himachal Pradesh and Punjab along the course of Sutlej River are important destinations for international, national and local tourists. High Himalayan Mountains, snow covered peaks, lush green forests, beautiful valleys, gushing streams, mighty rivers, serene high altitude wetlands, spectacular wildlife, historical places, ancient temples, prominent religious and cultural sites, famous hill stations and enormous opportunities for adventure, nature, wildlife, and religious tourism collectively attracts visitors from far flung areas within the country and overseas. Tourism has assumed a phenomenal significance for economic development and employment generation, particularly in remote and backward areas. The environmental and geographic suitability of the Himachal Pradesh for tourism has undoubtedly provided endless opportunities for the development of tourism sector in the region. In Punjab, Amritsar is one of the famous cities, and it is one of the major tourist

attractions in the State. The city is the home of the world famous Golden Temple apart from historic site (Jallianwala Bagh) and most popular place (Wagah Border) on the Indo Pak International border. Himachal Pradesh and Punjab receive a huge number of tourists. While Himachal Pradesh is having high flux mainly in summer season while Amritsar in Punjab gets tourists on the daily basis. Two important Wetlands and Ramsar Sites (i.e., Ropar Lake and Harike Lake) owing to rich diversity of migratory birds and another fauna are important tourist sites in the Sutlej River Basin. Recent rediscovery of Indus River Dolphin will surely add value for visitors coming to Harike and other prominent sites in Punjab. A number of prominent PAs with rich and unique biodiversity also offer vast opportunities for the development of nature and wildlife tourism.

Undoubtedly, growing tourism activities in Himachal Pradesh and Punjab have immensely helped the tourism sector within the country and in these two States by way of providing enormous opportunities for employment and other sundry business for the locals. However, as the vast experience from other tourist destinations in the world illustrates, there have been adverse impact on the environment, particularly Sutlej Rivers and its tributaries and associated wetlands, and the socioeconomics. Pal and Pal (2016) studied tourism and its impact on socioeconomic life, Shimla district and observed that it cannot be advocated that tourism should be stopped but should it be promoted and developed at the cost of socio economic environment. He recognized that tourism in the hill areas is a growing factor in the economy and tourism has become more egalitarian pursuit than what it used to be in the previous decades. According to them, unplanned, unchecked and mass tourism exerts a profound influence on the environment and ecology. Thus, recommended that plans for the development of tourism be prepared on sound ecological, environmental and socio economic considerations (Pal and Pal, 2016). Chadha and Choudhari (2016) have studied the nature, problems and prospects of rural tourism in Punjab and recommended to develop an effective tourism promotion strategy incorporating opportunities for highlighting State's art and craft, cuisines, folk items and integration of excursion outings with the aim to promote rural tourism alongside professionally managed Harke and Kanjli Wetlands.

(g) Other Activities: Himachal Pradesh and Punjab within the Sutlej River Basin have immense potential of hydropower generation. Accordingly, in last six decades or so a large number of major hydropower projects have been either commissioned or under execution or being investigated besides the establishment of small/ mini/micro hydel projects in Himachal Pradesh and Punjab. Indeed, Himachal Pradesh and Punjab were pioneers in the country in implementing ambitious programmes on interlinking prominent rivers (i.e., Beas and Sutlej; and Ravi and Beas) so as to safeguard interests of India on account of water sharing under the Indus Water Treaty, 1960, expand irrigation potential in rainfed regions for grow more food programmes and to realize the goals of green revolution, generation of much desired hydropower, and providing water to water thirsty regions in the desert State of Rajasthan, etc. On one hand, the major

programmes on large dams/ barrages and hydropower projects have provided multiple benefits to the respective State and the Nation as a whole. These activities have caused enormous irrecoverable environmental damages. Himachal Pradesh has longer International border with China on its east while the State of Punjab has a long international border on its west with Pakistan. Hence, there is presence and enhanced activities of GREF, BRO, Indian Armed Forces and Para Military Forces (BSF, ITBP and CSIF) due to surveillance and protection of country's International borders with neighboring countries, maintenance of strategic road network and communication in high altitude areas, and protection of important installations (e.g., hydroelectric projects, reservoirs, barrages, etc.). On one hand these activities boost the local economy and provide enormous opportunities for local employment, efficient road communication and other basic amenities, but at the same time these activities pose additional pressure on scant and fast depleting natural resources in the fragile Himalayan region and cold/ hot desert regions. In last three decades or so, there was sudden spurt in activities related to the collection of MAPs and other forest resources for commercial enterprises. The Sutlej River Basin in the mountainous tract of Himachal Pradesh and alluvial plains of Punjab have not only provided forest, agriculture, horticulture, fish, water for irrigation and hydropower resources, but the Sutlej River and other prominent rivers in Himachal Pradesh and Punjab also provide enormous valuable resources *viz.*, sand, boulders, *Bajri*, from the River beds, thus, contribution in a significant way to the construction industry. Traditionally, the Sutlej River and other rivers in Himachal Pradesh were used for transportation of timber logs and wood for railway sleepers, but currently prominent rivers are being used for water sports and recreation.

2.6 Development Programmes, Conservation Issues and Implications

The Himachal Pradesh and Punjab along the Sutlej River right from the ancient times as well as during past two centuries or so have been in the vanguard of all round development, starting with the process of civilization, invasions and wars, migration, settlement, forestry and forest management, agriculture expansion fisheries, creation of dams/ barrages and canals, establishment of hydropower projects, interlinking of rivers, industrialization, pilgrimage and more so the tourism activities in the recent past. Most of these events, developments and activities had undeniable impact on the natural ecosystems in Himachal Pradesh and Punjab. Traditional resource dependence, growing commercial activities and enhanced multifarious demands of human and livestock further exerted enormous pressure on scant natural resources. The Central as well as concerned State Governments and even local village level Institutions/ Communities have undertaken various initiatives to protect and conserve forests, wildlife, wetlands and other freshwater resources including rivers, but the pressure surmounting and there is evident decline in biodiversity and the overall environment.

The forgoing description on the physical, biological and socioeconomic environment in the context of Sutlej River Basin and the Riverscape has attempted to offer an insight on the existing situation of diverse natural ecosystems and associated flora and fauna besides the ecology of Sutlej River and its wider and complex environment. Certainly, the process of human

disturbances and decline in the quantity and quality of natural resources including freshwater have aggravated in several instances to the point of no return. In short, the present chapter on the Sutlej Riverscape and its environment has made an effort to provide an overview on the complex interrelationships of the Sutlej River with its broader environment and surroundings, highlighted important events/activities and their implications alongside narrating the conservation significance and issues those need urgent attention in order to restore/ rejuvenate one of the important rivers i.e., Sutlej so as to bring back its lost glory and conservation values.

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CHAPTER-3

APPROACH AND METHODOLOGIES

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3.1 River Management – Emerging Concept of Planning Areas

River managers face a wide array of challenges in managing rivers as they need to balance a range of competing interests, the complexity and scale of issues, and uncertainty over future conditions. The discipline of 'River Management' has evolved over time from one dimensional responses at addressing a single issue i.e., water quality, to more sophisticate approaches that involve both active management i.e., physically changing the river and landscape and passive management i.e., policy measures to change human behaviour. In the process, various concepts and approaches have emerged and evolved from the perspective of planning, assessment, management, and conservation of river ecosystems. These are river basin, watershed, riverscape, and riverscape management. A river basin is a portion of land drain by a river and its tributaries. A river basin is also known as catchment area, drainage basin, or catchment basin. Generally, river basins are separated by ridges, mountains, and hills. These drainages divide or landforms that divide river basin are called watershed. Watersheds are part of river basin and a river basin may have several smaller sub-watersheds or micro watersheds. The landscape approach to studying and managing river system – the 'Riverscape' approach has become increasingly dominant in recent decades with numerous studies integrating rivers with their landscape context. According to Ward (1998), a riverine landscape indicates a holistic approach linking the rivers and its banks, or its riparian area, within a fluvial system. The foregoing introductory chapter has emphasised the importance of a holistic perspective required for river management, wherein four types of connectivity, various interactions and exchanges all along the river course from origin to mouth occur and they contribute towards ecological processes and in maintenance of ecological integrity and river health. The rapidly evolving concept of riverscape now finds an important place in the growing literature on the river management. The concept of riverscape has been adopted for Forestry Interventions for Rejuvenation of Ganga River (FRI, 2016). The Riverscape approach integrates the broad scale physical, biological and aesthetic nature of river and aims to describe spatio-temporal pattern and processes over a stipulated time.

According to Naiman and Bilby (1998), the process of river or riverscape management can be constructed around four key questions: (a) What is the present condition of river ecosystems, (b) What are the desired ecosystem condition, (c) What is feasible, and (d) How can the desired conditions be achieved? The role of science, both the natural as well as the social sciences in studying river ecosystems and providing technical information is vital for answering the first question. It is essential to understand what elements make the ecosystem and their functional interrelationships. The science based technical information allows informative debate about the ecosystem in question. The second question about desired ecosystem conditions is fundamentally about values. Values derive the way humankind interacts with the environment.

Therefore, the second question highlights the importance of human use and their impact on the river ecosystem. Hence, it is essential to consider humans as an integral part of river ecosystem. The answer to the above second question provides the foundation on which programmes of resource and river management are built. The third question about feasibility implies the existence of limits and constraints. It rests heavily on trade offs among competing interests and values. If society is to adopt the ecosystem paradigm as a basis for management, it will be necessary to accept the notion of limits (Naiman and Bilby, 1998). The final question about how the desired condition can be achieved implies the joining of policies and programmes in a synergy. Policies establish broad social objective while programmes are specific activities undertaken to move toward those objectives. Ecosystems are dynamic and ever changing, and unanticipated changes or uncertainty in the system is inevitable. The successful river management will have strong focus on ends and will continually adapt means to nudge the system towards those ends.

3.1.1 Global Insight on Riparian Corridor

Riparian buffers are a critical component of watershed systems, mainly because they protect the surface and the quality of groundwater-related to human consumption and natural ecosystem functioning. These complex vegetated buffer ecosystems provide food and shelter for a wide variety of plant and animal species, and are vital for reducing and eco-friendly controlling source pollution. During development, the removal of stream side vegetation has led to a reduction in water resources both quality and quantity and a decrease in the number of human consumption, restoration function and industrial utilization (Welsch, 1991).

Due to anthropogenic activities, reactive nitrogen circulating on the Earth increases, creating excess nutrients across the terrestrial aquatic gradient. These excess nutrients have caused worldwide eutrophication; fundamentally affect the functioning of freshwater and marine ecosystems. Riparian zones have been recognized to buffer diffuse nitrate pollution, reducing delivery to aquatic ecosystems, but nutrient removal is not their only function in river systems. Traditionally, Riparian buffers are one of the most commonly applied nutrient management measures. Conventionally, Vegetated Buffer Strips (VBSs) are established without additional management, using natural grass and herb vegetation with the aim to control sediment, particulate, and dissolved forms of P, pesticides, and dissolved N losses to surface waters (Dorioz *et al.,* 2006; Borin *et al.,* 2010; Uusi Kämppä *et al.,* 2012).

In a landscape context, Riparian corridors are analogous to kidneys because they filter surface and subsurface inputs and reduce sediment and contaminant transport (Mitsch and Gosselink, 2015). Analogously to the skin of vertebrate animals, Riparian corridors act as semipermeable membranes that control the exchange of energy and matter between their surrounding environments and protect stream ecosystems from external disturbances. Riparian tree canopy regulates light and associated heat input to the stream, and roots protect river banks from erosion. Riparian vegetation slows flow during floods, causing sedimentation that maintains the floodplain. Riparian zones are recipients of organic matter and nutrients from both stream and

surrounding catchment, and these elements can be repeatedly mineralized, immobilized, or transported within and along Riparian corridors. For instance, nutrient spiraling theory postulated that the interaction of stream water with adjacent Riparian ecosystems can result in major changes in nutrient cycling and retention (Minshall *et al.,* 1983; Naiman and Décamps, 1990; Fisher *et al.,* 1998). Since the 1980s, it has been known that Riparian ecosystems have a large capacity to retain and remove nitrogen originating from upslope, highlighting their potential to regulate the exchange of material between terrestrial and aquatic ecosystems (Lowrance *et al.,* 1984; Peterjohn and Correll, 1984; Jacobs and Gilliam, 1985; Burt *et al.,* 2010). The bidirectional nature of the lateral exchange of material (i.e. from the catchment to the stream and *vice versa*) and their unique ecological and functional characteristics make Riparian corridors quintessential ecotones (Naiman and Décamps, 1990).

a) Issues with Maintaining a Riparian Corridor and Buffer Zone

Both natural and anthropogenic activities can have adverse effect on riparian functions, despite the best efforts to protect them. Past practices may have left areas that cannot provide full riparian functions for several centuries. Even the modern harvest techniques adversely affect the riparian zones. Natural disasters, such as floods or fires, also degrade riparian zones. The situation gets aggravated by various anthropogenic activities which enhance the risk and frequency of these natural disasters. Geomorphic and silvicultural techniques may be valuable in rehabilitating degraded Riparian resources (Gregory and Ashkenas, 1990).

In many cases the Riparian buffer zone approach failed, and the following are the possible causes of failure in the implementation of the buffer zone concept: (a) Social and economic causes social limitations were not adequately examined, Riparian buffer zone intents were not in line with local people's aspirations, difficulties arise from a unenthusiastic implementation of the perception of 'Community', economic assessment fails to integrate environmental ethics into decision making on buffer zone establishment; (b) Ecological causes Local environmental surroundings were not sufficiently taken into account, soil and climatic conditions were not taken into account, the role of the Riparian buffer zone in relation to particular species was not taken, the objectives of nature management were often inconsistent with development objectives; (c) Institutional causes Lack of harmony on objectives, location, shape and legalized uses, emphasis is on environmental protection while community settlement come second, lack of legal authority to establish or manage riparian zones; and (d) Other causes Buffer zones were not well distinct, local awareness was not adequately used, worries regarding sustainability of resource utilization (Ebregt and Greve, 2000). Therefore, the above mentioned possible causes of failure in maintaining Riparian buffer zone approach needs to be carefully considered while implementing buffer zone concept.

b) River Ecology Concepts and the Riparian Buffer

Although the principal objective of a Riparian buffer may appear simple enough so as to protect the aquatic zone from disturbance by forest operations or any other land use on the adjacent land,

it is important to understand the deeper logic and science behind the planning for such vegetation cover and plantations. In several instances, developing a Riparian corridor may actually not be a natural aspect of the ecological system at all, and it must be clearly seen as a management initiative which is planned for the protection and restoration of river water flow and quality. It is essential to appreciate the relevance of Riparian buffer from the perspective of various basic concepts of River ecology *viz.*, the River Continuum Concept, Nutrient Spiralling Concept, etc.

3.1.2 Rationale for Selection of Reasonable River Forest Buffer or Riparian Corridor

An appraisal of the exhaustive literature available on the theme of Riparian corridors revealed that Riparian buffers are complex ecosystems that provide habitat and improve the stream communities they shelter. Effective Riparian vegetative corridor is vital for water flow, quality and river health. It is also evident that not only the natural Riparian buffers have been lost in most places, particularly in human dominated country like India but also the lands surrounding streams and river courses have been drastically altered. The review of literature on the width of riparian corridor or forest buffer along river courses also revealed that there is wide variation in the global opinion on this priority theme as there cannot be 'One size fits all'.

The situation of major Indian rivers, particularly the Himalayan rivers *viz.*, the Indus, Ganga and



Plate 3. 1 Landslide in Sutlej River

Brahmaputra is conspicuously different in magnitude owing to their wider range in altitudinal gradient, steep slopes, and rugged terrain. Himalayan Mountains depict extremely high fragility

due to unstable geological formations, proneness to natural disasters i.e., high seismicity, avalanches, cloudbursts, highly variable tropical monsoonal rainfall patterns. Due to these factors it causes high sedimentation, landslides and floods, high biotic pressure (i.e., livestock grazing, extensive road network, wide spread densely populated habitations townships, sequential multipurpose Hydro-electric Projects) all along the river course.

The width of the Himalayan Rivers in high flood levels ranges from as low as 1 km to as high as to several kilometres. These rivers after descending the mountainous tract or after entering in the plains are highly braided and channels often change their course, resulting into creation of large number of river islands due to high siltation and enormous flow of sediments. In recent decades, the intensity of landslides and erodability in high altitude Himalayan Mountains has increased several folds owing to various natural factors and human disturbances. Further, most stretches of Himalayan rivers from their origin to confluence with other rivers or mouth are overburdened by growing townships and large cities and in most instances either devoid of natural vegetation/ forests in proximity to highly fluctuating river banks or even well-defined Riverine corridors. Moreover, most stretches of rivers in high altitude areas or in the plains are bounded by extensive orchards or agricultural lands. The urbanization along the major rivers and their tributaries has created concrete jungles in the immediate vicinity of river banks, damaging the aesthetics, natural flow regimes, enhanced localized flooding problems and direct influence on water quality due to sewage and waste disposal into the river.

The pilot exercise on the preparation of DPR for forestry interventions in the context of Ganga River based on an extensive consultative process adopted the Riverscape approach for proposed inputs. The consultative process was able to identify the critical requirements to treat the natural, Agriculture and Urban Landscapes within the defined width of the delineated Riverscape (5 km – main stem and 2 km – tributaries) on either side of the riverbank from the points of high flood levels of recent time. The rationale of 5 km and 2 km width/ buffer was applied on the main river once it has entered into the plains. However, in the case of high altitude areas of Himalayan Mountainous State, the whole catchment formed the part of the Riverscape for planning, assessment, and Proposed Forestry Interventions (FRI, 2016). Therefore, in the present DPR whole drainage area has been selected as riverscape or riverine buffer. Especially all the protected areas in the river basin will be included as riverine buffer or riparian corridor and further improve accordingly.

3.2 Identification of Knowledge Gaps

The Sutlej River flows majorly through the state of Himachal and Punjab is still facing challenges of natural (i.e., Climate change, topography, flood, landslides, silt & muck, exotic species, forest fire, etc.) and anthropogenic (construction of dams, diversion of water, drying up of natural resources, over dependency to forest by local communities, mining, declining of ground water table due to commercial exploitation, excessive use of pesticides, industries and households waste to river water, unplanned muck dumping etc.) Although various efforts have

been carried out by different governmental and non-Governmental organizations in the past for restoration and conservation of the Sutlej River, but compared to the existing challenges they seems to be very less and fragmented. The problems of landslides, silt, muck, pollution and poor water quality still exists in the region. Various knowledge gaps related to the problems faced by the Sutlej River basin includes:

a. Developing an understanding of the linkages between forest and creation of additional CO_2 sink and forested vegetation & forestry with river hydrology
b. Ground water depletion and existence of water pollution
c. Encroachment of forest land by local communities and similarly lack of proper implementable policy for excessive mining
d. Lack of holistic approach for river conservation and management
e. Maintainance of environmental flow in the river throughout the year
f. Invasion of Invasive Alien Species (IAS) and lack of cost effective technology for their eradication
g. Forest fire and its influence on ecology and hydrology in Sutlej Basin
h. Silt and Muck and their impact on elevation of river bed and diversion of river flow in flood plains

Planting stocks used in planting programme are not of desired quality in nature, i.e. unknown genetic source coupled with traditional nursery and management practices. Therefore, there is a dire need of integration of modern nursery practices with quality propagules collection and use of bio-fertilizers like mycorrhizae to improve survival rate and growth of the nursery stock.

Besides these, integration of tree crop with shrubs, grasses and medicinal herbs will also improve productivity and usefulness of the forests or watershed areas. These all gaps provides sufficient ground to prepare a detailed DPR for the Sutlej to increase quality forest/tree cover, enhance people livelihoods and restore the Sutlej River and its tributaries through forestry interventions including soil & water conservation treatments.

3.2.1 Planning and Assessment Area – Preparation of DPR on Forestry Interventions

Recognising the significance of holistic and complex nature of a river, the recent focus of river rejuvenation in India is on the Riverscape and the Ecosystem based management approaches. These approaches obviously rely on the expanding literature on successful river conservation efforts and river restoration programmes elsewhere in the world. In the present assignment, the MoEF&CC has sought a DPR on Forestry Interventions for the Sutlej River from HFRI, Shimla. The Sutlej River originates near Mansarowar Lake in Tibet and enters in Himachal Pradesh (India) near Shipki La, traverses through the mountainous tract of Trans Himalaya, Himalaya, Shivalik and finally flows into the plains of Punjab. Hence, the entire river course is along Himachal Pradesh and Punjab. However, the Catchment area of Sutlej River is 0.16% in Haryana, 55.64% in Punjab, 2.43% in Ladakh UT and 41.77% in Himachal Pradesh within the Indian Territory.

For the present assignment, a Riverscape covering an area of 24,110.83 km^2, falling in Himachal Pradesh and Punjab has been selected for the purpose of Proposed Forestry Interventions. The select Riverscape includes the entire catchment of Sutlej River in Himachal Pradesh. Small proportion of catchment areas represented in Ladakh UT has not been considered as a part of the delineated Riverscape in view of the fact that representative catchment area in the south-eastern part of Ladakh UT lies in Trans-Himalaya/Cold Desert which is sparsely populated, largely inaccessible, not much disturbed and hence insignificant opportunity/potential for proposed forestry intervention. Likewise, a small fraction (0.16%) of overall catchment of the Sutlej River lies in Haryana State and there is minimal feasibility of Proposed Forestry Interventions owing to the fact that area in Haryana is contiguous with Himachal Pradesh where in the catchment constitutes nearly 80% basin area of Sutlej River within Indian Territory and included for Proposed Forestry Interventions.

Details of the Riverscape under consideration from the point of view of present DPR are shown in Table. 3.1 and state wise distribution of the Riverscape is presented in Table 3.2

Table 3. 1 Area Coverage under the Sutlej Basin and in the Sutlej Riverscape

S.No	Consideration Unit	Area Covered (km^2)	Coverage area (States)
1.	Sutlej Basin (India)	48,321.62	Himachal Pradesh and Punjab
2.	Sutlej Riverscape	24,110.83	Himachal Pradesh and Punjab

(Source: Micro watershed Atlas of India; SLUSI, 2019)

Table 3. 2 State wise distribution of the Riverscape area of Sutlej River

State	Boundary	State Area (km^2)	Percentage (%)
Himachal Pradesh	Riverscape	20,154.61	41.71
Himachal Pradesh	Catchment beyond Riverscape	27.33	0.06
Ladakh (UT)	Catchment beyond Riverscape	1,172.22	2.43
Punjab	Riverscape	3,956.22	8.19
Punjab	Catchment beyond Riverscape	22,931.23	47.45
Haryana	Catchment beyond Riverscape	80.01	0.16
Catchment Area of Sutlej River		**48,321.62**	**100**

(Source: Micro watershed Atlas of India; SLUSI, 2019)

The state wise details of districts, micro-watersheds, tributaries, major cities and town and the spatial extent incorporated in the Sutlej Riverscape are presented below.

It is joined by various tributaries such as Spiti, Baspa, Ghanvi, Kashang, Kurpan, Nogli, Panwai, Roura, Sorang, Tidong and Throng, etc. Before entering the Punjab plains, it cuts a gorge in Naina Devi Dhar. A big dam across this gorge near Bhakra village has been constructed which has created a huge reservoir called the Gobindsagar in the district of

Bilaspur. The Beas River joins Sutlej River in Firozpur district (Punjab). Evidence suggests that the Indus Valley Civilization also flourished on the banks of Sutlej River. Continuing west southwest, the Sutlej River enters into the Punjab Province of Pakistan. The Sutlej River unites with the Chenab River, forming the Panjnad River, which finally flows into the Indus River. The Indus then flows through a gorge and the plains of Sindh (Pakistan), forming a large delta region, finally lapsing in the Arabian Sea.

State wise details of delineated Riverscape are presented below.

Himachal Pradesh: The Himachal Pradesh, having a geographical area of 55,673 km^2 represents 1.69% geographical area of the country. Out of this, the spatial extent included in the Sutlej Riverscape from the State is 20,154.61 km^2. The select area of the Riverscape falls in nine administrative districts of Himachal Pradesh. These districts are Kinnaur, Lahaul & Spiti, Shimla Solan, Kullu, Mandi, Bilaspur Hamirpur and Una, and form the upper and lower reaches of Sutlej River Basin. Tributaries *viz.* Spiti, Baspa, Ganwai, Kashang, Kurpan, Nogli, Panwai, Rour, Sorang, Tidong and Swan are included in the Riverscape for the purpose of planning, assessment and proposed interventions.

Punjab: The State of Punjab with a geographical area of 50,362 km^2 constitutes 1.53% of the geographical area of the country. Out of this, a small extent of 3,956.22 km^2 has been incorporated as a part of the Sutlej Riverscape. Thus, 15.6% area of the Riverscape lies in the State of Punjab. Out of 20 districts of Punjab, areas of only eight administrative districts fall within the Riverscape. These are Roop Nagar, Nawanshahr, Ludhiana, Jalandhar, Tarn Taran, Amritsar, Moga and Ferozpur.

3.3 Approach – Preparation of DPR on Forestry Interventions

The MoEF&CC and ICFRE have entrusted a major task to the HFRI, Shimla on the preparation of five separate DPRs of five major rivers i.e., Beas, Chenab, Jhelum, Ravi and Sutlej of the Indus River System concurrently during the financial year 2019-20 & 2020-21 and allowed one and half year time for the completion of the assigned task. Hence, the HFRI undertook the entrusted task concurrently on DPRs of five rivers. The task was initiated in April, 2019. The Institute has constituted five independent teams, one for each of the river led by Team Leader and River Coordinator. Each team comprised of a Senior Scientist, Chief Technical Officer, Project Fellows, Project Assistants and Data Entry Operators. The work of these five teams was supervised and steered by Nodal Officer, Project Coordinator and Chief Project Coordinator for the purpose of DPRs. The HFRI also engaged consultants for providing desired resource inputs for the preparation of DPRs. In addition, the Institute had availed technical inputs from concerned experts/ agencies, particularly for the themes *viz*., soil and water conservation, policy and law, Remote Sensing and GIS, and design, development of project Web Portal and potential benefits. The broad approach and the framework first time developed and adopted in the country in the case of DPR specific to the Ganga River (FRI, 2016) was employed for the preparation of five DPRs by HFRI. Accordingly, the approach in the preparatory phase for the present DPR of

the Sutlej River included seven key steps *viz*., (a) Project Initiation Background Analysis/ Contextual Analysis, (b) Analysis of Stakeholders and the Consultative Process, (c) Sutlej Riverscape Situation and Problem Analysis, (d) Development of Web Portal – Collection and Analysis of Primary Field Data, (e) Objective Analysis and Strategic Planning, (f) Preparation of Draft DPR Activities, Resource Planning and Schedule, and (g) Finalization of DPR, Implementation and Monitoring. These key steps and allied activities carried out as a part of the multipronged and multistakeholder consultative planning process for the preparation of DPR are diagrammatically presented in Fig. 3.1 and each of the key steps is briefly summarized below.

3.3.1 Project Initiation Background Analysis/ Contextual Analysis

The project of present nature on Forestry Interventions for Rejuvenation of Sutlej River is constantly influenced by economic, social and political processes that take place in society. The project planners and implementers thus seek information about the overall picture or the environment, including Technical, National and Sectoral information. Project activities started off by performing an overall preliminary study (*Prestudy*), feasibility study or the inception phase. The prestudy involved the understanding and assessment of project's external environment by collecting information about various related sectors, states and organizations involved as well as any data that existed about the target disciplines, sectors, themes, etc.

Further, it was realized that developing an understanding of the complex and dynamic nature of a river ecosystem and its linkages with forests and other surrounding landscapes requires adequate knowledge of relevant multidisciplinary subjects and application of various technologies. There is a growing literature on the wider subject of river ecology and management besides a long historical perspective on the management of the each of the major river including the Sutlej River. Thus, the foremost key step in the present planning exercise on the preparation of DPR was a systematic review of vast available literature on the subject through internet surfing and library consultation. The websites of prominent International, National and State Level Agencies and organizations dealing with any of the aspects related to river resources and conservation were extensively searched and required information was downloaded for developing the desired insight. The relevant secondary information from related organizations was also collected. The combined effort on the review of literature and collection of background information immensely helped in the contextual analysis. The contextual analysis also provided desired insight on the Sutlej Riverscape and its three sub environments i.e., Physical, Biological and Socio-economic.

3.3.2 Analysis of Stakeholders and the Consultative Process

The second vital step for successful planning and implementation required broader participation of stakeholders at all stages of planning of the project activities. Hence, it was essential to first identify which individuals and stakeholders are affected by the project and which one should be involved in the planning process. Likewise, it was critical to identify which stakeholders should be informed and involved during and after the project implementation. In the context of present assignment, broad five groups of stakeholders were identified as a part of the Step 1 on the contextual analysis. These five stakeholder groups included: (a) Target group (primary and

secondary target groups and beneficiaries); (b) Project owners and project groups; (c) Decision makers (at different levels, in organizations, at authorities and agencies, local politicians); (d) Experts and subject matter specialists; and (e) Financing agencies (those who sponsored/ finance the project as well as state/ national or international financiers who shall support and fund the project implementation (FRI, 2016; Örtengren, 2016). The preparatory phase included the extensive consultative process with identified groups of stakeholder right from the beginning. Table 3.3 provides a broad based list of stakeholders in five identified groups, highlighting the prominent Central/ State Governments Ministries, Departments, Agencies, Organizations besides Civil Agencies and NGOs that were consulted or their representatives participated in Project Launch and Brainstorming Workshop and subsequent sequential Consultative Meetings organized for the purpose at the Forest Circle/ Division and State levels in two States lying along the main river course. Details of the consultative process and sequential meetings are presented in Table 3.4.

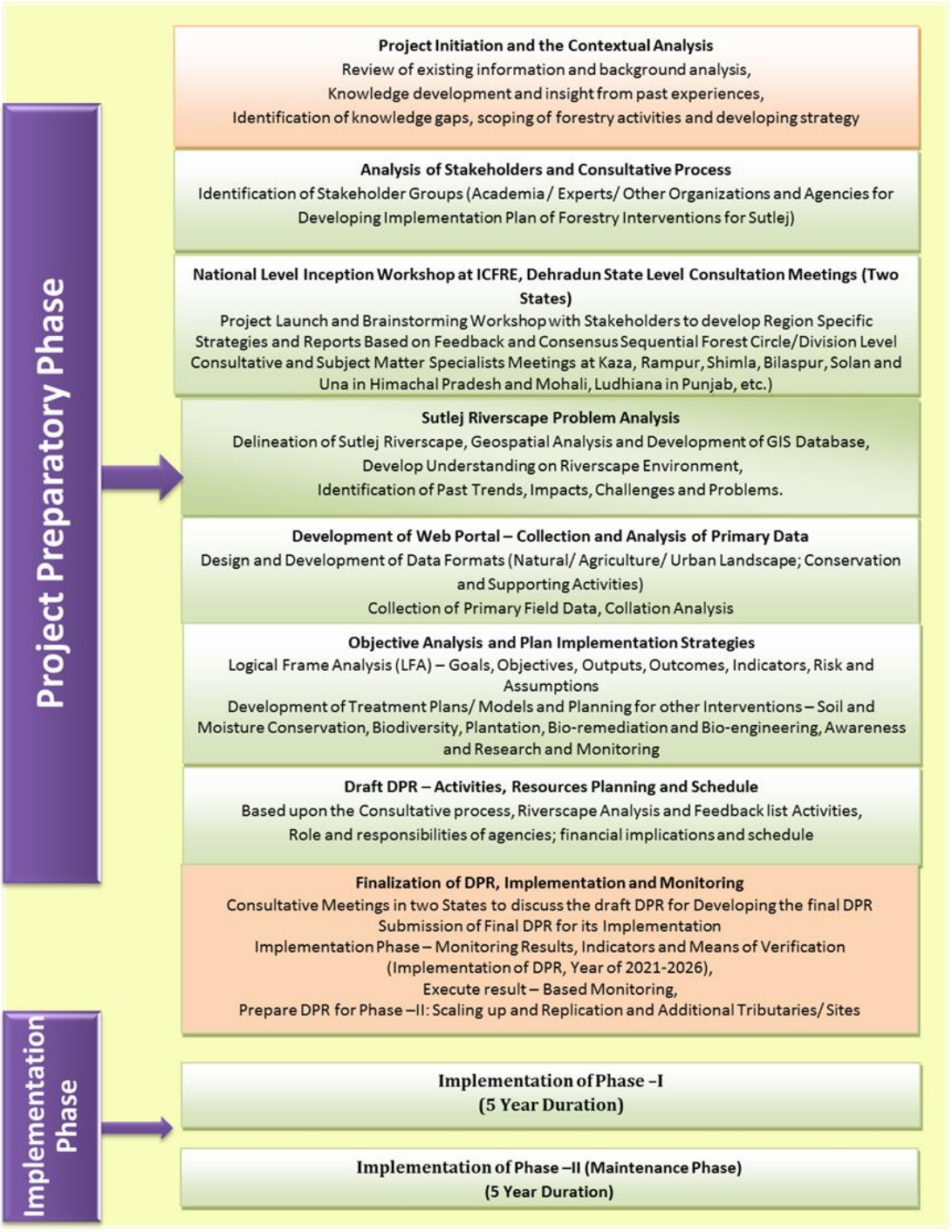


Fig.3. 1 Approach for Preparation of DPR

Table 3. 3 Group of Stakeholders or their Representatives involved in the Consultation Process in Himachal Pradesh and Punjab

A. Target Groups (Primary and Secondary Target Groups and Beneficiaries)
Civil Society – Villagers, Farmers, Fishermen and Urban Population

State Forest Departments (SFDs)
Department of Agriculture
Department of Animal Husbandry
Department of Horticulture
Department of Soil and Water Conservation
Department of Fisheries
Department of Highways and PWDs
Department of Irrigation
Hydroelectric Projects
Department of Tourism
Para Military Forces
Panchayats
Municipal Corporations/ Municipal Boards
B. Project Owners and Partner Organizations
Ministry of Environment, Forest and Climate Change (MoEF&CC), New Delhi
Indian Council of Forestry Research and Education (ICFRE), Dehra Dun, Uttarakhand
State Forest Departments (SFDs) – Himachal Pradesh and Punjab
Himalayan Forest Research Institute, Shimla, Himachal Pradesh
C. Decision Makers
The Central Government Ministries/ Departments/ Agencies/ Organizations
NITI Aayog, New Delhi
Ministry of Environment, Forest and Climate Change (MoEF&CC), New Delhi
Ministry of Jal Shakti, New Delhi
Ministry of Youth Affairs and Sports (MoYA&S), New Delhi
Ministry of Rural Development (MoRD), New Delhi

Ministry of Panchayati Raj (MoPR),New Delhi
Ministry of Defense (MoD), New Delhi Eco-Task Force (ETF)
Ministry of Home Affairs, New Delhi, Indo Tibetan Border Police (ITBP)
Bhakra Beas Management Board (BBMB), Chandigarh
Central Water Commission (CWC), New Delhi
National River Conservation Directorate (NRCD), New Delhi
Central Pollution Control Board (CPCB), New Delhi
National Medicinal Plants Board (NMPB), New Delhi
National Biodiversity Authority (NBA), Chennai
Nehru Yuva Kendra Sangathan (NYKS), New Delhi
State Government Ministries/ Departments/ Agencies/ Organizations in States – Himachal Pradesh and Punjab
State Governments and Concerned Ministries
State and District Administration
State Forests Department
State Forests Development Corporation
State Biodiversity Board
State Medicinal and aromatic Plant Board
State Agriculture Department
Irrigation and Public Health Department
Horticulture Department
Department of Animal Husbandry
State Disaster Management Authority
Indo Tibetan Border Police (ITBP)
Eco-Task Force (ETF)
State Pollution Control Board

D. Experts and Specialized Scientific Organizations
Indian Council of Forestry Research and Education (ICFRE)
Himalayan Forest Research Institute (HFRI)
Forest Survey of India (FSI)
Forest Research Institute (FRI)
Indian Institute of Soil and Water Conservation (IISWC)
National Institute of Hydrology (NIH) and Its Regional Centers
Central Water Commission (CWC)
Central Groundwater Board (CGWB)
Wildlife Institute of India (WII)
Indian Institute of Remote Sensing (*IIRS)*
Zoological Survey of India (ZSI)
Botanical Survey of India (BSI)
Survey of India (SOI)
National Horticulture Board (NHB)
National Bureau of Plant Genetic Resources(NBPGR)
National Bureau of Fish Genetic Resources (NBFGR)
Indian Agriculture Research Institute (IARI)
Centre of Inland Waters in South Asia (CIWSA)
Central Inland Fisheries Research Institute (CIFRI)
National Medicinal Plants Board (NMPB)
Bombay Natural History Society, Mumbai
WWF – India, New Delhi
Dr.Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh
Himachal Pradesh University, Shimla, Himachal Pradesh

CSK Himachal Pradesh Krishi Vishva Vidyalaya, Palampur, Himachal Pradesh
Punjab Agriculture University (PAU),Ludhiana, Punjab
Panjab University, Chandigarh
Punjab Central University, Bhatinda
Guru Nanak Dev University, Amritsar, Punjab
E. Identified Funding Agencies
Central Government – Ministry of Finance, MoEF&CC, MoJS, MoA, MoRD, Ministry of AYUSH, MoPR, etc.
State Government Ministry of Finance/ Environment and Forests/ Rural Development/ Agriculture/ Tribal Affairs/ Panchayati Raj, etc.

Table 3. 4 Consultative Meetings at the River Basin Levels for the Preparation of DPR

Sr. No.	Consultation Event	Date, Venue	No. of Participants
1	National Level Inception Workshop on Preparation of DPRs of Indian Major Rivers	24-25 April 2019 ICFRE, Dehradun	61
2	State Level Project Launch and Brainstorming Workshop – for all the three States viz. HP, Punjab and Erstwhile J&K	28-29 June 2019 Hotel Holiday Home, Shimla	178
3	Consultative Meeting for Rampur Forest Circle, Himachal Pradesh	2 August 2019 Office of the Rampur Forest Division, Rampur	55
4	Consultative Meeting for Kinnaur Forest Division, Himachal Pradesh	9 August 2019 Reckong Peo, Kinnaur	50
5	Consultative Meeting for Bilaspur Forest Circle, Himachal Pradesh	17 August 2019 Bilaspur,	47
5	State Level Consultative Meeting for the state of Punjab	21 August 2019 Forest Complex, Mohali, Punjab	65
6	Consultative Meeting for Lahaul & Spiti Forest Division, Himachal Pradesh	17 September 2019 Lahaul & Spiti	38
7	Consultative Meeting for Solan Forest Circle, Himachal Pradesh	1 October 2019 Solan	55
7	Subject Matter Specialists Meeting for Ludhiana, Punjab	16 October 2019 Punjab Agriculture University, Ludhiana	53
8	Consultation Meeting for Una Forest Division, Himachal Pradesh	14 November 2019 Office of the Una Forest Division, Una, Himachal Pradesh	43
9	Training to Punjab Forest Department	3-11 December 2019 at Ferozpur,	102

		Amritsar, Jalandhar, Phillaur, Ludhiana, Roop Nagar and Mohali	
10	Subject Matter Specialists meeting with Soil Conservation and Drainage Department of Punjab	9-10 December 2019 at Ludhiana	15
11	Final Consultative Meeting for Finalization of Detailed Project Reports (DPRs) for Rejuvenation of Beas, Ravi and Sutlej River Basins through Forestry Interventions'	12 March 2020 Forest Complex Mohali, Punjab	75
12	Final Consultative Meeting for Finalization of Detailed Project Reports (DPRs) for Rejuvenation of Indus River Basin through Forestry Interventions'	26 June 2020 (through Video Conferencing)	55

The following section provides the chronological summary of sequential Consultative Meetings at the National/ State/ Forest Circle levels and provides a gist of deliberations, recommendations, decisions and outcomes.

a) National Level Inception Workshop on Preparation of DPRs of Indian Major Rivers (ICFRE, Dehra Dun; 24-25 April 2019)

The ICFRE, Dehra Dun, being the Nodal and Coordinating Agency entrusted with the task to prepare DPRs for major Indian Rivers on Forestry Interventions, had organized the Inception Workshop at its Headquarters based at Dehra Dun on 24-25 April 2019 under the Chairmanship of DG, ICFRE. The representatives (the Director and Members of the Core Team) from all the Institutes of ICFRE those were involved in the preparation of DPRs and Resource Persons/ representatives from the Forest Research Institute (FRI), Dehra Dun Indian Institute of Soil and Water Conservation (IISWC), Dehradun; Forest Survey of India (FSI), Dehra Dun; State Forest Department, Uttarakhand; *Namami Gange* State Project Management Group, Dehra Dun besides professional agencies connected with RS and GIS; IT and Development of Web Portal; and select Resource Persons were the participants in the Workshop. Altogether, there were 61 participants in two days Workshop. The workshop also had four participants from HFRI, Shimla. The objectives of the Workshop included: (a) Familiarisation with the goals of the entrusted task, expected outputs and timelines; (b) Development of an acquaintance with the approach and framework on the preparation of DPR adopted in the case of Ganga River during 2015-16; (c) Creating awareness about the emerging and evolving concepts and strategies related to river ecology, linkages between forests and river, complex and dynamic nature of rivers, human disturbances in the context of river fragmentation, availability of water (environmental flow), and water quality; (d) Sharing of experiences and lesson learnt in the preparation of DPR on Ganga River; (e) Emphasizing on the need for adopting holistic and participatory approach based on the extensive consultations and the use of 'Riverscape Approach'; and (f) Highlighting

the need of knowledge management and sharing, science and results based planning and monitoring, development of appropriate strategies for planning, assessment and implementation.

The selected Resource Persons those were associated with the preparation of DPR on Ganga River made presentations and acquainted the workshop participants with the emerging concepts in the context of river conservation and broad framework and approach adopted for the preparation of DPR. The Resource Persons elaborated on the key steps and components involved, formats used for field data collection and the incorporated strategies on Forestry Interventions. The concepts of Riverscape, its RS and GIS based geospatial analysis and the requirement of assessing and describing the riverscape environment were shared with the participants. The Workshop allowed intensive deliberations and working out the modalities and mechanisms for implementation of time bound major project involving nine major Indian River Basin Systems.

b) State Level Project Launch and Brainstorming Workshop (Hotel Holiday Home, Shimla; 28-29 June, 2019)

The HFRI had organized two days State Level Project Launch and Brainstorming Workshop at Hotel Holiday Home (HHH), Shimla on 28-29 June, 2019 primarily involving participants from Himachal Pradesh and Punjab State and Jammu & Kashmir U.T., those are associated with the preparation of DPRs of five tributaries of the Indus River Basin. Large number of Experts, Resource Persons and representatives from the State Forest Departments and specialised National/ State Level Scientific Organisations *viz*., the Forest Research Institute (FRI), Indian Institute of Soil and Water Conservation (IISWC), Indian Institute of Remote Sensing (IIRS), Forest Survey of India (FSI), Zoological Survey of India (ZSI), Botanical Survey of India (BSI), Central Water Commission (CWC), National Institute of Hydrology (NIH), and State Pollution Control Boards (SPCB) took active participation in the workshop. Representatives of wide range of Line Agencies i.e., Agriculture, Animal Husbandry, Horticulture, State Medicinal Plants Board, Irrigation, Mining, Power, PWD, Rural Development, Hydroelectric Projects, Tourism, etc. also actively participated in the Workshop deliberations.



Plate 3. 2 Launch workshop for preparation of DPR Indus at Shimla

Area of Consideration

a. The issue of delineation of Riverscape involved extensive and exhaustive consultation process involving various stakeholders of the states. The participants were informed about the approach adopted for delineating the Riverscape. The participants were also apprised that, the FRI, Dehra Dun has also incorporated the entire catchment of Ganga River in hilly state of Uttarakhand while a buffer of 5 km on either side from the High Flood Level (HFL) in the case of main stem and 2 km buffer on either side from the HFL in the case of selected tributaries once they have descended in the plains was included. Initially, some of participants said to either consider the whole catchment or focus on the watershed approach.
b. After considerable deliberations, the unanimous consensus was built to consider the entire catchment of a river in the Himalayan region as a major part of the Riverscape while in the case of plains, a buffer of 5 km and 2 km for main stem and tributaries, respectively from the respective HFL was considered adequate for the Riverscape. It was also decided that selection of tributaries in the Riverscape should be on the basis of silt load and water flow.
c. It was further decided that careful selection of suitable species for plantation/ treatment models is prerequisite for effective recharge and rejuvenation of groundwater as in several instances *Nallah*s and streams were dried up due to plantations of Poplar and Eucalyptus.
d. Finally, the consensus was built around selecting native and fast growing species those can provide multiple benefits and to avoid exotics and species those have high water requirement.
e. Concerns about declining glaciated area in each River Basin, changing climatic and glacio- hydrological regimes of the Himalaya and effect of glacier recession on runoff were emphatically stressed upon.
f. Implications of depleting cryosphere under changing climate on water, energy and food security particularly in Indus River Basin were highlighted. A need for estimating the snow and glacier melts, rainfall runoff, permafrost contribution and base flow at each of the sub basin scale in the Indus River Basin was highlighted.
g. The significance of protecting high altitude wetlands in the fore fields of glaciers in the upper Indus River Basin that play a vital role in maintaining the hydrological regimes of rivers was also emphasized.
h. In view of the one year time for the preparation of DPR, stressed upon the need to review the progress after 2nd months so as to identify gaps and constraints in accomplishment of the targets and objectives.
i. Contributions by stakeholders, especially the specialized organisations towards varied information required in the process of preparation of DPR were considered of paramount importance.

Consultative Meeting for Rampur Forest Circle, Himachal Pradesh (Office of the Divisional Forest Officer, Rampur; 02 August, 2019)

After the successful completion of the Project Launch and Brainstorming Workshop held at Shimla and introduction of the task on the preparation of DPRs of five rivers to varied



Plate 3. 3 Consultative meeting at Rampur

stakeholders at the State level, the HFRI had decided to organize sequential Consultative Meetings with the stakeholders at the level of each Forest Circle in H.P. and Punjab to acquaint the forest officials, particularly the frontline staff with the process and providing templates for collecting primary field data that are required by HFRI in collation and synthesis of desired information and preparation of DPRs.

In the above response, the HFRI had organized Consultative Meeting and Training at the Rampur Forest Circle on 2 August, 2019. The Meeting was organized at Nogli near Divisional Forest Office, Rampur, (H.P.) The Meeting was attended by 55 participants representing eight Line Departments. Prominent stakeholders in the meeting were from the State Forest Department including the CCF, Rampur; DFO, Rampur; besides ACFs, RFOs and representatives from various line departments *viz*., Agriculture, Horticulture, Public Works, Tourism, Irrigation and Public Health, and Public Relation Office.

Following Key issues were raised during the consultative meeting:

a. Degradation of the soil and water resources in the Catchment area.
b. Decreasing quality and quantity of forests
c. Silt load and landslides
d. Over exploitation of forest resources by local communities
e. Sinking of river bed
f. There should be minimum environmental flow in the river at any particular period of time.
g. Diversion of river water must be upto the level that river and subsequent dependent lives must sustain.

Following recommendations were proposed at the end of the Meeting:

a. Plant tree and shrub species especially Medicinal and Aromatic Plants (MAPs) on the banks and in the catchment area of river basin wherever possible.
b. Construction of check dams for reduction of silt load in the basin area.
c. Proper muck management plan and disposal of solid waste from urban localities and hospitals need special care.
d. It was also suggested for bio-insecticides and bio-pesticides adaptation over chemical pesticides and insecticides by apple and pomegranate farmers in river basin area.
e. Inclusion of wild edible fruit species in plantation programmes to prevent human-animal conflict.
f. Wetland management activities in scientific lines.
g. Policy implementation of the Environmental flow regulations.

Consultative Meeting for Kinnaur Forest Division, Himachal Pradesh (Forest Complex and Udyan Bhawan, Reckong Peo; 9 August, 2019)

The sequential consultative meeting for stakeholders of Kinnaur Forest Division was organized at the Forest Complex on 9 August, 2019. Varied stakeholders including forest officials and representatives of various Line Agencies, Municipal Corporation/ Councils and select NGOs participated in the meeting.

In the afternoon session, similar meeting was also conducted at Udyan Bhawan, Department of Horticulture at Reckong Peo with representatives from Horticulture and Soil Conservation Department wherein different data collection formats *viz*., Natural, Agriculture, Urban Landscapes and other activities were discussed with the participants along with other issues pertaining to the preparation of Sutlej DPR.

Following key issues were raised during the meetings

a. Silt load in Sutlej
b. Improper Muck disposal during road and HEP construction in eco-sensitive zones.
c. Frequent Landslides
d. Avalanches in Higher reaches

e. Diversion of River water

Following recommendations evolved at the end of the meetings

a. Avalanche management
b. Plantation of native trees, shrubs and grasses on the banks and catchment of the river to prevent soil erosion.
c. Construction of Silt retention dams and other soil moisture conservation works
d. Inclusion of horticulture plants also to prevent soil erosion



Plate 3. 4 Subject Matter Consultative meeting at Kinnaur

Consultative Meeting for Bilaspur Forest Circle, Himachal Pradesh (Zila Parishad Bhawan, Bilaspur; 17 August, 2019)

The third Consultative Meeting at the Forest Circle level in Himachal Pradesh was organized in Bilaspur Forest Circle involving wide ranging stakeholders representing the State Forest Department and different Line Departments, *Panchayats*, NIT, etc. The Meeting was organized at Zila Parishad Bhawan, Bilaspur on 17 August, 2019. 47 participants representing different Departments and Organisations attended that important meeting.

Following key issues were raised during the meeting:

a. Silt in Sutlej River
b. Drying up of the natural water resources
c. Diversion of river water through tunnels
d. New road construction and widening (especially four lane construction work in river basin)
e. Power transmission lines

f. Weed problems in the catchment area

Following recommendations emerged during meeting:

a. Plantation of native trees, shrubs and herbs and grasses in the bank and in the catchment area, wherever possible to reduce soil erosion.
b. Treatment of polluted sewerage water through bio-remediation and bio-filtration.
c. River front development
d. Development of eco-parks
e. Weed problems must be addressed in the DPR.
f. Involvement of BBMB and other concerned departments/NGOs/JFMCs etc. for smooth implementation of different activities proposed under DPR.



Plate 3. 5 Consutative meeting at Bilaspur

First State Level Consultative Meeting for Punjab State (Forest Complex, Mohali, Punjab; 21 August, 2019)

Since the Sutlej, Beas and Ravi Rivers of the Indus River Basin flow through the plains of Punjab, a common Consultative Meeting at the State level was organized on the preparation of DPRs for rejuvenation of Beas, Sutlej and Ravi Rivers through Forestry Interventions on 21 August, 2019 at the Forest Complex, Mohali, Punjab. 65 participants representing various Departments i.e., Forest, Agriculture, Rural Development, Animal Husbandry, Water Resources, Sewage Board at State level, Central Water Commission, Punjab Agriculture University, World Wide Fund for Nature India and other participated actively in the Meeting.

Following key issues were raised during the meeting:

a. Flood in Sutlej River
b. Significant lowering of ground water table in the Punjab State
c. Excessive use of pesticides
d. Pollution by Buddha *Nallah* of industrial belt in Ludhiana and ultimately making the water of Indira Gandhi Canal (Rajasthan Feeder Canal) unfit for any human or irrigation use.
e. Erosion of river bank
f. Pollution by household waste and sewerage

Following recommendations were given during meeting:

a. Plantation of native trees, shrubs & herbs species and grasses on the banks and in the catchment area of river basin wherever possible to reduce soil erosion.
b. Treatment of polluted sewerage water through bio-remediation and bio-filtration.
c. River front development
d. Development of eco-parks
e. Encouragement and some incentives schemes to farmers to motivate them for inclusion of agroforestry models and marketing of produce
f. Appropriate steps must be taken to check, manage and control the effluents being thrown into the rivers.





Plate 3. 6 First State Level Consultative meeting at Forest Complex, Mohali, Punjab

Consultative Meeting for Spiti sub-division of Lahaul & Spiti district, Himachal Pradesh (O/o Additional District Magistrate Kaza, District Lahaul & Spiti; 17 September, 2019)

The Consultative Meeting was organized for stakeholders and forest personnel of Spiti Sub - Division of Lahaul & Spiti district on 17 September, 2019. The meeting was organized at the O/o Additional District Magistrate Kaza, District Lahaul & Spiti. 38 participants representing senior forest officials and wide range of stakeholders from different Line Agencies of Lahaul & Spiti district actively participated the meeting.



Plate 3. 7 Consultative meeting at Kaza

Following key issues were raised during the meeting:

a. Silt in Spiti and in Sutlej Rivers
b. Wind erosion in Cold desert areas
c. Pasture management
d. Wildlife conservation activities
e. Erosion of river bank
f. Avalanches
g. Wetland management

Following recommendations were evolved during meeting:

a. Plantation of native trees, shrubs, herbs and grasses on the banks and in the catchment area of river basin wherever possible to reduce soil erosion.
b. Scientific management of alpine pastures

c. Greening of cold desert areas
d. Avalanches and moraine management
e. Wild life and Wetland management

Consultative Meeting for Solan Forest Circle, Himachal Pradesh (1 October, 2019)

The Consultative Meeting was organized for stakeholders and forest personnel of Solan district on 1 October, 2019. 55 participants of representatives from Himachal Pradesh State Forest Department consisting of Conservator of Forest (CF), Divisional Forest Officers (DFOs) and Range Offices (ROs) and field staff from Solan Forest Circle and Officers/representatives of other line Departments viz. Agriculture, KVK (Horticulture), Zoological Survey of India, Irrigation and Public Health (IPH), HP Public Works Department, District Public Relation Office, faculty from AERIF India Pvt. Ltd and UHF, Nauni also participated in the meeting.

Following key issues were raised during meeting:

a. Pollution by Sarsa *Nallah*
b. Silt in the Sutlej River
c. Decline of ground water table in lower Himachal Pradesh
d. Excessive utilization of forestry resources by local communities
e. Weed problem due to invasive obnoxious weeds

Following recommendations emerged during meeting:

a. Aquifers channelization and ground water recharging
b. Treatment of Small *Nallah*s and tributaries must be given top priority
c. Waste water and sewerage treatment in the towns and other urban localities
d. Awareness programmes among local communities to educate them about sustainable harvesting of forest resources.
e. For improving livelihood of the local communities, suitable medicinal and aromatic plants must be proposed under treatment models
f. Weed problem especially *Lantana* must be addressed in the DPR

Subject Matter Specialists (SMS) Meeting for Punjab State (Punjab Agriculture University, Ludhiana; 16 October, 2019)

The Himalayan Forest Research Institute (HFRI), Shimla organized One Day Subject Matter Specialists Meeting at Punjab Agricultural University (PAU), Ludhiana on 16 October, 2019. 53 participants representing Officers, Experts and Academician from Research Organizations, Universities and various Line Departments including Agriculture, Horticulture, Forests, Soil Conservation, PWD, Tree Growers Association Remote Sensing Center, etc. actively participated in the meeting. Following key issues were raised during meeting:

a. Pollution by Buddha *Nallah* in Ludhiana
b. Silt in the Sutlej River
c. Decline of ground water table in Punjab

d. Excessive use of pesticides and fertilizers
e. Minimum support price for agroforestry species

Following recommendations were suggested during meeting:

a. Aquifers channelization and ground water recharging
b. Scientific management of industrial pollution
c. Farmers must be encouraged towards organic farming and awareness programmes for farmers must be on priority for judicious use of pesticides and fertilizers
d. Waste and sewerage water treatment in the towns through bio-remediation and bio-filtration.
e. Involvement of drainage department for various activities to be proposed in the Sutlej DPR.



Plate 3. 8 Subject Matter Specialists (SMS) Meeting for Punjab State at Ludhiana

Consultative Meeting cum training for Una Forest Division, Himachal Pradesh (Divisional Forest Office, Una, Himachal Pradesh; 14 November, 2019)

The Consultative Meeting was organized for stakeholders and forest personnel of Una district on 14 November, 2019. 43 representatives from Forest Division Una, Divisional Forest Officer (DFO), Assistant Conservator of Forests (ACFs), Range Officers (ROs), Dy. Rangers, Forest Guards and other representatives of Forest Department actively participated in the Meeting.



Plate 3. 9 Consultative meeting at Una

Following key issues were raised during meeting:

a. Pollution by sewerage
b. Silt in the Sutlej River
c. Decline of ground water table
d. Sand Mining of river bed
e. Seasonal flood in Swan River
f. Forest Fire
g. Weed problems

Following recommendations emerged during meeting:

a. Plantation of native trees, shrubs, herbs, medicinal & aromatic plants (MAPs) and grasses on the banks and in the catchment area of river basin wherever possible to reduce soil erosion and conserve soil moisture
b. Wildlife management strategies must be on priority
c. Policy issues and their implementations must be addressed to prevent mining of river bed
d. Flood control strategies of Swan River must be addressed
e. Prevention of forests from fire must be addressed in the proposed DPR
f. Some models must be proposed to address weed problems

Consultative Meeting cum training for Ferozepur Forest Division, Punjab (Divisional Forest Office, Ferozepur, Punjab; 3 December, 2019)

Consultative Meeting cum Training was organized for Forest Department personnel of Ferozepur Forest Division, Punjab on 3 December, 2019 at O/o DFO Ferozepur. 15 participants of Forest

Department from Ferozepur Forest Division *viz.*, Divisional Forest Officer (DFO), Assistant Conservator of Forests (ACF), Range Officers (ROs), Dy. Rangers, Forest Guards and other representatives of Forest Department actively participated in the meeting. Following key issues were raised during meeting:

a. Pollution of Sutlej River
b. Flood in the Sutlej River
c. Decline of ground water table
d. Soil Erosion

Following recommendations evolved during meeting:

a. Plantation of native trees, shrubs, herbs, Medicinal & Aromatic Plants (MAPs) and grasses on the banks and in the catchment area of River Basin wherever possible to reduce soil erosion and conserve soil moisture.
b. Pollution and Flood control strategies of Sutlej River must be addressed on top priority.
c. For upliftment of livelihood of local communities ecotourism activities must be proposed in the DPR.



Plate 3. 10 Consultative meeting at Ferozepur, Punjab

Consultative Meeting cum Training for Ferozepur (WL) Forest Division, Punjab (Divisional Forest Office, Ferozepur (WL), Punjab; 4 December, 2019)

Consultative meeting cum Training was organized for Forest Department personnel of Ferozepur Wildlife Division on 4 December, 2019 at O/o DFO Ferozepur (WL). 10 participants and officials from Ferozepur Wildlife Division *viz.*, Divisional Forest Officer (DFO) and other officers and officials of Wildlife Division actively participated in the meeting. Following key issues were raised during meeting:

a. Water hyacinth problem in Sutlej
b. Flood in the Sutlej River

c. Decline of ground water table
d. Soil Erosion
e. Pollution in Sutlej

Following recommendations evolved during meeting:

a. Pollution and Flood control strategies of Sutlej River must be addressed on top priority.
b. For upliftment of livelihood of local communities ecotourism activities must be proposed in the DPR.
c. Plantation of native trees, shrubs, herbs, medicinal & aromatic plants (MAPs) and grasses on the banks and in the catchment area of river basin wherever possible to reduce soil erosion and conserve soil moisture.
d. Wildlife and wetland management must be addressed in the proposed DPR.
e. Untreated and toxic industrial effluents released into the river system from big cities like Ludhiana, Jallandhar and Kapurthala etc. which damages aquatic ecosystem of the river and Harike Wetland must be treated to the best possible levels through bio-remediation and bio-filtration processes for cleaning polluted water

Consultative Meeting cum Training for Amritsar Forest Division, Punjab (Divisional Forest Office, Amritsar, Punjab; 5 December, 2019)

Consultative Meeting cum Training was organized for Forest Department personnel of Amritsar Forest Division on 5 December, 2019 at O/o DFO Amritsar. 25 representatives from Amritsar Forest Division *viz*., Divisional Forest Officer (DFO), Assistant Conservator of Forests (ACF), Range Officers (ROs), Dy. Rangers, Forest Guards and other representatives of Forest Department actively participated in the meeting. Following key issues were raised during the meeting:

a. Flood in the Sutlej River
b. Soil Erosion
c. Pollution in Sutlej

Following recommendations emerged during meeting:

a. Pollution and Flood control strategies of Sutlej River must be addressed on top priority.
b. Plantation of native trees, shrubs, herbs, medicinal & aromatic plants (MAPs) and grasses on the banks and in the catchment area of river basin wherever possible to reduce soil erosion and conserve soil moisture.

Consultative Meeting cum Training for Jalandhar Forest Division, Punjab (Divisional Forest Office, Jalandhar, Punjab; 6 December, 2019)

Consultative Meetings cum Training in the sequence was organized for Forest Department personnel of Jalandhar Forest Division on 6 December, 2019 at O/o Conservator of Forest, Jalandhar. 20 numbers of representatives from Jalandhar Forest Division, Divisional Forest Officer (DFOs), Assistant Conservator of Forests (ACF), Range Officers (ROs), Dy. Rangers,

Forest Guards and other representatives of Forest Department actively participated in the Meeting. Following key issues were raised during meeting:

a. Flood in the Sutlej River
b. Soil Erosion
c. Pollution in Sutlej

Following recommendations evolved during meeting:

a. Pollution and Flood control strategies of Sutlej River must be addressed on top priority.
b. Plantation of native trees, shrubs, herbs, medicinal & aromatic plants (MAPs) and grasses on the banks and in the catchment area of river basin wherever possible to reduce soil erosion and conserve soil moisture.

Consultative Meeting cum Training for Ludhiana Forest Division, Punjab (Divisional Forest Office, Ludhiana, Punjab; 9 December, 2019)

Consultative Meeting cum Training was organized for Forest Department personnel of Ludhiana Forest Division on 9 December, 2019 at O/o DFO, Ludhiana. 20 representatives from Ludhiana Forest Division *viz*., Divisional Forest Officer (DFO), Assistant Conservator of Forests (ACF), Range Officers (ROs), Dy. Rangers, Forest Guards and other representatives of Forest Department actively participated in the meeting. Following key issues were raised during meeting:

a. Flood in the Sutlej River
b. Soil Erosion
c. Pollution in Sutlej by Buddha *Nallah*

Following recommendations emerged during meeting:

a. Pollution and Flood control strategies of Sutlej River must be addressed on top priority.
b. Plantation of native trees, shrubs, herbs, medicinal & aromatic plants (MAPs) and grasses on the banks and in the catchment area of river basin wherever possible to reduce soil erosion and conserve soil moisture.

Subject Matter Specialist Meeting for Divisional Soil Conservation Office (DSCO), Ludhiana, Punjab; 9-10 December, 2019)

Subject Matter Specialist meeting was organized with Divisional Soil Conservation Officer on 9 December, 2019 at O/o DSCO, Ludhiana. 15 officers/officials actively participated in the meeting. Following key issues were raised during meeting:

a. Soil Erosion on the bank of Sutlej River
b. Pollution in Sutlej by Buddha *Nallah*

Following recommendations emerged during meeting:

a. Plantation of native agroforestry species on the banks and in the catchment area of river basin wherever possible must be given priority to reduce soil erosion and conserve soil moisture.
b. Pollution in Sutlej River must be addressed in the Present DPR

Consultative Meeting cum Training for Mohali Forest Division, Punjab (Divisional Forest Office, Mohali, Siswan Range, Punjab; 11 December, 2019)

Consultative meeting cum Training was organized for Forest Department personnel of Mohali Forest Division on 11 December, 2019 at O/o DFO, Mohali. 12 representatives from Mohali Forest Division *viz*., Divisional Forest Officer (DFO), Assistant Conservator of Forests (ACF), Range Officers (ROs), Dy. Rangers, Forest Guards and other representatives of Forest Department actively participated in the meeting.

Following key issues were raised during meeting:

a. Natural regeneration
b. Soil Erosion
c. Forest fire

Following recommendations were suggested during meeting:

a. Some models must be proposed for assisting natural regeneration in the forest.
b. Soil moisture conservation models must be proposed for conserving soil moisture.
c. Forest fire must be addressed in the DPR to prevent loss of biodiversity.

c) Final Consultative Meeting for Finalization of Detailed Project Reports (DPRs) for Rejuvenation of Beas, Ravi and Sutlej River Basins through Forestry Interventions' for the State of Punjab, Held at Forest Complex Mohali, Punjab; 12.03.2020

Himalayan Forest Research Institute (HFRI), Shimla, Himachal Pradesh in collaboration with Punjab Forest Department organized 'Final Consultative Meeting for the Finalization of Detailed Project Reports for Rejuvenation of Beas, Ravi and Sutlej River Basins through Forestry Interventions on 12 March, 2020 at Forest Complex, Mohali, Punjab. 75 participants from Central and State Govt. Departments, R&D Organizations, Punjab Forest Department and various other Departments like SPCB, Indus Basin Organization (IBO), Bhakhra Beas Management Board, Central University, Bhatinda, Punjab; Punjab University, Chandigarh, Panjabi University Patiala, Punjab Agriculture University, Ludhiana, Department of Water Resources Mohali, Agriculture Department, Soil and Water Conservation Department, Punjab State Council for Science & Technology and various other stakeholders including representatives from NGOs participated in the Meeting.

Following Key issues were raised during the meeting:

a. There must be flexibility in mid course adjustments process while implementation of the models proposed in the DPR.
b. General guidelines must be proposed for smooth implementation of different activities in different landscapes in the DPR.
c. Organized marketing and some buyback arrangements for agroforestry produce.

Following recommendations were emerged:

a. Protected areas and Wetland models needs to be revisited.

b. Cost norms of sub mission on agroforestry should be considered while finalizing models for agriculture landscape.
c. Preference must be given to native species in natural landscape over commercial exotic species
d. HFRI, team should remain in touch while finalizing DPR with all stakeholders in Punjab



Plate 3. 11 Final Consultative meeting at Forest Complex, Mohali, Punjab

d) Final Consultative Meeting for Finalization of Detailed Project Reports (DPRs) for Rejuvenation of Sutlej, Beas, Ravi, and Chenab River Basins through Forestry Interventions' for the State of Himachal Pradesh held through Video Conferencing on 26.06.2020

The HFRI organized One Day Final Consultative Meeting on 26 June, 2020 primarily involving Officers/Officials and other staff persons from Himachal Pradesh Forest Department. 55 Officers/Officials including PCCF & HOFF, H.P., PCCF, Finance, PCCF cum Chief Wildlife Warden, PCCF (CAT Plan), CCFs, CFs, DFOs and other Officers and Officials of different Forest Circles and Divisions from HPSFD (Himachal Pradesh State Forest Department) and Chief Project Coordinator, Project Coordinator, Nodal Officer-Indus and River Coordinators, Team Leaders from HFRI, Shimla were also present in the Meeting held through Video Conferencing.



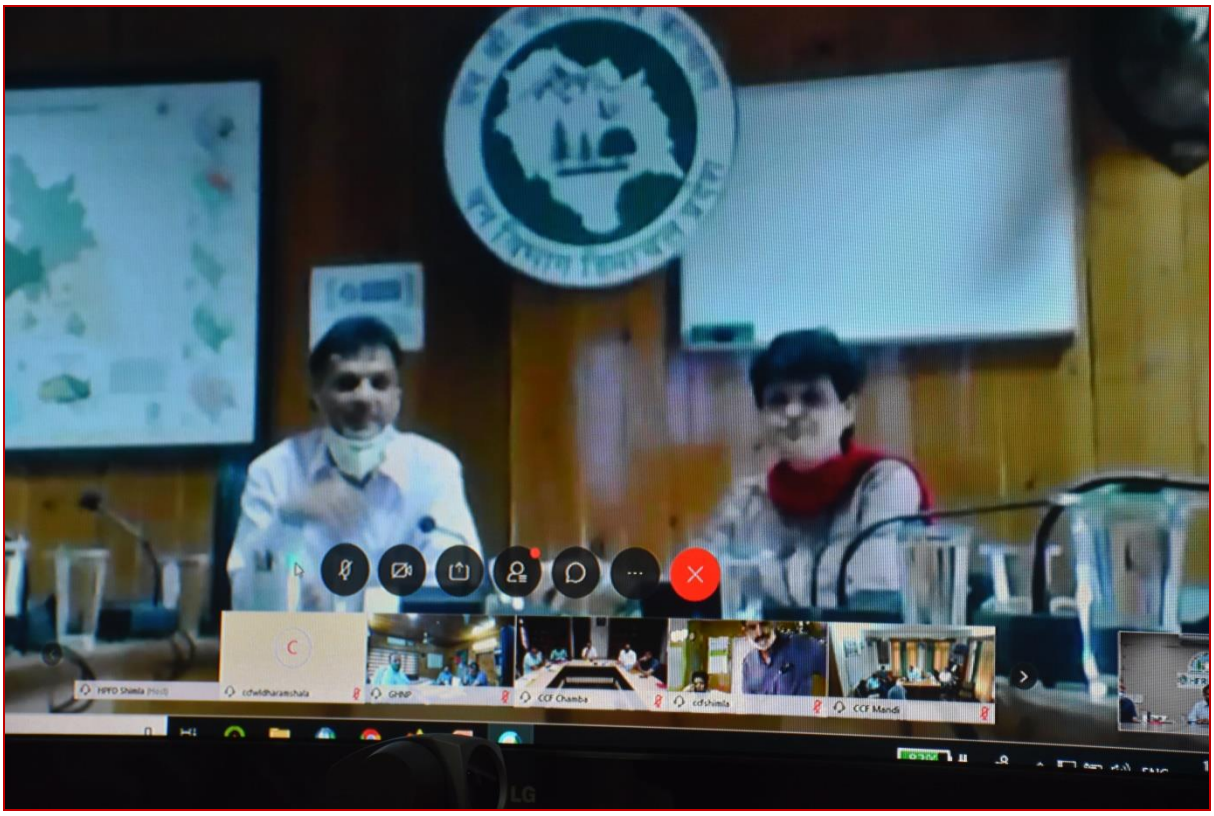


Plate 3. 12 Final Consultative meeting with Himachal Pradesh State Forest Department

Following Key issues were raised during the meeting:

a. There must be flexibility in selection of sites and mid-course adjustments while implementation of the models proposed in the DPR
b. General guidelines must be proposed for smooth implementation of different activities in different landscapes in the DPR
c. Cost norms given in various proposed treatment models
d. Models proposed for protected areas and Wetland management
e. Implementation mechanism

Following recommendations were emerged:

a. Revisit the cost norms of proposed treatment models in consultation with SFD officers
b. Activities to be defined in protected areas and wetland treatment models
c. Clarity in implementation mechanism
d. Inclusion of some native species in treatment models
e. Sharing of details of natural regeneration protection model for further refinement

Recommendations of the Meeting

a. It was recommended to prefer Indigenous species for the plantations in the priority areas. It was also suggested to include separate plantation models for industrial and urban areas in the DPRs.

b. It was advocated to give more emphasis to those forestry species which provide more livelihood options to the local populace besides conservation of the soil and moisture. Thus, high value broad leaved fodder species, milk yielding grasses and high value Medicinal and Aromatic Plants (MAPs) were suggested to be preferred in the plantation models.
c. Bund plantations proposed to be included in the models along with very dense plantations.
d. Interventions related to pollution removal proposed to be highlighted as high priority area.
e. Provisions of monitoring of soil erosion and conservation of water bodies and biodiversity was also proposed to be included in the DPRs.
f. Besides these, activities related to addressing Silt Problems, Muck disposal, Pollution by Sarsa, Buddah *Nallah*, Pasture Development, Weeds problem, fire problem, Moraine/Avalanches management, drying of Natural Water Resources and groundwater recharging, etc. proposed to be included on priority basis.
g. Inclusion of Remote Sensing during the implementation for effective monitoring of the DPR was also advocated.
h. Last but not the least, involvement of local communities/community participation during the implementation process was highly stressed.

3.3.3 Sutlej Riverscape – Problem Analysis

The next crucial action in the process of preparation of DPR was to lay out the Sutlej Riverscape for the purpose of planning, situation and problem analysis, developing an insight on the Riverscape environment, and prioritization of areas for proposed Forestry Interventions. The background analysis/ contextual analysis and the consultative process adopted at the National, State and Forest Circle Levels provided the much desired insight on the Sutlej River, its basin and tributaries, terrestrial and aquatic biodiversity, past management, associated States, and developmental activities. A Riverscape within the larger river basin was delineated. Detailed geospatial analysis of the Riverscape using Remote Sensing and GIS technologies was carried out. It provided an understanding on the situation of physical attributes – land use and land cover, altitudinal variation, slope, aspect, soil, erosion, forest types and forest cover, fragmentation, etc. The review of secondary information from a variety of sources (National/ State Level Agencies/ Departments, Scientific Organizations and Universities) allowed developing an understanding on the riverscape environment i.e. physical, biological and socio-economic) and identification of challenges, constraints, problems, and threats in river conservation. The situation analysis facilitated developing an insight on State specific challenges and threats for HP and Punjab wherein the river flows depicts contrasting situation owing to large variations in the physical, biological and socio-economic sub environments. The consultative process and the sequential meetings with varied stakeholders definitely helped in the

identification of focal problems in both the states, understanding their reasons/ causes, and effects or implications on the river itself and surrounding lands.

SWOT Analysis of Sutlej River Ecosystem and its Environment

On the completion of extensive consultative process carried out as a part of the present task, and also on the basis of a thorough review undertaken to understand and appreciate the existing situation of the Sutlej River and its environment, its past trends, and implications, the SWOT Analysis was performed. The findings of the SWOT Analysis are summarized below

Strength

A. Sutlej River is one of the five major rivers of the Indus River System in India, mainly fed by snow and glacial melt. It forms the largest catchment area in the Himalayan Mountainous tract in Himachal Pradesh and drains through the Trans Himalaya, Great Himalaya, Middle Himalaya, and the Lower Himalaya before descending into Alluvial Plains of Punjab.

B. Sutlej Riverscape exhibit varied landforms along vast range of altitudinal gradient and climatic conditions, and thus, harbours a wide range of forests, grasslands, alpine pastures and wetlands those are home to a variety of rare, endemic and threatened floral and faunal species. These diverse natural ecosystems not only provide enormous biodiversity values but significantly contribute for the maintenance of the ecological integrity, overall health and sustained environmental flows of the Sutlej River and its tributaries.

C. Sutlej Riverscape harbours a large number of glaciers, high altitudinal lakes and extensive snowcapped peaks sustaining water flow in the river all through the year.

D. Sutlej Riverscape harbours several large, contiguous and compact forest blocks along the altitudinal gradient those constitute some of the important Protected Areas (PAs) (Fig 3.2). The Pin Valley National Park and Kibber wildlife Sanctuary in Sutlej River Basin have recognition of its global significance.

E. Sutlej River is a major source for irrigation and hydroelectric power projects in Northern India. It is the largest tributary of Indus River and flows from the Tibetan plateau through Himachal Pradesh & Punjab in India and then in Pakistan before meeting Indus. At Bhakra, Himachal Pradesh, a major dam has been constructed to utilize water for hydroelectricity generation and irrigation. The Reservoir also receives water from the Beas River through the Beas–Sutlej link. The Bhakra Reservoir (i.e., Gobind Sagar Lake) has a water storage capacity of 9,340 million cubic meters and receives 65–80% of its inflow from Sutlej River and the remaining 20–35% from the Beas River. The Sutlej River supports generation of 4,566 MW of hydropower, with potential for future expansion (Prasad *et al,* 2019).

F. Sutlej River continues to be major source of varied economic values (e.g., drinking water, irrigation, hydropower, fish, sand, boulders, recreation, tourism, etc.) besides a source of prosperity and aspirations of different Sectors, Agencies, and Local Communities. Additionally, in view of its religious and cultural values, the river also receives desired attention and support from the Central, State and Local Governments; user agencies and masses

those are traditionally dependent on the river for subsistence, livelihoods and commercial activities.

Weakness

A. Sutlej River, surrounding lands and its varied resources are excessively burdoned due to high and competing demands of various sectors/ users, human needs and greed, abuse and neglect. As a result, the river ecosystem exhibits numerous signs of degradation and deterioration. Moreover, the survival of several tributaries and the ecological integrity of the main river have been threatened.

B. Rapid retreat of the prominent Glaciers within the Riverscape along with melting of several other smaller glaciers with the river basin, enhanced landslides, intense sedimentation and erosion; sequential HEPs all through the river course, result fragmentation and reduced connectivity (i.e., longitudinal, vertical, lateral and temporal) and environmental flows, increased pollution, and excessive use/exploitation of forests, alpine pastures and important wetlands are some of the main issues of concern.

C. In spite the government has enacted multiple legislative acts relevant to forests, environment, wildlife, pollution control, waste management, etc.; formulated several relevant policies and strategies; established different authorities to regulate use of river resources, and numerous judiciary interventions in the recent decade, there are enormous challenges in enforcing laws and regulating use of river resources.

D. Most agencies concerned with use of the water from river, regulation and law enforcement continue to work in isolation and overlook the complex and intricate environment of the river ecosystem and continue to adopt piecemeal and fragmentary approaches to management and conservation instead of much desired holistic and comprehensive perspective of the Riverscape.

E. Slope failure mechanism, dam dimension and dam stability evaluation were used as potential approaches for landslide damming. The Urni landslide, located on the left bank of the Sutlej River in Himachal Pradesh (India), was considered as a case study. Urni landslides have been the culmination of a series of landslides over the past decade (2000-2016) and have been dammed off the Sutlej River since 2013, damaging the 200-meter National Highway (NH05). The erosion crown is located at an altitude of ~2180-2190 m amsl, near the village of Urni of about 500 people. The slight increase in rainfall per year also means that it emerged since 2013. June 11 (~100 mm) and June 16 (~115 mm) 2013 were observed as extreme rainfall days and considered as one of the responsible reason for the failure of the slope (Kumar *et al*., 2019).

Further the weakness of the Catchment can be categorized into:

a. Topography/ Fragile Terrain
b. Lack of adequate and dependable means of transport.
c. Railway tracks are very difficult to be laid down.
d. Roads get blocked due to extreme weather conditions
e. Poor Mineral resources of the Catchment
f. Difficult weather conditions

g. Development of channels and kuhls for irrigation schemes get adversely affected by the bad weather conditions
h. Agriculture, especially production of food grains, suffers from land limitations.

Reclamation of land on slopes of hills for cultivation of food grains is neither economical nor beneficial.

Opportunities

A. Sutlej River has been bestowed with enormous resources, power, capacity and potential to flourish, resist and recover (resiliency) even after natural catastrophes and human disturbances. Despite such exigencies and disturbances, the river has been able to withstand and cope with adverse impacts and continue to provide benefits of multiple goods and various other ecosystem services.

B. In recent decades, various government sectors/ departments, law enforcement agencies, scientific organizations/ universities, nongovernmental organizations, and civil society organizations have come forward to undertake researches on varied priority themes, standardize protocols for monitoring different processes and resources, and their execution. These efforts amply reflect the wider awakening and their meaningful involvement in conservation, and restoration initiatives. Thus, increasingly environment favorable to River ecosystem is being gradually built. In the process, a greater constituency of law enforcement agencies, policies and law makers, field practitioners, scientific experts, technocrats, corporates, religious leaders and masses is being established for the sake of conservation and revival of the Sutlej River to its past splendor and ecological integrity.

C. Through preservation and, where necessary, restoration of the ecological balance has been used for maintenance of environmental stability at the places where the ecological balance has poorly been agitated by severe exhaustion of the forests of the Sutlej River basin.

D. Conserving the natural heritage of the Sutlej River Basin by preserving the remaining natural forests with the vast variety of flora and fauna, which represent the remarkable biological diversity and genetic resources of the Nation.

E. Checking soil erosion and denudation in the catchment areas of rivers, lakes, reservoirs in the "Interest of soil and water conservation, for mitigating floods and droughts and for the retardation of siltation of reservoirs.

F. Increasing substantially the forest/tree cover in the country through massive afforestation and social forestry programmes, especially on all denuded, degraded and unproductive lands.

G. Meeting the requirements of fuel wood, fodder, minor forest produce and small timber of the rural and tribal populations.

H. Increasing the productivity of forests to meet essential National needs.

I. Encouraging efficient utilization of forest produce and maximizing substitution of wood.

J. Creating a massive people's movement with the involvement of women, for achieving these objectives and to minimize pressure on existing forests.

K. Existing forests and forestlands should be fully protected and their productivity improved. Forest and vegetal cover should be increased rapidly on hill slopes, in catchment areas of rivers, lakes and reservoirs.

L. Diversion of good and productive agricultural lands to forestry should be discouraged in view of the need for increased food production.

M. For the conservation of total catchment, the network of National Parks, wildlife Sanctuaries, Biosphere Reserves and other protected areas should be strengthened and extended adequately.

N. Provision of sufficient fodder, fuel and pasture, especially in areas adjoining forest, is necessary in order to prevent depletion of forests beyond the sustainable limit. Since fuel wood continues to be the predominant source of energy in rural areas, the programme of afforestation should be intensified with special emphasis on augmenting fuel wood production to meet the requirement of the rural people.

O. Minor forest produce provides sustenance to tribal population and to other communities residing in and around the forests. Such produce should be protected, improved and their production enhanced with due regard to generation of employment and income.

P. DPR provides strategy for area under forests, afforestation, social forestry & farm forestry, management of state forests, rights and concessions, diversion of forest lands for non forest purposes, wildlife conservation, tribal people and forests, shifting cultivation, damage to forests from encroachments, fires and grazing, forest based industries, forest extension, forestry education and forestry research.

Threats

A. Sutlej River originates and flows through the high seismic zone that experiences several geological (i.e., tectonic upheaval, seismic activities, and landslides), environmental (i.e., avalanches, cloud bursts, and climate change implications) and human induced (i.e., deforestation, diversion of river water, forest fires, conversion of forests/ grasslands/ wetlands to agriculture/ horticulture, air and water pollution, sand mining and disturbance to bedrock, construction of roads and HEPs, sewage and waste disposal from cities and townships, unregulated tourism, etc.) processes/ disturbances.

B. Sutlej River flow is contributed by snow and ice melt. However, water reserves held by glaciers are likely to be altered considerably in the future due to climate change, as glaciers are highly sensitive to variations in temperature and precipitation. Observations show that near surface air temperature in North Western Himalaya has increased by 0.65°C during 1991–2015, as compared to the mean global temperature rise of 0.47°C. These changes will also affect the snow and glacier melt runoff and water availability.

C. Sutlej River carries the maximum amount of silt among the Indian rivers. The maximum flows in it occur during June-August resulting from combined contribution of rainfall and snowmelt. Three floods that submerged the entire Sutlej River Basin in 1997, 2000 and 2005 have affected the Sutlej River catchment area immensely. In the last 12 years, over 40 incidents of flashflood, cloudbursts have occurred in Himachal. Most of these were extremely fierce, like

the Rakchham-Chitkul and Wangtoo (Parchu) flashflood, where even the army fell helpless. Over 350 people were killed.

D. Lying in the sensitive Himalayan belt, the region is prone to seismic activity. Scientific investigations reveal that most of the earthquakes in the region are the result of the movement along thrusts/faults. The existence of major active thrust sheets is the probable cause of the high vulnerability of the area to earthquakes and it being classified as seismic zone IV and V. Earthquakes having a magnitude greater than 5 on the Richter scale occur at frequent intervals.

E. Besides earthquakes, landslides are the other natural hazard that plagues the Sutlej River Basin. Landslides are the downslide movement of soil, debris or rocks, resulting from natural causes, vibrations, overburden of rock material, removal of lateral supports, change in the water content of rock or soil bodies, blocked drainage, etc. In the river basin, the mass movement varies in magnitude from soil creep to landslides. Solifluction (i.e., form of creep in which snow or water saturated rocks move down the slope) is another type of movement that is common on the higher snow covered ranges. The problem of landslides is common and frequent in Himachal Pradesh. Almost every year one or more major landslides affect the State. Loss of life, damage to houses, roads, and means of communication, agricultural land, and floods are some of the major consequences of landslides in the region. Flash floods, particularly in the narrow river gorges are one of the leading causes of landslides in Himachal Pradesh.

F. Dams have been criticised for the role they play in submerging forests and creating instability in relatively nascent mountains, instability that causes landslides, muck and silt to transform the ecology of local rivers. Sedimentation is seen as a problem which reduces the life of reservoirs. This raises questions about the viability and cost effectiveness of HEPs. To many planners ROR projects are the solution. But, now it is being recognised that ROR projects have their own problems in that they create considerable muck and silt. They generate huge amount of muck because of tunnelling, which when dumped causes environmental degradation. It also results in increased silt level in downstream reservoirs. This silt, when flushed out of the reservoirs, leads to further environmental problems.

G. Originating in the foothills of the Shiwalik range, Sarsa has Himachal's biggest industrial cluster at Baddi, Barotiwala, and Nalagarh located on its banks, comprising over 1000 industrial units mainly engaged in manufacturing pharmaceuticals and textiles. Of the cluster's 1000 units, 900 are classified as orange (Pollution Index Score between 41- 59), and 83 units as red (Pollution Index Score above 60) (Pollution Index is a categorization of industries by Government of India on the basis of their pollution load). Industrial discharge and urban sewage are also responsible for the pollution in Sutlej River. Notably, a large quantity of industrial effluent is discharged in both Chitti Bein and Buddha *Nallah* and both these water sources flow into the Sutlej River.

H. Encroachments in the River beds is sighted as one of the reasons or flood like situations during the monsoons as it has, over the years, reduced the water carrying capacity of the rivers, especially Sutlej. Bhakra Beas Management Board (BBMB) claimed that it had all along been

asking the district administration across Punjab to ensure the removal of encroachments and in the River beds for ensuring the natural flow of water.

I. Forests in HP have a high degree of susceptibility to forest fires and these forest fires have destroyed precious forest wealth and caused harms to the flora and fauna. It was made clear from the interview of forest officers that forest fire incidences are mainly human induced and are common during the summer season. Local people believe that the burning of forest areas improves the fodder resources by getting a fresh grass and tender herbs in the following season. Some of the common measures to mitigate this is controlled burning, and maintenance of fire lines.

J. Sutlej Landscape and pastures are under threat by invasive species and weeds. Key species of concerns are *Lantana camara* L.; *Parthenium hysterophorus* L.; *Ageratum conyzoides* L; and *Eupatorium adenophorum*. These invasive are a major issue in the subtropical and lower temperate areas in the State and affect the quality of forests and the pasture lands, and availability of fodder.

K. Land and ecosystem degradation, enhanced demands of high HEPs, excessive abstraction of groundwater are some of the major threats to the sustainability of River ecosystem.

L. Since multiple States share water and other resources (power) of the Sutlej River, controlled under the Indus Water Treaty, 1960, and several agencies involved in its use, regulation, and management of resources, often issues related to inter State, Centre State, interagency coordination and cooperation crop up.

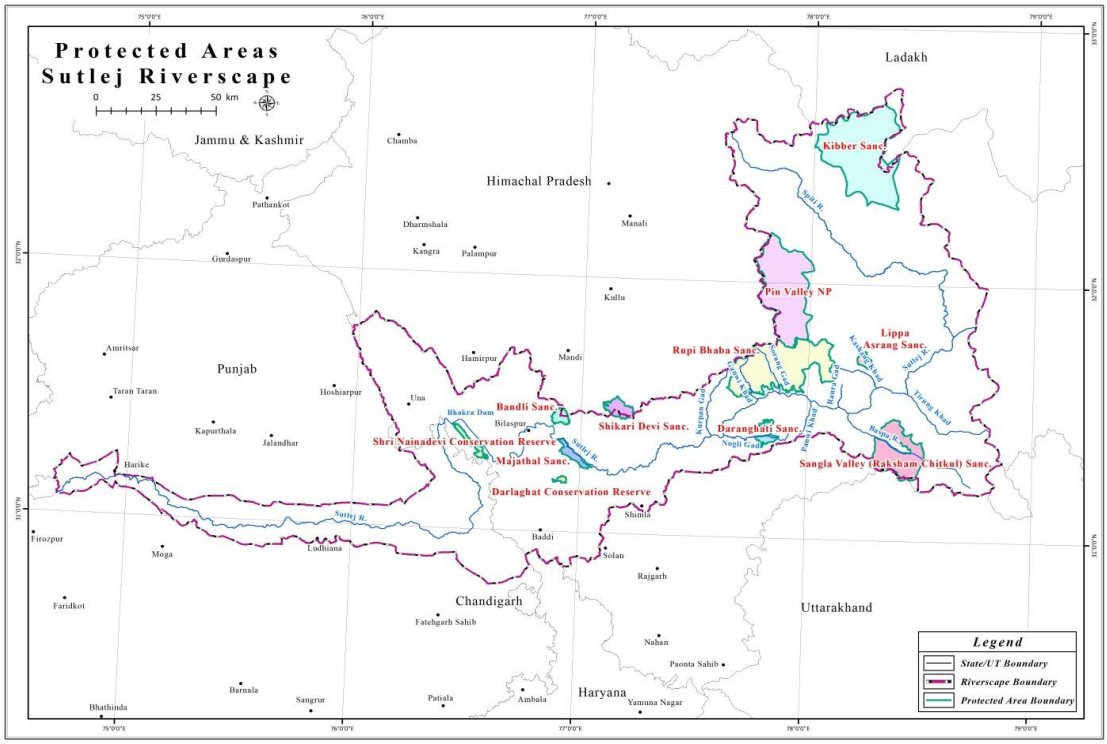


Fig.3. 2 Map of Protected Areas of Sutlej Riverscape

3.3.4 Development of Web Portal, Collection and Analysis of Primary Field Data

Above three steps of the process adopted allowed an insight on the hierarchical organizational structure of the States, River Basin, and the Forest Department, being identified as the Nodal Agency for the purpose of planning and implementation of DPR. The present project has envisaged collection of primary field data for the entire Riverscape with the support of State Forest Department (SFD), Agriculture Department and other Line Agencies. Prior to the collection of primary field data, the essential requirement was on the development of plantation and treatment models, design of field data formats and software for analysis of field data.

3.3.5 Suggested Plantation and Treatment Models

The multidisciplinary expertise available at the HFRI, Shimla has visualized three types of Landscapes within the Sutlej Riverscape. These were: (i) Natural, (ii) Agriculture, (iii) Urban Landscapes. Potential plantation models of varied nature were identified, designed and developed by the HFRI Expert Team considering the type of natural ecosystems, native vegetation, soil conditions and agro climatic zones. HFRI has suggested a variety of models for each of the Landscape type in Himachal Pradesh. The purpose of various models planned in the Natural Landscape was primarily protection, eco-restoration and conservation. Each treatment/ plantation model had incorporated details of various proposed activities planned, criteria for selection of sites, planting species, spacing, and cost norms during the establishment and maintenance phases.

The Sutlej River originates in the Himalayan Mountains and traverses a long distance in Himachal Pradesh before it descends into the plains and flows through the state of Punjab before its confluence with Beas River. By and large, there is much more resemblance in the physical and biological sub-environments between two rivers. Thus, taking a clue from the past experience on development of treatment models, the multidisciplinary expertise at HFRI developed in all 28 treatment/ plantation models specific to Natural, Agriculture, and Urban Landscapes and shared them with the SFDs of H.P. and Punjab so as to seek their valuable feedback and modify, if the need arises. Finally, based on the feedback from two States, HFRI finalized 28 treatment models to be implemented in the case of Sutlej Riverscape. These models were presented and discussed in the Final Consultative Meetings held at Punjab Forest Complex, Mohali, and through Webinar with Himachal Pradesh Forest Department. HFRI, Shimla obtained suggestions from the Experts and Participants and incorporated in treatment Plantation Models which were finally validated.

3.3.6 Design of Field Data Formats

HFRI has adopted and modified five formats earlier developed and prescribed in the context of Ganga River by FRI, Dehra Dun (Annexure 2). Five elaborate formats were meant for the collection of primary field data. Details of these five data formats, types of information required, and the procedure to collect desired information were shared with stakeholders, particularly the forest officials and frontline staff during the consultative process. Adequate soft and hard copies

of formats were made and widely distributed to forest officials and other stakeholders during the consultative process.

3.3.7 Development of Software and Web Portal

The State Forest Departments of H.P. and Punjab returned 1,296 number of duly filled in field data forms to HFRI. It necessitated taking help of software so as to effectively collate, analyze, synthesize, and interpret the voluminous data sets and retrieval of desired information relevant to each of the involved States/ Forest Divisions/ Forest Ranges and the three predefined Landscapes within the Riverscape. For this purpose, HFRI engaged a commercial vendor to develop a web based software.

3.3.8 Objective Analysis and Strategic Planning

The Chapter 1 (Section1.8.9) has already highlighted the significance of the Logical Framework Analysis (LFA) and Results Based Management (RBM) while section 1.8.10 has dwelt upon the broad objectives of River rejuvenation efforts. These concepts emphasize on the structure and clarity of a results oriented participatory planning process, the principles of 'Change' and 'Impact' of a development project, continuous monitoring and organizational learning. The consultative process with stakeholders allowed an understanding to develop the long term vision and goals that indicate the desired direction or pathways for actions and activities. In the process, it was also understood which changes the project can contribute to in the longer term and why is the project important for the society, biodiversity and the River ecosystem.

The multidisciplinary team of HFRI with resource inputs form wide range of stakeholders was able to decide the goals, objectives, outputs and outcomes that can be attained. The consultative process gave desired insight on the problems in achieving various objectives and identification of priority actions for rejuvenation of the River. Ultimately, the process also immensely helped in firming up the strategies for implementation of the project. Accordingly, it was decided that the programme implementation has to be concurrent in Natural, Agriculture and Urban Landscapes within the Riverscape. Further, a variety of Conservation and Supporting Activities would also be required for effective implementation, knowledge management and sharing, capacity development, monitoring, and adaptive management.

3.3.9 Preparation of Draft DPR – Activities, Resource Planning and Schedule

The aforesaid key steps and the process adopted ultimately helped HFRI in the preparation of draft DPR presenting the background information, situation analysis and environment of the delineated Sutlej riverscape, formulation of strategies, planning of specific activities, resource planning (i.e., manpower, equipment and the finances), and year wise schedule of operations. Draft DPR (Vol. I and II) was shared with H.P. and Punjab, SFDs and other stakeholders in the States as well as the National Level Consultation Meetings seeking their feedback and valuable inputs. Copies of the draft DPR were also submitted to the ICFRE, Dehra Dun and the MoEF&CC, New Delhi and comments were invited. Necessary presentations were also made at ICFRE and MoEF&CC for the input validation and finalization of DPR.

3.3.10 Finalization of DPR, Implementation and Monitoring

The draft DPR was finalized incorporating the feedback and specific comments received from the respective States, SFDs, ICFRE and the MoEF&CC. Initially, the implementation during Phase 1 has been planned for duration of five years, by respective States and SFDs as the Nodal Agencies. A provision for inbuilt, Results Based Monitoring has been made for continuous monitoring, organizational learning and adaptive management. The Phase II after five year implementation would deal with the scaling up of the activities and covering of the left over tributaries.

3.4 Sutlej Riverscape – Application of Remote Sensing and GIS for Spatial Analysis

Sutlej River is one of the major and perennial tributaries of the Indus River system. The main stem of Sutlej River stretches about 605 km in India. The surrounding forests, agriculture and human activities collectively exert enormous influence on the River, its flow and numerous associated ecological characteristics and processes. Vegetation cover in general and forest cover in particular, are vital and serve as indicators for the quality and functioning of the riverine environment or riverscape. Thus, the present task on the preparation of DPR for forestry interventions on Sutlej required a better insight and understanding not only of Sutlej and its tributaries but also of the surrounding lands and expanding human footprints.

3.4.1 Remote Sensing

Remote sensing techniques offer unparalleled help to monitor green and nongreen land changes in the surroundings of the River at the regional and local scales, while it also facilitates in understanding the channel dynamics, particularly channel morphology, changes in the River course, and trends in sedimentation over a long period. Recent advancements in the fields of remote sensing due to satellites with improved temporal frequency of data acquisition and better spatial and spectral resolution have offered unparalleled opportunities for resource inventory and surveys, planning, management and monitoring of varied natural and manmade resources and objects. New sensors with moderate and high resolution data have enabled evaluation of impacts on biodiversity of specific management policies (Parsad *et al.,* 2015). The accelerated rate of deforestation, forest fragmentation, and forest degradation is not only a threat to continuous supply of forest products for the livelihood of local people but also has several adverse consequences on multiple levels, particularly the downstream. Further, planning for Sutlej River management, particularly the proposed forestry interventions for Sutlej rejuvenation need a pre requisite information on the farthest bank lines during the maximum flood period for the main River and its tributaries to avoid such areas from the perspective of proposed forestry interventions. Furthermore, an insight is needed on distribution and extent of diverse forests, land use, and identification of likely available sites for proposed plantations and forestry interventions. Remote sensing technology combined with Geographic Information System (GIS), which excels in storage,

manipulation and analysis for geographic information and socioeconomic data provides a wider application. Land resources managers and environmental decision makers require quantitative information on the spatial distribution of land use types and their conditions as well as temporal changes (Hughton, 1994).

3.4.2 Geographic Information System (GIS)

Geographic Information System (GIS) is an information system working with geographically referenced spatial and nonspatial data for planning, monitoring and effective implementation of the management plans. The role of GIS is invaluable for optimal land use planning and making integrated development plans. A GIS database is a structured collection of digital spatial and nonspatial data that describes map features, spatial relationship and character of features. They may be linked to GIS through common identifier or other mechanisms. GIS has two distinct utilization capabilities, the first pertaining to querying and obtaining information and the second pertaining to integrated analytical modeling (Burroughs, 1986). However, both of these capabilities depend upon the GIS database for queried results through a GIS package having the capability of handling both spatial and nonspatial databases.

3.4.3 Global Positioning System (GPS)

The Global Positioning System (GPS) technology greatly enhances the ease and versatility of spatial data acquisition and diversifies the approaches with which it is integrated with remote sensing and GIS (Gao, 2002; Thakur *et al.*, 2017). GPS technology has rendered an excellent opportunity for location measurements and has become an essential tool for management of agricultural and natural resources.

3.4.4 Geospatial Modeling

Spatial modeling is an analytical process performed in conjunction with a geographic information system (GIS) to define the basic processes and structures of a given set of geographical features. The purpose of spatial modeling is to be able to study and mimic spatial objects or phenomena that’s work through problem solving and planning. One of the most important utilities of Geospatial data is its ability to integrate decision-making with the creation of local and unfounded information within the application framework. Geospatial modeling techniques come from the types that seek to enter the images for effective decision making and include integrated processing of multiple parameter data (mean maps and non-logical data). To address this, there are two key factors: a model / indicator that define the concept of integrated information analysis and the relative importance or weight of each parameter for the final purpose.

3.4.5 Application of RS and GIS in present assignment

Remote sensing and Geospatial modeling has much role to play in identification of suitable sites for forest plantations in the Sutlej River catchment and its tributaries. Land evaluation analysis involve the execution and interpretation of basic surveys of climate, soils, vegetation and other technical aspects of land in terms of requirement of alternative forms of land use, land use requirement of land utilization types and the availability of existing land quality and land characteristics. It has been well documented that remote sensing techniques have been highly effective and useful in this regard. The significant inputs which we can derive from remote sensing technology in the field of land evaluation are based on all cover type information which are ultimately stratified into different land units containing different land qualities and land characteristics. The ground truth information substantiates the land use requirement of land utilization types *viz*., Forest Types/Individual tree species and Management/Silvicultural practices in a particular site condition. It has been now well established that remote sensing techniques have been highly effective and useful in developing a better understanding of land evaluation and land use patterns.

The main objective of the use of RS and GIS technologies in the present assignment was for the identification, selection and delineation of suitable sites for proposed forest plantations and other forestry interventions and to relate these with the selection of appropriate plantation species on the basis of their requirements and matching with the existing qualities and characteristics of the available lands/potential sites. This essentially involves several aspects relevant to the technical, social and economic suitability of land along the delineated buffer or influence areas within the Sutlej riverscape, as it is not feasible to manually integrate, analyze and manipulate such vast amount of spatial and nonspatial data and retrieve the desired information for site suitability analysis. Hence, the use of geospatial modeling has been made in selecting suitable sites.

Remote Sensing and GIS

Image processing and GIS tools used in the present assessment were ERDAS Imagine, Geo media Professional, ArcGIS, etc. The GIS software provides the tools needed to store, analyze and display geographic information.

Satellite data used

Landsat 8 satellite data for the month November -December month of 2018 has been used for preparation of Land use/ Land cover map of the riverscape. The Row, Path along with Date of Pass of the satellite data used in the current study for the parts of two states of Himachal Pradesh and Punjab covering the riverscape is given in Table3.5 and Fig.3.3.

Table 3. 5 List of data downloaded and used in the study

State	Path	Row	Date	Satellite

Himachal Pradesh	146	037	21 Dec., 2018	Landsat 8
Himachal Pradesh	146	038	21 Dec., 2018	Landsat 8
Himachal Pradesh	147	037	10 Nov., 2018	Landsat 8
Himachal Pradesh	147	038	10 Nov., 2018	Landsat 8
Himachal Pradesh	147	039	10 Nov., 2018	Landsat 8
Himachal Pradesh	148	038	17 Nov., 2018	Landsat 8
Punjab	147	038	10 Nov., 2018	Landsat 8
Punjab	147	039	10 Nov., 2018	Landsat 8
Punjab	148	038	17 Nov, 2018	Landsat 8

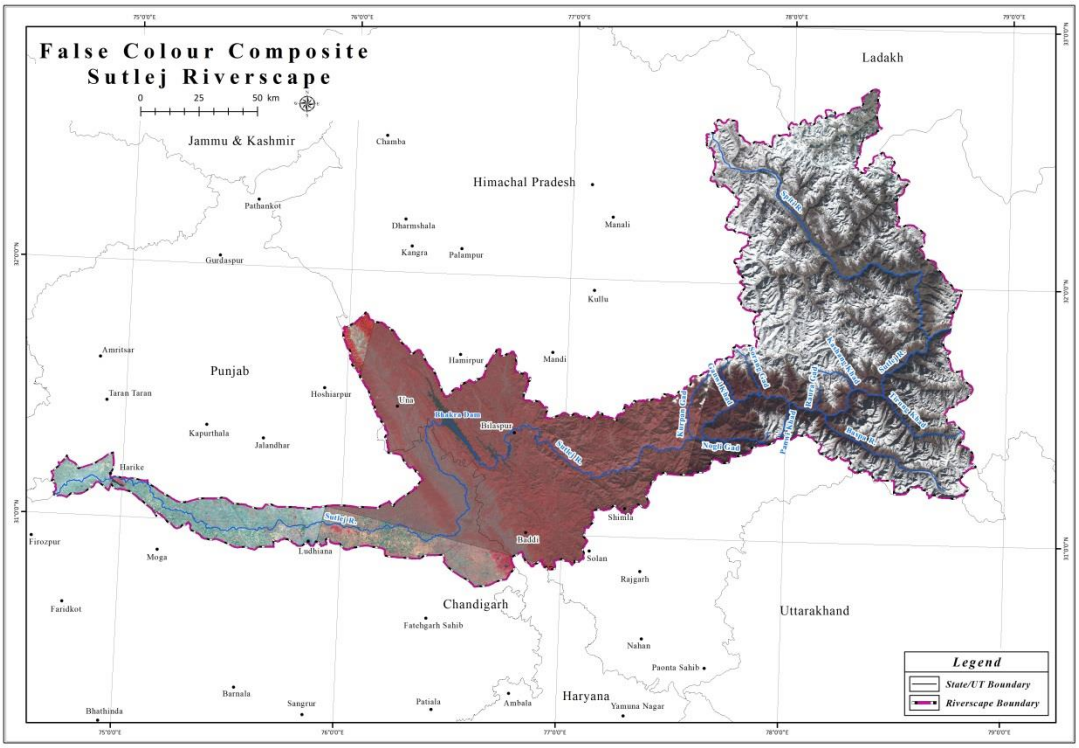


Fig. 3.3 Satellite map (False Colour Composite) of Sutlej riverscape

Ancillary data

Almost all of the ancillary information has been taken from various Government of India sources. Information about the state and district boundaries for the riverscape taken up for analysis was obtained from the Survey of India. Basin boundary, Catchment boundary, Sub Catchment boundary, Watershed boundary and Micro watershed boundaries where obtained from Soil and Land Use Survey of India, New Delhi. Village and Tehsil boundaries were obtained from the published document "Administrative Atlas of Himachal Pradesh and

Punjab (Census of India, 2011). Forest Type and Forest Density data were obtained in digital format from Forest Survey of India. Soil map and soil depth information was obtained from published maps of National Bureau of Soil Survey & Land Use Planning, Nagpur. Soil erosion data which is the backbone of multi criterion analysis was obtained in GIS format from the Indian Institute of Soil & Water Conservation, Dehradun. Topographical sheets on 1:50,000 scale obtained from Survey of India have been used for Geo reference only. Bhuvan data was also referred, wherever required for the preparation of land use map.

Data downloading

Relevant Landsat 8 satellite datasets specific to the riverscape were downloaded from ***www.earthexplorer.usgs.gov***. The time frame has been selected by keeping in mind the post monsoon seasons, maximum differentiation in various land cover features. A list of data downloaded and used is given in Table 3.6.

Map to Image registration as per accepted projection system

Image registration is one of the important components for area analysis and display of output on definite projection system as well as integration and modeling the land cover parameters. The projection parameters used in the current assessment are defined below:

Table 3.6 Projection Parameters

Projection:	**Lambert Conformal Conic**
Spheroid:	WGS84
Datum:	WGS84
First Standard parallel	12^0 28’ 22.6”
Second Standard Parallel	35^0 10’ 22.10”
Longitude of Central meridian	82^0 00’ 00.00”
Latitude of origin of projection	20^0 00’ 00.00’
False Northing	2000000 m
False Easting	2000000 m

Spatial data creation and analysis

Spatial database creation is considered as the most important step in Geospatial Modeling. Spatial integration of basic layers is of utmost importance from the perspective of study/ assessment.

Pan sharpening of Landsat Imagery

In this operation the 30m multispectral image was sharpened using the 15m panchromatic imagery. This operation was to enhance the spatial resolution of the multispectral imagery while preserving the spectral information. The pan sharpening was performed on the Landsat 8 image using the HPF resolution merge algorithm in ERDAS software.

Delineation of Riverscape Boundary

Initially, Landsat 8 satellite images of 2018 were used for the digitization of main stem and major tributaries taken into consideration the current DPR. The SOI topographical sheets of 1:50000 scale were used as a reference for the identification of the streams. Furthermore, a tentative riverscape boundary was created, covering 5 km on either side of the bank line for the main channel of Sutlej flowing through Punjab and the entire catchment area as per the demarcation of the same by Soil and Land Use Survey of India in the maps from Micro watershed atlas of India was used. In the later stage of the preparation of this DPR, stakeholder consultation resulted in the idea to merge micro watershed boundaries in the Plains of to arrive at the final riverscape used in the current study. In other words the 24,110.83 km^2 riverscape area which comprises of the total catchment area has been demarcated by considering the whole sub catchment area falling within Himachal Pradesh and selected micro watershed boundaries merged together for the state of Punjab.

Selection and Demarcation of Watershed Boundaries up to Micro watersheds

The sites for adoption of various treatment models of propose forestry interventions have been carefully selected considering the geospatial analysis, modeling and resultant prioritization of treatment areas. The following section, thus, presents the geospatial analysis and findings of modeling and prioritization of sites for proposed interventions.

(i) Watershed boundary up to Micro Watershed

The watershed boundaries up to micro watershed level were delineated using source maps from Soil and Land Use Survey of India, New Delhi. Each micro watershed has been depicted with a code as per the codifications standards in five stages. All the seven stages are described below to offer an understanding of the codes.

Stage One – Water Resource Regions (denoted by Arabic Numbers) for example 1,2,3

1. Indus drainage

2. Ganges drainage

3. Brahmaputra drainage

4. All drainage flowing in Bay of Bengal except Sl. No. 2 & 3.

5. All drainage flowing into Arabian Sea except at Sl.No. 1

6. Western Rajasthan mostly ephemeral drainage.

Stage Two – Basin – Each Water Resource Regions (WRR) was divided into a basin which constitutes big individual rivers. They were denoted by Capital English alphabets suffixed to WRR code for example A, B, C. Thus, the basin will be denoted as 1A Sutlej River.

Stage Three – Catchments: Each basin was further divided into a number of catchments which mainly pertains to main tributaries or a group of contiguous small tributaries or individual stream. They were denoted by Arabic number suffixed to Basin Code for example 1, 2, 3….. Thus catchments were expressed as 1A1.

Stage Four– Sub catchments: The Subcatchments were further subdivided into a number of subcatchments which were mainly smaller tributaries or streams. They were denoted by capital English alphabets suffixed to catchment code as A, B, C …… Expressing the sub-catchment as 1A1A.

Stage Five – Watersheds – Each sub catchment were divided into a number of watersheds, which was the smallest hydrological unit delineated in 1: 1 m Watershed Atlas of India in the macro level category. They were denoted by Arabic numbers suffixed to sub-catchment code for example 1, 2, 3 and watershed will be symbolized as 1A1A7.

Stage Six – Sub watersheds: This delineation and codification was transferred in 1: 50,000 Survey of India topo maps for further delineation at micro level. The watersheds were subdivided in sub watersheds which are either the banks of small tributaries or discreet streamlet. They were denoted by small English alphabets suffixed to code of watershed. However, the use of i.e., 0 and l alphabets are avoided. Thus the sub watershed will be expressed as, 1A1A7a.

Stage Seven– Micro watersheds: The sub-watersheds were further divided to the smallest micro-level hydrological unit i.e. micro-watersheds which are part of small streams or streamlets. They were denoted by Arabic numbers but restricted to 9 only and suffixed to sub-watersheds code. This completed the delineation and codification at micro-level. Thus the micro-watershed was coded as 1A1A7a1, 1B1A2a9, etc. The micro-watershed code 1A1A7a1 represents water resource region 1, basin 1A, catchment 1A1, sub-catchment 1A1A, watershed 1A1A7, and sub-watershed 1A1A7a. (Source: MICROWATERSHED ATLAS OF INDIA).

It is using this dataset that the layers of Catchment of Sutlej River, followed by Sub Catchment (Table. 3.7, Fig 3.4), Watershed (Table 3.8 & Fig. 3.5), Sub Watershed and

Micro Watersheds (Fig 3.6, Fig 3.7) were derived. The lists under each category falling within Riverscape along with the maps are given below:

Table 3.7 Distribution of riverscape area under various sub-catchment categories

Sub-Catchment	Area Covered (km^2)	Area Percentage (%)
1A1D	2,028.05	8.41
1A2A	2,457.08	10.19
1A2B	4,036.44	16.74
1A2C	4,892.29	20.29
1A2D	6,740.75	27.96
1A1B	1,738.73	7.21
1A1C	1,325.96	5.5
1A1D	677.91	2.81
1B1A	213.62	0.89
Total	**24,110.83**	**100.00**

(Source: Micro watershed Atlas of India)

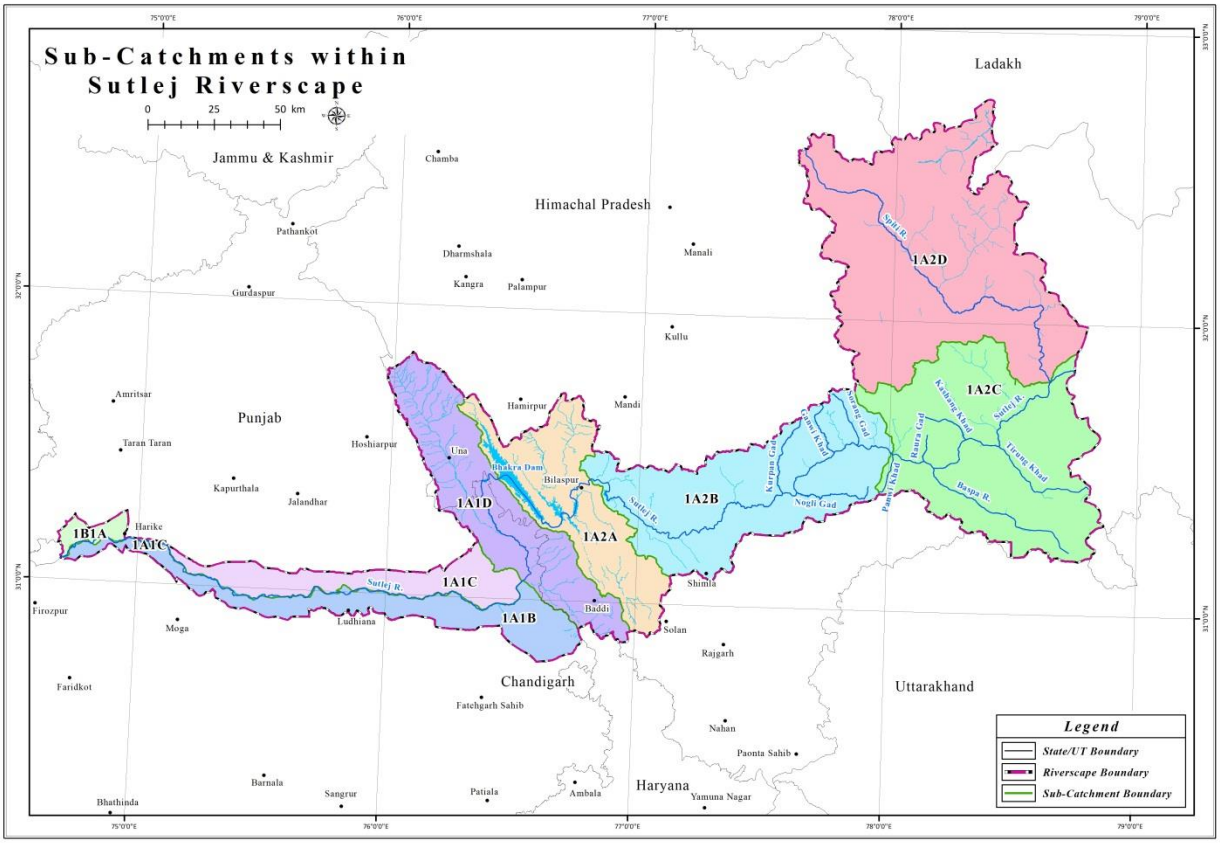


Fig. 3.4 Map of Sub catchments within Sutlej Riverscape

Table 3.8 Distribution of riverscape area under various watershed categories

Watershed	Area Covered (km^2)	Area Percentage (%)

1A1D1	580.92	2.41
1A1D2	284.33	1.18
1A1D3	488.24	2.02
1A1D4	674.56	2.80
1A2A1	657.74	2.73
1A2A2	643.75	2.67
1A2A3	486.47	2.02
1A2A4	669.12	2.78
1A2B1	967.35	4.01
1A2B2	714.85	2.96
1A2B3	689.93	2.86
1A2B4	613.16	2.54
1A2B5	685.05	2.84
1A2B6	366.10	1.52
1A2C1	632.47	2.62
1A2C2	1,251.92	5.19
1A2C3	650.50	2.70
1A2C4	1,040.81	4.32
1A2C5	621.65	2.58
1A2C6	694.94	2.88
1A2D1	654.10	2.71
1A2D2	984.85	4.08
1A2D3	1,237.04	5.13
1A2D4	616.47	2.56
1A2D5	438.26	1.82
1A2D6	899.28	3.73
1A2D7	1,060.07	4.40
1A2D8	850.68	3.53
1A1B1	92.49	0.38
1A1B4	427.09	1.77
1A1B5	641.13	2.66

1A1B6	578.02	2.40
1A1C1	15.32	0.06
1A1C5	719.71	2.99
1A1C6	590.93	2.45
1A1D1	22.27	0.09
1A1D2	508.21	2.11
1A1D3	147.43	0.61
1B1A2	213.62	0.89
Total	**24,110.83**	**100.00**

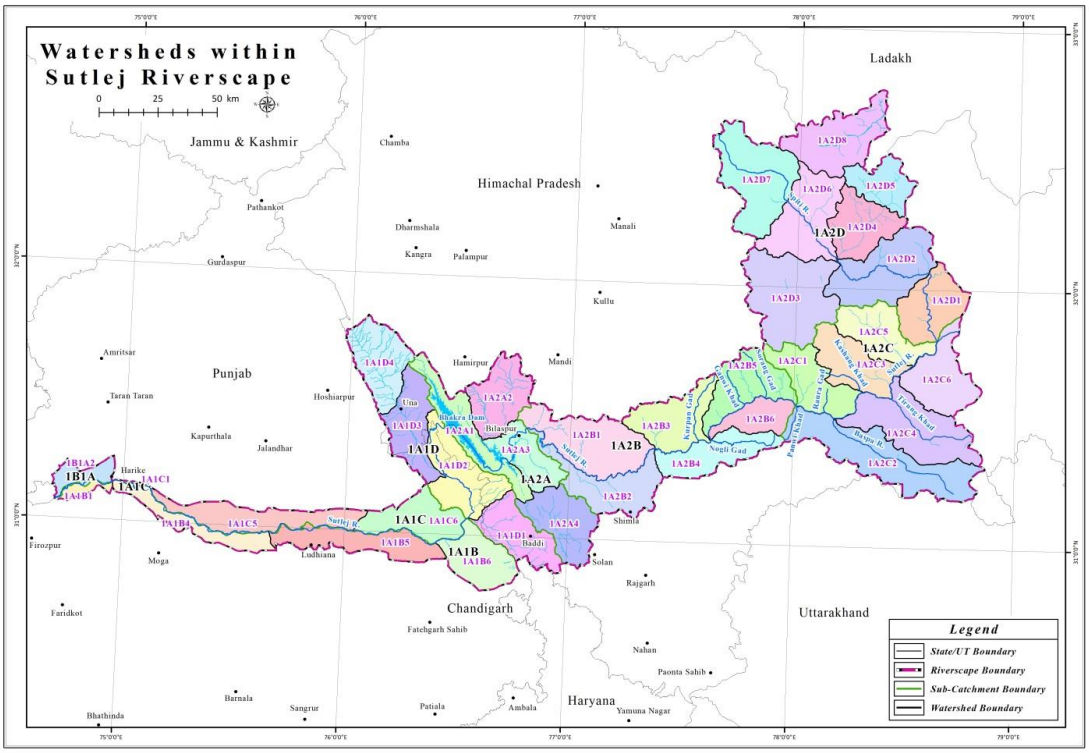


Fig. 3.5 Map of Watersheds within Sutlej Riverscape

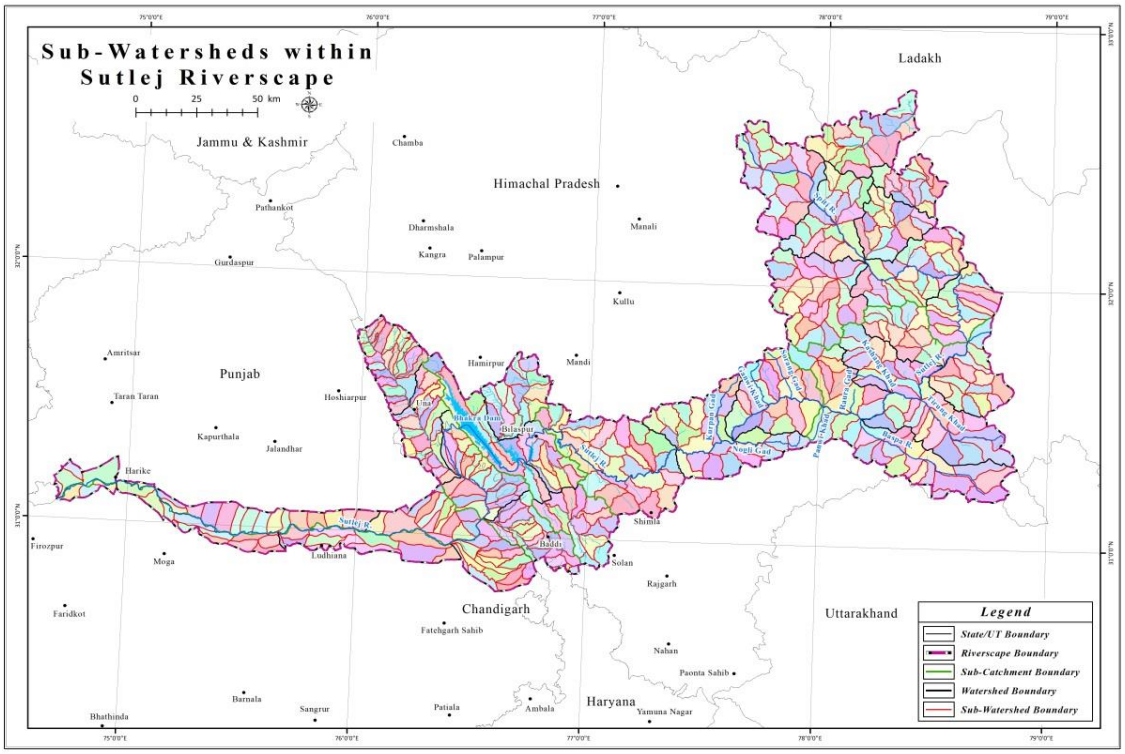


Fig. 3.6 Map of Sub watersheds within Sutlej Riverscape

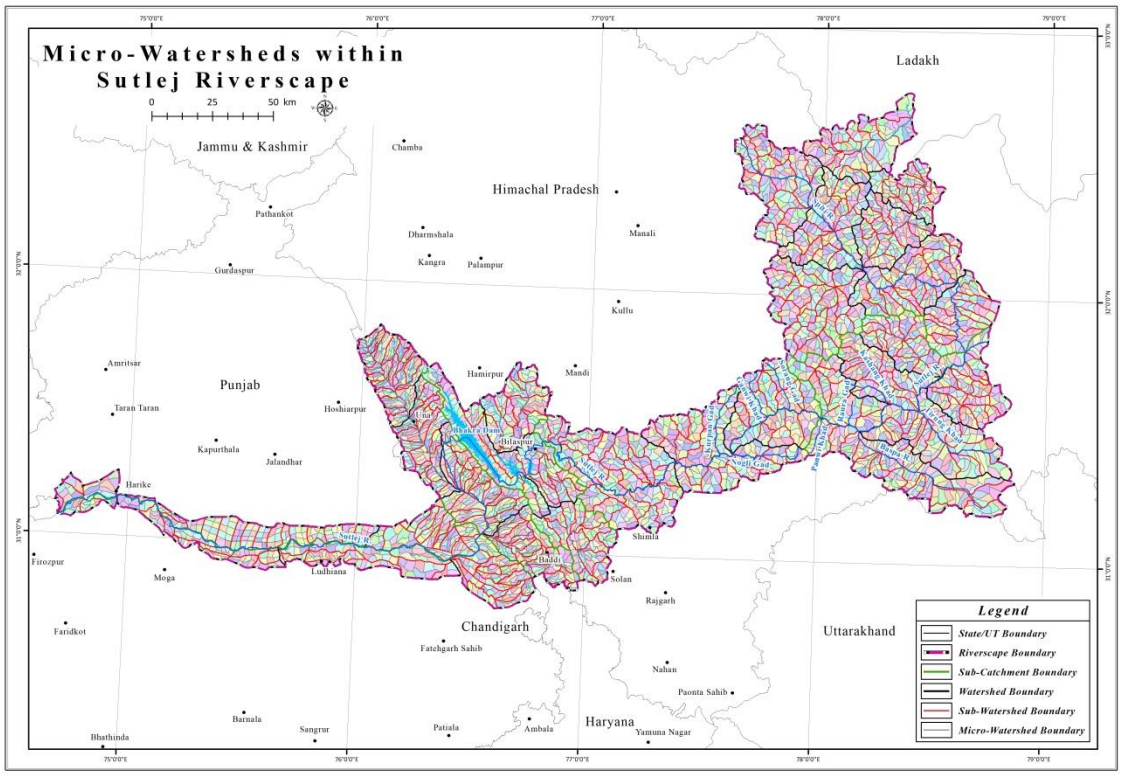


Fig. 3.7 Map of Micro watersheds within Sutlej Riverscape

3.4.6 Modelling for Prioritization of Sites for Forestry Interventions through Geospatial Analysis of the Sutlej Riverscape

The Purpose of the present DPR on forestry interventions for rejuvenation of Sutlej River is to approach to the delineate Sutlej Riverscape, its geospatial analysis and criteria for modelling to prioritize sites for proposed forestry interventions within the delineated riverscape. Further, the preceding section has described the physical and biological sub environments of the Sutlej Riverscape so as to comprehend the existing situation of the physical conditions and biological diversity within the riverscape and at the same time to appreciate the factors responsible for the current state of the environment and degradation of natural resources, particularly the River ecosystem, the analysis of River environment also helped in understanding the past trends and in recognizing the major challenges, issues, threats and constraints relevant to conservation of Sutlej River Ecosystem. The following section presents the findings based on geospatial analysis of the Sutlej Riverscape and priority sites identified for forestry interventions on the basis of multi criteria modelling performed for the purpose.

a) Altitude and Digital Elevation Model (DEM)

The riverscape form North East to South West direction depicts large altitudinal variation from 134m amsl to very high altitude of 6,722m amsl. Altitude plays an important role in the physical characteristics, biological diversity and its distribution and socio economic uses and consumption patterns. In particular, higher altitudes greatly influence River flow, rate of sedimentation, vegetation, wild animal use and even human settlements and their uses. Advanced Land Observing Satellite based digital elevation model (ALOSDEM) data was downloaded from http://www.asf.alaska.edu/ and used to derive the elevation classes (Fig 3.8). The different elevation classes were re grouped, and a total of elevation classes have been derived (Fig 3.9). The distribution of areas under different elevation classes within the riverscape is given in Table 3.9 revealed that the maximum extent of km^2 or area of the riverscape, lies in the lowest category of the elevation class i.e. Less than 250 m.

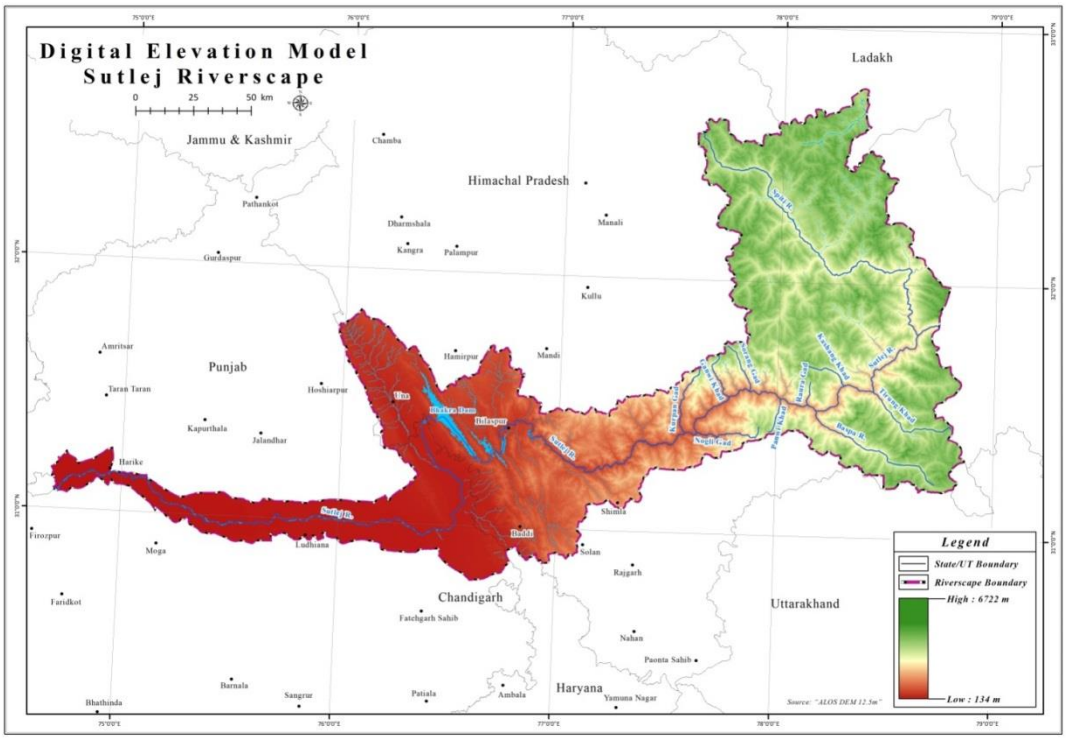


Fig. 3.8 Digital Elevation Model of Sutlej Riverscape

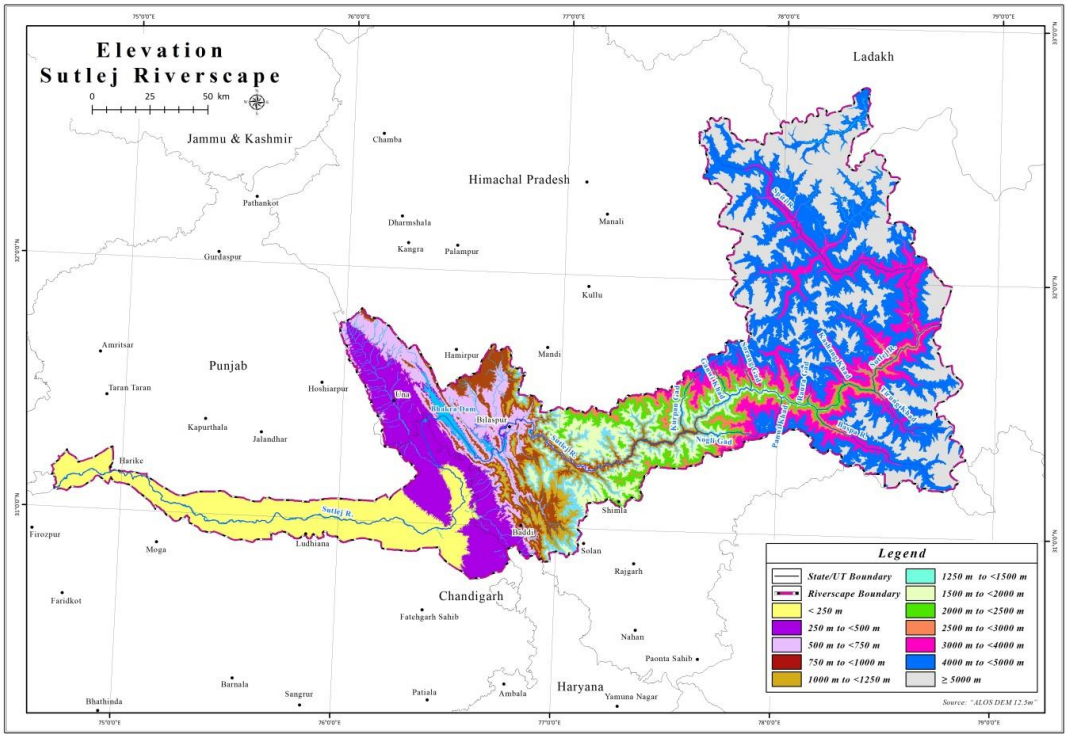


Fig. 3.9 Altitudinal variation in Sutlej Riverscape

Table 3.9 Distribution of Area under Different Elevation Classes in Sutlej Riverscape

Sr. No.	Elevation Classes (meter)	Area (km^2)	Percentage of Total Area (%)
1.	<250	2,920.37	12.11
2.	250 - <500	2,547.59	10.57
3.	500 - < 750	1,459.98	6.06
4.	750 - <1000	1,062.98	4.41
5.	1000 - <1250	749.58	3.11
6.	1250 - <1500	681.29	2.83
7.	1500 - <2000	1,182.29	4.9
8.	2000 - <2500	887.25	3.68
9.	2500 - <3000	784.69	3.25
10.	3000 - <4000	2,223.45	9.22
11.	4000 - <5000	5,076.91	21.06
12.	≥5000 m	4,534.45	18.81
Total		**24,110.83**	**100**

b) Slope

Slope information is considered vital while suggesting suitability of areas for forestry interventions, particularly plantations. The higher degree of slopes (>30°) usually cause a lot of soil erosion and are prone to landslides, greater runoff, etc. Thus, areas with slopes >30° to 45° require safeguards from erosion while raising plantations of multiple values (fuelwood, fodder, small timber, etc.). These types of forest resources are in heavy demand in higher reaches by increasing pressure of pilgrimage, presence of paramilitary forces, transhumance pastorals and widespread human settlements. A total of 10 classes of slope have been derived in the riverscape. The distribution of areas under different slope classes is given in Table. 3.10; Fig. 3.10.

Table 3.10 Distribution of Area of Sutlej Riverscape under Different Slope Categories

Sr. No.	Slope (Degrees)	Area (km^2)	Percentage of Total Area (%)
1	<2.5°	2,844.99	11.8
2	2.5°- <5°	2,069.31	8.58
3	5°- <10°	1,875.42	7.78
4	10°- <15°	1,734.77	7.19
5	15° -<20°	2,061.55	8.55
6	20°- <25°	2,300.23	9.54
7	25°- <30°	2,776.23	11.51
8	30° <35°	2,777.16	11.52
9	35° <40°	2,341.31	9.71

10	≥40°	3,329.86	13.81
Total		**24,110.83**	**100**

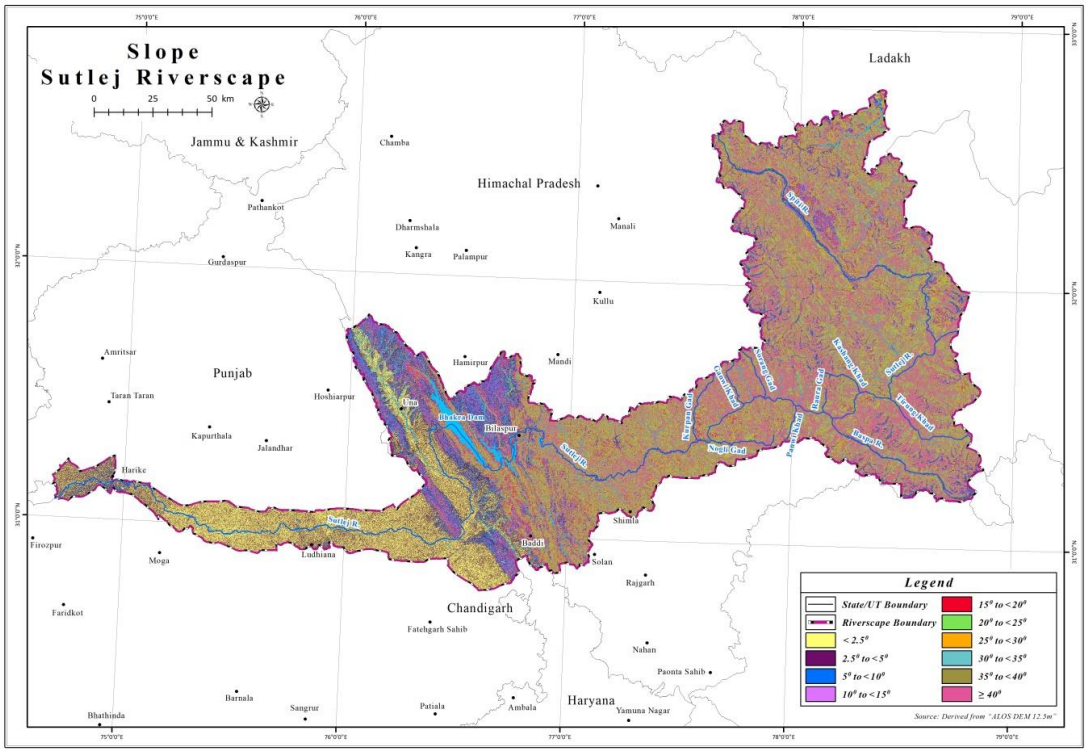


Fig. 3.10 Different Slope Categories Distribution map of Sutlej Riverscape

c) Aspect

Aspect, particularly in the Himalaya, influences the diversity and distribution of vegetation and microclimate. In the Himalaya, this effect can be seen to an extreme degree. North and South facing opposing slopes vary in their microclimate; light intensity, soil and air temperature, humidity, soil moisture and evaporation and duration of growing periods and these differences are closely associated with differences in vegetation composition and structure. The aspect map has been derived from the ALOS DEM. A total of nine categories viz., North, North East, East, South East, South, South West, West, North West and the Flat land have been analyzed in the study area. The distribution of areas under different aspect classes are given in Table 3.11; Fig. 3.11.

Table 3.11 Percentage Distribution of Total area in Different Aspect Categories of Sutlej Riverscape

Sr. No.	Aspect	Area (km^2)	Percentage of Total Area (%)
1.	Flat (1)	692.25	2.87
2.	North (0- <22.5; 337.5 -<360)	2,743.68	11.38
3.	Northeast (22.5 -<67.5)	2,971.73	12.33
4.	East (67.5 -<112.5)	2,841.95	11.79

5.	Southeast (112.5- <157.5)	2,938.76	12.19
6.	South (157.5- <202.5)	2,836.91	11.77
7.	Southwest (202.5- <247.5)	3,365.32	13.96
8.	West (247.5 - <292.5)	2,892.76	12
9.	Northwest (292.5 -<337.5)	2,827.47	11.73
Total		**24,110.83**	**100**

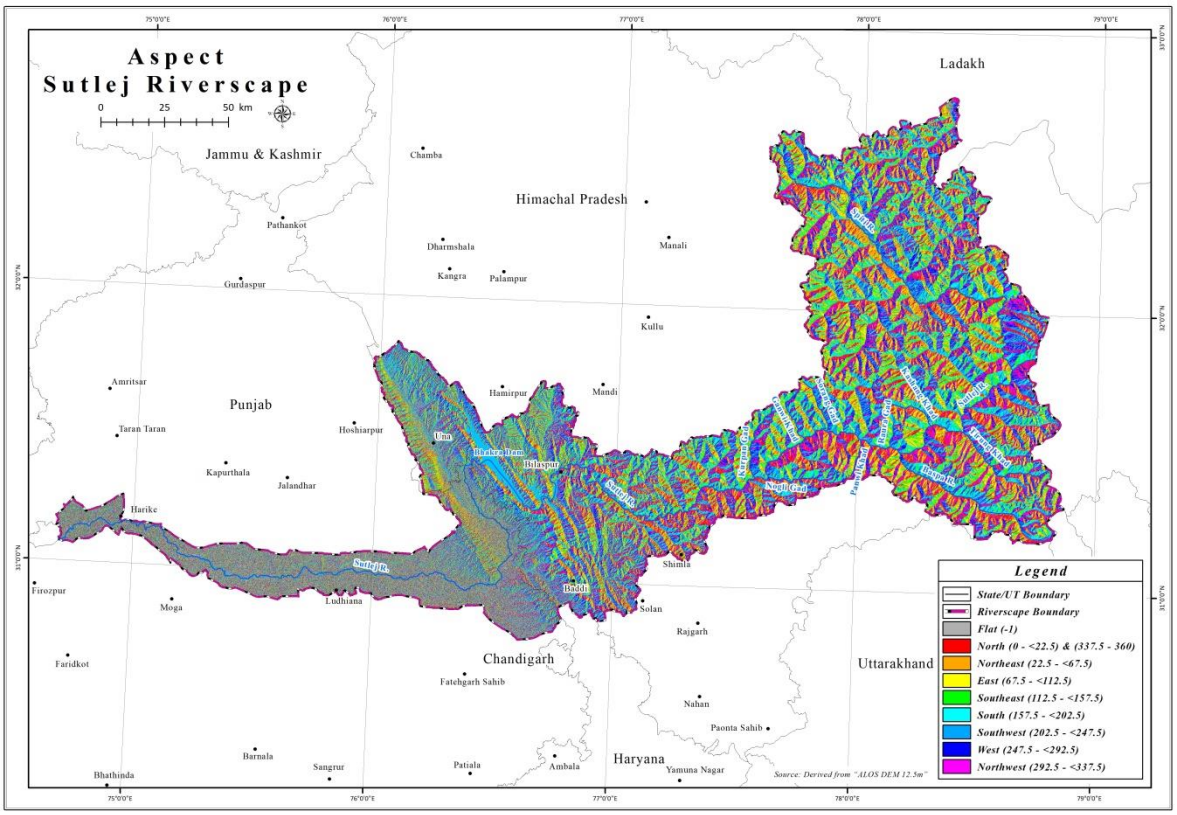


Fig. 3.11 Map Showing Distribution of Aspect in Sutlej Riverscape

d) Soil Types

Organic matter, minerals, gases, liquids, and organisms are the main components of the Soil mixture that together supports life. Pedosphere constitutes the body of earth's soil and mainly performed four major functions. These functions are categories as: (a) supportive medium for plant growth, (b) functions as resources for water storage, supply and purification, (c) assist in modification of earth's atmosphere and store carbon, and (d) provide environment for a wide-ranging organisms including invertebrates, microorganisms, etc. Soil is a product of several factors *viz*., the influence of climate, relief (elevation), orientation, slope of terrain, organisms, and the soils parent materials (original minerals) interacting over time. Soils continuously undergo development by way of numerous physical, chemical and biological processes including weathering and associated erosion. Natural ecosystems (forests, grasslands, wetlands and agro

ecosystems) are impacted in far reaching ways by the various processes carried out in the soil. Hence, from the perspective of present DPR, understanding of soils in the riverscape is critical as they form an important biotic variable that determines the suitability of site conditions for proposed forestry interventions, mainly tree and other plantations (grass, herbs, shrubs, medicinal and aromatic plants, orchids, etc.). Since choice of species mainly depend upon the soil type and soil depth, these parameters have been derived from the Soil map prepared by the NBSSLUP for further use in modelling in the present study on geospatial analysis. A total of soil type classes have been recorded in the Riverscape (Fig. 3.12). Various soil types and their proportionate area estimates are given in Table 3.12.

Table 3.12 Distribution of Area under Different Soil Types and Other Land Attributes in Sutlej Riverscape

Sr. No.	Soil type	Area (km^2)	Percentage of Total Area (%)
1.	**Dystric Eutrochrepts:** Deep, well drained, thermic and fineloamy soils on very steep slopes with loamy surface and severe erosion.	1,392.90	5.77
2.	**Fluventic Ustochrepts:** Very deep, moderately well drined coarse loamy soils, occurring on very gentle slopes in active alluvial plains with fluvial parent material.	51.84	0.22
3.	**Lithic Cryorthents:** Poorely developed soils, semipermanent snow, bank is simply a thin sandy Ahorizon over a Chorizon.	732.15	3.04
4.	**Typic Cryochrepts:** Soils of glaciogluvial valley with moderate slopes occupied with moderately shallow.	19.47	0.08
5.	**Typic Cryorthents:** Soils of glaciogluvial valley with moderate slopes occupied with moderately shallow, excessively drained, sandyskeletal, neutral to slightly acidc, moderately eroded, and strongly stony.	5,612.74	23.28
6.	**Typic Eutrochrepts:** Deep, well drained, thermic, fineloamy, calcareous soils on moderately steep slopes with loamy surface and severe erosion.	1,453.16	6.03
7.	**Typic Udifluvents:** Have moderately good or good drainage, occur in relatively high areas on flood plains, and the water table is deeper than 50 cm all of the time.	977.29	4.05
8.	**Typic Udorthents:** Found on moderate to steep slopes, are slightly to moderately acidic, moderately eroded, and moderate to strong stony.	8,591.91	35.64
9.	**Typic Ustifluvents:** Very deep imperfectly drained fine soils occurring on flat to nearly level active alluvial plain.	1,346.62	5.59
10.	**Typic Ustipsamments:** Sand that have deep ground water and a thick regolith.	667.30	2.77
11.	**Typic Ustochrepts:** Coarseloamy soils derived from mixed alluviam or residium weathered from sand stone and shale.	1,026.16	4.26
12.	**Typic Ustorthents:** Soils those are deep or moderately deep to hard rock and those do not have ground water within 150 cm.	1,122.47	4.66
13.	**Udic Ustochrepts:** Coarseloamy soils derived from mixed allluviam or residium weathered from sand stone and shale.	559.44	2.31

14.	**Non Soil:** Areas that do not support plant growth are not considered but mapped. These may be glaciers, bedrock outcrops, urban land, active quarries, etc.	557.38	2.3
Total		**24,110.83**	**100**

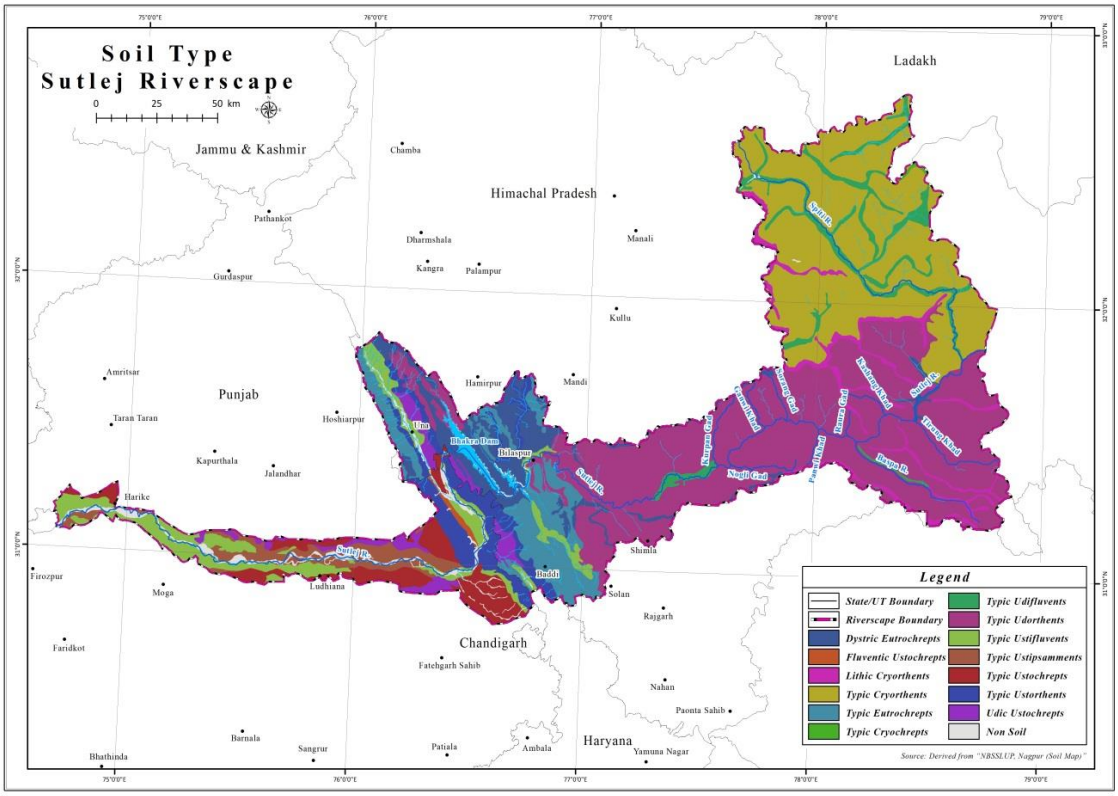


Fig. 3.12 Distribution of Soil Types in Sutlej Riverscape

e) Soil Depth

Soil depth, in addition to soil type texture and structure can influence water availability, limit root growth and can influence nutrient access. Soil depth can greatly influence the type of plants that can grow in them. Deeper soils generally provide more water and nutrients to plants than more shallow soils. Thus, soil depth is another important variable for suggesting suitability of tree species for a plantation model. The depth is important for the penetration of the roots of plant or tree species. Five depth classes, *viz.* Very Deep, Moderately Deep, Deep, moderately shallow and Shallow have been mapped (Fig. 3.13). These areas could be suggested as suitable for plantations based on other ground parameters. The distribution of area under different soil depth classes is given in Table 3.13. Nearly 41.37% area of the riverscape has moderately deep soils while shallow soils accounted for 23.88% area of the riverscape. About 12.75% area of the Riverscape has very deep soils while 18.12% area harbours deep soils. Shallow soils are distinctly prominent in the northern and south eastern part of the Riverscape. The larger mountainous part of the Riverscape in Himachal Pradesh has moderately deep to deep soils. Very deep soils were conspicuously prominent in the alluvial plains or North Western, lower part

of the Riverscape. The moderately deep soils predominantly occurred around the course of the main channel and various tributaries.

Table 3.13 Distribution of Area under Different Soil Depth Categories in Sutlej Riverscape

Sr. No.	Soil Depth	Area (km^2)	Percentage of Total Area (%)
1.	Very Deep	3,073.21	12.75
2.	Moderately Deep	9,974.85	41.37
3.	Deep	4,368.74	18.12
4.	Moderately Shallow	379.43	1.57
5.	Shallow	5,757.22	23.88
6.	Non Soil	557.38	2.31
Total		**24, 110.83**	**100**

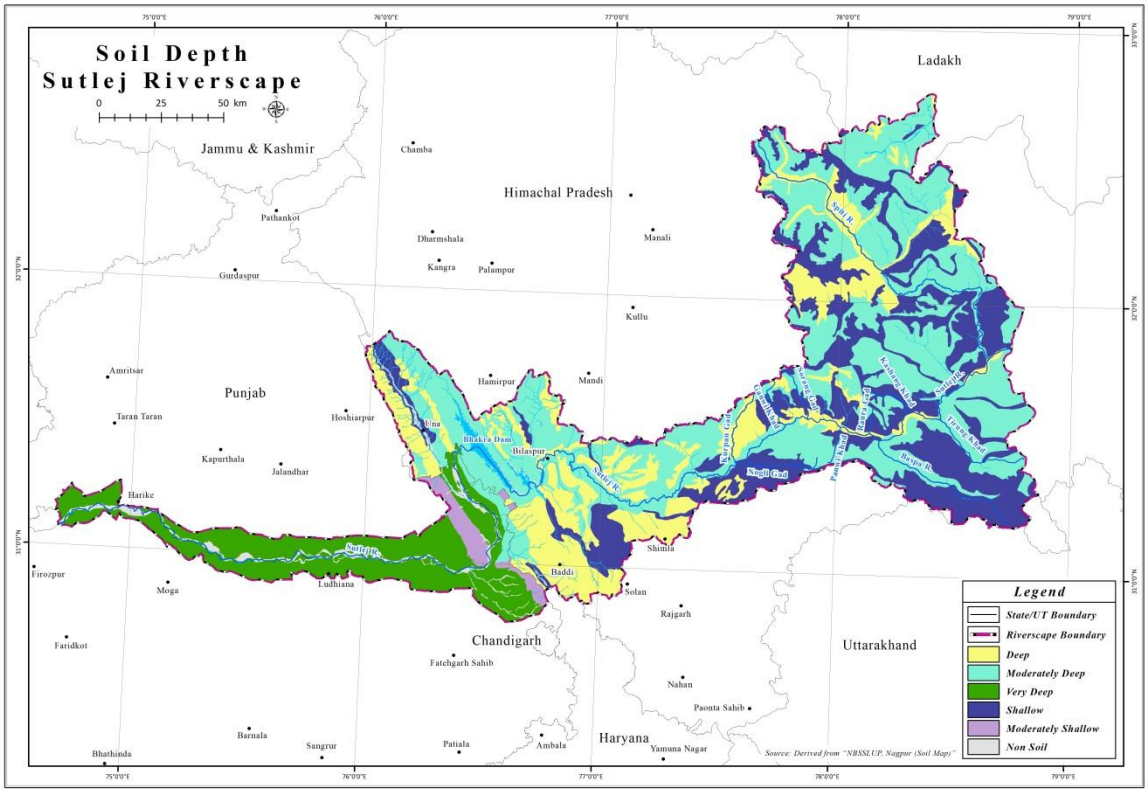


Fig. 3.13 Soil Depth variation in Sutlej Riverscape

f) Soil Erosion

Displacement of the upper layer of soil is called Soil erosion and it is the one form of soil degradation. It is a naturally occurring process mainly caused by the vigorous activity of erosive agents i.e. water, ice, snow, air, plants, animals, and humans that affects all landforms. It is a

slow process that is hardly noticed, or it may occur at an alarming rate causing a serious loss of top layer of soil. Anthropogenic activities like intensive agriculture, deforestation, construction/ widening of roads, construction of hydroelectric projects, urban sprawl and erratic climatic conditions are some of the prominent factors responsible for soil erosion in the mountainous catchment of Sutlej River. Based on information obtained from the Indian Institute of Soil and Water Conservation, Dehra Dun, an insight on the status of soil erosion within the Sutlej Riverscape has been developed. Altogether, total five categories of erosion classes have been recorded in the riverscape, *viz*. < 5 t/ha/yr; 5 <10 t/ha/yr; 10 < 20 t/ha/yr; 20 <40 t/ha/yr; and ≥ 40 t/ha/yr. The distribution of areas under different erosion classes and their proportion are given in Table 3.14. An area of 10,568.47 km^2 falls under non-soil category. These areas may not be suitable for forest plantations (Fig. 3.14).

Table 3. 14 Distribution of Soil Erosion Categories in Sutlej Riverscape

Sr. No.	Soil Erosion (t/ha/yr)	Area (km^2)	Percentage of Total Area (%)
1.	<5	2,886.24	11.97
2.	5 - <10	1,677.46	6.96
3.	10 - <20	4,724.58	19.6
4.	20 - <40	2,693.97	11.17
5.	≥40	1,560.11	6.47
6.	Non Soil	10,568.47	43.83
Total		**24, 110.83**	**100**

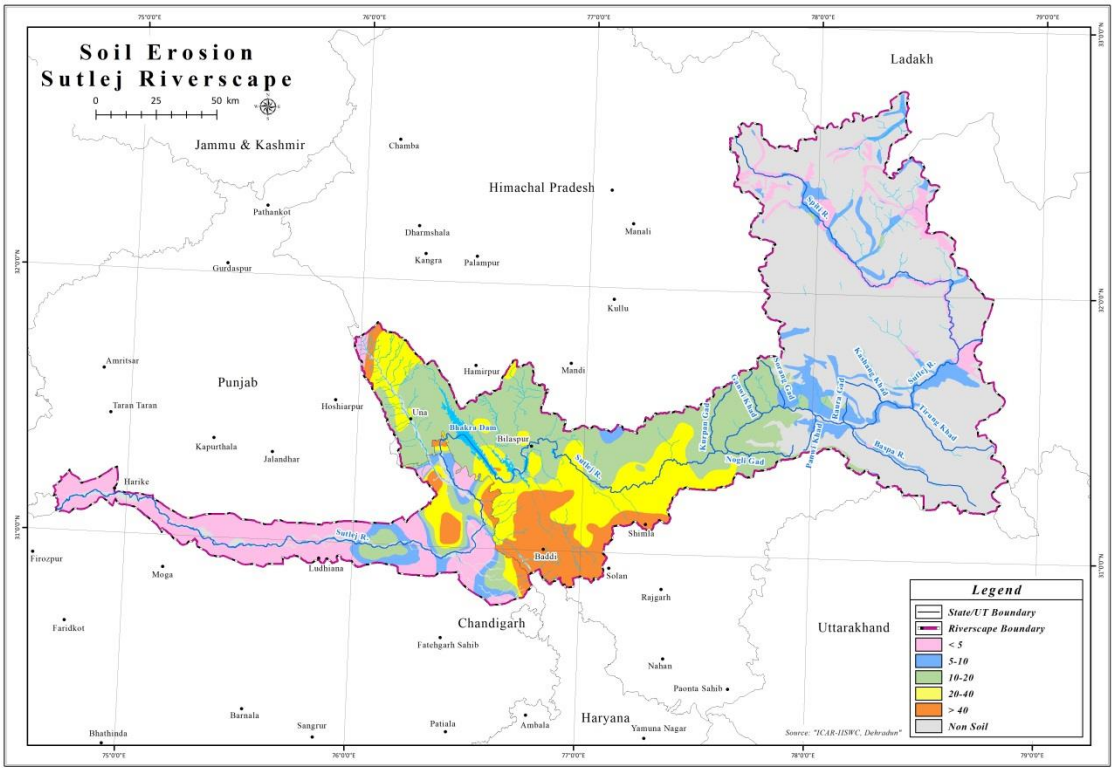


Fig. 3.14 Soil Erosion Map of Sutlej Riverscape

g) Forest Types and Forest Density

The information on forest types are of utmost importance in suggesting suitable sites for forestry interventions based on areas which do not have dense forest cover, or which fall in the categories of scrub or grasslands along the riverbanks. The forest type and cover map have been prepared using data provided by the Forest Survey of India. Altogether, seven forest types and one non forest categories were recorded in the Sutlej Riverscape. The non-forest category contributed almost 77.2% area of the riverscape. Thus, Scrub occurred only in about 3.19% area of the riverscape. The subtropical pine forest recorded the maximum area amongst various forest types and represented about 6.75% area of the riverscape. The Himalayan moist temperate forest represented about 5.53% area of the riverscape. Tropical dry deciduous forests covered 1,213.76 km^2 and covered 5.03% area of the riverscape. Subalpine forests and dry alpine forests together covered nearly 5.59 and 75.04% area respectively of the riverscape (Table 3.15), on distribution of different forest cover categories in the Sutlej Riverscape revealed that a greater proportion (77.2%) of the riverscape falls under non forest category (Fig. 3.15). Out of remaining area under different forest cover categories, the moderately dense forest occupied the highest cover and represented 7.31% of all forest types. Dense forests constituted 4.68% of all forest cover categories. The open forests represented 7.63% area of all forest types while scrub represented a meagre proportion of 3.19% of all forest types (Table 3.16, Fig. 3.16). The Himalayan Moist

Temperate Forests and Himalayan Dry Temperate Forests mainly concentrated around Kinnaur, Shimla and Kullu (Fig 3.17). Two forest types *viz*. Sub-Alpine Forest and Dry Alpine Forest in very small patches predominantly concentrated mainly in Kinnaur and Shimla District. The non forest area in two larger pockets was prominent in the riverscape, firstly, in north eastern area and secondly, in the south western portion of the alluvial plains (Fig 3.18). Forests within the riverscape belonging to two States (Himachal Pradesh and Punjab) are managed by 32 Forest Divisions, 133 Forest Ranges, 232 Forest Blocks and 730 Forest Beats. Out of total 32 Forest Divisions, 22 Forest Divisions are within Himachal Pradesh while remaining 10 FDs are in Punjab (Table 3.17). A small proportion of Kullu, Hamirpur and Suket FDs are covered in the riverscape. Likewise, the riverscape incorporates parts of Roopnagar, Mohali, Nawanshahr, Jalandhar, Ludhiana, Amritsar and Ferozepur Forest Divisions in Punjab (Fig. 3.19).

Table 3. 15 Distribution of Area under Different Forest Type Categories in Sutlej Riverscape

Sr. No.	Forest Type	Area (km^2)	Percentage of Total Area (%)
1.	Dry Alpine Forests	75.04	0.31
2.	Himalayan Dry Temperate Forests	428.29	1.78
3.	Himalayan Moist Temperate Forests	1,333.08	5.53
4.	Sub Alpine Forests	51.59	0.21
5.	Subtropical Pine Forests	1,627.33	6.75
6.	Tropical Dry Deciduous Forests	1,213.76	5.03
7.	Scrubs	768.06	3.19
8.	Non Forest	18,613.68	77.2
Total		**24,110.83**	**100**

Table 3. 16 Distribution of Area under Different Forest Cover Categories in Sutlej Riverscape

Sr. No.	Forest Cover	Area (km^2)	Percentage of Total Area (%)
1.	Dense Forests	1,127.44	4.68
2.	Moderately Dense Forests	1,762.55	7.31
3.	Open Forests	1,839.14	7.63
4.	Scrubs	768.06	3.19
5.	Non Forests	18,613.64	77.19
Total		**24,110.83**	**100**

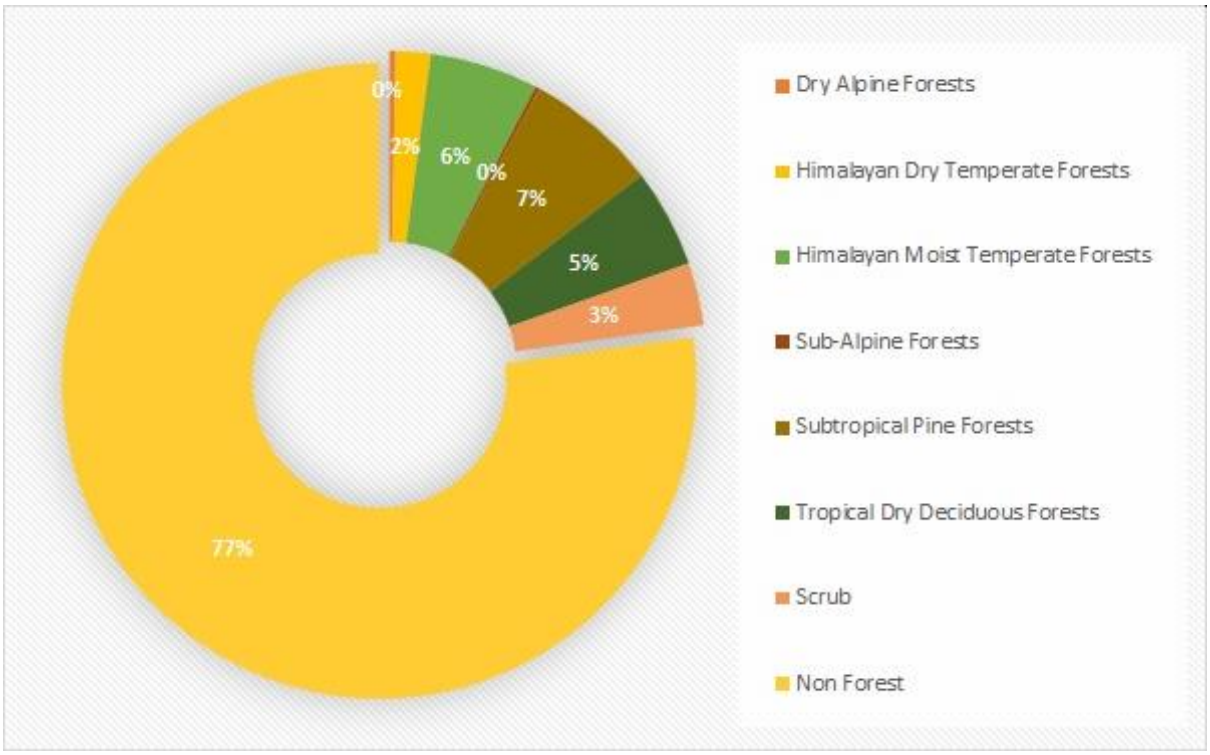


Fig. 3.15 Distribution of Area under Different Forest Types Categories in Sutlej Riverscape

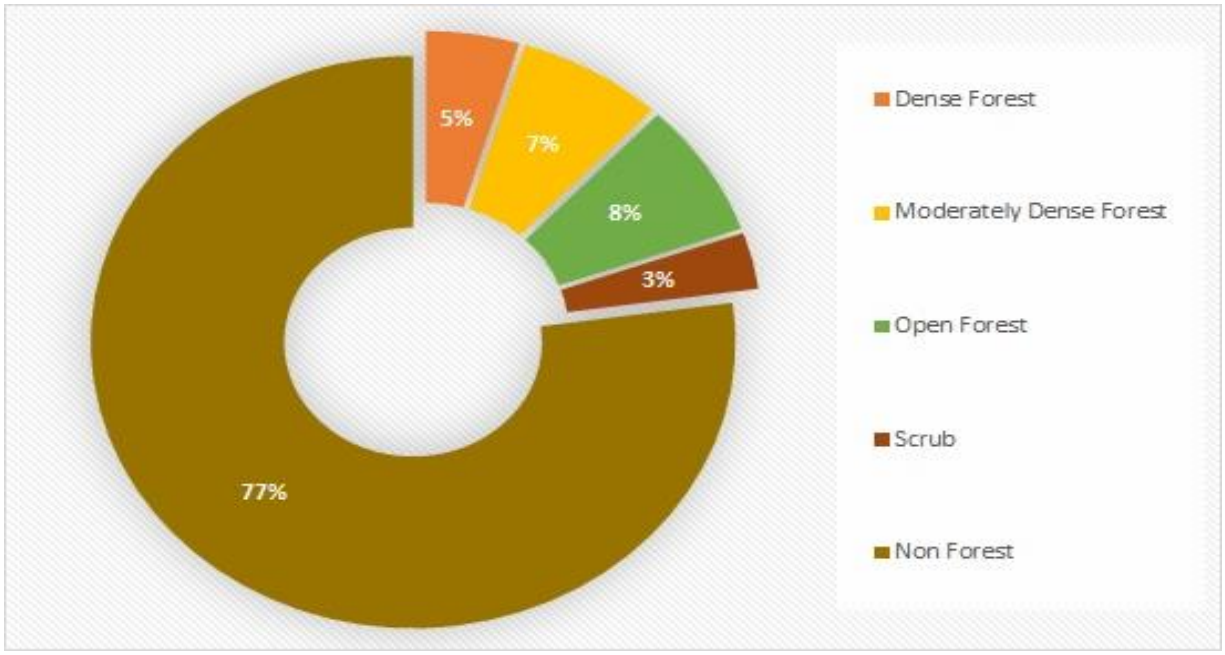


Fig. 3.16 Distribution of Areas under Different Categories of Forest Density of Sutlej Riverscape

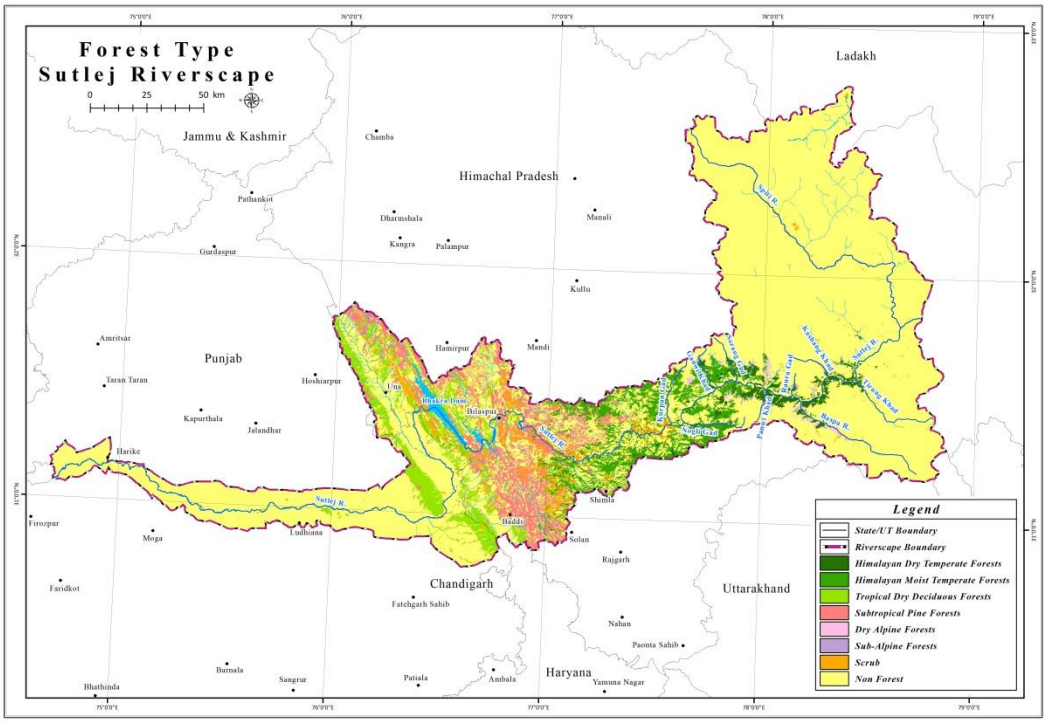


Fig. 3.17 Forest Types of Sutlej Riverscape

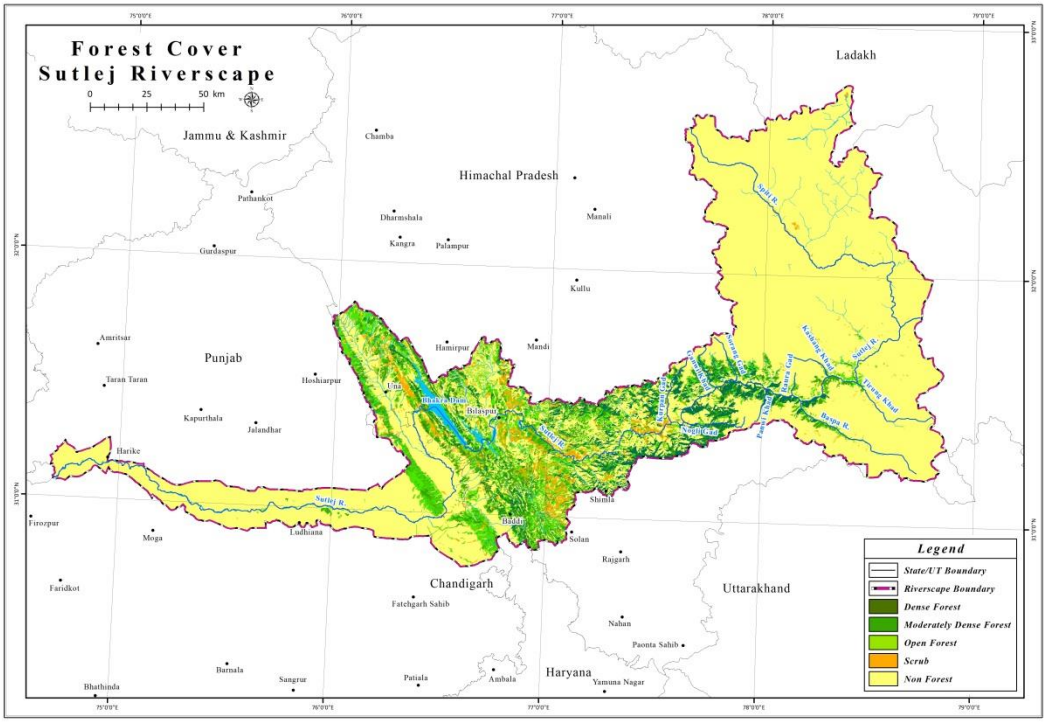


Fig. 3.18 Forest Cover of Sutlej Riverscape

Table 3.17 Administrative divisions of forest in Sutlej Riverscape

Sr. No.	State	Number of Divisions	Number of Ranges	Number of Blocks	Number of Beats
1	Himachal Pradesh	22	100	187	621
2	Punjab	10	33	45	109
Total		**32**	**133**	**232**	**730**

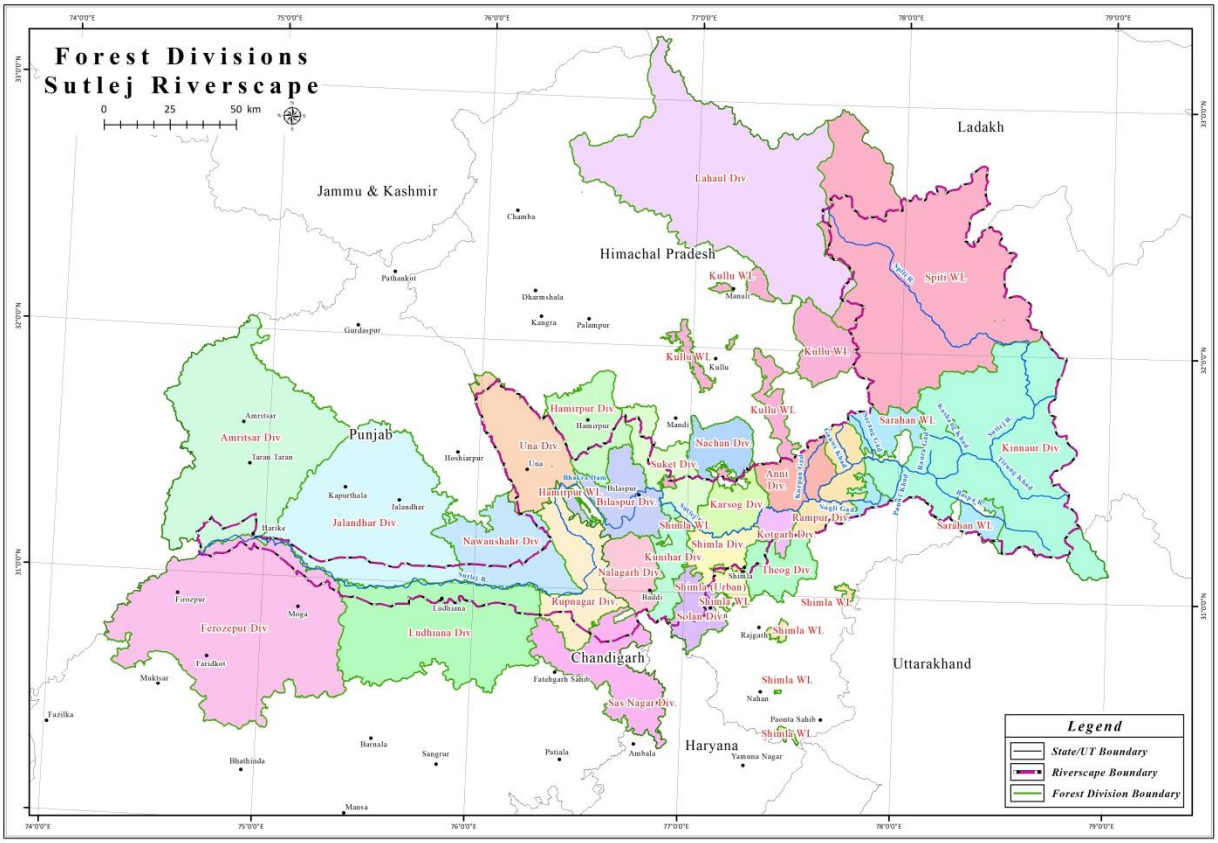


Fig. 3.19 Forest Administrative Divisions of Sutlej Riverscape

h) Number of Patches in Major Land Use Categories

Numbers of patches have also been found for Five Land use classes. Firstly, these classes such as Dense Forest, Moderately Dense Forest, Open Forest, and Scrub, were reclassified according to Geometric interval. After reclassification number of patches and area of each class have been calculated. Maximum numbers of patches in Open Forest class are 3,098 and minimum patches in Scrub class are 1,233. Table 3.18 shows number of patches in select categories of natural and manmade land use and land cover (Fig. 3.20 to Fig. 3.25).

Table 3.18 Distribution of Patches in Various Natural and Manmade Land Use and Land Cover Categories

Sr. No.	Area (km^2)	Number of Patches	Percent Representation (%)
Dense Forests			
1	0.00 - <0.12	309	24.54
2	0.12 -<0.26	326	25.89
3	0.26- <0.57	311	24.7
4	≥ 0.57	313	24.86
		1259	**100**
Moderate Dense Forests			
1	0.00-< 0.09	643	25.1
2	0.09- <0.23	627	24.47
3	0.23- <0.59	649	25.33
4	≥ 0.59	643	25.1
		2562	**100**
Open Forests			
1	0.00-< 0.08	822	26.53
2	0.08-< 0.18	745	24.05
3	0.18-< 0.46	765	24.69
4	≥ 0.46	766	24.73
		3098	**100**
Scrub			
1	0.00-< 0.08	323	26.2
2	0.08-< 0.19	297	24.09
3	0.19-< 0.48	306	24.82
4	≥ 0.48	307	24.9
		1233	**100**
Agriculture			
1	0.00-< 0.07	568	23.31
2	0.07-< 0.18	663	27.21
3	0.18-< 0.52	596	24.46
4	≥ 0.52	610	25.03
		2437	**100**
Barren			
1	0.00-< 0.06	547	26.74
2	0.06 -< 0.12	458	22.39
3	0.12-< 0.35	528	25.81
4	≥ 0.35	513	25.07
		2046	**100**

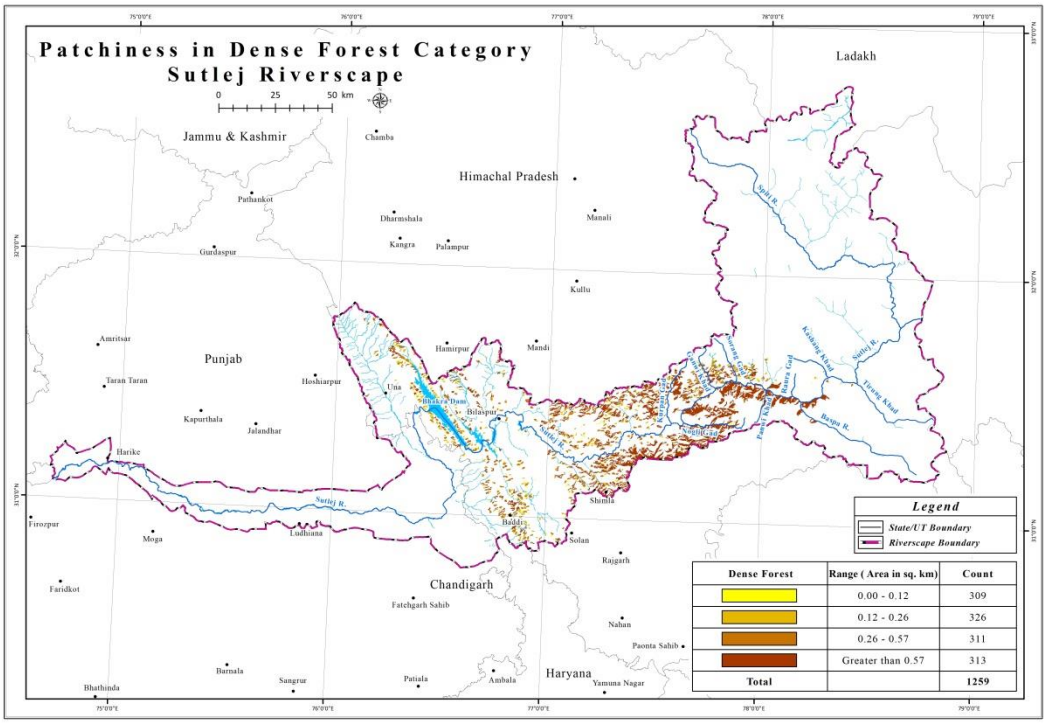


Fig. 3.20 Patchiness in Dense Forests of Sutlej Riverscape

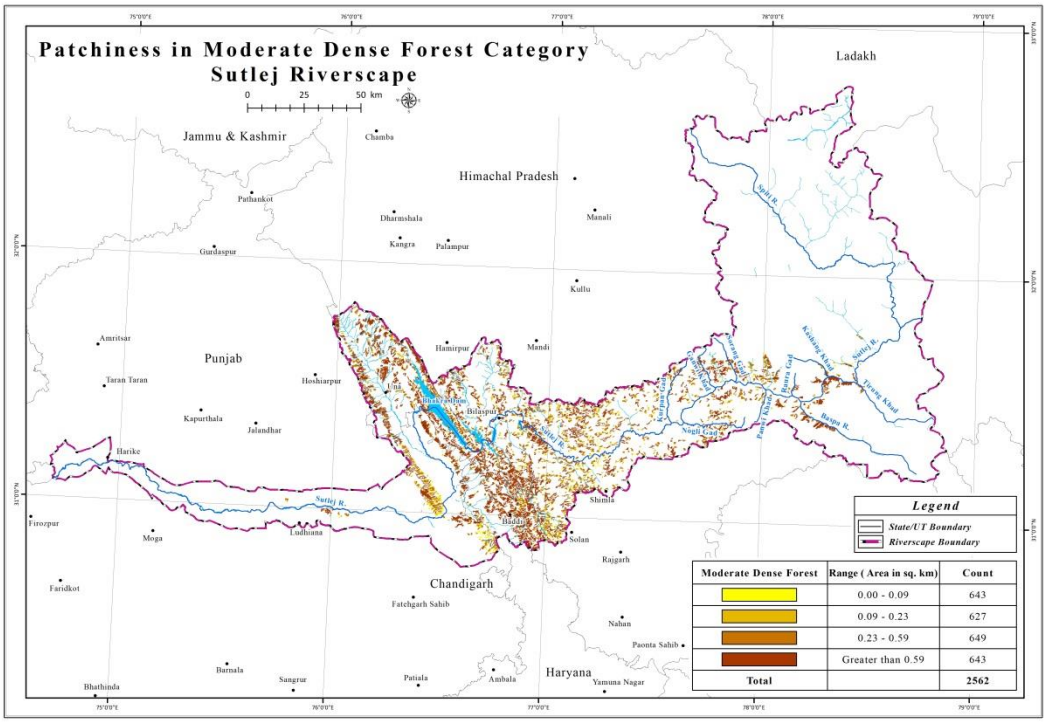


Fig. 3.21 Patchiness in Moderately Dense Forests of Sutlej Riverscape

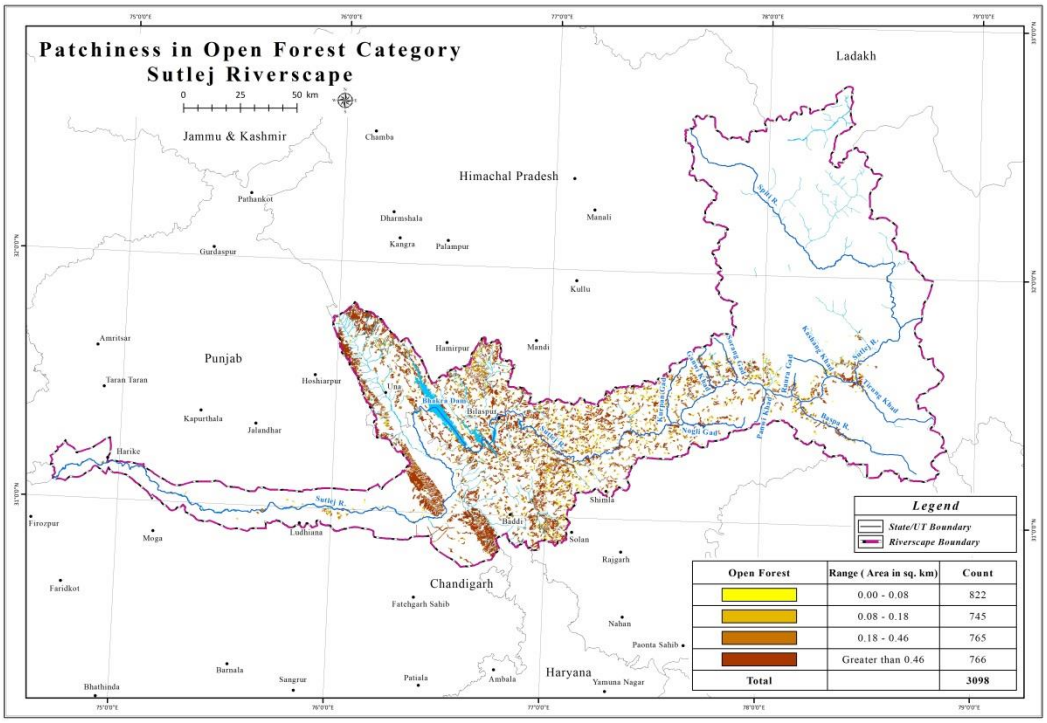


Fig. 3.22 Patchiness in Open Forest of Sutlej Riverscape

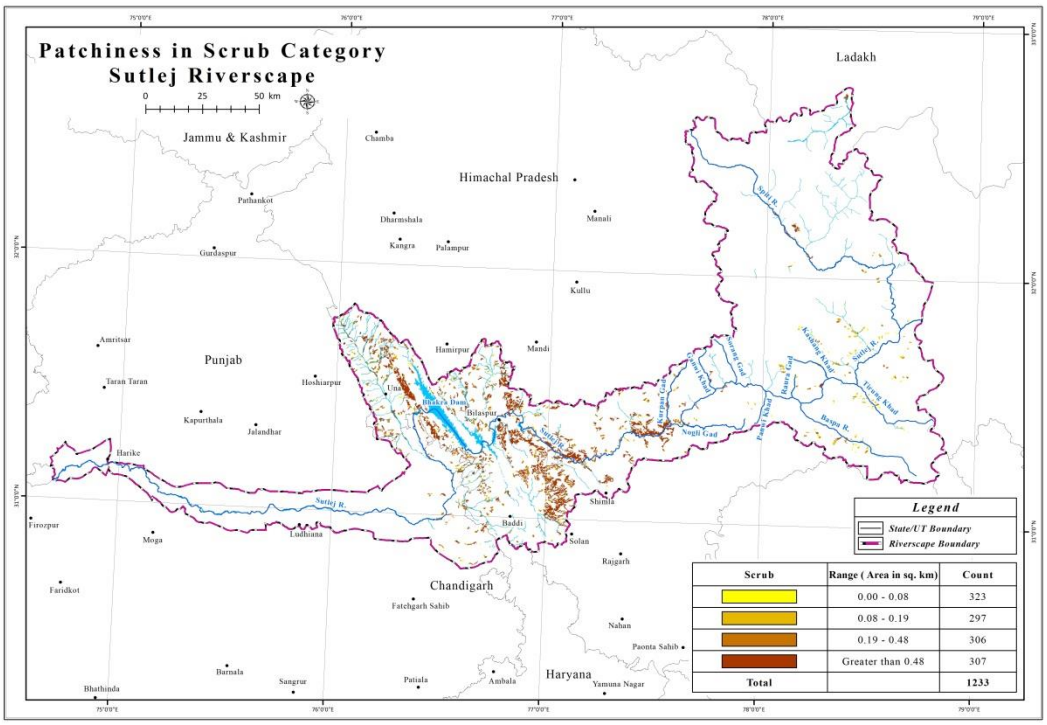


Fig. 3.23 Patchiness in Scrub Forests of Sutlej Riverscape

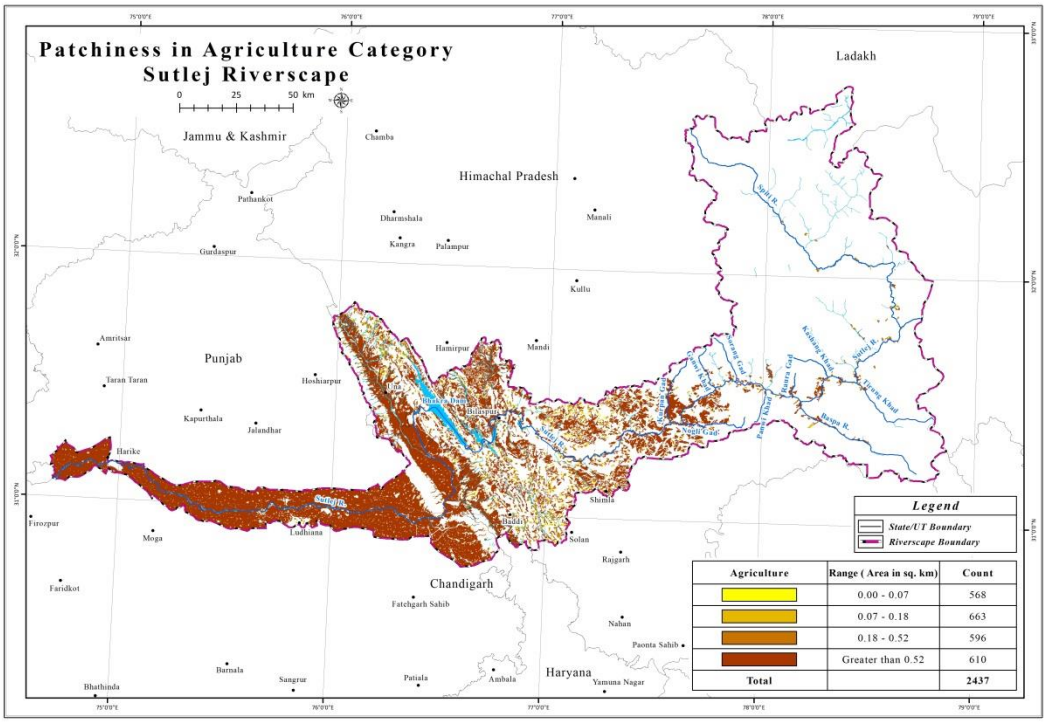


Fig. 3.24 Patchiness in Agriculture category of Sutlej Riverscape

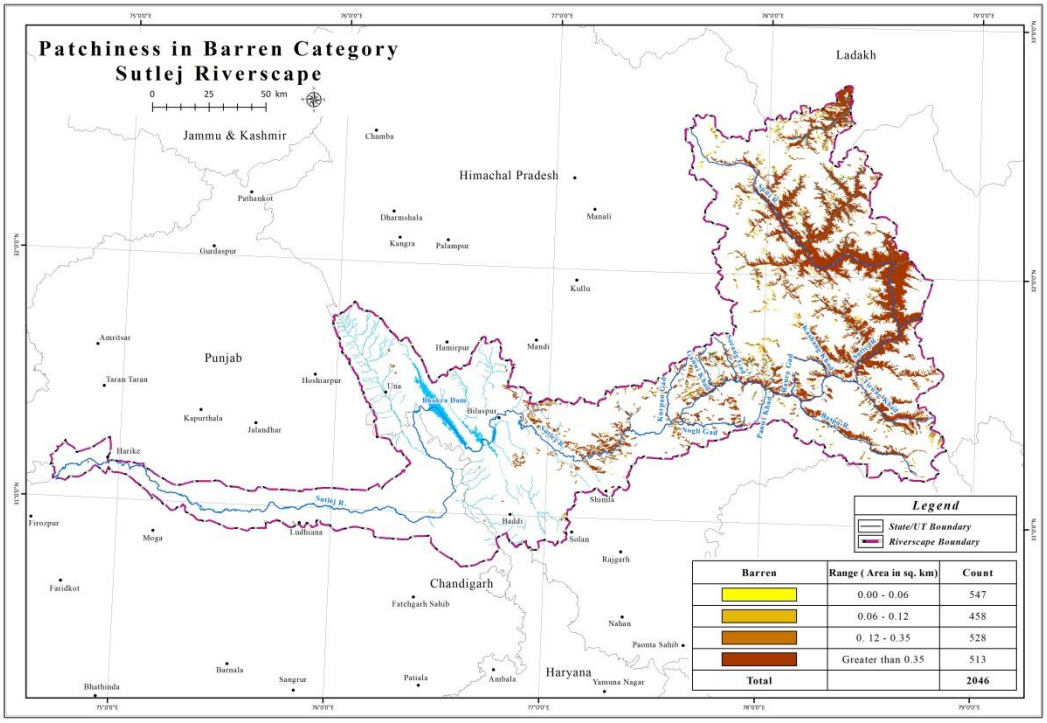


Fig. 3.25 Patchiness in Barren category of Sutlej Riverscape

i) Land Use and Land Cover (LULC) analysis

The preprocessed geometrically, radio metrically corrected, and resolution merged Landsat 8 satellite datasets were displayed on screen for attempting visual interpretation of various land use classes. Standard image interpretation keys, viz., shape, size, color, tone, texture, pattern, shadow, site, association, and phenology have been used to generate Image Interpretation scheme. Onscreen visual interpretation technique has been used for delineating major land use & land cover types i.e., Dense Forest, Moderately Dense Forest, Open Forest, Scrub, Agriculture, Alpine Pastures, Barren, Settlement, Canal, Water body, Wetland, River (Dry)/River Sand, River (Perennial), Snow/Glaciers etc. Thus, the distribution of area under corresponding land cover and land use classes for the entire riverscape state wise was computed.

Land use and land cover

Land information is important to a wide variety of human activities such as agriculture, forestry, water resources, as well as other types of land resource management. The preprocessed geometrically and radio metrically corrected PAN merged satellite datasets were displayed on screen for attempting visual interpretation of various land use classes. Standard image interpretation keys, viz., shape, size, color, tone, texture, pattern, shadow, site, association, and phenology have been used to generate Image Interpretation scheme (Fig. 3.26 & 3.27; NRSA, 2006).

a) Agricultural Land

This Landscape is primarily used for farming and production of food, fiber, horticulture, etc. They are mainly the lands with standing crops i.e., cropland; bright red to red color on satellite image, fallow land i.e., uncropped for one or more season; yellow to greenish blue tone, agriculture plantation i.e., tea, coffee, herbs, nurseries, orchards, etc.; dark red to red and regular sharp edged shapes.

b) Natural/Semi natural Grassland

These are the areas grasslands, dominated by the grasses and forbs. They appear in light red to light brown of varying sizes and irregular shapes.

c) Alpine/Subalpine: These are the places between the coniferous forest and permanent snow covered areas. An alpine zone commences is variable and line between 3000-5600 m amsl (Above sea level).

d) Barren: This is delineated of the basis of bright white to light blue to yellow to brown color tone depending upon the rock type. These are located on isolated hill slopes, plateau, etc.

e) Water bodies

This category comprises areas with surface water i.e., ponds, lakes, rivers, canals, etc. these can clearly be seen on a satellite image in blue to dark blue or cyan color depending on the depth of water.

Rivers (perennial/dry): Rivers are natural course of water flowing on the land surface along a definite channel/slope regularly or intermittently towards another water body in most cases, sea, another River, lake, marsh, etc. They appear in light to dark blue, irregular shape (nonlinear). There are two major categories of rivers, perennial (flow continuously throughout the year) and dry (flow only during monsoon period).

River Sand: River sand /Riverine sand are those areas that are seen as accumulations in the flood plain as sheets which are the resultant phenomena of River flooding.

Canal: These are artificial water course constructed for irrigation purposes it has a regular linear shape on image.

f) Forest

These are the areas bearing an association predominantly of trees and other vegetation types (within the notified forest boundaries).

Dense Forest: These are areas with Dark red to red color tone and includes canopy cover/density more than 70%.

Moderately Dense Forest: These are areas with red to light red in color tone and includes the canopy cover/ density between 40-70%.

Open forest: These are the areas with light red color tone and includes the canopy cover/density between 10-40%.

g) Scrub

This land is prone to deterioration due to erosion. These land generally occupy higher locations (excluding mountains and hills). They appear light yellow to brown to greenish blue depending upon the surface moisture and vegetation cover. It varies in sizes from small to large and generally surrounded agriculture, River area, and forests.

h) Built-up/Settlement

These are the human habitation developed due to nonagricultural use and that has a cover of buildings, transport, and communication utilities associated with water, vegetation and vacant lands. They appear in dark bluish green in the core and bluish in the periphery; the size varies from small to big; can be centered, clustered, or in scattered form.

i) Industrial Area

These are the areas where human activities were observed in the form of manufacturing along with other supporting establishment of maintenance. On a satellite image these areas have bright bluish to white tone with smooth and uniform texture.

j) Mining/Mining Dump

Mining dump are the areas where the debris is accumulated after extraction of minerals. These areas are often associated with the mining fields.

k) Snow covered/Glacial area

These are the areas under perpetual snow cover confined to the Himalayan region. It appear bright white to white in color depending on the moisture and thickness of snow. It poses irregular shape and located in mountain peaks in the higher altitude areas.

l) Wetlands

All submerged or water saturated lands, natural or manmade, inland or coastal, vegetated or non-vegetated. They have greenish blue to cyan to brown color depending upon different vegetation cover and depth of water.

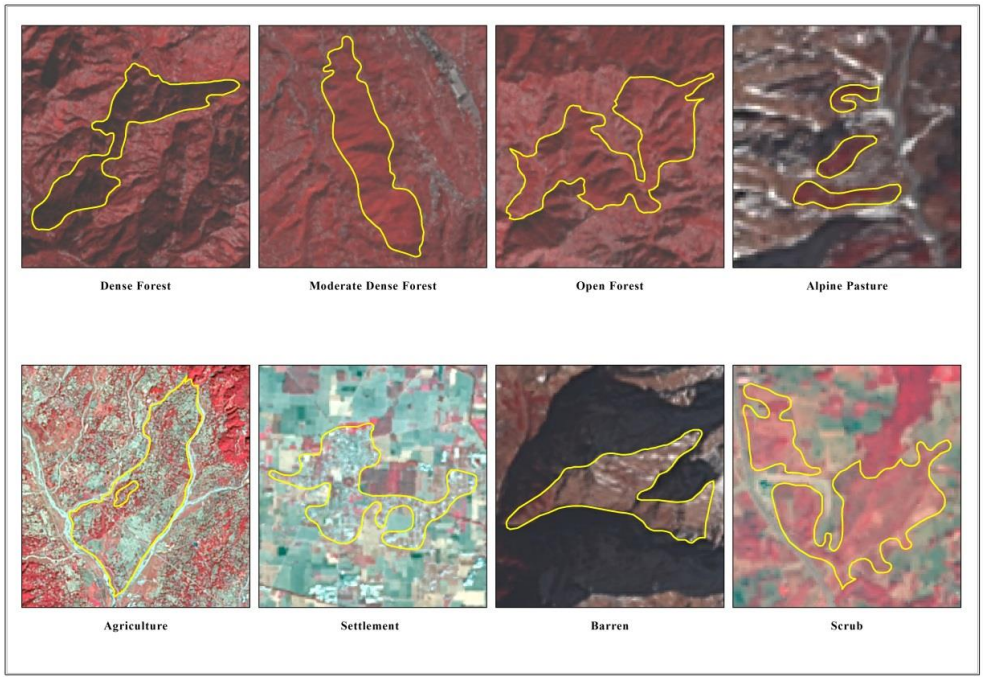


Fig. 3.26 Land Use and Land cover classification key

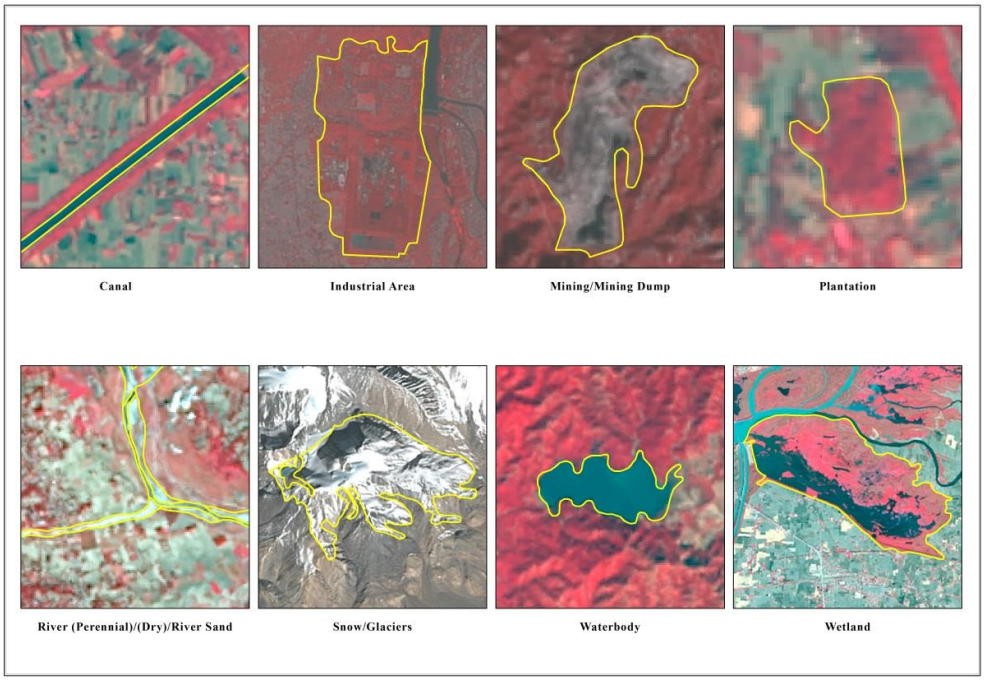


Fig. 3.27 Land Use and Land cover classification key

Onscreen visual interpretation technique has been used for delineating major land use/ land cover types i.e., Agriculture, Alpine pastures, Barren, Canal, Cloud, Cloud shadow, Dense forest, Moderately dense forest, Open forest, River (Dry)/River Sand, River (Perennial), Scrub, Settlement, Snow/Glaciers, Water body and Wetland in the riverscape is given in Table 3.19 and Fig. 3.28 and 3.29.

Table 3.19 Distribution of area under different land use and land cover categories in Sutlej Riverscape

Sr. No.	LULC	Area (km^2)	Percentage of Total Area (%)
1.	Agriculture	5,930.99	24.6
2.	Alpine Pastures	1.42	0.01
3.	Barren	3,143.78	13.04
4.	Canal	14.13	0.06
5.	Cloud	38.72	0.15
6.	Cloud Shadow	2.32	0.01
7.	Dense Forest	1,127.44	4.68
8.	Industrial Area	15.83	0.07
9.	Mining/Mining Dump	5.34	0.02
10.	Moderately Dense Forest	1,762.55	7.31
11.	Open Forest	1,839.14	7.63
12.	Plantation	35.45	0.15
13.	River (Dry)/River Sand	140.08	0.58
14.	River (Perennial)	242.42	1.01
15.	Scrub	768.06	3.18
16.	Settlement	241.64	1.00
17.	Snow/Glaciers	8,781.77	36.42
18.	Water body	3.07	0.01
19.	Wetland	16.68	0.07
Total		**24,110.83**	**100**

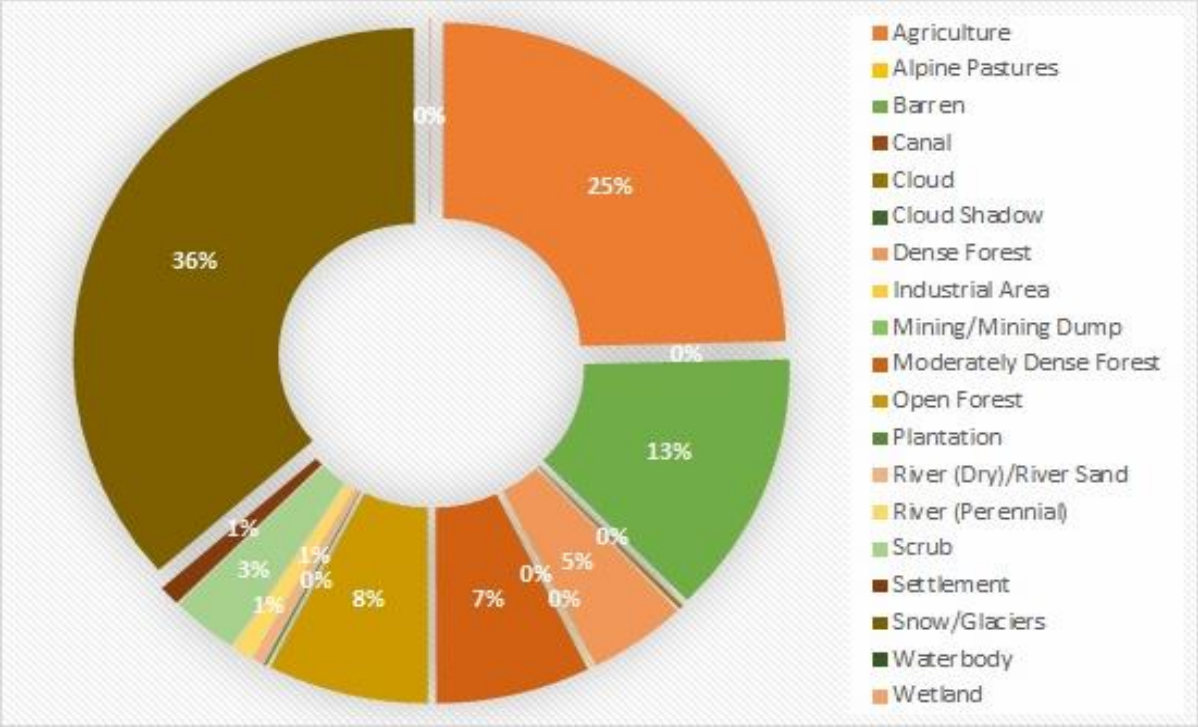


Fig. 3.28 Distribution of area under different Land Use and Land Cover categories in Sutlej Riverscape

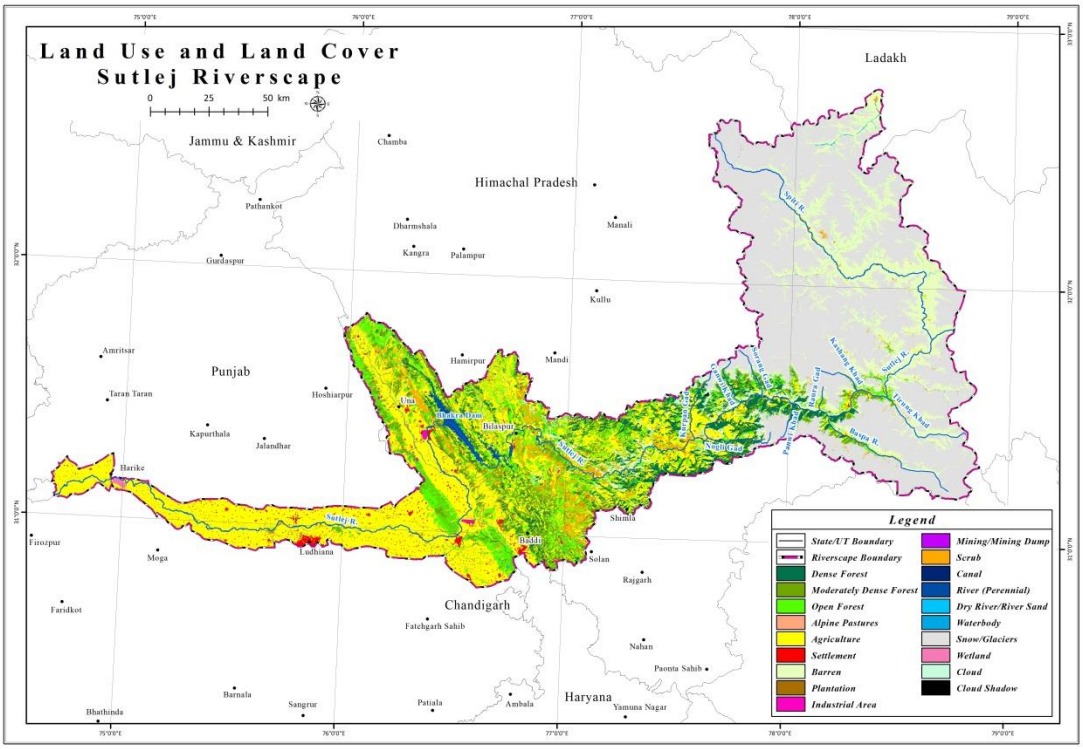


Fig. 3.29 Land Use and Land Cover categories of Sutlej riverscape

3.4.7 Prioritization of Suitable Areas for Proposed Forestry Interventions

For the purpose of preparation of DPR and for identification of priority areas for the proposed treatment/forestry interventions in the Sutlej riverscape, GIS assisted decision making process by way of geospatial analysis and modelling was used (Fig. 3.36). GIS was used to generate different layers within the riverscape like land use, soil erosion rates, and slope of the topography. The following shape files were superimposed to obtain a combination matrix of various layers that revealed the prevalent features of any area within the riverscape with regard to vegetation, land use, erosion, and degree of slope. The land use & land cover classes were merged in to 7 classes *viz.* Dense forest, Alpine Pastures, Open forest, Agriculture, Barren, Settlement, and Others. A weightage from 1 to 6 scales was given to the above land use & land cover classes. Further, the slope layer was categorized into three categories and each category was assigned a weightage of 1 to 3 based on the degree of slope. The erosion layer received from Indian Institute of Soil and Water Conservation (IISWC) had 5 major categories of erosion *Vis* <5, 5 to 10, 10-20, 20-40, and >40 (erosion in t/ha/year). Each category of erosion was given a weightage (Table 3.20) in multiples of 1.5. GIS overlay operations were carried out on the above three layers and the weightages for various combinations were combined together by means of addition to arrive at summed weightage for each combination. These values were then categorized in to low medium and high based on statistical quartile. For example, an Agriculture area is classified as 'high priority' if it has an erosion 10 to greater than 40 t/ha/year devoid of any slope class. Likewise, the agriculture area having slope 0-30 and erosion rate <5 t/ha/year has been classified as 'low priority'. It is this data which was then depicted on map as low, medium and high priority zones. The priority weightage and map of priority zones for Sutlej riverscape is given in Table 3.21, Fig. 3.30 and 3.31.

Table 3.20 Weightage to different LULC, slope, and erosion categories for MCA

Sr. No.	LULC	Weightage	Slope (Degree)	Weightage	Erosion (t/ha/year)	Weightage
1.	Dense Forest	6	0º to 30º	1	<5	1.5
2.	Open Forest	5	30º to 40º	2	5 to 10	3
3.	Alpine Pasture/Scrub	6	> 40º	3	10 to 20	4.5
4.	Agriculture	4			20 to 40	6
5.	Barren	3			> 40	7.5
6.	Wetland	7				
7.	Others	1				
8.	Settlement	2				

Table 3. 21 Priority zones for forestry intervention in the Sutlej riverscape

Land use	Slope	Erosion	Weightage (Slope)	Weightage (Erosion)	Weightage (LULC)	Total	Priority
Dense Forest	0° - 30°	<5	1	1.5	6	8.5	Moderate
Dense Forest	30°- 40°	<5	2	1.5	6	9.5	Moderate
Dense Forest	0º - 30º	5 10	1	3	6	10	Moderate
Dense Forest	> 40º	<5	3	1.5	6	10.5	High
Dense Forest	30º - 40 º	5 10	2	3	6	11	High
Dense Forest	0º - 30º	10 20	1	4.5	6	11.5	High
Dense Forest	> 40º	5 10	3	3	6	12	High
Dense Forest	30º - 40º	10 20	2	4.5	6	12.5	High
Dense Forest	0º - 30º	20 40	1	6	6	13	High
Dense Forest	> 40º	10 20	3	4.5	6	13.5	High
Dense Forest	30º - 40º	20 40	2	6	6	14	High
Dense Forest	0º - 30º	>40	1	7.5	6	14.5	High
Dense Forest	> 40º	20 40	3	6	6	15	High
Dense Forest	30º - 40º	>40	2	7.5	6	15.5	High
Dense Forest	> 40º	>40	3	7.5	6	16.5	High
Open Forest	0º - 30º	<5	1	1.5	5	7.5	Moderate
Open Forest	30º - 40º	<5	2	1.5	5	8.5	Moderate
Open Forest	0º- 30º	5 10	1	3	5	9	Moderate
Open Forest	> 40º	<5	3	1.5	5	9.5	Moderate
Open Forest	30º - 40º	5 10	2	3	5	10	Moderate
Open Forest	0º - 30º	10 20	1	4.5	5	10.5	High
Open Forest	> 40º	5 10	3	3	5	11	High
Open Forest	30º - 40º	10 20	2	4.5	5	11.5	High
Open Forest	0º - 30º	20 40	1	6	5	12	High
Open Forest	> 40º	10 20	3	4.5	5	12.5	High
Open Forest	30º- 40º	20 40	2	6	5	13	High
Open Forest	0º - 30º	>40	1	7.5	5	13.5	High
Open Forest	> 40º	20 40	3	6	5	14	High
Open Forest	30º - 40º	>40	2	7.5	5	14.5	High
Open Forest	> 40º	>40	3	7.5	5	15.5	High
Alpine Pasture/Scrub	0º - 30º	<5	1	1.5	6	8.5	Moderate
Alpine Pasture/Scrub	30º - 40º	<5	2	1.5	6	9.5	Moderate
Alpine Pasture/Scrub	0º - 30º	5 10	1	3	6	10	Moderate
Alpine Pasture/Scrub	> 40º	<5	3	1.5	6	10.5	High
Alpine Pasture/Scrub	0º - 30º	10 20	1	4.5	6	11.5	High
Alpine Pasture/Scrub	30º - 40º	10 20	2	4.5	6	12.5	High
Alpine Pasture/Scrub	0º- 30º	20 40	1	6	6	13	High
Alpine Pasture/Scrub	>40º	10 20	3	4.5	6	13.5	High

Alpine Pasture/Scrub	30º - 40º	20 40	2	6	6	14	High
Alpine Pasture/Scrub	0º - 30º	>40	1	7.5	6	14.5	High
Alpine Pasture/Scrub	>40º	20 40	3	6	6	15	High
Alpine Pasture/Scrub	30º - 40º	>40	2	7.5	6	15.5	High
Agriculture	0º - 30º	<5	1	1.5	4	6.5	Low
Agriculture	30º - 40º	<5	2	1.5	4	7.5	Moderate
Agriculture	0º -30º	5 10	1	3	4	8	Moderate
Agriculture	30º - 40º	5 10	2	3	4	9	Moderate
Agriculture	0º - 30º	10 20	1	4.5	4	9.5	Moderate
Agriculture	>40º	5 10	3	3	4	10	Moderate
Agriculture	30º - 40º	10 20	2	4.5	4	10.5	High
Agriculture	0º - 30º	20 40	1	6	4	11	High
Agriculture	>40º	10 20	3	4.5	4	11.5	High
Agriculture	30º - 40º	20 40	2	6	4	12	High
Agriculture	0º - 30º	>40	1	7.5	4	12.5	High
Agriculture	>40º	20 40	3	6	4	13	High
Agriculture	30º- 40º	>40	2	7.5	4	13.5	High
Agriculture	>40º	>40	3	7.5	4	14.5	High
Barren	0º - 30º	<5	1	1.5	3	5.5	Low
Barren	30º - 40º	<5	2	1.5	3	6.5	Low
Barren	0º - 30º	5 10	1	3	3	7	Low
Barren	>40º	<5	3	1.5	3	7.5	Moderate
Barren	30º - 40º	5 10	2	3	3	8	Moderate
Barren	0º - 30º	10 20	1	4.5	3	8.5	Moderate
Barren	>40º	5 10	3	3	3	9	Moderate
Barren	30º - 40º	10 20	2	4.5	3	9.5	Moderate
Barren	0º - 30º	20 40	1	6	3	10	Moderate
Barren	>40º	10 20	3	4.5	3	10.5	High
Barren	30º - 40º	20 40	2	6	3	11	High
Barren	0º - 30º	>40	1	7.5	3	11.5	High
Barren	>40º	20 40	3	6	3	12	High
Wetland	0º - 30º	<5	1	1.5	7	9.5	Moderate
Others	0º - 30º	<5	1	1.5	1	3.5	Low
Others	30º - 40º	<5	2	1.5	1	4.5	Low
Others	0º - 30º	5 10	1	3	1	5	Low
Others	>40º	<5	3	1.5	1	5.5	Low
Others	30º - 40º	5 10	2	3	1	6	Low
Others	0º - 30º	10 20	1	4.5	1	6.5	Low
Others	>40º	5 10	3	3	1	7	Low
Others	30º - 40º	10 20	2	4.5	1	7.5	Moderate
Others	0º - 30º	20 40	1	6	1	8	Moderate

Others	>40º	10 20	3	4.5	1	8.5	Moderate
Others	0º - 30º	>40	1	7.5	1	9.5	Moderate
Settlement	0º - 30º	<5	1	1.5	2	4.5	Low
Settlement	0º - 30º	5 10	1	3	2	6	Low
Settlement	0º - 30º	10 20	1	4.5	2	7.5	Moderate
Settlement	0º - 30º	20 40	1	6	2	9	Moderate
Settlement	0º - 30º	>40	1	7.5	2	10.5	High

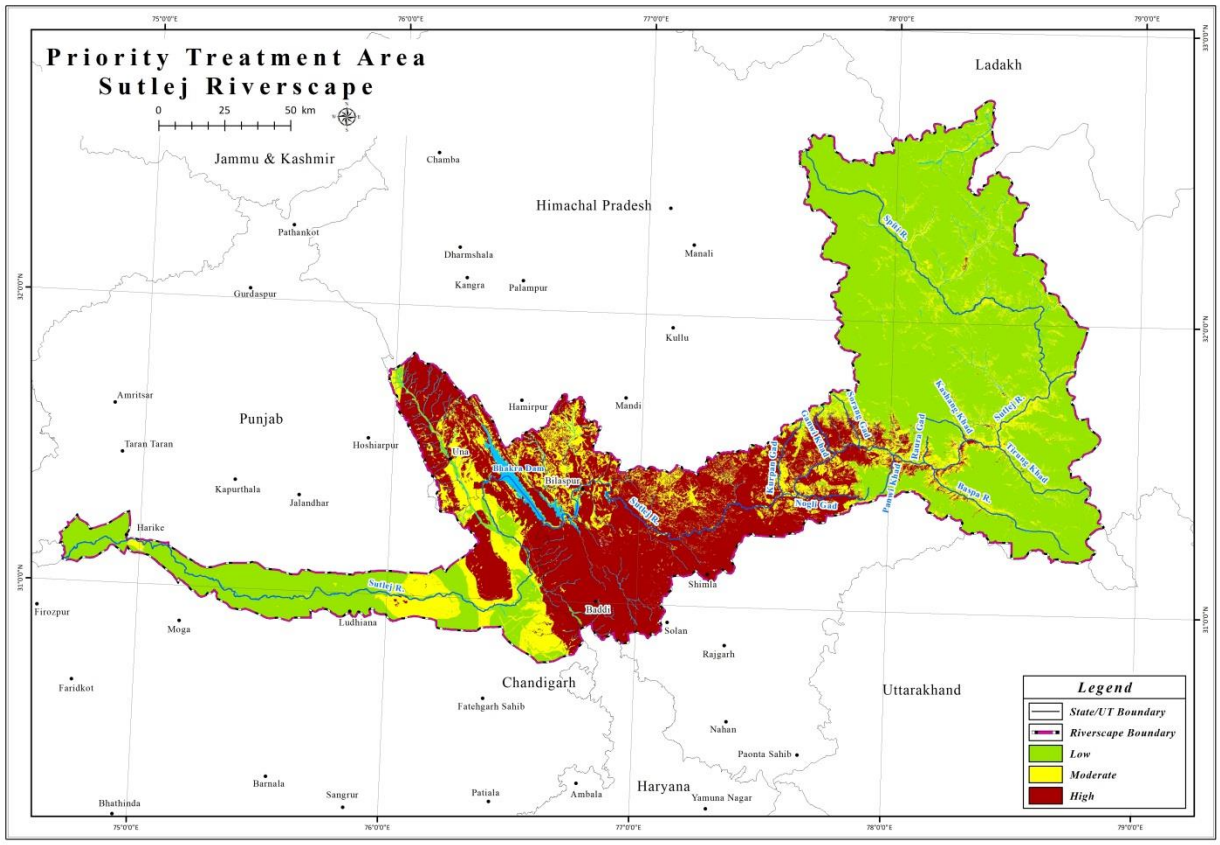


Fig. 3.30 Priority zones for forestry intervention in Sutlej Riverscape.

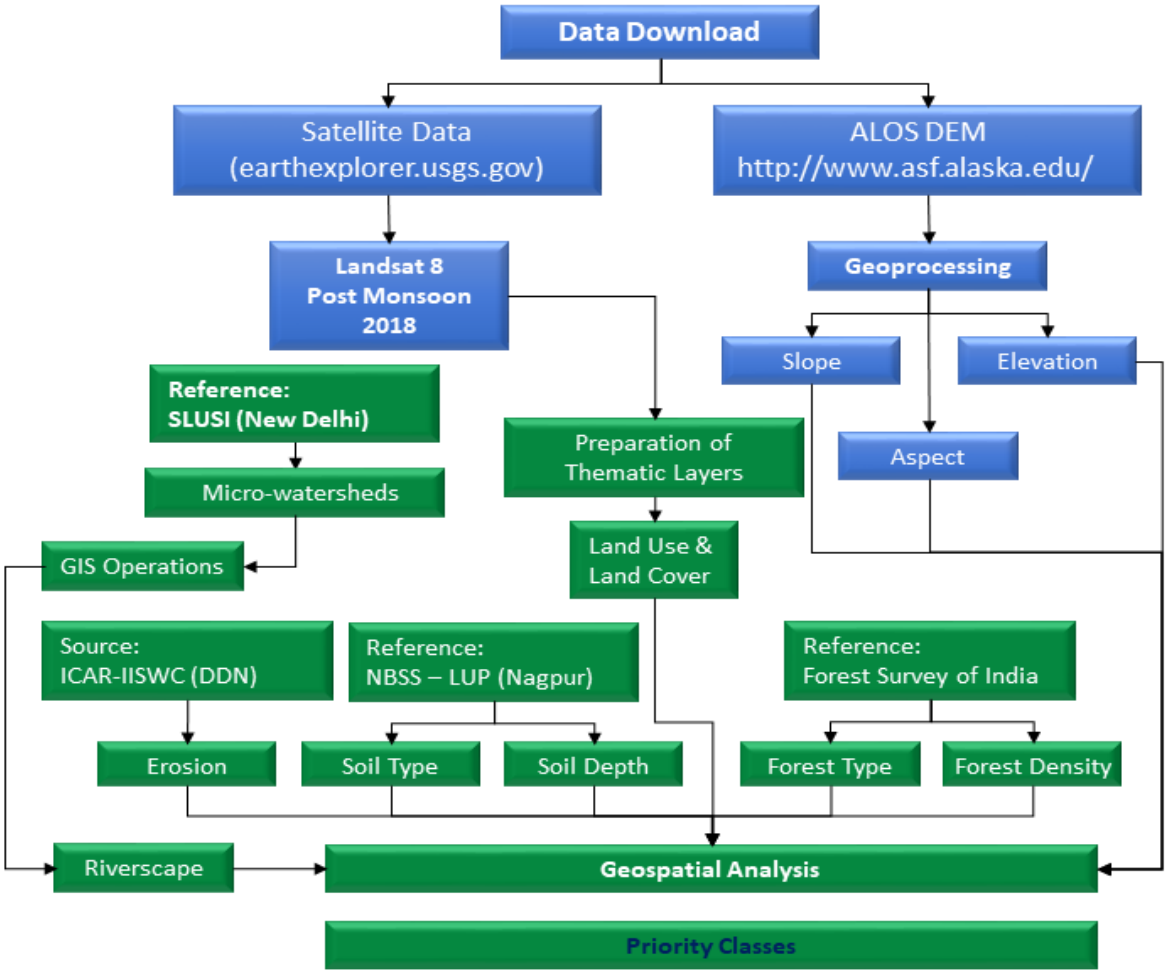


Fig.3. 31 The Adopted Approach for Geospatial Analysis and Prioritization of Areas

3.4.8 Riverscape Secondary Information, Collation, and Synthesis

An understanding of overall environment of the riverscape under consideration from the perspective of its physical, biological and socioeconomic environments was considered vital for proposed forestry interventions, Sutlej rejuvenation, biodiversity conservation, involvement of local communities and institutions in these efforts, sustainable livelihoods and awareness. Much of the information on the physical and social environment of the Sutlej Basin and the riverscape in particular are widely available in existing literature.

The first step (background analysis/ contextual analysis) of the broad approach for much desired insight on the riverscape environment, adopted for the preparation of the DPR. The primary sources of relevant information on physical attributes and socioeconomic condition were different agencies/ organizations at the state and National Levels. Much of the information on the biological sub-environment (biodiversity, forests, alpine pastures, wetlands, floodplain, wildlife and their habitats, threatened species, protected areas, conservation initiatives, etc. was collected from the MoEF&CC, ICFRE, FSI, FRI, HFRI, WII, GBPNIHESD, WWF India, State

Department(s) – Forest, Agriculture, Animal Husbandry, Fisheries, Science and Technology, Environment, Medicinal and aromatic Plants, etc., and state level universities. Information thus, obtained from departments/ agencies or collected from respective websites were optimally used for the synthesis of an insight on biological sub-environment of the riverscape. Hence, a large number of studies and reports were referred in the synthesis. The demographic and other socioeconomic information was either obtained from the state government websites or downloaded from the primary web source of censusindia.gov.in. Altogether, 232 forest blocks are covered either partially or fully in the riverscape. Tehsil wise information on demography and socioeconomic condition was extracted, collated and synthesized for developing an insight on the socioeconomic sub-environment of the riverscape.

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CHAPTER-4

SUTLEJ RIVER LEGISLATIVE, POLICY AND INSTITUTIONAL CONTEXT

CHAPTER 4
SUTLEJ RIVERLEGISLATIVE, POLICY AND INSTITUTIONAL CONTEXT

4.1 Legislative, Policy and Institutional Context

Rejuvenation of a River requires holistic basin/ riverscape approach to deal with the visible impacts on the River course. The traditional approach towards River basin management was very restrictive, and was only concentrated on the River channel. However, in the recent years, there has been a definite change in the way River basin management is looked at. Consequently, the entire River basin including the groundwater regime is viewed as an intricate physical system based on intricate interrelationships between the hydrological and geomorphologic characteristics of the basin and its rivers and streams. When it comes to water or River as a resource, the traditional model of development may not be best suited. Iyer (2001) states that there is a need for 'reorientation of attitudes and approaches' by moving from 'Water Resource Development' to a 'Water Resource Management' (demand management and resource conservation in recognition of finite supply), and further emphasized on the need to move from a 'centralised, top down, technology driven planning to a decentralised, bottom up, people centred planning' approach. In reality, rivers are not allowed to sculpt land due to structural interventions. Real estate muscles in and encroaches upon any elbow room available to the rivers. The construction of even crucial public infrastructure like airports (in Kochi, Chennai, Mumbai and even the upcoming one in Navi Mumbai) remains devoid of any such consideration for the rivers. Sealed floodplains, flattened ponds, mangroves, wetlands, and riverbeds prevent the natural mechanisms of land to absorb, contain in, and thus mitigate the impacts of heavy rainfall. It paves the way for flooding, further land degradation, and subsequent drought conditions.

Sutlej River Basin is the largest out of the five rivers comprising the larger Indus River System in India (Chauhan *et al.*, 2016). It supports diverse ecosystems including several protected areas as well as, is a source of livelihood to the communities residing in the said area. However, the basin is facing severe threat due to unsustainable activities such as sand and boulder extraction, operation of crusher units in close proximity of the river, infrastructure development including four laning of highways, uncontrolled growth of tourism activities, etc. Interestingly, the Nehruvian dream of constructing large hydropower projects as temples of 'Modern India' started with the development of the Bhakra dam in Himachal Pradesh on the Sutlej River. These very 'temples' have now become one of the largest threats to the said River and its basin (Nehru, 1958). Sutlej River Basin is also becoming more and more vulnerable to visible impacts of climate change.

Sutlej River in Punjab flows for another 400 km before entering Pakistan. Herein, the river flows through the plains catering to agricultural, domestic and industrial needs. Thus, the issues to be focused in the case of Punjab are mainly in relation to pollution abatement. The river passes through the highly urbanized and industrial centres of Ludhiana, Firozepur which discharges

highly polluted effluents as well as domestic sewage into the river. These issues have been dealt with in the present Chapter, presenting issue wise relevant legislative, policy and institutional framework in order to achieve the ultimate purpose of the present DPR to rejuvenate the Sutlej River.

4.1.1 Mandate under the Constitution of India

Article 48A of the Constitution of India puts an obligation on the State to protect and improve the environment and safeguard the forests and wildlife of the country. The Supreme Court (2007) has emphasised on the role of the State in protecting the environment in several cases by bringing it under the ambit of 'Right to Life' under Article 21 of the Constitution. In a recent judgment, the Court has taken a strict view on the constitutional mandate on the State under Article 48A by holding that '*in cases pertaining to environmental matter the State has to act as facilitator and not as obstructionist'* (Supreme Court, 2019). A corresponding duty has also been cast upon every citizen under Article 51 A (g), in the form of 'fundamental duties' to protect and improve the natural environment, including forests, lakes, rivers and wildlife, and to have compassion for living creatures. The Supreme Court has invoked Article 48A and intrinsically connecting it with the 'Public Trust Doctrine' while directing for demolition of an illegal hotel construction on the banks of River Periyar in Kerala.

With respect to rivers, it is important to locate this subject under the Constitutional scheme, i.e., power to legislate on rivers. The 7th Schedule to the Constitution, drawing on the provisions of Article 246 classifies subjects into three different lists i.e., the Union List, State List and the Concurrent List. Whereas '*regulation and development of interstate rivers and River valleys*' finds mention at Entry 56 of the Union List, the subject of 'water' falls within the State List at Entry 17.This dichotomy in the Constitutional setup calls for a concerted effort between the Central and State Governments with respect to rejuvenation, especially in the Sutlej context, since the river flows through both Himachal Pradesh as well as Punjab. Another constitutional provision which is relevant is Article 249, which permits the Central Government to legislate on a subject mentioned in the State List in national interest. The most relevant enactment dealing with issues of Water pollution, i.e. Water (Prevention and Control of Pollution) Act, 1974 was enacted invoking the said provision of the Constitution. Thus, what is required is not a decentralised mechanism, but to involve all stakeholders, especially local communities to actively participate in the rejuvenation campaign.

4.1.2 National Forest Policy, 1988

The National Forest Policy was developed by the Central Government as a basic document enumerating the principles to be followed while undertaking any activity in forest areas as well as in conservation efforts of forest areas in the country. Therefore, the National Forest Policy, 1988 would be an important guide to have an effective rejuvenation programme in place. The policy was relied on by the Supreme Court (2011) in the *Lafarge Umiam* case wherein the Court directed that the National Forest Policy must be read as part of the Environment (Protection) Act, 1986 and the Forest (Conservation) Act, 1980. More importantly, the Court held that the

National Forest Policy, 1988 must necessarily govern the grant of forest clearance under the provisions of the Forest (Conservation) Act, 1980. The directions of the court are noteworthy.

'The time has come for this Court to declare that the National Forest Policy, 1988 which lays down far reaching principles must necessarily govern the grant of permissions under Section 2 of the Forest (Conservation) Act, 1980 as the same provides the road map to ecological protection and improvement under the Environment (Protection) Act, 1986. The principles/guidelines mentioned in the National Forest Policy, 1988 should be read as part of the provisions of the Environment (Protection) Act, 1986 read together with the Forest (Conservation) Act, 1980. This direction is required to be given because there is no machinery even today established for implementatn of the said National Forest Policy, 1988 read with the Forest (Conservation) Act, 1980. Section 3 of the Environment (Protection) Act, 1986 confers a power coupled with duty and, thus, it is incumbent on the Central Government, as hereinafter indicated, to appoint an appropriate authority, preferably in the form of regulator, at the State and at the Central level for ensuring implementation of the National Forest Policy, 1988.'

One of the important principles of the National Forest Policy, 1988 included checking soil erosion and denudation in the catchment areas of rivers, lakes, reservoirs in the 'interest of soil and water conservation' for mitigating floods and droughts and for the retardation of siltation of reservoirs (MOEF,1988).The National Forest Policy, 1988 also emphasises on the need to include community and ensure their active participation in conservation and rejuvenation efforts of the forest areas. In the context of Sutlej River, the National Forest Policy, 1988 and the principles envisaged therein would give an appropriate perspective for a basin level rejuvenation as the river flows through forested areas which support a very vibrant ecosystem as well as livelihoods of local/tribal communities.

4.1.3 National Water Policy, 2012

The Central Government has issued an overarching policy on utilisation and conservation of water resources of the country. The first such policy was issued in 1987 which had laid down the hierarchy of use of water resources for drinking water, irrigation, hydropower, navigation industrial and other purposes. This policy was revised in 2002 and again in 2012 which is the policy currently in force (MoWR, 2012). The National Water Policy, 2012 lists out the guiding principles for implementation of laws relating to sustainable utilisation and conservation of water resource. The Policy identifies that water must not be simply considered as a scarce resource but also a sustainers of life and ecology. Therefore, water needs to be managed as a community resource, held by the state, under public trust doctrine to achieve food security, livelihood, and equitable and sustainable development for all. The Policy also recognises the need for encompassing issues relating to climate change while planning and appraising any activity which involves utilisation of water. These overarching principles, especially relating to community participation as well as climate adaption become critical when formulating and implementing a rejuvenation scheme for the Sutlej River.

4.1.4 Indus Water Treaty, 1960

The Indus Water Treaty is one of the oldest Inter State; transboundary river water sharing treaties signed in the world and widely accepted being one of the most successful treaties on trans boundary water sharing (Hanes, 2017). According to this treaty, India and Pakistan have agreed to demarcate the six rivers which fall within the Indus River Basin for their respective use, management and exploitation of resources. Therefore, as per the Agreement, India has full rights to use and exploit the three eastern rivers i.e., Beas, Ravi and Sutlej; whereas, Pakistan has unfettered rights of exploitation of the western rivers, i.e., Indus, Chenab and Jhelum. India has limited rights on the catchment area of these rivers within Indian Territory.

As per the provisions of the Treaty, if either party wants to exploit resources of a river which has been assigned to the other party, an elaborate mechanism has been laid down this includes consultations, filing of objections, sharing of data, etc. The Indus Permanent Commission was also set up as per the Treaty which has been tasked with ensuring proper implementation of the Treaty. In case of any dispute regarding any activity, the Treaty has specific provisions with respect to dispute resolution. For the purposes of the current Chapter, the Indus Treaty does not have much relevance, as India has unfettered rights over the Sutlej River.

4.1.5 Policy scenario of Hydro-electric Projects

It may be ntoed that hydro-electric projects and related issues arise only in respect of the Sutlej Sub-basin in Himachal Pradesh. As of 29th EAC Meeting of River Valley and Hydro-electric projects of MoEF&CC, GOI, New Delhi, 2019, 153 projects are in different stages of Development in this Sub-Basin (ICFRE, 2019) There are several large projects which are already commissioned, which include Bhakra, Nathpa-Jhakri, Karchham-Wangtoo, etc. In fact, as per the Draft Cumulative Impact Assessment (CIA) Report prepared by the Indian Council for Forestry Research and Education (ICFRE), the river only flows freely for about 19 km out of 239 km in Himachal Pradesh.

'Hydro-electric Projects (HEPs) result in stretches of rivers where water is diverted and also some River stretches which are submerged.

Main Sutlej River stem from the location it enters India and up to Kol Dam the effected length is 220 km out of a total River length of 239 km. This effected length has 70% diverted stretch and 22% submerged. Spiti River is proposed with only 29% diverted/submerged.

A total stream length of 853 km, under the study area, comprises of 220 km of Sutlej main stem, 174 km of Spiti River, 80 km of Baspa, 42 km of Nogli khad, 41 km of Tidong Khad, 40 km of Kirang Khad and 12 other tributaries.

For all 38 projects a total 43% of stream length out of which 36% of stream length of 308 km and 7% of stream length of 58 km is affected. Percentage of affected length for these streams varies from 7% to 92%.'

Such projects have led to the river and its tributaries to flow in tunnels, and have adversely impacted aquatic fauna as well as traditional irrigation channels (*kuhls*) used by local communities. Thus, it becomes imperative that cumulative impacts of these projects are assessed properly in terms of impact on the river ecology as well as impact on the local communities. This becomes even more important in light of the fact that it has been found that around 10 Mega Hydropower projects of Himachal Pradesh are under maximum threat of landslide followed by large hydropower projects which fall under medium landslide hazard risk (GoHP, 2015).Within Kinnaur and Mandi Districts, the river flows mostly in tunnels from the tail race tunnel of one project to the head race tunnel of the next one. Karcham-Wangtoo (1000 MW) hydroelectric project in the private sector built by Jaypee, in Kinnaur has already led to drying up of water bodies in the catchment area. Right after the Karcham-Wangtoo project, the river has been reduced to a trickle as Sutlej is diverted in a 17 km long tunnel. Further, downstream is Nathpa-Jhakri HEP, followed by the 412 MW Rampur project which was only recently commissioned. Next is the 750 MW Luhri dam which is now in amidst controversy following local opposition. After this, comes the 800 MW Kol Dam which is located in Bilaspur District and got commissioned in 2015 (Himdhara Collective, 2016).

The proliferation of hydropower projects on the Sutlej basin was also flagged with serious concern by the One Man Committee Report submitted to the High Court of Himachal Pradesh (H.P. High Court, 2009). The following observations and recommendations are noteworthy:

'During visits to the major River basins of the State Sutlej, Beas and Ravi, it has been found that the main valleys have already been saturated with hydel projects every few kilometers and now projects are being allotted in ever increasing numbers in the side valleys of the tributaries. The effects of such large scale felling of trees, dumping of muck and diversion of waters over the entire River basin (not just a few isolated spots) has never been studied by the Govt. before allotting these projects. Individual EIAs and EMPs for individual projects do not address the larger concerns for, where environmental impacts are concerned; the whole is larger than the sum of the parts. Unlike the pure manufacturing process where the incremental cost of production is always a declining figure, in matters of environmental costs (such as in generation of hydel power) the incremental environmental cost is always an increasing figure as environmental impacts accumulate, in other words, the environmental cost of producing the second megawatt of power is more than that of producing the first megawatt. The Committee therefore recommends that the State govt. should carry out basin wise EIAs for all the River basins of the state and till these are finalized no more hydel projects should be allotted or, where allotted their clearances should be withheld. [This is precisely what has been ordered by the Forest Advisory Committee of the MoEF in respect of more than 100 proposed hydel projects in the Ganga basin of Uttarakhand, as per the Times of India's report on 17.6.2010'

The Committee follows this critical observation with a recommendation to have mandatory distance requirement between the tail race tunnel of a dam and the head race of another to ensure River sustainability:

'*Hydel projects have been /are being allotted along the rivers and their tributaries in a cascading manner, that is, one project after another in a series along the entire length of the River.*

Since these are all Run of the River projects, the waters are being repeatedly diverted from the River bed into HRTs (Head Race Tunnels), rendering the River itself dry for huge stretches (the 15% mandatory discharge is not being followed in most cases as mentioned in report, or, where complied with, the discharge is so small that it makes no material difference).

Where this process appears to be becoming an environmental hazard in HP is that practically no linear distance is being left between the tail race of one project and the intake of the next. This would eventually result in entire river drying up, their waters diverted into tunnels and serving no purpose other than the generation of power certainly not what Nature had intended. …This cannot be anything but an unmitigated disaster, for a River is not just a flowing mass of water it is an entire ecosystem, sustaining human, animal and rich aquatic life within it and along its banks, creating green belts of vegetation on both sides, recharging underground aquifers, feeding surface streams, creating microclimates along its path. And yet, the state and central governments have not carried out any EIAs of such a cascading pattern from independent experts before allowing this cascade of projects.

The Committee, therefore, strongly recommends that some minimum Riparian distance must be maintained between the tail race tunnel of one project and the intake of the next in order to enable the River to recharge itself and to continue to sustain life along its length. Until some expert body gives its advice this distance should be kept at 5 km. Projects which have not yet received clearances and which do not conform to this requirement should be put on hold until such time that this entire issue is fully examined and a proper policy framed.

In fact, the National Green Tribunal has also taken judicial notice of the adverse impact of the Karcham-Wangtoo project while considering the correctness of clearance granted to another project which is highly contentious in Kinnaur on one of the tributaries of Sutlej River, i.e., Integrated Kashang HEP (NGT, 2016).

"*14. Our conviction on the adverse consequence on the environment highlighted by the One Man Committee as reproduced above appears to be well justified in view of the reply Annexure A9 furnished by the Executive Engineer, IPH Division /Peo, District Kinnaur, Department of I& PH, Government of Himachal Pradesh in response to an application under the RTI Act. The letter reveals that as many as 167 water sources have been adversely affected in the project areas of Karcham Wangto HEP which is another project on the same River. The numbers of water sources that have dried up and where discharge of water have been affected or reduced in the same area are 35 and 66, respectively. These illustrate the adverse effect on only one aspect*

of the environment within just one project area. , therefore, it can be well imagine the cumulative impact of the 150 projects.'

Similar to the case of Sutlej River basin, the problem is magnified in light of the cascade model of hydropower development being adopted in Himachal Pradesh. In contrast to a reservoir based dam, recent trends show a shift towards run of the River hydropower projects in India. This cascade model means that at the tail of one project, the head of the next is located, thereby creating a cascade/series of these projects built bumper to bumper on the streams and rivers to harness the capacity of the rivers to produce power to its maximum. Other significant impacts of hydropower projects are the associated impacts of road and other infrastructure development (H.P. High Court, 2009). Special emphasis on this sector has to be given in light of climate change related discussion.

While regulating hydro power projects, the following laws become important:

(a) Environmental Clearance under the EIA Notification, 2006

As per the scheme under the EIA Notification, 2006, a hydro-power project proposing more than 50 MW power generation would require obtaining prior Environmental Clearance from the Ministry of Environment, Forest and Climate Change (MoEF&CC) and if the power generation is 25 MW or more but less than 50 MW, clearance has to be obtained from the State Level Impact Assessment Authority (SEIAA). While applying for such clearance, the Project Proponent must undertake an Environment Impact Assessment (EIA) Study and conduct public consultations with the affected communities and submit the report to the Expert Appraisal Committee (EAC) or the State Expert Appraisal Committee (SEAC). Before grant of such clearance, the concerned EAC or SEAC and the regulatory Authority is mandated to conduct a 'detailed scrutiny' of the documents submitted and then recommend for grant or rejection of the Environmental Clearance (MoEF, 2006). An Environmental Clearance if granted is valid for a period of ten years.

It is mandatory for the project proponent to submit six monthly compliance reports of the conditions of the Environmental Clearance. The Environmental Clearance for hydro- power projects usually has specific conditions with respect to the construction phase of the dam i.e., muck disposal plans, height of the dam, etc. These conditions need to be strictly monitored at the construction stage. During the operation phase, the conditions relating to the release of minimum environmental flows, Catchment Area Treatment (CAT) Plan, etc. Therefore, the Environmental Clearance becomes an important instrument to ensure minimal damage to the river system.

(b) Cumulative Impact Assessment (CIA)

The Ministry of Environment Forest and Climate Change had commissioned 'Cumulative Impact Assessment (CIA)' study for important River basins across the country. The study in case of Sutlej River was undertaken by ICFRE and report was submitted to the MoEF&CC in February, 2019. However, as per the Minutes of 29thEAC Meeting of River valley and Hydroelectric projects of MoEF&CC, GOI held on 5th December, 2019, and thetotal number of HEPs

recommemnded, precluded, considered and accepted by EAC. The Report covers an impact assessment of 38 projects in the Basin and also considered issues relating to about hundred small hydropower projects (SHPs) below 10MW. The CEIA conducted for 153 HEP, include 37 large HEP (IC>10 MW) and 116 small HEP (IC< 10MW); of which majority (107 HEP) of the projects are under development. A holistic approach was adopted to characterize the potential impacts on ecosystems; valued ecosystem and social components.

(c) Forest Clearance under the Forest (Conservation) Act, 1980

In addition to obtaining Environmental Clearance, in most cases hydro-power projects require prior Forest Clearance under Section 2 of the Forest (Conservation) Act, 1980 for diversion of forest land. The forests groups in Sutlej River Basin comprises of 24 forest types as per classification (Champion and Seth 1968) with the total forest cover area of 2550.90 km^2. (ICFRE 2014) Under the Forest Clearance process, what is most critical is the CostBenefit Analysis which has to be undertaken by the UserAgency which is to be scrutinised by the Central Government before granting Forest Clearance. As per the Guidelines of the MoEF&CC (2017), while considering a proposal for diversion of forest land, it is essential that ecological and environmental losses and economic distress caused to the people who are displaced are weighted against economic and social gains. Thus, the cost of ecosystem services, and fragmentation of wildlife, economic distress to the displaced communities, and cost of settlement of these communities should be added as cost of diversion in addition to the project cost.

(d) Settlement of Forest Rights of Forest Dwelling Communities under the Forest Rights Act, 2006

An important aspect of Forest Clearance process is the mandatory requirement of settling forest rights of tribal communities and obtaining consent from the *Gram Sabhas* concerned under the provisions of the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. In this regard, the MoEF has issued letter dated 3.08.2009 wherein the MoEF has listed out the necessary compliances to be undertaken by the UserAgency and State Government before grant of Forest Clearance under Section 2 of the Forest (Conservation) Act, 1980. The said condition has been categorically brought under the purview as now mandatory as per the Forest (Conservation) Rules, 2003, vide amendment dated 06.03.2017,MoEF (2003).This becomes more important in terms of Kinnaur and Lahaul and Spiti Districts those are notified under the Schedule V areas. In specific context of Kinnaur District and Sutlej basin, the case of competing claims of forest rights of the tribal communities in Lippa Village and the development of Kashang Stage II and III Hydro Power Projects (130 MW) is highly contentious and the matter is pending before the High Court of Himachal Pradesh wherein the *Gram Sabha* has approached the Court in order to enforce the provisions of the Forest Rights Act, 2006 which has been completely overlooked by the State owned Himachal Pradesh Power Corporation Ltd. (HPPCL)(H.P. High Court, 2019).

Dealing with Prolific growth of Mini-hydro Power Projects

As mentioned earlier, there is a serious need to relook at the issue of mini hydro -power projects in Himachal Pradesh. It may be noted that small hydro-power projects (SHP) (1MW to <25MW) are not included under the purview of the EIA Notification, 2006 of the Environmental (Protection) Act, 1986. Hence, all SHPs are legally exempted from requiring environmental clearances and conducting environment impact assessments and public hearings. Further, the said category of hydro-power projects have also been exempted from the need to obtain consent under the provisions of the Air (Prevention and Control of Pollution) Act, 1981 as well as the Water (Prevention and Control of Pollution) Act, 1974(CPCB, 2016).This is primarily due to the assumption that small hydro-power projects, on account of being 'small' will have minimal or no adverse environmental and social impacts. Contrary to such assumptions, there is enough documentation to conclude that these SHPs also have adverse environmental as well as social impacts. In fact, they are also capable of influencing microclimate as well as spatial distribution of macro invertebrates of the project site and surrounding area of hydropower projects (Lata *et al.*, 2017).

Thus, with respect to SHPs, the only permissions that are required by the project proponent include the techno-economic clearance and those from the Irrigation and Public Health Department, Fisheries Department and Public Works Department. However, there are no procedures and regulations in place at the state level to ensure a cost benefit analysis with an environment and social impact assessment of these HEPs. Similarly, no cumulative impact assessment is ever conducted.

In the context of Sutlej River Basin, it may be noted that as per the information available on the website of Himurja, Govt. of Himachal Pradesh (HIMURJA, 2019), there are about 95 approved projects which falls within the category of 0<5MW (Himurja, 2018).With respect to >5<25 MW category, as per data presented in the draft CIA Study for Sutlej basin in Himachal Pradesh, there are about 18 projects varying from 9 MW to 24.6 MW.

Thus, what has been overlooked is that small projects are coming up not just on the main River channel, but also on the smaller streams which sustain local livelihoods of remotely located poor communities and fragile but biodiverse ecosystems in numerous ways. Across the state, these streams support the traditional irrigation channels or *kuhls*. Watermills are run on these and in many places they even supply drinking water to villages. When looked at from a larger basin perspective, there is a need for assessing the cumulative impacts of SHPs and bringing the same under a definite legal regime which looks at cumulative impacts of the project as well as ensures that the project is being permitted with the consent of the local people.

4.1.6 Climate Change: Flash Floods and threat of GLOF

The Sutlej sub-basin in Himachal Pradesh, especially in the upper reaches of the river basin is becoming more and more susceptible to adverse impact of climate change induced disasters. The major natural disasters or hazards experienced by the region over the years include earthquakes,

landslides, flash floods, cloud burst, avalanches, hailstorms and droughts (Lata *et al.*, 2017). As per a recent research paper published in the Current Science journal, presently, Sutlej River Basin has approximately 2000 glaciers, 1426 km^2 glacier area and 62.3 Gt glacier stored water (Prasad, 2019).It is important to note that more than 50% of the annual flow of Sutlej River is contributed by snow and glacier melt. The study has predicted that:

' …by 2050 (averaged over 2045–2055), the Sutlej basin will experience an increase in summer temperature by 1.48°C and 8% decrease in winter snowfall compared to 2010 (averaged over 2005–2015). By 2090 (averaged over 2085– 2095), the CNRMCM5 model predicts an increase of 3.5°C in summer temperature and 24% increase in winter precipitation.'

It is clear that this study paints a bleak picture for the Sutlej basin. The study further concludes that the loss of glaciers will have a direct impact on the flow of the Bhakra dam as well as the overall availability of water to the hundreds of the hydropower projects located in the downstream areas of the basin. Further, the loss of glaciers would also be coupled with increased frequency of disaster events such as Glacier Lake Outburst Flood (GLOF). The study thus calls for an *'extensive investigation and improvement in existing water management practices and new investments to improve resilience of mountain community to climate change.'*

In the legislative domain, it may be noted that there is no National Level or State level legislation which directly deals with Climate Change issues. On the policy level, the State of Himachal Pradesh has constituted a State Level Governing Council on Climate Change, under the chairmanship of the Chief Minister and a State Level Action Plan on Climate Change was brought out in the year 2012 (HPSCCAP,2012). However, the said policy needs to be updated and target based action plan is required to be prepared to deal with the alarming situation as mentioned above. It is highly inadequate in many respects, particularly in terms of capacity and welldesigned institutional mechanisms at the stage of implementation and monitoring. The 2012 Policy document derives from the eight missions identified under the National Action Plan on Climate Change which was adopted in the year 2008 and has not been updated since. There is a critical need for State of Himachal Pradesh to take into account the harsh realities of impacts of Climate Change on the river systems, and come out with a more realistic and practical policy which can be implemented within the current legal framework.

4.1.7 Protecting the 'Protected Areas' in the Basin

The Sutlej sub-basin in Himachal Pradesh, with its unique structural compositions has 10 Protected Areas (PAs), supports with habitats for umbrella and keystone species of wildlife (ICFRE, 2014).However, it may be noted that there are no Community Reserve or Conservation Reserve notified under the provisions of the Wildlife (Protection) Act, 1972 as well as Biodiversity Heritage Sites under the Biological Diversity Act, 2002. Under the provisions of the Section 35 (6) of the Wildlife (Protection) Act, 1972, there is a specific prohibition on destroying or damaging or diverting the habitat of any wild animal by any act or diverting, stopping or enhancing the flow of water inside or outside the National Park. Similar provision

for protection of Wildlife Sanctuaries has been given in Section 29. These activities are allowed on the exception that a permit is granted by the Chief Wildlife Warden and that no such permit granted unless the State Government is satisfied in consultation with the National Board for Wildlife that such removal of wildlife from the National Park or the change in the flow of water into or outside the National Park is necessary for the improvement and better management of wildlife therein.

The Sutlej subbasin is rich in avifaunal biodiversity. A total of 390 species of birds have been identified of which seven are globally threatened (ICFRE, 2014).In this context, it may be noted that several Important Bird Areas (IBAs) have been identified based upon the criteria defined by Birdlife International in the subbasin.

In the Sutlej subbasin in Himachal Pradesh, Some of the IBAs harbour critically endangered Western Tragopan and Vulnerable Cheer pheasant (ICFRE, 2014).Another such process of identification conducted by the International Union for Conservation of Nature and Natural Resources (IUCN) is that of Key Biodiversity Areas (KBA). KBAs is an umbrella term commonly used to include areas that contribute to the global persistence of biodiversity, including vital habitat for threatened plant and animal species in terrestrial, freshwater and marine ecosystems. Globally KBAs are designated based on 11 criteria defined under five broad categories of threatened biodiversity; geographically restricted biodiversity; ecological integrity; biological processes; and, irreplaceability. The criteria for designating a site as KBA have been described in the document 'Global Standard for the Identification of Key Biodiversity Areas (2016)'. IUCN identified 531 KBA sites in India. Although, these are not legally notified, the fact that these 531 areas qualify as KBA reflects their ecological importance. There are several KBAs identified within the Sutlej subbasin in Himachal Pradesh.

The Sutlej subbasin in Himachal Pradesh is also known to support around 51 species of cold water fish including exotic trout, snow trout and several species of hill stream fishes (HPSCCAP 2012). This becomes important in light of proliferation of hydro projects in the basin which pose a serious threat to these endemic species of fish, affecting their spawning habits and impeding migratory routes (Theophilus, 2014). The issue of proper ecological flow assessments and ensuring proper flow in the river to support the rich flora and fauna thus becomes very necessary. The draft CIA report of ICFRE admits and states that the prolific development of hydropower projects poses a serious threat to the faunal biodiversity of the subbasin.

'The PAs within the study area fall under varied altitudinal range, and supports rich biodiversity specific to the region. The PAs are managed through effective stakeholder accepted strategy of encouraging sustainable livelihood adoption in the buffer zone. The landscapes are unique in that wildlife populations are not restricted to PAs, but occur across the landscape (Mishra, 2001)."

The Sutlej sub-Basin in Punjab has relatively lesser floral and faunal diversity in comparison to the Himalayan sub-basin. Prime factors for this are densely populated pockets, industrial and

agricultural land-use of the catchment area. However, there are four PAs which fall within the catchment area of the river, Jhajjar Bachauli Wildlife Sanctuary, Takhani Rehmanpur Wildlife Sanctuary, Nangal Wildlife Sanctuary and the Harike Wildlife Sanctuary

4.1.8 Eco- Sensitive Zones: An Effective Conservation tool for Sutlej River

Eco-Sensitive Zones around Protected Areas (PAs) are declared and notified under section 3(v) of the Environment (Protection) Act, 1986 and Rule 5 (viii) & (x) of the Environment (Protection) Rules. The purpose of notifying Eco -Sensitive Zones around Protected Areas is to create 'shock absorber' for such areas, and they would also act as a transition zone from areas that are highly protected to areas requiring less protection (MoEF Guidelines 2011). The status of the ESZ around the protected areas in Sutlej sub basin is given in Table 4.1

Table 4. 1 The Statistics of Eco Sensitive Zones around Protected Area

Sr. No.	Protected Areas	Area (km^2)	Status of ESZ Notification	Extent of ESZ As Per Notification
1.	Rakchham Chitkul WLS	304.00	Final Notification (26/07/2017)	The extent of Eco-sensitive Zone varies from 0 m to 15 km from the boundary of the WLS.
2.	Daranghati I and II WLS	167.00	Final Notification (16/03/2016)	Upto 375 meters around the WLS
3.	Lippa Asrang WLS	29.00	Draft Notification (26/11/2015)	Upto 14 km on northeast (coincides with Pin Vallley National Park), north and northwest from the boundary of WS. The extent of Eco-sensitive Zone is zero kilometer on east, south and south west side of the Wildlife Sanctuary
4.	Bandli WLS	32.11	Draft Notification (17/07/2015)	Upto 50 m from the boundary of the WLS.
5.	Kibber WLS	1353.12	Draft Notification (27/04/2016)	Upto an extent of 160 m around the Western and south Western boundary of Wildlife Sanctuary.
6.	Kanawar WLS	107.29	Draft Notification (19/04/2016)	Upto 2.7 km around the WS except on South Eastern Side.
7.	Pin Valley National Park	675.00	Draft Notification (11/03/2016)	Upto 45.82 km. The ESZ has been proposed on the north –west, northeast and south east of the NP.

8.	Majthal Wildlife Sanctaury	37.71	Final Notification (7/06/2017)	From zero to 2.252 km from the boundary of the WLS.
9.	Great Himalayan National Park Conservation Area	1615.4	Draft Notification (25/07/2016)	Upto 6 km around the NPCA except except Eastern side, North-Eastern side and Northern Side.
10.	Nangal Wildlife Sanctuary	7.15		Upto an area of 100 meters all around the boundary of the WLS
11.	Takhani Rehmanpur Wildlife Sanctuary	3.82	Final Notification (29/11/2016)	Upto an area of 100 meters all around the boundary of the WLS
12.	Harike Bird Sanctuary	86	Final Notification (12/05/2017)	Upto an area of 100 meters all around the boundary of the WLS
13.	Jhajjar Bachauli Wildlife Sanctuary	1.16	Final Notification (14/03/2017)	Upto an area of 100 meters all around the boundary of the WLS

From the above Table, it is very clear that most of the PAs within the Himachal Pradesh sub-basin do not have a notified Eco Sensitive Zone, while every PA falling within the sub-basin in Punjab have a uniform 100m notified ESZ. It is also ponderable if the extent of the proposed as well as notified Eco Sensitive Zone (ESZ) would be sufficient to act as a 'shock absorber'. With respect to the proposed prohibited activities, most of the Draft Notifications stipulate a conditional prohibition for instance 'construction of major thermal power project or hydro power projects' finds mention in the list of prohibited activities. However, the Notification states that it is 'prohibited except as otherwise provided as per applicable law'. There is a definite need to strengthen these provisions and ensure that the activities permitted in this 'buffer zone' are minimal. It may be noted that while the provisions of the Wildlife (Protection) Act, 1972 do provide certain safeguards, ensuring properly demarcated Eco Sensitive Zone is a much more effective conservation tool for rejuvenating rivers, since it covers not only the river and its ecology, but also the catchment area, in terms of regulation of permissible activities. This is so because the Notification which is issued under the provisions of the Environment (Protection) Act, 1986 have mandatory provisions with respect to activities which are prohibited and which are permissible but with conditions. In most cases, River sand/boulder mining and setting up of stone crusher units within the notified ESZ are prohibited. The State of Himachal Pradesh is making efforts to notifying the ESZ for the remaining areas falling within the basin/riverscape.

4.1.9 Conservation of Wetlands

Riverine wetlands are an important component of a River system and play a critical role in improving flood protection, recharging ground water and increasing the biodiversity, thus providing several ecological services. The State is under a legal obligation both under the Wetland Rules, 2017 issued under the provisions of the Environment (Protection) Act, 1986 as well as under India's international obligation under the Convention on Migratory Species (CMS), the Ramsar Convention and the Convention on Biological Diversity to protect and preserve wetlands as well as the avian ecology that they support.

The Himachal Pradesh has notified the constitution of the State Wetland Authority in 2017 itself (HIMCOSTE, 2017). However, it is not clear as to how much progress has been with respect to identification and notification of wetlands as per the Wetland Rules, 2017. Similar situation persists in relation to the constitution and operation of the State Wetland Authority in Punjab. The timeline as per the Rules for various steps in the identification of wetlands and notification is given in the Table 4.2.

Table 4. 2 List of activities and timeline for identification of wetlands

Activity	**Timeline as Per Rules**
Constitution of Technical Committee to review brief documents, management plans and advise on any technical matter referred by the Wetland Authority; and constitution of Grievance Committee consisting of four members to provide a mechanism for hearing and forwarding the grievances raised by public to the Authority;	3 months from date of publication of Rules.
Prepare a list of all wetlands of the State or Union Territory	3 months from date of publication of Rules.
Prepare a list of wetlands to be notified,	6 months from date of publication of Rules.
Prepare a comprehensive digital inventory of all wetlands	1 year from date of publication of Rules.

It is clear that the Himachal Pradesh and Punjab are yet to take the above stated mandatory steps as per the Wetland Rules, 2017. It is therefore necessary to initiate and complete, in a time bound manner, the process of identification and notification of wetlands under the provisions of the Wetland Rules, 2017 so that they come under legal protection. It may be noted that the main River channel is specifically excluded from the legal definition of Wetland under the Rule (MoEFCC, 2017). However, the Wetlands which are part of the basin, or which form part of the

larger catchment area of the river are important from the perspective of a holistic exercise for River rejuvenation.

4.1.10 Mineral Extraction and Industrial Land Use Ensuring Sustainable Extraction and Replenishment of Minerals

(i) River Sand/Boulder Mining and associated industries

The Sutlej River and its tributaries are not unknown to the problems of large scale illegal and unscientific mining, especially in Himachal Pradesh (Business Standard, 2019). The ill effects of River sand mining have got judicially acknowledged in several cases by the Supreme Court as well as the National Green Tribunal (NGT, 2019). In 2012, the Supreme Court had noted with serious concern that India's rivers and the Riparian ecology have been badly affected by the alarming rate of unrestricted sand mining which damges the exosystem of rivers and safety of bridges, weakening of river beds, destruction of natural habitats of oragnisma living on the river beds affects fish breeding and migration, spell disaster for conservation of many bird species, increases saline water in the rivers, etc. (Supreme Court (2012): Deepak Kumar v. State of Haryana & Ors)

Thus, the Supreme Court had, directed that all river sand mining projects irrespective of the area would mandatorily require prior Environmental Clearance under the provisions of the EIA Notification to ensure that impact from such projects is minimized and mitigated to the extent possible. Thus, any rejuvenation efforts for Sutlej River and its basin would necessarily have to concentrate on creating effective mechanism to deal with illegal mining and regulate the mining activities in the river and its basin.

Under the legislative domain, regulation for mining of sand and boulder material falls under the purview of the State Government as per the provisions of the Mines and Minerals (Development and Regulation) Act, 1957(MMDR Act) (GOI,1957). In addition to this, mining of minor minerals require prior Environmental Clearance under the provisions of the EIA Notification, 2006 issued by the Ministry of Environment, Forest and Climate Change. As per the scheme under the notification, if mining lease area is more than 50 ha, such a project would fall within Category 'A' project wherein the clearance has to be obtained from the MoEF&CC. If the lease area is 25 ha or more, but, less than 50 ha, the project would fall under Category 'B' project and in such cases clearance has to be obtained from the State Level Impact Assessment Authority (SEIAA). If the lease area is less than 25 ha, then it would be categorized as B2 projects and require clearance from the District Level Impact Assessment Authority which is headed by the District Collector/Magistrate (MoEFCC, 2016). With respect to B2 category projects, before granting clearance, there is a prerequisite condition regarding preparation of District Survey Reports with the objective of '*identification of areas of aggradations or deposition where mining can be allowed; and identification of areas of erosion and proximity to infrastructural structures and installations where mining should be prohibited and calculation of annual rate of replenishment and allowing time for replenishment after mining in that area*'. The idea is to

make a prior assessment of the available reserves in the river and to extract the same in a sustainable manner without adversely impacting the river ecology. These reports are to be updated every five years as per the EIA Notification, 2006. For the state of Himachal Pradesh, DSR Reports are available for some of the districts falling in the Sutlej Sub-basin i.e., Kinnaur, Bilaspur, Shimla, Mandi and Una. In the case of sub-basin in Punjab, DSRs have been prepared for the districts of Ludhiana, Hoshiarpur, Moga and Firozepur. The MoEF&CC has also issued sustainable sand mining guidelines (MoEF&CC, 2016) in which, interalia, addresses the issues relating to regulation of sand mining.

(ii) Stone Crusher Units

The Himachal Pradesh Government in 2014 has issued mandatory siting criteria under the provisions of the Environment (Protection) Act, 1986 (GOHP, 2012). The Notification prohibits setting of stone crushers within 500 m of lakes, wetlands and reservoir of irrigation schemes, hydropower projects and within 100 m of a canal or 'perennial rivulet'. The Notification further mandates a joint inspection by a Committee which includes the Divisional Forest Officer as a member. The Committee has to ensure that no proposal for setting up of a stone crusher is violating the siting criteria. Interestingly, the National Green Tribunal is currently considering the said notification with respect to the distance from rivulets (NGT, 2016).The issue before Tribunal is whether the distance of 100 m needs to be maintained only with respect to perennial rivulets. In an order dated 29.10.2018, the Tribunal applying the Precautionary Principle held as follows.

'8. A reference to above Entry shows that there is prohibition for location of a stone crusher within 100 m from springs, canals, reservoirs or functional water supply schemes and natural water schemes. The rivulets of perennial nature are specifically included in the said expression but, it cannot be read as excluding nonperennial water bodies. The object of the regulatory notification issued under the Environment (Protection) Act, 1986 is to protect the ecology from the adverse impact of location of a stone crusher nearby. The intention is not to permit a stone crusher within 100 m of a water body. Importance of protection of water bodies can hardly be overemphasized. Interpretation of a regulatory provision must be consistent with the 'precautionary principle' and 'sustainable development principle'. Location of a stone crusher very close to a water body is against the principle of 'sustainable development' as well as the 'precautionary principle'. The above Notification cannot be read as meaning that stone crushers can be allowed to be located just on the edge of a water body even if such water body is not perennial. Thus, the stone crushers set up within 100 m of a water body will be illegal and in violation of Environment (Protection) Act, 1986 and the Notification issued thereunder.

9. Accordingly, the consent to operate granted to any stone crusher in the State of Himachal Pradesh within 100 m of a water body will stand quashed. The Himachal Pradesh State Pollution Control Board will take steps to stop operation of any such stone crusher and furnish a report to this Tribunal within two months.

The said order came to be challenged by the State of Himachal Pradesh and several stone crusher units before the Supreme Court on the ground that they were not heard by the Tribunal while passing such orders. The Supreme Court thus, remanded the matter back for the Tribunal to consider the submissions of the State as well as the Stone Crushers. The Tribunal by order dated 2.04.2019 constituted an Expert Committee to look into this issue and give recommendations. As per order dated 10.07.2019, the Tribunal had noted the recommendations of the Expert Committee that the minimum distance from any watercourse should be 100 m irrespective of the nature of the water course perennial or nonperennial. Thus, any crusher units in violation of the siting criteria must be shut down. The department responsible for such action would be the Pollution Control Board as well as the concerned Deputy Commissioner/District Magistrate. Ensuring such polluting industries does not have an adverse impact on the river and its catchment area is an important facet of river rejuvenation.

The similar siting criteria have been notified by the Punjab government, (GOP, 2013). However, the enforcement of these siting criteria are usually seen to be weak, leading to a situation of operation of illegal and unauthorised stone crushers.

4.1.11 Urbanisation/ Infrastructure Development

Floodplains of Sutlej River and its tributaries are under major stress due to large scale reclamation for construction or infrastructure development in the form of road construction under 'Pradhan Mantri Gram Sadak Yojana' or expansion of existing highways. In the case of Kiratpur to NerChowk, four lane express way, there have been several reports of illegal muck dumping by the Project Proponent (IL&FS) into the Sutlej River in Bilaspur and Mandi Districts of Himachal Pradesh. This issue was also highlighted before the National Green Tribunal by one of the affected local persons and strict directions were passed prohibiting dumping of muck into the river (NGT, 2016). Illegal and unscientific muck dumping from infrastructure development projects have a heavy impact on the river, affecting its flow patterns and inducing flood like situation. The 2013 Uttarakhand floods were largely attributed to muck dumped by the several hydroprojects in the Ganga basin.

4.1.12 Tourism Woes –Need for a composite eco-tourism policy

One of the biggest challenges threatening the health of Sutlej River, especially in Himachal Pradesh, is the tremendous impact and stress on the river due to unsustainable tourism activities. As such, there is no definition under law for the term 'ecotourism'. In the causes of degradation of rivers, urbanisation and the heavy inflow of tourists both are emerging as problems because of the disposal of solid waste, encroachment upon the river waterways and water extraction involved. To ensure that tourism activities are sustainable, and achieves the true meaning of 'ecotourism', it is critical that the concerned Authority Local Government, Municipal Corporations as well as the Pollution Control Board take effective steps to comply with laws relating to issuance of construction licenses (GOHP, 1977), consents under the Air (Prevention and Control of Pollution) Act, 1981 and the Water (Prevention and Control of Pollution) Act, 1974, compliance with the various Waste Management Rules including the Solid Waste

Management Rules, 2016, Plastic Waste Management Rules, 2016, Construction and Demolition Waste Rules, 2016, etc.

Amongst all tourism related activities in the Sutlej River Basin, one remains largely unregulated camping and River rafting. The unsustainable practices arising out of these activities have received judicial notice in the past, with respect to River Ganga in the State of Uttarakhand. The National Green Tribunal has discussed in detail the adverse impacts of unsustainable rafting and camping activities on the river as well as the forest areas along the banks of the river (NGT, 2015). Holding that beach camping would constitute a 'nonforest' activity, the Tribunal held that the provisions of the Forest (Conservation) Act, 1980 would be applicable to these activities. Further, the State of Uttarakhand was directed to develop a regulatory regime for such activities to ensure minimum damage to the river as well as its floodplains. A similar approach may be adopted by Himachal Pradesh in ensuring that such activities have minimal impact on the Sutlej River and its floodplains.

4.1.13 Water Quality Ensuring No Untreated Sewage/Industrial Effluent Falls into the River

Water Pollution is dealt with by the Water (Prevention and Control of Pollution) Act, 1974. This is done by mandating a process of regulating discharge of domestic sewage or industrial effluent through a regime of grant of 'prior consent' by the State Pollution Control Board (SPCB). Thus, the Act (Section 24) stipulates a mandatory regime for every industry, process, activity etc. to obtain prior consent from the concerned SPCB for such a discharge of sewage or industrial effluent (GOI, 1974). The provision lays down a twopronged consent regime a prior consent to be obtained before establishing the unit/industry and consent to be obtained after setting up of the unit/industry, but before starting operations. These consents are referred to as Consent to Establish (CTE) and Consent to Operate (CTO). The CTE is granted on the basis of the location of the proposed site, its pollution potential, proximity to sensitive areas etc. Once the plant/unit/industry is set up, on the basis of the compliance status of the conditions stipulated in the CTE, the SPCB grants the CTO. The Section 49 of the Water (Prevention and control of Pollution) Act, 1974 envisages that SPCB may also initiate penal proceedings against the violator for the harm caused to the environment due to violation/noncompliance of the consent conditions (GOI, 1974).

A major component of rejuvenation of Sutlej River would be tackling the outfall of untreated sewage and industrial effluent into the river. Sutlej basin supports several industrial towns across both Himachal Pradesh as well as Punjab, thus the water quality has reached alarming levels of toxicity from the poorly treated or untreated effluents from these areas.As per data available with Central Pollution Control Board (CPCB), the river stretch of Sarsa River at Baddi Nalagarh, in District Solan, Himachal Pradesh has been identified as a polluted stretch (CPCB, 2015).

Even as Sutlej enters the plains in Punjab, the river and its tributaries are subjected to high levels of pollution (Table 4.3) from agricultural runoff from pesticides and fertilisers as well as untreated sewage and industrial effluents from the towns of Ludhiana and Jalandhar. As per the

CPCB Report, the following stretches have been identified as critically polluted in Sutlej sub-basin in Punjab.

Table 4. 3 Critically polluted stretches in Sutlej subbasin in Punjab

River/Tributary	Stretch	Priority
Sutlej	Roop Nagar to Harike Bridge	Priority I
Chitti Bein	The Chitti (White)Bein passes through all districts of doaba and drains into the Sutlej, near Harike in Amritsar District	Priority IV

Taking cognisance of the above referred CPCB report, the National Green Tribunal has passed several directions in a *suomoto* case, wherein the Tribunal has directed for setting up of River Rejuvenation Committees (RRC) in each State to come out with implementable action plans to rejuvenate the identified polluted River stretches in each State (NGT, 2018). The matter is being monitored by the Tribunal on a regular basis. Thus, the RRC would be an integral stakeholder while discussing rejuvenation of the Indus Basin Rivers in a whole. In this regard, the Himachal Pradesh SPCB has prepared an action plan for the rejuvenation of Sirsa River in Baddi in Himachal Pradesh (HPPCB, 1999).The said report identifies the following areas as part of the action plan Rain Water Harvesting/ Ground Water Recharge aspects, Maintaining EFlows, Watershed Management, Use of Treated Sewage, Good Irrigation Practice, and Development of Biodiversity Parks. The Punjab Pollution Control Board has also prepared an action plan for cleanup of the Sutlej River in the State (PCCB, 2019).

In addition to the broader monitoring by the National Green Tribunal in the abovementioned case, the Tribunal has also passed elaborate directions in a case relating to River pollution in Sutlej River in Punjab (NGT, 2019). The directions, *inter alia*, include construction and proper operation of Common Effluent Treatment Plants (CETP) in industrial clusters as well as plugging untreated sewage by passing specific directions to the Punjab Water Supply and Sewerage Board (PWSSB). The implementation of these directions is being overseen by a Monitoring Committee which is headed by a former Judge of the Punjab and Haryana High Court. Thus, in specific context of Sutlej River, there has to be concerted efforts by the respective SPCBs, Water Supply and Sewerage Boards as well as the Municipal Corporations to ensure plugging of untreated sewage and industrial effluents into the river. It would also be important that an effective coordination between the various Courts /Tribunal appointed Committeesis required for implementation of their directions for ultimately improving water quality of Sutlej River.

4.1.14 Catchment Area Conservation Measures

While looking at rejuvenating a river, it is important to not just consider the river in isolation. A river is more than just the channel of flowing water, and has to be understood in terms of its catchment, the river bed, bank and floodplain as well as the vegetation on the floodplain. A healthy catchment area is thus integral to ensuring healthy River. In this regard, issues which need to be looked at include floodplain protection measures and measures to ensure efficient retention capacity of rain water in the soil.

Flood plains Protection and Conservation

Floodplains protection is critical to River conservation and ensuring good River health. They also support ecological diversity in a River system by providing carbon and nutrients supply to River channel, which finally governs productivity of the entire River system and by providing geomorphic (habitat) diversity in River space to support biodiversity (Richards, *et al.*, 2002; Gurnell and Petts, 2002; Thoms, 2003). It is thus, very important that floodplains are correctly demarcated and protected. The importance of floodplain demarcation has been highlighted in several cases before the National Green Tribunal with regard to rivers in Maharashtra and River Yamuna in Delhi and Agra. Zoning of the floodplains by demarcating prohibited zone and regulatory zone is an efficient tool for protecting and conserving floodplains. For instance in the State of Maharashtra, as early as 1989, the Government had issued an order directing for demarcation of the floodplains into prohibited zone (blue zone) (GOM, 1989).

4.1.15 Involving Communities in River Rejuvenation Efforts

Any efforts of River rejuvenation would not be successful unless and until local communities, dependent upon the river are actively consulted and engaged with. There are several legal policy tools which can be referred to and employed to achieve this key process. In fact, the National Forest Policy, 1988 and the National Water Policy, 2012 recognises the critical role played by communities in ensuring conservation as well as the rejuvenation of the forest lands as well as water resources in the country. In the context of Sutlej basin, it may be noted that in Himachal Pradesh, the entire districts of LahaulSpiti and Kinnaur have been declared as Scheduled Areas under the provisions of the H.P. Panchayati Raj (Second Amendment) Act, 1997 which in turn had extended the provisions of *Panchayats* (Extension to the Scheduled Areas) Act, 1996 (hereinafter PESA) to the Scheduled Areas in the State. Communities can be involved with the help of the following laws/ policies which are in force:

(i) Panchayats (Extension to the Scheduled Areas) Act (PESA), 1996

The PESA legally recognizes the right of tribal communities to govern themselves through their own systems of selfgovernment and also acknowledges their traditional rights over natural resources. In pursuance of this objective, PESA empowers *Gram Sabhas* to play a key role in approving development plans, controlling all social sectors – including the processes and personnel who implement policies, exercising control over minor (nontimber) forest resources,

minor water bodies and minor minerals, managing local markets, preventing land alienation and regulating intoxicants among other thing (GoI,1996).

(ii) Forest Rights Act, 2006

The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 can also be used as an effective tool to empower and engage with tribal communities for participation in the rejuvenation efforts of SutlejRiver. Forest dwelling tribal communities and traditional forest dwelling communities have community forest rights whereby they are empowered to protect, regenerate, conserve and manage a community forest resource (GoI, 2006) By acknowledging title of communities to the forested areas in the catchment area of the river, the State Government can actively engage in specific conservation and rejuvenation measures for Sutlej River basin, especially in Himachal Pradesh. With respect to the Integrated Kashang Hydropower Project coming up on one of the tributaries of SutlejRiver, the National Green Tribunal had upheld the rights of the *Gram Sabha* under The Forest Rights Act, 2006 directed the State of Himachal Pradesh to place the project before the *Gram Sabha* for its consent as per the provisions of the Forest Rights Act, 2006 as well as the conditions under the Forest Clearance granted to the project (NGT, 2016).

(iii) Biological Diversity Act, 2002

As per the Biological Diversity Act, 2002, it is mandatory for every local selfgoverning institution in both rural and urban areas to constitute Biodiversity Management Committee (BMC) within their area of jurisdiction. The objective behind BMC constitution is promotion of conservation, sustainable use and documentation of biological diversity. One of the important functions of the BMC is to prepare and maintain the Peoples' Biodiversity Register (PBR) in consultation with the local people. A PBR comprehensively documents information on the availability and knowledge of local biological resources (those falling within the territorial jurisdiction of the BMC), their medicinal and aromatic or any other use of traditional knowledge associated with them. The PBR thus prepared then serves as a legal document which confirms the sovereign rights of that BMC over the resources documented in the PBR. In addition to preparation of a PBR, the roles and responsibilities of a BMC takes various forms such as ecorestoration of the local biodiversity, management of sacred groves and sacred water bodies, conservation of traditional varieties/breeds of economically important plants and animals. The BMC can be thus, actively consulted while undertaking specific measures to rejuvenate the river. Further, the PBRs can be a good source of knowledge of indigenous species of plants and trees which can be considered while undertaking plantation drives, or afforestation measures.

The NGT is also monitoring the implementation of the provisions of the Biological Diversity Act, 2002 NGT, 2016. As per the latest report of the MoEF&CC to the Tribunal as on August 2019, in Himachal Pradesh, out of 3,370 local bodies, BMCs have been constituted in 730 only, which implies the compliance rate is only 21.66%. With respect to preparation of PBRs, only six BMCs have prepared the same. With respect to State of Punjab, out of 1,477 local bodies, BMCs

have been constituted only in 74, i.e. 5% compliance rate. 43 BMCs have prepared PBRs. In a series of orders, the Tribunal has issued strict directions to all State Governments and Union Territories to ensure 100% compliance with respect to constitution of BMCs and preparation of PBRs by 31.01.2020. In case of noncompliance, the Tribunal has imposed a hefty penalty of 10 lakhs per month on the defaulting States. The NGT (2019) in August, 2019 emphasised on the importance of the Act of 2002 stating that the Act was enacted to give effect to the United Nations Convention on Biological Diversity (CBD) and that the delay of more than sixteen years in complying with the mandate of law was a matter of serious concern.

4.1.16 Identifying Stakeholders

This Section identifies the various Official Departments and their role in ensuring that the rejuvenation of Sutlej River is effective and successful. It is also important to have an active coordination between these departments and ensure that there is no overlapping of functions. The role of each Department that has been identified on the basis of the discussion has been given in Table 4.4. The summary of existing relevant legislations, policies and other documents has been given in Table 4.4.

Table 4. 4 Departments Associated with the Subject of River Conservation

Departments	**Existing Rules/Guidelines/ Norms**
State Pollution Control Board (SPCB)	i. Consent should not be granted as a matter of routine. ii. Consent to Establish should not be granted in areas which are ecologically sensitive. iii. The practice of granting standalone Consent should be done away with and should be based on carrying capacity assessment. iv. The Renewal of Consent to operate should not be a mechanical process but should be based on proper ground verification. v. The SPCB should put special focus on the main objective of the Water Act, 1974 i.e., maintaining the wholesomeness of water. Any project seeking approval must show how the proposed activity is not in contradiction to the said objective. vi. Projects which are granted Environmental or Forest Clearance should not be granted Consent to Establish as a matter of routine. The SPCB should play a proactive role in examining the impact the project will have on the water quality including flow. vii. The small hydro projects are currently exempted from the

		requirement of obtaining Consent under the Water Act, 1974. This has to change, and the SPCB must ensure the protection on Riparian rights of the people as well as maintaining the flow. There needs to be an objective assessment of the level of compliance with these conditions.
	viii.	Monitoring water quality under Water (Prevention and Control of Pollution) Act, 1974 and Rules.
State Water Department/ Sewerage Board	I.	Proper maintenance of Sewage Treatment Plants and ensuring that no untreated sewage is discharged into the River or its tributaries.
	II.	Ensuring that the treated water is meeting the standards set under the Environment (Protection) Act, 986 and Water (Prevention and Control of Pollution) Act, 1974.
State Environment Impact Assessment Authority (SEIAA)	i.	The SEIAA along the SEAC are key bodies for protection of the Sutlej sub basin. However, the SEIAA and SEAC grant approvals to project without a thorough assessment of its likely impact on the ecology. No consideration is given as to what impact the proposed project will have on the River and the riverine ecosystem. It is essential that before any project is allowed, the SEAC and SEIAA should conduct a thorough assessment of the proposed site; examine the project along with other projects which have similar effect and take a decision keeping the totality of environmental situation into account. Both ground truthing and GIS application should be relied on.
	ii.	There is a need to make the SEAC and SEIAA as robust institutions which have both the capacity and ability to take decision that protect the environment rather than favouring destructive projects. Areas which have crossed the threshold in terms of its cumulative impacts should have a moratorium in place.
	iii.	Instead of general compliance condition, site specific and project specific conditions should be imposed.
	iv.	Third party monitoring which also involves the local community should be done by SEIAA specifically for those projects which are seeking expansion of the

	production capacity.
Regional Office, Ministry of Environment, Forest and Climate Change, GoI	i. Monitoring of compliance of conditions stipulated in the Environmental Clearance granted under the EIA Notification, especially with respect to eflow from hydro projects.
State Forest Department (SFD)	i. Ensuring proper implementation of forestry measures including catchment area treatment, compensatory afforestation, etc. ii. Ensuring active synergies and viamedia between the communities and other departments in rejuvenation efforts.
Irrigation Department/Revenue Department	i. Floodplain demarcation for one in 25 years and one in hundred years. ii. Issue directions demarcating proper setbacks, and developing a prohibitory and regulatory regime for activities permissible within the River bank and floodplains.
Municipal Corporations/*Panchayats*	i. Compliance and monitoring of the Waste Rules, 2016 under the Environment (Protection) Act, 1986 especially segregation of waste at source and ensuring plastic waste is disposed of as per the provisions of the Plastic Waste Rules, 2016 and does not find its way into the River. ii. Ensuring no buildings or construction activities are permitted on the active floodplains or banks of the River.
Town and Country Planning	i. Ensuring proper setbacks are provided for the River in Development Plans of the cities on banks of the River.
Tourism Department	i. Preparation of an effective policy on ecotourism which emphasises on mandatory setbacks from the River bank, and prohibits any construction on the River bank, and its active floodplain ii. To develop proper guidelines /regulatory regime iii. To regulate the River rafting and camping activities in line with the judgment of the National Green Tribunal in SAFE v. Union of India & Others
River Rejuvenation Committees	i. Coordination between all the official departments in ensuring proper and effective rejuvenation efforts.

(Constituted under the orders of the National Green Tribunal)	I. Effective Implementation of the action plan submitted to the National Green Tribunal.
Biodiversity Management Committees (BMC)	I. Preparation of PBRs and utilising traditional knowledge of communities for ensuring better catchment area treatment measures in the form of afforestation, etc. II. Ensuring PBRs are used as an effective tool in terms of documentation of the biodiversity and thereby ensuring proper impact assessment of any developmental activity that is proposed in the River Basin.
National Afforestation and Eco-Development Board (NAEB)	I. Ecological restoration of degraded forest areas and adjacent lands through systematic planning and implementation, in a cost effective manner. II. Responsible for coordinating and monitoring of the Action Plans for afforestation, reforestation, ecological restoration and eco-development. III. Sustainable management of degraded forest areas and adjoining lands

4.1.17 Legislative Policies, Authorities, Conservation and management tools

The overview of different laws and included reference to a wide range of rules, policies, and authorities has highlighted important judgements by various Courts addressing degradation of natural ecosystems and directives given to concerned agencies by the Courts. The overview tried to attempt as well as to provide an insight into the existing legal environment that supports River conservation. Thus, it is considered appropriate to sum up and also provide brief narration on relevant laws, rules, policies, and even definitions for better appreciation by different stakeholders involved in planning, assessment, protection, management, regulation and use of wide array of River resources (Table 4.5, 4.6, 4.7 and 4.8).

Table 4. 5 List of Relevant Legislations, Policies and Other Documents

S .No.	Legislations/Policies/Guidelines
1.	Environment (Protection) Act, 1986 1. Solid Waste Management Rules, 2016 2. Plastic Waste Management Rules, 2016 3. Wetland (Conservation and Management) Rules, 2017 4. EIA Notification, 2006 5. Notification dated 29.05.2014 issued by Government of Himachal Pradesh for siting criteria for stone crushers. 6. District Survey Reports prepared under the EIA Notification, 2006
2.	Wildlife (Protection) Act, 1972
3.	Air (Prevention and Control of Pollution) Act, 1981
4.	Water (Prevention and Control of Pollution) Act, 1974
5.	Forest (Conservation) Act, 1980 Forest (Conservation) Rules, 2003
6.	Biological Diversity Act, 2002
7.	Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006
8.	Himachal Pradesh Town and Country Planning Act, 1977
9.	River Ganga (Rejuvenation, Protection and Management) Authorities Order, 2016. (as a reference to see how Basin level management has been proposed for River Ganga)
10.	National Forest Policy, 1988
11.	National Water Policy, 2012
12.	National Action Plan for Climate Change
13.	Himachal Pradesh State Climate Change Action Plan
14.	Guidelines for implementation of Wetland Rules, 2020

15.	CGWA Guidelines/Criteria for evaluation of proposals/requests for ground water abstraction, 2015
16.	MoEF&CC Guidelines on Sustainable Sand Mining, 2016
17.	MoUD Guidelines on Urban Greening, 2014

Table 4. 6 Relevant authorities and their Functions

Sr. No.	**Relevant Authorities**	
	Authority	**Functions**
1	Central Empowered Committee	Constituted under the Environmental (Protection) Act pursuant to the Order of the Supreme Court in 2002 for all matters relating to the application of the Forest (Conservation) Act, 1972
2	Expert Appraisal Committee	Constituted under the EIA Notification to appraise and grant clearance for projects
3	Pollution Control Board	The Central Pollution Control Board is entrusted with promoting the cleanliness of the streams (including rivers and sea). And laying down the standards of quality of water. State Pollution Control Board can establish standards for discharge of effluents. It is also responsible for minimizing water pollution through granting consent for the establishment and operation of units.
4	Water Quality Assessment Authority	Constituted under the Environment (Protection) Act to standardize methods for monitoring of water quality and ensuring quality of data generation and utilization. The powers and functions of the authority include preparing schemes for restriction of discharge of treated sewage/ trade effluent on land, rivers and other water bodies with a view to mitigate crisis of water quality. The authority can also review the status of quality of national water resources (both surface and ground water) and identify 'hot spots' for taking necessary actions for improvement in water quality.

Sr. No.	Relevant Authorities	
	Authority	**Functions**
5	Central Water Commission	Central Water Commission (CWC) is a premier Technical Organization of India in the field of Water Resources, and is presently functioning as an attached office of the Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation, Government of India. The Commission is entrusted with the general responsibilities of initiating, coordinating and furthering in consultation of the State Governments concerned schemes for control, conservation and utilization of water resources throughout the country, for purpose of Flood Control, Irrigation, Navigation, Drinking Water Supply and Water Power Development.
6	National Green Tribunal	The National Green Tribunal (NGT) has been established under the National Green Tribunal Act, 2010 for effective and expeditious disposal of cases relating to environmental protection and conservation of forests and other natural resources including enforcement of any legal right relating to environment and giving relief and compensation for damages to persons and property and for matters connected therewith or incidental thereto. It is a specialized body equipped with the necessary expertise to handle environmental disputes involving multidisciplinary issues.

Table 4. 7 Relevant Conservation and Management Tools

Conservation and Management Tools		
Sr. No.	**Conservation and Management tools**	**Implications in Context of River Management**
2	Cumulative Impact Assessment; Carrying Capacity Study	The impact assessment of individual project in isolation does not reflect the combined impact of a cascading development of projects in River basins, which may be significantly higher. The

Conservation and Management Tools		
Sr. No.	**Conservation and Management tools**	**Implications in Context of River Management**
		carrying capacity of the River basin should be carefully studied and the impact resulting from all past, present and foreseeable developments in the region should be viewed in light of the carrying capacity of the River basin. This is a fundamental tool for sustainable River development planning. An Office Memorandum (OM) of the MoEF&CC, dated 29.5.2013 requires State Governments to conduct Cumulative Impact Assessment and Carrying Capacity Study of River basins, As per the OM: 'Cumulative impact study of a basin would reflect the cumulative impact of commissioned/ upcoming hydropower projects in the basin on environmental flows, biodiversity, muck disposal sites, traffic flow in the region, R&R issues, etc. It should be incumbent on the developer to incorporate all possible and potential impact of other project(s) in the basin to get a Cumulative Impact Assessment done'. The carrying capacity study of a River basin is important to plan optimal number of power projects in a basin. All State Governments will be required to get such studies done for River basins in their State. The carrying capacity study report would be made a prerequisite for considering EF/FC cases of projects of any basin'. In the context of the Ganga River basin,

Conservation and Management Tools		
Sr. No.	**Conservation and Management tools**	**Implications in Context of River Management**
		the Supreme Court in Alaknanda Hydropower corporation *vs.* Anuj Joshi &Ors. has ordered a Cumulative Impact Assessment and Carrying Capacity in the upper reaches of the Ganga. The MoEF&CC has set up an Expert Body in 2015 pursuant to the order of the Supreme Court.
3	Environmental flows	An approach similar to the one in place with respect to Ganga Basin can be adopted. The Jal Shakti Ministry has notified e-flow regimes for the entire river stretch as well as a Notification under the Environment (Protection) Act, 1986 wherein strict provisions with respect to floodplain and catchment area protection have been included along with penal provisions for any violations of such strictures. Order of the National Green Tribunal in the matter of Pushp Saini Vs. Ministry of Environment, Forest & Climate Change & Others dated 09/08/2017 regarding environmental flow of the rivers which should be permitted despite hydro projects. Counsel appearing for Ministry of Environment, Forest and Climate Change submits that the Ministry has already completed river basin study of 6 river basins i.e. Siang River Basin, Twang River Basin, Bichom River Basin, Subansiri River Basin, Dibang River Basin and Lohit River Basin and upon study the Ministry has recommended the

Conservation and Management Tools		
Sr. No.	**Conservation and Management tools**	**Implications in Context of River Management**
		minimum flow of the river to be 18% of the average of lean season flow of the river. However, in some of the cases, it has stated to be even 20%. NGT directs that all the rivers in the country shall maintain minimum 15 % to 20% of the average lean season flow of that river.
4	Development master plans for cities	The NGT has asked the State authorities to demarcate the floodplain for the flood of once in 25 years and to prohibit any kind of development activity in such areas (NGT, ManojMisra *vs*. Union of India, 2015). Guidelines for Conservation, Development and Management of Urban Greens, 2013 provide for integration of existing trees/ green areas within the development master plans of cities.
5	Eco-Sensitive Zone and Zonal Master Plan	The State Government has to prepare a Zonal Master Plan, which has to be approved by the MoEF&CC. The Plan should specifically address issues like restoration of denuded areas, conservation of water bodies, management of catchment area, and soil and moisture conservation.
6	'Brief Document' under the Wetlands Rules	The State Government has to identify the 'protected wetlands' in the State and submit the proposal to the Central Wetlands Regulatory Authority. Considering the important function of wetlands in River basins, they should be included in the Brief Document, and

Conservation and Management Tools		
Sr. No.	**Conservation and Management tools**	**Implications in Context of River Management**
		adequate measures should be undertaken to improve and conserve these wetlands
7	Memorandum of Understanding between Joint forest Management committee and the Forest Department of the State	The MoU should contain locationspecific work programme for forestry initiatives, and also provide for the consumption and livelihood needs of forest dependent communities.
8	Working Plan of the forest Department of the State	The Working Plan lays down the manner in which trees within forest areas can be felled. State governments are responsible for drawing up a working Plan to ensure sustainable forest management and utilization practices. The Working Plan should also enable the proper and simultaneous application of different legislations relating to forests, wildlife and biodiversity. The National Working Plan Code, 2014 of the MoEF&CC provides a uniform code for drawing up the Working Plans of each Forest Division by State Government

(Source: Adopted from FRI, 2016)

4.1.18 Implications and the Way Forward

The management issues those are involved in the conservation and restoration of the Sutlej River are numerous, intricate and challenging. The policy and legal provisions need to facilitate the management of rivers and factors affecting them. It is pertinent to address and fulfil the gaps in the existing regulatory mechanism. Some of the gaps can be potentially addressed within the existing regulatory framework while others may require a fresh look and inclusion of appropriate provisions or revision of existing ones. The past experience illustrates that the piecemeal and fragmentary approach to River conservation, particularly the environmental impact assessment has not yielded desired insight and failed to reflect a true and comprehensive picture of the range of impacts. The relationships between upstream and downstream, forests and their hydrological functions, River and surrounding lands have been poorly understood. Until the studies or

decisionmaking process factor in the intricate relationships and incorporate cumulative assessment of impacts and evaluate carrying capacity of rivers, outcomes will continue to remain suboptimal.

The degraded River ecosystems require restoration and efficient management for not only the long term sustainability of the River but also for the associated biodiversity and the ecosystem services they offer. A comprehensive approach towards management of forests is essential. It is necessary to apply the provisions of the various existing laws relevant to forest, environment and the biological diversity collectively so as to accomplish the goals of long term protection of forests along with the rivers. The existing legal and policy framework can immensely help in the following:

(a) Declaration of select biodiversity Rich River stretches of conservation priority as protected areas under the Wildlife (Protection) Act, 1972.

(b) Declaration of biodiversity rich areas as the biodiversity heritage sites under the Biological Diversity Act, 2002.

(c) Declaration of identified areas as the ecologically sensitive sites under the Environment (Protection) Act, 1986.

(d) Ensuring cumulative EIA as well as comprehensive EIA with respect to any developmental project or biotic interference such as sand and bolder mining.

(e) Facilitating implementation of the Wetland Rules, 2017, particularly in demarcation of the zone of influence as far as wetland areas are adjacent to rivers.

The maintenance of environmental flow (e-flow) is critical for ensuring the River connectivity and various ecological processes. Therefore, it is important to enforce the rules/ directives relevant to eflow issued from time to time. It is important that any proposal for diversion of forest land in close proximity to the River or its tributary is examined thoroughly and carefully to avoid any adverse implications on River ecosystem. Considering the vast extent of River from its origin to confluence/ mouth, a wide range of stakeholders (agencies, departments, users, etc.) involved, and intricate nature of River, it would be desirable to designate an appropriate Riverauthority in case of each of the prominent River of the country. Undoubtedly, there is a strong mandate and available avenues within the existing legal framework to develop proactive interventions with adequate legal backing for River restoration and conservation. Moreover, the existing legal framework has been adequately supplemented with insightful judicial interpretations and specific directives for implementation and to develop a rich body of environmental jurisprudence. The above overview has amply reflected that the existing legal and policy framework is adequate to take care of the complexities of rivers in human dominated country like India.

i) Institutions and Implementing Agencies – Central and State Government

The preceding chapters and the forgoing sections have given ample idea about the wide array of government and nongovernmental agencies at the Centre and State levels besides diverse stakeholders and the civil society those are involved with the prominent disciplines/ sectors of forest management, wildlife conservation, environmental management, water resource management, River development and restoration of rivers in the country. The Chapter 2 on the Sutlej riverscape and its environment has appropriately highlighted the intricacies of the physical, biological and socioeconomic subenvironments in the context of River besides numerous sectors and agencies directly connected and responsible for the maintenance of uninterrupted eflows and clean water of Sutlej River. In general, the Union Ministry of Jal Shakti and the Ministry of Environment, Forest and Climate Change at the centre are the two prominent ministries those are directly concerned with the Sutlej River, its environment, and much desirable restoration process. Details of the Ministry of Jal Shakti, its mandate, programmes and activities have already been provided. From the perspective of Sutlej River, the role of Bhakra – Beas Management Board (BBMB) has also been highlighted. However, from the perspective of proposed forestry interventions, details of the Implementing Agencies at the National and State levels are much desirable. Hence, the following section provide details on the MoEF&CC as the nodal agency for overseeing and steering the programme implementation; the ICFRE, Dehra Dun and its institute i.e. the HFRI, Shimla as the national partner organization for capacity development and monitoring; and the pivotal role of the concerned State Forest Department in two States as the Implementing Agencies.

a) The Ministry of Environment, Forest and Climate Change (MoEF&CC)

The MoEF&CC at the Centre is the Nodal Ministry responsible for the planning, promotion, coordination and overseeing the implementation of country's environmental and forestry policies and programmes aiming for sustainable management of wide range of natural ecosystems i.e., forests, grasslands, wetlands including lakes and rivers, and coastal and marine, associated biodiversity, ensuring the welfare of animals, and the prevention and abatement of pollution. While implementing various policies and programmes related to forests, environment and wildlife, the Ministry is guided by the principle of sustainable development and enhancement of human wellbeing. The Ministry also serves as the nodal agency in the country for the United Nations Environment Programme (UNEP), South Asia Cooperative Environment Programme (SACEP), and International Centre for Integrated Mountain Development (ICMOD), and for the follow up of the strategies and programmes of the United Nations Conference on Environment and Development (UNCED). The Ministry is also entrusted with important tasks related to multilateral bodies such as the Commission on Sustainable Development (CSD), Global Environmental Facility (GEF), and of regional bodies like the Economic and Social Council for Asia and Pacific (ESCAP) and the South Asian Association for Regional Cooperation (SAARC) on matters related to the environment. The Ministry is also entrusted to implement programmes

related to various international conventions *viz*., the United Nations Convention on Biological Diversity (UNCBD), United Nations Convention on Combat of Desertification (UNCCD), United Nations Framework on Climate Change (UNFCC), Ramsar Convention on Wetlands, Convention on Control of International Trade in Endangered Species of Wild Fauna and Flora (CITES), etc. for which the country is signatory and thus, committed. Till recent past the MoEF&CC also dealt with the various programmes and activities related to River Ganga *viz*.,the Ganga Action Plan, National Ganga River Basin Authority (NGBRA), and National Mission for Clean Ganga. These subjects and activities were transferred to the Ministry of Water Resources (presently Ministry of Jal Shakti) with it's enlarge mandate. The MoEF&CC is supported in its mandate, functions and responsibilities by wide range of Authorities, Agencies, Organizations/ Institutions and Subordinate offices.

b. National Afforestation and Eco-Development Board (NAEB)

The NAEB was established in August 1992 in the Ministry of Environment, Forest and Climate Change, Government of India. The main role of board includes promotion of afforestation, reforestation, ecological restoration and eco-development activities in the country, especially with main focus on degraded forests and land adjacent to the forest areas, National Parks, Wildlife Sanctuaries and other protected areas. Besides, the NAEB pays due attention to ecologically fragile areas such as the Western Himalaya, Aravalis, Western Ghats, etc. The main function of NAEB pertains to evolving mechanisms for ecological restoration of degraded forest areas and adjacent lands through systematic planning and implementation, in a cost effective manner. It is also responsible for coordinating and monitoring of the Action Plans for afforestation, reforestation, ecological restoration and eco-development. The creation of general awareness to encourage the involvement of people, voluntary agencies, NGO's, Panchayati Raj Institutions (PRI) in afforestation and sustainable management of degraded forest areas and adjoining lands; is also important function of the NAEB. It also sponsors research and extension of research findings among masses.

c. The Indian Council of Forestry Research and Education (ICFRE) and Himalayan Forest Research Institute (HFRI)

The Indian Council for Forestry Research and Education (ICFRE), an autonomous Council under the MoEF&CC is supported by 9 institutes and four advanced centres in performing the wide range of functions across the country those include conduct of forestry research; transfer of innovative technologies in the field of forestry relevant to the different biogeographic regions of the country to the States/ UTs and other agencies; and to impart forestry education. The Himalayan Forest Research Institute (HFRI) at Shimla is one of the regional institutions under the umbrella of ICFRE and mandated to generate, preserve, disseminate and advance knowledge, technologies and solutions for addressing issues arising out of interactions between people and forests and environment on a sustained basis through research, education and outreach and the specific goal of contributing research relevant to the conservation of Western Himalayan forests

and forest ecosystems. The HFRI has been assigned the jurisdiction of two Union Territories – Jammu and Kashmir and Ladakh, and one State i.e. Himachal Pradesh. As stated earlier in the Chapter 1, the MoEF&CC has entrusted a major task to ICFRE on the preparation of DPRs on forestry interventions for rejuvenation of major Indian rivers. Considering the expertise and appropriate location of HFRI in the Himalayan State of Himachal Pradesh, the ICFRE assigned the responsibility of preparing the DPR on the Sutlej River along with four other DPRs on major rivers of the Indus River system. The HFRI with its long standing for past more than three decades and expertise in the field of forestry relevant to the North-Western Himalaya, multidisciplinary scientific staff including practising professional foresters, wellplaced vast campus amidst deodar forests and adequately equipped various laboratories and other physical infrastructure is the most appropriate Government of India's scientific agency not only for the preparation of present DPR but for its effective implementation, capacity development and monitoring through the State Forest Department (s) of the two involved States. The HFRI has strong network with various forestry related sister institutions under the umbrella of ICFRE as well as other organizations and other sister institutions under the MoEF&CC.

d) Institutional Framework of State Forest Departments

As per the Constitution of India, the subjects of Forests, Wildlife and Environment are in the Concurrent List. Accordingly, the MoEF&CC is the Nodal Agency in the administrative structure of the Central Government for the planning, promotion, coordination and overseeing the implementation of India's environmental, forestry and wildlife policies & programmes. However, the State Forest Department (SFD) in each State/ UT is the custodian of forests and wildlife of the State, besides being responsible for management, conservation, and protection of the environment i.e., land, water and air. The State Forest Department is also responsible for the management of forest lands or Recorded Forest Area, irrespective the type of vegetation these lands harbour. The State Governments and SFDs area mandated for the enforcement of laws and implementation of various policies and strategies enacted/ formulated by the Central Ministry from time to time.

1) Mandate of State Forest Departments

The SFDs manned by the Indian Forest Service (IFS) and State Forest Service (SFS) Officers not only have the well organized hierarchical organizational setup, state wide infrastructure, and long experience of managing diverse forests alongside other natural ecosystems, but also have much desired capacity, multidisciplinary expertise and well equipped with modern equipment, tools and technologies. This makes the SFDs more amenable to capacity development at even short notice to adopt newer approaches and improved methods and also to diversify as per the emerging needs in the fields of ecosystem management, climate change mitigation and adaptation, River conservation and sustainable development.

During 150 years or so, the discipline of forestry as well as the mandate, objectives, strategies and working have undergone sea changes. Since then, emerging needs led to paradigm shift in

forest management. Thus, the forest management gradually moved from exploitation to conservation, multiple use to multiple benefits, sustainable yield to sustainable management, species to ecosystem management, authoritative (policing) type of management to participatory approaches to management, just silviculture to modern technologies like Remote Sensing, GIS and GPS. Obviously, the SFDs have evolved into multipurpose, adaptable and dynamic organizations, ready to tackle multifarious challenges relevant to forestry, wildlife management, biodiversity conservation, rural development, human environment, integrated watershed management, eco-restoration, River restoration/rejuvenation, climate change mitigation and adaptation, and sustainable development.

In view of the above, the primary mandate of SFDs can be summarized as below:

a. Protection of forests, enforcement of various laws, and management of forests pests
b. Creation of physical infrastructure (forest roads, patrolling stations, waterholes, barriers, watch towers, etc.) and their management
c. Implementation of Silviculture based forest management
d. Afforestation and restoration activities to increase forest cover of the State/ Country
e. Conservation of forests and other natural ecosystems(grasslands, alpine pastures, wetlands including rivers, coastal and marine)
f. Integrated watershed management through soil and moisture conservation works and afforestation
g. Wildlife management and conservation of biodiversity including population estimation of prominent wildlife
h. Eco development, joint forest management, improvement of livelihoods, management of sustainable livelihoods in forest fringe villages and protected areas
i. Promotion and management of nature tourism/ ecotourism in forests/ PAs
j. Mitigation of PA people and human wildlife conflict
k. Nature education, nature interpretation, mass awareness, outreach and advocacy
l. Research and monitoring activities
m. Establishment and maintenance of forestry/ wildlife/PA management/ biodiversity conservation &related databases
n. Capacity development

Thus, from the above activities of the SFDs, it is amply clear that scope of works and mandates have significantly enlarged and diversified in just 150 years or so. Most of the activities, roles, responsibilities, and functions cut across different disciplines viz., silviculture, ecology, hydrology, law, socioeconomics, etc. guided by scientific principles and administrative

excellence, the newer perspective of natural resource management requires adoption of landscape/riverscape/seascape approach to conservation. In past three decades or so, the SFDs have been successful in providing the desired thrust on the ecosystem management, landscape approach, and participatory approaches so as to contribute to the larger agenda of sustainable development. In the process, the focus of working of SFDs has shifted from small extent of forest stands/ coupes to large landscapes those incorporate protected areas, managed forests and the dominating 'matrix'. The newer approaches seek interagency cooperation and sectoral convergence in order to meet diverse goals and multiple objectives of forestry. Hence, in recent decades, SFDs have been working in close cooperation of allied sectors.

4.1.19 Multi Sectoral Convergence

The newer requirements of above stated enlarged scope, mandate and adopted holistic approaches to conservation and sustainable management of forests for multiple values, demand that SFDs work in close cooperation with various line agencies, *Gram Panchayats* and other local self governance bodies at the grassroots level, NGOs and local communities. The new mandate has made the SFDs a focal point of convergence among various allied departments. Accordingly, in recent decades, increasingly SFDs have worked in partnership with the Department of Agriculture and Horticulture, Department of Animal Husbandry, Public Works Department, Public Health Department, Department of Tribal Development, Panchayati Raj, Revenue Department, Irrigation Department, District Rural Development Agency, Department of Science and Technology, etc. The SFDs have made considerable contribution in various centrally sponsored schemes relying on inter sectoral convergence. In past 3-4 decades, the SFDs have implemented several externally funded forestry and conservation projects by various international agencies *viz*., the World Bank, International Development Agency (IDA), Global Environmental Facility (GEF), Unbhited Nations Development Programme (UNDP), Food and Agriculture Organization (FAO), United States Agency for International Development (USAID), Japan International Cooperation Agency (JICA), German Developmental Agency (GIZ), etc. and gained considerable experience. Majority of these externally funded projects required working with various stakeholders including Line Departments and local communities seeking multi sectoral convergence. In addition, SFDs extensively consult and either avail expertise or resources from various Forestry Institutions, other state/ National Level Scientific Organisations, Universities, State Biodiversity Boards, National Medicinal Plants Board, National Bamboo Mission, National Afforestation and Eco development Board in meeting various R&D needs or capacity development programmes.

4.1.20 Decentralised Approach

The National Forest Policy, 1988 envisaged people centric approach towards management of forest and wildlife resources in the country and laid emphasis on participatory and decentralized approaches involving local communities, both in decision making as well as in programme

implementation. In past four decades or so, the SFDs witnessed a paradigm shift from top down approach to bottom up approach. The SFDs adopted the concept and approach of the Joint Forest Management (JFM), promoting the creation of Joint Forest Management Committees (JFMCs) so as to restore degraded forest areas and elicit people's support in forest and wildlife conservation. JFMCs are known by different names in various States, such as Van Sanrakshan Samiti (VSS), Village Forest Development Committees (VFDCs), Village Forest Protection Committees (VFPCs) and Village Forest Development Societies (VFDSs). However, their functions were essentially similar to each other. These Community Based Organisations (CBOs) included the local representatives in the executive body and all the adult villagers as member in the general body. The CBOs were either registered as Societies under the Society Registration Act, 1860 or as a constituent of the Division level Forest Development Agency (FDA) which in turn is registered under the Society Registration Act. The MoEF&CC has issued detailed rules and Operational Guidelines of National Afforestation Project (NAP) including benefit sharing mechanism under JFM. In accordance with these guidelines, the respective State Government has also framed resolutions and rules for implementation. The JFMCs across the country along with SFDs carried out forestry activities related to protection, regeneration, afforestation, utilization and sustainable management of forest areas allotted to them. Certainly, the initiative on the formation of CBOs by the SFDs was a significant move towards the process of decentralization and people's empowerment. Already existing JFMCs and their variants in two States (Himachal Pradesh and Punjab) can be optimally utilize for ensuring public participation and eliciting their support at all the stages *viz*., planning, implementation, monitoring and evaluation of any major project related to management of forests, wildlife or River restoration.

4.1.21 The Indian Armed Forces and Central Armed Police Forces

The Republic of India has the military force represented by the Indian Armed Forces (IAFs) consisting of three professional uniformed services *viz*., the Indian Army, the Indian Navy, and the Indian Air Force. In addition, the Indian Armed Forces supported by the Central Armed Police Forces (CAPFs), formerly referred as the Paramilitary Forces. However, the Union Ministry of Home Affairs (MoHA) adopted uniform nomenclature of CAPF in the case of six forces *viz*., CRPF, BSF, ITBP, CISF, SSB, and the NSG. As such, the primary mandates of the IAFs and CAPFs include: protection of the frontiers to safeguard the country's sovereignty, and important and sensitive establishments (airports, sea ports, industrial units, hydroelectric projects, temples, etc.), but these forces have also been helping in conservation of nature and wildlife resources in difficult terrain and harsh climatic conditions all along the frontiers of the country whether on the land or in coastal and marine water. Further, under the aegis of MoEF&CC and Ministry of Defence (MoD), dedicated force such as the Eco-Task Force (ETF) was raised as the Territorial Army Unit in conjunction with States to take on challenging assignments in the ecologically fragile and sensitive areas. The ETF battalions have successfully achieved twin objectives of their establishment; (a) eco regeneration of degraded areas, and (b) rehabilitation of ex-service man. Presently, nine infantry battalions (TA), comprising 22

operational companies are carrying out afforestation in difficult and degraded areas in States/ UTs of Uttarakhand, Rajasthan, J&K, Ladakh, Delhi, Himachal Pradesh, Assam and Maharashtra. In addition, a Composite ETF (CETF) for National Mission for Clean Ganga has also been raised at Allahabad. One company each at Kanpur, Varanasi and Allahabad have been planned for the said mission. Till date, various ETF battalions across the country have planted nearly 60.8 million saplings and covered an area of 727.4 km^2, with 7580% of survival rate. The CETF is supposed to patrol the sensitive River areas for the protection of biodiversity and other tasks such as safeguarding the River from pollution and illegal sand mining, etc. The 127 ETF Battalion in Uttarakhand was awarded the Indira Priyadarshini Paryavaran Puruskaar by the MoEF&CC for the commendable work in the field of ecological restoration. In recent past, High Court of Himachal Pradesh had ordered for involving ETFs protecting different rivers of the State from illegal sand mining.

Recognizing the past contributions and experience of ETFs in ecological restoration of degraded land and protecting rivers like Ganga, the potential of ETF battalions can be utilized in forestry interventions in difficult areas in Kinnaur, Shimla, Kullu and Mandi districts as well as along the River stretches in Punjab, so as to protect the River from industrial pollution, illegal activities including protection of biodiversity.

4.1.22 Sutlej River and the Civil Society

With the main aim of 1) Sustainable forest ecosystem management, 2) Biodiversity Conservation 3) Livelihood improvement support 4) Institutional capacity Strengthening Himachal Pradesh and Punjab government have taken various initiatives for the better forest intervention in the Sutlej River basin. There are various projects run by the state government and the civil society for the forestry intervention and the rejuvenation of the Sutlej River and that is why various organization played an important role like *Van Panchayats, Panchayats, Joint Forest Management Committees, Anganwadi workers, Nehru Yuva Kendras, Mahila Mandals,* that are formed for the cleaning of Sutlej River, plantation and the monitoring along the Sutlej River basin.

The externally supported projects and state wide programs of participatory/ joint forest management, launched by the HPFD in 1998 encouraged the direct involvement of the communities in protection, conservation and maintenance of forests. Of these institutions, VFDSs are registered under the Societies Registration Act; while VFDCs, VDCs and VEDCs are registered by the Divisional Forest Officer. The GoHP sets policy and strategic direction for the forest sector, in line with statewide priorities and national obligations. For example the current 'Vision 2020' exercise, envisioned for the Government of HP, incorporates the HP Forest Department's 'Vision' and will contribute to the overall national 'Vision'.

There are some international organizations that played the important role along the Sutlej River basin like JICA (Japan International Cooperation Agency). The JICA supported Project for

Improvement of Himachal Pradesh Forest Ecosystems Management and Livelihoods was officially inaugurated on, July 23, 2018. The objective of the Project is to manage and enhance forest area ecosystems in the project area, by sustainable forest ecosystem management, biodiversity conservation, livelihood improvement support and strengthening institutional capacity, thereby contributing to environmental conservation and sustainable socioeconomic development in the state of Himachal Pradesh (H.P.), one of the example of that is Sholtu Nursery along the Sutlej River basin which is not only creating the better ecological environment but also providing employment to the local people.

4.1.23 Nehru Yuva Kendras

Nehru Yuva Kendras (NYK) were established in the year 1972 with the objective of providing rural youth avenues to take part in the process of nation building as well providing opportunities for the development of their personality and skills. *Nehru Yuva Kendra Sangathan* which is one of the largest youth organizations in the world was set up as autonomous organization in the year 1987-88 under the Government of India, Ministry of Youth affairs and Sports (MoYA&S), to oversee working of these Kendras. NYKs is the largest grassroots level youth organization; one of its kind in the world. It channelizes the power of youth on the principles of voluntarism, selfhelp and community participation.

Over the years, *Nehru Yuva Kendra Sangathan* has established a network of youth clubs in villages, where *Nehru Yuva Kendras* have been set up. NYKs has targeted to identify areas of harnessing youth power for development by forming Youth Clubs, which are village level voluntary action groups of youth at the grassroots level to involve them in nation building activities. The core strength of NYKS lies in its network of youth clubs. Youth Clubs are village based organizations working for community development and youth empowerment. NYKs has a countrywide network of village based Youth Clubs. Capacity building, skill development and networking through volunteers are the basic elements of all the programmes of MoYA&S that are implemented through NYKs. Its network of 28 Zonal Offices, 501 District level offices and 1.25 lakh Youth Clubs in about half of the villages of the country constitute a strong force of a voluntary movement under the auspices of the MoYA&S. The youth of a nation are its primary building block. The youth bulge of the present demographic structure of India makes a very important and promising future force. Hence, it is essential that the youth are provided with their entitlements through all sectors of human and physical development. NYKs, through the programmes and schemes provided by the Ministry, attempts to provide yet another dimension of youth development and empowerment especially to the rural, nonstudent youth who are generally out of any institutional framework of formal learning or training apart from the few rural schools and colleges.

4.1.24 National Service Scheme

National Service Scheme (NSS), under the Ministry of Youth Affairs & Sports, Govt. of India, popularly known as NSS was launched during Gandhiji's Birth Centenary Year in the year 1969, in 37 Universities involving 40000 students with primary focus on the development of personality of students through community service. Today, NSS has more than 3.2 million student volunteers on its roll spread over 298 Universities and 42 (+2) Senior Secondary Councils and Directorate of Vocational Education all over the country. Community service rendered by university and +2 level students has covered several aspects like adoption of villages for intensive development work, carrying out the medicosocial surveys, setting up of medical centers, programmes of mass immunization, cleaning, afforestation activities etc. The NSS will be actively involved in Forestry Interventions for Sutlej by way of carrying out afforestation in institutional areas and mass awareness campaigns.

4.1.25 Bharat Vikas Parishad

Bharat Vikas Parishad (BVP), established in 1963 is a *service cum sanskar* oriented, non political, sociocultural voluntary organisation. It is dedicated to the development and growth of our country in all fields of human endeavour – cultural, social, academic, moral, national and spiritual – by promoting a sense of patriotism, national unity and integrity. BVP has launched *'Green India Project'* under which 150 to 300 trees are planted by each of its branches. Similarly each branch has to distribute 150 to 300 sacred plants like Tulsi (*Ocimum sanctum*) for homestead planting in urban colonies.

In year 201314, branches of BVP planted 58,831Tulsi plants. It has also started *Harit Bharat Balgokulam*, an eco-club. The event takes place in schools/colleges/ universities. The programme starts with a talk by the subject matter specialist and eco friendly suggestions are provided.

BVP do the regular plantation work under the Harit Bharat Balgokulam in the different regions of the Himachal Pradesh along the Sutlej River with the help of its regional centre's: Shimla, Rampur, Jhakri, Kinnaur and Bilaspur. In Punjab: Rupnagar, NawanShehar, Ludhiana, Ferozpur are the main branches of the BVP through which it carry out all its plantation activities. BVP lays emphasis on developing the competence of the beneficiaries through their involvement so that they are no longer dependent on charity and lead a dignified and honourable life. BVP have started 1600 projects and implementation of these projects are carried out on weekly basis and some of the projects that are introduced in the Himachal Pradesh are Park adoption, Water huts , Nursery plantation, which are helping in the development of the area as well as providing the healthy environment to the local people.

4.1.26 Red Cross Society

The Indian Red Cross Society (Indian Red Cross) is a common public service that is a permanent pillar of our national life. The principal purpose of Indian Red Cross is to bring help and hope to all who are in the hour of their need. The strength of Indian Red Cross lies in their hundreds of thousands of community based volunteers who are active in cities and villages. The Indian Red Cross serve all without any social or political distinction, with priority given to the poorest and most vulnerable people. The Indian Red Cross always act in consistency with their Fundamental Principles. The organization play a proactive role in organising Blood Donation camps, while activities like provision of firstaid/home nursing training and ambulance services for the ailing are equally emphasised. Regular plantation activities were also carried out by the Red Cross Society for example Over 5,000 saplings were planted under the campaign, jointly organised by the forest department and State Red Cross Society at Ganevag (Nehra) near Shimla on the occasion of the 69th Van Mahotsava Day in the year 2018.

4.1.27 Plantations by H.P. State Legal Services Authority

A scheme to strengthen participation of local communities in conservation and development of forests through plantation of useful plant species is already being implemented in the State of Himachal Pradesh. A good beginning has already been made to involve students in plantation drive under the aegis of H.P. State Legal Service Authority, where under 11, 11, 600 number of plants have been planted through the involvement of school students over the past 4 years.

H.P. State Legal Service Authority is already coordinating afforestation campaign through senior advocates along with forests and education departments since the year 2014-15 involving schools across the state and will continue to coordinate and extend support under the ambit of this scheme.

4.1.28 Incorporation of Laws, Policies and Institutions in DPR

This Chapter has helped in the broad based understanding of pertinent laws, policies and institutions in the context of management and restoration of River and proposed forestry interventions. At the same time, the elaborate description on wide range of Central and State government organisations including the SFDs, Central Armed Police Forces and Civil Societies those have vital role in implementation of the present DPR has been narrated.

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CHAPTER-5

PROPOSED FORESTRY INTERVENTIONS

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5.1 The Sutlej River Ecosystem – Environmental Trends

The past trends of environmental degradation of various associated natural ecosystems (i.e., forests, grasslands, and wetlands) along the course of Sutlej River profoundly reflected that human activities have perilously influenced not only the river, but also all its tributaries and associated natural ecosystems, and in turn the vital life support systems. Thus, factors responsible for extensive destruction, deterioration, and degradation resulting in decline of ecological integrity and the river health were adequately documented by various workers. The degradation of land and water resources, erosion of biodiversity, enhanced levels of resource use and pollution, and likely implications of climate change were emphasized. The appraisal also revealed that extensive environmental degradation is the precursor to poverty, unsustainable livelihoods, growing conflicts, damage of property and physical assets, water crisis, food insecurity, and overall vulnerability of communities and the natural ecosystems. The need of the hour is to ensure that rapid development and rising prosperity in the Basin/ Riverscape occur in such a way that they do not jeopardize the natural ecosystems offering multiple ecosystem services on which the human survival depends.

5.2 Key Thrust Areas

India is not alone in its fight against the declining state of Sutlej River environment, but depletion of global commons and resultant rising concerns *viz*., degradation of land and water resources, poverty, water crisis, hunger, malnutrition, climate change, etc. besides other social issues related to gender, equity, security, and peace. Alarmed at growing environmental concerns and depleting state of natural ecosystems, particularly rivers, the Government of India (GoI) has undertaken policies and legislative initiatives and launched multifocal area programmes so as to address priority concerns about land and ecosystem degradation, dwindling biodiversity, ever increasing pollution and implications of climate change that are closely intertwined and in most instances share common drivers and stressors. In past four to five decades, India has initiated actions to either halt or reverse the process of environmental degradation by way of numerous countrywide programmes and implementation of global and National Level strategies relevant to different sectors *viz*., sustainable land and ecosystem management, conservation of biodiversity, watershed management, urban environment, climate change, rural livelihoods, and sustainable development. In her quest to address various environmental and social issues, India has also joined bandwagon of global conventions and committed to fulfill its global obligations and assurances. India as a National Priority, has a firm belief in conservation of biodiversity and recognizes its crucial linkages with the livelihood and wellbeing of millions of its people, particularly the poor and the vulnerable (IBA, 2018). India's National Biodiversity Action Plan (NBAP), formulated through a comprehensive inter-ministerial process and approved by the Union Cabinet in 2008, was developed prior to Convention on Biological Diversity's (CBD's)

strategic plan for biodiversity (2011-2020) and the Aichi Biodiversity Targets Convention on Biological Diversity's(CBD, 2010). India's fifth National Report (NR5) on the CBD made a special effort to assess the funding support for biodiversity conservation in India and reported that country was spending about Rs. 92,000 million in 2013-2014 on activities that have a direct as well as indirect bearing on conservation of biodiversity (MoEF&CC, 2014). Likewise, much prior to the signing of the Paris Agreement on Climate Change, the country has formulated the National Action Plan on Climate Change (NAPCC) in 2008 with eight specific missions and adopted the multipronged strategy to address issues related to climate change mitigation and adaptation. Considering the significance of rivers, River development and priority to rejuvenate the major rivers of the country, the GoI declared the Ganga River as the India's National River in 2008, constituted the National Ganga River Basin Authority (NGRBA) on 20 February, 2009 and established National Council for Rejuvenation, Protection and Management of Ganga River in 2011, and created the National Mission for Clean Ganga (NMCG) as the implementation wing of the National Ganga Council. Subsequently, the Union Government approved a comprehensive mission i.e., the National Water Mission (NWM) in 2012 and also renamed the Ministry of Water Resources (MoWR) as the Ministry of Water Resources, River Development and Rejuvenation of Ganga (MoWR, RD&GR) in 2014. The Government of India soon faced the challenge of restoration of Ganga River and recognized the multi-sectoral, multidimensional and multi-stakeholder nature of the river ecosystem and in view of this key ministries comprising of; (a) MoWR, RD&GR, (b) MoEF&CC, (c) MoS, (d) MoT, (e) MoUD, (f) MoDW&S, and (g) MoRD work together to arrive at an action plan on Ganga River. The Union Budget 2014-15 announced the setting of an Integrated Ganga Conservation Mission called 'Namami Gange' and since then the Central Government and concerned State Governments are implementing the Namami Gange Programme. In May 2019, this Ministry was merged with Ministry of Drinking Water and Sanitation to form the Ministry of Jal Shakti. Even, to improve the Sutlej River water catchment, a Comprehensive Catchment Area Treatment (CAT) plan was prepared (HPFD, 2019). Thus, it is evident that the subjects of water resources, rivers, and river rejuvenation are not only amongst the highest priority agendas of the current government, but also the Government is fully committed to achieve the mission goals in a time bound manner. Further, the present DPR and concurrent preparation of DPRs of other major Indian rivers testify the priority and commitment of the Union Government towards Restoration/ Rejuvenation of rivers.

5.3 Vision, Mission, Goals, and Objectives

Broadly, the present plan aims to contribute towards the clean and healthy Sutlej River by way of continuous flow (*Aviral Dhara*) and clean water flow (*Nirmal Dhara*) besides maintenance of ecological and geological integrities. The following shared vision emerged for the Implementation Plan based on an extensive consultative process carried out as a part of the larger exercise undertaken to prepare this DPR.

Vision: Various conservation values of the Sutlej River are identified, recognized, conserved, restored, and maintained in order to ensure the ecosystem diversity, ecological integrity and healthy river while allowing sustained flow of ecosystem services and other uses/ benefits essential for all life forms and the prosperity of the region.

Mission: The mission is to accomplish the above shared vision by adopting multipronged strategy and pursue of five strategic priorities for Sutlej River: (a) address drivers of environmental degradation and arrest biodiversity loss, (b) adopt integrated, innovative and nature based solutions, (c) enhance resilience and adaptation, (d) build alliances and foster synergies, and (e) opt for the right influential models and interventions so as to achieve reduced pressure on biodiversity, restore degraded ecosystems, promote sustainable use of biological and water resources, enhance capacities, mainstream biodiversity, augment policy and law support, and facilitate science based efficient decision making.

Goals: In view of the above and in accordance with the National and Global level priorities, commitments, agendas, strategies, and approaches; the Implementation Plan on proposed Forestry Interventions seeks to address the following focal areas or goals in an integrated manner:

(a) Riverscape Management: Aiming a holistic Riverine Landscape (Riverscape) approach for sustainable management of Sutlej River, its banks, or its Riparian areas, within its fluvial system.

(b) *Aviral Dhara, Nirmal Dhara*, Ecological Rejuvenation and Biodiversity Conservation: Aim to address the drivers and stressors of River Ecosystem and promote sustainable use by balancing ecological requirements with the needs of sustainable livelihoods.

(c) Improved Ecosystem Services and Sustainable Livelihoods: This goal aims to specifically seek enhanced ecosystem services so as to maintain sustainable livelihoods.

(d) Effective Implementation, Knowledge Management, and Innovative Approaches: This goal aims to ensure effective implementation of the project, knowledge management, development of innovative approaches (i.e., nursery techniques, afforestation, bio-filters and Bioremediation), and adoption of appropriate modern technologies.

Project Outputs and Outcomes: This plan aims to fulfill the requirements of above stated four focal areas in a phased manner and visualizes specific outputs and outcomes. Hence, the following objectives are proposed:

Project Objectives

1. To identify important issues and problems of Sutlej River along with its tributaries, promote sustainable land and river ecosystem based management approaches focusing on reduced

soil erosion, enhanced forest/ vegetation cover in the buffer zone, enhanced connectivity and e-flow, and restoration of Sutlej River and its tributaries

2. To carry out appropriate forestry interventions to restore river connectivity, enhance e-flow, improve water quality, and conserve the terrestrial and aquatic biota within the Sutlej Riverscape for ecological rejuvenation of the River
3. To promote improved ecosystem services and support sustainable livelihood opportunities for local communities, particularly forest dwellers, fishermen and other vulnerable groups
4. To adopt, integrate and implement innovative approaches and modern technologies for rejuvenation of Sutlej and its tributaries, knowledge management, enhanced capacity, and monitoring and evaluation

Project Outcomes

Above Plan objectives will be achieved through the following outcomes.

1. Creation of an enabling environment for climate resilient, sustainable terrestrial, aquatic (River and wetlands), and floodplain ecosystem management
2. Interagency and civil society driven, climate resilient approaches for appropriate forestry and other allied interventions demonstrated in adequate extent(s) of Natural, Agriculture, and Urban Landscapes of the Riverscape
3. Enhanced ecosystem services from Natural (forest, grassland, river and wetland) ecosystems, agroecosystems, and Urban Landscapes
4. Sustainable livelihoods, particularly of forest dwellers, fishermen and other vulnerable groups
5. Capacities for adaptive management, learning, and replication of project lessons are developed

The following specific outputs are foreseen under the above stated outcomes:

Outcome 1: Identification of issues, Creation of an enabling environment for climate resilient, sustainable terrestrial, aquatic (River and wetlands) and floodplain ecosystem management

The purpose of this significant outcome is to build an appropriate environment wherein multiple agencies/ sectors working for various production sectors (i.e., forest, watershed, agriculture, livestock, mining, tourism, tribal welfare, infrastructure development, hydropower, communication, highways and waterways) converge and adopt climate resilient and sustainable approaches of terrestrial, aquatic and floodplain ecosystem management by mainstreaming biodiversity concerns. These sectors shall also work together so as to address gaps and inadequacies in realizing Global and National Policy objectives relevant to the environment, biodiversity, water resources, and climate change. Following outputs are envisaged to accomplish above broad based outcome.

Output1.1: Enhanced levels and enabling environment created for:

(a) Multisector convergence, alliances, and integration;

(b) Favorable National and State level policies (i.e., forest, agriculture, animal husbandry, watershed management, river management, tribal welfare, infrastructure development, tourism, etc.) those reflect principles of climate resilience, sustainable land and ecosystem management, and mainstreaming biodiversity concerns in production sectors.

A wide range of Policies and Legislative Acts concerning the above stated different production/ environment sectors already exist. So far, fragmentary and preliminary efforts have been made for interagency cooperation and convergence and even adoption of Landscape/Riverscape/ Seascape approaches for conservation and ecosystem management. Nevertheless, the current experience on the sectoral convergence is grossly inadequate. The appraisal of river environment in the context of Sutlej River amply revealed for the urgent requirements of adopting a comprehensive and holistic approach for River Restoration, interagency cooperation and sectoral convergence, mainstreaming biodiversity concerns in production sectors, and the need for harmonization amongst competing and conflicting sectors through adequate support of relevant policies and enforcement of laws. This plan on the proposed forestry interventions will provide an opportunity to bring diverse Stakeholders/Agencies/Sectors/Civil Society Organizations together for the realization of above stated vision and goals relevant to healthy River and sustainable ecosystem. SFDs in Himachal Pradesh and Punjab States would be the primary Implementing Agencies (IAs) and they would facilitate the process for this vital output while working with different agencies/ sectors and CSOs. The National Level Nodal Organization i.e., HFRI would be responsible for technical backstopping, and monitoring and evaluation besides the current role being played on planning and preparation of the present DPR. A highly consultative and cooperative approach is being planned in creating the enabling policy environment, and developing recommendations and mechanisms for programme implementation. The Nodal Institution (HFRI) and two IAs (SFDs) in Himachal Pradesh and Punjab would be required to play a major role in addressing the threats arising from the climate change and suitably integrate them with current land use, production sectors, and ecosystem management.

Output 1.2 Capacity of Government Officials and Civil Society Organizations is developed in promoting community driven, climate resilient, sustainable land and ecosystem approaches, and holistic approach for the management of River ecosystem

The Project aims to propose extensive plantation activities in Natural, Agriculture, and Urban Landscapes so as to enhance the forest cover, provide multiple benefits to local communities and help in the processes relevant to retention of water, recharge of ground water, functioning of bio-filters, and bioremediation. In addition, varied activities *viz*., soil and moisture conservation works, grassland and rangeland management, wetland management, cultivation of medicinal and aromatic plants, weed management, conservation of threatened species, riverfront development, etc. are also being considered and planned. Obviously, various proposed activities will be undertaken on the Government and community/ private lands. The SFDs will be the IAs in case

of planned activities on the Government owned forest lands and protected areas. However, large scale efforts those are being planned on private agriculture lands and other lands (i.e., revenue, urban and riverfronts) owned by the various Government Agencies, proposed activities are being planned through CAPFs (i.e., ITBP, Eco-Task Force) and CSOs (i.e., *Panchayats*, *Gram Sabhas*, *JFMC*s, EDCs, BMCs, *NYKS*, Youth Clubs and *Mahila Mandals*, NGOs, Religious Organizations, etc.). Interagency cooperation and sectoral convergence are essential for the success of project of this nature. Awareness campaigns for masses, particularly women and youth are being planned. Capacity development of government officials, CSOs and local communities is being planned. Innovative approaches *viz*., bio-filters and bio0remediations are being considered alongside incorporation of modern technologies (i.e., RS and GIS, meteorological, water quality, monitoring of aquatic animals telemetry, etc.) have been envisaged. The project includes the logical framework analysis and results based monitoring. Capacity development of officials and CSOs in these aspects is vital and thus, being appropriately addressed in the plan.

Outcome 2: Interagency and civil society driven, climate resilient approaches for appropriate forestry and other allied interventions demonstrated in adequate extent(s) of Natural, Agriculture, and Urban Landscapes of the Riverscape

The Riverscape includes wide ranging Natural ecosystems (i.e., terrestrial, aquatic, and floodplain) besides vast Agriculture and Urban Landscapes. Forestry Interventions in such Landscapes are envisaged.

Output 2.1 Plans to reduce/ check erosion in the mountainous region and floodplains of Sutlej River and its tributaries by appropriate soil and moisture conservation works and development of optimal strategy for riverbed mining. Sites of landslides are adequately treated and stabilized

Project plans for considerable inputs by way of appropriate Soil and Moisture Conservation works so as to check and reduce erosion and treating specific sites of landslides within the Riverscape. At the same time, convergence of related sectors, development of policy framework on sand mining in River beds would be initiated and guidelines developed.

Output 2.2 Plans for restored and sustainably managed forest lands, agriculture lands in targeted villages and Forestry Interventions in urban environment for improved forest/ vegetation cover achieved. Enhanced assisted natural regeneration through improved protection and other measures is also accomplished

The Project's main focus is on an integrated ecosystem management approach in the context of Sutlej River by taking into account all diverse natural (i.e., forest, grassland, and wetland) ecosystems by adopting sustainable land and ecosystem management principles. The primary objective of this output would be to improve the forest/ vegetation cover in the mountainous part of the riverscape in Himachal Pradesh and Punjab Plains. In addition, this output envisages appropriate cover of Trees Outside Forests (TOFs) through suitable plantations on private

agriculture lands and various other government lands (i.e., Along canals, Cantonments, Schools, Institutions, Public Facilities, Riverfronts, and Urban Landscapes). Enhanced forest and vegetation cover will directly help in improved biodiversity, productivity, reduction in erosion, and efficient functioning of bio-filters.

Output 2.3 Plans for improved protected area management by implementing appropriate protection strategies, habitat management (i.e., **weed control and water management), research & monitoring inputs, and enhanced capacity**

The Sutlej Riverscape includes several small and large widely scattered Protected Areas (PAs) along the altitudinal gradient in its mountainous part as well as in the lower part of alluvial plains. These PAs include some of the prominent National Park *viz*., Pin Valley National Park, numerous high altitude and other wetlands including two Ramsar Sites i.e., Ropar and Harike Lake in Punjab; and Gobind Sagar Lake and Kol Dam in Himachal Pradesh besides a number of wildlife Sanctuaries, Conservation and Community Reserves. Several of these PAs sites are designated IBAs. These PAs are repository of representative biodiversity and facilitate various ecological and evolutionary processes including climate resilience. Majority of these PAs suffer on account of smaller size, large PA-People interface, traditional resource dependence, proliferation of invasive alien species and incompatible land use in their surrounds. It is pertinent to protect and improve these PAs from the perspective of biodiversity values and a wide range of ecosystem services they offer to the local populace including serving as an important catchment area in the context of Sutlej River and its tributaries. Therefore, the Plan envisage multiple activities aiming to support the protection of these PAs; management of threatened species and their habitats including weeds, development of essential physical infrastructure, eco-development, research and monitoring, awareness campaign and ecotourism, and capacity development.

Output 2.4 Plans for improved management of prominent wetlands in the Riverscape by protection, restoration, zoning, habitat management, and wise use of wetland resources

The Riverscape harbours diverse natural and manmade wetlands along the River course as well as in proximity to the main channel of Sutlej River and its tributaries. They are not just biological supermarkets but have vital role in maintenance of environmental flow, water purification, groundwater recharge, and control of floods besides majority of them are major attraction for tourism activities. Most wetlands are threatened on account of enhanced siltation, chemical pollutants from Agriculture Landscapes, and influence of industrial effluents and sewage disposal from cities/ towns. The plan visualizes a wide range of activities for management and conservation of wetlands within the riverscape and continues to provide multiple benefits to the society as well as to the River ecosystem. The monitoring of wetlands, particularly the resident and migratory birds and Wetland flora are important planned activity in the present DPR.

Output 2.5 Plans for improved Riverfronts and development of Eco-Parks

The Sutlej River and its tributaries traverse through major cities/ towns within two States besides important locations of pilgrimage and tourism activities. The plan envisages the development of Riverfronts and Eco-Parks in select locations so as to enhance the potential of ecotourism in such sites provide improved livelihoods to local people by way of ecotourism, and ultimately to help the River ecosystem from pollutants and other biotic disturbances in prominent stretches.

Output 2.6 Plans for development of forests and River based ecotourism

In past four to five decades, there has been exponential increase in tourism activities all along the Sutlej River and its tributaries, and adjoining forested tracts. Both Himachal Pradesh and Punjab within the Riverscape are major attractions for such activities. Moreover, in past, local inhabitants have primarily relied on natural resources from terrestrial and aquatic ecosystems for their subsistence and commercial activities and obviously there has been an excessive pressure on harvest and collection of scarce forest and River resources. Hence, it is essential to provide Alternate Income Generation (AIG) activities to local communities and engage them meaningfully in various efforts towards protection and conservation of natural ecosystems. Thus, the plan envisages activities those promote and provide support for the development of alternate income generation activities by way of ecotourism, and allied Small and Micro Entrepreneurships (SMEs) so as to enhance income of communities, traditionally dependent on forests and other natural resources for their subsistence.

Outcome 3: Enhanced ecosystem services from Natural (i.e., forest, grassland, River, and wetland ecosystems), Agroecosystems, and Urban Landscapes

Since time immemorial, varied Natural ecosystems have been offering a wide range of ecosystem services to the human society and in most instances these services have drastically declined owing to the fact the very foundation and existence of Natural ecosystems have been severely impacted by growing population, unplanned development and other human disturbances. Thus, there is an urgency not only to curb adverse human activities, restore degraded ecosystems including manmade agroecosystems and even the built up environment. Hence, planned activities by way of protection, afforestation, reforestation, assisted natural regeneration, weed control and management, water management, etc. have been envisaged in the plan.

Output 3.1 Plans for reduced traditional forest dependence, developed alternate income generation activities, improved livelihoods, and facilitate establishment of viable Small and Micro-Enterprises (SMEs)

The rural population in remote, rugged terrain and harsh climatic conditions of the upper mountainous part constitutes nearly 90% population of Himachal Pradesh. Traditionally, the rural population has primarily dependent on forests and livestock for majority of their daily

requirements. Gradual expansion of agriculture and horticulture and various developmental activities in the region enhanced opportunities for improved livelihoods. However, a substantial section of the rural society is either Below the Poverty Line (BPL) or continues to solely depend upon natural resources, primarily diverse forests including alpine pastures, wetlands and rivers. A significant portion of the rural population depends upon the collection of medicinal and aromatic herbs and other NTFPs. There is ample opportunity to reduce traditional resource dependence by way of AIGs and SMEs. Over past few decades, various ethnic groups, particularly women have been engaged in area specific handicrafts and allied cottage industries. However, there is enormous scope to organize communities in AIGs and SMEs by developing and supporting appropriate mechanisms for linkages with markets and supply chain management.

Output 3.2 Plans for enhanced levels of protection, conservation, and sustainable harvests of medicinal and aromatic plants and development of herbal sector

Specifically, the mountainous tract of Himachal Pradesh in middle and higher altitudes has been bestowed with enormous diversity of Medicinal and Aromatic Plants (MAPs). Traditionally, local people have been collecting and using such plants for their own consumption and varied uses in remote areas. However, once the road network was created and avenues for commercial requirements were opened up, there was sudden spurt in activities related to harvest, collection, cultivation, and marketing of MAPs. In turn, these activities have expanded human disturbances in high altitude natural areas. The plan envisages select treatment models related to the cultivation of MAPs in Natural and Agriculture Landscapes, and development of herbal sector within the Riverscape. The plan also envisages to create awareness and scientific know how about the harvest, collection and cultivation of MAPs so as to enhance the productivity and reduce degradation of natural areas.

Outcome 4: Sustainable livelihoods, particularly of forest dwellers, fishermen and other vulnerable groups

One of the major outcomes expected from the implementation of present DPR on Forestry Interventions pertains to improved rural livelihoods, particularly, of forest dwellers, fishermen and other vulnerable groups inhabiting the remote mountainous tract or living along the stretches of Sutlej River and its tributaries. The concept of sustainable livelihoods provided by the Department for International Development (DFID), UK emphasized on the maintenance of five livelihood assets *viz*., human, natural, financial, physical, and social. The uncertain climatic conditions and other natural exigencies pose enormous challenges, risks and vulnerability of forest dwellers, fishermen and other susceptible and weaker groups. The plan lays equal emphasis on ecological restoration and the sustainable livelihoods. Hence, essential and priority activities supporting the sustainable livelihoods of local populace are being planned. Efforts will be made to make them aware about the significance of Natural Capital besides other prominent livelihoods assets such as human and social.

Outcome 5: Development of capacities for adaptive management, learning, and replication of project lessons

One of the five outcomes envisaged from the implementation of the project pertains to enhanced capacity for adaptive management of natural resources including the River ecosystem. The following two outputs are foreseen:

Output 5.1 Development of plans for integrated, science based, and community based monitoring and assessment of impacts, as well as periodic evaluation of the project

The natural resource management demands comprehensive and holistic approaches besides adoption of the principle of adaptive management. Increasingly, the International and National development agencies emphasize on the Results Based Monitoring (RBM) as an essential and integral activity of a developmental project related to any sector. Considering the long stretches of the River and its tributaries, vast extent of the Riverscape, diverse natural resources and stakeholders involved, and wide range of activities planned in Natural, Agriculture, and Urban Landscapes besides several Conservation and Supporting Activities across H.P. and Punjab, it is essential to devise science, evidence and indicator based diagnostic concurrent monitoring so as to ascertain the impact of planned activities on the river ecosystem, its wider environment, and the rural livelihoods. The concept of adaptive management requires monitoring, learning and adaption. Thus, the plan aims to incorporate participatory and community driven monitoring system.

Output 5.2 Plans for documentation of lessons learned and preparation of information dissemination products for wider audiences and applicability

The wider subject of river conservation and restoration in India is relatively much newer and visibly, there is hardly any evidence of successful and well documented experience. Indeed, the river restoration is a huge task in human dominated country like India wherein there is the presence of human all around and their varied intensive activities have adversely impacted the natural environment. The only little experience available is from the implementation of ambitious *Namami Gange* Programme on the Ganga River and some sporadic efforts such as the Seechewal initiative in the case of Kali Bein River in Punjab. Hence, it is important to document the experiences and lessons learned in the planning, implementation, and monitoring of project execution of this nature. Accordingly, the plan envisages activities related to documentation of project execution, lessons learned and wider dissemination of knowledge gained for appropriate replication in case of other rivers and their tributaries. Till date, there is no singular agency in the country that provides comprehensive and holistic insight as well as information on the River ecosystem. The appraisal of River environment evidently reflected this shortcoming. Hence, there is an urgency to develop the knowledge management centre on the much desired and priority subject of River conservation and restoration. At the same time, there is vast opportunity to develop innovative approaches for execution of Forestry Interventions along the River and its tributaries, and the catchment. Thus, this specific output pertains to development of innovative

approaches suitable for different agro-climatic conditions within the Riverscape besides documentation of experiences and lesson learned, dissemination and replication of similar efforts as either the Phase II of the project or elsewhere.

5.4 Problems in Achieving Objectives

The actual and potential problems identified in achieving various project objectives are as follows:

a. Fragility of the Himalayan environment owing to increased seismic activity and active landslides, wide spread soil and riverbank erosion, and enhanced sedimentation.
b. Harsh climatic conditions, erratic and changing patterns of snowfall, rainfall, and ambient temperature, unpredictable avalanches, retreat of glaciers, increase snowmelt and runoff, and prevailing uncertainties.
c. Rugged terrain, steep slopes, inaccessible areas, shallow soil depth and low soil fertility.
d. Alteration in River course by linking River or diversion of water; sequential physical barriers by construction of dams, barrages, and establishments of HEPs.
e. Traditional resource dependence, enhanced biotic activities, and human disturbances on Natural ecosystems; limited opportunities for alternate occupation and income generation; unsustainable harvest practices; illiteracy, lack of awareness, and poverty and vulnerable communities.
f. Widespread and extensive land use changes and faulty land use; expansion and intensification of agriculture and horticulture; and excessive use of fertilizers, pesticides, weedicides, etc.
g. Encroachment of forest lands, PAs, and other Natural ecosystems; and all round rapid developmental activities (i.e., highways, road network, cities/ towns, irrigation and hydropower projects, transmission lines, etc.).
h. Forest fragmentation, enhanced patchiness, habitat loss and degradation of terrestrial and aquatic ecosystems by proliferation of invasive alien species and decline in productivity and lack of regeneration of native species.
i. Erosion of biodiversity value, smaller and isolated populations of threatened species and reduced distributional range of prominent faunal species.
j. Enhanced pilgrimage, mass congregations, and unplanned and unchecked tourism activities and allied developmental activities and their impact on terrestrial and aquatic ecosystems including rivers, their flow and water quality.
k. Fragmentary approach of environmental impact assessment in case of sequential developmental projects and inadequate efforts for cumulative assessments.
l. Multiplicity of policies and laws, isolationist, conflicting or counterproductive strategies/ approaches adopted by different agencies/ sectors, lack of sectoral convergence, and lackadaisical law enforcement and implications of judiciary activism.
m. Inadequate researches, databases, and baseline information, ineffective monitoring, lack of technological support, innovations and inadequate capacity.

5.5 Strategies

The preceding section has presented the shared vision of the Implementation Plan (IP) along with four broad goals aiming to address four distinct thrust areas relevant to the river conservation and restoration. These thrust areas are: (a) Sustainable land and Riverscape Management through appropriate Forestry Interventions, (b) Conservation of biodiversity in the terrestrial and aquatic environment of the river, (c) Enhanced benefits and sustainable livelihoods, and (d) Project implementation, knowledge management and innovative approaches. In order to achieve four goals through proposed Forestry Interventions, important supporting activities such as policy level interventions, strategic adaptive research and development, innovative and low cost bioengineering methods for stream/ riverbank stabilization, participatory monitoring, evaluation, awareness, capacity development and project management are also envisaged. The Implementation Plan has incorporated four Project Objectives with five broad outcomes and twelve specific outputs.

The developed understanding on the Riverscape environment has amply revealed that the Riverscape is a mosaic of varied land uses and it includes: (a) Natural ecosystems, (b) Rural system predominated by agroecosystems, and (c) Builtup urban environment represented by cities and towns. Each of these broad land use category represents significant area of the Riverscape with unique conditions and situation, and varied use patterns, ownerships and management needs. Hereafter, three broad land use categories within the riverscape are being referred as the 'Natural', 'Agriculture', and 'Urban' Landscapes. These three Landscapes immensely influence the intricate and vibrant nature of Sutlej River ecosystem, especially the environmental flow, water quality, and aquatic biota besides terrestrial biodiversity in surrounding lands, and the various ecological processes of the *Lotic* System. Hence, in view of the prominence of three types of landscape elements within the Riverscape, a multipronged strategy for proposed Forestry Interventions addressing specific requirements of each of the Land Use Type/ Landscape Category has been planned for the execution as a part of the Implementation Plan during the Phase I. As a part of the broader strategy, zoning within the Riverscape is visualized keeping in view three distinct Landscape Categories and specific targeted Forestry Interventions are being planned in each of the zone.

5.5.1 Zoning and Lower Order Zone Plans

Three broad and distinct Landscape types or 'three zones' have been deciphered within the Riverscape for the purpose of proposed Forestry Interventions. The following section presents an elaborate account of specific Forestry Interventions in each of the zone or represents the self-contained 'Lower Order Zone Plan' for the Natural, Agriculture and Urban Landscapes, respectively within the Riverscape.

Following three Lower Order Zone Plans/Landscape Plans in the Riverscape are incorporated for the purpose of proposed Forestry Interventions.

In general, following guidelines would be applicable to all proposed Plantation Models meant for three different Landscapes viz. Natural, Agriculture and Urban Landscape and Three types of Conservation Interventions viz. Soil & Water Conservation, Riverine and Riparian Management, and Wetland Management within the riverscape:

1. All the Models/ Interventions are prescribed which come under Forestry Interventions in proposed DPR of Rivers.
2. Native species of trees, shrubs, herbs and grasses would be selected for proposed treatment models/ plantations in consultation with stakeholders of the respective States/UT. Traditional and prominent horticultural and ornamental species those under cultivation in the region for quite sometime, are proposed in the Agriculture and Urban Landscapes. Mixed plantations are proposed as far as possible instead of monoculture for enhancing plant diversity and greater ecosystem services. The species are proposed according to their occurrence in the altitudinal zones however, Implementing Agencies may plant site specific species also.
3. Suitable native species suggested for different plantation models are finalized after due consultation with Forest Department and other stakeholders of concerned States/UTs. Native species proposed for plantation under each treatment models are provided in the following section. In addition, landscape-wise model description has been further supplemented with the species-wise attributes and model-wise listing in Annexure 3 and Annexure 4, respectively
4. The necessary preparations for planting works including digging of pits would be completed two-three months before the onset of monsoon or planting season. However, the period between pit digging and scheduled planting time would not be more than four months so that run-off of soil by wind and water could be minimized.
5. Appropriate quantity of farmyard or organic manure or AM would be applied to boost plant growth in nurseries and plantation sites. Eco-friendly measures (i.e. physical or mechanical methods, use of natural products, etc.) for weed and pest control would be adopted without resorting to the use of synthetic chemicals
6. Plantation sites would be protected against all types of biotic disturbances and abiotic stresses so as to effectively safeguard planted material for three years through fence, watch and ward, as well as local public awareness programmes and their active involvement.
7. The Implementing Agency should either develop modern and centralized nurseries or identify various certified Research Institutes, Universities, NGOs, Institutions and progressive farmers for supply of best quality planting material.
8. The Schedule of Rates (SoR) is adopted from prevailing SoR of respective States/UTs. For Himachal Pradesh, SoR of Shimla Forest Circle for the year 2012-13 @ wage rate of Rs.150/ with increase of 66.66% i.e., Rs. 250/-, for J&K UT SoR of 2017 @ Rs. 225/- has been applied. Also an increase of 7% has been added each year i.e., 2nd year onwards to compensate inflation.

9. The budget will be provided after submission of Annual Plan Operations (APO) for each year. So the prevailing wage rate will be applicable whenever DPR is implemented. Also site can be changed as per the availability at the time of implementation wherever required.
10. In Himachal Pradesh, further 25% hike in wage rates would be applied for Tribal Areas
11. The fencing cost has been calculated on average basis of enclosure of area to the extent of 5 hectare and average carriage lead is taken as 1 km (up & down)
12. The nursery time for plants in multitier model is taken on average basis i.e., 1.5 – 4.5 year so average is 3 years, for calculating the norm. Also the plant cost is taken from the norm prescribed by the Forest Department of respective States.
13. These cost Norms indicate the upper limits. The expenditure will be booked under various items shown in the detailed models as per actual work done in the field as per Schedule of Labour rates of the respective States/UTs and will not exceed these Departmental Norms.
14. The suggestive cost models are to create multistoried forest cover for improving the bio-diversity of the area which in turn conserves the water and soil in-situ.
15. In *Lantana* eradication models or wherever Lantana removal is involved, the Cut Root Stock (CRS) method should be adopted.
16. The fencing work includes the 4-strands of barbered wire with interlacing of thorny bushes.
17. In Fire Protection Model, as area is virtually targeted, hence Implementing Agency should rotate fire protection operations in areas of the Division so that each selected area takes operations after 3 years.
18. In Agriculture models the guidelines of Sub-Mission on Agroforestry (SMAF) of Central Government should be considered as being adopted in States and UT.
19. Under Urban Landscapse, the Seechewal Model (Punjab) for bio-remediation and bio-filtration may be taken into consideration.
20. Also in Urban Landscape, Eco-Park Development, Institutional Plantation and Riverfront Development models can be converged with Nagar Van Yojna as launched by GoI.
21. In Soil and water conservation models, the watershed approach and techniques should be adopted for desired results. For this intervention the Annual Plan Operation (APO) should be submitted each year with the proposal of micro plan of specific sites with detailed estimates.
22. In Riverine and Riparian Management and Wetland Management models, areas shown in budgetary provisions are virtual and concerned Implementing Agency (IA) should clearly mention the proposed activities in Annual Plan operation (APO) to be taken up in particular area with detailed micro plan and estimates.

23. Plantation models are for the general areas as proposed by the Territorial Divisions but for the protected areas, two models under Conservation Intervention *viz*. Riverine and Riparian Management and Wetland Management.

24. The suggested interventions is to be considered flexible and not rigid, in terms of changing the site location, area, species and minor changes in the models and the applicable schedule rates if the circumstances demand so while implementation the DPR Sutlej and the concerned Conservator of Forest shall exercise the power to approve such changes as and when required.

25. The project costs have been worked out on the basis of rate prevalent during year 2019-20 in the respective State/UTs and 7% escalation in the project cost during the subsequent years has been incorporated in anticipation of the cost escalation in future. However, actual project cost at the time of implementation on yearly basis shall need revision as per the change in Wholesale Price Index (WPI) on year to year basis. The Conservator of Forest may be empowered to revise the project cost accordingly for the quality desired output of the project.

5.5.2 Natural Landscapes (NL)

Proposed treatment models in Natural Landscapes are broadly grouped in three categories: (a) Mountainous tracts/ hills of Himachal Pradesh, (b) Shivalik Hills of Punjab, and (c) Alluvial plains of Punjab. Elaborate details on various treatment models are presented in the following section.

The distribution of different Land Use and Land Cover categories within the Sutlej Riverscape revealed that various categories of Land Use and Land Cover within the natural environment represented almost 66.47% extent of the Riverscape. Prominent Natural Land Use and Land Cover categories were Dense Forest, Moderately Dense Forest, Scrubs, and Alpine Pastures covering about 15.18% area of the Riverscape; 36.58% area was under snow/ glaciers, clouds and cloud shadow; and 13.04% area was barren. In addition, perennial rivers and River (dry)/ seasonal rivers and covered 1.59% area of the Riverscape while wetlands and waterbodies represented just 0.08% area. Thus, the 'Natural Landscape' constitutes the largest zone within the Riverscape. Hence, from the perspective of Forestry Interventions, this zone acquires the greatest significance for River conservation and restoration. Various planned Forestry Interventions; thus, include protection, habitat improvement and management by way of soil and water conservation works, weed control, Afforestation/Reforestation, Eco-restoration, Bio-filters and Bioremediation, etc. Keeping in view the diversity of forests and other natural ecosystems, native vegetation, soil conditions, and agro-climatic zones, potential models of various types of forestry intervention, particularly plantations have been identified, designed and developed by the HFRI using its multidisciplinary expert knowledge. For developing treatment models, insights obtained from the consultative process, field acquaintance, professional judgment, Forest Working Plans, and CAT Plans were optimally used. Suggested models for the Natural

Landscape, segregated into three broad groups: (a) Models for the Himalayan Mountainous tract in Himachal Pradesh, (b) Models for the Shivalik Hills in Punjab, and (c) Models for the alluvial plains of Punjab. The primary purpose of various models planned and proposed in the Natural Landscape is protection, eco-restoration, and conservation. Each recommended treatment model includes background information on site characteristics, recommended plant species for the proposed plantation besides details on spacing, quantity of different activities and man days during the establishment year as well as in subsequent years of maintenance. Details of potential treatment models were shared with SFDs in Himachal Pradesh and Punjab seeking feedback for appropriate finalization. Altogether, 21 models selected for Natural Landscapes numbered from SL/HP/NL/01 to SL/HP/NL/16 in the hilly region of Himachal Pradesh while 05 models for Natural Landscape in Shivalik Hills and alluvial plains of Punjab, numbered from SL/PB/NL/01 to SL/PB/NL/05 have been included. Details of these models in Natural Landscapes relevant to hills, Shivalik Hills and alluvial plains along with incorporated abbreviations/ code are summarized in Table 5.1.

In all, 16 models for Natural Landscape in the mountains (Trans Himalayan region) and Shivalik hills of Himachal Pradesh are proposed for treatment through Forestry Interventions. The model SL/HP/NL/01 and SL/HP/NL/02 specific to Cold Desert areas between 3000 to 4500 m amsl, and is having extreme climatic conditions. The major focus of this model is on conservation and enrichment of native biodiversity and additional livelihood generation for local communities, while two other models SL/HP/NL/03 and SL/HP/NL/04 are specific to subalpine and alpine areas (2,900-4,500 m). These models are dealing with enrichment and development of subalpine and alpine areas, respectively. Seven different models (SL/HP/NL/05 to SL/HP/NL/11) are proposed for upper, middle and lower temperate forested tracts in the Himalayan Mountains of Himachal Pradesh. SL/HP/NL/06 model especially designed for the pasture and grazing land development. SL/HP/NL/12 and SL/HP/NL/13 pertained for the removal of *Lantana* and removal of other invasive species including *Lantana* respectively. Model SL/HP/NL/14 has been designed for the natural regeneration while SL/HP/NL/15 is the fire protection model. All these 15 models prescribed for the Natural Landscapes will be implemented by the SFD, Himachal Pradesh with the exception of model SL/HP/NL/16 which will be implemented by the Eco-Task Force in temperate regions of Himachal Pradesh representing inhospitable topography and refractory conditions.

In the vast area of alluvial plains of Punjab, altogether five different treatment models are proposed and included in the DPR. The treatment model SL/PB/NL/01 will be specifically applied in Shivalik Hills Forest Enrichment while SL/PB/NL/02 will be applied in degraded Shivalik areas in protected forests or vacant areas in village common lands or community lands. Like-wise, in the Shivalik Hills Model for *Lantana* removal, SL/PB/NL/03 has been designed for the removal of invasive species including *Lantana*. In alluvial plains of Punjab, Model SL/PB/NL/04 will be dealing with the restoration of the degraded forests while SL/PB/NL/05 have been designed and proposed for plantations along roadsides, railway tracks, and canals in alluvial plains of Punjab. Besides, natural landscape models, various models recommended for

agriculture landscape, urban landscape, conservation and other interventions have been designed and proposed in this DPR.

Table 5. 1 Recommended Treatment Models in Different Landscapes of Himachal Pradesh and Punjab

Sr. No.	Model Type	Model Number
I	**Natural Landscape (NL)**	
A	**Himachal Pradesh**	
1	Cold Desert Greening	SL/HP/NL/01
2	Cold Desert Conservation	SL/HP/NL/02
3	Alpine Conservation	SL/HP/NL/03
4	Sub-Alpine Enrichment	SL/HP/NL/04
5	Dry Temperate Conifer Forest Enrichment	SL/HP/NL/05
6	Temperate Conifer Forest	SL/HP/NL/06
7	Temperate Mixed Forest	SL/HP/NL/07
8	Pasture and Grazing Land Development	SL/HP/NL/08
9	Himalayan Chir Pine Forest	SL/HP/NL/09
10	Himalayan Mixed Forest	SL/HP/NL/10
11	Sub-Tropical Dry Deciduous Forest	SL/HP/NL/11
12	Eradication of *Lantana*	SL/HP/NL/12
13	Control/ Removal of Invasive Species < 50% *Lantana*	SL/HP/NL/13
14	Protection Model for Natural Regeneration	SL/HP/NL/14
15	Fire Protection Model	SL/HP/NL/15
16	Plantation by Eco-Task Force in temperate regions	SL/HP/NL/16
B	**Punjab (Shivalik Hills)**	
17	Shivalik Hills Forest Enrichment	SL/PB/NL/01
18	Degraded Model with Staggered Trench and Pits	SL/PB/NL/02
19	Control / removal of Invasive species and *Lantana*	SL/PB/NL/03
C	**Punjab**	
20	Restoration of Degraded Forests Model	SL/PB/NL/04
21	Road Side Plantation	SL/PB/NL/05
II	**Agriculture Landscape (AL)**	
A	**Himachal Pradesh**	
22	Boundary Plantation Model	SL/HP /AL/01
23	Block Plantation Model	SL/HP /AL/02
B	**Plains – Punjab**	
24	Boundary Plantation Model	SL/PB/AL/01
25	Block Plantation Model	SL/PB/AL/02
III	**Urban Landscape (UL)**	
A	**Himachal Pradesh**	
26	Bioremediation and Bio-filtration	SL/HP/UL/01
27	Riverfront Development	SL/HP/UL/02
28	Institution Plantation	SL/HP/UL/03
29	Eco-Park Development	SL/HP/UL/04
B	**Punjab**	
30	Bioremediation and Bio-filtration	SL/PB/UL/01
31	Riverfront Development	SL/PB/UL/02

32	Institution Plantation	SL/PB/UL/03
33	Eco-Park Development	SL/PB/UL/04
IV	**Conservation Interventions (CI)**	
A	**Himachal Pradesh**	
34	Brushwood Interventions	SL/HP/CI/01
35	Dry Stone Activities	SL/HP/CI/02
36	Crate Wire Activity	SL/HP/CI/03
37	Water Pond	SL/HP/CI/04
38	Silt Detention Dam Type Activity	SL/HP/CI/05
B	**Punjab**	
39	Brushwood Interventions	SL/PB/CI/01
40	Dry Stone Activities	SL/PB/CI/02
41	Crate Wire Activities	SL/PB/CI/03
42	Water Ponds	SL/PB/CI/04
43	Silt Detention Dam Type Activities	SL/PB/CI/05
V	**Other Interventions (OI)**	
A	**Himachal Pradesh**	
44	Riverine and Riparian Management	SL/HP/CI/06
45	Wetland Management	SL/HP/CI/07
B	**Punjab**	
46	Riverine and Riparian Management	SL/PB/CI/06
47	Wetland Management	SL/PB/CI/07

(A) Treatment Models for Natural Landscapes in Himachal Pradesh

As already stated, various natural Land Use and Land Cover categories together constitute the largest area of the Sutlej Riverscape and it is represented by diverse forests, cold desert areas, alpine pastures, scrubs, snow cover/ glaciers, rivers, wetlands, etc. Thus, the maximum number of treatment models has been proposed in the mountainous/ hill portion of the Riverscape. Various Forestry Interventions are proposed to be implemented in the entire upper Basin of the Sutlej River and its tributaries. Primarily, these models would be applied on forest lands under the control of State Forest Department (SFD). The proposed treatment sites would mainly include areas under open forests, scrubs, grasslands, alpine pastures and cold deserts or along the Sutlej River and its tributaries. One of the Models namely SL/HP/NL/16 pertaining to plantation in temperate and cold desert regions, particularly in higher reaches and difficult areas is proposed to be executed by the Eco-Task Force (ETF). Details of each of the 21 treatment models prescribed in the Natural Landscapes are described below from Fig 5.1 to Table 5.24.

Model: Cold Desert Greening (SL/HP/NL/01)

Zone: Cold Desert Areas

The Cold Desert lies between 3000-4500 amsl, and is having extreme climatic conditions. The temperature remains below 20^0 C during winter months and 35^0C during summer seasons. The growing period is around five to six months i.e., from April to September. Annual precipitation in these areas is below 300 mm and mostly in the form of snow. The main vegetation of the area is shrubs and herbs i.e., *Rosa webbiana*, *Hippophae rhamnoides* ssp. *turkestanica*, *Caragana*

brevifolia, C. versicolor, Colutea nepalensis, Capparis spinosa, Ribes orientale, Ribes alpestre, Ribes himalense,Ephedra gerardiana, Myricaria germanica, etc. The tree species includes *Juniperus polycarpos* and *Betula utilis* in small pockets along with *Populus ciliata, Populus alba, Salix alba, Salix tetrasperma, Salix fragilis, Salix flabellaris* and *Salix daphnoides* which are planted by the local communities near villages for their requirement of fuel wood, timber and fodder for feeding their livestock, some among them naturalised along moist streams and rivulets.

In this model, it is proposed to green cold desert areas with the blend of exotic and native species around water channels, *nallahs*, rivers and other water bodies. The major focus will be on conservation of native biodiversity and livelihood generation for local communities. Conservation practices as prescribed in Working Plan of the respective Territorial Forest Division and Wildlife Management Plan of protected areas will be applicable. Collection of medicinal and aromatic plants species would be regulated as per the State's policy on Medicinal and Aromatic Plants and accordingly benefit will be shared with local communities.

In this model, trees@800plants/ha at 3m x3m spacing and shrubs @ 400/ ha at 2m x2m spacing will be planted. Dry shrubs will be planted towards hill side and moisture loving shrubs near *nallah* side. The cold desert species require 3 years nursery period and planting will be done in the 4^{th} year. For producing quality nursery stock of desired species, native zone soil will be used in cold desert species and Mycorrhiza will be added in nursery to boost growth either species specific or as consortium. The plants will be maintained in the field during 5^{th}, 6^{th} and 7^{th} years.

List of Species for plantation

Trees: *Juniperus polycarpos, Salix alba, Salix tetrasperma, Salix fragilis, Salix flabellaris, Salix daphnoides, Populus ciliata, Populus alba*, etc.

Shrubs (Near water bodies**):** *Hippophae rhamnoides* ssp. *turkestanica, Hippophae salicifolia, Myricaria germanica, Myricaria elegans, Lonicera hypoleuca*,etc.

Shrubs (Dry Areas**):** *Ephedra gerardiana, Capparis spinosa, Rosa webbiana, Colutea nepalensis, Caragana brevifolia, C. versicolor, Ribes orientale, R. alpestre, R. himalense*, etc.

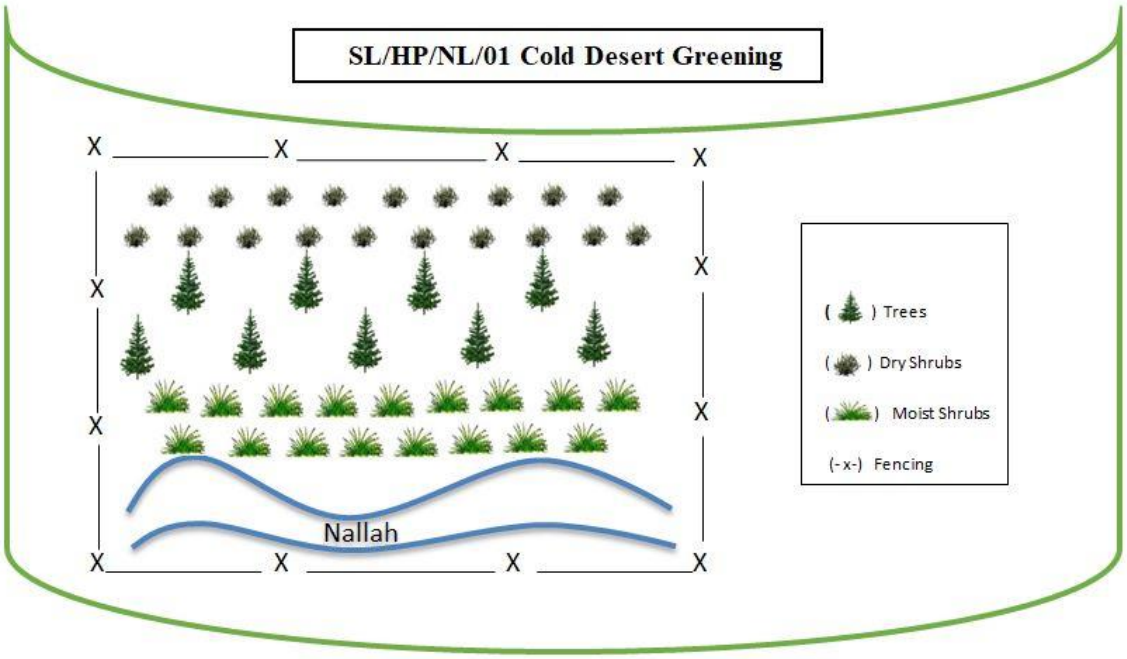


Fig. 5. 1 Plantation Design of Cold Desert Greening Model SL/HP/NL/01

Trees = 800 No, Spacing (m)3x3, Pit size (cm) – 30x30x30
Shrubs = 400 no., Spacing (m) 2x2, Pit size (cm) – 30x30x30, Pit = 400 no.
(x – x) **Fencing:** Cement pole/ local material wood/ branches

Table 5. 2 Cost norms and details of work of Cold Desert Greening model (SL/HP/NL/01) (in Tribal area)

Year	Item	Detail of works	Amount (Rs/ha)	Man days
	Number of Plants (No.)	Plants 800, Shrubs 400		
1st Year	Advance Work Labour Cost	Establishment of nursery	1400	4
2nd Year	Advance Work Labour Cost	Establishment of Ist year maintenance of plants	13,351	41
3rd Year	Advance Work Labour Cost	Ist and IInd year maintenance of plant nursery	17,968	50
4th Year	Advance Work Labour Cost	1st, 2nd and 3rd year maintenance of trees nursery	47,665	124
	Advance Work Material	Cost of seed, Farm Yard Manure (FYM), barbed wire and reinforced cement concrete (RCC) poles	52,000	0

	Advance Work Labour Cost	Site preparation Site preparation including survey & demarcation, bush cutting in strips , collection of debris, burning of debris, preparation inspection path, carriage of fence RCC pole and RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire	75,775	198
5th Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance works in 1st and 2nd year	29,248	71
	Creation	Carriage of plants, lay out of pits and pitting & planting of plants& preparation of strips including sowing in strips, weeding and mulching	70,055	171
Total Establishment Cost (Rs.)			**3,07,462**	**659**
MAINTENANCE				
6th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works	36,950	82
7th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works	26,546	55
8th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works	15,820	30
Total Maintenance Cost (Rs.)			**79,316**	**167**
Total Cost of Plantation			**3,86,778**	**826**

Model: Cold Desert Conservation (SL/HP/NL/02)
Zone: **Cold Desert Areas**

The Cold Desert area ranges between 3000 to 4500 m amsl, and faces extreme climatic conditions. The main vegetation of the area is shrubs and herbs i.e., *Rosa webbiana*, *Hippophae rhamnoides* ssp. *turkestanica*, *Caragana brevifolia, C. versicolor*, *Colutea nepalensis, Capparis spinosa, Ribes orientale, Ribes alpestre, Ribes himalense, Ephedra gerardiana*, *Myricaria germanica*, etc. The tree species includes *Juniperus polycarpos* and *Betula utilis* in small pockets along with *Populus ciliata, Populus alba, Salix alba, Salix tetrasperma, Salix fragilis, Salix flabellaris* and *Salix daphnoides* which are planted by the local communities near villages for their requirement of fuel wood, timber and fodder for feeding their livestock. In general, the cold desert region is quite barren and very few green pockets are present here and there.

In this model, it is proposed to plant shrubs and herbaceous species of cold desert areas for soil conservation purpose beyond water channels and water bodies. As these areas are prone to air sheet erosion due to high wind velocity, hence, these cold desert species are quite useful for controlling soil erosion. The high valued MAPs found in these hills will be beneficial for the

local communities. The major focus under this model will be on conservation and enrichment of native biodiversity and additional livelihood generation for local communities. Conservation practices as prescribed in Working Plan of the respective Territorial Forest Division and Wildlife Management Plan of protected areas will be applicable. Collection of MAPs would be regulated as per the State's policy on MAPs and accordingly benefit will be shared with local communities.

In this model, shrubs @800plants/ha at 2m x 4m spacing and herbs @ 600 patches/ha at 2m x 8m spacing along with grasses @ 600 patches/ha at 2m x 8m spacing will be planted. Dry shrubs will be planted towards hill side and moisture loving shrubs near *nallah* side. The cold desert species require 3 years nursery period and planting will be done in the 4th year. For producing quality nursery stock of desired species, native zone soil will be used in cold desert species and VAM will be added in nursery to boost growth either species specific or as consortium. The plants will be maintained in the field during 5th, 6th and 7th years.

List of Species for Plantation

Shrubs: *Ephedra gerardiana, Capparis spinosa, Rosa webbiana, Colutea nepalensis, Caragana brevifolia, C. versicolor, Ribes orientale, Ribes alpestre, Ribes himalense*, etc.
Herbs: *Arnebia euchroma, Arnebia guttata, Artemisia maritima, Heracleum candicans, H. wallichii, Rheum australe, Inula racemosa, Hyssopus officinalis, Hyoscyamus niger, Allium carolinianum,* etc.
Grasses and Forbs: *Festuca pratensis, Trifolium pretense, Poa pratensis, Poa alpina, Dactylis glomerata, Eragrostis* spp., *Melilotus* spp., *Koeleria* spp., *Potentilla* spp., *Agrostis* spp., *Danthonia* spp., *Medicago* spp., *Cicer songaricum, Artemisia* spp.,etc.

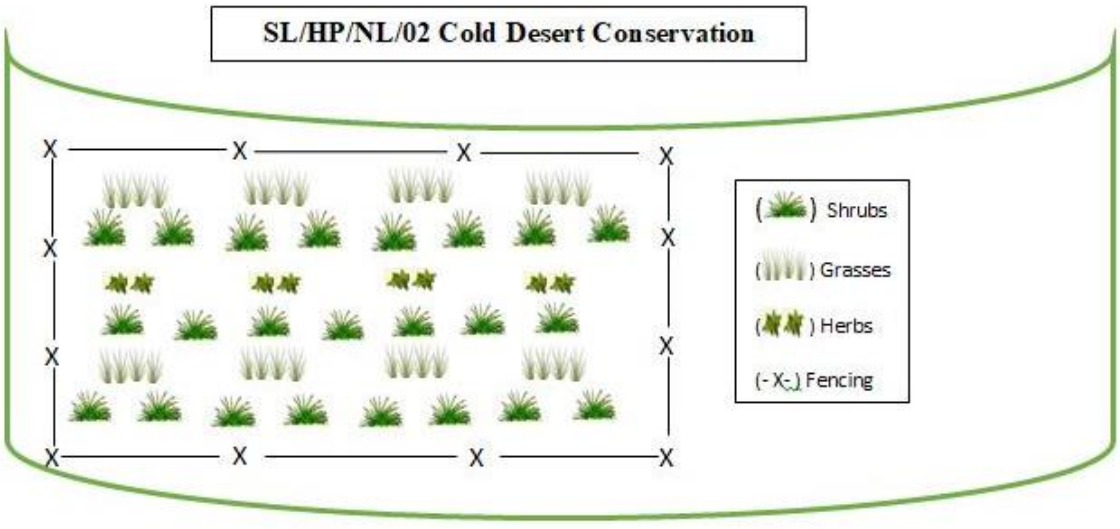


Fig. 5.2 Plantation Design of Cold Desert Conservation model SL/HP/NL/02

Shrubs: Plants: 800 no., Spacing (m) 2x4, Pit size (cm) – 30x30x30.
Herbs: Plants: 2400, Patch no 600, Patch size (cm) 30x30x5. Spacing (m)2x8, plant per Patch 4, Spacing (cm) 20x20
Grasses: Patch no 600, Patch size (cm) 100x30x5. Spacing (m)2x8, Seed per patch (gm) – 6gm, Spacing (cm) 10x10
(x – x) **Fencing:** Cement pole/ local material wood/ branches

Table 5.3 Cost norms and details of work of Cold Desert Conservation model (SL/HP/NL/02)

Year	Item	Detail of work	Amount (Rs)/ ha	Man days
	Number of Plants (No.)	Shrubs 800, Herbs 2400 and 600 patches of Grasses		
1st Year	Advance Work Labour Cost	Establishment of nursery	16,916	54
2nd Year	Advance Work Labour Cost	Maintenance of nursery + establishment of I st year maintenance	49,492	148
	Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), barbed wire and reinforced cement concrete (RCC) poles	58,000	0
	Advance Work Labour Cost	Site preparation Site preparation including survey & demarcation , bush cutting in strips, collection of debris, burning of debris, preparation inspection path, carriage of fence RCC pole and RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire	66,185	198
3rd Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance works in 1st and 2nd year	38,623	108
	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding and mulching	66,765	187
Total Establishment Cost			**2,95,981**	**695**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works	50,566	126
5th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works	38,328	89

6th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works	25,792	56
7th Year	Maintenance Cost IV Year	Maintenance cost of fencing	728	2
Total Maintenance Cost			**1,15,414**	**273**
Total cost of Plantation			**4,11,394**	**968**

Model: Alpine Conservation (SL/HP/NL/03)
Zone: Sub-Alpine and Alpine Areas

The subalpine and moist alpine zones range between 3,600–4,500 m amsl, and are mostly snowbound. The temperature remains below 5° C for 6 months in a year. The active plant growth season is of almost 46 months. This region is above the tree line with varied rock formations. Vegetation is dominated by grasses and herbs with scattered shrubs. A low deciduous scrub formation usually about 1 m high forms a dense cover in some patches.

Under this model, it is proposed to conserve and augment vegetation of the alpine meadows. The major focus will be on conservation of native species and livelihood generation for local communities. The conservation practices as prescribed in the Working Plan of respective Territorial Forest Division and Wildlife Management Plan of protected areas will be applicable. The collection of MAPs species would be regulated as per the State's policy on the MAPs and accordingly the benefit will be shared with local communities. Under this model, medicinal and aromatic plant species will be planted at the rate of 2,400 plants/ha in the blank areas in 600/ha patches. Root slips/ seeds of native grasses will be put in continuous contour strips immediately after melting of snow in 600/ha patches. The high altitude MAPs require at list two years nursery period and third year planting in the field along with grasses. For producing quality nursery stock of desired species, native zone soil will be used and VAM will be added in nursery to boost growth either species specific or as consortium. It will be followed by two years maintenance. Harvesting can be started after 5th year onwards in sustainable manner.

List of Species for Plantation

Herbs/Medicinal and Aromatic Plants: *Aconitum heterophyllum, Ainsliaea aptera, Arnebia benthamii, Dactylorhiza hatagirea, Heracleum candicans, H.* wallichii, *Angelica glauca, Polygonatum verticillatum, Selinum wallichianum, Allium humile, Geranium wallichianum, Rheum australe, Rheum moorcroftianum, Sinopodophyllum hexandrum, Saussurea costus,Potentilla* spp., *Artemisia* spp., etc.

Grasses and Forbs: *Festuca pratensis, Festuca valesiaca, Trifolium pretense, Poa pratensis, Poa annua, Dactylis glomerata, Medicago*spp., *Melilotus* spp., *Ainsliaea* spp., *Agrostis gigantea, Agrostis pilosula, Agrostis munroana, Agropyron* spp., *Danthonia* spp., *Calamagrostis*

montanus, Koeleria spp., *Brachypodium sylvaticum, Bromus himalaicus, Bromus ramosus, Stipa roylei*,etc.

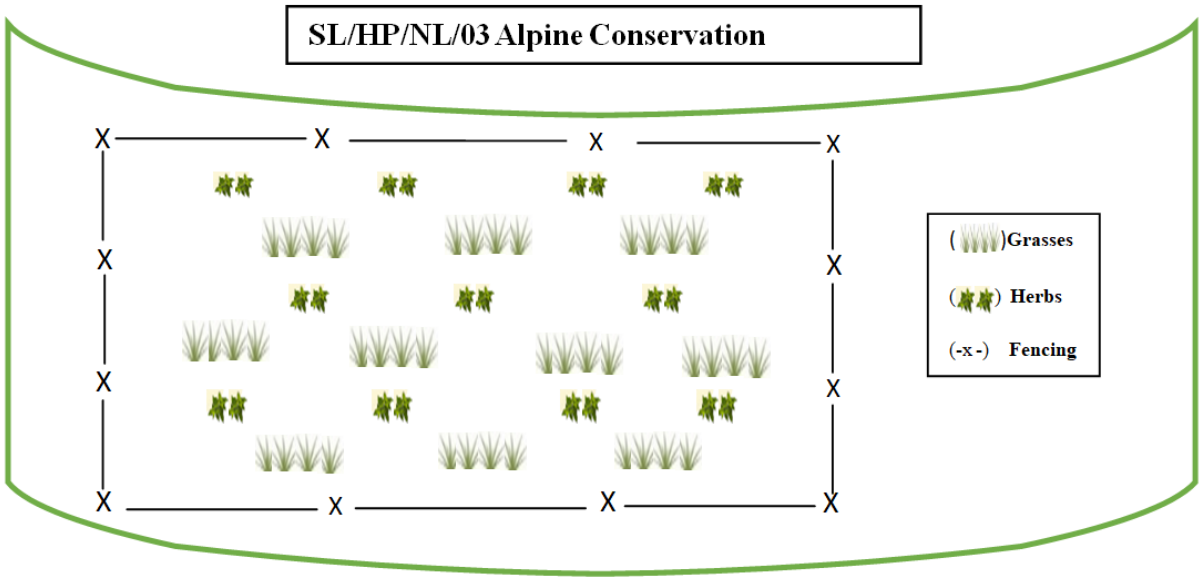


Fig. 5.3 Plantation Design of Alpine Conservation Model (SL/HP/NL/03)

Patch number 600, Patch size (cm) 30 x 30 x 5. Spacing (m) 2 x 8, Plant per patch 4, Spacing (cm) – 20 x 20 : Patch number 600, Patch size (cm) – 100 x 30 x 5. Spacing (m) – 2 x 8, Seed per patch (gm) – 6gm, Spacing (cm) – 10 x 10 ing: Cement pole/ Local material wood/ branches

Table 5.4 Cost norms and details of work of Alpine Conservation Model (SL/HP/NL/03)

Year	Item	Detail of work	Amount (Rs)/ ha	Man days
	Number of Plants (No.)	2400 Herbs + 600 patch of Grasses		
1st Year	Advance Work Labour Cost	Establishment of nursery	15,000	48
2nd Year	Advance Work Labour Cost	Maintenance of nursery+ establishment of I st year maintenance	12,000	36
	Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), barbed wire and Reinforced Cement Concrete (RCC) poles	55,600	0
	Advance Work Labour Cost	Site preparation Site preparation including survey & demarcation, bush cutting in strips, collection of debris, burning of debris, preparation inspection path, carriage of fence	66,185	198

		RCC pole and RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire		
3rd Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance works in 1st and 2nd years	10,200	29
	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding and mulching	23,686	66
Total Establishment Cost			**1,82,671**	**377**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works	24,132	58
5th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works	18,906	43
6th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works	14,337	30
7th Year	Maintenance Cost IV Year	Maintenance cost of fencing	728	2
Total Maintenance Cost			**58,103**	**133**
Total cost of Plantation			**2,40,775**	**510**

Model: Sub-Alpine Enrichment (SL/HP/NL/04)
Zone: Subalpine Zone

The Subalpine zone occurs between 2,900–3,600 m amsl, in the Sutlej Riverscape, and is covered with snow for 4 to 5 months. The temperature remains below 5° C for around 4 months in a year. Vegetation in subalpine zone is dominated by trees, herbs, grasses and shrubs of *Rhododendron* spp. and *Juniperus* spp. Area is sloppy and generally soil depth is very low. Under this model, it is proposed to conserve and augment vegetation in subalpine zone by adopting specific interventions to enrich such areas. The major focus will be on conservation and enrichment of native species besides generation of sustainable livelihoods for local communities. Conservation and enrichment practices as prescribed in the Working Plan of respective Territorial Forest Division /Wildlife Management Plan of a protected area will be applicable. The collection of MAPs species would be regulated as per the State's policy on MAPs and accordingly the accrued benefit will be shared with local communities. In this model, native trees @ 200 plants/ha at 6 m x 8 m spacing and medicinal and aromatic plant species @ 800 plants/ha at 6 m x 8 m spacing in 200/ha patches will be planted in blank areas. The high altitude tree species requires around 3 years nursery period and planting will be done in the 4th year. For producing quality nursery stock of desired species, native zone soil will be used in conifer

species and VAM will be added in other forestry species either species specific or as consortium. To synchronize planting of trees and MAPs in the 4th year, nursery of high attitude MAPs will be raised 2nd year onwards. The plants will be maintained in the field during 5th, 6th and 7th year of project implementation.

List of species for plantation

Trees: *Betula utilis, Pinus wallichiana, Picea smithiana, Acer caesium. Acer pictum, Corylus jacquemontii, Prunus cornuta, Quercus semecarpifolia,* etc.

Herbs/Medicinal and Aromatic Plants: *Aconitum heterophyllum, Arnebia benthamii, Dactylorhiza hatagirea, Heracleum candicans, Polygonatum verticillatum, Selinum wallichianum, Allium humile, Geranium wallichianum, Bergenia stracheyi, Phytolacca acinosa, Angelica glauca, Picrorhiza kurrooa, Rheum* spp., *Saussurea* spp., *Dracocephalus* spp., etc.

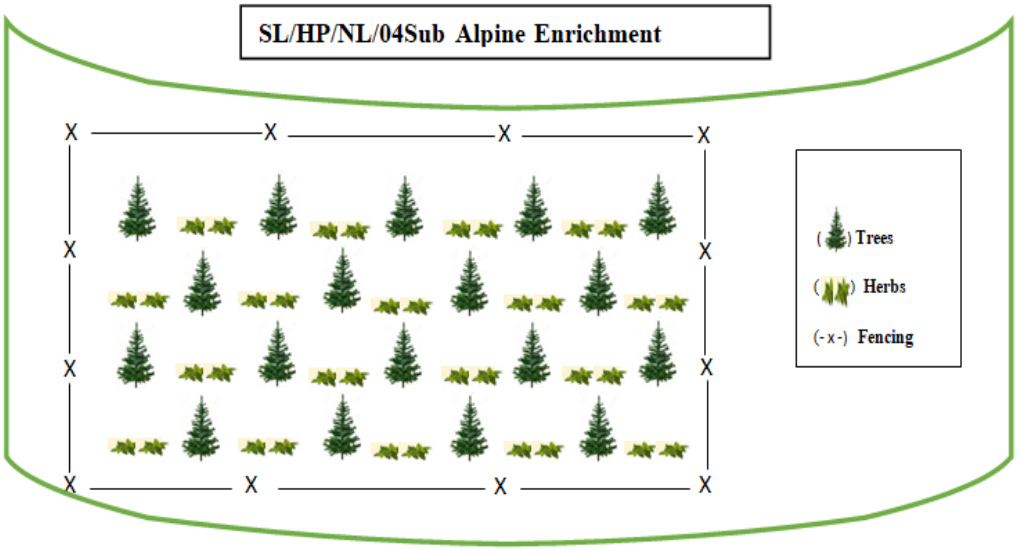


Fig. 5.4 Plantation Design of Sub Alpine Enrichment Model SL/HP/NL/04

Trees: 200/ha., Spacing (m) 6 x 8, Pit size (cm) – 30 x 30 x 30
Plants: 800/ha, Patch no – 200/ha, Patch size (cm) 30 x 30 x 5. Spacing (m) 6 x 8, plant per patch 4, Spacing (cm) – 20 x 20
Fencing: Cement pole/ local material wood/ branches

Table 5.5 Cost norms and details of work of Sub-Alpine Enrichment Model (SL/HP/NL/04)

Year	Item	Detail of works	Amount (Rs/ha)	Man days
	Number of Plants (No.)	800 Herbs + Plants 200		
1st Year	Advance Work Labour Cost	Establishment of nursery	500	2

2nd Year	Advance Work Labour Cost	Establishment of Ist year maintenance of plants	4,682	14
3rd Year	Advance Work Labour Cost	Maintenance of nursery of herbs+ Ist and IInd years maintenance of plant nursery	13,312	37
4th Year	Advance Work Labour Cost	Nursery 1st of herbs+ 1st, 2nd and 3rd years maintenance of trees nursery	22,234	12
	Advance Work Material	Cost of seed, Farm Yard Manure (FYM), barbed wire and reinforced cement concrete (RCC) poles	51,400	0
	Advance Work Labour Cost	Site preparation Site preparation including survey & demarcation, bush cutting in strips, collection of debris, burning of debris, preparation inspection path, carriage of fence RCC pole and RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire	75,775	198
5th Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance works in 1st and 2nd years	16,006	39
	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding and mulching	7,252	18
Total Establishment Cost (Rs.)			**1,91,161**	**320**
MAINTENANCE				
6th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works	14,798	32
7th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works	9,659	19
8th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works	2,917	5
Total Maintenance Cost (Rs.)			**27,374**	**56**
Total Cost of Plantation			**2,18,535**	**376**

Model: Dry Temperate Conifer Forest Enrichment (SL/HP/NL/05)

Zone: Dry Temperate Area

This model is recommended for altitudinal zone ranging between1800 m up to alpine forests at about 3250 m. This conifer forest consists of open nearly pure *Pinus gerardiana* crops locally with Blue pine, Deodar and Spruce forests. This zone is characterized by steep slopes, exposed

sites and loose strata. Soil depth is very less. The rainfall rarely exceeds 1000 mm. This type mainly occurs in Kinnaur district of Sutlej River catchment.

The suggested plantation model for this site is Dry Temperate Conifer Forest Enrichment Model. Planting of 400 plants/ha of native conifer species and 400 patches of MAPs will be planted. The trees will be planted at spacing of 5 m x 5 m in the blank patches. *Pinus gerardiana* is specially recommended for planting in Kinnaur to provide ultimate benefits to local communities. Between two rows of trees of the treatment site will be planted with MAPs in patches (30 x 30 cm). The collection of MAPs species in protected areas would be regulated as per the State's policy on MAPs and in accordance with the rights of local communities for ultimately generating additional income to those tribal communities. Most of conifer plants require around 3 years of nursery period and planting will be done in the 4th year. For producing quality nursery stock of desired species, native zone soil will be used in conifer species and VAM will be added in herb either species specific or as consortium To synchronize planting of trees, MAPs in 4th year, the nursery for selected herbs and shrubs will be raised 2nd year onwards. The plants will be maintained in the field during 5th, 6th and 7th year of the project implementation.

List of Species for Plantation

Tress: *Pinus gerardiana, Pinus wallichiana, Cedrus deodara, Fraxinus xanthoxyloides, Olea cuspidata, Alnus nitida, Celtis australis*, etc.

Herbs: *Hyoscyamus niger, Artemisia maritima, Heracleum candicans, H.wallichii, Angelica glauca, Geranium wallichianum, Viola* spp., *Valeriana jatamansii, Sinopodophyllum hexandrum, Polygonatum verticillatum, Angelica glauca, Selinum wallichianum, Selinum vaginatum*, etc.

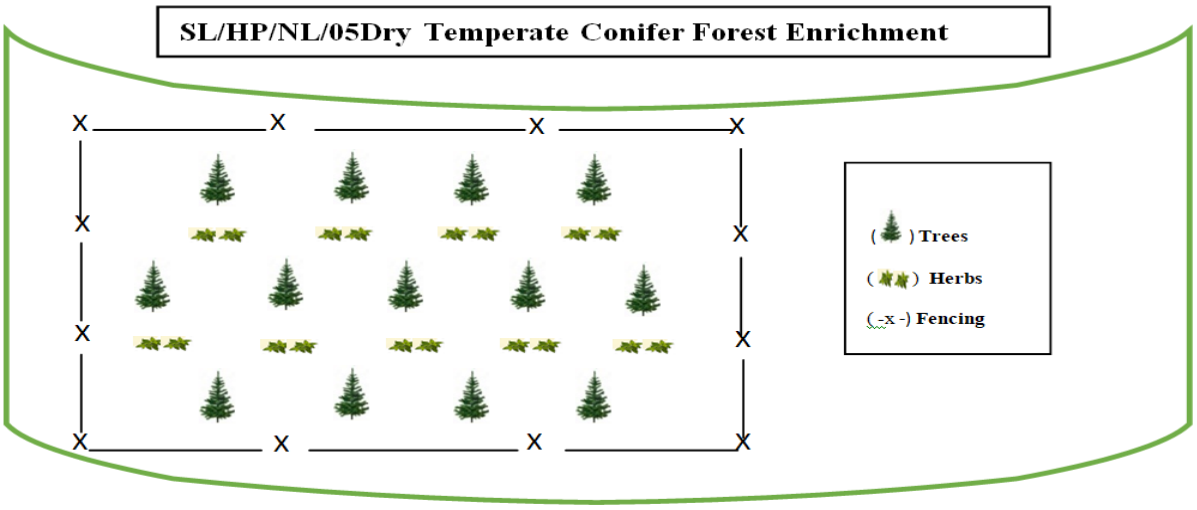


Fig. 5.5 Plantation Design of Dry Temperate Conifer Forest Enrichment Model SL/HP/NL/05

Trees= 400 No, Spacing (m)5x5, Pit size (cm) – 45x45x45
Herbs: Plants: 1600 Patch no 400, Patch size (cm) 30x30x5. Spacing (m)5x5, plant per patch 4, Spacing (cm) 20x20
(x – x) Fencing: Cement pole/ local material wood/ branches

Table 5.6 Cost norms and details of work of Dry Temperate Conifer Forest Enrichment Model (SL/HP/NL/05)

Year	Item	Detail of works	Amount (Rs/ha)	Man days
	Number of Plants (No.)	Plants 400, Herbs 1600		
1st Year	Advance Work Labour Cost	Establishment of nursery	1000	3
2nd Year	Advance Work Labour Cost	Establishment of Ist year maintenance of plants	9,364	28
3rd Year	Advance Work Labour Cost	Maintenance of nursery of herbs + Ist and IInd year maintenance of plant nursery	26,624	74
4th Year	Advance Work Labour Cost	Nursery 1st of herbs+ 1st, 2nd and 3rd year maintenance of trees nursery	44,468	24
	Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), barbed wire and Reinforced Cement Concrete (RCC) poles	51,400	0
	Advance Work Labour Cost	Site preparation Site preparation including survey & demarcation, bush cutting in strips, collection of debris, burning of debris, preparation inspection path, carriage of fence RCC pole and RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire	75,775	198

5th Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance works in 1st and 2nd year	32,012	78
	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding and mulching	43,696	107
Total Establishment Cost (Rs.)			**2,84,339**	**512**
MAINTENANCE				
6th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works	36,779	82
7th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works	25,509	53
8th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works	10,833	22
Total Maintenance Cost (Rs.)			**73,121**	**157**
Total Cost of Plantation			**3,57,460**	**670**

Model: Temperate Conifer Forest (SL/HP/NL/06)
Zone: Moist Temperate Area

The moist temperate area lies between 1,800 to 3,500 m amsl. This zone is characterized by dense forests, mainly of conifer species. However, blank patches too occur at several places which will be taken up for proposed treatment. In some areas, especially in fir and spruce forests, soil is covered with a thick layer of humus as the decomposition rate is very slow in these areas. The suggested treatment model for these areas is being referred as the Temperate Conifer Forest Model.

Planting of 300/ha plants of various tree species and 300/ha shrub species will be carried out per ha. In addition, 300/ha patches of medicinal and aromatic plants with 1200 plants/ha will also be planted out in the treatment site. The small stream or *nallah* facing side of the treatment area will be planted with two rows of hill bamboo at 2 m x 2 m spacing with 200/ha plants of hill bamboo.

The major focus will be on the conservation and development of native species and livelihood generation for local communities. The collection of MAPs species in protected areas would be regulated as per the State's policy on MAPs and in accordance with the rights of local communities. Most of conifer plants require around 3 years of nursery period and planting will be done in the 4th year. For producing quality nursery stock of desired species, native zone soil will be used in conifer species and VAM will be added in shrubs and herbs either species specific or as consortium. To synchronize planting of trees, MAPs and shrubs in 4th year, the nursery for selected herbs and shrubs will be raised 2nd year onwards. The plants will be maintained in the field during 5th, 6th and 7th years of the project implementation.

List of Species for Plantation

Trees: *Cedrus deodara, Pinus wallichiana, Picea smithiana, Taxus wallichiana, Cupressus torulosa*, etc.

Shrubs: *Drepanostachyum falcatum, Daphne papyracea, Prinsepia utilis, Rosa sericea, Rosa macrophylla, Rosa moschata, Debregeasia saeneb, Cotoneaster bacillaris, Viburnum cotinifolium, Viburnum grandiflorum, Cornus oblonga, Syringa emodi, Indigofera heterantha, Desmodium elegans, Hypericum oblongifolium*,etc.

Herbs: *Aconitum heterophyllum, Picrorhiza kurrooa, Heracleum candicans, Angelica glauca, Geranium wallichianum, Sinopodophyllum hexandrum, Polygonatum verticillatum, Polygonatum cirrhifolium, Bergenia stracheyi, Bergenia ciliata, Viola pilosa, Trillium govanianum, Phytolacca acinosa, Valeriana jatamansii*, etc.

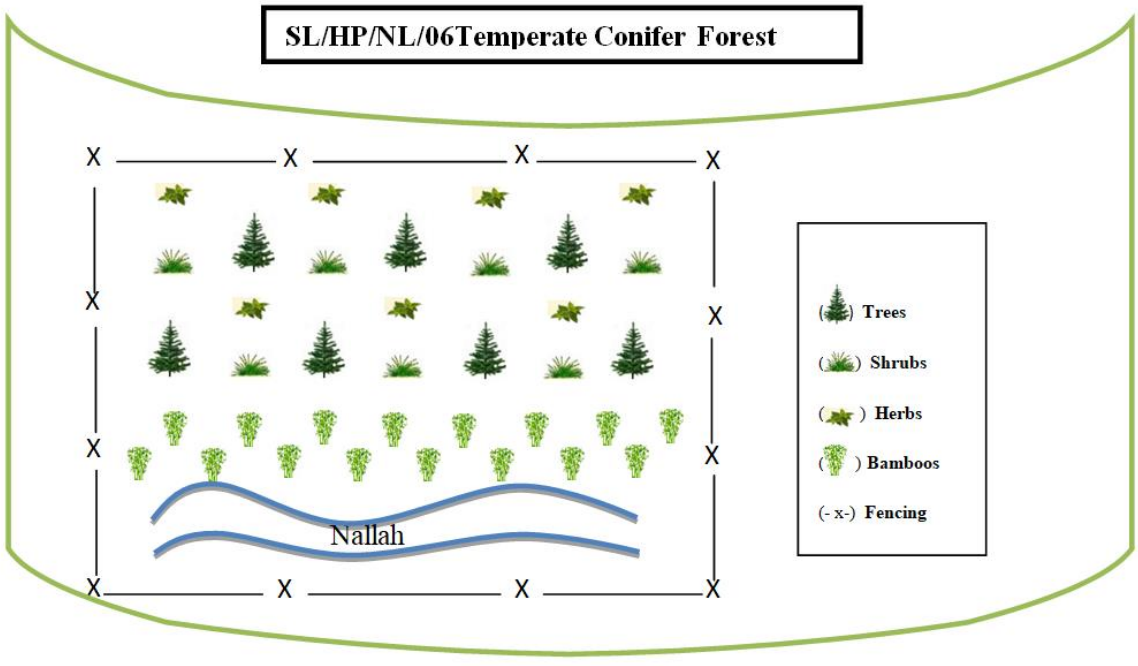


Fig. 5.6 Plantation Design of Temperate Conifer Forest Enrichment Model SL/HP/NL/06

Temperate Conifer Forest model SL/HP/NL/06

Trees = 300/ha, Spacing (m) – 5 x 5, Pit size (cm) – 45 x 45 x 45
Bamboo (hill): 200/ha, Spacing (m)2 x 2, Pit size (cm) – 45 x 45 x 45 (along *Nallah*)
Plants: 300/ha., No. of Pit 300, Spacing (m) 5 x 5, Pit size (cm) – 30 x 30 x 30
Plants: 1200/ha, Patch no – 300/ha, Patch size (cm) 30 x 30 x 5. Spacing (m) – 5 x 5, Plant/patch 4, Spacing (cm) – 20 x 20
Fencing: Cement pole/ local material wood/ branches

Table 5.7 Cost norms and details of work of Temperate Conifer Forest Model (SL/HP/NL/06)

Year	Item	Detail of work	Amount(Rs/ ha)	Man days
	Number of Plants (No.)	Plants 300 No., Bamboo 200, Shrubs300 no., Herbs 1200 no (300 no. patches)		
1st Year	Advance Work Labour Cost	Establishment of nursery	10,000	40
2nd Year	Advance Work Labour Cost	Maintenance of nursery+ establishment of Ist year Maintenance	38,879	145
	Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), barbed wire and Reinforced Cement Concrete (RCC) poles	52,000	0
	Advance Work Labour Cost	Site preparation Site preparation including survey & demarcation, bush cutting in strips, collection of debris, burning of debris, preparation inspection path, carriage of fence RCC pole and RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire in 4 strands	54,910	205
3rd Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance works in 1st and 2nd years	28,603	100

	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding and mulching	45,157	158
Total Establishment Cost (Rs.)			**2,29,549**	**648**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works	37,034	118
5th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works	20,711	61
6th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works	16,107	44
7th Year	Maintenance Cost IV Year	Maintenance Cost of fencing	582	2
Total Maintenance Cost (Rs.)			**74,434**	**225**
Total cost of Plantation			**3,03,985**	**873**

Model: Temperate Mixed Forest (SL/HP/NL/07)

Zone: Moist Temperate Area

The moist temperate forest area occurs between 1,800 to 3,500 m amsl. Dominant species of the area are: *Betula utilis, Betula alnoides, Aesculus indica, Quercus oblongata, Quercus floribunda, Quercus semecarpifolia, Alnus nitida, Acer caesium, Acer pictum, Acer cappadocicum, Ulmus wallichiana, Pinus wallichiana, Cedrus deodara, Picea smithiana, Abies pindrow, Abies*

spectabilis and *Cupressus torulosa*. This zone is often characterized by degraded stretches along the River banks running close to the area of dense temperate forests, mainly of conifers. This zone experiences snowfall and rainfall several times during winter months and enjoys a cool climate with plenty of monsoon rains.

Annual precipitation in this zone is between 1,000-1500 mm. In some areas, snow lasts till spring season. The soil in many places is shallow, exposed and prone to erosion. This zone is heavily grazed by domestic animals and cause huge damage to the vegetation. Besides this, road construction and other developmental activities also cause severe soil erosion, resulting in damage to vegetation. There is heavy dependence of local communities on Oak fodder within Sutlej Riverscape. Further, owing to several famous tourist spots *viz*. Kalpa, Kinner Kailash, Sarahan, Sangla, Chhitkul, Sunni Tatapanni, Bilaspur, etc. and the enhanced tourism activities in such zones within the Riverscape cause damage to vegetation and disturbance to wild fauna.

Temperate mixed forest treatment model has been proposed specifically for the blank and degraded patches within the temperate zone. Planting of trees @300/ha belonging to conifers and broadleaved species will be carried out in the blank and degraded patches. In this model preferably broadleaved plant will be planted in general and conifer plants can be planted on the ridges and shallow soil depth area. The native shrubs @300 plants/ha will be carried out in between the tree planted. The MAPs species will also be planted in patches @ 4 plants/ patch and that means planting of total of 1,200 MAPs/ ha. The small stream or *nallah* facing side of the treatment site will be planted with two rows of hill bamboo @ 200/ha at 2 m x 2 m spacing. The major focus of the proposed treatment model will be on the conservation and propagation of native species alongside improved livelihoods for local communities. Most of conifer plants require around 3 years of nursery period and planting will be done in the 4^{th} year. For producing quality nursery stock of desired species, native zone soil will be used in conifer species and VAM will be added in shrubs and herb either species specific or as consortium. To synchronize planting of trees, MAPs and shrubs in 4^{th} year, the nursery for selected herbs and shrubs will be raised 2^{nd} year onwards. The plants will be maintained in the field during 5^{th}, 6^{th} and 7^{th} years of the project implementation. The collection of MAPs in protected areas would be regulated as per the State's policy on MAPs and in accordance with the rights of local communities.

List of Species for Plantation

Trees: *Cedrus deodara, Pinus wallichiana, Picea smithiana, Taxus wallichiana, Aesculus indica, Prunus cornuta, Prunus cerasoides, Acer caesium, Acer cappadocicum, Carpinus viminea, Betula alnoides, Myrica esculenta, Cornus macrophylla, Alnus nitida, Ulmus wallichiana, Quercus glauca, Quercus oblongata, Quercus floribunda, Quercus semecarpifolia, Cornus capitata*,etc.

Shrubs: *Drepanostachyum falcatum , Daphne papyracea, Prinsepia utilis, Rosa moschata, Debregeasia saeneb , Cotoneaster bacillaris, Viburnum grandiflorum, Elaeagnus conferta, Hypericum oblongifolium, Rubus biflorus, Rubus niveus, Rubus ellipticus, Rubus foliosus,*

Zanthoxylum armatum, Viburnum mullaha, Rosa spp., *Deutzia staminea, Deutzia corymbosa, Spiraea canescens,*etc.

Herbs: *Aconitum heterophyllum, Heracleum candicans, Angelica glauca, Geranium wallichianum, Polygonatum verticillatum, Polygonatum cirrhifolium, Sinopodophyllum hexandrum, Bergenia ciliata, Viola pilosa, Valeriana jatamansii, Viola canescens, Hedychium spicatum,*etc.

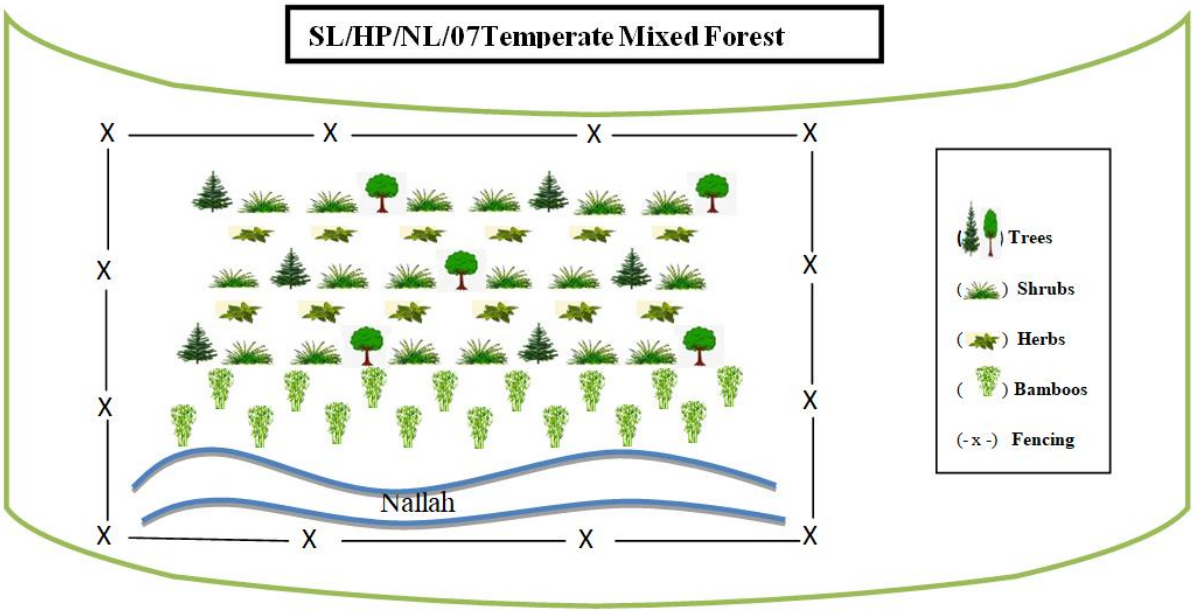


Fig. 5.7 Plantation Design of Temperate Mixed Forest model SL/HP/NL/07

Trees = 300, Spacing (m) 5 x 5, Pit size (cm) – 45 x 45 x 45 (50;50 of Broad leaved& Conifer)
Bamboo (hill): 200, Spacing (m) 5 x 5, Pit size (cm) – 45 x 45 x 45 (along *Nallah*)
Plants: 300, No. of Pit 300, Spacing (m) 2 x 5, Pit size (cm) – 30 x 30 x 30
Plants: 1200, Patch no – 300, Patch size (cm) 30 x 30 x 5. Spacing (m) 3 x 5, plant per patch 4, Spacing (cm) 20 x 20
Fencing**:** Cement pole/ local material wood/ branches

Table 5.8 Cost norms and details of work of Temperate Mixed Forest Model (SL/HP/NL/07)

Year	Item	Detail of works	Amount (Rs/ ha)	Man days
	Number of Plants (No.)	Plants 300 No., Bamboo 200, Shrubs 300 no., Herbs 1200 no (300 no. patches)		
1st Year	Advance Work Labour Cost	Establishment of nursery	14,491	58
2nd Year	Advance Work Labour Cost	Maintenance of nursery+ establishment of I st year maintenance	33,045	124

	Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), barbed wire and Reinforced Cement Concrete (RCC) poles	52,000	0
	Advance Work Labour Cost	Site preparation Site preparation including survey & demarcation, bush cutting in strips, collection of debris, burning of debris, preparation inspection path, carriage of fence RCC pole and RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire	54,910	205
3rd Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance works in 1st and 2nd years	28,925	101
	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding and mulching	45,157	158
Total Establishment Cost (Rs.)			**2,28,528**	**646**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works	38,815	117
5th year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works	20,711	61
6th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works	16,107	44
7th Year	Maintenance Cost IV Year	Maintenance cost of fencing	582	2
Total Maintenance Cost (Rs.)			**76,215**	**224**
Total Cost of Plantation			**3,02,743**	**870**

Model: **Pasture and Grazing Land Development (SL/HP/NL/08)**
Zone: **Sub-Tropical to Temperate Areas**

These areas located between 600-3,200 m amsl, particularly on southern slope and around habitations are characterized by pasture and grazing lands. This zone experiences snowfall and rainfall several times during winter months and enjoys a cool climate with plenty of monsoon rains. Annual precipitation is around 1,000 to 2,000 mm. In some areas, snow lasts till spring season. The soil is shallow, exposed and prone to erosion, particularly in moderate to steep slopes. This zone is heavily grazed by livestock and cause huge damage to the vegetation and results into heavy soil erosion. Besides disturbance by livestock, road construction and other developmental activities also cause significant soil degradation and damage to native flora by proliferation of invasive alien species. The local communities are heavily dependent on these grasslands in the Sutlej Riverscape. This zone also severely suffers on account of enhanced

tourism activities in several popular tourist destinations *viz.*, Kalpa, Kinner Kailash, Sarahan, Sangla, Chhitkul, Sunni Tatapanni, Bilaspur etc. causing damage to flora and disturbance to fauna.

Under this model, pasture and grazing land development are proposed by protection, development and enrichment of areas within this zone. Suitable grass species will be planted/ sowing of seeds after carrying out necessary land development works like trenching/ terracing/ moisture conservation measures, etc. besides removal of weeds and unpalatable grasses. The proposed treatment model mainly includes plantation of native and nutritionally important grass species. In this model, grass sowing in furrows/ strips of 100 cm x 30 cm x 5 cm along contours at interval of 2 m apart is proposed. Selected species will be raised / maintained in the nursery during 1st year and planting will be done in the second year. The grasses will be replenished in the field during 3rd and 4th year.

List of Species for Plantation

Grasses/Forbs: *Festuca pratensis, Trifolium pretense, T. repens, Poa pratensis, Poa annua, Dactylis glomerata, Erianthus* spp., *Agrostis* spp., *Agropyron* spp., *Calamagrostis* spp., *Koeleria* spp., *Saccharum spontaneum, Chrysopogon gryllus, C. serrulatus, Arundinella nepalensis, Arundinella pumila, Themeda anathera, Drepanostachyum falcatum, Cymbopogon distans, Pennisetum glaucum, Alopecurus aequalis, Alopecurus nepalensis, Bothriochloa pertusa, Bothriochloa parviflora, Dichanthium annulatum, Digitaria* spp., *Polypogon fugax*, etc.

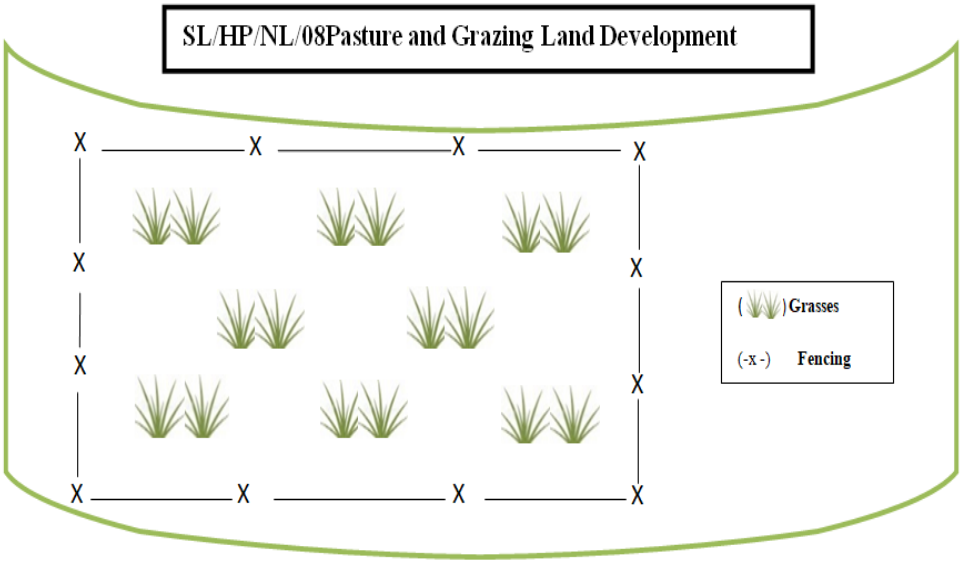


Fig. 5.8 Plantation Design of Pasture and Grazing Land Development Model SL/HP/NL/08

Patch no 2000, Patch size (cm) – 100 x 30 x 5. Spacing (m) – 2 x 2, Seed per patch (gm) 6, seed, Spacing (cm) – 10 x 10, Type Staggered Fencing: Cement pole/ Local material wood/ Branches/ Brushwood fencing

Table 5.9 Cost norms and details of work of Pasture and Grazing Land Development Model (SL/HP/NL/08)

Year	Item	Detail of works	Amount (Rs/ha)	Man days
	Number of Plants (No.)	Grasses 2000 no. patches		
1st Year	Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), barbed wire and Reinforced Cement Concrete (RCC) poles	66,400	0
	Advance Work Labour Cost	Site preparation Site preparation including survey & demarcation, bush cutting in strips, collection of debris, burning of debris, preparation inspection path, carriage of fence and RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire	54,910	205
2nd Year	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding and mulching	40,850	143
Total Establishment Cost (Rs.)			**1,62,160**	**348**
MAINTENANCE				
3rd Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works	27,994	67
4th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works	20,711	61
5th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works	16,107	44
6th Year	Maintenance Cost IV Year	Maintenance Cost of fencing	582	2
Total Maintenance Cost (Rs.)			**76,215**	**224**
Total Cost of Plantation			**238375**	**572**

Model: Himalayan Chir Pine Forest (SL/HP/NL/09)

Zone: Sub-Tropical to Lower Temperate Area

This zone occurs in mid hill region of Himachal Pradesh on southern aspect and is dominated by Chir pine. The altitude ranges between 800–1,800 m amsl and annual rainfall varies from 1,000 to 1,700 mm. In these areas, high temperatures and humidity conditions prevail during summer. Ground is densely covered with pine needles during winter to summer season and such areas are prone to forest fires. Grasses flush during monsoon season. Heavy rains in monsoon lead into severe soil erosion in this zone, ultimately results into high rate of sedimentation in Sutlej River and its tributaries. This is one of the major causes of siltation of dams and floods in Punjab

plains. Open and degraded forests on southern aspect with sparse vegetation coupled with agriculture on steep slopes, construction and developmental activities are prominent reasons behind large scale soil erosion in this zone. These areas experience heavy rainfall during monsoon season and modest rainfall during the winter season. Snowfall occurs in cooler aspects of higher reaches in a limited scale and snow stays for a few days only. Most of the rainwater flows down the streams washing away top soil especially on sloppy sites. The soil is acidic in nature and shallow on steep slopes while valleys have deep soil. The biotic pressure in terms of livestock grazing and fuel wood and tree fodder collection is conspicuous. Suitable forestry interventions in this zone can immensely help in improvement of pastures and grazing lands besides checking soil erosion and siltation into Sutlej River and its tributaries.

For such areas in this zone, the Himalayan Chir Pine Forest Model is proposed. Grass species such as *Heteropogon contortus, Chrysopogon fulvus, C. serrulatus*, etc. are proposed to be sown in the treatment site, particularly towards the river or *nallah* side. The area will be planted with *Pinus roxburghii* mainly in drier sites with shallow soil depth whereas broadleaved species like *Quercus oblongata*, *Lyonia ovalifolia*, Bamboo spp., etc. on moist sites are proposed to be planted at 5 m x 5 m spacing. A total of 300 plants of trees/ha, 100 bamboo species/ha along with 300 plants of shrubs/ha and 800 patches of grasses will be planted 2m apart in staggered fashion. Chir pine and associated broadleaved species require around 2 years nursery period and planting will be done in the 3rd year. For producing quality nursery stock of desired species, native zone soil will be used in conifer species and VAM will be added in shrubs and herbs either species specific or as consortium. The plants will be maintained in the field during 4th, 5th and 6th years. The fire line of width 5m both side along the fencing of the plantation area to be maintained twice a year.

List of Species for Plantation

Tree: *Pinus roxburghii, Quercus oblongata*, *Q. glauca*, *Lyonia ovalifolia, Myrica esculenta, Syzygium venosum, Dendrocalamus strictus, Dendrocalamus hamiltonii, Prunus cerasoides,Cinnamomum tamala, Bambusa* spp., *Holoptelea integrifolia , Ficus benghalensis, Ficus racemosa, Ficus rumphii, Albizia* spp., *Phyllanthus* emblica, *Diospyros montana, Pistacia chinensis subsp. integerrima,Bauhinia variegata, Grewia optiva, Pyrus pashia, Azadirachta indica, Mallotus philippensis, Aegle marmelos*, etc.

Shrubs: *Desmodium elegans, Desmodium triquetrum, Trifolium repens, T. pretense, Malva* spp., *Scrophularia* spp., *Parietaria debilis, Tephrosia hamiltonii, Justicia adhatoda, Myrsine africana,Murraya koenigii, Murraya paniculata , Ricinus communis, Tinospora sinensis , Woodfordia fruiticosa, Isodon rugosus , Maesa indica, Nyctanthes arbortristris, Vitex negundo, Carissa spinarum, Inula* spp., *Jasminum* spp., *Berberis lycium, Berberis aristata, Flemingia semialata, Rosa* spp., *Rubus* spp., *Thysanolaena latifolia*, etc.

Grasses/Forbs: *Heteropogon contortus, Chrysopogon fulvus, Chrysopogon serrulatus, Boerhavia diffusa, Festuca pratensis, Festuca arundinacea***,** *Poa pratensis, Erianthus filifolius, Erianthus rufipilus, Agrostis gigantea, Agropyron* spp., *Phleum pratense***,** *Themeda anathera,*

Arundo donax, Cymbopogon martini, C. jwarancusa,Phragmites karka, Bothriochloa pertusa, Bothriochloa intermedia, Eulaliopsis binata, Calamograstis spp., etc.

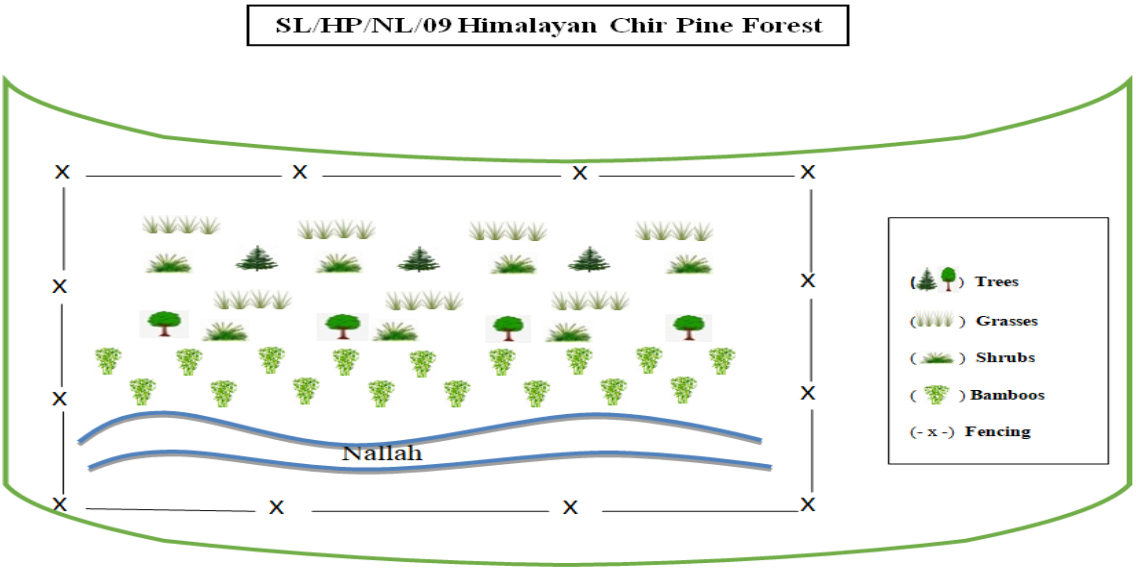


Fig. 5. 9 Plantation Design of Himalayan Chir Pine Forest Model SL/HP/NL/09

Trees: 300 , Spacing (m) 5 x 5, Pit size (cm) – 45 x 45 x 45
Bamboo : 100, Spacing (m) 5 x 5, Pit size (cm) – 45 x 45 x 45 along *Nallah* (if available)
Shrubs**:** Plants: 300, No. of Pit 300, Spacing (m) 5 x 5, Pit size (cm) – 30 x 30 x 30
Patch no 800, Patch size (cm) – 100 x 30 x 5. Spacing (m) – 2 x 5, Seed per patch (gm) 6, seed, Spacing (cm) 10 x 10, Type – Staggered
Fencing: Cement pole/ Local material wood/ Branches /Brushwood fencing

Table 5.10 Cost norms and details of work of Himalayan Chir Pine Forest Model (SL/HP/NL/09)

Year	Item	Detail of works	Amount (Rs/ha)	Man days
	Number of Plants (No.)	Plants 300 No., Bamboo100, Shrubs300 no., Grasses 800 no. patches		
1st Year	Advance Work Labour Cost	Establishment of nursery	8,397	34
2nd Year	Advance Work Labour Cost	Maintenance of nursery+ establishment of I st year maintenance	11,861	44
	Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), barbed wire and Reinforced Cement Concrete (RCC) poles	58,000	0

	Advance Work Labour Cost	Site preparation Site preparation including survey & demarcation, bush cutting in strips, collection of debris, burning of debris, preparation inspection path, carriage of fence and RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire	54,910	205
3rd Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance works in 1st and 2nd years	11,890	42
	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding and mulching	52,006	182
Total Establishment Cost (Rs.)			**1,97,064**	**507**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works	39,786	118
5th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works	31,875	90
6th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works	26,144	70
7th Year	Maintenance Cost IV Year	Maintenance cost of fencing	8588	24
Total Maintenance cost (Rs.)			**106,393**	**302**
Total cost of Plantation			**3,03,457**	**809**

Model : Himalayan Mixed Forest (SL/HP/NL/10)

Zone: Sub-Tropical to Lower Temperate Area

This zone occurs in mid hill region on the northern aspect and is dominated by broadleaved species with some Chir pine in exposed areas. The altitudinal variation of this zone is between 800–1,800 m amsl, the zone receives annual rainfall ranging from 1,000-1,700 mm. It experiences high temperatures and humidity prevails during the summer season. In areas wherein Chir pine species is around 50%, the ground is mostly covered with pine needles and area is prone to forest fires. Grasses in slopes flush during the monsoon season. Heavy rains in the monsoon season cause severe soil erosion and sedimentation in Sutlej River and its tributaries. Moderately dense to open forests on the northern aspect coupled with agriculture on terraces along moderately steep slopes and construction and development activities are primary reasons for large scale soil erosion in this zone. These areas experience heavy rainfall during the monsoon season and modest rainfall during the winter season. Snowfall occurs on cooler aspects of higher reaches, but the snow stays for a short duration of few days. Most of the rainwater

flows down the streams washing away top soil especially on sloppy sites. The soil is neutral to acidic in nature and shallow on slopes while valleys have deep soils. The biotic pressure (i.e., livestock grazing and collection of fuel wood & tree fodder) is severe. Appropriate Forestry Interventions in this zone can immensely help in improvement of the zone and also River flow.

The Himalayan Mixed Forest Model is recommended for this zone. Grass species such as *Heteropogon contortus, Themeda anathera, Chrysopogon fulvus, Chrysopogon serrulatus, Cymbopogon* spp., etc. will be sown or planted in the part of treatment site, particularly on the ridges. The treatment area will be planted with broadleaved species like *Quercus oblongata, Q. glauca, Lyonia ovalifolia, Pistacia chinensis subsp. integerrima, Toona ciliata, Syzygium venosum, Grewia optiva, Pyrus pashia, Albizia* spp., *Phyllanthus emblica, Holoptelea integrifolia , Ficus* spp., *Punica granatum, Bauhinia variegata, Prunus* spp., etc. Plants will be planted at 5 m x 5 m spacing. A total of 300 plants of tree/ha., 300 plants of shrubs/ha and 200 patches of 2x2 m apart grasses on the ridges/degraded sites will be planted. Broad leaved species of this zone require around one and half year to two years of nursery period and planting will be done in the 3rd year. For producing quality nursery stock of desired species VAM will be added either species specific or as consortium. The plants will be maintained in the 4th to 6th year. The fire line of width 5m both side along the fencing of the plantation area be maintained twice a year.

List of Species for Plantation

Tree: *Quercus oblongata, Q. glauca, Lyonia ovalifolia, Holoptelea integrifolia , Boehmeria rugulosa, Ficus benghalensis, Ficus racemosa, Pistacia chinensis subsp. Integerrima, Ficus rumphii, Albizia* spp., *Alstonia scholaris, Cinnamomum tamala, Phyllanthus* emblica, *Bauhinia variegata, Grewia optiva, Pyrus pashia, Toona ciliata, Syzygium venosum, Morus alba, Punica granatum, Terminali*a spp., *Symplocos paniculata,* etc.

Shrubs: *Rosa moschata, Debregeasia saeneb , Elaeagnus conferta, Zanthoxylum armatum, Trema politoria, Berberis lycium, Berberis aristata, Ziziphus* spp., *Carissa spinarum, Murraya koenigii, Desmodium gangeticum, Tephrosia hamiltonii, Justicia adhatoda, Murraya paniculata , Ricinus communis, Tinospora sinensis , Woodfordia fruiticosa, Maesa indica, Nyctanthes arbortristris, Vitex negundo, Inula* spp., *Thysanolaena latifolia,*etc.

Grasses/Forbs: *Heteropogon contortus, Chrysopogon fulvus, Chrysopogon serrulatus, Boerhavia diffusa,Parietaria debilis, Crotalaria* spp., *Strobilanthus* spp., *Festuca pratensis, Festuca arundinacea***,** *Poa pratensis, Saccharum filifolium , Erianthus rufipilus, Agrostis gigantea, Agropyron* Spp., *Phleum pratense***,** *Themeda anathera, Arundo donax, Cymbopogon martini, Phragmites karka, Bothriochloa pertusa, Bothriochloa intermedia, Eulaliopsis binata, Calamograstis* spp., etc.

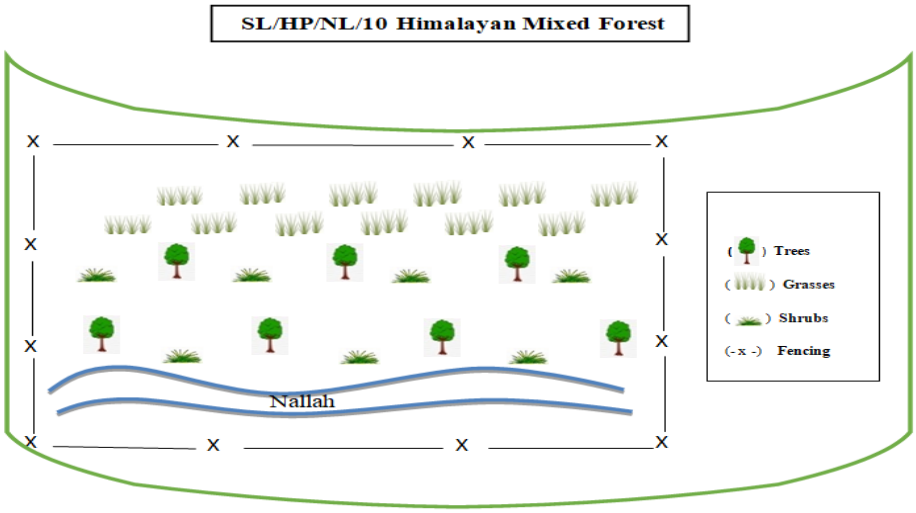


Fig. 5. 10 Plantation Design of Himalayan Mixed Forest Model SL/HP/NL/10

Trees: 300 , Spacing (m) – 5 x 5, Pit size (cm) – 45 x 45 x 45
Shrubs: 300, spacing (m) – 5 x 5, Pit size (cm) – 30 x 30 x 5.
Patch number – 200, Patch size (cm) – 100 x 30 x 5. Spacing (m) – 2 x 2, Seed per patch (gm) – 6gm, Spacing (cm) – 10 x 10, Type –Staggered,
Cement pole/ Local material wood/ Branches /Brushwood fencing

Table 5.11 Cost norms and details of work of Himalayan Mixed Forest Model (SL/HP/NL/10)

Year	Item	Detail of works	Amount (Rs/ha)	Man days
	Number of Plants (No.)	Plants 300 no., Shrubs 300 no., Grasses 200 no., patches		
1st Year	Advance Work Labour Cost	Establishment of nursery	8,397	34
2nd Year	Advance Work Labour Cost	Maintenance of nursery+ establishment of Ist year maintenance	11861	44
	Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), barbed wire and Reinforced Cement Concrete (RCC) poles	52,600	0
	Advance Work Labour Cost	Site preparation Site preparation including survey & demarcation, bush cutting in strips, collection of debris, burning of debris, preparation inspection path, carriage of fence RCC pole and RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire	54,910	205

3rd Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance works in 1st and 2nd years	11,890	42
	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding and mulching	39,849	139
Total Establishment Cost (Rs.)			**1,79,507**	**464**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works	34,284	108
5th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works	27,652	81
6th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works	22,920	63
7th Year	Maintenance Cost IV Year	Maintenance cost of fencing	8,588	23
Total Maintenance cost (Rs.)			**93,444**	**275**
Total cost of Plantation			**2,72,951**	**739**

Model: Sub-Tropical Dry Deciduous Forest (SL/HP/NL/11)
Zone: Sub-Tropical Area

This zone occurs in low hill region of Himachal Pradesh and dominated by broadleaved deciduous species. The altitude ranges between 300 to 900 m amsl and the zone experiences annual rainfall varying from 1,000-1,500 mm. Several broadleaved species grow in this zone which shed their leaves during summer months. The zone is represented by deep soil and moderate slope and experiences heavy rainfall during the monsoon season and modest rainfall during the winter season. Heavy rains during the monsoon season transport silt from these areas through number of seasonal water channels, *nallah*, rivulets, etc. to the Sutlej River causing siltation and floods in downstream areas. Besides this, agriculture on slopes and construction and developmental activities are the main reasons for soil erosion from these areas. A large part of rainwater flows down the streams within a few hours of rainfall as surface run off. The soil is shallow on slopes while valleys have deep soil depth. The biotic pressure (i.e., livestock grazing, fuel wood and tree fodder collection) is significant in this zone. Appropriate forestry interventions in this zone would not only check soil erosion and improve vegetation but would also help in improvement in the e-flow of the Sutlej River and its tributaries.

The Sub-Tropical Dry Deciduous Forest Model is recommended in this zone. Under this model, it is proposed to plant 300 trees of broadleaved species or bamboos. 300 shrubs at 5 m x 5 m will be planted in between the tree rows. Strong soil binding grasses like *Arundinella nepalensis*,

Apluda mutica, Chrysopogon fulvus and sedges like *Carex* spp., *Cyperus* spp. will be planted on the river or *nallah* facing side of the treatment site. In case of trees, a mixture of timber species like *Dalbergia sissoo, Senegalia catechu, Adina cordifolia,* etc. along with medicinal and aromatic trees like *Terminalia* spp., *Phyllanthus emblica, Oroxylum indicum, Sapindus mukorossi,* etc. will be planted at 5 m x 5 m spacing. Management practices and conservation measures as prescribed in the Working Plan of the respective Territorial Forest Division or the Wildlife Management Plan of the protected area will be applicable. Collection of medicinal and aromatic plants and other NTFP's along with sharing of accrued benefits to local communities would be regulated as per the State's policy on MAPs. Nursery of selected trees/shrubs etc. will be established during 1st year and 2nd years and planting will be done in 3rd year. For producing quality nursery stock of desired species VAM will be added either species specific or as consortium. Subsequently, the plantation will be managed during next three years. The fire line of width 5m both side along the fencing of the plantation area will be maintained twice a year.

List of Species for Plantation

Trees: *Dalbergia sissoo, Senegalia catechu, Adina cordifolia, Aegle marmelos, Terminalia bellirica, Terminalia chebula, Terminalia arjuna, Mallotus philippensis, Syzygium venosum, S. venosum, Oroxylum indicum, Sapindus mukorossi, Dendrocalamus strictus, Dendrocalamus hamiltonii, Bambusa* spp., *Holoptelea integrifolia , Ficus benghalensis, Ficus racemosa, Ficus rumphii, Albizia lebbeck, Albizia procera, Celtis australis, Cinnamomum tamala,Myrica esculenta, Pyrus pashia, Alstonia scholaris, Phyllanthus* emblica, *Diospyros montana, Bauhinia variegata, Grewia optiva, Azadirachta indica, Morus alba,*etc.

Shrubs: *Rosa moschata, Debregeasia saeneb , Zanthoxylum armatum, Berberis lycium, Ziziphus* spp., *Carissa spinarum, Desmodium gangeticum, Tephrosia hamiltonii, Justicia adhatoda, Murraya koenigii, Murraya paniculata , Ricinus communis, Tinospora sinensis , Woodfordia fruiticosa, Maesa indica, Nyctanthes arbortristris, Thysanolaena latifolia, Vitex negundo, Crotalaria*spp., *scrophularia* spp., *Euphorbia* spp., *Strobilanthus* spp., Vigna spp., etc.

Grasses/Forbs: *Heteropogon contortus, Chrysopogon fulvus, Chrysopogon serrulatus, Boerhavia diffusa, Festuca pratensis, Festuca arundinacea**,** Poa pratensis, Saccharum filifolium , Erianthus rufipilus, Agrostis gigantea, Agrostis* spp., *Phleum pratense**,** Themeda anathera, Arundo donax, Cymbopogon martini, Cyperus*spp., *Phragmites karka, Bothriochloa pertusa, Bothriochloa intermedia, Eulaliopsis binata, Calamograstis* spp., *Carex* spp., etc.

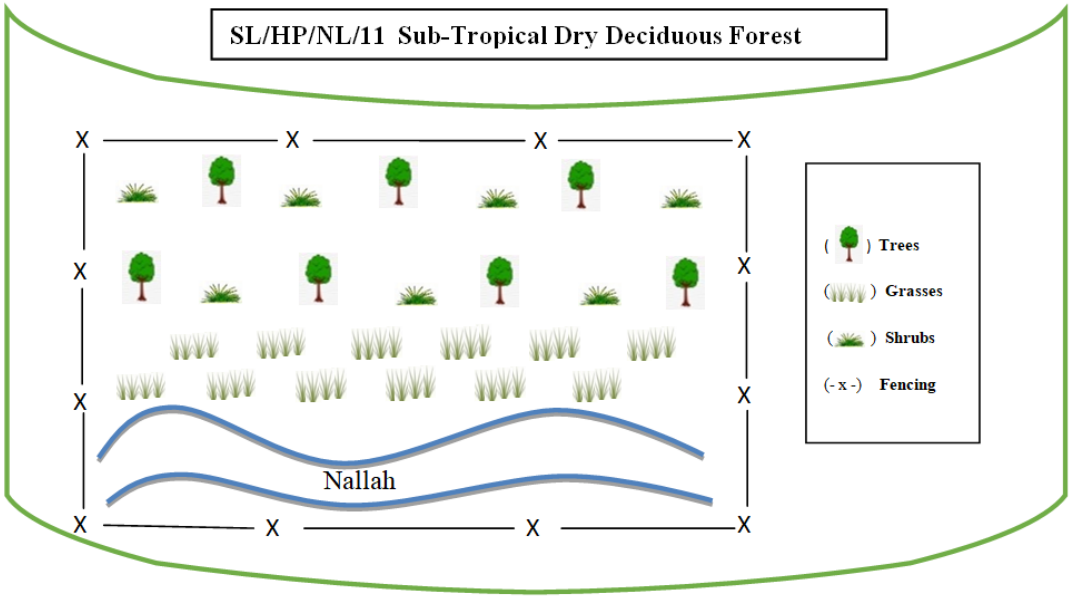


Fig. 5. 11 Plantation Design of Sub-Tropical Dry Deciduous Forest Model SL/HP/NL/11

Trees: 300 No, Spacing (m) 5 x 5, Pit size (cm) – 45 x 45 x 45
Shrubs: 300 no., spacing (m) 5 x 5, Pit size (cm) – 30 x 30 x 30
Grasses: Patch no 200, Patch size (cm) 100 x 30 x 5. Spacing (m) 2 x 2, Seed per patch (gm) 6, seed, Spacing (cm) 10 x 10, Type –Staggered, along *Nallah*/ depressions(if available)
Fencing: Cement pole/ Local material wood/ Branches/Brushwood fencing

Table 5. 12 Cost norms and details of work of Sub-Tropical Dry Deciduous Forest Model (SL/HP/NL/11)

Year	Item	Detail of works	Amount(Rs/ha)	Man days
	Number of Plants (No.)	Plants 300 No., shrubs300 no., grasses 200 no. patches		
1st Year	Advance Work Labour Cost	Establishment of nursery	7,940	32
2nd Year	Advance Work Labour Cost	Maintenance of nursery+ establishment of Ist year maintenance	11,657	44
	Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), barbed wire and Reinforced Cement Concrete (RCC) poles	52,600	0
	Advance Work Labour Cost	Site preparation Site preparation i/c survey & demarcation , bush cutting in strips, collection of debris, burning of debris, preparation inspection path, carriage of RCC poles, digging of holes for fixing poles, stretching & fixing of Barbed wire	54,910	205

3rd Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance work 1st and 2nd years	9,544	33
	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding and mulching	39,849	139
Total Establishment Cost (Rs.)			**1,76,500**	**453**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works	33,563	105
5th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works	27,154	80
6th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works	22,521	62
7th Year	Maintenance Cost IV Year	Maintenance cost of fencing	8,588	23
Total Maintenance cost (Rs.)			**91,826**	**270**
Total cost of Plantation			**2,68,326**	**723**

Model: Eradication of *Lantana* (> 50%) (SL/HP/NL/12)

Zone: Lower Temperate to Sub-Tropical Areas

Invasive alien species are plants which hamper natural regeneration and growth of native species, thereby replacement of native plant species coupled with loss of biodiversity, forage, habitat, aesthetics and productivity of native species in subtropical and lower temperate areas. Owing to considerable area of this zone under the influence of *Lantana camara*, tangible and intangible benefits from subtropical and lower temperate forests within the Sutlej Riverscape have been adversely affected.

The area for the proposed model referred as 'Eradication of *Lantana* (>50%)' covers forest sites between around 300 to 1,200 m amsl, wherein the topography is with gentle slopes. Such areas have subtropical to lower temperate climate with around 1,000-1,500 mm annual rainfall. Soils are generally fertile and moderately deep. The propose treatment area for this model usually has open or moderately dense forest or scrub vegetation. Luxuriant growth of *Lantana camara* forms dense undergrowth in the forest suppressing the native vegetation of that area.

It is proposed to cut and manually uproot above stated invasive species in treatment sites as per the prescription of Cut Root Stock (CRS) method for complete eradication of this obnoxious weed. These areas after *Lantana* eradication will be planted in the third year of project implementation. Grass species such as *Heteropogon contortus*, *Chrysopogon fulvus*, etc. will be sown in the part of treatment site. The treatment area will be planted with broadleaved species like *Toona ciliata*, *Syzygium venosum*, *Grewia optiva*, *Pyrus pashia*, *Albizia* spp., *Phyllanthus emblica*, *Holoptelea integrifolia*, *Ficus* spp., *Punica granatum*, *Bauhinia variegata*, *Dendrocalamus* spp., *Bambusa* spp. etc. Plants will be planted at 4 m x 4 m spacing. A total of 600 plants of trees and bamboos /ha along with 600 patches of 4x4 m apart grasses on sites will be planted. Alternate rows of bamboo and broadleaved species will be planted throughout the treatment area. Broadleaved species of this zone require around two and half years of nursery period to produce sturdy plants and planting will be done in the 3rd year. For producing quality nursery stock of desired species VAM will be added either species specific or as consortium. The plants will be maintained in the 4th to 6th years.

List of Species for Plantation

Tree: *Dalbergia sissoo*, *Senegalia catechu*, *Toona ciliata*, *Adina cordifolia*, *Aegle marmelos*, *Terminalia bellirica*, *Terminalia chebula*, *Terminalia arjuna*, *Mallotus philippensis*, *Syzygium venosum*, *Oroxylum indicum*, *Sapindus mukorossi*, *Punica granatum*, *Dendrocalamus strictus*, *Dendrocalamus hamiltonii*, *Bambusa* spp., *Holoptelea integrifolia* , *Ficus benghalensis*, *Ficus racemosa*, *Ficus rumphii*, *Albizia* spp., *Celtis australis*, *Litsea glutinosa* , *Pyrus pashia*, *Alstonia scholaris*, *Phyllanthus* emblica, *Diospyros montana*, *Bauhinia variegata*, *Grewia optiva*, *G. elastica*, etc.

Grasses, sedges and Forbs: *Arundinella nepalensis*, *Apluda mutica*, *Chrysopogon fulvus*, *Parietaria debilis*, *Crotalaria* spp., *Carex* spp., *Cyperus* spp., *Boerhavia diffusa*, *Heteropogon contortus*, *Trifolium repens*, *Eragrostis nigra*, *Deschamsia* spp., *Panicum maximum*, *Phleum pratense*, *Cymbopogon* spp., *Arundo donax*, *Phragmites karka*, *Themeda arundinacea*, *Eulaliopsis binata*, *Dichanthium annulatum*, *Sporobolus diandrus*, *Hierochloe laxa*, etc.

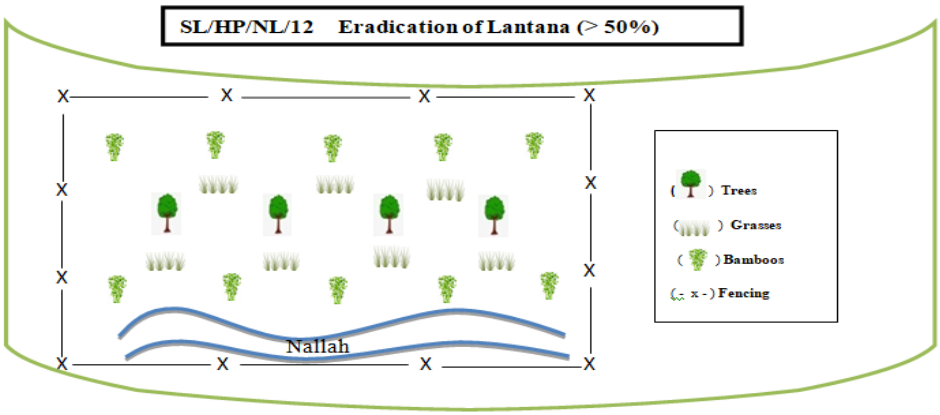


Fig. 5.12 Plantation Design of Eradication of *Lantana* (> 50%) Model SL/HP/NL/12

Trees/Bamboo: 600 No, Spacing (m) 4 x 4, Pit size (cm) – 45 x 45 x 45
Grasses, Sedges and Herbs: Patch no 600, Patch size (cm) 100 x 30 x 5. Spacing (m) 4 x 4, Seed per patch (gm) – 6gm, Spacing (cm) 10 x 10, Type –Staggered
Fencing: Cement pole/ Local material wood/ Branches/Brushwood fencing

Table 5.13 Cost norms and details of work of Eradication of *Lantana* (>50%) Model (SL/HP/NL/12)

Year	Item	Detail of works	Amount(Rs/ha)	Man days
	Number of Plants (No.)	Plants/ Bamboo 600 No., Grasses 600 no. patches		
1st Year	Advance Work Labour Cost	Establishment of nursery	5,955	24
1st Year	Advance Work Labour Cost	*Lantana* eradication by cut root stock method and cleaning of *Lantana* (sprouts) and seedlings, one times (100%) and @15% one cut in Ist year	31,501	126
2nd Year	Advance Work Labour Cost	Maintenance of nursery+ establishment of Ist year maintenance	8,743	33
	Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), barbed wire and Reinforced Cement Concrete (RCC) poles	55,600	0
	Advance Work Labour Cost	Site preparation, Site preparation including survey & demarcation, bush cutting in strips, collection of debris, burning of debris, preparation inspection path, carriage of fence and RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire	62,609	234
3rd Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance works in 1st and 2nd years	7,158	25
	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding, mulching, *Lantana* eradication by Cut Root Stock method and cleaning of *Lantana* (sprouts) and seedlings in 2 times in 3rd year @ 15% of unit cost establishment.	49,258	172
Total Establishment Cost (Rs.)			**2,20,824**	**614**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works, clearing of fire line along fencing, *Lantana* removal by cut	41,842	128

		root stock method and cleaning of *Lantana* (sprouts) and seedlings in 2 times in 4th year @ 15% of unit cost establishment.		
5th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works and clearing of fire line along fencing.	26,028	74
6th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works, clearing of fire line along fencing.	21,812	59
7th Year	Maintenance Cost IV Year	Maintenance cost of fencing and clearing of fire line along fencing.	8,588	23
Total Maintenance Cost (Rs.)			**98,270**	**284**
Total Cost of Plantation			**3,19,094**	**898**

Model: Control/ Removal of Invasive Species or <50% *Lantana* (SL/HP/NL/13)
Zone: Lower Temperate to Sub-Tropical Areas

Invasive Alien Species (IAS) are plants those hamper regeneration and growth of native species, thereby replacement of native plant species coupled with loss of biodiversity, forage, habitat, aesthetics and productivity of native species. Owing to considerable area of this zone under the influence of invasive alien or weed species, tangible and intangible benefits from sub-tropical to sub-temperate forests within the Sutlej Riverscape have been adversely affected.

The area for the proposed model referred as 'Control/ Removal of Invasive Species or <50% *Lantana*' covers forest sites between 300-1,200 m amsl, wherein the topography is with gentle slopes. Such areas have subtropical to lower-temperate climate with 1,000-1,500 mm annual rainfall. Soils are generally fertile and moderately deep. The propose treatment area for this model usually has open or moderately dense forest or scrub vegetation. Luxuriant growth of weed species including *Lantana camara* (<50%) forms considerably dense undergrowth in the forest suppressing the native vegetation of that area. *Ageratum conyzoides* and *Parthenium hysterophorus* also cause considerable hazard especially near agriculture fields and settlements.

It is proposed to cut and manually uproot above stated invasive species in treatment sites prior to their flowering, and immediately to be followed by planting of native plant species. In case of *Lantana* infested areas, Cut Root Stock (CRS) method will be used for complete eradication/ control of these obnoxious weeds. In case of other weeds, cuttings and removal of infested plants will be done at such a time and such a way as to cause least disturbance to soil and provide opportunity to the nearby economically important plants to occupy the space vacated by weeds. These areas after plantation will be intensively managed subsequently for two years to minimize the chances of their regrowth. For controlling herbaceous weeds like *Ageratum conyzoides* and *Parthenium hysterophorus*, ecofriendly measures (e.g., physical or mechanical methods, use of natural products, etc.) will be adopted without resorting to the use of synthetic chemicals. These

areas after *Lantana* eradication will be planted in the third year of project implementation. Grass species such as *Heteropogon contortus*, *Themeda anathera*, *Cymbopogan* spp., *Chrysopogon fulvus*, etc. will be sown in the part of treatment site.

The treatment area will be planted with broadleaved species like *Toona ciliata*, *Syzygium venosum*, *Grewia optiva*, *Pyrus pashia*, *Albizia* spp., *Phyllanthus emblica*, *Holoptelea integrifolia*, *Ficus* spp., *Punica granatum*, *Bauhinia variegata*, *Dendrocalamus* spp. and *Bambusa* spp.etc. Plants will be planted at 5 m x 5 m spacing. A total of 400 plants of trees and bamboo/ha a mixture of broad leaved species and bamboos will be planted. In additions, 400 patches of grasses 5x5 m apart will be planted on the proposed sites. The rows of trees and grasses will be planted alternatively. Broadleaved species of this zone require around two and half year of nursery period to produce sturdy plants and planting will be done in the 3rd year. For producing quality nursery stock of desired species VAM will be added either species specific or as consortium in the potting media. The plants will be maintained in the 4th to 6th years.

List of Species for Plantation

Trees: *Toona ciliata, Dalbergia sissoo, Senegalia catechu, Adina cordifolia, Aegle marmelos, Terminalia bellirica, Terminalia chebula, Terminalia arjuna, Mallotus philippensis, Syzygium venosum, Sapindus mukorossi, Dendrocalamus* spp., *Punica granatum, Bambusa* spp., *Holoptelea integrifolia, Albizia* spp., *Celtis australis, Pyrus pashia, Alstonia scholaris, Phyllanthus* emblica, *Diospyros montana, Bauhinia variegata, Morus alba, Grewia optiva*, etc.

Grasses/Sedges/Forbs: *Arundinella nepalensis, Apluda mutica, Chrysopogon fulvus, Boerhavia diffusa, Carex* spp., *Cyperus* spp., *Malvastrum* spp., *Parietariadebilis, Crotalaria*spp., *Blumea* spp., *Heteropogon contortus, Trifolium repens, Eragrostis nigra, Deschamsia* spp., *Panicum maximum, Phleum pratense, Cymbopogon citratus, Arundo donax, Phragmites karka, Themeda arundinacea, Eulaliopsis binata, Dichanthium annulatum, Sporobolus diandrus, Thysanolaena latifolia, Hierochloe laxa*, etc.

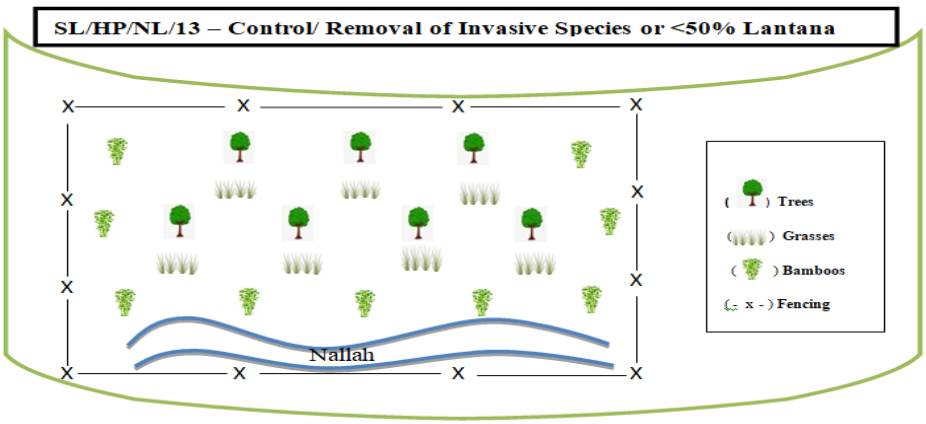


Fig. 5.13 Plantation Design of Control/ Removal of Invasive Species or <50% *Lantana* Model SL/HP/NL/13

Trees/Bamboo: 400 No, Spacing (m) 5 x 5, Pit size (cm) – 45 x 45 x 45 Patch no 400, Patch size (cm) 100 x 30 x 5. Spacing (m) 5 x 5, Seeds per patch (gm) 6, seeds, Spacing (cm) 10 x 10, Type –Staggered Cement pole/Local material wood/ Branches/Brushwood fencing

Table 5.14 Cost norms and details of work of Control/ Removal of Invasive Species or <50% *Lantana*Model (SL/HP/NL/13)

Year	Item	Detail of works	Amount (Rs/ha)	Man days
	Number of Plants (No.)	Plants/ Bamboo 400 No., Grasses, sedges & forbs 400 no. patches		
1st Year	Advance Work Labour Cost	Establishment of nursery	3970	16
	Advance Work Labour Cost	*Lantana* removal by Cut Root Stock method and cleaning of *Lantana*(sprouts) and seedlings, one times (100%) and @15% one cut in Ist year	31501	126
2nd Year	Advance Work Labour Cost	Maintenance of nursery+ establishment of Ist year maintenance	5829	22
	Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), barbed wire and Reinforced Cement Concrete (RCC) poles	54400	0
	Advance Work Labour Cost	Site preparation includes *Lantana* removal by Cut Root Stock method and cleaning of *Lantana* (sprouts) and seedlings 3 times a year @15% in 2nd year @ 15% of unit cost establishment preparation inspection path, carriage of RCC poles, digging of holes for fixing poles, stretching & fixing of barbed wire	62609	234
3rd Year	Advance Work Labour Cost	Maintenance of nursery for creation and maintenance works in 1st and 2nd year	4772	17
	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, patches & planting of herbs, preparation of strips including sowing in strips, weeding, mulching, *Lantana* removal by Cut Root Stock method and cleaning of *Lantana* (sprouts) and seedlings in 2 times in 3rd year @ 15% of unit cost establishment.	49258	172
Total Establishment Cost (Rs.)			**212339**	**587**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Nursery maintenance, material cost, planting cost & other maintenance works, clearing of fire line along fencing, *Lantana* removal by cut	39675	123

		root stock method and cleaning of *Lantana*(sprouts) and seedlings in 2 times in 4th year @ 15% of unit cost (establishment)		
5th Year	Maintenance Cost II Year	Nursery maintenance, material cost, planting cost & other maintenance works and clearing of fire line along fencing	25046	72
6th Year	Maintenance Cost III Year	Nursery maintenance, material cost, planting cost & other maintenance works clearing of fire line along fencing	21372	58
7th Year	Maintenance Cost IV Year	Maintenance cost of fencing and clearing of fire line along fencing	8588	23
Total Maintenance Cost (Rs.)			**94681**	**276**
Total Cost of Plantation (Rs.)			**307020**	**863**

Model: Protection Model for Natural Regeneration (SL/HP/NL/14)

Zone: All Hill Areas

All the hill areas between 1,300 to 4,500 m amsl is characterized by dense forests, mainly conifers and Oak forests, Sub-Alpine vegetation i.e. herbs, grasses, sedges, shrubs and trees and alpine pastures. However, blank patches too occur at several locations that can be taken up for the proposed treatment. In selected areas, especially in Deodar, Blue pine, Fir, Spruce, Oak forests and even the Sub-Alpine and Alpine areas, adequate regeneration can be observed under favorable conditions. Owing to varied disturbances by human and livestock in such areas, establishment of natural regeneration is generally poor and need immediate attention. Often, a thick layer of humus is typically present and the soil is generally moist and conducive for natural regeneration.

Under this treatment model, it is proposed to protect and conserve the existing vegetation so as to promote ample establishment and recruitment of natural regeneration. The major focus will be on protection of special areas like patches of good natural regeneration of various conifers, broadleaved species, shrubs, etc. and thereby conserving native plant species, particularly herbs. In Natural regeneration areas, cleaning operation twice a year in the month of September and March be carried out *viz.*,climber cutting, obnoxious weeds, unwanted species, pruning of plants, removing dead and dying trees. The broadcasting of desired seed is done in the closed area to supplement the natural regeneration.

List of Species for Plantation

Trees: No plantation proposed

Shrubs: No plantation proposed

Herbs: No plantation proposed

Cleaning Operations: Cleaning and unsaleable thinning (noncommercial) in regeneration areas, Climber cutting in the forests/ plantation area, Debris collection and burning
Seeds broadcasting: Seeds (2 kg for conifer and 15 kg for Broad leave per hectare)
Fencing: Cement pole/ Local material wood/ Branches

Table 5.15 Cost norms and details of work of Protection Model for Natural Regeneration Model (SL/HP/NL/14)

Year	Item	Detail of works	Amount (Rs./ha)	Man days
	Number of Plants (No.)	Seeds Broadcasting (2 kg for conifer and 15 kg for Broad leave)		
1st Year	I-Advance Work Material	Cost of seeds, Farm Yard Manure (FYM), Barbed wire and Reinforced Cement Concrete (RCC) poles	50,400	0
	II-Advance Work Labour Cost	Site preparation, i/c survey & demarcation, debris collection and burning, preparation inspection path, carriage of RCC poles, digging of holes for Fixing poles, stretching and fixing of Barbed wire	55,207	221
2nd Year	III Creation	Cleaning and unsaleable thinning (noncommercial) in regeneration areas, climber cutting in the forests/ plantation area, broadcasting sowing in plantation/ regeneration area, preparation of fire lines 2.5m wide, pruning of established saplings in plantation/regeneration 1/3 portion and burning/maintenance of lines 2.5m around the fencing	22,694	85
Total Establishment Cost (Rs.)			**1,28,301**	**306**
MAINTENANCE				
3rd Year	Maintenance Cost I Year i/c Material	Cleaning and unsaleable thinning (non-commercial) in regeneration areas, climber cutting in the forests/ plantation area (50%), broadcasting sowing in plantation/regeneration area (50%), pruning of established saplings in plantation/ regeneration 1/12 portion and burning/ maintenance of lines 2.5 m around the fencing (2 times)	15,389	50
4th Year	Maintenance Cost II Year	Cleaning and unsaleable thinning (non-commercial) in regeneration areas, climber cutting in the forests/ plantation area (30%), broadcasting sowing in plantation/regeneration area (30%), pruning of established saplings in plantation/ regeneration 1/15 portion and burning/maintenance of lines 2.5 m around the fencing (2 times)	14,216	44
5th Year	Maintenance Cost III Year	Cleaning and unsaleable thinning (non-commercial) in regeneration areas, climber	13,174	39

		cutting in the forests/ plantation area (20%), broadcasting sowing in plantation/regeneration area (20%), pruning of established saplings in plantation/ regeneration 1/18 portion and burning/maintenance of lines 2.5m around the fencing (2 times)		
6th Year	Maintenance Cost IV Year	Cleaning and unsaleable thinning (non-commercial) in regeneration areas, Climber cutting in the forests/ plantation area (15%), broadcasting sowing in plantation/regeneration area (15%) and burning/maintenance of lines 2.5m around the fencing (2 times)	8,146	23
Total Maintenance Cost (Rs.)			**50,925**	**156**
Total Cost of Plantation (Rs.)			**1,79,226**	**462**

Model: Fire Protection Model (SL/HP/NL/15)
Zone: Sub-Tropical Area to Lower Temperate Area

This zone occurs in subtropical i.e., from foot hills to mid hill region of Himachal Pradesh. It is dominated by Chir pine in southern aspects and mixed vegetation in other aspects. The altitudes ranges between 800–1800 m amsl, and annual rainfall is 1000 –1500 mm and mostly during monsoon and some portion in winter months. This zone experiences 78 dry months every year making these forests highly vulnerable to forest fires. Even a small negligence during dry months in Chir pine dominated areas carries the great risk of igniting forest fires that spread very fast riding on the wind. Damage caused by the forest fire during 201516 was in 5734 ha forest in Himachal Pradesh with loss to regeneration, pole crop and productivity and ecosystem services, Wildlife etc. Heavy monsoon rains in the burnt out areas transport huge qualities of silt to Sutlej River carrying siltation of dams and floods in Punjab plains. Effective fire control measures can help significantly in reducing the silt load in Sutlej River and its tributaries.

For these fire prone forest area, 'Fire Protection Model' is recommended. In this model, existing fire lines are cleared of vegetation and maintained all around the forest in such a way that a compact block or area is separated from adjoining areas. These fire lines are usually cleared before the start of the fire seasons in order to avoid the spread of fires from one forest to another. Engagement of fire watchers in fire sensitive beats, procurement of fire fighting equipments and use of elide fire extinguishing balls. Construction of water harvesting and storage structure with locally available materials will be done e.g., Ponds, Khals, etc. Besides these, awareness campaign among rural masses particularly about overall damage by forest fires to nature flora and fauna, soil and other ecosystem services of the forest such as hydrological functions, moderation of local climate etc. influencing horticulture/ agriculture productivity of farmlands.

Role of local communities in bringing down the forest fire incidences in Chirpine zone and is very important and need to be highlighted at various levels.

Cleaning of Fire lines Control burning Engagement of fire watchers Procurement of fire fighting equipments/ Elide fire extinguishing balls Constructions of Ponds/ water harvesting structures Awareness campaign, Community awareness.

Table 5. 16 Cost norms and details of work of Fire Protection Model (SL/HP/NL/15)

Year	Item	Detail of work	Amount (Rs.) /ha	Man days
1st Year	Establishment Cost	Cleaning of fire lines (2.5 meter width), control burning, engagement of fire watchers, constructions of ponds/ water harvesting structures, procurement of firefighting equipment's elide fire extinguishing balls and maintenance, awareness campaign and community awareness	32,863	131
MAINTENANCE				
2nd Year	Maintenance Cost I Year i/c Material	Cleaning of fire lines (2.5 meter width), control burning, engagement of fire watchers, procurement of firefighting equipments / elide fire extinguishing balls and maintenance, awareness campaign and Community awareness	24,462	91
3rd Year	Maintenance Cost II Year	Cleaning of fire lines (2.5meter width), control burning, engagement of fire watchers, procurement of firefighting equipments elide fire extinguishing balls and maintenance, awareness campaignand community awareness	24,265	85
4th year	Maintenance Cost III Year	Cleaning of fire lines (2.5 meter width), control burning, engagement of fire watchers, procurement of firefighting equipments / elide fire extinguishing balls and maintenance, awareness campaignand community awareness	23,922	78

5th year	Maintenance Cost IV Year	Cleaning of fire lines (2.5 meter width), control burning, engagement of fire watchers, procurement of firefighting equipments / elide fire extinguishing balls and maintenance, awareness campaign and community awareness	23,411	71
Total Maintenance Cost (Rs.)			**96,060**	**325**
Total cost of model (Rs.)			**1,28,923**	**456**

Model: Plantation by Eco-Task Force in Temperate Forests (SL/HP/NL/16)
Zone: Lower Temperate to Sub-Tropical Areas

Some sites in the upper Sutlej River Basin have rugged topography, harsh conditions, shallow soils with low moisture content, etc. Such areas are mostly located on the southern slopes. These sites require continued presence and close supervision by planting and maintenance teams. The Eco-Task Force (ETF) in the past has exhibited great success in regeneration of such harsh sites. It is proposed to utilize this unique ability of ETF in planting on such difficult sites under this DPR. A total of 2,000 ha land in such areas will be identified in the Sutlej Riverscape in liaison with Himachal Pradesh State Forest Department. The selected areas may not necessarily be contiguous. The task of establishment and maintenance of proposed plantations will be carried out by the existing unit of ETF at Thali near Tatapani, Mandi district and one more unit will be proposed under this DPR to be established in Pooh area of tribal district Kinnaur with over all Command Headquarters at Kufri, Shimla district. These units will work in close coordination with Himachal Pradesh State Forest Department. One or more of the proposed plantation models amongst suggested models (SL/HP/NL/01 to SL/HP/NL/13) will be selected for replication by the ETF under this model.

Table 5. 17 Cost norms and details of Plantation by Eco-Task Force work model (SL/HP/NL/16)

Year	Item	Amount (Rs)
1st Year	Establishment of cost of Eco-Task force, cost of vehicle, equipment for plantation, firefighting & protection	7,00,00,000
2nd Year	Material cost of plantation (ha) and petrol and vehicle maintenance per year	60,00,000
	Cost of Salary and maintenance of Eco-Task Force per year	3,00,00,000
3rd Year	Material cost for plantation (ha) and	66,00,000

	maintenance of plantation and carriage of planting material	
	Cost of salary and maintenance of Eco-Task Force	3,15,00,000
4th Year	Material cost for plantation (ha) and maintenance of plantation and carriage of planting material	72,00,000
	Cost of salary and maintenance of Eco-Task Force	3,20,00,000
5th Year	Material cost for plantation (ha) and maintenance of plantation and carriage of planting material	80,00,000
	Cost of salary and maintenance of Eco-Task Force	3,30,00,000
6th Year	Material cost for plantation (ha) and maintenance of plantation and carriage of planting material	90,00,000
	Cost of salary and maintenance of Eco-Task Force	3,40,00,000
7th Year	Material cost for plantation (ha) and maintenance of plantation and carriage of planting material	24,00,000
	Cost of salary and maintenance of Eco-Task Force	3,50,00,000
8th Year	Material cost for plantation (ha) and maintenance of plantation and carriage of planting material	18,00,000
	Cost of salary and maintenance of Eco-Task Force	3,50,00,000
9th Year	Material cost for plantation (ha) and maintenance of plantation and carriage of planting material	8,00,000
	Cost of salary and maintenance of Eco-Task Force	3,50,00,000
10th Year	Material cost for plantation (ha) and maintenance of plantation and carriage of planting material	4,00,000
	Cost of salary and maintenance of Eco-Task Force	3,50,00,000
Grand Total		**41,27,00,000**

Total	**Material cost including carriage**	**4,22,00,000**
Total	**Cost of Salary and maintenance of Eco-Task Force**	**37,05,00,000**

(200 hectare of plantation to be raised by one company each year starting from 2nd year to 6th years and including maintenance from 3rd year to 10th years).

(B) Treatment Models for Natural Landscapes in Shivalik Hills of Punjab

In order to address the problems and challenges narrated in the context of forest lands and diverse forests of the Sutlej River catchment in Shivalik Hills of Punjab, the following Forestry Interventions have been proposed for Natural Landscapes in the Shivalik Hills. Interventions will be executed in total drainage area of Sutlej River in Shivalik zone.

Areas under the control of the State Forest Department will be treated through various recommended Natural Landscape Models. The treatment sites usually have open forest, scrub vegetation or grasslands. Native trees, shrubs and herbs will be planted and maintained for a period of four years. Altogether, three models have been proposed for Natural Landscapes in the Shivalik areas. Details of the each treatment models are given below.

Model: Shivalik Hills Forest Enrichment (SL/PB/NL/01)
Zone: Shivalik Hills of Punjab

This zone occurs in Shivalik region of Punjab, and is dominated by scattered trees in small groups typical of this forest type. However, in the climax state, it would appear that this upper canopy would be thin, but fairly complete, most trees having low spreading crown. *Anogeissus latifolia* is the main species of this area where as Chir pine stands singly or in groups with a scattered lower deciduous tree storey more numerous in depressions and cooler aspects. Generally, Chir pine found at appropriate altitudes on cooler aspects. It is also found typically on steep dry slopes below 800 m on the Shivalik conglomerates and sandstones. The soil is dry, shallow and stony as well. The other main species in these areas are *Senegalia catechu, Lannea coromandelica, Aegle marmelos, Mitragyna parvifolia, Flacourtia indica, Mallotus philippensis, Dendrocalamus strictus, Bauhinia vahlii, Terminalia bellirica, Terminalia chebula, Terminalia arjuna, Pyrus pashia, Syzygium venosum, Albizia* spp., *Phyllanthus emblica, Murraya koenigii,* etc.

Heavy monsoon rains in this zone transport huge quantities of silt to Sutlej River causing siltation and floods in Punjab plains. Open and degraded forests with sparse foliage coupled with agriculture on slopes and construction and developmental activities are reasons behind largescale soil erosion in this zone. The pressure for grazing, fuel wood and tree fodder collection is considerable. Effective Forestry Interventions in this zone can help significantly in improvement of the flow of Sutlej River and its tributaries.

For these areas, Shivalik Hills forest enrichment model is recommended to improve the existing vegetation there. Under this model, it is proposed to plant 400 trees, 400 shrubs and 400 patches of MAPs like *Rauvolfia serpentina, Withania somnifera, Andrographis paniculata, Bacopa monnieri, Acorus calamus, Eclipta alba,* etc. Conservation and other management practices as prescribed in working plan of respective Territorial/Wildlife Divisions will be applied. Collection of MAPs and other NTFPs would be regulated as per the State's MAPs policy and benefit will be shared with local communities. Broadleaved species of this zone require around one and half years of nursery period to produce sturdy plants and planting will be done in the 2nd year. For producing quality nursery stock of desired species VAM will be added either species specific or as consortium in the potting media. The plants will be maintained in the 3rd to 5th years.

List of Species for Plantation

Trees: *Senegalia catechu, Lannea coromandelica, Aegle marmelos, Pongamia pinnata, Mitragyna parvifolia, Flacourtia indica, Mallotus philippensis, Terminalia bellirica, Terminalia chebula, Terminalia arjuna, Syzygium venosum,Dalbergia sissoo, Adina cordifolia, Sapindus mukorossi, Bambusa bambos, Dendrocalamus strictus, Dendrocalamus hamiltonii, Oroxylum indicum, Holoptelea integrifolia , Ficus benghalensis, Ficus racemosa, Ficus religiosa, Albizia lebbeck, Albizia procera, Alstonia scholaris, Phyllanthus* emblica, *Ziziphus jujuba, Azadirachta indica, Bombax ceiba, Anogeissus latifolia, Desmodium oojeinense , Diospyros montana, Melia azedarach, Mangifera indica, Santalum album,* etc.

Shrubs: *Bauhinia vahlii, Murraya koenigii, Murraya paniculata, Desmodium gangeticum, Tephrosia hamiltonii, Woodfordia fruiticosa, Maesa indica, Clerodendrum* spp., *Nyctanthes arbortristris, Vitex negundo,* etc.

Medicinal and Aromatic Plants: *Andrographis paniculata, Bacopa monnieri, Acorus calamus, Rauvolfia serpentina, Withania somnifera, Eclipta alba, Boerhavia diffusa, Mentha* spp., etc.

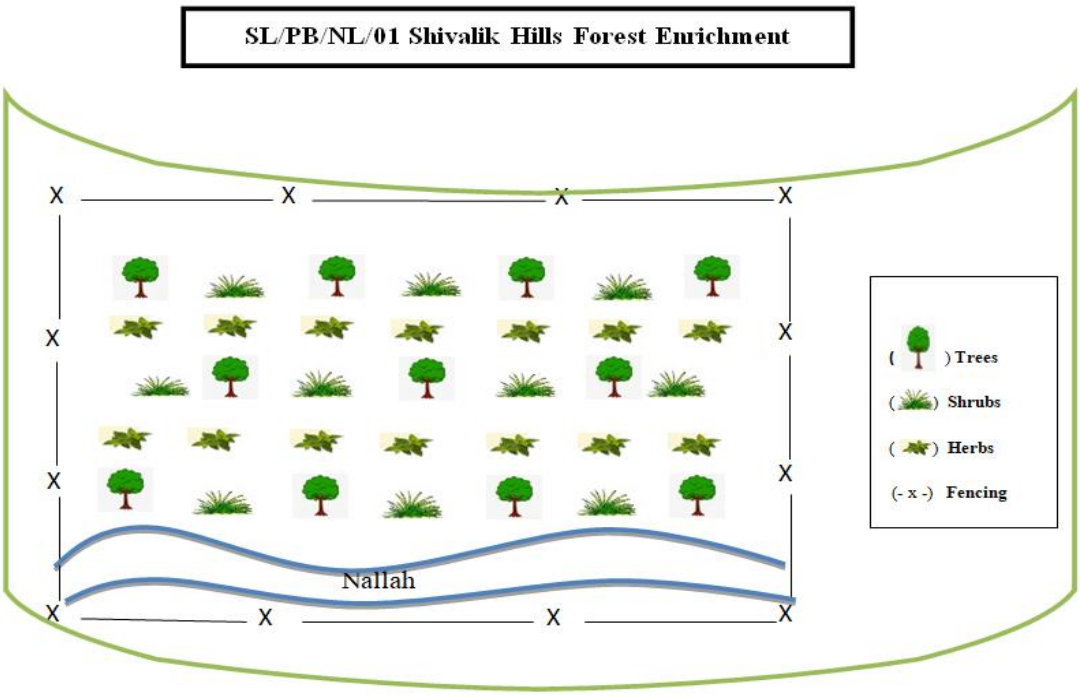


Fig. 5. 14 Plantation Design of Shivalik Hills Forest Enrichment Model SL/PB/NL/01

Trees/Bamboo: 400/ha, Spacing (m) – 5 x 5, Pit size (cm) – 50 x 50 x 40
Shrubs: 400/ha, Spacing (m) – 5 x 5, Pit size (cm) – 30 x 30 x 30
Herbs: Plants 1600 no, Patches 400 no., Spacing (m)5x10, Patch size(cm) 100x30x5, Herbs – 4 no. in each patch
Fencing: Angle Iron/Cement Pole/ Local material wood/ Branches/Brushwood fencing

Table 5.18 Cost norms and details of work of Shivalik Hills Forest EnrichmentModel (SL/PB/NL/01)

Year	Item	Details of work	Amount (Rs./ha)	Man days
	Number of Plants (No.)	Plants/Bamboo 400, Shrubs 400, Herbs1600.		
1st Year	Nursery Advance Work Labour Cost	Cost of seedlings raising including (a) Original planting =400 per ha, (b) Shrubs400, (c) Herbs 1600, replacement 10%= 240 per ha, Total 2640 No. in Biodegradable polybag	26,972	79
2nd Year	Advance Work Labour Cost	Cutting of *Lantana*/Mallah (0.5ha) etc, Kana stubbing (0.25ha), survey and alignment Earth work i.e., digging of pit of size; a) 400 no x .5m x 0.5m x 0.40m b) 400 no x 0.3 x 0.3 x 0.3m and Patch c) 400 no x 1.00 x 0.3 x 0.10m, refilling of pits, fencing (5% of plantation cost)	33,118	80

3rd Year	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers(twice), providing thorny protection to plants against porcupine attack, covering and uncovering of frost tender plant species (25%), preparation of inspection path, watch and ward for every 10 ha. of plantation, Cutting of *Lantana*/Mallah IInd and IIIrd times, spot irrigation (8+1 times), reopening of trenches and pits,and cost of bio-insecticide & bio-fertilizer, etc. including carriage, overhead charges (10% of planation cost) POL, OE and Miscellaneous	74,907	170
Total Establishment Cost (Rs.)			**1,34,997**	**329**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Cost of seedlings (25%), cutting of *Lantana*/Mallah etc., kana stubbing, Earth work i.e.re digging of pit refilling of pits,(25%) fencing (5% of plantation cost), carriage of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers(twice), providing thorny protection to plants against porcupine attack, covering and uncovering of frost tender plant species (25%), of inspection path, watch and ward for every 10 ha. of plantation, spot irrigation (4+1 times), reopening of trenches and pits, Bio-Insecticides including carriage, Bio-Fertilizers, etc. Including carriage, overhead charges (10% of maintenance planation cost) POL, OE and Miscellaneous	53,201	127
5th Year	Maintenance Cost II Year	Earth work i.e. refilling digging of pit refilling of pits (15%) fencing (5% of plantation cost), carriage of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers(twice), Providing thorny protection to plants against Porcupine attack, Covering and uncovering of frost tender plant species (25%), of inspection path, Watch and ward for every 10 ha. of plantation, spot irrigation (4+1 times), reopening of trenches and pits, BioInsecticides, including carriage, Bio Fertilizers, etc. Including carriage, overhead charges (10% of maintenance of planation cost) POL, OE and Miscellaneous	23,989	55
6th Year	Maintenance Cost III Year	Weeding hoeing (twice), application of bio-insecticides, application of FYM/ fertilizers	5,863	30

		(twice), providing thorny protection to plants against porcupine attack, watch and ward for every 10 ha. of plantation, Bio-Fertilizers, etc. Including carriage, overhead charges (10% of maintenance of planation cost) POL, OE and Miscellaneous		
Total Maintenance Cost (Rs.)			**83,053**	**212**
Total Cost of Plantation (Rs.)			**2,18,050**	**521**

Model: Degraded Model with Staggered Trench & Pits (SL/PB/NL/02)
Zone: Shivalik Hills of Punjab

This zone occurs in Shivalik region of Punjab and is dominated by scattered trees in very small groups are typical of degraded forest devoid of tree vegetation. However, in the climax state, it would appear that this upper canopy would be thin but fairly complete, most trees having low, spreading crown. The soil is mostly dry shallow, stony as well and unstable. In upper areas, soil may be very porous, hot and dry during the summer months. Because of the undulating topography and fair amount of rainfall, normal erosion is quite common. The fertility of the soil is medium to low and the texture is loamy to clayey. The height of Shivalik ranges between 400-700 m amsl. It consists of conglomerated, clays and silts all having the character of fluvial deposits of rivers, streams and small water channel.

Heavy monsoon rains in this zone transport huge quantities of silt to Sutlej River causing siltation and floods in Punjab plains. Open and degraded forest with sparse foliage coupled with agriculture on slopes and construction and developmental activities are reasons behind large scale soil erosion in this zone. The pressure for grazing, fuel wood and tree fodder collection is considerable. Effective Forestry Interventions especially in moderate to high slopes in this zone can help significantly in improvement of the flow of Sutlej River and its tributaries and also reducing the silt load.

For developing these areas, Degraded Model with staggered Trench and Pit is recommended for highly degraded areas of Shivalik Hills devoid of tree vegetation. Under this model, it is proposed to develop site by digging staggered trenches to control soil erosion and enhance moisture availability. After land development, 1000 plants mainly of broadleaved species like *Acacia nilotica, Senegalia catechu, Melia azedarach, Ailanthus excelsa, Toona ciliata, Morus alba, Tectona grandis, Dalbergia sissoo, Azadirachta indica,* etc. will be planted. Besides this, 200 patches of soil binding grasses will be planted in between and on mounds. Conservation and other management practices as prescribed in working plan of respective Territorial/Wildlife Divisions will be applied. Collection of MAPs and other NTFPs would be regulated as per the State's MAPs policy and benefit will be shared with local communities. Broadleaved species of this zone require around one and half years of nursery period to produce sturdy plants and planting will be done in the 2nd year. For producing quality nursery stock of desired species

VAM will be added either species specific or as consortium in the potting media. The plants will be maintained in the 3rd to 5th year.

List of Species for Plantation

Trees: *Senegalia catechu, Aegle marmelos, Pongamia pinnata, Mitragyna parvifolia, Mallotus philippensis, Terminalia bellirica, Terminalia chebula, Terminalia arjuna, Syzygium venosum, Dalbergia sissoo, Adina cordifolia,Sapindus mukorossi, Bambusa bambos, Dendrocalamus strictus, Dendrocalamus hamiltonii, Oroxylum indicum, Holoptelea integrifolia , Ficus benghalensis, Ficus racemosa, Ficus religiosa, Albizia lebbeck, Albizia procera, Alstonia scholaris, Phyllanthus* emblica*, Ziziphus jujuba, Azadirachta indica, Bombax ceiba, Anogeissus latifolia, Desmodium oojeinense , Diospyros montana, Hymenodictyon orixense, Melia azedarach, Mangifera indica, Santalum album*, etc.

Grasses, Sedges and Forbs: *Saccharum spontaneum, Saccharum bengalense,* C*arex* spp., *Scirpus* spp., *Cyperus* Spp., *Bacopa monnieri, Eclipta alba, Chrysopogon zizanioides, Chrysopogon fulvus, Arundinella nepalensis, Apluda mutica, Boerhavia diffusa, Heteropogon contortus, Trifolium repens, Eragrostis nigra, Deschamsia* spp., *Panicum maximum, Phleum pratense, Cymbopogon citratus, Arundo donax, Phragmites karka, Themeda arundinacea, Eulaliopsis binata, Dichanthium annulatum, Sporobolus diandrus, Thysanolaena latifolia, Hierochloe laxa*, etc.

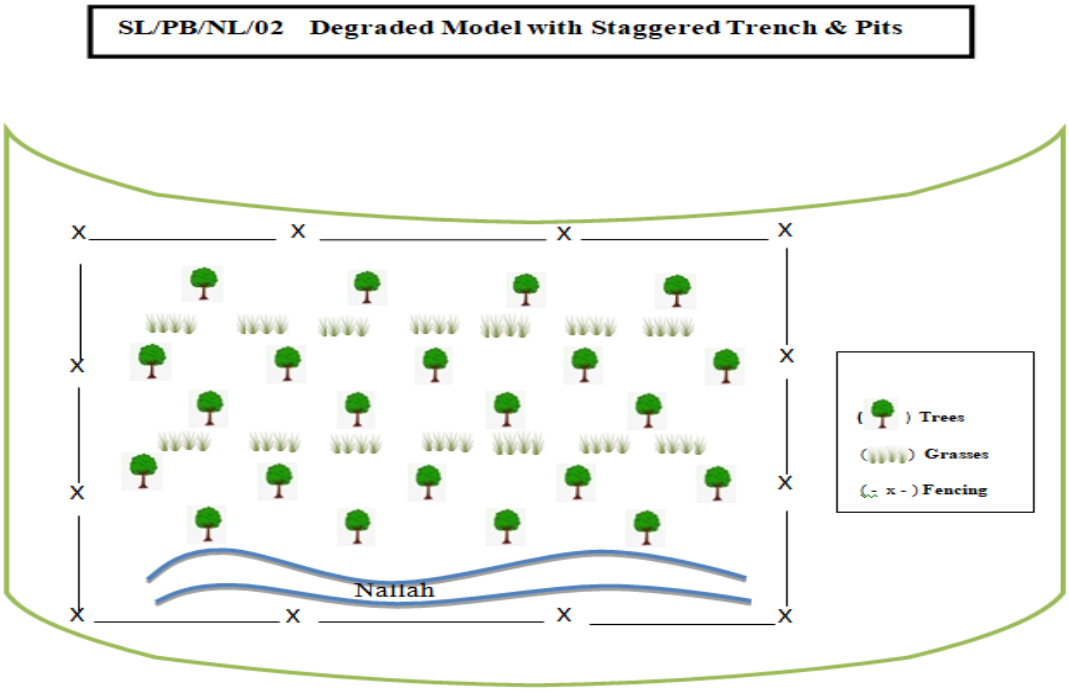


Fig. 5.15 Plantation Design of Degraded Model with Staggered Trench & Pits Model SL/PB/NL/01

Trees: 1000/ha, Spacing (m) – 3 x 3 , Pit size (cm) – 45 x 45 x 45 Type –Staggered
Grasses, Sedges and Forbs: Patch no – 200, Patch size (cm) – 100 x 30 x 5. Spacing (m) – 5 x 5, Seed/ patch (gm) – 6gm, , Spacing (cm) – 5 x 10,
Fencing: Angle Iron/Cement Pole/ Local material wood/ Branches/Brushwood fencing

Table 5. 19 Cost norms and details of work of Degraded Model with Staggered Trench & Pits Model (SL/PB/NL/02)

Year	Item	Detail of work	Amount Rs./ha	Man days
	Number of Plants (No.)	Plants 1000 No. Grasses 200 patch		
1st Year	Nursery Advance Work Labour Cost	Cost of seedlings including (a) Original planting =1000 per ha (b) Replacement 10%= 100 per ha Total 1100 No. in Biodegradable polybag	14,650	43
2nd Year	Advance Work Labour Cost	Cutting of *Lantana*/Mallah, etc. kana stubbing, Survey and alignment earth work i.e., digging of trenches of size 1000m x 0.35m x 0.30m and earth work i.e., digging of patch c) 200 no x 1.00m x 0.3m x 0.10 m, refilling of pits, fencing (5% of plantation cost)	36490	91
3rd Year	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers (twice), providing thorny protection to plants against porcupine attack, covering and uncovering of frost tender plant species (25%), preparation of inspection path, watch and ward for every 10 ha. of plantation, cutting of *Lantana*/Mallah IInd and IIIrd times, spot irrigation (8+1 times), reopening of trenches and pits, insecticides including carriage, Fertilizers i.e., urea, etc. including carriage, overhead charges (10% of planation cost) POL, OE and Miscellaneous.	72027	164
Total Establishment Cost (Rs.)			**1,23,167**	**298**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Cost of seedlings (25%), cutting of *Lantana*/Mallah, etc. kana stubbing, earth work i.e., redigging of pit refilling of pits, (25%) fencing (5% of plantation cost), carriage of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers (twice), providing thorny protection to plants against porcupine attack, covering and uncovering of frost tender plant species (25%),	44,612	105

		of inspection path, watch and ward for every 10 ha. of plantation, spot irrigation (8+1 times), reopening of trenches and pits, insecticides including carriage, fertilizers i.e., urea, etc. including carriage, overhead charges (10% of maintenance planation cost) POL, OE and Miscellaneous.		
5th Year	Maintenance Cost II Year	Earth work i.e., refilling digging of pit refilling of pits, (15%) fencing (5% of plantation cost), carriage of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers (twice), providing thorny protection to plants against porcupine attack, covering and uncovering of frost tender plant species (25%), of inspection path, watch and ward for every 10 ha of plantation, spot irrigation (8+1 times), reopening of trenches and pits, insecticides including carriage, fertilizers i.e., urea, etc. including carriage, overhead charges (10% of maintenance of planation cost) POL, OE and Miscellaneous.	22,221	50
6th Year	Maintenance Cost III Year	Weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers (twice), providing thorny protection to plants against porcupine attack, watch and ward for every 10 ha of plantation, fertilizers i.e., urea, etc. including carriage, overhead charges (10% of maintenance of planation cost) POL, OE and Miscellaneous.	5863	10
Total Maintenance Cost (Rs.)			**72,696**	**165**
Total cost of Plantation (Rs.)			**1,95,863**	**463**

Model: Control/ Removal of Invasive Species and *Lantana* (SL/PB/NL/03)

Zone: Shivalik Hills of Punjab

Invasive Alien Species (IAS) are plants those hamper regeneration and growth of native species, thereby replacement of native plant species coupled with loss of biodiversity, forage, habitat, aesthetics and productivity of native species. Owing to considerable area of this zone under the influence of invasive alien or weed species, tangible and intangible benefits from sub-temperate to sub-tropical forests within the Sutlej Riverscape have been adversely affected.

The area for the proposed model referred as 'Control/ Removal of Invasive Species' covers forest sites between around 300 to 1,200 m amsl wherein the topography is with gentle slopes. Such areas have sub-tropical to low temperate climate with 1,000 to 1,200 mm annual rainfall. Soils are generally fertile and moderately deep. The propose treatment areas for this model

usually has open or moderately dense forest or scrub vegetation. Luxuriant growth of weed species including *Lantana camara* (<50%) forms considerably dense undergrowth in the forest suppressing the native vegetation of that area. *Ageratum conyzoides* and *Parthenium hysterophorus* also cause considerable hazard especially near agriculture fields and settlements.

It is proposed to cut and manually uproot above stated invasive species in treatment sites prior to their flowering, and immediately to be followed by planting of native plant species. In case of *Lantana* infested areas, Cut Root Stock (CRS) method will be used for complete eradication/ control of this obnoxious weed. In case of other weeds, cuttings and removal of infested plants will be done at such a time and such a way as to cause least disturbance to soil and provide opportunity to the nearby economically important plants to occupy the space vacated by weeds. These areas after plantation will be intensively managed subsequently for two years to minimize the chances of their regrowth. For controlling herbaceous weeds like *Ageratum conyzoides* and *Parthenium hysterophorus*, ecofriendly measures (e.g. physical or mechanical methods, use of natural products, etc.) will be adopted without resorting to the use of synthetic chemicals. These areas after *Lantana* eradication will be planted in the third year of project implementation. Grass species such as *Heteropogon contortus*, *Chrysopogon fulvus*, etc. will be sown in the part of treatment site. The treatment area will be planted with broadleaved species like *Toona ciliata, Syzygium venosum, Senegalia catechu, Dalbergia sissoo, Grewia optiva, Pyrus pashia, Albizia* spp., *Phyllanthus emblica, Holoptelea integrifolia , Ficus* spp., *Punica granatum, Bauhinia variegata, Dendrocalamus* spp., *Bambusa* spp., etc. Plants will be planted at 5 x 5 m spacing. A total of 400 plants of trees and bamboo/ha a mixture of broad leaved species and bamboos will be planted. In additions, 400 patches of grasses, sedges and forbs 5x5 m apart will be planted on the proposed sites. The rows of trees and grasses will be planted alternatively. Broadleaved species of this zone require around two and half year of nursery period to produce sturdy plants and planting will be done in the 3rd year. For producing quality nursery stock of desired species VAM will be added either species specific or as consortium in the potting media. The plants will be maintained in the 4th to 6th years.

List of Species for Plantation

Trees: *Senegalia catechu, Aegle marmelos, Pongamia pinnata, Mitragyna parvifolia, Mallotus philippensis, Terminalia bellirica, T. chebula, T. arjuna, Syzygium venosum, Dalbergia sissoo, Adina cordifolia,Sapindus mukorossi, Bambusa bambos, Punica granatum, Dendrocalamus strictus, D. hamiltonii, Oroxylum indicum, Holoptelea integrifolia , Ficus benghalensis, F. racemosa, F. religiosa, F. hispida, Albizia lebbeck, A. procera, Alstonia scholaris, Phyllanthus* emblica*, Zizyphus jujuba, Azadirachta indica, Bombax ceiba, Anogeissus latifolia, Desmodium oojeinense , Diospyros montana, Hymenodictyon sauveolens, Melia azedarach, M. composita, Mangifera indica, Santalum album* etc.

Grasses/Forbs: *Saccharum spontaneum, S. bengalensis, S. munja, Chrysopogon zizanioides , Chrysopogon fulvus,Arundinella nepalensis, Apluda mutica, Boerhavia diffusa, Heteropogon contortus, Trifolium repens, Eragrostis nigra, Deschamsia* spp, *Panicum maximum, Phleum pratense, Cymbopogon citratus, Arundo donax, Phragmites karka, Themeda arundinacea, Eulaliopsis binata, Dichanthium annulatum, Sporobolus diandrus, Thysanolaena latifolia, Hierochloe laxa* etc.

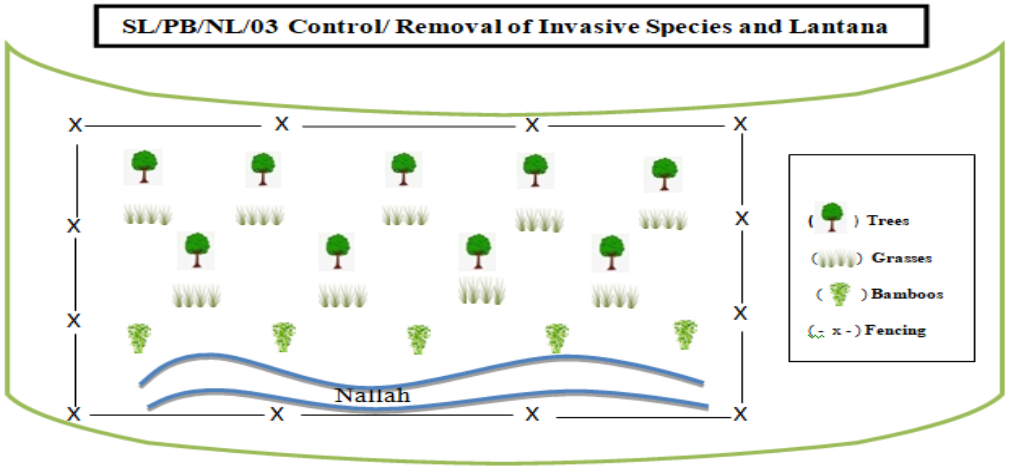


Fig. 5.16 Plantation Design of Control/ Removal of Invasive Species and *Lantana* Model SL/PB/NL/03

Trees/Bamboo: 400/ha, Spacing (m) – 5 x 5, Pit size (cm) – 45 x 45 x 45 Grasses, Sedgse and Forbs: Patch no – 400, Patch size (cm) – 100 x 30 x 5. Spacing (m) – 5 x 5, Seed/ patch (gm) – 6gm, , Spacing (cm) – 10 x 10, Type –Staggered Fencing: Angle Iron/Cement Pole/ Local material wood/ Branches/Brushwood fencing

Table 5. 20 Cost norms and details of work of Control/ Removal of Invasive Species and *Lantana* Model (SL/PB/NL/03)

Year	Item	Detail of work	Amount Rs./ha	Man days
	Number of Plants (No.)	Trees/Bamboo: 400 , Grasses 200 patch		
1st Year	Nursery Advance Work Labour Cost	Cutting/removal/disposal of *Lantana* (CRS), *Lantana* cleaning (Sprouts &seedlings) one time after 1st cut, tending operations, cost of Seeds and broadcast sowing of grass pellets contingency @5% of total cost	25,620	72
Total Establishment Cost (Rs.)			**25,620**	**72**

MAINTENANCE				
2nd Year	Maintenance Cost I Year i/c Material	*Lantana* cleaning (Sprouts & seedlings) one time after 1st cut, tending operations, cost of seeds and broadcast sowing of grass pellets	13,210	36
3rd Year	Maintenance Cost II Year	*Lantana* cleaning (Sprouts & seedlings) one time after 1st cut, tending operations, cost of seeds and broadcast sowing of grass pellets	14,131	36
4th Year	Maintenance Cost III Year	*Lantana* cleaning (Sprouts & seedlings) one time after 1st cut and tending operations	12,284	36
Total Maintenance Cost (Rs.)			**39,625**	**108**
Total cost of Plantation (Rs.)			**62,245**	**180**

(C) Treatment Models for Natural Landscapes in alluvial plains of Punjab

The Chapter on river and its Environment has highlighted the existing situation of forests in the alluvial plains of Punjab and also elaborated on challenges faced by extremely small extent of forests owing to the fact that the entire tract is heavily populated as well as extensively cultivated. In view of this, the following forestry interventions by way of different treatment models are proposed.

Model: Restoration of Degraded Forests (SL/PB/NL/04)
Zone: Tropical Areas

This Model is specifically proposed for restoration of degraded protected forests or plantation in village common lands or community lands. Proposed sites are mostly flat and covered either with shrubs/ herbs/ grasses, sedges and Forbs or Invasive Alien Species. Often such areas are inhabited by arbor or wild pig and locally abundant populations of these two herbivore species could be a menace to propose plantation activities. Moreover, such sites also face severe biotic pressure by way of livestock grazing, and collection of fodder and fuel wood. Hence, effective fencing of sites selected for proposed forestry interventions is a prerequisite so as to ensure full protection to young plantation. Heavy monsoon rains cause severe siltation in Sutlej River and resultant flooding in larger tracts of Punjab Plains.

Suitable and effective Forestry Interventions in above sites can immensely help in improvement of vegetation cover, checking soil erosion, and enhancing groundwater recharge. Block plantations of native broadleaved species are proposed for such areas. Trees will be planted at the rate of 1000 plants ha^1 at 3 m x 3 m spacing. Pit size of 50 cm x 50 cm x 40 cm will be used for proposed plantations under this model.

After land development, pit digging, etc. plants mainly of broadleaved species like *Acacia nilotica, Senegalia catechu, Dalbergia sissoo, Melia azedarach, Ailanthus excelsa, Toona ciliata, Morus alba, Tectona grandis, Azadirachta indica*, etc. will be planted. Conservation and other management practices as prescribed in the forest working plan of the respective Forest

Division would be applicable. Nursery of selected tree species will be established during first year and planting will be done in the second year. For producing quality nursery stock of desired species VAM will be added either species specific or as consortium in the potting media. Subsequently the plantation will be managed during next three year of the project.

List of Species for Plantation

Trees: *Acacia nilotica, Senegalia catechu, Dalbergia sissoo, Melia azedarach, Ailanthus excelsa, Toona ciliata, Tectona grandis, Azadirachta indica, Cordia myxa, Morus alba, Pongamia pinnata, Tecomella undulata, Capparis decidua, Prosopis cineraria, Bombax ceiba, Sesbania sesban, Aegle marmelos, Pterocarpus marsupium, Grewia eriocarpa, Cassia fistula,*etc.

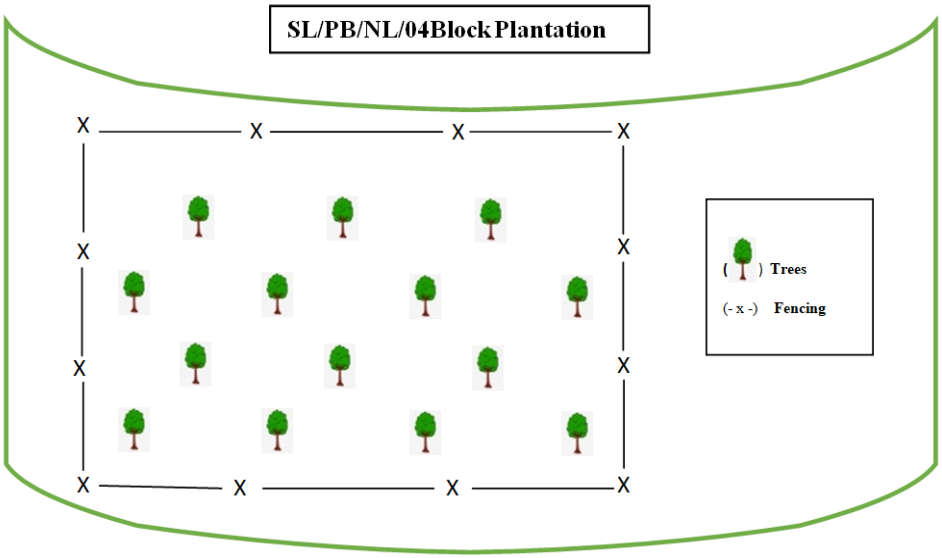


Fig. 5.17 Plantation Design of Restoration of Degraded Forests Model SL/PB/NL/04

Trees: 1,000 No, Spacing (m) – 3 x 3, Pit size (cm) – 50 x 50 x 40 Fencing: Angle Iron/Cement Pole/Local material wood/ Branches /Brushwood fencing

Table 5.21 Cost norms and details of work of Restoration of Degraded Forests Model (SL/PB/NL/04)

Year	**Item**	**Detail of work**	**Amount (Rs./ha)**	**Man days**
	Number of Plants (No.)	Plants 1000 No.		

1st Year	Nursery Advance Work Labour Cost	Cost of seedlings including; (a) Original planting =1000 per ha (b) Replacement 10%= 100 per ha Total 1100 No. in Biodegradable polybag	16,115	47
2nd Year	Advance Work Labour Cost	Cutting of *Lantana*/Mallah, etc. kana stubbing, survey and alignment Earth work i.e., digging of pit of size; a) 1000 no. x 0.5m x 0.5m x 0.40m, refilling of pits and fencing (5% of plantation cost)	25,100	70
3rd Year	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers (twice), providing thorny protection to plants against porcupine attack, covering and uncovering of frost tender plant species (25%), preparation of inspection path, watch and ward for every 10 ha. of plantation, Cutting of *Lantana*/Mallah IInd and IIIrd times, spot irrigation (8+1 times), reopening of trenches and pits, insecticides including carriage, fertilizers i.e., urea, etc. including carriage, overhead charges (10% of planation cost) POL, OE and Miscellaneous	1,10,424	305
Total Establishment Cost (Rs.)			**1,51,639**	**422**
MAINTENANCE				
4th Year	Maintenance Cost I Year i/c Material	Cost of seedlings (25%), cutting of *Lantana*/Mallah, etc. kana stubbing, earth work i.e., redigging of pit refilling of pits,(25%) fencing (5% of plantation cost), carriage of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers (twice), providing thorny protection to plants against porcupine attack, covering and uncovering of frost tender plant species (25%), of inspection path, watch and ward for every 10 ha of plantation, spot irrigation (8+1 times), reopening of trenches and pits, insecticides including carriage, fertilizers i.e., urea, etc. including carriage, overhead charges (10% of maintenance planation cost) POL, OE and Miscellaneous.	51,534	118
5th Year	Maintenance Cost II Year	Earth work i.e., refilling digging of pit refilling of pits, (15%) fencing (5% of plantation cost), carriage of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers (twice), providing thorny protection to plants against porcupine attack, covering and	21,346	41

		uncovering of frost tender plant species (25%), of inspection path, watch and ward for every 10 ha of plantation, Spot irrigation (8+1 times), reopening of trenches and pits, insecticides including carriage, fertilizers i.e., urea, etc. including carriage, overhead charges (10% of maintenance of planation cost) POL, OE and Miscellaneous.		
6th Year	Maintenance Cost III Year	Weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers (twice), providing thorny protection to plants against porcupine attack, watch and ward for every 10 ha of plantation, fertilizers i.e., urea, etc. including carriage, overhead charges (10% of maintenance of planation cost) POL, OE and Miscellaneous.	7,394	10
Total Maintenance Cost (Rs.)			**80,274**	**169**
Total cost of Plantation (Rs.)			**2,32,725**	**592**

Model: Road Side Plantation (SL/PB/NL/05)
Zone: Tropical Areas

This model is specifically proposed for the purpose of road side plantations. Hence, proposed plantations will be in narrow strips along the roads. Generally, proposed sites along the roads are either sparsely covered by native vegetation or select invasive alien species or often blank. Stray cattle as well as wild animals like *Nilgai* and Wild pig could be a menace to proposed plantations. Hence, effective fencing of sites proposed for plantation is a prerequisite. The proposed road side plantations would help in enhancing the forest cover in a State which is otherwise deficient in natural vegetative cover besides checking soil erosion and runoff.

Strip plantations on both sides of the road are proposed. The planting area will be cleaned and one row of shrubs is proposed at 1 m x 1 m spacing towards the road side. Fast growing ornamental shrub species are proposed. Two rows of native broadleaved tree species is recommended under this road side plantation model at 3 m x 2 m spacing. Pit size of 45 cm x 45 cm x 45 cm will be used for plantation. After land development, pit digging, etc. Plants mainly of broadleaved species *viz., Dalbergia sissoo, Terminalia bellirica, Terminalia chebula, Terminalia arjuna, Melia azedarach, Acacia nilotica, Azadirachta indica, Anthocephalus cadamba, Ailanthus excelsa, Toona ciliata,* etc. will be planted. Nursery of selected tree species will be established during first year and planting will be done in the second year. For producing quality nursery stock of desired species VAM will be added either species specific or as

consortium in the potting media. Subsequently the plantation will be managed during next three year of the project.

List of Species for Plantation

Trees: *Dalbergia sissoo, Terminalia bellirica, Terminalia chebula, Terminalia arjuna, Melia azedarach, Acacia nilotica, Albizia lebbeck, Albizia procera, Butea monosperma, Kigelia africana , Azadirachta indica, Anthocephalus cadamba, Ailanthus excelsa, Toona ciliata, Jacaranda mimosifolia, Grevillea robusta, Salix alba, Morus alba, Delonix regia, Sesbania sesban, Alstonia scholaris, Ficus rumphii, F. benjamina, Syzygium venosum,*etc.

Shrubs: *Nerium oleander*, *Bougainvillea* spp., *Nyctanthes arbortristris*, *Spiraea* spp., *Rosa* spp., etc.

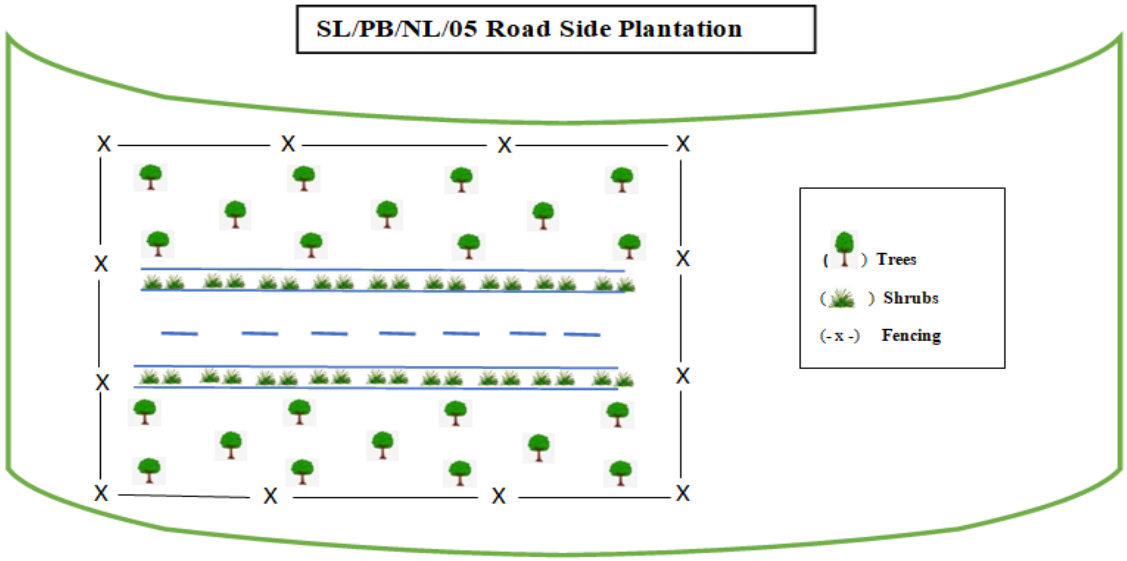


Fig. 5.18 Plantation Design of Road Side Plantation Model SL/PB/NL/05

Trees: 1,000 No, Spacing (m) – 3 x 3, Pit size (cm) – 50 x 50 x 40 Shrubs: 2,500 No, Spacing (m) – 2 x 2, Pit size (cm) – 30 x 30 x 30 Fencing: Angle Iron/Cement Pole/ Local material wood/ Branches/ Brushwood fencing

Table 5.22 Cost norms and details of work of Road Side Plantation Model (SL/PB/NL/05)

Year	Item	Detail of works	Amount (Rs/ha)	Man days
	Number of Plants (No.)	Plants 1000 No., Herbs 2500		
1st Year	Nursery Advance Work Labour Cost	Cost of seedlings including; (a) Original planting =3500 per ha (b) Replacement 10%= 350 per ha Total 1100 No. in Biodegradable polybag Cost of Herbs	38115	111

		(a) Original planting =2500 per ha (b) Replacement 10%= 250 per ha Total 2750 No. in Biodegradable polybag (I^{st} year)		
2^{nd} year	Advance Work Labour Cost	Cutting of *Lantana*/Mallah, etc. kana stubbing, survey and alignment earth work i.e., digging of pit of size; a) 1000 no. x 0.5m x 0.5m x 0.40m, b) 2500 no. Spacing (m) 2 x 2, Pit size (cm) – 30 x 30 x 30, Refilling of pits, Fencing (5% of plantation cost)	52361	119
3^{rd} Year	Creation	Carriage of plants, lay out of pits and patches, pitting & planting of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers (twice), providing thorny protection to plants against porcupine attack, covering and uncovering of frost tender plant species (25%), preparation of inspection path, watch and ward for every 10 ha. of plantation, cutting of *Lantana*/Mallah II^{nd} and III^{rd} times, spot irrigation (8+1 times), reopening of trenches and pits, insecticides including carriage, fertilizers i.e., urea, etc. including carriage, overhead charges (10% of plantation cost) POL, OE and Miscellaneous.	180376	442
Total Establishment Cost (Rs.)			**2,70,852**	**620**
MAINTENANCE				
4^{th} year	Maintenance Cost I Year i/c Material	Cost of seedlings (25%), cutting of *Lantana*/Mallah, etc. kana stubbing, earth work i.e. refilling digging of pit refilling of pits, (25%) fencing (5% of plantation cost), carriage of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers (twice), providing thorny protection to plants against porcupine attack, Covering and uncovering of frost tender plant species (25%), of inspection path, watch and ward for every 10 ha of plantation, spot irrigation (8+1 times), reopening of trenches and pits, insecticides including carriage, fertilizers i.e., urea, etc. including carriage, overhead charges (10% of maintenance of plantation cost) POL, OE and Miscellaneous.	125712	311

5th year	Maintenance Cost II Year	Earth work i.e., refilling digging of pit refilling of pits, (15%) fencing (5% of plantation cost), carriage of plants, weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers(twice), providing thorny protection to plants against porcupine attack, covering and uncovering of frost tender plant species (25%), of inspection path, watch and ward for every 10 ha of plantation, spot irrigation (8+1 times), reopening of trenches and pits, Insecticides including carriage, fertilizers i.e., urea, etc. including carriage, overhead charges (10% of maintenance of plantation cost) POL, OE and Miscellaneous.	47220	114
6th year	Maintenance Cost III Year	Weeding hoeing (twice), application of insecticides, application of FYM/ fertilizers (twice), providing thorny protection to plants against porcupine attack, watch and ward for every 10 ha of plantation, fertilizers i.e., urea, etc. including carriage, overhead charges (10% of maintenance of plantation cost) POL, OE and Miscellaneous.	5863	10
Total Maintenance Cost (Rs.)			**1,78,795**	**435**
Total cost of Plantation (Rs.)			**4,49,648**	**1,107**

5.5.3 Agriculture Landscapes

The second largest Lower Order Zone within the Sutlej Riverscape in terms of extent was the Agriculture Landscape, as it covered 24.6% area of the Riverscape and was widely distributed along the altitudinal gradient in Himachal Pradesh and in the vast expanse of alluvial plains of Punjab along the Sutlej Riverscape. The Agriculture Landscape largely in the rural environment in hills and plains constitutes the 'Matrix' of the Riverscape. The primary activity in this zone is agriculture and horticulture production. A wide range of agricultural and horticultural crops are being grown by farmers on their private lands. The purpose of this Lower Order Zone i.e., Agriculture Landscape is to enhance productivity of agricultural lands by appropriate soil and moisture conservation measures and planting of economic and fruit trees so as to support the overall conservation values and other expected ecological functions and ecosystem services along with additional income to farming communities.

The tree cover outside recorded forest area, particularly on farm lands is of vital importance from ecological functions of agroecosystems (Pollinators, Soil and Moisture Conservation regime, Carbon Sequestration (CS), environmental amelioration, etc.). As per the strategies given in the foregoing description, 'Agriculture Landscapes' have been recognized as one of the zones in the Sutlej Riverscape. Comprehensive afforestation/ plantations on private farm lands in Agriculture Landscape have been proposed in DPR. The Forest Survey of India (FSI) in the biennial 'India State of Forest Report (ISFR)' also includes information on forest cover outside green wash area, tree cover and 'Trees Outside Forests (TOFs)' for the entire Country/ State-wise to distinguish it from actual pure forest cover of the country as the digitalized information on public and private land is lacking in most of the States. The proportion of TOFs and tree cover is increasing trend in several States as per past two ISFRs. According to the FSI, 2019 report, the Agricultural Landscape which accounts for forest cover outside green wash area plus tree cover accounts for 27.72% and 3.67% of the total geographical area of the Himachal Pradesh and Punjab, respectively. The growing stock in TOF which is 25.19 M m^3 in case of Himachal Pradesh and 18.56 M m^3 in case of Punjab accounts for 1.53% and 1.13% contribution to the country's growing stock (Table 5.23).

Table 5.23 Forest Cover, Tree Cover and TOF Growing Stock of Himachal Pradesh and Punjab

Sr. No.	Forest Cover, Tree Cover and TOF Growing Stock	Himachal Pradesh	Punjab
1.	Forest Cover Outside Green Wash Area (km^2)		
	Very Dense Forest	3,113	8
	Moderately Dense Forest	7,126	801
	Open Forest	5,195	1,040
	TOTAL	**15,434**	**1,849**
2.	Tree Cover Area (km^2)	829	1,592
	Total of Forest Cover and Tree Cover Area (km^2**)**	**16,263**	**3,441**
3.	**Growing Stock in TOF (M m^3)**	**25.19**	**18.56**

Thus, it is evident that farmers/ villagers do recognize significance of trees on farm/private lands and they come forward for availing saplings of economic and fruit trees for plantations not only to augment their income but they also do recognize ecological merits of such plantations. The current DPR, therefore, also proposes plantation activities in Agriculture Landscapes by adopting four models (SL/HP/*AL*/01, SL/HP/AL/02, SL/PB/AL/01 and SL/PB/AL/02). Two Models for the Agriculture Landscape in Himachal Pradesh are proposed. They are: (a) Model SL/HP/AL/01

of Boundary plantation, and (b) Model SL/HP/AL/02 of Block plantation. Like-wise, in the alluvial plains of Punjab, similar, two Models (SL/PB/AL/01 and SL/PB/AL/02) specifically designed for plantations along the boundaries of crop fields and plantations in blocks, respectively have been proposed.

NYKS, *Mahila Mandals*, Clubs and other NGOs/CBOs may play an important role in awareness campaigns about Forestry Interventions which have also been included in the DPR. It is widely assumed and accepted that farmers usually do not indulge in cutting of such economic and fruits tress except those are solely planted as agroforestry plantations of fast growing species as they do recognize multiple values obtained from such tree plantations on farmlands. Moreover incentives in the form of maintenance cost to be provided to the farmer at the rate of Rs. 70/, 35/, 35/ and 35/ per plant for first, second, third and fourth year, respectively will motivate them to protect and retain these planted tree species on their private land. The monetary aid proposed for the plantation will ensure sustainability of proposed plantations (maximum 150 trees/ ha) in Agriculture Landscapes and thus adding ecological benefits. Further, though the ownership of the plantation raised under the Agriculture Landscapes is vested with farmers, but the felling, removal, and transportation of such plantation material are regulated under the framework of various acts and procedures, (e.g., State Felling and Transit Regulations, Land Preservation Act, etc.) and other relevant regulations enforced from time to time by the Himachal Pradesh and Punjab.

The proposed Agricultural Models will be implemented in private farmland and community/*Panchayat* land in rural areas. Availability of land will be ascertained by local officials of State Forest Department based upon proposals from local farmers and communities. Plants will be supplied to farmers and local communities who will carry out planting in their farmland. Maintenance cost will be given to the land owners based upon plant survival at the end of first, second, third and fourth years. *Nehru Yuvak Kendra* may play a pivotal role in facilitating coordination between State Forest Department and farmers/communities. The details of proposed Agriculture Models are provided below in Tables 5.24 and 5.31.

(D) Treatment Models for Agriculture Landscape in Himachal Pradesh

Model: Boundary Plantation Model (SL/HP/AL/01)

Zone: Agriculture/Horticulture land in Himachal Pradesh

This model will be implemented in agricultural land in subtropical and temperate zones in Himachal Pradesh. The area is mostly hilly for most of this zone with moderate to steep slopes. The sites proposed for this model are agricultural or horticultural lands where off season vegetables and fruit crops are grown; hence these sites possess better soil fertility and managerial care with occasional subsistence irrigation mostly available water judiciously divided among local communities collectively by them.

The farmers/ orchardists will decide the tree species and no. of plants per unit area of economically important tree species and hill bamboos keeping in view their requirements; they may freely grow agricultural/horticultural crops of their own choice with the trees in any planting geometry mostly tree planting will be done on vacant areas around farms/ orchard and near settlements. Hill bamboos will be planted on boundaries and will also act as live fencing for farm/ orchard in future. Quality Planting Material will be supplied to the local communities through HPSFD. Planting and maintenance of the plants will be done by farmers/ orchardist. Financial incentive to the growers will be provided keeping in view the performance of the plantation especially survival. The local communities/ beneficiaries would be provided technical knowledge for the purpose through Institutes or Universities, etc.

The methodology for deciding physical targets have been finalized after consultation with stakeholders. A simple methodology has been adopted based on number of farmers and their landholdings. For Boundary Plantation Model, out of total farmers of the various forest divisions in the Sutlej Riverscape, 10% farmers have been included under this treatment model irrespective of their landholdings. Distribution of 150 plants per farmer would be taken as virtual one hectare area for budgetary provisions.

List of Species for Plantation

Trees: *Prunus armeniaca, Prunus mira, Prunus cerasifera, Prunus domestica, Prunus persica, Myrica esculenta, Diospyros lotus, Diospyros nigra, Diospyros kaki, Phyllanthus* emblica, *Hippophae salicifolia,Terminalia arjuna, Terminalia bellirica, Terminalia chebula, Toona ciliata, Acer* spp., *Dalbergia sissoo, Senegalia catechu, Acer* spp., *Morus alba, Salix* spp., *Populus* spp., *Grewia optiva, Celtis australis, Bauhinia* spp., *Dendrocalamus* spp., *Bambusa* spp., *Sapindus mukorossi, Aegle marmelos,*etc.
Shrubs: *Drepanostachyum falcatum, Thamnocalamus spathiflorus, Hippophae rhamnoides* spp. *turkestanica, Buddleia* spp., *Berberis* spp., *Zanthoxylum armatum, Vitex negundo, Rosa* spp., etc.

Cost Sharing: The Government will share cost Material i.e., plant cost Rs. @ 70/, 35/, 35/, 35/ for I^{st} to IV^{th} year and maximum of 150 trees per ha.

Table 5.24 Cost Norms and Pattern of Assistance for plantation in Agriculture Models Peripheral and Boundary Plantation (PBP)

S. No	Type of Interventions	Indicative Unit cost per plant (Rs.)
1	Pre-plantation activities/Land clearing/maintenance etc.	20
2	Digging /Planting, etc.	12
3	Single unit Planting material, etc.	30
4	Transportation charges	3

5	Critical inputs viz., FYM, fertilizer, seed treatment, Vesicular Arbuscular Mycorrhizae (VAM), etc.	20
6	Planting cost	5
7	Fencing	20
Maintenance (Weeding+ watering, etc.)		**40**
Total		**150**
Note: (i) The activity wise cost indicated above are tentative and State(s) have the flexibility to formulate their own estimate based on local requirements subject to a maximum of Rs. 150/ per plant. (ii) The assistance will be given in the year wise proportion of 40:20:20:20.		

Table 5.25 Model – SL/HP/AL/01 Boundary Plantation Model

Year	Amount (RS)/ha	Man days
Ist year Establishment	9,000	36
Maintenance Ist	4,815	18
Maintenance IInd	5,152	18
Maintenance IIrd	5,513	18
Total	**24,480**	**90**

Model: Block Plantation Model (SL/HP/AL/02)

Zone: Agriculture/Horticulture Land in Himachal Pradesh

This Model will be implemented in Agricultural/ Horticultural land in subtropical to temperate zones in Himachal Pradesh. The area is hilly and the slope is moderate to gentle. The sites proposed for this model are agricultural/ horticultural/ grassland where grains, off season vegetables, stone fruit crops, grasses etc. are grown, hence these sites possess better soil fertility and managerial care with occasional subsistence irrigation mostly available water judiciously divided among local communities collectively by them.

The zone experiences heavy rainfall during monsoon season and modest rainfall during winter months. Heavy rains during monsoon transport silt from these areas through no of seasonal water channels, *Nallah*s, rivulets, etc. to Sutlej River causing siltation and floods down streams. Besides this, agriculture, construction and developmental activities are the main reasons behind soil erosion from these areas. A large part of rainwater flows down the streams within a few hours of rainfall as surface runoff causing lot of soil erosion. The pressure for grazing, fuel wood and tree fodder collection is considerable. Effective forestry interventions in this zone in agricultural/ horticultural/ grassland areas can help significantly in improvement of the flow of Sutlej River and its tributaries.

For these areas, Planting of Trees of economic importance in hills is recommended for this zone. The farmer/ orchardist will decide the species and no of plants of per unit area of economically

important tree species i.e., Harad (*Terminalia chebula*), Bahera *(Terminalia bellirica)*, Amla (*Phyllanthus emblica*), Reetha (*Sapindus mukorossi*), Chandan (*Santalum album*), etc. Block plantation in vacant and fallow lands can be taken up by the farmers to increase their income as well as judiciously utilising the fallow lands and other grass lands also.

Similarly as in Model SL/HP/AL/01, for deciding Physical Targets, Enlist the number of farmers District/ Division wise whose land holdings comes under small farmers and above (as described category) by Agriculture Department of the State to be considered under the proposed model. About 5% of total such farmers enlisted in the Sutlej Riverscape would be included division wise in the proposed treatment Model. Block plantation per farmer would be taken as virtual one hectare area for budgetary provisions and no. of plants/ha can vary from 500 to > 1500 as per the requirements of species specific high density plantations.

List of Species for Plantation

Trees: *Prunus armeniaca, Prunus mira, Prunus cerasifera, Prunus domestica, Prunus persica, Myrica esculenta, Diospyros lotus, Diospyros nigra, Diospyros kaki, Phyllanthus* emblica*, Hippophae salicifolia,Terminalia arjuna, Terminalia bellirica, Terminalia chebula, Toona ciliata, Acer* spp.*, Dalbergia sissoo, Senegalia catechu, Morus alba, Salix* spp.*, Populus* spp.*, Grewia optiva, Celtis australis, Bauhinia* spp.*, Dendrocalamus* spp.*, Bambusa* spp.*, Sapindus mukorossi, Aegle marmelos,* etc.

Table 5.26 Cost Norms and Pattern of Assistance for plantation of High Density Block Plantation (HDBP)

Sl. No.	Magnitude of Block Plantations (no of plants/block of 1 ha)	Total cost (Rs./ha) for the Block			
		1st Year	2nd Year	3rd Year	4th Year
1	500 to 1000 (Spacing 3.5mX3.5m)	28,000	14,000	14,000	14,000
2	1000 to 1200 (Spacing 3mX3m)	33,600	16,800	16,800	16,800
3	1200 to 1500(Spacing 2.5mX2.5m)	48,000	24,000	24,000	24,000
4	≥1500(Spacing less than 2.5mX2.5m))	52,000	26,000	26,000	26,000

Table 5. 27 Model – SL/HP/AL/02 Block Plantation Model

Sl. No.	Magnitude of Block Plantations (No of plants/Block of 1 ha)	Total cost (Max.) (Rs./ha) for the Block (or in proportion to planting intensity)				Total
		1st Year	2nd year	3rd Year	4th Year	
1	1200	48,000	25,680	27,478	29,401	1,30,559
Man days		192	96	96	96	480

(F) Treatment Models for Agriculture Landscapes in Punjab

Model: Boundary Plantation Model (SL/PB/AL/01)

Zone: Agriculture/ Horticulture land in Punjab

The Model will be applied in agriculture fields in the plains of Punjab. These fields are intensively under cultivation of wheat, rice, sugarcane, etc. and open to soil erosion especially during flood irrigation.

Heavy monsoon rains in this zone transport huge quantities of silt to Sutlej River causing siltation and floods in adjoining plains. Intensive cultivation in this zone makes these areas vulnerable to soil erosion. Effective Forestry Interventions in these sites can help significantly in improvement of the flow of Sutlej River and its tributaries.

The sites proposed for this model are agricultural lands where selected clones of Poplar, Drek, Neem, Chandan, Shisham, etc., will be planted at 4m x 4m spacing. Pit size of 50cm x 50cmx 40cm will be used for plantation. Selected plants will be distributed to farmers for planting on their agricultural land. Planting will be done by the farmers. The farmers will place requirement for plants to local forest officials who will supply the plants to the farmers at the start of the planting season.

The methodology for deciding physical targets have been finalized after consultation with stakeholders. A simple methodology has been adopted based on number of farmers and their landholdings. For boundary plantation model, out of total farmers of the various forest divisions in the Sutlej Riverscape, 10% farmers have been included under this treatment model irrespective of their landholdings. Distribution of 150 plants per farmer would be taken as virtual one hectare area for budgetary provisions.

List of species for Plantation

Trees: *Populus deltoides, Melia azedarach, Phyllanthus* emblica*, Aegle marmelos, Albizia* spp.*, Azadirachta indica, Syzygium venosum, Ficus racemosa, Gmelina arborea, Holarrhena pubescens, Santalum album, Tamarindus indica, Terminalia arjuna, Terminalia bellirica, Terminalia chebula, Grewia* spp., etc.

Cost Sharing: The Goverment will share cost Material i.e., plant cost Rs. @ 70/-, 35/-, 35/-, 35/- for Ist to IV year and maximum of 150 trees per ha.

Table 5.28 Cost Norms and Pattern of Assistance for plantation in Peripheral and Boundary Plantation (PBP)

S. No	Type of Interventions	Indicative Unit cost per plant (Rs.)
1	Pre-Plant Activities/Land clearing/Maintenance, etc.	20
2	Digging /Planting, etc.	12
3	Single unit planting material, etc.	30
4	Transportation charges	3

5	Critical inputs viz., FYM, fertilizer, seed treatment, Vesicular Arbuscular Mycorrhizae (VAM), etc.	20
6	Planting cost	5
7	Fencing	20
Maintenance (Weeding+ watering, etc.)		**40**
Total		**150**
Note: (i) The activity wise cost indicated above are tentative and state has the flexibility to formulate their own estimate based on local requirements subject to a maximum of Rs. 150/ per plant. **(ii) The assistance will be given in the year wise proportion of 40:20:20:20.**		

Table 5.29 Model – SL/PB/AL/01 Boundary Plantation Model

Year	Amount (Rs/ha)	Man days
Ist year Establishment	9,000	26
Maintenance Ist	4,815	13
Maintenance IInd	5,513	14
Maintenance IIrd	5,899	14
Total	**25,226**	**68**

Model: Block Plantation Model (SL/PB/AL/02)

Zone: Agriculture/ Horticulture Land in Punjab

This Model will be applied in agriculture fields in the plains of Punjab. These fields are intensively cultivated for wheat, rice, sugarcane, etc. and open to soil erosion especially during flood irrigation.

Heavy monsoon rains in this zone transport huge quantities of silt to Sutlej River causing siltation and floods in adjoining plains. Intensive cultivation in this zone makes these areas vulnerable to soil erosion. Effective Forestry Interventions in these sites can help significantly in improvement of the flow of Sutlej River and its tributaries.

The sites proposed for this Model are agricultural lands where selected tree species will be planted at 4m x 4m spacing, Pit size of 50 cm x 50 cm x 40 cm will be used for plantation. This is a practice of growing tree in rectangular or square planting pattern throughout the field as mostly adopted by farmers having large land holding. Poplar, Shisham, Drek, etc. are the important tree species for block plantation. Wheat, potato, mustard, berseem, turmeric, sugarcane, etc. can be profitably raised intermixed with block plantation of trees. Planting will be done by the farmers. The farmers will place requisition for desired plant species to local forest officials who will supply the quality nursery stock to the farmers at the start of the planting season.

Similarly as in model SL/PB/AL/01, for deciding Physical Targets, enlist the number of farmers District/ Division wise whose land holdings comes under small farmers and above (as described

category) by Agriculture Department of the State to be considered under the proposed model. About 5% of total such farmers enlisted in the Sutlej Riverscape would be included division wise in the proposed treatment model. Block plantation per farmer would be taken as virtual one hectare area for budgetary provisions and no. of plants/ha can vary from 500 to > 1500 as per the requirements of species specific high density plantations.

List of Species Plantation

Trees: *Populus deltoides, Melia azedarach, Phyllanthus* emblica, *Aegle marmelos, Azadirachta indica, Syzygium venosum, Gmelina arborea, Holarrhena pubescens, Santalum album, Tamarindus indica, Terminalia arjuna, Terminalia bellirica, Terminalia chebula, Sapindus mukorossi, Acacia nilotica, Senegalia catechu Dalbergia sissoo, Toona ciliata, Tectona grandis, Morus alba, Pongamia pinnata, Prosopis cineraria, Bombax ceiba, Sesbania sesban, Grewia elastica,* etc.

Table 5. 30 Cost Norms and Pattern of Assistance for plantation of High Density Block Plantation (HDBP)

Sl. No.	Magnitude of block Plantations (no of plants/block of 1 ha)	Total cost (Rs.) for the block			
		1st Year	2nd year	3rd Year	4th Year
1	500 <1000 (Spacing 3.5mX3.5m)	28,000	14,000	14,000	14,000
2	1000<1200 (Spacing 3mX3m)	33,600	16,800	16,800	16,800
3	1200<1500(Spacing 2.5mX2.5m)	48,000	24,000	24,000	24,000
4	≥1500(Spacing less than 2.5mX2.5m)	52,000	26,000	26,000	26,000

Table 5. 31 Model – SL/PB/AL/02: Block Plantation Model

Sl. No.	Magnitude of Block Plantations (No of plants/Block of 1 ha)	Total cost (Max.) (Rs.) for the Block(or in proportion to planting intensity)				Total
		1st Year	2nd year	3rd Year	4th Year	
1	1200	48,000	25,680	27,478	29,401	1,30,559
	Man days	140	70	70	70	351

5.5.4 Urban Landscapes

The built up environment represented by the Land Use and Land Cover category of 'Settlement' covered about 1% area of the Riverscape. This category of Land Use and Land Cover was widely distributed throughout the Riverscape, predominantly all along the Sutlej Riverscape and its tributaries and formed the Third Lower Order Zone referred as the 'Urban Landscape (UL)'.

Under this zone, altogether four models focusing on Bioremediation and Bio-filter, Riverfront development, plantations in Institutional and Industrial Estates and Eco-Park development have been proposed.

Wetlands including rivers, lakes, streams, etc., particularly in the urban environment of Hills and valleys of Himachal Pradesh along with alluvial plains of Punjab have been severely impacted due to anthropogenic activities including large scale pollution originating from extensive use of fertilizers and other chemicals in crop fields and orchards, industrial effluents, and urban sewage and waste disposal. Hence, a small number of pilot demonstration sites adopting model SL/HP/UL/01 for Himachal Pradesh and SL/PB/UL/01 for Punjab on Bioremediation and Bio-filteration have been proposed. Similarly, two proposed models SL/HP/UL/02 and SL/PB/UL/02 pertaining to Riverfront Development have been proposed with the primary intention to plant avenue trees and shrubs along the River bank so as to prevent the erosion of soil and banks in both the states, respectively. The proposed model would help in stabilizing the banks of the River. In addition, the area so developed would provide the aesthetic environment to the visitors. Two separate models for both States SL/HP/UL/03 and SL/PB/UL/03, specific to the Institutional and Industrial Estates have been proposed in the Urban Landscape. Under this model, mainly ornamental, shade and fruit trees will be encouraged for planting. The model SL/HP/UL/04 and SL/PB/UL/04 pertains to the development of Eco-Parks has been purposed for the Himachal Pradesh and Punjab respectively. Eco-Parks would have both vegetation and non-vegetation components so as to provide better equipped facilities to visitors as well as for localities.

A) Treatment Models for Urban Landscapes in Himachal Pradesh

a) Bioremediation and Bio-filtration: Under the Urban Landscape models, Bioremediation and Bio-filteration are the important Forestry Intervention activity proposed for Rejuvenation of Rivers/Tributaries. Varied anthropogenic activities and ever burgeoning population have resulted in deterioration of River ecosystems making them unfit for survival of indigenous biological forms. Rampant industrialization, improper agricultural methods, unchecked discharge of pollutants both organic and inorganic into water bodies, drains, *nallahs*, hillsides, rivulets and streams ultimately leads to the contamination of the river systems. Heavy metal effluents from the processing units of industrial agglomerations situated in the towns are refused in the river systems which degrade the quality of water, rendering of little or no use in the downstream.

Water bodies including rivers, lakes and streams have been heavily impacted due to the indiscriminate human activities and sometimes natural calamities and there is a great loss to their biodiversity or utility.

In this dismal scenario, cleaning of water bodies and removal of toxic pollutants from the River ecosystems to Rejuvenate fresh water bodies by making them free of contaminants is urgently required.

In comparison to the conventional methods like physical, chemical and thermal processes, Bioremediation techniques involving biological systems such as microorganisms or their products and plants are sustainable, cost effective options for abatement of pollution of the water bodies. In Bioremediation, biological systems are applied for reclamation of the contaminated water by transformation of toxic pollutants into less hazardous or completely nonhazardous forms. The Bioremediation technology includes use of microorganisms or their enzymatic machineries, phytoremediation (plants) and rhizo-remediation (i.e., plant and microbe interactions) techniques. Thus Bioremediation is an effective and ecofriendly technique for removing toxic pollutants from aquatic environment.

Water pollution from untreated municipal wastewater is an enormous problem in urban agglomerations. Low cost, decentralized, wetland based bio-filters have strong potential to dramatically improve the water quality. Well designed bio-treatment systems with inclusion of appropriate native species are ideal for removing pollutants from municipal wastewater. They can be applied extensively in rural areas, small towns, peri-urban areas of large cities, industrial townships or institutional campuses, as well as for certain types of industries such as agrofood/beverage, etc. The bio-filters are simple to construct, easy to operate, and cost effective. Major advantage of this method is that the pollutant is converted into biodegradable waste which can decompose within a moderate time frame, thus producing no secondary pollutants.

Broadly, in this technique plants and microbes associated with plant root systems are used to remove the pollutants in the form of inorganic and organic wastes. Selection criteria of plants for achieving high efficiency are always important. For example, plants such as *Tecoma stans, Scirpus grossus, Cyperus* spp., *Scirpus* spp., *Typha* spp., *Phragmites* spp., *Eichhornia crassipes* (water hyacinth), *Spirodela polyrrhiza* (aquatic plant), etc. have been found good for dye degradation.

Organic and inorganic substances released from various sources into the existing natural water bodies cause their contamination. Among various water pollutants, nitrogen compounds form a significant role in wastewater contamination due to increase in anthropogenic sources like agriculture. Release of nitrate into fresh water poses severe problems including eutrophication. Biological denitrification is one of the more versatile and promising methods for the treatment of nitrate contaminated waters.

Biofilter plant plays a great role in removing phosphates, nitrates, nitrites and ammonia. Many substances harmful to people and animals are conducive to plant growth. Plants require ammonia, phosphates and nitrates, and most synthetic fertilizers. Duckweed, nut grass and water lilies are known to absorb these substances.

The pollution control board already released the list of Urban/ Semi Urban area which are polluting the Sutlej River and their tributaries, so the areas are identified in the Riverscape accordingly, and one site can be termed as 1 hectare (virtually) and where possible Seechewal

Model of Punjab or its modification can also be adopted. The details of models proposed under Urban Landscapes for Himachal Pradesh and Punjab have been described in Table 5.32 and 5.33

Model: Bioremediation and Bio filtration (SL/ HP/UL/01)

The State Forest Department and Municipality or *Panchayat* Bodies have to adopt the suitable approach for bio-filter suiting to the specific requirements and site characteristics. The Model will include the following activities.

1) Waste water treatment through mechanical measures as per the site requirement.

2) Drainage line treatment by planting grasses, herbaceous vegetation and shrubs.

3) Bio-filters: Bio-filters may be of different types i.e., Free-floating macrophyte biofilters, emergent macrophyte bio-filters, submerged macrophyte bio-filter and multispecies algal bio-filters.

List of Species for plantation

Tecoma stans, Scirpus grossus, Scirpus spp., *Typha* spp., *Cyperus* spp., *Phragmites* spp., *Eichhornia crassipes* (water hyacinth), *Spirodela polyrrhiza*

b) River Front Development

Many cities, towns and semiurban areas are located along the Sutlej River and its tributaries. Urban and Periurban areas along the Riverscape may be developed to attract residents and visitors and provide them a grand sight of the River along with fresh air, mental peace, solace and spiritual fulfilment that would connect them with the River.

Riverfront development envisages riverbank plantation to stabilize it by protecting it from soil erosion. This involves covering the entire ground by intercepting the sunlight at various heights of canopy through multiple layers of vegetations. At the ground surface, the grasses or surface growers are allowed to cover and to bind the surface soil and control the surface soil erosion like sheet erosion, splash erosion and rill erosion. It also promotes the rain water percolation and minimizes the surface runoff. At the second layer of vegetation, small to medium sized herbs and shrubs are accommodated to intercept some amount of sunlight and slow down the speed and reduce the erosive force of rain drops falling directly from sky and/or upper layers of canopy thereby reducing soil erosion (splash erosion). At the third layer of canopy above the ground surface, small to medium sized trees or larger shrubs are accommodated to provide a dense crown cover. This comprises light loving plants having good timber value and multipurpose benefits like fodder, fuel, etc. Scattered taller strong light demander trees may make one or two higher layers of canopy. Strong root binders are promoted on this type of site. Multitier planting methods are preferred. A basic support system may also be developed for the convenience of visitors.

The Riverfront of Sutlej River and its tributaries have different owners: farmers, Municipal Corporations, *Panchayat*, Irrigation Department, Institutions, Forests Department, etc. and

substantial portion are under private ownership. Suitable steps will be taken to ensure smooth coordination of the activities among different agencies.

In this model, the river Team had identified the major areas around district Headquarters or any other prominent places of religious importance in consultation with various stakeholders and area were decided as per availability at those places. During implementation phase, it can be shifted to other more suitable site with the consent of all stakeholders.

One model for Riverfront development has been proposed. Site-specific activities will be carried out at different places commensurate with the local site conditions available for Riverfront development. The model has been described below.

Model –Riverfront Development (SL/HP/ UL/02)

The proposed Model of Riverfront Development would involve plantation of avenue shrubs and trees along the Riverbank to stabilize the soil and protect the bank from erosion. It would also have beds of annual flowering plants and patches of grasses. The area is so developed that would provide a pleasing and relaxing environment to the visitors. It would be a typical landscaping area comprised of vegetation and non-vegetation components.

According to requirements following components need to be created for Riverfront Development.

1. **Vegetation part**: Grove consisting of shade trees, ornamental trees & bamboos, small herbal garden, climbers, hedges, grasses for lawn, etc.
2. **Non-vegetation part:** Stairs, pathways, walking trails, stone pitching, benches, rain shelters, e-public utilities, parking area, information centre, refreshment area, etc. as per the site specific requirements.

The vegetation and non-vegetation components will be arranged in such a way to enhance the aesthetic beauty of riverfront. Ornamental species will be planted according to their recommended spacing and site specific suitability.

For using the available space economically and efficiently multitier planting methods will be used. Soil binding and water loving ornamental tree and shrub species are ideal choice for Riverbank planting. To bind the surface soil, grasses and surface growers will be allowed to cover the surface and protect soil from erosion especially during rainy season or River flooding. It will minimise soil loss through sheet erosion, splash erosion and rill erosion. It will also improve rain water per collation or absorption. Besides this, small to medium sized herbs and shrubs will be accommodated at the second layer of vegetation to intercept some amount of sunlight and stop the fast/ forceful falling of rain drops directly from sky in turn which stop soil erosion (splash erosion). Small to medium sized ornamental trees or larger shrubs i.e., mainly light demanding plants will be accommodated at the third layer of canopy to cover the crown area. This layer will provide small timber, fuel, fodder and intangible benefits. The top canopy

will be occupied by the strong light demanding species which are ultimately the dominant species on Riversides.

In this Model, the River Team has identified the major areas around district Headquarters or any other prominent places of religions important with consultation of various stakeholders and will be decided as availability at those places.

List of Species for Plantation

Trees: *Jacaranda mimosifolia, Grevillea robusta, Cassia fistula, Ficus rumphii, Azadirachta indica, Albizia chinensis, Albizia procera, Butea monosperma*, *Kigelia africana* , *Delonix regia, Dalbergia sissoo, Salix alba*, *Saraca asoca, Polyalthia longifolia, Callistemon citrinus, Syzygium venosum, Magnolia* spp., *Michelia* spp., etc.

Shrubs: *Bougainvillea* spp., *Rosa* spp., *Nerium oleander, Nyctanthes arbor-tristis, Spiraea* spp., *Jasminum* spp., etc.

c) Institutional Plantations

Many educational institutes, hospitals, government and private sector offices, factories, religious places, historical places, hotels, guest houses etc., are located in the whole stretch on the bank of Sutlej River and its tributaries. Many of such Institutions and Industries may have possibility to plant trees of different sizes for beautifying the overall landscape. Tree/shrub/climber plantations will be encouraged on such lands within the project area. This would improve aesthetics, provide shade, produce non-wood and wood produce, reduce air, noise and dust pollution, harbour birds, reduce erosion, and create awareness about importance of trees. Some of the trees may serve religious purpose too and could be developed as small Sacred Grooves with the approval of management of such Institutions.

The river Team has consulted the secondary data of District wise/ Block wise in Riverscape regarding Schools, Universities, Colleges, Corporate/ Factory, Big hotels, Corporations, other NGO's, the Railways, etc. Total numbers be worked out and 20% of those can be taken in this component and individual institution would be taken as one hectare (virtual) for calculating budgetary provision. The forest Department and Commissioner of District can be taken on board for providing the land in institutions for establishing plantations under this model. The budgetary provision for those institutions can be distributed in three years in equal proportion or in the ratio of 30:30:40 in each year.

One model has been proposed for Institutional and Industrial Estate Plantation. Site-specific activities will be carried out according to the site conditions. Description of the Model is given below.

Model: Institution Plantation (SL/HP/ UL/03)

Under this Model, mainly ornamental, shade and fruit plants will be encouraged for planting. Evergreen plants especially Silver oak (*Grevillea robusta*) will be preferred so that the leaves do not shed during winter months when air pollution is usually high in plains. Plantation of forest species will be raised near the vicinity of various Institutions and Industries at 3m x 3m. Pit size of 45 cm x 45 cm x 45 cm will be used for plantation. After land development, pit digging, etc. plants mainly of broadleaved species such as *Syzygium venosum, Dalbergia sissoo, Melia azedarach, Grevillea robusta, Holoptelea integrifolia*, *Morus* spp., *Saraca* spp., etc. will be planted. The initiative will beautify the area, create awareness among people associated with Institutions and Industries and promote environmental services, besides providing economic returns from underutilized land.

List of Species for Plantation

Trees: *Cedrus deodara*, *Aesculus indica*, *Prunus* spp., *Quercus* spp., *Bambusa* spp., *Dendrocalamus* spp., *Holoptelea integrifolia, Syzygium venosum, Anthocephalus cadamba, Dalbergia sissoo, Melia azedarach, Morus* spp., *Thuja orientalis, Cryptomeria japonica, Araucaria araucana, Cupressus torulosa, Cupressus sempervirens, Jacaranda mimosifolia, Grevillea robusta, Albizia chinensis, Albizia procera, Delonix regia, Salix alba, Saraca asoca, Polyalthia longifolia, Callistemon citrinus, Kigelia africana* , etc.

d) Eco-Park Development

Development of some sites of Urban Landscape into Eco-Park is an important activity keeping in view the growing population and settlements in urban areas. Actually landscaping and beautification is proposed to be done for Urban and Peri-Urban Landscapes of frequent public visitation to bring forth aesthetics and entertainment coupled with natural awareness. The natural layout of the land will be maneuvered in such a way that the aesthetic beauty will be enhanced without much investment by greening the blank areas. Landscaped area will be designed to afford good soil, moisture and biodiversity conservation, in addition to improvement in aesthetic values.

The Team constituted to prepare DPR has been consulted various stakeholders having land for developing Eco-Park development which can be near any Urban/Semi-urban area. The availability of land should be taken after consultation with respective stakeholders that can be anything from 0.5-2 ha.

One model has been proposed for Eco-Park Development. Site-specific activities will be carried out at different places in harmony with the selected site conditions. Description of the model is given below.

Model: Eco-Park Development (SL/HP/ UL/04)

An Eco-Park will be better equipped than Riverfront development to facilitate visitors. An Eco-Park will have both vegetation and non-vegetation components. In the Eco-Parks, the proportion of ornamental plants will be relatively more than in the Riverfront development model.
According to requirement, list of components to be created under this model are:
1. Vegetation part: Miscellaneous ornamental plant species e.g., trees, shrubs, herbs, creepers, hanging plants, etc.
2. Non-vegetation part: Fencing, stairs, pathways, walking trails, stone pitching, rain shelter, e-public utilities, benches parking area, information centre, children playing area, pond beautification, landscaping, etc. as per site specific requirements.

Lis of Species for Plantation

Trees: *Cedrus deodara, Aesculus indica, Platanus orientalis, Magnolia grandiflora, Jacaranda mimosifolia, Grevillea robusta, Albizia chinensis, Albizia procera, Delonix regia, Butea monosperma, Thuja orientalis, Cryptomeria japonica, Araucaria araucana, Cupressus torulosa, Cupressus sempervirens, Dalbergia sissoo, Morus* spp. *Salix* spp., *Saraca asoca, Polyalthia longifolia, Callistemon citrinus, Syzygium venosum,*etc.

Shrubs: *Bougainvillea* spp., *Rosa* spp., *Nerium oleander, Euphorbia pulcherrima, Cactus* spp., *Nyctanthes arbor-tristis, Spiraea* spp., etc.

Table 5.32 Treatment Models for Urban Landscapes in Himachal Pradesh

Sr. No.	Model No.	Amount Rs./Ha	Man days	Amount Rs./Ha	Man days	Amount Rs./Ha	Man days	Amount Rs./Ha	Man days
		Establishment		1st year Maintenance		2nd year Maintenance		3rd year Maintenance	
1	SL/HP/UL/01 Bioremediation and Bio filtration	15,00,000	1800	450 000	540	3,00,000	360	2,25,000	270
2	SL/HP/UL/02 Riverfront Development	1,50,00,000	18000	450 000	5400	30,00,000	3600	15,00,000	1800
3	SL/HP/UL/03 Institution Plantation	2,60,000	728	78 000	218	52,000	146	39,000	109
4	SL/HP/UL /04 Eco-Park Development	1,50,00,000	18000	450000	5400	30,00,000	3600	22,50,000	2700

B) Treatment Models for Urban Landscapes in Punjab

a) Bioremediation and Bio-filtration
Model: Bioremediation and Bio-filtration (SL/PB/UL/01)

The State Pollution Control Board of Punjab has already released the list of Urban/ Semi Urban areas which are polluting the Rivers and their tributaries, so that the areas are identified in the Riverscape accordingly, and one site can be termed as 1 hectare (virtually) and where possible Seechewal Model of Punjab or its modification can also be adopted.

The State Forest Department, Municipality and/or *Panchayat* Bodies have to adopt the suitable approach for Bio-filter suiting to the specific requirements and site characteristics. The Model will include the following activities.

1. Waste water treatment through mechanical measures as per the site requirement.
2. Drainage line treatment by planting grasses, herbaceous vegetation and shrubs.
3. Bio-filters: Bio-filters may be free floating macrophyte bio-filter, emergent macrophyte bio-filter, submerged macrophyte Bio-filter and multispecies algal Bio-filter.

List of Species for Plantation
Tecoma stans, *Eichhornia crassipes* (water hyacinth), *Spirodela polyrrhiza*, *Acorus calamus*, *Typha* spp., *Cyperus* spp., *Scirpus* spp., *Phragmites* spp., etc.

b) Riverfront Development
Model – Riverfront Development (SL/ PB / UL/02)

The proposed Model of Riverfront Development would involve plantation of avenue shrubs and trees along the riverbank to stabilize the soil and protect the bank from erosion. It would also have beds of annual flowering plants and patches of grasses. The area is so developed that would provide a pleasing and relaxing environment to the visitors. It would be a typical landscaping area comprised of vegetation and non-vegetation components.

According to requirements, following components need to be created for Riverfront Development.

1. **Vegetation Part:** Grove consisting of shade trees, ornamental trees and bamboos, small herbal garden, climbers, hedges, grasses for lawn, etc.
2. **Non-vegetation part:** Stairs, pathways, walking trails, stone pitching, benches, rain shelters, e-public utilities, parking area, information centre, refreshment area, etc. as per the site specific requirements.

The vegetation and non-vegetation components will be arranged in such a way to enhance the aesthetic beauty of riverfront. Ornamental species will be planted according to their recommended spacing and site specific suitability.

For using the available space economically and efficiently multitier planting methods will be used. Soil binding and water loving ornamental trees and shrubs are ideal choice for Riverbank planting. To bind the surface soil, grasses and surface growers will be allowed to cover the surface and protect soil from erosion especially during rainy season or River flooding. It will minimise soil loss through sheet erosion, splash erosion and rill erosion. It will also improve rain water percolation or absorption. Besides this, small to medium sized herbs and shrubs will be accommodated at the second layer of vegetation to intercept some amount of sunlight and stop the fast/ forceful falling of rain drops directly from sky in turn which stop soil erosion (splash erosion). Small to medium sized ornamental trees or larger shrubs i.e., mainly light demanding plants will be accommodated at the third layer of canopy to cover the crown area. This layer will provide small timber, fuel, fodder and intangible benefits. The top canopy will be occupied by the strong light demanding species which are ultimately the dominant species on Riversides.

List of Species for Plantation

Trees*:* *Jacaranda mimosifolia, Grevillea robusta, Pongamia pinnata, Albizia* spp., *Butea monosperma, Kigelia africana, Dalbergia sissoo, Delonix regia, Salix* spp., *Saraca asoca, Polyalthia longifolia, Callistemon citrinus* etc.

Shrubs: *Bougainvillea* spp., *Rosa* spp., *Nerium oleander, Nyctanthes arbor-tristis, Spiraea* spp., etc.

c) Institutional Plantations

Model: Institution Plantation (SL/ PB / UL/03)

Under this Model, mainly ornamental, shade and fruit plants will be encouraged for planting. Evergreen plants *Ficus rumphii*, *Alstonia scholaris*, *Sesbania sesban*, *Syzygium venosum* and *Grevillea robusta*will be preferred so that the leaves do not shed during winter months when air pollution is usually high in plains. Plantation of forest species will be raised near the vicinity of various Institutions and Industries at 3m x 3m. Pit size of 45 cm x 45 cm x 45 cm will be used for plantation. Pit size of 45 cm x 45 cm x 45 cm will be used for plantation. After land development, pit digging, etc. plants mainly of broadleaved species *Syzygium venosum, Anthocephalus cadamba, Dalbergia sissoo, Melia azedarach, Pongamia pinnata, Holoptelea integrifolia , Acacia nilotica*, etc. will be planted. The initiative will beautify the area, create awareness among people associated with Institution and Industries and promote environmental services, besides providing economic returns from underutilized land.

The River Team has consulted the secondary data of District wise/ Block wise in Riverscape regarding Schools, Universities, Colleges, Corporate/ Factory, Big hotels, Corporations, other NGO's, the Railways, etc. Total numbers be worked out 20% of these can be taken in this component and the institution taken as one hectare. The Forest Department and Commissioner of the District can be taken on board for providing the land for institutional plantations. The 20% of number can be distributed in these years in equal proportion or in the ratio of 30:30:40 in each year.

List of Species for Plantation

Trees:*Syzygium venosum, Anthocephalus cadamba, Dalbergia sissoo, Melia azedarach, Pongamia pinnata, Thuja orientalis, Holoptelea integrifolia Cryptomeria japonica, Araucaria araucana, Jacaranda mimosifolia, Grevillea robusta, Albizia* spp., *Delonix regia, Salix* spp.,*Saraca asoca, Polyalthia longifolia, Callistemon citrinus, Kigelia africana ,* etc.

d) Eco-Park Development

Model: Eco-Park Development (SL/ PB/ UL/04)

An Eco-Park will be better equipped than Riverfront Development to facilitate visitors. An Eco-Park will have both vegetation and non-vegetation components. In the Eco-Parks, even the proportion of ornamental plants will be relatively more than in the Riverfront Development Model.

According to requirement list of components to be created under this model

1. **Vegetation part:** Miscellaneous ornamental plant species e.g., trees, shrubs, herbs, creepers, hanging plants, etc.
2. **Non-vegetation part:** Fencing, stairs, pathways, walking trails, stone pitching, rain shelter, e-public utilities, benches parking area, information centre, children playing area, pond beautification, landscaping, etc. as per site-specific requirements.

The River Team has consulted various stakeholders having land for developing Eco-Park Development which can be near any urban/ semi urban area. The availability of land should be taken after consultation with respective stakeholders that can be anything from 0.5 ha – 2 ha.

List of Species for Plantation

Trees: *Jacaranda mimosifolia, Grevillea robusta, Thuja orientalis, Cryptomeria japonica, Araucaria araucana, Albizia* spp., *Delonix regia, Butea monosperma, Kigelia africana , Dalbergia sissoo, Pongamia pinnata, Salix* spp., *Saraca asoca, Polyalthia longifolia, Callistemon citrinus, Cinnamomum tamala,* etc.

Shrubs: *Bougainvillea* spp., *Rosa* spp., *Nerium oleander, Nyctanthes arbor-tristis, Spiraea* spp. *Murraya koenigii, Jasminium* spp., etc.

Table 5. 33 Treatment and Cost Models for Urban Landscapes in Punjab

Sr. No	Model No.	Amount Rs./Ha	Man days	Amount Rs./Ha	Man days	Amount Rs./Ha	Man days	Amount Rs./Ha	Man days

		Establishment		1st Year Maintenance		2nd Year Maintenance		3rd Year Maintenance	
1	**SL/PB/UL/01 Bioremediation and Bio filtration**	15,00,000	1316	4,50,000	395	3,00,000	263	2,25,000	197
2	**SL/PB/UL/02 Riverfront Development**	1,50,00,000	21930	75,00,000	6579	50,00,000	4386	37,50,000	3289
3	**SL/PB/UL/03 Institution Plantation**	2,60,000	228	78,000	68	52,000	46	39,000	34
4	**SL/PB/UL/04 Eco-Park Development**	1,50,00,000	13158	45,00,000	3947	30,00,000	2632	22,50,000	1974

5.6 Theme Plans

'Conservation Interventions' and 'Supporting Activities' those are common to two or more lower order subzones or three type of Landscapes described above, referred as 'Theme Plans'. Details of proposed Conservation Interventions and Supporting Activities are provided below.

5.6.1 Conservation and other Interventions

The following three types of Conservation and other Interventions are envisaged for implementation by Himachal Pradesh and Punjab.

(i) Soil and Water Conservation (Table 5.41 and 5.42)

(ii) Riparian Wildlife Management

(iii) Wetland Management

Proposed Conservation and other Interventions will be implemented at the State and local field levels. Details of three types of Conservation Interventions proposed are presented below:

(i) Soil and Water Conservation Measures

The catchments of the Sutlej River, particularly in the mountainous tract of Himachal Pradesh suffers on account of landslides, bank erosion, habitat loss, construction activities and other unsustainable human activities resulting into severe problem of soil erosion and sedimentation. Conservation Interventions by way of appropriate soil and water conservation measures are of paramount importance in order to ensure *Aviral Dhara*, *Nirmal Dhara* and ecological integrity of the river. Accordingly, bioengineering and mechanical measures are envisaged for the purpose of soil and water conservation. The conservation measures mainly divided into mechanical and biological measures. These are adopted on hill slopes to conserve soil and water. The

microwatersheds located along the Sutlej River and two to three kilometers away from the river along its main distributaries would require Soil Conservation Measures basically to reduce silt loads and to moderate flood peaks in the main river. Potential bioengineering and mechanical measures used to control drainage line treatment of microwatershed directly draining in Sutlej River, mechanical measures on non-arable hill slopes of watersheds, bioengineering measures on hill slopes of non-arable lands, treatment of landslides located along the banks of the river, stream bank erosion control and Treatment of special problems of the Sutlej River Basin *viz.*, Glacial Wash, Wind erosion in Cold desert, etc. are described below.

A) Drainage line treatment of microwatershed directly draining in Sutlej River

The treatment of the drainage lines using both vegetative and mechanical measures forms an important part of the Watershed Development. As a matter of principle, if the forest catchment area is well vegetated, a major part of the rainfall is intercepted by layered vegetation and leaf litter. The rainfall peaks are then moderated and as a result most of the drainage lines remain sufficiently vegetated and hardly requires special treatment. In such a case the enforcement of effective closure coupled with some soil and water conservation measure in critical areas would make the drainage lines free from soil erosion problem. The need for Drainage Line Treatment (DLT), emerges when the vegetation cover on the hilly forest slopes is inadequate. Any action plan to be prepared must consider bringing back natural vegetation (i.e., tree, shrubs, forbs, and grasses) on the hill slopes for which enforcement of effective closure would be a prerequisite.

i. Efforts should be made to retain as much rainwater in the catchment area as possible by both mechanical and biological measures

ii. The conservation measures should preferably be coupled with planting of local, sod forming perennial grasses in addition to trees. Plants like bamboo and agave which have proven erosion control value should be included for planting at suitable places

iii. The basic principle should be that water should not run, it should walk. All possible ways should be adopted to create vegetative barriers in series against the flow of water

iv. The sole objective of forestation, soil and water conservation and DLT is to bring back vegetation so that it may resume its play against water. Most mechanical measures are, therefore, only an initial support for the vegetation to get established. Better the vegetation cover, lesser would be the intensity of these Supportive Measures

a) Adoption of watershed approach

The planning of soil and water conservation measures may be planned keeping in view the main sources of sediment and runoff generated. Most appropriately and in line with the National Policy, the watershed based concept has been adopted, need and demand driven, top to bottom

and participatory planning of Soil and Water Conservation Interventions has been planned. The ridge to valley approach has been followed in designing of treatment measures. Contour trenching has been chosen to be the most preferred bioengineering method. Local species of flora has been identified after an analysis of the biodiversity research done by HFRI. The most surviving and dominant species are thus recommended for plantation in contour trenches. All available information from forest working plans and works already done is collected from concerned Forest Divisions and used in the watershed planning.

The microwatersheds directly draining into Sutlej River are marked in figure 5.19. Adopting a watershed development approach, such microwatershed would be treated with package of practices starting from top. These include brush wood check dams and live hedges, dry stone check dams and gabion structures in the drainage lines and contour trenches on hill slopes and plantation of grasses on the berms of trench and trees. This approach is illustrated in the schematic diagram of the typically treated watershed (Fig 5.19).

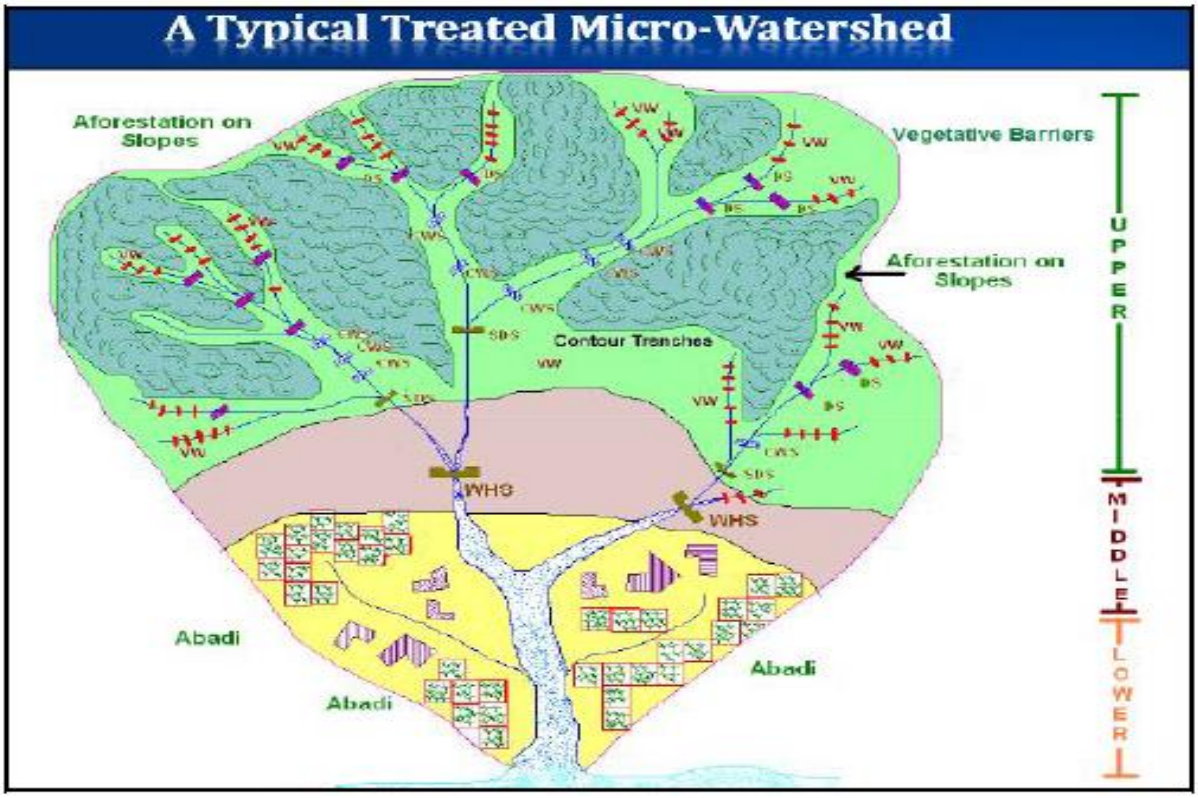


Fig. 5. 19A typical Treated Micro Watershed

b) Planning, design and construction of check dams

Brushwood Check Dam

Brushwood check dams can be planted at the following locations

a. Where 7.5cm of wood 10cm thick and 1.2m to 1.5m length poles are available

b. Where bushes or twigs of trees are available to fill in the dams
c. Where the ravine starts and its depth are 12m and width is 25m
d. The stick should be green so that it gets buried in the soil and starts growing as a plant
e. Brushwood check dam (Fig 5.20 and 5.21) can be single and double line
f. They are planted in two lined craters and one lined small craters

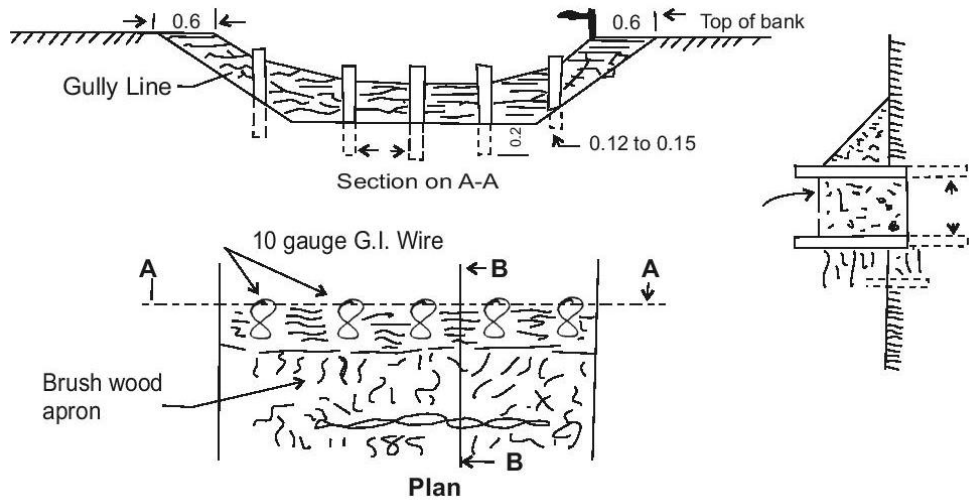


Fig. 5.20 Diagrammatic representation of Brushwood Check Dam

Method of Construction

a. 15-30cm deep and 60 cm wide foundation is dug
b. The lower side of the pole is giver sharp edge
c. The twigs are first filled in with the pole
d. The parts of the branches are placed upwards
e. Shrubs are filled with 45 to 60 cm lengths on top of it
f. The bushes can be tied with fine wire
g. Pressing bushes in the middle of two poles is done pressed by placing stones from above
h. With the pole, the twigs are placed like a moon with the pole down
i. Pressing bushes in the middle of two poles by placing stones from above
j. Agave, bamboo, nada, elephant grasses are planted with some mud and stone in the front
k. After soil filling, 56 bamboo plants are planted on the sides

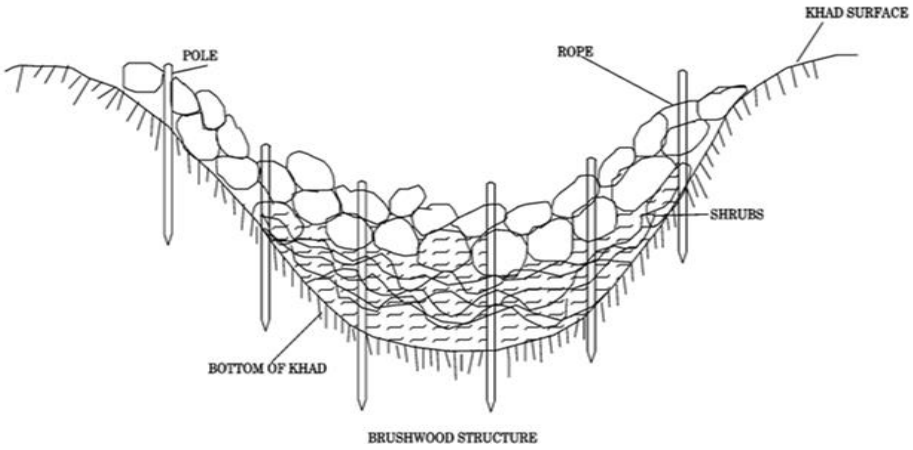


Fig. 5.21 Diagrammatic representation of Brushwood Structure

Bamboo and Agave plantation along the drainage lines

Bamboo is the most preferred plant species for checking soil erosion along the banks of the drainage lines. It is a multipurpose plant and grows well on moist soils. Agave is very hardy plant and best suited for degraded poor quality slopes (Plate 5.1).



Plate 5.1 Bamboo and Agave plantation along the drainage lines

Dry Stone Check Dam

a. Such structures are constructed where stones are available in and around the structure
b. Flattened stones are used after doing some dressing
c. These are placed at the bottom of each other
d. Height is kept from 0.6 to 1.2m
e. Foundations of about 0.3 to 0.4m are dug
f. The depth of the foundation is kept as 1/3 of the height of the dam
g. Each step is made by laying 23to 30 cms stones

h. The cracks are filled with small stones

i. Large stones are laid where the water falls to serve as apron

j. On the front side, soil and gravel are put in up to 1/3 of height

k. Spillway is kept at 1/3 of the width of the ravine for run off disposal

l. Stones are placed in moon shape so that the pressure of water remains in the middle

m. Dry stone structures (Fig 5.22 and Plate 5.2) are constructed in series one above the other. These have a head to toe ratio

n. It is very important to put nirgundi, bamboo, and agave on both sides above and below them, so that the vegetation can come from the moisture created in the ravine and prevent soil erosion

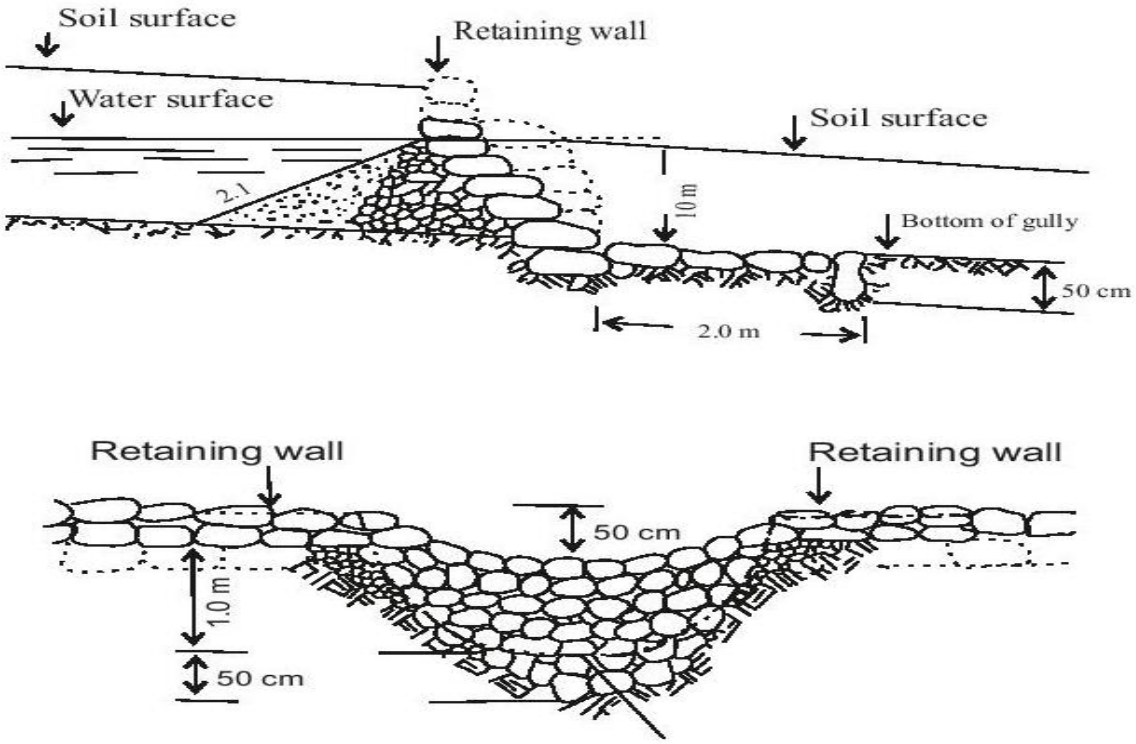


Fig. 5. 22 Diagrammatic representation of Dry Stone Check Dam



Plate 5.2 Dry Stone Check Dam

Gabion Drop Structures

a. Gabion Drop Structures (Fig 5.23 and Plate 5.3) may be constructed in series one over the other
b. First a smaller dam and then a bigger down the line as per discharge
c. Their height is kept from 1.5 to 2.5 m
d. A lot of care is required in selecting and constructing gabion structures
e. The construction site should be narrow and open from the front
f. Crate is inserted inside the side slopes by 0.5 to 1.0 m
g. Place of check dam should not be on the bend
h. Sides should not have vertical cliff or rocky slope
i. Do not choose the place where there is a fear of land slips
j. The wires should not rust. Therefore, galvanized wires are used

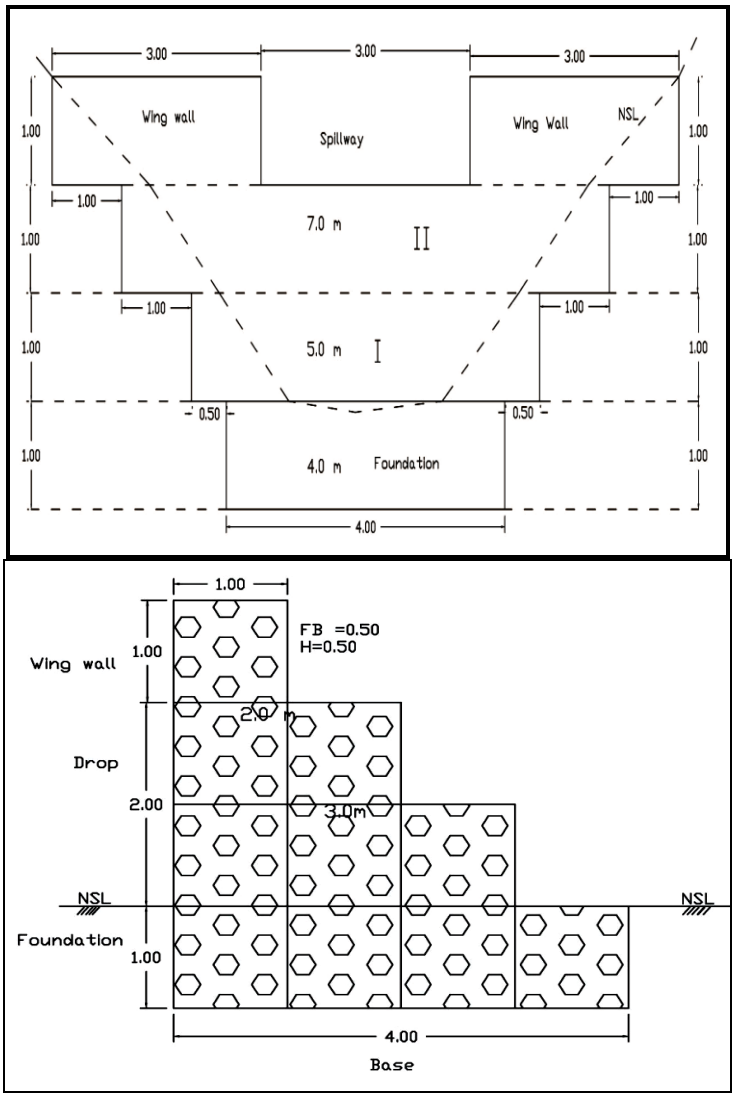


Fig. 5. 23 Diagrammatic representation of Gabion Drop Structures

k. Water can come out of stone barriers
l. During construction, fine stones, pebbles, rocks fill are filled in the holes in crest body
m. Where the water falls, the apron of large stones is made to check scouring
n. The length and height of the structure are kept according to the amount of discharge
o. To make the dam strong and stable, large flat stones are put on the outer side of the wall



Plate 5.3 Gabion Drop Structures

p. Small stones are filled in the center of the wall.
q. Further, 1/3 of the height is filled with soil and *gatka*
r. The wire mesh should not be less than 15x15cm.
s. The walls of the stones should be straight and in line so that the wire can be tightened completely.

Masonry Drop Spillways

a. The right place for these spillways (Fig 5.24 and Plate 5.4) is the lower part of the catchment.
b. The slope in the ravine above should be very low so that water and soil can accumulate.
c. The site should be narrow at dam site but open in front.
d. The place where two side hills converge is generally narrow and best for structure.
e. The cement, sand and water should reach the site easily.
f. Clean gravel and good type of sand is required for quality structure.

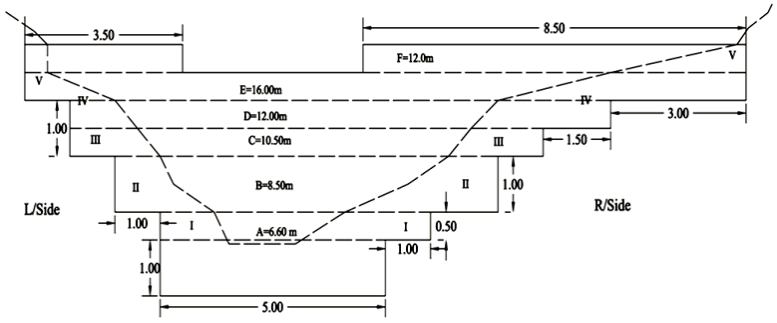


Fig. 5. 24 Diagrammatic representation of Masonry Drop Spillways



Plate 5. 4 Masonry Drop Spillways

Mechanical Measures on Non-arable Hill Slopes of Watersheds

The conservation measures are mainly divided into mechanical and biological measures. These are adopted on hill slopes to conserve soil and water. The microwatersheds located along the Sutlej River and two to three kilometers away from the river along its main distributaries would require soil conservation measures basically to reduce silt loads and to moderate flood peaks in the main river. Some of the suggested mechanical measures ae described in this section.

i) Diversion Drains

Excessive runoff water entering into an area from upstream is often a cause of high erosion and land degradation. Diversion drains, made across the slope, can be used in such situations to divert runoff water away in order to protect the downstream area and discharge it safely into a protected waterway. Diversion drains are suitable at places where runoff from the area situated above is damaging or likely to damage the area lying on the downstream side.

1) Diversion drains should be aligned on non-erosive as well as non-silting grades.
2) The gradient of diversion drain should preferably be kept within 0.5 %.
3) A narrow and deep drain does not get silted up as rapidly as a broad and shallow drain of the same cross-sectional area and is, therefore, self-maintaining.

ii) Contour Trenching

Contour trenching is a widely used practice for moisture conservation in plantations and grassland development. It is a practice of excavating trenches along a uniform level across the slope of land. Bunds are formed along the trenches on the downstream side with material taken out of them. The expected service life of a trench is about 3 to 4 years during which time the vegetation is supposed to perform the conservation function.

Contour trenches break the velocity of runoff and store whole or a part of runoff. Trenches should be designed to store 60-70 % of runoff from 6 hrs storm with 4 years return period in coarse textured soils. In fine textured soils about 50 % of the runoff water may be stored. The intercepted runoff percolates through the soil slowly and is made available to the plants. Contour trenches may be of two types *viz*., continuous and staggered.

a) Continuous Trenches: The trenches are called continuous (Fig 5.25) when there is no break in length and can be 10- 20m long across the slope depending upon width of the field. Generally, trenches are dug with a cross-section varying from 30cm x 30cm to 45 cm x 45cm.

b) Staggered Trenches: The staggered contours trenches (Fig 5.25) are laid scattered with inter space between them. In staggered trenching, the trenches are located directly below one another in alternate rows and in a staggered fashion. Staggered trenches may be made to a length of 23m and spacing between the rows may vary from 35m.

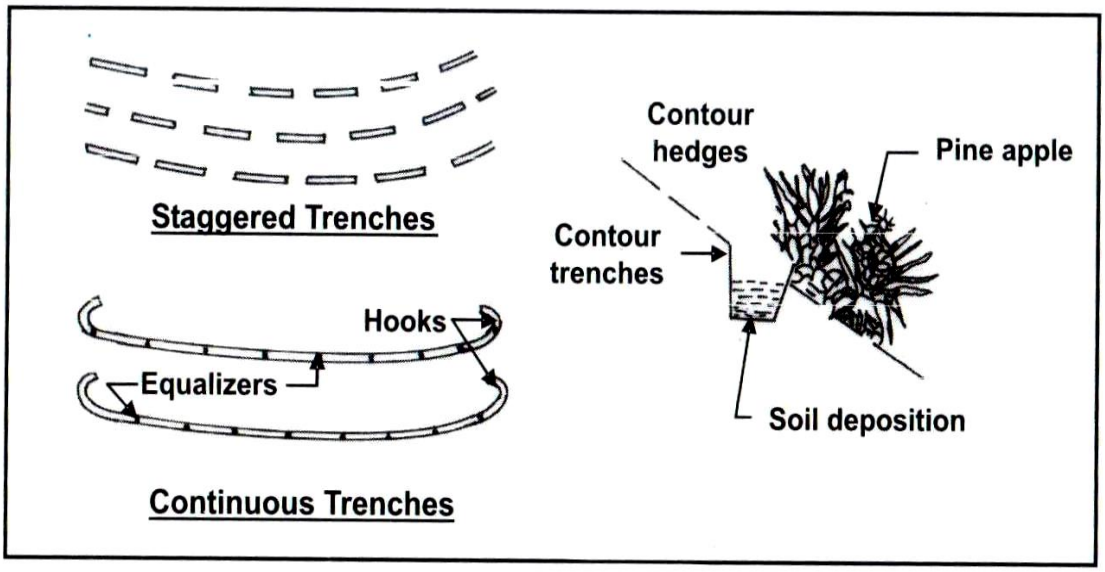


Fig. 5. 25 Diagrammatic representation of Continuous Trenches and Staggered Trenches

1. Contour trenches are normally used in the upper portion of the watershed for plantation of forestry/horticultural plants.
2. Continuous contour trenches are generally used in low rainfall areas for moisture conservation.
3. In high rainfall areas, staggered contour trenches are generally adopted. There is a potential danger of overflow and breach in case of continuous trenches in such areas.
4. Fodder grasses like *Pennisetum pupureum* (Napier hybrid) should be planted on the bund and horticultural/fuel/fodder trees may be planted just downstream of the trench or in the trench itself in gravelly soils.
5. On steep and irregular sloping lands, staggered trenches are more suitable. Over saturation be avoided near banks.

iii) Stone Walls

Stone walls (Fig 5.26) can be constructed across the hill slopes at predetermined spacing for developing land for cultivation, if stones are readily available in the locality. Stone walls can be constructed on contour or at minor gradient depending upon the need. Stone walls are suitable at places where stones are readily available. The stone walls help in retaining soil and subsequent formation of a bench terrace as well as drainage of the excess water.

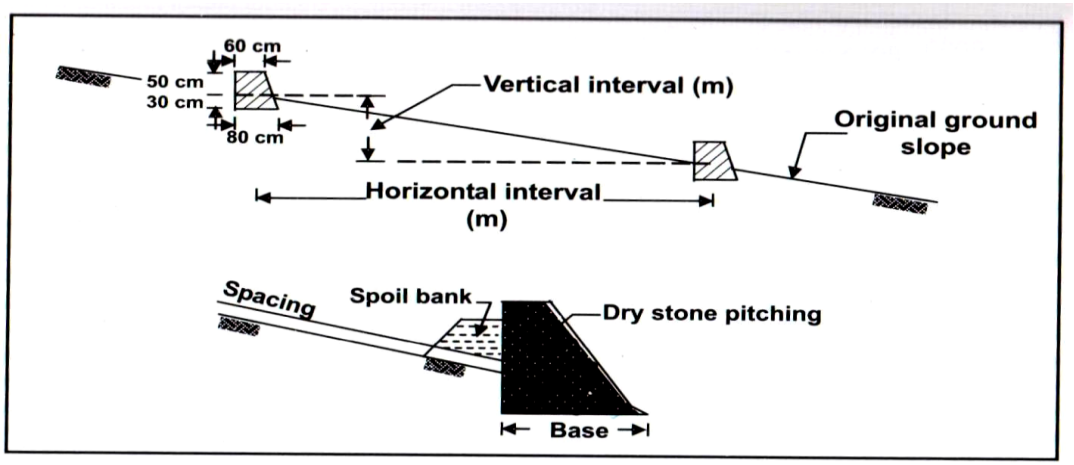


Fig. 5. 26 Diagrammatic representation of Stone Walls Structure

iv) Wattling

Wattling is a method of breaking the length of slope (up to 33 %) into shorter portions by providing contour wattles at 35 m interval (Fig 5.27). Trenches 0.3 m wide 1 m deep are dug up on contour and filled with brushwood bundles (56 cm diameter) lying horizontally. Posts of species which sprout on planting are placed at 100-125cm spacing on the downhill side of the trenches. Some such self-sprouting indigenous species are *Ficus infectoria, Lannea coromandelica, Erythrina suberosa, Vitex negundo, Salix tetrasperma* (Willow), *Hamiltonia suaveolens,* etc.

The inter space between the wattles is protected by mulching with a thick layer (5 cm) of locally available grasses and tied with a thin wire (20 gauge) or rope to avoid its displacement by wind/water. This interspace area may be planted with suitable grasses/shrubs.

a. Live contour wattles obstruct movement of debris and allow runoff to pass through.

b. These are preferred on fragile slopes where soil working is difficult.

c. Vegetative material for wattling and mulching should be available in the area.

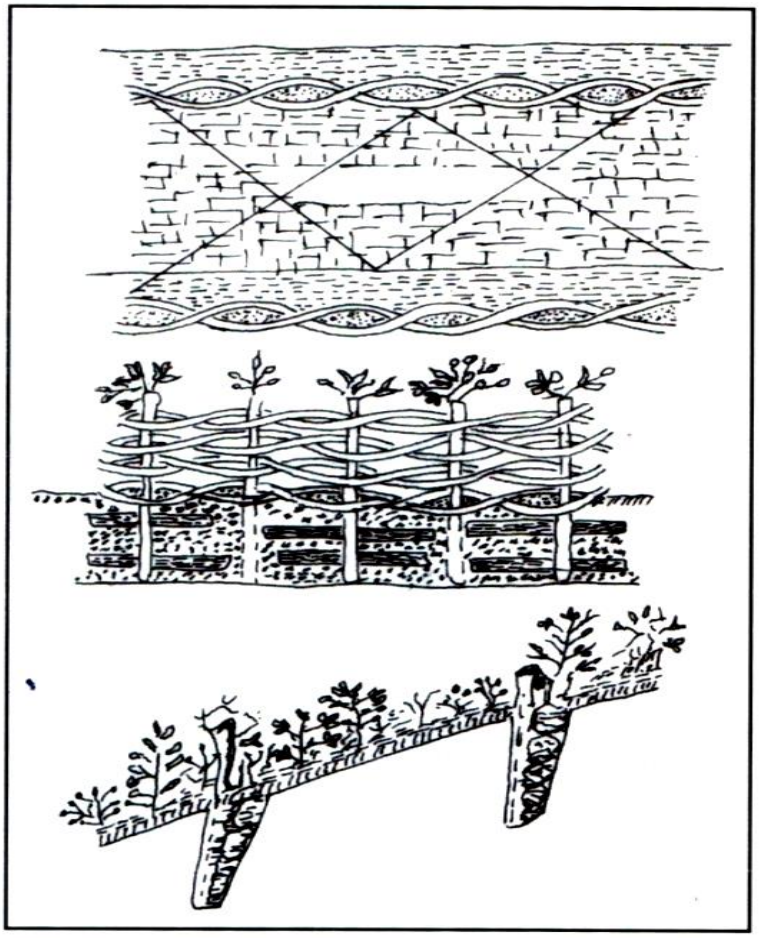


Fig. 5. 27 Diagrammatic representation of Wattling Structure

v) Geotextiles

Geotextiles are woven nets of natural fibers of jute or coir used in soil conservation and slope stabilization works. The geotextiles are basically used for initial establishment of vegetation on highly degraded sloping lands by holding the vegetation in place and conserving moisture and fine soil for its growth. The geotextiles material biodegrades in about 2 years period by which time the vegetation gets established and takes control of the erosion problem. The geotextile with an open mesh size of 25 x 25 mm is generally used for soil conservation purposes. The vegetation comprising of grasses, shrubs and fodder/horticulture trees may be planted with geotextiles as per site suitability and needs. The cost of geo textile application may vary from Rs.27 to Rs.62 m^2 for jute and coir geo textile, respectively. The technique of geo jute application includes; (a) Spreading of geo jute by overlapping and joining adjacent widths, (b) Driving wooden stick to secure the net in place, and (c) Planting rooted slips of local grasses and cuttings of bushes in openings between the geojute strands at close spacing. It is successful for initial establishment of vegetation on degraded slopes (up to 60-70%).

vi) Crib Structures

Log wood crib structures filled with stone/brushwood can be used in stabilizing steep slopes (>40%). Poles of 2-3m length and 8-12cm diameter are driven to a depth of 50-75 cm and erected in two lines, 1 m apart line to line and pole to pole which are nailed together by providing horizontal braces of poles. The height of structure may be kept 1.5-2.0m above the ground. The interspace may be vegetated with suitable quick growing vegetation species (Fig 5.28).

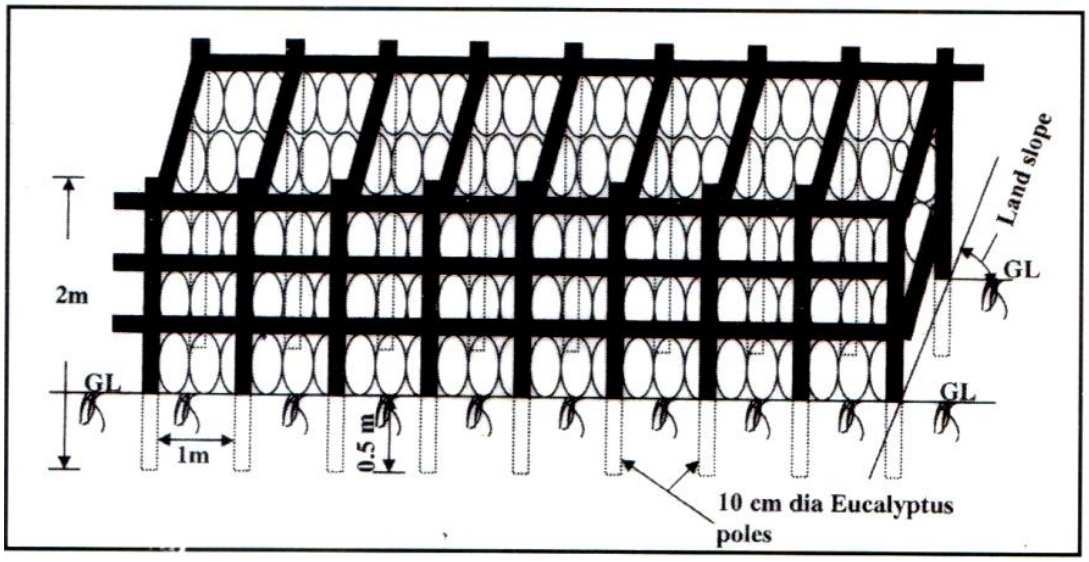


Fig. 5. 28 Diagrammatic representation of Crib Structures

vii) Retaining Walls

For stabilizing precipitous hill slopes and providing stability to River banks, retaining walls are needed. A general thumb rule method for calculating the bottom width of gabion walls upto 6m high is to take base width as two-third the height of the wall. For example, a wall of 3m height would require a bottom width of 2m. The width is reduced in steps to 1m at the top if there is no surcharge. Where there is surcharge, a 2m top width may be adopted. In many of the *khads* suitable size of stones are available and used for the construction of retaining walls (Fig 5.29 and Plate 5.5A) and spurs.

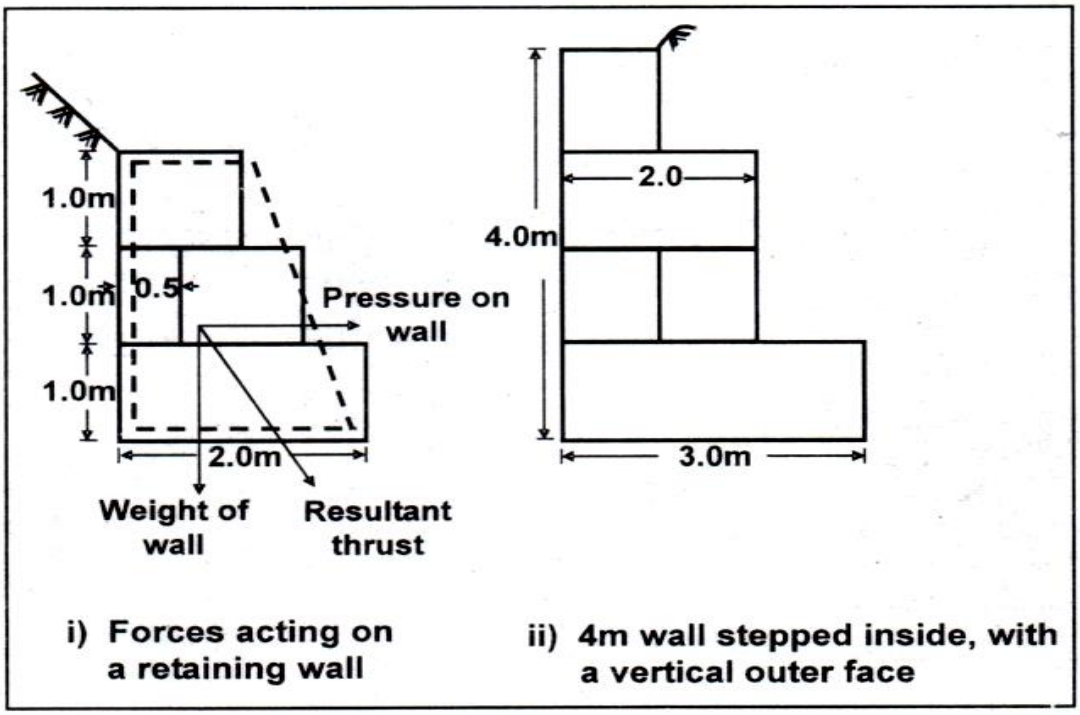


Fig. 5. 29 Diagrammatic representation of Retaining Walls



Plate 5. 5A retaining wall to protect the bank of a stream

C) Bio Engineering Measures on Hill Slopes of Non-arable Lands

Bioengineering is the use of vegetation (Table 5.39 and 5.40), either alone or in conjunction with civil engineering structures, to reduce instability and erosion on slopes. Bioengineering is an effective way of enhancing civil engineering structures to increase stability as far as possible. This is mainly because it provides the best way to armor slopes against erosion, and can also provide a significant contribution to soil reinforcement and other anti-failure measures. Vegetation can provide protection and reinforcement of backfill and surrounding slope areas,

protection from scour and the undercutting of the foundations and sides of structures and a flexible extension to a wall through large bamboos, shrubs or trees close to it adding to the engineering functions of catching, supporting and buttressing. Bioengineering measures supplement the strength and stability of mechanical measures. The bioengineering measures have the following salient features:

a. Involve local available materials and skills providing benefits through economical use
b. Cost effective, better slope stabilization and erosion control, Designed as per prevailing condition of the site, environment friendly solution to stabilize cut slopes along the banks
c. Under most circumstances, bioengineering can be effectively combined with appropriate and low cost geotechnical applications to provide the most cost-effective, integrated solution to slope stability problems
d. The vegetative structures are also flexible, being capable of absorbing movement and recovering from damage. In this respect, bioengineering is simply part of wise and sustainable asset management since it helps to ensure the life of physical structures and reduces overall maintenance costs. Roadside plants reduce the flow of debris from degrading slopes

The vegetation has twin role namely protection and production. Protection through rainfall energy dissipation, interception, stem flow, litter layer, infiltration, root binding, barriers, splash control, runoff retardation, soil aggregation and aeration. In the production role, the vegetation may provide usage biomass in the form of grasses, fodder and thatched roof materials, etc.

i) Bioengineering techniques for erosion control and/or hill slope stabilization

For slope stabilization the benefits of vegetation depend on the type of vegetation as well as on the nature and extent of slope degradation processes. A number of practices can be adopted for stabilizing various hill slopes in addition to erosion control; these could be classified into broad groups of Grass planting techniques, vegetative structures and RipRap Drain (Table 5.34, 5.35 and 5.36). Additionally, a number of low cost related techniques have also come into practice and these are usually practiced with bioengineering interventions. This section provides summarized features of these techniques. However, it needs to be emphasized that these measures need to be practices at community level with active peoples' participation to ensure success.

Table 5. 34 Grass planting technique for erosion control and/or hill stabilization

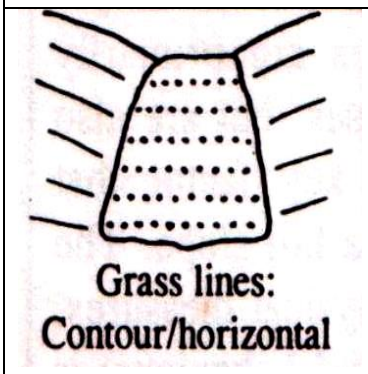
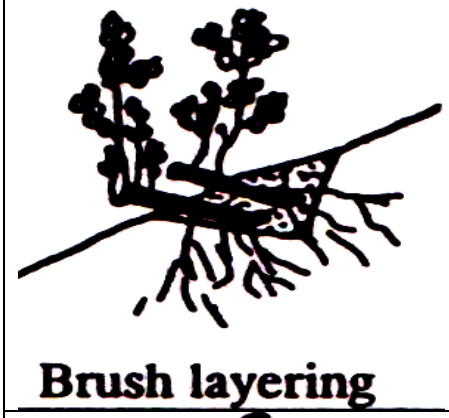
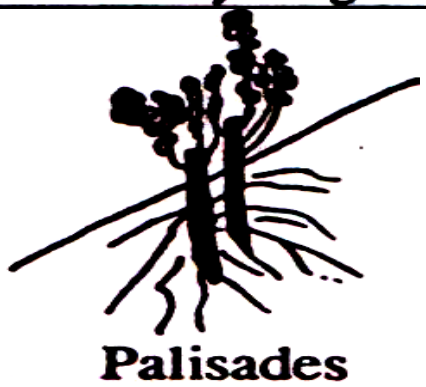
Configuration	Features	Advantages/Limitations
	Description: Planting of grass slips in geometric lines across the slope or along the contour. Critical slope: $\leq 65^0$ Spacing: Plants at 100mm centers within rows. Row spacing: Slope$<30^0$:100cm; Slope 30^0-45^0: 500mm; Slope$>45^0$:250mm	Traps material moving down slope. Retards runoff on highly impermeable materials. Can increase the infiltration rate to the point of liquefaction on porous materials. Cost would vary according to location

Table 5. 35 Vegetative structure for erosion control and/or hill slope stabilization

Configuration	Features	Advantages/Limitations
	Description: Lines of woody cuttings laid in trenches with tops protruding above. Critical slope: $\leq 45^0$ Spacing: Cuttings laid in double rows at 50mm centers (i.e., 40 cuttings/ running m). Layer Spacing: Slope $<30^0$:400cm; Slope 30^0-45^0:200cm	Strong and low cost barrier to trap material and reinforce the soil. Construction causes disturbance to the slope
	Description: Lines of woody cuttings inserted in ground with tops protruding above surface. Critical slope: $<60^0$ Spacing: Cuttings planted in double rows at 50mm centers (i.e., 40 cuttings/running m) Row Spacing: Slope$<30^0$:400cm; Slope 30^0-45^0:200cm	Strong and low cost barrier to trap material and reinforce the soil. Not as strong as brush layering

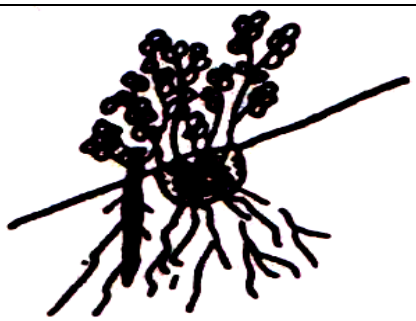
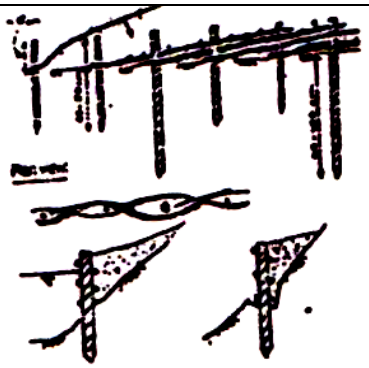
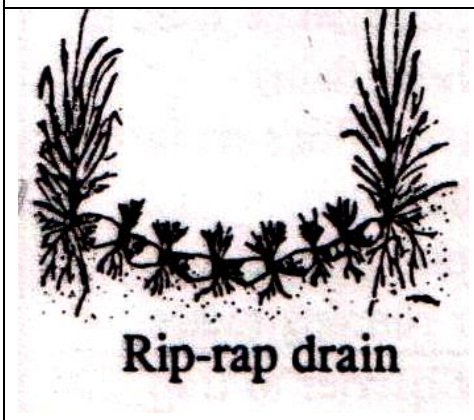
 Live check dams	Description: Flexible check dams made from a variety of woody cuttings Critical slope: $<45^0$ Spacing: Spacing depends on gully conditions but they should normally be at 300-500cm .centers.	Low cost structure to reduce erosion in smaller gullies. Can also be used in between masonry check dams. Large and very active gullies require stronger measures that cannot be provided by vegetation alone.
 Fascine	Description: Bundles of lives woody cuttings are laid in trenches just below the surface. Critical slope: $<45^0$ Spacing: Cuttings planted @4 or 8 cuttings/running m) Fascine Spacing: Slope $<30^0$:400cm; Slope 30^0-45^0:200cm	Strong and low cost barrier to trap material and reinforce the slope. Fascines do not form a barrier immediately like brush layers. Construction causes disturbance to slope.
 Wattle fence	Description: Live cuttings laid horizontally in trenches and interwoven with elastic cuttings. Critical slope: $<45^0$ Spacing: Cuttings planted @ 4 cuttings/m with long (1m)& small (0.3m) cuttings intermittently. Spacing – 100cm row to row. Rows at an angle of 10^0 with horizontal	Effective measure for immediate back holding of sliding material. Labor and material intensive. Loosens the soil while construction.

Table 5. 36 Rap Drain for erosion control and/or hill slope stabilization

Configuration	Features	Advantages/Limitations
	Description: Stone pieces are laid in 60cmwide parabolic drain. Live hardwood pegs are driven 300mm all along the drain. Critical slope: $\leq 50^0$ Spacing: Spacing depends on site conditions. Anchoring pegs at 200cm centers. Drain aligned the slope to prevent stagnation.	Safe disposal of spring or rain discharge from slope soil mass adds to slope stability. May require intermittent cleaning, repair etc.

ii) Single Row or Double Row Brush wood Check Dams

This type of check dams (Fig 5.30) are provide in gullies where wooden poles are locally available and the side slope of the gully is less than 45^0. Depending upon the size of the gully & catchment area, poles of about 7.5cm diameter are driven into the ground in a single row or a double row across the *Nallah* at right angle to the flow and accordingly these are called single row or double row brush wood check dams (Fig 5.30). The posts used should preferable be of species *Lannea coromandelica*, *Dalbergia sissoo* and *Ficus* spp., which will strike roots.

In case of a single row check dam wooden poles are driven 90cm deep into the ground and the centre to centre spacing between two consecutive poles should be 60cm. Whereas in case of a double row brushwood check dam poles are placed about 90cm apart in two parallel rows and the embedment of these poles into the *nallah* bed should be 90-120cm. The distance between two rows should not exceed 90cm.The brushwood is packed against the u/s face of the poles and the poles are tied up with G.I. wire. The height of the poles in the middle of the *nallah* bed should be about 3060 cm less than those of the poles on the banks so that a deep concave curve is formed at the top.

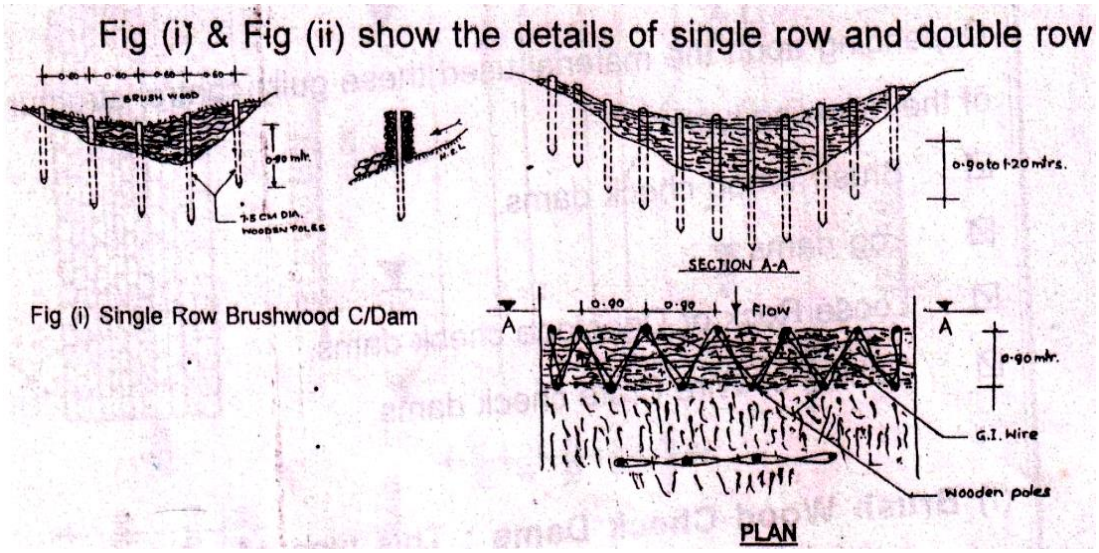


Fig. 5. 30 Diagrammatic representation of single row or double row brush wood check dams

iii) Log Dams: The use of these type of check dams (Fig 5.31) should be restricted only to the places where no other material such as stones, bricks, etc. is available and the wooden logs are available in abundance. The use of wooden logs for the construction of a check dam is explained diagrammatically in Fig 5.31 white ants are the greatest enemy of this type of structures and accordingly the required measures should be taken before hand.

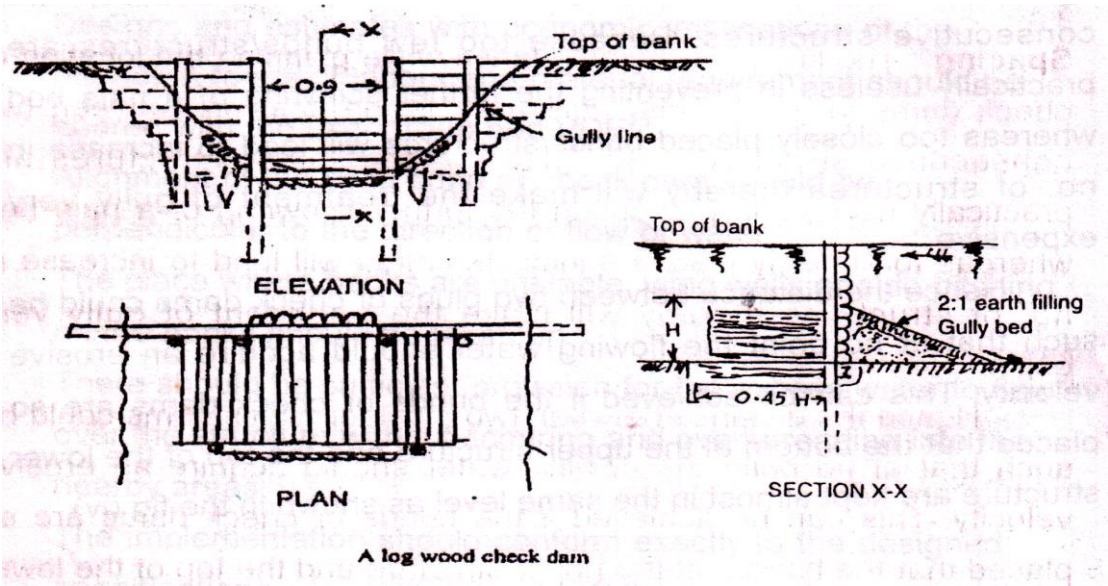


Fig. 5. 31 Diagrammatic representation of Log Dams

iv) Live Hedge

Live hedges are commonly employed in small streams and torrents successfully. Shoots of *Ipomoea carnea, Arundo donax, Hybrid napier, Vitex negundo, Murraya koenigii, Jatropha curcas,* etc. may be planted in trenches (60 cm wide) to serve as live hedges. *Arundo donax* (Narkul) has very strong root and shoot systems to resist the flood flows and ideally suited for bank protection.

v) Bamboo Crib Wall

Saturated slopes of the hills tend to slip down due to excessive moisture particularly during the rainy season and the soil mass often block the roads and also falls into the River beds. In such a case bamboo crib walls are constructed particularly at places where 58cms diameter bamboo logs are available. The bamboo logs are placed in series one over the other with a difference of roughly 60cm and bamboos are held back on the slope by putting wooden nails at regular interval. Once bamboos are stable with 3-4 layers, the cuttings of plants like poplar are inserted in the space between the bamboo logs. Due to good moisture available, the poplar sticks form roots and shoots very quickly. These shoots in a period of 3–4 months would cover the entire slope and the slope would be stabilizing in the due course of time. This type of bamboo crib walls can be created wherever the lands slips are taking place.

vi) Contour Hedgerow Technology

The rapid repletion of natural resources due to increased human population has increased the pressure on land. As a consequent, this has adversely affected the sustainability of production systems by enhancing soil erosion manifold and leaving soil nutrient deficient. The contour hedgerow technology involves planting two rows of hedge of nitrogen fixing plants along the contour lines on the slope at a distance of 1.5-2m; the space between the contour hedgerows, i.e., the alley, is used for production systems.

Double hedgerows can be established by direct seeding, transplanting or using cuttings. Application of N-fertilizer or farmyard manure is necessary during early stages; replanting and gap filling need to be done to make hedgerows dense. Planting is done in alleys according to requirement. Some recommended hedgerow species are: *Desmodium rensonii, Tephrosia candida, Leucaena leucocephala, Indigofera dosua* and *Crotalaria tetragona*. Other species can be tried depending upon need and availability.

This technology ensures adequate control of soil erosion (about 50% reduction in average annual soil loss over control over a period of 3 years), help restore soil structure, improve fertility and conserve soil moisture. It meets the requirement of fodder, fuel and timber along with income generation. It also provides green manure and reduces fertilizer inputs in the field. Expenditure incurred is small and thus can be applied by upland farmers using local resources.

Table 5. 37 List of Plant species suitable for Bioengineering

Gully plugging	**Vegetative check dams**	**Posts for brushwood check dams and vegetative spurs**	**Vegetative spurs**
1. *Agave* spp. 2. *Euphorbia* spp. *3. Ipomoea biloba* *4. Pueraria thunbergiana* *5. Ipomoea carnea* 6. Perennial grasses 7. *Pueraria phaseoloides* – tropical kudzu vine 8. *Aloe* spp.	*1. Ipomoea carnea* *2. Agave* spp. 3. *Euphorbia* spp. *4. Arundo donax* 5. Bamboo *6. Tamarix articulata* 7. *Populus* spp. 8. *Salix* spp. *9. Vitex negundo*	*1. Lannea coromandelica* *2. Boswellia serrata* *3. Ficus* spp. *4. Cordia myxa* *5. Delonix elata* *6. Tamarix articulata* *7. Erythrina suberosa* 8. *Populus / Salix* spp. *9. Dalbergia sissoo* *10. Bombax malabricum* 11. *Moringa pterygosperma*	*1. Ipomoea carnea* *2. Arundo donax* *3. Vitex negundo* *4. Jatropha curcas* *5. Tamarix articulata* *6. Aloe* spp. *7. Dalbergia sissoo* 8. *Saccharum bengalense* (tufts) *9. Salix* spp. 10. *Populus* spp.
Vegetative revetments	**Planting on land slips and wattling**	**Afforesting new sites along stream banks**	**Vegetative revetments**
1. *Cynodon dactylon* 2. Other perennial grasses 3. *Ipomoea biloba* 4. *Peuraria thunbergiana* 5. *Dodonaea viscosa*	1. *Eulaliopsis binata* (Baib) 2. *Agave* spp. 3. *Aloe* spp. 4. *Wendlandia exserta* 5. *Robinia pseudoacacia* 6. *Lannea coromandelica* 7. *Populus ciliata* 8. *Salix* spp. 9. *Prunus* spp. 10. *Saccharum bengalense* 11. *Senegalia catechu*	1. *Saccharum bengalense* 2. *Ipomoea carnea* 3. *Acacia farnesiana* 4. *Senegalia catechu* 5. *Dalbergia sissoo* 6. *Bombax ceiba* 7. *Populus* spp. 8. *Alnus nitida* 9. *Alnus nepalensis* 10. *Salix* spp. 11.*Tamarix dioica*	1. *Cynodon dactylon* 2.Other perennial grasses 3.*Ipomoea biloba* 4. *Peuraria thunbergiana* 5.*Dodonaea viscosa*

Table 5. 38 Plant Species Recommended for Bioengineering in Sutlej River Basin

Species for the bioengineering have been recommended along the altitudinal gradients of Sutlej River Basin according to their occurrence. Three tiers plantation of species i.e., (i) Herbs, grasses and sedges; (ii) Shrubs; and (iii) Trees have been suggested as happens in natural succession. The altitudinal zone wise recommended species are given below, which can be considered as per the site conditions.

Altitudinal Zone <1000m	**Trees** *Senegalia catechu, Aegle marmelos, Bixa orellana, Bombax ceiba, Cassia javanica, Dalbergia sissoo, Delonix regia, Elaeodendron glaucum, Eucalyptus tereticornis, Ficus benghalensis, F. religiosa, F. benjamina, F. rumphii, F. racemosa, Flacourtia indica, Holarrhena pubescens,*

	Lagerstroemia parviflora, L. speciosa, Limonia acidissima, Mallotus philippensis, Magnolia grandiflora, Michelia champaca, Mimusops elengi, Oroxylum indicum, Peltophorum pterocarpum, Populus deltoides, Salix tetrasperma, Cassia fistula, Terminalia spp., *Holoptelea integrifolia , Celtis australis, Phyllanthus emblica, Diospyros montana, Hymenodictyon orixense, Albizia* spp., *Azadarachta indica, Tamarindus indica, Alstonia scholaris, Sysygium venosum, Butea monosperma, Camellia sinensis, Boehmeria rugulosa, Dendrocalamus hamiltonii, D. strictus, Sapindus mukorossi, Cinnamomum tamala, Olea grandiflora, Holoptelea integrifolia, Celtis australis,* etc. **Shrubs** *Buddleja asiatica, Bambusa bambos, Berberis asiatica, Celastrus paniculatus, Justicia adhatoda, Rhus parviflora, Duranta repens, Flemingia semialata, Clerodendron* spp., *Murraya koenigii, M. paniculata, Meizotropis buteiformis, Senna tora, Thysanolaena latifolia, Vitex negundo, Nyctanthes arbourtristis, Woodfordia fruiticosa, Carissa spinarum, Maesaindica* spp., *Tinospora sinensis , Boehmeria platyphylla, Withania somnifera, Asparagus racemosus, Sporobolus diandrus,Themeda arundinacea, Saccharum* spp., C*ymbopogon martini,* etc. **Herbs, Grasses and Sedges** *Arundo donax, Calendula officinalis, Cardiospermum halicacabum***,** *Carthamus oxyacantha, Centella asiatica, Chamaecrista pumila, Cichorium intybus, Citratus colocynthis, Desmodium triflorum, Eclipta prostrata, Hyptis suaveolens***,** *Malva parviflora, Malvastrum coromandelianum, Medicago polymorpha, Chrysopogon zizanioides , Cymbopogon citratus, C. microthecus, Saccharum bengalense, Phragmites* spp., *Polygonum* spp., *Heteropogon contortus, Chrysopogon serrulatus, Fimbristylis* spp., *Polypogon fugax, Bothriochloa* spp., *Carex* spp., *Cyperus* spp., *Neyraudia reynaudiana,Eulaliopsis binata,* *Hierochloe laxa, Boerhavia diffusa,* etc.
Altitudinal Zone 1001<2000m	**Trees** *Albizia julibrissin, A. chinensis, Alangium chinense, Alnus nitida, Bauhinia variegata, Carpinus viminea, Cornus capitata, Cinnamomum tamala, Cupressus torulosa, Dalbergia sissoo, Debregeasia saeneb, Dendrocalamus hamiltonii, D. strictus, Ficus semicordata,* F. *nemoralis, Fraxinus micrantha, Grewia optiva, Melia azedarach, Pistacia chinensis, , Pinus roxburghii, Populus ciliata, Pyrus pashia, Salix babylonica, Symplocos paniculata, Toona ciliata, Quercus oblongata, Q. glauca, Wendlandia heynei, Myrica esculenta, Syzygium venosum, Cornus*

	macrophylla, Cornus capitata, Prunus cerasoides, Neolitsea pallons, Rhododendron arboretum, Olea ferruginea, Engelhardtia spicata, etc. **Shrubs** *Berberis lycium, Cornus oblonga, Asparagus racemosus,Woodfordia fruiticosa, Inula cuspidata, Colquhounia coccinea, Dodonaea viscosa, Duranta repens, Flemingia semialata, Myrsine africana, Drepanostachyum falcatum , Rubus ellipticus, Rubus biflorus Vitex negundo, Withania somnifera, Woodfordia fruticosa, Zanthoxylum armatum, Coriaria nepalensis, Hypericum oblongifolium, H. uralum,* C*oreopsis,* spp.,*Buddleja* spp., *Rosa* spp., *Deutzia* spp., *Viburnum* spp., *Desmodium elegans, Indigofera heterantha, Sorbaria tomentosa, Cotoneaster* spp., *Pyracantha crenulata, Colebrookea oppositifolia, Justicia adhatoda, Cotinus coggygria,* etc. **Herbs, Grasses and Sedges** *Saccharum spontaneum, Bergenia ciliata,Hedychium spicatum, Heteropogon contortus, Hyptis suaveolens***,** *Rumex hastatus,Cynodon dactylobn, Swertia angustifolia Melilotus officinalis, Mentha arevensis, Pennisetum purpureum, Trifolium repens, T. pratense, Valeriana jatamansi, Eulaliopsis binata, Erianthus rufipilus, Themed anathera, Cyperus* spp., *Carex* spp., *Fimbristylis* spp., *Arundinella nepalensis, A. pumila, Apluda mutica, Cymbopogon distans, Chrysopogon gryllus, C. serrulatus, Polygonum* spp., *Polypogon fugax, Bothriochloa* spp., *Alopecurus* spp., etc.
Altitudinal Zone 2001<3000m	**Trees** *Abies pindrow, Acer caesium, A. acuminatum, Aesculus indica, Alnusnitida, Quercus oblongata, Q. floribunda, Cedrus deodara, Corylus jacquemontii, Euonymus tingens, E. lucidus,E. pendulus Ilex dipyrena, Juglans regia, Lyonia ovalifolia, Myrica esculenta, Morus serrata, Pinus wallichiana, Picea smithiana, Prunus cerasoides, P. cornuta, Salix tetrasperma, S. daphnoides, Toona sinensis, Taxus wallichiana, Symplocos paniculata, Cupressus torulosa, Cornus macrophylla, C. capitata, Ccarpinus viminea, Neolitsea pallens, Betula alnoides, symplocos paniculata, Cupressus torulosa,* etc. **Shrubs** *Berberis aristata, B. lycium, Clematis buchananiana, C. montana, Cotoneaster bacillaris, Daphne papyracea, Desmodium elegans, Hypericum oblongifolium, Indigofera heterantha, Prinsepia utilis, Pyracantha crenulata, Rosa moschata, R. sericea, R. macrophylla, Salix elegans, S. denticulata, Drepanostachyum falcatum , Sorbaria tomentosa,*

	Syringa emodi, Skimmia laureola, Thamnocalamus spathiflorus, Viburnum cotinifolium, V. grandiflorum. Sarcococca saligna, Lonicera spp., *Asparagus filicinus,* etc. **Herbs, Grasses and Sedges** *Agrostis gigantea A. pilosula, A. munroana, Anemone rivularis, Arundinella pumila, Ainsliaea aptera, Angelica glauca, Agropyron*spp., *Carex*spp., *Cyperus* spp., *Bergenia* spp., *B.ciliata, Dactylis glomerata, Festuca pratensis, F. valesiaca, Geranium wallichianum, Koeleria* spp., *Poapratensis, P. annua, Sinopodophyllum hexandrum, Polygonatum verticillatum, P. cirrhifolium, Phytolacca acinosa, Potentilla fulgens, Trifolium pretense, T. repens, Trillium govanianum, Viola biflora,V. canescens, Valeriana jatamansi, Verbascum Thapsus, Ajuga* spp., *Erianthus* spp., *Mendo intermedices, Impatiens* spp., *Strobilanthus* spp., *Rumex hastatus,Plantago lanceolata,Senrab chrysanthemoides,* etc.
Altitudinal Zone >3000m	**Trees** *Abies spectabilis, A. pindrow, Acer acuminatum, Betula utilis, Pinus wallichiana, Populus ciliata, Prunus cornuta, Quercus ilex, Q. semecarpifolia, Salix daphnoides.,* etc **Shrubs** *Colutea nepalensis, Cotoneaster bacillaris, C. acuminatus, Daphne oleoides, Juniperus communis, J. indica, J. squamata, Rhododendron campanulatum, R. anthopogon, R. lepidotum, Rosa sericea, Rosa macrophylla, R. webbiana, Salix* spp., *Syringa emodi, Thamnocalamus spathiflorus, Skimmia laureola, Lonicera* spp., *Ribes* spp., *Spiraea* spp., *Myricaria* spp., *Hippophae* spp., etc. **Herbs, Grasses and Sedges** *Aconitum heterophyllum, Anemone polyanthes, A. tetracephala, Arnebia benthamii, A. euchroma, Artemisia* spp., *Dactylorhiza hatagirea, Danthonia cachemyriana, Heracleum candicans, H. wallichii, Polygonatum verticillatum, P. cirrhifolium, P. multiflorum, Selinum wallichianum, S.vaginatum, Allium humile, Geranium wallichianum, Bergenia stracheyi, Angelica glauca, Picrorhiza kurroa, Sinopodophyllum hexandrum, Rheum* spp., *Carex* spp., *Potentilla* spp., *Bromus* spp., *Bistorta* spp., *Potentilla* spp., *Rumex* spp., *Impatiens* spp., *Phlomis* spp., etc.

Source: HFRI, Shimla

D) Treatment of Landslides located along the Banks of the River

Landslides in Himachal Pradesh are a very serious problem particularly during monsoon season. The roads are frequently blocked, the communication system is disrupted and often there is loss

of life and property. The forest plantations are damaged and a huge mass of loose soil is carried to rivers during rains. There are manmade and natural causes of landslides in the young and fragile Himalayan ecosystem.

i) Causes of Landslides

Landslides are simply defined as the mass movement of rock, debris or earth down a slope and have come to include a broad range of motions whereby falling, sliding and flowing under the influence of gravity dislodges earth material. They often take place in conjunction with earthquakes, floods and volcanoes. At times, prolonged rainfall causing huge landslides temporarily block the flow of River for quite some time. The formation of River blocks can cause havoc to the settlements downstream on its bursting. In the hilly terrain of the Himalaya, landslides have been a major and widely spread natural disaster the often strike life and property and occupy a position of major concern. The Himalayan mountain belt comprise of tectonically unstable younger geological formations are subjected to severe seismic activity. The slides in the Himalayan region are huge and massive and in most cases the overburden along with the underlying lithology is displaced during sliding particularly due to the seismic factor. The causes of land slides are as follows.

a. Excavation (particularly at the toe of slope)
b. Loading of slope crest
c. Draw down (of reservoir)
d. Deforestation
e. Irrigation of orchards causing over saturation
f. Mining
g. Artificial vibrations
h. Water impoundment and leakage from utilities

ii) Other factors responsible for land slides

a. Almost all mass movements occur during monsoons (SW and NE monsoon) indicating that main triggering mechanism is the over saturation of overburden caused by heavy rains
b. There seems to be a relation between intensity of rainfall and slope failures.
c. Majority of the catastrophic mass movements is confined to the overburden without affecting the underlying bedrock.
d. Improper land use practices such as heavy tilling, agricultural practices and settlement patterns have contributed to creep and withdrawal of toe support in many cases
e. A common factor noticed in most of these vulnerable slopes is deforestation in the recent past, cultivation of seasonal crops and increase in settlements.
f. In all the vulnerable slopes terracing/ contour bounding is adopted mainly to prevent soil erosion and to enhance percolation during dry season for cultivation of cash crops as well as seasonal crops. Invariably, in all these cases, natural drainage lines on slopes are

blocked or modified without adequate provision for surface drainage of excess storm water during high intensity rains prevalent in the area.

g. In some areas developmental activities like construction of buildings, road cutting, embankments, cut and fill structures causes modification of natural slopes, blocking of surface drainage, loading of critical slopes and withdrawal to toe support promoting vulnerability of critical slopes.

These causes are summarized in Fig 5.32.

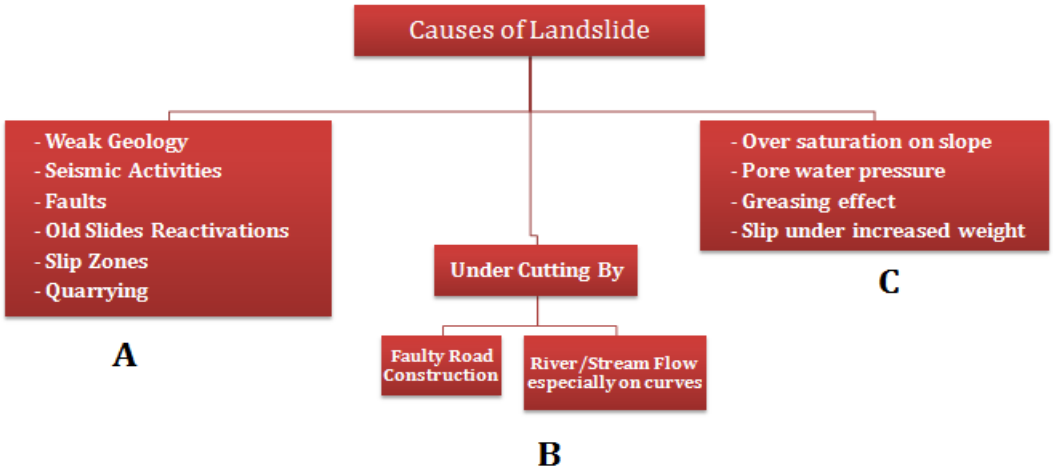


Fig. 5. 32 Flow chart for causes of Landslides

iii) Mitigation Measures

a) **Drainage correction**: The most important triggering mechanism for mass movements is the water infiltrating into the overburden during heavy rains and consequent increase in pore pressure within the overburden. When this happens in steep slopes the safety factor of the slope material gets considerably reduced causing it to move down. Hence, the natural way of preventing this situation is by reducing infiltration and allowing excess water to move down without hindrance. As such, the first and foremost mitigation measure is drainage correction. This involves maintenance of natural drainage channels both micro and macro on slopes.

b) **Proper land use measures:** The universal use of contour bounding for all types of terrain without consideration of the slope, overburden thickness and texture or drainage set up needs to be controlled especially in the plateau edge regions. It is time to think about alternative and innovations, which are suitable for the terrain, to be set up. It need not be overemphasized the governmental agencies have a lot to contribute in this field.

c) **Reforestation in areas of degraded vegetation:** Leaving aside the 'Critical Zones' with settlements areas with degraded vegetation should be preferably for permanent vegetation. The 'Highly Unstable Zones' generally lie in the upper regions, which are occupied by highly degraded vegetation. These areas warrant immediate afforestation measures with suitable plant species. The afforestation program should be properly planned so the little slope modification is done in the process. The selection of suitable plant species should be such that can with stand the existing stress conditions in this terrain.

d) Creation of awareness among local population: Community participation in planning, implementation and post plantation maintenance is necessary and Joint Forest Management approaches should be followed. Awareness should be generated among the local communities about the need and importance of such initiatives.

iv) Major Causes of Landslides and Treatment Measures

1. Construction of houses and hotel building on critical slopes

The construction of buildings on highly vulnerable slopes not only increase the load on the unstable strata but also the uncontrolled waste water released from roof tops and utilities over saturate the soil and land slips under increased load. Note the construction at a very vulnerable area and one of the buildings has already gone and the second is likely to collapse (Plate 5.6).
The building construction at such critical areas should be banned by law.



Plate 5. 6 Major Causes of Landslides

2. Landslide triggered by weak geology

The Himalaya is young, fragile and heterogeneous mountains with highly variable geological strata which is unstable and prone to disturbances in the landscape. Many areas are highly prone to landslides.

Solution

i. Close the area with bio-fence of Ramban
ii. Retaining wall at the base
iii. Dry stone walls at strategic location (1 m x 45 m)
iv. Geojute at pockets (as trial)
v. Planting of local plants species *viz.*,*Delbergia sissoo*, Bamboos spp., *Populus ciliata*, *Alnus nitida* (Kunish), *Ailanthus excelsa*, *Agave americana* (Ramban), *Punica granatum* (Dharu), *Dodonaea viscosa*, *Vitex negundo,* etc.
vi. Grass seeding, planting of grass slips, *Artemisia* (broom) and deep rooted species.

It may be noted that certain grass species have tried to colonize on the slided soil mass. Obviously, such species are most suited for landslide stabilization and slips of those should be planted.

3. Landslide Triggered By Faulty Road Construction

Himachal Pradesh is a fast developing state and providing connectivity to scattered rural areas is a high priority of the state government. The funds are limited and roads are constructed by compromising on standard norms for road construction. Moreover, large numbers of hydroelectric projects are being set up on the Sutlej River and its tributaries. Such projects require heavy machinery and carriage of heavy equipment needs wider roads. The existing roads are being widened by giving sharp cuts to hill slopes. These unstable slopes collapse during rains. Unfortunately the waste material is not dumped at proper dumping sites but unloaded on forest slopes (Plate 5.7).



Plate 5. 7 Landslide by Faulty Road Construction

Solution of disposal of muck of road construction on forest slopes

a. Making slopes according to angle of repose
b. Disposal of muck at defined muck sites
c. Diversion of water from top to stable *nallah*
d. Retaining wall at the base and all sections on road cuts
e. Channelizing flow through a waterway
f. Planting bushes and grasses all along the waterway
g. Cross drainage works along roads
h. Plantation on muck disposed material

4. Land slide due to over saturation

In the topo sequence of hills, the most cultivated lands are either along the rivers or at the top or mid slopes. When these mid slopes are terraced for cultivation and are irrigated, the seepage of

water in the soil profile saturates the substratum. The sub surface water moves down stream because the lower strata are rocky or impervious. The moist zone reaches a sloping land down below. The saturated soil mass slides on to the sloping land down below (Plate 5.8).



Plate 5. 8 Landslide triggered by over saturation

Over saturated soil mass slipping under its own weight, note the slip zone.

Solutions

a. Diversion of flow to stable drainage line
b. Main Drainage Channel
c. Secondary Drainage Channel
d. Grassed water
e. Retaining wall
f. Bioengineering measures
g. Tree Species sticks of *Populus* spp.,*Salix* spp.,etc.
h. Bushes – Ramban
i. Grasses – Sod forming/ local
j. Water Disposal Channel and cross drainage works (Fig 5.33, 5.34)

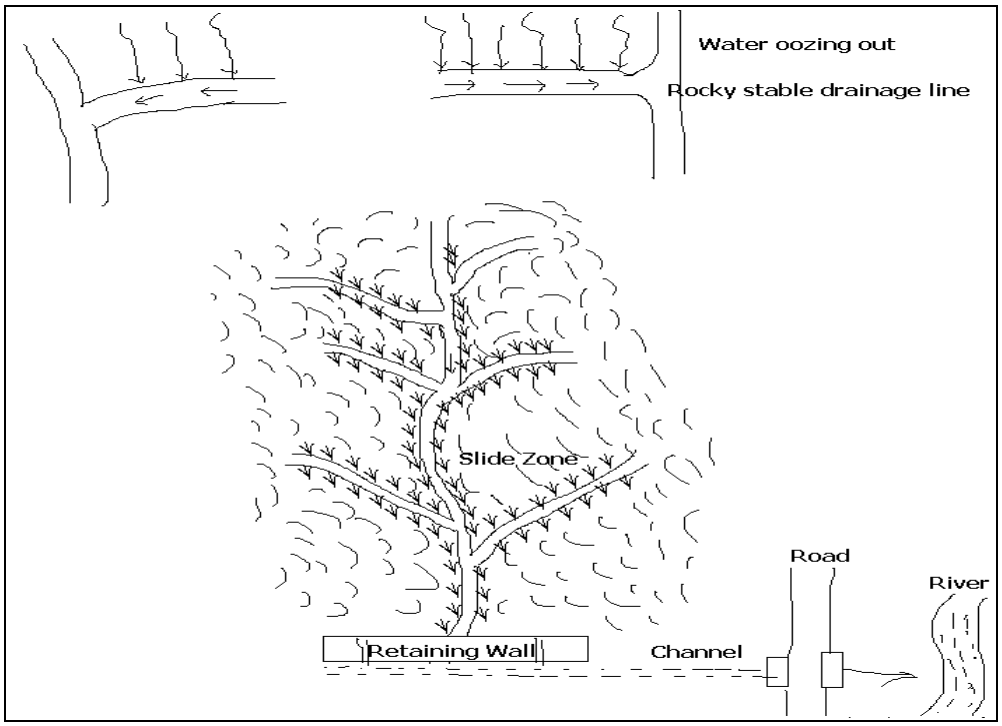


Fig. 5. 33 Diagrammatic representation of system of subsurface drainage in a saturated hill slope

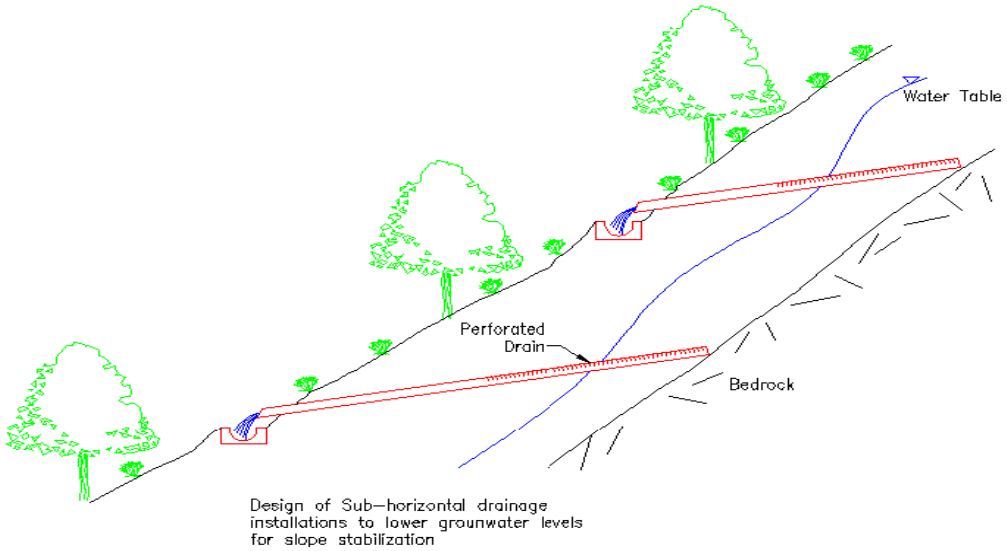


Fig. 5. 34 Diagrammatic representation of design of Sub-Horizontal drainage

5. Landslides due to deforestation

The areas prone to heavy biotic pressure and forest fires particularly common lands near village are generally devoid of adequate protective vegetation cover. When such lands are located on steep slopes and remain saturated during rains, landslides commonly occur.

A highly denuded common land located on hill slope and soil mass is held by dry stone and crate –wire structures.

Solution

i. Close the area in pockets
ii. Carry out intensive plantation of grasses using local fodder species
iii. Provide retaining walls at strategic locations

6. Land slips due to over saturation and deforestation

The grazing lands near villages have thick forest in upper areas and these moist forest lands saturate the lower slopes which slip under the weight of saturated soil mass (Plate 5.9).



Plate 5. 9 Series of retaining walls for land slip control

Solution

i. Closure of the area
ii. Grass land development
iii. Construction of retaining walls

E) Stream Bank Erosion Control

The stream bank erosion is a serious problem in the catchment areas of the Sutlej River which cause deepening and widening of the drainage lines. Lot of damage is caused to land, property, infrastructure and forest lands located along the banks (Plate 5.10). In the lower Shivalik Hills, torrents are a major problem. Torrents (Plate 5.11), the ephemeral streams, known by different names such as *Choes, Raos, Khuds* etc. are characterized by flash flows accompanied with high debris load during monsoon season. They cause extensive flood damage to adjoining land, life and property as a result of frequent changes in their course and associated flash flows with heavy debris loads.When torrents reach the flat valley, their debris carrying capacity diminishes due to reduction in flow velocity and the debris is deposited in the water courses as gravel and sandbars. As a result, the flow tend to braid and migrate laterally overtopping and undermining the low erodible banks and affecting the adjoining forest/agriculture lands and utility services such as roads and bridge.



Plate 5. 10 Bank Cutting in Shivalik hills



Plate 5. 11 Vertical cuts and cliffs formed by torrents

The causes of stream bank failure are

1. Washing away of the soil by flowing current
2. Sliding of unstable slope
3. Undermining the toe of the bank by currents, waves, swirls, etc. followed by collapse of overhanging material
4. Sloughing – sliding of slopes when saturated with water
5. Return flow sloughing
6. Sloughing because of longer duration flows
7. Runoff water of the adjoining areas inflowing over protection less banks

i) Stream Bank Protection Measures

There are mainly two types of protection measures

a) Direct protection works: Constructed directly on the banks and consists of

1) Stabilizing stream bank by vegetation

2) Protection of bank slopes

3) Protection of lower banks

b) Indirect protection works: Construction in front of banks and consists of :

1) Deflection of current and deposition of sediment by installing retards and spurs

2) Diversion of runoff of the stream banks to prevent gully formation.

The stream bank erosion control measures are listed in Fig 5.35.

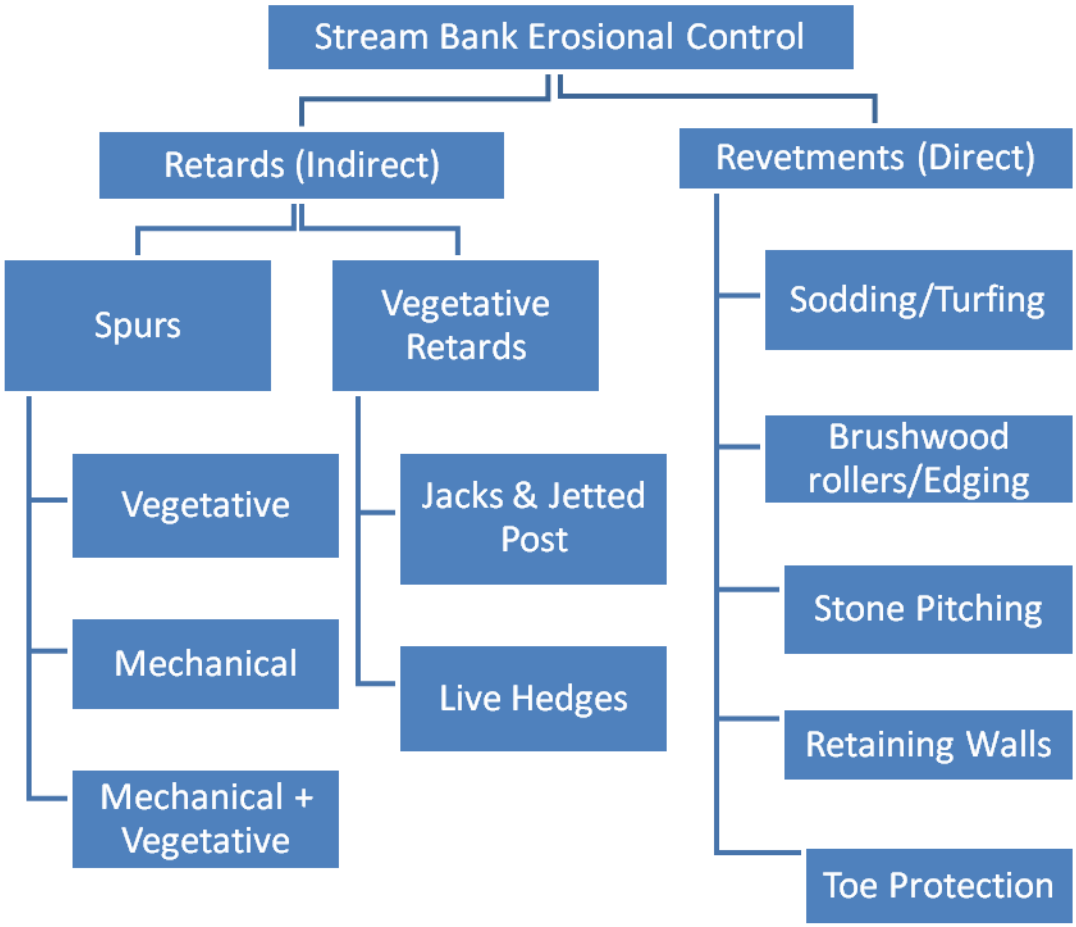


Fig. 5. 35 The stream bank erosion control measures

ii) Stream bank protection by retards

Construction of spurs

Spurs (Fig 5.36) are the commonly used structures for torrent and stream training. These structures are constructed transverse to river flow extending from one of the banks at an angle to the flow. According to the function served, spurs may be of three types: (i) Attracting type

(Pointing downstream at an angle of $30^0 – 45^0$), (ii) Deflecting type (at 90^0), and (iii) Repelling type (Pointing upstream, $5^0 – 20^0$ normal to flow).

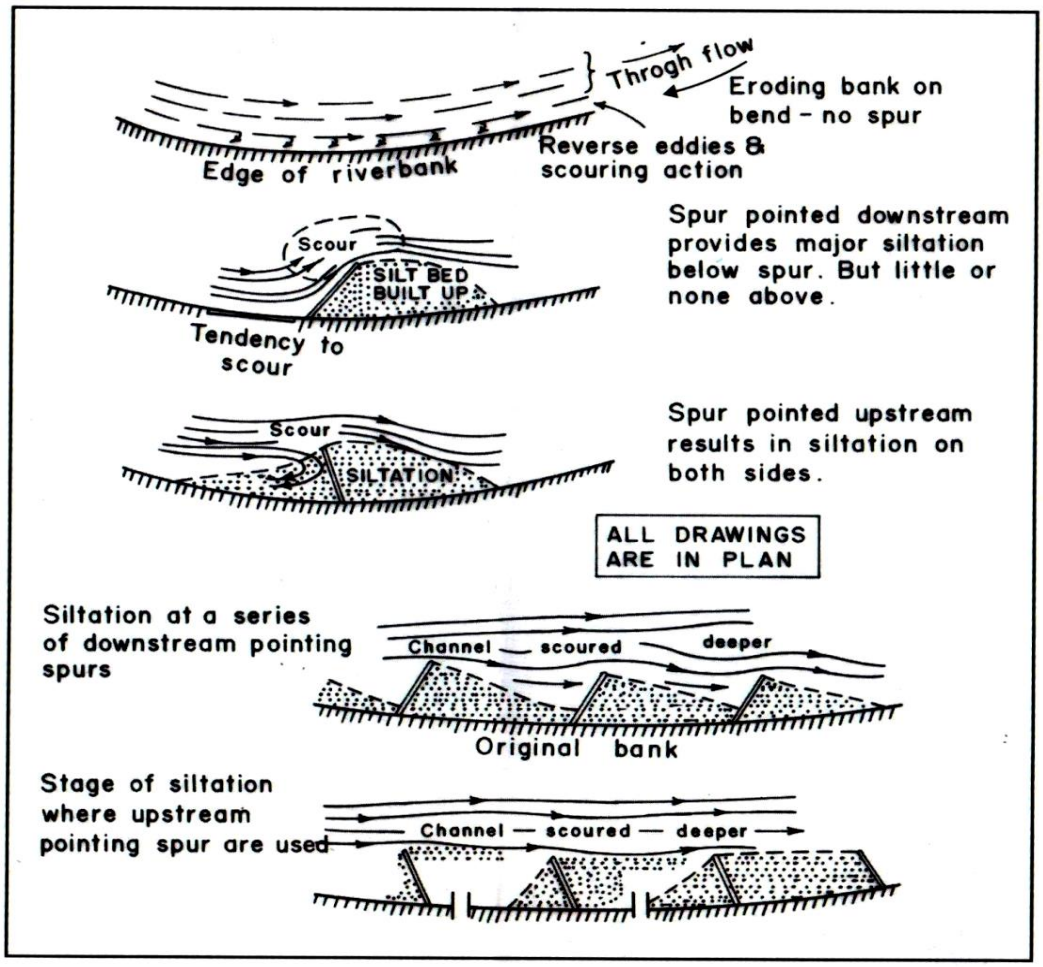


Fig. 5. 36 Diagrammatic representation of Spur

As spurs are quite expensive, they should be judiciously planned and optimally executed at the most crucial reaches along a river course. In the vicinity of the spur (Fig 5.37 and Plate 5.12 and 5.13) and particularly at its nose, suitable shrubs and grasses may be planted to prevent scour. *Arundo donax* (Narkul or Nada), *Vitex negundo*, *Ipomea carnea* (Besharam), etc. have been found useful for vegetative reinforcement of the structures.

Function of Spurs

The functions of a spur system may be one or a combination of the following.

i. Protection of river banks including land, road, buildings, bridge abutments and other structures along them.
ii. Reclamation of land along torrent beds, in excess of that required for the flow discharge.
iii. Narrowing of floodway to induce scouring along defined lines to create a narrow, deep, straightened channel instead of one which is more wide, shallow and meandering.
iv. Diversion of current in a desired direction.

Types of Spurs

The spurs may be classified according to:

i) Method and material of construction– permeable and solid/impermeable types
ii) Function served –attracting, deflecting and repelling types
iii) Height of spur with respect to high water submerged or unsubmerged type and
iv) Special type – Theaded, Hockey type, etc.

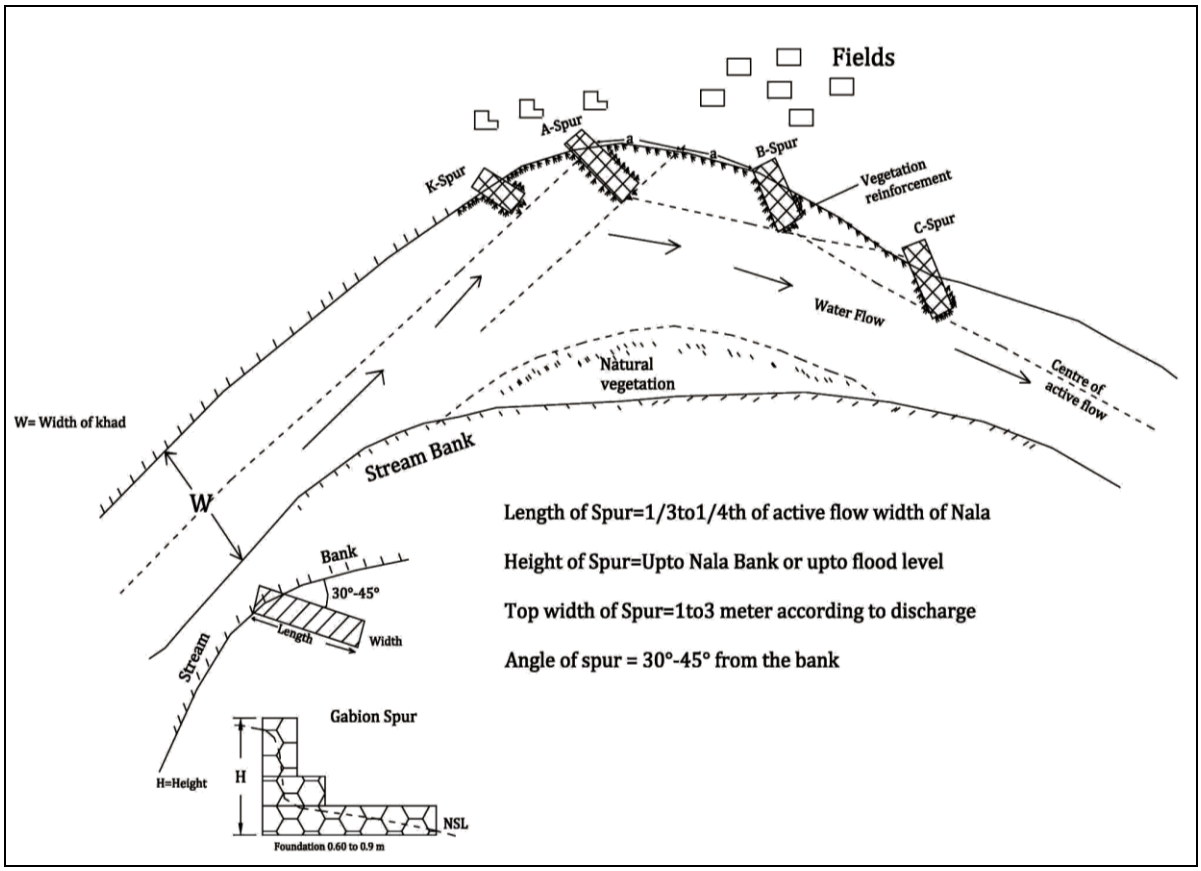


Fig. 5. 37 Location of Mechanical Spurs in Torrent

Design Specification of Spurs

Some of the important factors that determine the use and design parameters of spurs are

i. **Nature and extent of the problem:** River damage is severe and poses a threat to the adjoining life property.
ii. **River characteristics:** River geometry (i.e., width, flow depth, bank heights), flow velocity, flow pattern bed slope, sediment –debris boulder movement, River meandering and curvature, etc.
iii. **Spur geometry:** The length of spur, its alignment to flow, shape and permeability are important design considerations.

iv. **Spur length:** The 'Blockage Ratio' b/B, where b is projected length of spur and B is the river width, the projected length of the spur should not exceed 1/3rd of the width of River.

v. **Alignment of Spur:** The spur alignment is defined by the angle the spur make with the flow direction as measured from the downstream as the angle of the inclination of the spur along the flow direction increases, its sedimentation capacity increases, but stability decreases due to greater scour.

Design Specification of Spurs

i. **Shape of Spur:** Stream lined shapes create fewer disturbances and hence produce less scour than blunt shapes.

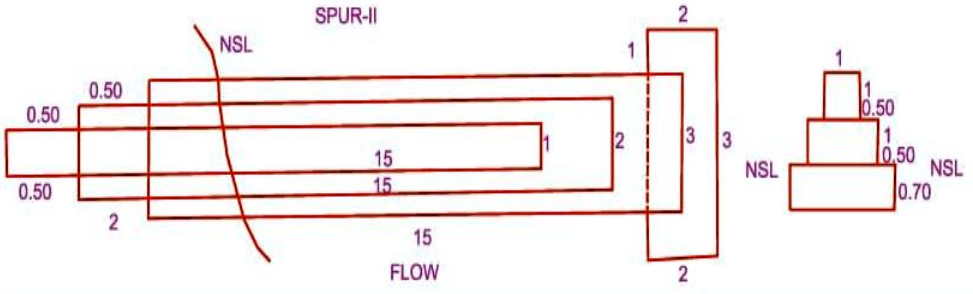
ii. **Permeability of Spur:** Permeable spurs are less expensive and can be made by locally available material. Their stability is better than the solid ones due to lesser scour around them.

iii. **Spacing of Spur:** The recommended optimum spacing of spurs is 3-4 times the projected spur length. A larger spacing can be adopted for convex bank and a smaller one for concave bank i.e., 2 -2.5 times the length of spurs.

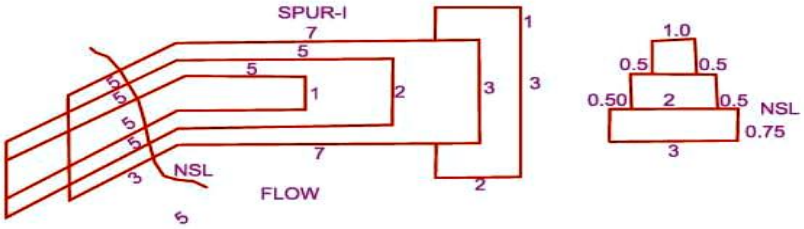
iv. **Sediment:** The differential mobility in a mixture of particles of different diameter is responsible for armouring or paving of the channel bed. Armour layer formation in non uniform sediments leads to reduce scour depths.

a) Crate Wire Spurs

Gabion spurs (Fig 5.38 A and B and 5.39) are made of boulders packed closely in wire crates made of 10 gauge G.I. wires. Semipermeable gabion structures are being used extensively for stream bank protection because they are flexible and economical.



A



B

Fig. 5. 38 (A,B) Diagrammatic representation of Crate Wire Spurs



Plate 5. 12 Mechanical spur



Plate 5. 13 Mechanical Spurs with vegetation

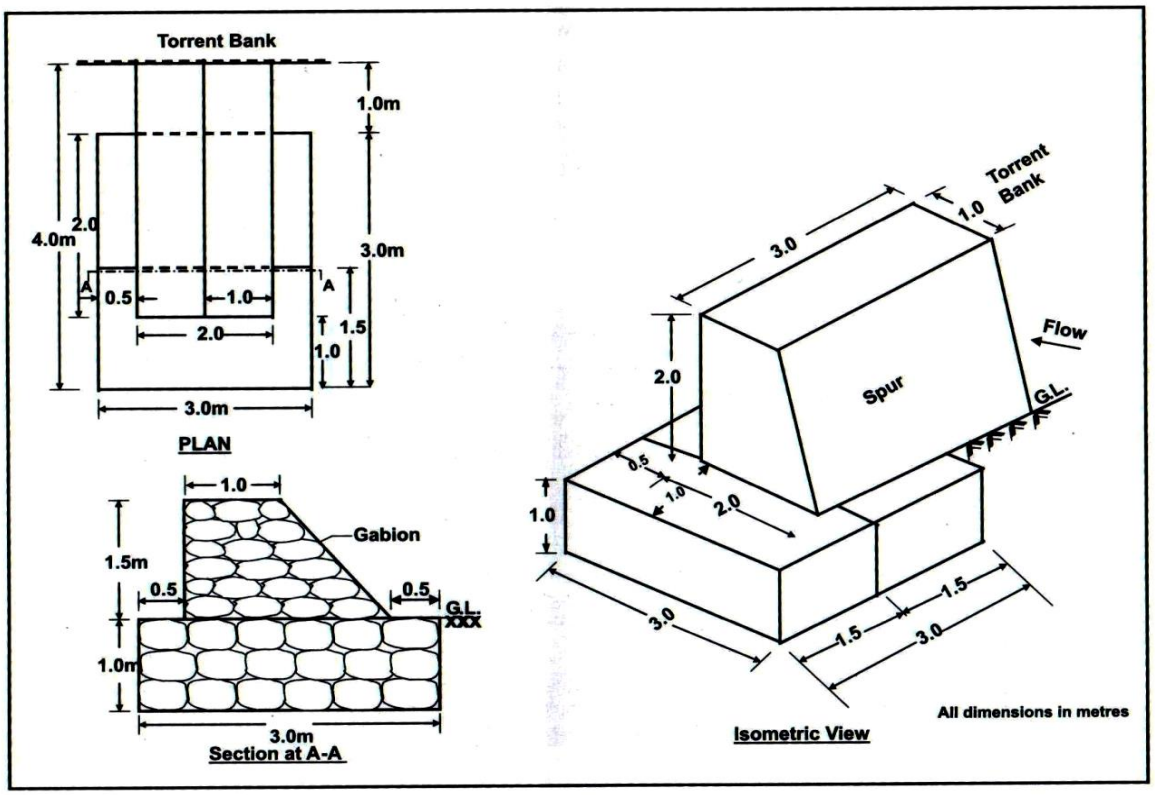


Fig. 5. 39 Line diagram with dimensions of Crate Wire Spurs

b) Vegetative Spurs

Arundo donax (*Nada*), *Ipomoea carnea* (*Besharam*), etc. are planted just like gabion structures along the bank to deflect the flow (Fig 5.14).



Plate 5. 14 Vegetative Spurs

c) Mechanical and Vegetative Spurs

These are made in combination of mechanical and vegetative. The above said plant species are planted around the spurs and also the cut ends between the spurs. They have complimentary role and support each other. An active bank erosion site was fully stabilized by the combination of gabion spur and vegetative support along banks and around the spur (Plate 5.15).



Plate 5. 15 Mechanical and vegetative spurs

d) Vegetative Retards

The vegetative retards are constructed along the stream and serve the purpose of dampening the stream velocity sufficiently near the bank to prevent erosion of the banks or scouring of its toe by inducing deposition. There are of following types:

i) **Live hedges:** Live hedges are commonly employed in small streams and torrents successfully. Shoots of *Ipomoea carnea, Arundo donax*, *Hybrid napier*, *Jatropha curcas,* etc. may be planted in trenches (60 cm wide) to serve as live hedges. *Arundo donax* (Narkul) has very strong root and shoot systems to resist the flood flows and ideally suited for bank protection.

ii) **Jacks and Jetted Posts**: Jacks are wooden posts (Fig 5.40) of 8cm diameter and 2 - 3 m length, which are placed in series along the eroding bank and are tied together. Jetted posts are green posts of 2 - 2.5 m in length and 6 -12 cm diameter which are erected along the actively eroding banks in two rows, 1.0m apart.

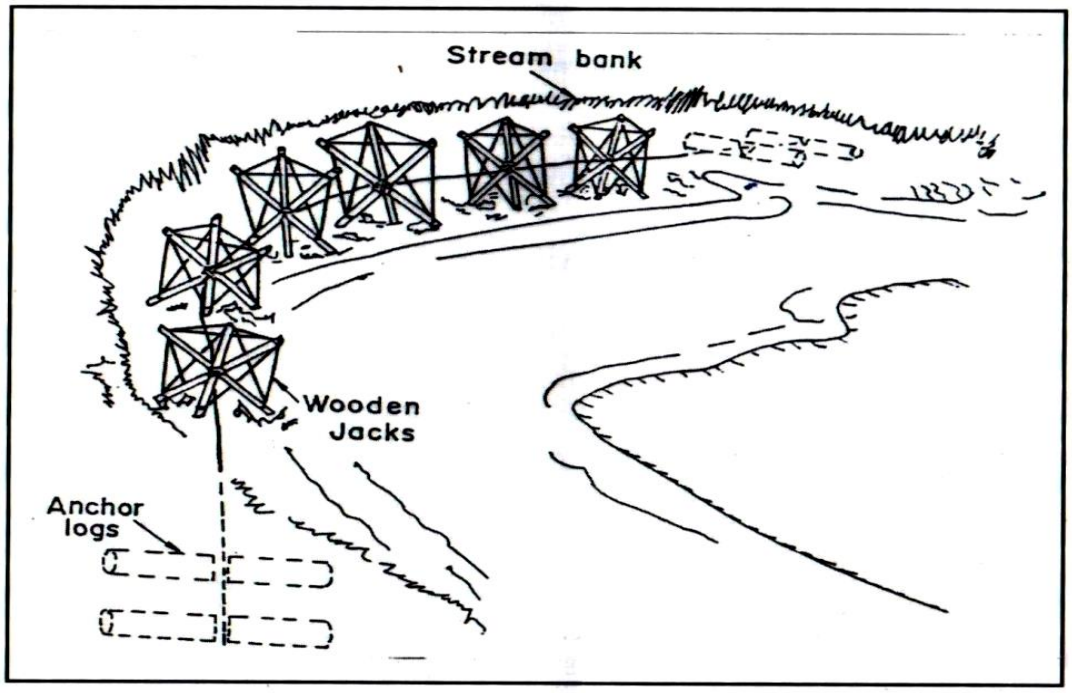


Fig. 5. 40 Diagrammatic representation of Jacks and Jetted Posts

e) Stream bank protection by revetments

Revetments are used where the protection by plantation is not possible and valuable properties extend right up to the edge of the stream bank. They are provided to cover the slope of the stream bank, preferably after easing out the slopes. The side slopes for those measures should not be steeper than 1.5:1. Both vegetative (brush mat revetment) and/or mechanical measures (rock riprap) are used to cover the stream banks depending upon the site conditions and fund availability. Gabion revetments, about 0.5m thick laid on 1.5:1 or flatter slope can also be used.

Revetments maintain the river bank in its existing position and involve the use of vegetation by using grasses or grass reinforced with geonets or geomats, live woody cutting which can be planted through geonets, bitumen impregnated geomats below highest water level or by bank armouring adopting riprap, gabions, or concrete structures. Silty and sandy soils become susceptible to erosion at velocities of the order of 0.2 to 1.5 m/sec. Grass can help to extend the resistance of these soils but in extended flood events, say, in excess of about 2.5 m/sec. Reinforced grass can increase this resistance to about 6m/sec. Live woody cuttings have an aesthetic benefit but need to be used in conjunction with the more complete binding qualities of a continuous grass sward. Therefore, for higher flows the choice becomes one of using stone in riprap or gabions. Riprap and gabion boxes can be planted with live wood or aquatic grasses which besides enhancing the visual appeal can eventually help in binding and anchoring the stone structure. The purpose, selection criteria, advantages and maintenance of revetment are briefly described below:

Purpose: The purpose of revetments is to stabilize river or stream banks and their protection from erosion, besides protection of land from tidal waves and banks of meandering streams.

Selection Criteria: The minimum selection criteria require a cross-section and layout surveys of the eroded stream bank and adjacent stream bed. The layout of the cross sections will depend on the hydraulic analysis to be done. For uniform flow calculations (where these are justified), a few cross sections are required to establish typical River cross sections and the streambed slope. Revetment is a recommended practice for eroded portion of stream banks.

Advantages: Revetments are capable of stabilizing slopes of stream banks and help in establishment of permanent vegetation cover and this vegetation cover acts as filter to minimize pollution of streams.

Maintenance: Riprap revetments require inspection and survey, particularly after major floods, in order to check their performance and upgrade them, if necessary. These inspections should examine launching of toe rock, and if it has occurred, ensure that an adequate volume of rock as placed in the toe berm or launching apron. Toe rock may not be visible as it may have launched into scour holes formed during the flood peak, which have subsequently refilled the bed material deposited. If rock has been lost from the toe, or if scour is deeper than anticipated, it would be prudent to add additional riprap. It may also be valuable to reassess the required rock sizes and gradation based on observations following a large flood.

i) Sodding and turfing

The bank slopes are protected by easing the bank slopes to 1.5:1 and slopes are sodded with *Vitex negundo, Lantana camara, Ipomoea carnea, Arundo donax,* etc**.** These species colonize the banks very quickly and banks are not eroded.

ii) Brush wood rollers and edging

Brush wood rollers are made of bundles of rolled up grass and brush of 30cm diameter and silt filled inside These are tied with a 2-3 m long rope or wire tied with a peg driven at the top of the bank/ The rollers are driven into bank slopes be wooden poles to fasten them tightly. They are purely temporary in nature. The gives good result when used with stone revetments.

In case of protection of banks by brush wood edging, bamboo poles are used to prepare rectangular frames like boxes which are nailed together and filled with grass rollers. These are pegged to the banks.

iii) Stone pitching

When the problem of soil erosion is serious or some infrastructure is to be protected, stone pitching is done, but it is quite expensive. The bank slopes are eased and compacted. On the

slope starting with foundation flat edging, stone of 30- 45 cm diameter are lies over each other up to the top. Sometimes, the pitching is strengthened by stone masonry supporting pitching along the slope (Fig 5.41, 5.42 and Plate 5.16). This ensures that stones are held in place and not get displaced. The detail is given in Fig. 5.41.

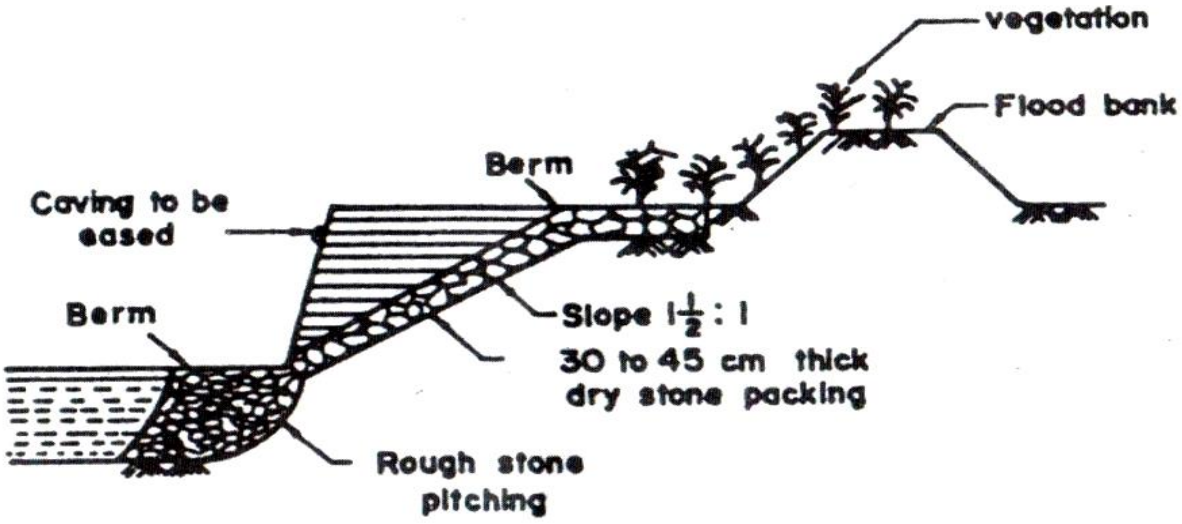


Fig. 5. 41 Diagrammatic representation of Stone pitching

Stone pitching is done in exceptional cases at strategic locations where threat to land infrastructure is serious.

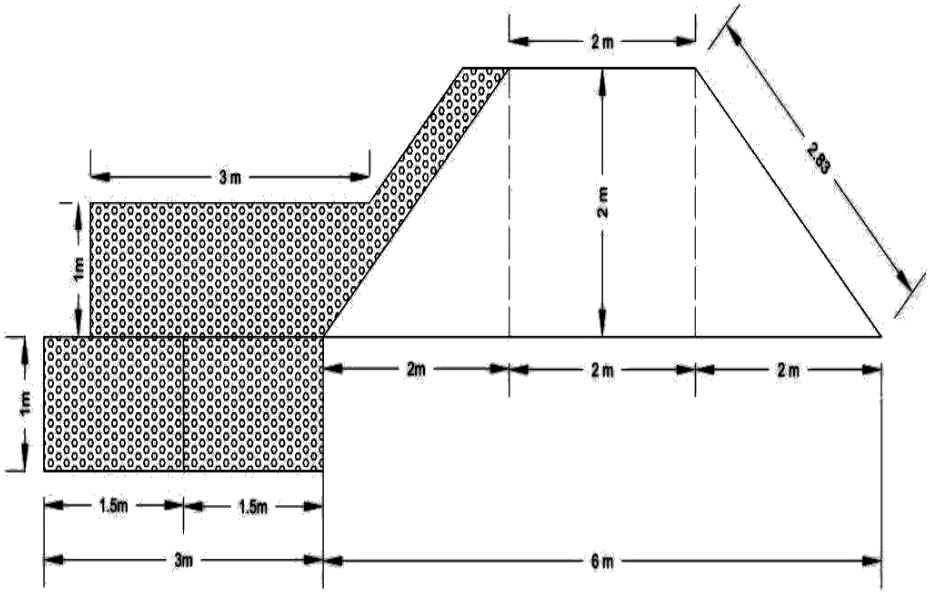


Fig. 5. 42 Line diagram with dimensions of Stone Pitching Structure



Plate 5. 16 Stone Pitching Structure

iv) Retaining Walls

The purpose of retaining walls construction is many and briefly explained below:

a. The retaining walls are constructed to stabilize steep hill slopes
b. To provide stability to stream banks
c. In the hill roads, masonry or gabion retaining walls are constructed to retain the sliding debris from the hill sides
d. Also constructed to provide support to buildings made on steep but unstable slopes
e. In case slope length is small, then only one retaining wall may be sufficient
f. The bottom width of the retaining wall is kept as two-third of the height
g. In case there is surcharge, 2 m top width may be adopted for gabion and one meter for masonry walls

Large size retaining walls are sometimes needed where flow discharges are high and protection is needed for bridges, infrastructure and valuable lands

1. **Crate wire retaining wall**: It is constructed along the bank of a stream has provided protection from erosion and good vegetation cover has developed above the wall. Sometimes very strong retaining walls are needed to protect roads or building or bridges and they turn out to be very expensive (Plate 5.17). In many of the *Khads*, suitable size of stones is available and used for the construction of gabion retaining walls. The height is decided by the level of flood flow. The size is determined by the size of the *Khad* and flood discharge. One meter foundation is provided. This type of heavy structures along banks of the rivers are beyond the purview of this DPR and taken up by the drainage wing of the PWD.



Plate 5. 17 Crate wire retaining wall along the bank of River

2. **Masonry Retaining Walls** The retaining walls are constructed to stabilize steep hill slopes and to provide stability to stream banks. In the hill roads, masonry or gabion retaining walls (Fig 5.43) are constructed to retain the sliding debris from the hill sides. The retaining walls are also constructed to provide support to buildings made on steep but unstable slopes. In case *nallah*/gullies are cutting the banks and there is costly land, buildings or road near the top of the banks, then retaining walls are constructed to provide stability to the banks. In case slope length is small, then only one retaining wall may be sufficient. But, if slope length is more than series of retaining walls, one over the other are made to provide necessary protection. Generally, the bottom width of the retaining wall is kept as two-third of the height. The base width is reduced in steps to 1 m at the top if there is no surcharge in case of gabion structures. In case there is surcharge, 2 m top width may be adopted for gabion and one meter for masonry walls. The retaining walls are broadly classified as structures subjected to water pressure (i.e., dams and weirs) and earth pressure. In the later case, angle of repose of soil is considered in design and its value depends upon nature of earth and its wetness. The stability of gravity retaining walls is due to the self-weight of the wall which should be more than the pressure generated by the water or the earth mass.

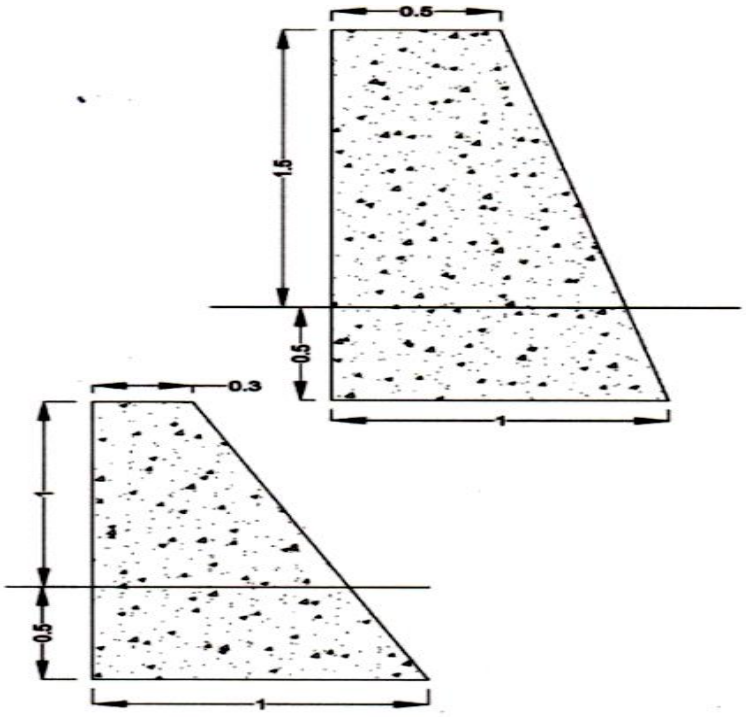


Fig. 5. 43 Design of Masonry Retaining Walls

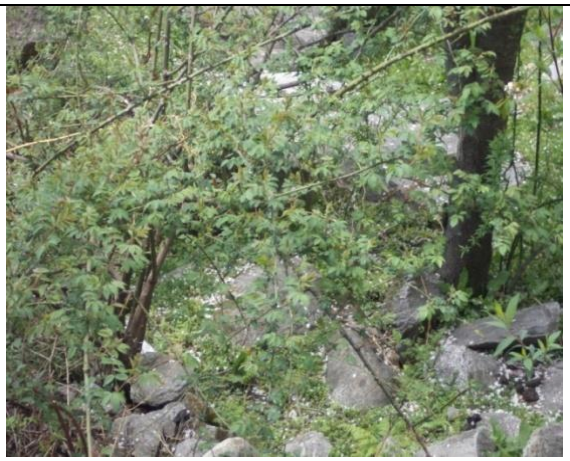
iv) Toe Protection

Gabion protection/toe walls (Plate 5.18) are constructed along the vulnerable torrent banks to prevent bank cutting and erosion. They may be used singly or in combination with spurs. Generally the height of wall is restricted to 3m. The top width is kept 1m and base width can be taken 2/3rd of the height of the wall.



Plate 5. 18 Gabion protection/toe walls

In case of Sutlej River the following type of bushes were seen growing along the banks (Plate 5.19) and they are the best colonizers on highly degraded mountain slopes.



Rosa moschata



Berberis lycium



Punica granatum



Wild Rose



Hippophae rhamnoides ssp.turkestanica

Plate 5. 19 A drainage line rehabilitated by suitable species

F) Special Problems of the Sutlej River Basin

In addition to Soil and Water Conservation measures in Micro watersheds drain directly into the Sutlej River, problem of landslides and stream bank protection, there are couple of special problems in the Sutlej River Basin. These are briefly described in this section.

i) Glacial Wash

The upper areas of Sutlej River receive lot of snow and slow melt after the winter season cause the problem of glaciers moving down the hill slopes when the snow melts in the area touching the ground and glaciers in their movement takes away lot of soil which is called the glacial wash. There are no practical solutions to this problem but snow harvesting has been attempted in which the movement of the glacier is control by number of retaining walls constructed in the bed as well as on the slopes parallel to the slope gradient. These structures create obstruction in the sliding of snow which slowly melts and release smaller amounts of water. A micro watershed near Kalpa was treated for snow harvesting in which such type of retaining walls were constructed and also large number of cuttings of poplar were planted along the banks (Plate 5.20).



Plate 5. 20 A treated micro watershed near Kalpa for snow harvesting

Treatment of a typical glacial wash problem in Khosharang *Nallah*, Kalpa Range, Deodar Zone:

a) Crate Wire Check dams/walls alternate
b) Plant tree species : Willow & Poplar
c) Plant Shrubs Species : *Indigofera heterantha*, *Spirea bella* and *Hiphophoes ramnoides ssp. turkestanica*
d) Construct series of retaining walls for snow harvesting (Plate 5.21).



Plate 5. 21 Control of glacier movement by retaining walls

ii) Wind Erosion in Cold Desert

In the no tree area of Sutlej River, the muck wash spreads along the banks of the River and as flow decreases it dries up and take the shape of fine sand layer. This fine sand is blown by strong winds and gets deposited on the bank slopes. There seems no visible solution of this problem as development of vegetation cover is a problem (Plate 5.22).



Plate 5. 22 Major wind erosion problem Sutlej River bank between Kaurik& Morang

iii)Quarry Wastes Disposed in Sutlej River

There are large number of stone crushers (Plate 5.23) on the banks of Sutlej River and its tributaries which dispose of quarry waste into the River and it becomes source of sediment. These may have the approval of the Government for setting up the plant but the waste is not disposed as per prescribed norms.



Plate 5. 23 A crusher on the bank of Nogli Khad

iv) Wetlands / Dam Reservoirs

These include 55km long reservoir of Bhakra Dam, Reservoir of Kol Dam and large number of reservoirs of Hydro Electric Projects (HEPs). There are wet lands above barrages at Ropar and Harike-Pattan in Punjab. The silt discharge system has been installed in the HEPs. The silt from one project to the other keeps on moving and ultimately reached the Reservoir of Bhakra Dam. It is reported that 30 % capacity of Bhakra Dam has been lost due to siltation in the last 70 years. The only solution suggested is to go in for intensive soil conservation works in the catchment areas.

The ill effects of siltation are clearly seen in the Sutlej River (Plate 5.24) and its tributaries. HEPs on Sutlej River and its tributaries are being adversely affected.



Plate 5. 24 Sutlej River at Nathpa Dam Site

Several natural calamities are also responsible for excessive silt load in the Sutlej River. An example of this is the breaching of the Pareechu Lake in China resulting in flash floods. During this crisis, the silt levels were alarming and reached 1,51,000 ppm mark. In view of the increasing silt load at an alarming rate in the Sutlej River Basin, several bioengineering measures are proposed.

v) Pollution by tributaries

The water of Sutlej River is polluted by sewage and industrial effluents disposal from large number of towns located along its banks (Plate 5.25). The tributaries also bring polluted water for example, Sarsa Nadi which bring highly polluted water from the Baddi –Nalagarh Industrial area. Similarly, Budha *Nallah* (Plate 5.26) brings highly toxic materials from the industries of Ludhiana City and Eastern Bein brings polluted water from Jalandhar, Kapurthala, Lohian which ultimately drains into wetland of Harike-Pattan.



Plate 5. 25 Industrial Pollution in Kali Bein



Plate 5. 26 Budha *Nallah* Ludhiana

No viable solutions are emerging in spite of NGT and orders of the honorable courts. The sewage treatment plants are treating only limited quantity of effluents. The bio-filtration techniques are suggested by several institutions. One of the solution is to plant vetiver (*Chrysopogon zizanioides*) grass along and across such drainage lines. Vetiver is said to have the properties of filtering such effluents.

Vetiver Grass

Vetiver (*Chrysopogon zizanioides*) (Plate 5.27) is a densely tufted, perennial clump grass with stiff leaf bases which overlap. It forms narrow, dense hedges when planted along the contours of sloping land, slowing down runoff and helping the water soak into the soil rather than washing off the slope. In addition it has dense root system which absorbs lot of chemicals flowing with water.



Plate 5. 27 Vetiver Grass

Table 5. 39 Treatment Models for Soil and Water Conservation Interventions in Himachal Pradesh

Sr.No.	Model No.	Amount Rs/Cumt	Mandays
1	SL/HP/CI/01 Brushwood Interventions	300	2
2	SL/HP /CI /02 Dry Stone Activities	1,800	8
3	SL/HP /CI /03 Crate Wire Activities	4,500	15
4	SL/HP /CI/04 Water Ponds	65,000	288
5	SL/HP /CI /05 Silt Detention Dam Type Activities	80,000	248

Table 5. 40 Treatment Models for Soil and Water Conservation Interventions in Punjab

Sr.No.	Model No.	Amount Rs/Cumt	Mandays
1	SL/PB/CI/01 Brushwood Interventions	300	1

2	SL/PB/CI /02 Dry Stone Activities	1,800	5
3	SL/PB/CI /03 Crate Wire Activities	4,500	13
4	SL/PB/CI/04 Water Ponds	65,000	190
5	SL/PB/CI/05 Silt Detention Dam Type Activities	80,000	164

(ii) Riparian and Riverine Wildlife Management

It is considered appropriate to firstly, differentiate between the two terms; 'Riparian' and 'Riverine', and secondly to understand the strong linkages between Riparian zone and Riverine habitats. *Riparius* is a Latin word meaning 'of or belonging to the bank of a River'. The term *Riparian* has generally replaced the Latin *Riparius* and refers to biotic communities living on the shores of streams, rivers, ponds, lakes, and some wetlands (Naiman *et al.*, 1998). In short, 'Riparian' means relating to; living, growing or located on the banks of a stream (California State Parks, 2001).The Riparian zone is an area between the upland zone and the shore line. It forms a corridor between land and water allowing animals to travel between different biomes. Riparian zones, as interfaces between terrestrial and aquatic ecosystems, encompass sharp gradients in environmental and community processes. Lining the border of the water, the Riparian zone provides distinct rich, moist soils in which diverse plant communities can grow. A healthy Riparian zone contains diverse plant species, aquatic and terrestrial wildlife. Riparian zones are an unusually diverse mosaic of landforms, communities, and environments within the larger landscape. The Riparian area or corridor interacts with adjacent water body through reciprocal exchanges of materials and energy (NRC, 2002; Verry *et al.*, 2004; Naiman *et al.*, 2005; StoffynEgli and Willison, 2011). As such, Riparian areas strongly influence the ecological integrity of freshwater ecosystem.

In contrast, the term 'Riverine' means living in, growing in, or located in a River or stream (California State Parks, 2001).In other words, it refers to the aquatic wildlife. It could be plankton, macroinvertebrates or chordates (i.e., fishes, amphibians, reptiles, water birds and aquatic mammals).

The phrase Riparian forest refers to floodplain vegetation or vegetation directly adjacent to rivers and streams (Naiman *et al.*, 1998). The Riparian forests extend laterally from the active channel to include the active floodplain and terraces. Forests contributing organic matter such as leaves, branches, and large woody debris directly to the active channel or the flood plain are included in this definition (Gregory *et al.*, 1991).

It is now well established that Riparian vegetation particularly trees and soil perform various Riparian functions including; (a) Thermal regulation of the water, and more generally,

establishment of unique microclimates (i.e., wind, light, temperature, and humidity conditions); (b) Supply of coarse organic matter (e.g., leaves), a food source for many benthic invertebrates; (c) Supply of large woody debris that affect channel shape and water flow while providing refugia for fish and substrate for aquatic invertebrates; (d) Water purification and regulation of nutrients inputs to streams and lakes; (e) Dampening of floods and droughts by decreasing surface runoff and helping replenishment of groundwater by infiltration of precipitation; and (f) Bank stabilization, control of erosion, and corresponding streambed sedimentation (StoffynEgli and Willison, 2011). According to Dudgeon *et al.* (2006), Riparian areas support high level of biodiversity on relatively small areas of the landscape.

It is now well established that forest and stream ecosystems exchange subsidies (Hjälteń *et al.*, 2016). The exchange of lateral subsidies between forests and stream habitats make Riparian environments key areas for landscape scale biodiversity (Sabo *et al.*, 2005). According to Hjälteń *et al.* (2016), aquatic communities depend on subsidies provided by Riparian forests whose canopy cover, provision of leaf litter and large dead wood often increase with forest age. Large wood in streams has different effects on various aquatic populations. It can benefit big fish, whereas densities of young trout and bullhead are negatively correlated with the volume of large wood (Langford *et al.*, 2012). Leaf litter from Riparian forests has strong influences on invertebrate communities in the aquatic environment, as well as top predators such as fish (Wallace *et al.*, 1997; Hagen *et al.*, 2012). Terrestrial subsidies clearly affect both the functional and structural attributes of aquatic ecosystems, but the quantities knowledge of these inputs and their impacts on stream biota is limited. Just as terrestrial matter and organisms contributes to aquatic communities, aquatic subsidies contribute to terrestrial environment. Organic matter disperse by streams add nutrients and structure to terrestrial soils (Xiong and Nilsson, 1997). Plants propagules dispersed by water eventually strand and can establish populations in Riparian or even upland habitats (Nilsson *et al.*, 2010). Insects emerging from aquatic larval stage are an important food resource for several terrestrial predators *viz*., birds, bats, lizards, spiders and beetles (Baxter *et al.*, 2005).

The functioning of aquatic ecosystems depends on the exchange of subsidies, but various human activities act as stressors and easily disrupt reciprocal flows. The clear felling of trees can increase the input of silt, nutrients, and pollutants to streams and influence assemblages of aquatic insects (Gundersen *et al.*, 2010). Changes in forest composition caused by forestry also influence terrestrial input to rivers. Planted coniferous forests, for instance, will produce fewer subsidies for fish growth than broad leaved forests (Inoue *et al.*, 2013). There is ample evidence that the use of exotic tree species in forestry, particularly *Eucalyptus* can reduce decomposition and nutrients levels, which in turn affect macroinvertebrates as leaves of *Eucalyptus* are poor quality food for invertebrates owing to their oil and polyphenolic content, ultimately can also affect fish growth and survival (Richardson and Rejmanaek, 2011; Larranaga *et al.*, 2014; Morrongiello *et al.*, 2013; Hjälteń *et al.*, 2016). The presence of exotic tree and shrub species is

likely to have a significant influence on forest stream links. Flow regulation and stream channelization have profound impacts on aquatic and adjacent habitats.

The wildlife community within Riparian zones is composed of obligate and generalist Riparian species as well as introduced species. Riparian obligates are species considered so highly dependent on Riparian and aquatic resources that they would disappear with the loss of this habitat from the drainage basin. Amphibian species dominate the list of Riparian obligates when the proportion of obligates is compared to the total number of species present in a given situation. Species that utilize both Riparian and upland forests are considered Riparian generalists. Obligate Riparian bird species require aquatic or Riparian habitat for either breeding, nesting, roosting, or feeding, although several species do not require aquatic or Riparian habitat at all times. Fishing eagle and some raptors are best examples of obligate species as they depend for roosting/ nesting on large trees in the Riparian zones while they depend exclusively on the aquatic/ riverine environment for feeding on fishes.

The enhanced extraction of forests and water resources has led to habitat degradation, biodiversity loss and decline in ecosystem services. As a consequence, ecological restoration has become a conservation priority. Restoration efforts to offset this trend, however, are not always effective owing to the fact that several restoration projects target single ecosystem and fail to acknowledge functional links between ecosystems. Despite the clear evidence of strong linkages between aquatic (riverine) and terrestrial (Riparian) ecosystems, there are still few scientific studies evaluating and highlighting combined efforts jointly restore streams and forests (Hjälteń *et al.*, 2016).

In the context of Sutlej Riverscape, the Riparian forests as well as riverine ecosystem have been severely imperiled in the mountainous tract of Himachal Pradesh and the alluvial plains of Punjab due to enhanced human activities. It is very well established fact that riverscape and its environment, wild flora and fauna in the Riparian zone as well as the aquatic environment have been adversely impacted due to various anthropogenic stressors. Several protected areas (i.e., Rakchham Chitkul, Rupi Bhaba, Lippa Asrang, Kibber, Majathal, Harike and Pin Valley National Park) are some of the prominent PAs along the Riverscape of Sutlej River and its tributaries and these PAs are repository of representative biodiversity of North-Western Himalaya and Western Himalaya biotic provinces and harbours several Rare, Endemic and Threatened (RET) species.

In view of the above enormous significance of Riparian zones and Riverine ecosystem, protected areas, and associated threatened biodiversity, it is vital to have appropriate Conservation Interventions to protect the wildlife habitat and associated wildlife. The following Forestry Interventions are proposed in the present DPR:

a) Collection of baseline information – Status, distribution and population dynamics
b) Ecological research on select threatened taxa
c) Protection and improved management of Protected Areas

d) Protection and conservation measures for Riparian and Riverine wildlife
e) Habitat improvement including control of invasive and alien species in the terrestrial and aquatic environment
f) Conservation breeding and reintroduction of gharial, turtle, otter, etc.
g) Awareness creation
h) Capacity development
i) Long term ecological monitoring

The River team have consulted the list of riverine riparian area and wildlife areas and made list of prominent or high prioritized area in consultation with stakeholders which can be taken under this component. The part of area the Riverine and Riparian area also can be taken up as this is package for the whole Protected Area concerned. The area taken for management can be taken up with the concerned stakeholder (Department as well as NGO or any other secondary sources).

The activities included in the proposed Models along with Nomenclature for Himachal Pradesh and Punjab is as follows:

In Himachal Pradesh

SL/HP/CI /06

In Punjab

SL/PB/CI /06

Component-wise details of activities under Riverine and Riparian Management

Sr. No.	**Components**	**Activities**	**Year**				
			1	**2**	**3**	**4**	**5**
1	Protection	General Protection from illicit felling, illegal grazing, mining, poaching, etc.	√	√	√	√	√
		Survey and demarcation of boundaries and establishment and maintenance of permanent boundaries	√		√		√
		Physical Infrastructure (Watch Tower, Patrolling Path); Electric Vehicle;	√	√	√		
		Field Equipment - Tranquillization Gun, Night Vision with Binoculars, GPS, Surveillance equipment, Camera trap etc.	√	√	√		

		Communications equipment including laptops, wifi system etc.	√	√	√		
2	Habitat Management	Water ponds in every 2x2 km grid	√	√	√	√	
		Habitat enrichment plantations 1. Slopy area, 2. Riverine area (receded area broadcasting of lintels in strips 3. Riparian area 4. Grass land development	√	√	√	√	√
		Soil and Water Conservations Measures	√	√	√	√	√
		Control of Invasive and Alien Species	√	√	√	√	√
3	Wild Faunal Species Management	Conservative Breeding; Re-introduction of Species, etc.	√	√	√	√	√
4	Research and Development	Short Term Projects up to 1 year; Long Term Projects (5-Year) Essential Equipment and Field Infrastructure for facilitation of Research and Development and Monitoring	√	√	√	√	√
5	Eco-development	Basic Infrastructure; Training to Tourist Guides of Peripheral Villages; Interpretation Centre for Nature Education	√	√	√	√	
6	Community Awareness and Participation	Creation of Self-help Groups (SHG), Provision of Revolving Fund for SHG; Alternate Income Generation Activities; Federation for Developing Entrepreneurship and Supply Management, etc.	√	√	√	√	√
7	Ecotourism	Provision of Essential Facilities; Regulation of Tourism Activities, with respect to carrying capacity of the area etc.	√	√	√	√	

In view of the above proposed Forestry Interventions and allied activities, necessary budget provisions for IAs in two Himachal Pradesh and Punjab within the Riverscape have been made towards site specific activities for the protection, management, restoration, and conservation of wildlife relevant to Riparian zones and Riverine (aquatic) ecosystem.

(iii) Wetland Management

Natural and manmade wetlands of the Himachal Pradesh and Punjab help in maintaining the ecological balance, serving the various needs of the society by recycling nutrients, purifying water, attenuating floods, maintaining stream flow, recharging groundwater, etc. Wetlands are not only one of the most productive ecosystems, but are also repository of rich and unique biodiversity. In addition, majority of wetlands in Himachal Pradesh and Punjab offer enormous opportunity of livelihood for local communities, and are major attraction centers for recreation and tourism activities. In the context of Sutlej Riverscape, the Gobind Sagar Lake, Kol Dam Lake, Harike Lake and Ropar Wetland are some of the prominent wetlands of greater ecological, cultural and recreational importance. Majority of these wetlands on account of small size, large interface with urban/ rural environments, traditional resource dependence, and enhanced biotic activities are either deteriorated or in the process of degradation. In view of this, as a part of the proposed forestry interventions in Himachal Pradesh, Punjab and as one of the strategies on Conservation Interventions, the present DPR focuses on Wetland Conservation and Restoration efforts. The proposed strategy for conservation and restoration of wetlands is broadly two pronged i.e., i) The proposed strategy aims to protect, manage and restore priority wetlands within the Sutlej Riverscape; ii) The strategy also focuses on restoration and conservation of featured species and species of concern those are relevant to various wetlands. The activities included in the proposed Model along with nomenclature for the states of Himachal Pradesh and Punjab is as follows:

In Himachal Pradesh (SL/HP/CI /07)

In Punjab (SL/PB/CI /07)

Component-wise details of activities under Wetland Management (Natural and Artificial)

Sr. No.	**Components**	**Activities**	**Year**				
			1	**2**	**3**	**4**	**5**
1	Protection	General Protection from illicit felling, illegal grazing, mining, poaching, etc.	√	√	√	√	√
		Survey and demarcation of boundaries and establishment and maintenance of permanent boundaries	√		√		√
		Physical Infrastructure (Watch Tower, Patrolling Path); Electric Vehicle; Field Equipment - Tranquillization Gun, Night Vision with Binoculars, GPS, etc.	√	√	√		

		Communications	√	√	√		
2	Habitat Management	Habitat enrichment plantations 1. Sloppy area, 2. Riverine area (receded area broadcasting of lintels in strips 3. Riparian area 4. Grass land development	√	√	√	√	√
		Soil and Water Conservations Measures	√	√	√	√	√
		Control of Invasive and Alien Species	√	√	√	√	√
		Creations of Mounds/ Highlands	√	√	√	√	√
3	Wild Faunal Species Management	Conservative Breeding; Re-introduction of Species, etc.	√	√	√	√	√
4	Research and Development	Short Term Projects up to 1 year; Long Term Projects (5-Year) Essential Equipment and Field Infrastructure for facilitation of Research and Development and Monitoring	√	√	√	√	√
5	Eco-development	Basic Infrastructure; Training to Tourist Guides of Peripheral Villages; Interpretation Centre for Nature Education	√	√	√	√	
6	Community Awareness and Participation	Creation of Self-help Groups (SHG), Provision of Revolving Fund for SHG; Alternate Income Generation Activities; Federation for Developing Entrepreneurship and Supply Management, etc.	√	√	√	√	√
7	Ecotourism	Provision of Essential Facilities; Regulation of Tourism Activities, etc.	√	√	√	√	

The following section provides the details of proposed strategy towards Wetland Conservation and Restoration has been described below.

(a) Protection, Management and Restoration of Wetlands along the Sutlej River

In majority cases, the foremost requirement is to; ensure protection of various wetlands and facilitate their scientific management. The Space Application Center, Ahemdabad has provided the baseline information on various natural and manmade wetlands in Himachal Pradesh and

Punjab by way of preparing the inventories and mapping. However, such information is more than 10 years old and there are large scale land use and land cover changes besides rapid development and enhanced biotic activities in Himachal Pradesh and Punjab. Hence, it is of utmost importance that similar exercise is carried out/ repeated on a periodic interval of at least every five year so as to keep track on the current status of distribution and extent of wetlands. Being complex, fragile and dynamic ecosystems, majority wetlands require much desired protection and scientific management. This urgently calls for the preparation of comprehensive management plans adopting the landscape approach incorporating insights from research and monitoring activities. Majority wetland sites require creation of awareness, reduction in biotic pressure, and eliciting people support for conservation of wetlands through the execution of appropriate, site specific strategies on the eco-development. The conservation of wetlands and restoration of degraded wetlands require multidisciplinary insight and appropriate approaches. The officials and frontline staff involved in the protection and management of various wetlands require opportunities for capacity development and support of modern technologies and tools so as to implement prominent activities related to protection, habitat improvement, species management, control of invasive and alien species, eco-development, tourism and visitor management, nature interpretation, and monitoring.

(b) Restoration and Conservation of Aquatic and Riparian Wildlife

The available published literature has revealed the declining state of several prominent and featured species (i.e., fishes – snow trout, exotic trout and several species of hill stream fishes) and narrated recent efforts to restore/ conserve such species. The community led participatory approaches are thus, visualized so as to augment and strengthen populations of RET species. The foregoing review also revealed that there is conspicuous devoid of much desired scientific insight on most of the Rare, Endemic and Threatened (RET) species with respect to their distribution and status, population dynamics, ecology, habitat preference, reproductive behavior, and their likely response to climate change. The Wildlife Wing, State Forest Department of Himachal Pradesh and Punjab, need support for various above stated activities so as to ensure effective protection and management of Wetland Sites/ Protected Areas and conservation of threatened floral and faunal species. Much of the ongoing activities within various Wetlands/ Protected Areas along the Riverscape and its tributaries need augmentation and strengthening.

In view of the above, the following site specific activities are being proposed towards wetland management and conservation as a part of the present DPR and proposed Forestry Interventions:

- **a)** Protection of wetlands and associated floral and faunal species including survey and demarcation
- **b)** Habitat improvement works i.e., desiltation, control/ removal of invasive alien species, creation of mounts, protection of embankments, soil and moisture conservation works, and afforestation
- **c)** Conservation of Rare, Endemic and Threatened (RET) species
- **d)** Ecological and management oriented research

e) Eco-development measures *viz.*, awareness, mitigation of people PA/ human wildlife conflict, sustainable livelihoods and participatory management

f) Nature interpretation and ecotourism

g) Long term ecological monitoring

Accordingly, necessary budget provisions for concerned Implementing Agencies i.e., Forest Departments in Himachal Pradesh and Punjab have been made towards proposed activities for wetland management and conservation (Table 5.41 and 5.42).

Table 5. 41 Cost norms of Treatment Models for Other Conservation Interventions in Himachal Pradesh

Sr. No	Year	SL/HP/CI /06 Riverine and Riparian Management		SL/HP/CI /07 Wetland Management	
		Amount Rs/ha	Mandays	Amount Rs/ha	Mandays
1.	1st year	3,20,000	512	2,80,000	448
2.	2nd year	2,80,000	448	2,50,000	400
3.	3rd year	1,90,000	304	1,60,000	256
4.	4th year	1,20,000	192	1,20,000	192
5.	5th year	90,000	144	90,000	144

Table 5. 42 Cost of Treatment Models for other Conservation Interventions in Punjab

Sr. No	Year	SL/HP/CI /06 Riverine and Riparian Management		SL/HP/CI /07 Wetland Management	
		Amount Rs/ha	Mandays	Amount Rs/ha	Mandays
1.	1st year	3,20,000	374	2,80,000	327
2.	2nd year	2,80,000	306	2,50,000	273
3.	3rd year	1,90,000	194	1,60,000	163
4.	4th year	1,20,000	115	1,20,000	115
5.	5th year	90,000	80	90,000	80

5.6.2 Supporting Activities

In addition to the above stated proposed Forestry Interventions in three types of Landscapes (Natural, Agriculture, and Urban) and three types of Conservation Interventions, execution of priority supporting activities is considered vital for the successful implementation of the present DPR and envisaged wide range of specific activities in the priority sites identified within the Riverscape on the basis of geospatial analysis and inputs from the field. A list of supporting activities is discussed below:

Table 5. 43 List of Supporting Activities

Sr. No.	Himachal Pradesh	Punjab
1.	SL/HP/SA/01- Policy Level Intervention	SL/PB/SA/01- Policy Level Intervention
2.	SL/HP/SA/02- Strategic Adaptive Research and Development	SL/PB/SA/02- Strategic Adaptive Research and Development
3.	SL/HP/SA/03- Participatory Monitoring	SL/PB/SA/03- Participatory Monitoring
4.	SL/HP/SA/04- Capacity Development	SL/PB/SA/04- Capacity Development
5.	SL/HP/SA/05- Awareness	SL/PB/SA/05- Awareness
6.	SL/HP/SA/06- Evaluation	SL/PB/SA/06- Evaluation
7.	SL/HP/SA/07- Project Management	SL/PB/SA/07- Project Management

a) **Policy Level Interventions**

It is evident from the review that the complex and emerging subject of River conservation and Restoration in country like India is backed up by numerous acts and policies. There is a growing concern about the plight of rivers in India at all levels. However, at the same time, there have been several governmental and nongovernmental initiatives towards river conservation including a large number of judgments and specific directives by the various Hon'ble Courts including NGT so as to safeguard the interests of River ecosystem, surrounding lands, dependent communities, and various user agencies. However, despite considerable progress in recent decades, there are gaps and several issues those continue to affect the River and associated

biodiversity, production sectors, and even the human communities all along the main Riverscape and its tributaries. Undoubtedly, a wide range of stakeholders including numerous government agencies are involved in efforts towards River conservation and there are competing demands and conflicts. By and large, isolationist approaches are still being applied. In the absence of single agency overseen River conservation, there are serious issues of coordination and monitoring. In absence of appropriate alternatives, most concerned government agencies find difficult to effectively implement/ enforce various legislative acts and even the directives of the Hon'ble Courts. In general, the desired institutional framework and infrastructure is inadequate to tackle the complex nature of River ecosystem spread over large extent. Hence, augmentation and strengthening of existing policy and legal frameworks are desirable and much needs to be done so as to recover the past glory of the Sutlej River and its tributaries. In view of this, appropriate interventions related to improvement in the policy, law and institutional context are proposed as a part of the present DPR and to be implemented in the plan period. Necessary budget provision for envisaged policy level interventions by way of Reviews, Seminars, Workshops, Visits, Field Level Assessments and Monitoring has been made. An amount of Rs.44.86 crore has been provisioned for this purpose for the National Level Partner Organization while a provision of Rs.60.61 crore for Himachal Pradesh and Punjab has also been envisaged.

b) Strategic Adaptive Research and Development

Certainly, the discipline of River ecology, management, restoration and conservation is relatively newer in the country and not much work has been done. Moreover, the approach has been largely piecemeal, fragmentary, and isolated in nature. Much of the information on various aspects of rivers come from different government agencies those are responsible for cryosphere, surface water, groundwater, pollution control, irrigation, hydropower, etc. Most of the researches by various Scientific Organizations, Universities and Individual efforts have focused so far on inventory of glaciers and wetlands, glacier retreat/ snowmelt, surface water, groundwater recharge and development, water quality and impact of various developmental and biotic activities. Often, such initiatives are just one time efforts or in project mode. In several instances, information is obsolete or specific to a particular tributary or stretch of a larger river. Only recently, first time effort has been made to carry out comprehensive study on cumulative impact of HEPs and carrying capacity. Ecological insight on threatened taxa in the Riparian and Riverine environments is generally poor. There have been hardly studies on the various aspects of socioeconomics and human impacts on the River ecosystems. The subject of restoration of rivers in India is almost new. Hence, neither desired knowledge nor essentially required tools and techniques are available those can be deployed in the socioeconomic milieu of the country. In view of this, priority action research is proposed during the plan period by concerned agencies and expert organizations. The experience towards proposed holistic forestry interventions for restoration of a major Himalayan Rivers like Sutlej River is relatively new, except little experience gained by the country in programme implementation in the context of rejuvenation of Ganga River. Thus, the present DPR seeks adoption of holistic, integrated, multidisciplinary and

multiscale approach to forestry interventions by executing plantation activities, soil and water conservation measures, Riparian and Riverine wildlife management, and Wetland management. As a part of the supporting activities, priority research as the concurrent activity is proposed by the national partner organization, SFDs and other concerned agencies. Research findings would immensely help the agencies ineffective implementation of the present DPR and in similar efforts on other rivers. Concurrent research is proposed to be taken up on the following priority thrust areas

i) Forest Hydrology Studies

It is well established fact that forests not only influence the hydrological cycle, but they also have profound effect on water resources both quantitatively and qualitatively. The study of water in forests called *Forest Hydrology* includes, the distribution, storage, movement, and quality of water; hydrological processes within forested areas; and the delivery of water from forested areas (Sun *et al*., 2016; NRC, 2008). Forest hydrological science is regarded as the foundation of modern integrated watershed management. Hence, the subject of Forest Hydrology has been of great interest for long to natural resource professionals and policy makers. As such, Forest Hydrology is an interdisciplinary science that evolved from the specialization of traditional hydrological science and forest ecosystem science during the past century and enormous literature exists on the subject, primarily from the western world. However, in spite of nearly 125 years old elaborate countrywide infrastructure exists on forestry research in India, the discipline of Forest Hydrology has been poorly addressed. The comprehensive review on the subject in Part 1 of the present DPR amply revealed this situation. All major rivers in the country and other freshwater resources are on decline. There is growing concern about the poor state of rivers and other freshwater resources. Hence, there is an urgency to initiate priority research in the field of Forest Hydrology in diverse forests of the country so as to understand how different forests are helping in distribution, storage, movement, supply and quality of water. Likewise, to answer the pertinent question that how Forestry Interventions, particularly plantations in different biogeographic/ agro climatic zones.

ii) Screening of Suitable Species and Pilot Trials on Bio-remediation and Bio-filtration

Most rivers in the country suffer on account of multitude of pollutants, waste and sewage originating from agricultural lands, industries and the urban environment. Both organic and inorganic contaminants find their way into rivers and other freshwater resources. Heavy metals are likely to be more in both municipal waste waters and industrial effluents. Approaches like Phytoremediation, Bioremediation, and Bio-filters have been developed to treat pollutants in such waters. Removal of metals through phytoremediation techniques and the subsequent recovery of the metals or their safe disposal are attracting research and commercial interests. Bioremediation is being used as a method to treat waste water wherein biological organisms are used to convert the hazardous waste into nontoxic or less toxic substances. Usually, microorganisms are being used for Bioremediation of sewage. Much work has been done in

these emerging technologies, mainly in developed nations. However, in India these technologies are relatively newer and infancy. Only handful sporadic efforts have been made so far in this direction and the success stories have been inadequately documented and disseminated. Nevertheless, these technologies have enormous potential to treat contaminated water prior to their release in the river or other wetlands. There is an urgency to initiate and support pilot trials in these priority fields in collaboration with potential scientific institutions and also to undertake researches on screening of suitable species for such purposes. The results obtained can be applied not only to Sutlej River, but also on its tributaries, other major river systems and water bodies of the country.

iii) Evaluation of Ecosystem Services Especially in Provisioning of Water Supplies

The concept of ecosystem services has become part of any approach towards conservation of biodiversity water, primary industries, human settlements, regional planning and climate change. The role of natural ecosystem towards contributions to the quality of human life and human wellbeing has gained public interest in recent decades (Close *et al.,* 2009). Ecosystems services and their continued provision underpin human existence, health and prosperity. Diverse natural ecosystems provide ecosystem services within four categories *viz*., provisioning, regulating, supporting and cultural. Different forest ecosystems and forestry plantations provide a wide range of goods and services, both tangible and intangible in nature. Tangible benefits like timber, Non-Timber Forest Products (NTFPs) including MAPs, fuel wood, and fodder have been adequately quantified arising from various provisioning services. However, water supply under provisioning services, soil conservation under supporting services, and environmental amelioration under regulatory services are yet to be quantified. Likewise, River ecosystems also provide a wide array of ecosystem services. In general, researches in the context of services provided by forests as well as River ecosystems in the country are wanting. Hence, it is proposed to support priority researches in this field.

iv) Bio-engineering Methods for Soil Conservation and Stream/ River Bank Stabilization

The review on the Riverscape and its environment highlighted that the Himalayan Rivers like Sutlej River and its tributaries are severely impacted by soil erosion and eroding stream/ River banks owing to landslides, steep slopes, higher rates of runoff, and enhanced developmental/ biotic activities. Thus, soil and moisture conservation, and stabilization of stream/ River banks are amongst the priority activities towards river restoration. The use of biological and engineering measures in combination or biological interventions alone to control soil erosion and improve moisture conservation is referred as bioengineering measures. Appropriate bioengineering measures involving suitable cultural practices and plant species in addition to engineering structures have proven to be the cost effective methods to check soil erosion and efficient soil moisture conservation strategy. Newer ecofriendly materials (e.g., geojute) are being extensively used in stabilizing steep slopes and checking soil erosion. However, researches

in this emerging field need augmentation and strengthening, particularly in identification of newer ecofriendly materials, appropriate use of solid waste, screening of suitable plant species, and designing new bioengineering models. Hence, proposed research activities in this emerging field with a focus on innovative and low cost bioengineering methods for Riverbank Stabilization and Soil and Moisture Conservation are envisaged by the National Level Partner Organization in collaboration with SFDs and the Indian Institute of Soil and Water Conservation, Dehra Dun and its Regional Centers.

v) Biodiversity, Forestry and Livelihoods

The world over, humanity is strongly intertwined with forests as they offer wide range of ecosystem services. Forests also provide habitat for wildlife, and are repository of biodiversity. Forests play a vital role in the rural economy. In India, it has been observed wherever there is a large concentration of forests, there is also high concentration of tribal people in particular and of the rural population in general. Rural people are dependent on forest resources for their livelihood. Forests not only provide resources for economic subsistence, but they are also a way of life socially and culturally. Sustainable livelihood is increasingly linked to the maintenance of 'Natural Capital' and environmental conservation at large. The Sustainable Forest Management (SFM) has been recognized as the pillar of biodiversity conservation and ensuring livelihood security of the local people. The United Nations adopted the Agenda 2030 with its core element, the 17 Sustainable Development Goals (SDGs) in September, 2015. Further, it has been realized that forests not only have a special role to just contribute to the Goal 15 (Life on Land),but forests have greater role to play in achieving several interconnected SDGs. Like most other natural ecosystems, the world over forests has also suffered due to enhanced human activities and face enormous challenges. In past five decades or so, country has made concerted efforts to protect and conserve diverse forests in different States and UTs through appropriate innovations, policy and legal interventions, setting aside significant proportion of forest lands as protected areas, wildlife management and conservation of biodiversity, wetland management, integrated watershed management, adoption of participatory community led approaches, implementation of Afforestation Programmes, actions for recovery and conservation of RET floral and faunal species, research and monitoring, capacity development, etc. However, much needs to be done. A comprehensive research agenda on priority themes relevant to SFM, biodiversity conservation, management of NTFPs, fire management, eco-development and sustainable livelihoods needs to be planned and implemented. It is proposed that the National Level Partner Organisation made responsible under this DPR for research, monitoring and capacity development will carry out researches on the above stated thrust areas in collaboration with SFDs and other National/ State Level Scientific Organisation.

vi) Climate Change Mitigation and Adaptation

The Sutlej River originates in the Tibet (China), flows into Himachal Pradesh, traverses through the steep mountains, and finally flows through the alluvial plains of Punjab. The fragile mountain environment of the Riverscape in Himachal Pradesh is extremely sensitive to the

changes in the global climate system, with widespread glacial retreat being one of the major signals of warming temperatures over the past century. The glacial retreat coupled with enhanced human activities by way of expansion of agriculture, infrastructural development, urban growth, and other environmental pressures are considered as significant climate related threats to the River ecosystem, snow cover and high altitude wetlands, forests and biodiversity including aquatic biota, human lives, and livelihoods. The review on the Riverscape and its environment has highlighted that one of the prominent/ larger glaciers in Sutlej Riverscape is Baspa glacier occupies an area of about 35 km^2in the southeastern part of Kinnaur District, Himachal Pradesh. Likely implications of climate change are expected to alter the structure and composition of forests and the distributional range of some of the featured floral and faunal species. Uncertain climatic events (i.e., avalanche, cloud burst, floods, droughts, etc.) are expected to impact the River, surrounding lands, and environmental flows besides local communities and their livelihoods. The State of Punjab is considered as the granary of the country due to its contribution towards the green revolution and production of food crops. The semiarid State is overdeveloped in terms of its groundwater and prone to droughts and floods. Climatic perturbations arising due to global warming are recognised as serious threats to this economically important agriculture horticulture belt and food security in the region. Thus, the slightest changes in the climate patterns can have large implications on the Sutlej River and its tributaries, not only for their own ecological values but also for larger humanity in two States. As of now, there is poor insight on the nature of impending impacts and the ways and mean to adapt and mitigate. Hence, it is proposed that the National Level Partner Organisation undertakes the priority researches relevant to this important theme involving other State/ National Level Scientific Organisations.

viii) Support of Modern Technology in Natural Resource Management (NRM)

Degradation of natural resources is a growing concern that threatens the livelihoods of millions of people. Innovations by research and development organisation, and local communities themselves have produced several promising technologies and practices for making natural resource management more productive and sustainable. The advent of modern technologies in the fields *viz*., remote sensing and GIS, IT, biotechnology and genetics, waste management, forestry and agricultural operations, wildlife conservation, nanotechnology, water use and efficiency etc. have opened several avenues for effective planning and managing of vital natural and manmade resources including cryosphere, forests, wetlands, wildlife, agriculture. However, the potential of advanced technological interventions in NRM is yet to be fully explored. Hence, collaborative researches with the aim to augment and strengthen advanced technological support in NRM are envisaged and proposed as part of the present DPR. The National Level Partner Organisation is expected to play a lead role in this endeavor so as to encourage active involvement and partnership of related organisations. In addition to National Level endeavors, the site specific researches in the aforementioned technology fields are proposed to be encouraged, supported, and facilitated by the state level organisations. As the subject of River conservation and restoration is relatively new for the country and very little experience exists at

this juncture, it is proposed that the National Level partner organisation would organize a research need analysis workshop involving all the probable research organisation so as to plan the research agenda for this priority field and to facilitate the cooperative research.

c) Participatory Monitoring

The adverse impacts of past river use and developments have been widely recognized in recent decades (Malmqvist and Rundle, 2002; Tockner and Stanford, 2002; Woolsey *et al.*, 2007). Thus, elaborate restoration attempts are underway worldwide to return human impacted rivers to more natural states and to restore lost ecosystem services (Palmer *et al.*, 2004; Speed *et al.*, 2016, Jhonsan *et al.*, 2019). Off late, the Government of India has also decided to restore major rivers of the country and new initiatives have been launched. Assessing the outcome of River restoration projects is vital for adaptive management, evaluating project efficiency, optimizing future programmes and gaining public acceptance. Participation of the various stakeholders and the public in River restoration is increasingly prompted because it is expected to improve resource management and enable participants to engage freely and equally in management. The present DPR has earlier provided an overview on the diverse stakeholders associated with the River, its use, management, restoration, and those are impacted by the River. As a part of the preparation of this DPR, one of the key components was on the involvement of various stakeholders and following the process of extensive consultation at all levels. Concurrent, participatory, results based monitoring is envisaged while implementing the present DPR on Forestry Interventions.

d) Monitoring: Monitoring, evaluation and adaptive management play vital roles in supporting effective River restoration. Monitoring against defined and measurable objectives is critical for assessing the effectiveness of river restoration measures and for guiding adaptive management. Monitoring describes the process of gathering qualitative or quantitative data at periodic intervals, using predetermined indicators of progress towards project or programme objectives. The following regions dictate that the process of monitoring be made an integral part of the programme implementation on proposed Forestry Interventions in the Sutlej River

a) **Seasonal Activities and Timely Implementation:** Most proposed Forestry Interventions (i.e., soil and moisture conservation, planting and allied activities) are seasonal in nature. Moreover, the Himalayan mountainous tract in the upper part of the Riverscape allows limited time for field activities owing to harsh climatic conditions and the larger extent of the Riverscape is inaccessible during winter when areas are covered by snow. Timely implementation of proposed seasonal activities is vital for the success of the programme. Thus, regular monitoring of progress is essential so as to minimize any risk of failure.
b) **Involvement of Multiple Agencies and Stakeholders:** Proposed Forestry Interventions so as to rejuvenate the Sutlej River would be spread across Himachal Pradesh and Punjab and it would involve multiple agencies and stakeholders in its implementation. Forestry Interventions have been planned in Natural, Agriculture and Urban Landscapes. Obviously,

it would include a wide range of stakeholders and implementing partners. Hence, periodic monitoring of the progress of various works through appropriate mechanisms is considered essential.

c) **Adaptive Management:** River conservation and restoration are complex activities and prone to several uncertainties. Moreover, river restoration programmes such as forestry interventions in the context of a river are relatively new and very little experience exists within the country. Thus, the adaptive management as an inbuilt programme is vital. Adaptive management is often used in generic sense to reflect the need for flexibility in project and programme management in the light of evidence gathered through monitoring and evaluation programme. Adaptive management is a tool that can be used not only to change a system but also to learn about the system. Since adaptive management is based on practice and learning through monitoring, therefore, it improves long run management outcomes and builds adaptive capacity (Speed *et al.*, 2016).

d) **Transparency and Accountability:** Increasingly, there is greater emphasis on transparency and accountability in the prevailing system of governance, particularly when the tax payer's money is involved. Regular and periodical monitoring ensures much desired transparency and accountability in the programme implementation at various levels.

Monitoring Needs: Thorough review on the existing situation of the River and its Environment, of the present DPR has provided much desired insight about the varied monitoring activities (i.e., glaciers and snow cover; climate – rainfall, snowfall, temperature, wind, etc.; surface water and runoff, groundwater and aquifers, sedimentation, forest cover, growing stock, carbon sequestration and fire incidences, e-flow and water quality, wetlands and water birds, fish production, population monitoring of RET floral and faunal species; visitors to tourism sites; and demography), undertaken by different Central/ State Level Departments and Agencies. Some of these monitoring activities are well designed, planned, executed and supported by appropriate institutional mechanisms and carried out either on regular basis or for longer stretches. Definitely, to a great extent baseline information for several important themes, components and variables is available. Nevertheless, there is ample scope to strengthen and augment the current monitoring activities. The Logical Framework Analysis provides a broad based insight on verifiable indicators. However, it is proposed to firm up the verifiable indicators, methods and periodicity besides monitoring sites, etc. so as to ensure a meaningful and diagnostic monitoring on regular basis for vital aspects of the River ecosystem. It is also proposed to plan for collection of baseline data wherever required during the first year itself. This can be facilitated by the National Partner Organization responsible for research, monitoring and capacity development.

Concurrent Monitoring Mechanisms for Proposed Forestry Interventions: Considering the complex and dynamic nature of river ecosystem, and the fact that the vast area is covered within the Riverscape and much of the area is in difficult terrain and inaccessible, it is essential to adopt various concurrent monitoring mechanisms and relevant tools for carrying out envisaged monitoring activities. Thus, concurrent monitoring mechanisms include: (a) IT enabled

monitoring, (b) RS and GIS based monitoring, (c) Online monitoring through Web portal, (d) On ground monitoring, and (e) Participatory monitoring. In recent times, increasingly Mobile app based monitoring on real time basis in a much more transparent manner is possible. Thus, it is proposed to incorporate IT/ Mobile app based monitoring. Since large, difficult and inaccessible areas form the major part of the River Basin/Riverscape, optimal use of RS and GIS technologies, particularly for monitoring glaciers; sedimentation in reservoirs; and changes in channel morphology, Land Use and Land Cover, snow cover, forest cover, wetlands, cropping pattern, etc. The SFDs and other Governmental Agencies have established their own state of the art RS and GIS facilities which can be used effectively for the monitoring purpose. However, single time financial assistance is proposed to SFDs in two States for upgradation of existing GIS facilities, procurement of desired hardware and software, and high resolution satellite data. The Forest Survey of India, Dehra Dun or its Regional Centers would play an important role in carrying out RS based monitoring of forest cover. Online monitoring of the proposed interventions is being planned through Web Portal developed by the HFRI, Shimla during the process of preparation of DPR. The Portal would be able to incorporate and process all vital information like area and extent, geo references and locations of each of the activity, financial expenditure, plantation survival status, maintenance works, and actual pictures of field sites at various stages of programme implementation and progress. This online web based monitoring shall not only facilitate the compilation of desired information for each of the type of Landscape/ Forest Division/ State and even the entire Riverscape on yearly basis, but would also facilitate instant query and report generation. In addition, on ground monitoring by way of participatory monitoring at division level and third party monitoring are envisaged. The proposed monitoring would include physical as well as financial progress aspects at the local level and shall be monitored jointly by the field level staff of Forest Department and select Community Based Organizations. The monitoring reports shall be submitted by the Divisional Forest Officers to the Principal Chief Conservator of Forests. The scope of monitoring would include the extent treated, expenditure details, survival of plantations, performance of other activities, flow of tangible benefits to the community and adherence to time schedules. The SFDs may design Performa for participatory monitoring based on local needs. Local Level Monitoring is proposed to be carried out annually while incorporating vital physical parameters such as e-flow/ discharge rate of streams and silt load at randomly selected field sites in each of the Forest Divisions. In addition, it is proposed to select at least ten points each on different streams/ tributaries contributing to the main channel and shall be randomly selected in different micro watershed areas in each division. Monitoring of environmental flow and siltation shall be carried out seasonally. Further, the DFOs will submit a quarterly progress report of physical and financial achievements. The quarterly reports so obtained from the divisions/ FDAs shall be compiled for analysis by the PMU under SFDA at the State level and submitted further to the PMU of the Central Nodal Ministry and the National Partner Organizations for consolidated monitoring purpose. The proposed multi-tiered monitoring mechanism for Proposed Forestry Interventions in Sutlej Riverscape is depicted in Fig. 5.44.

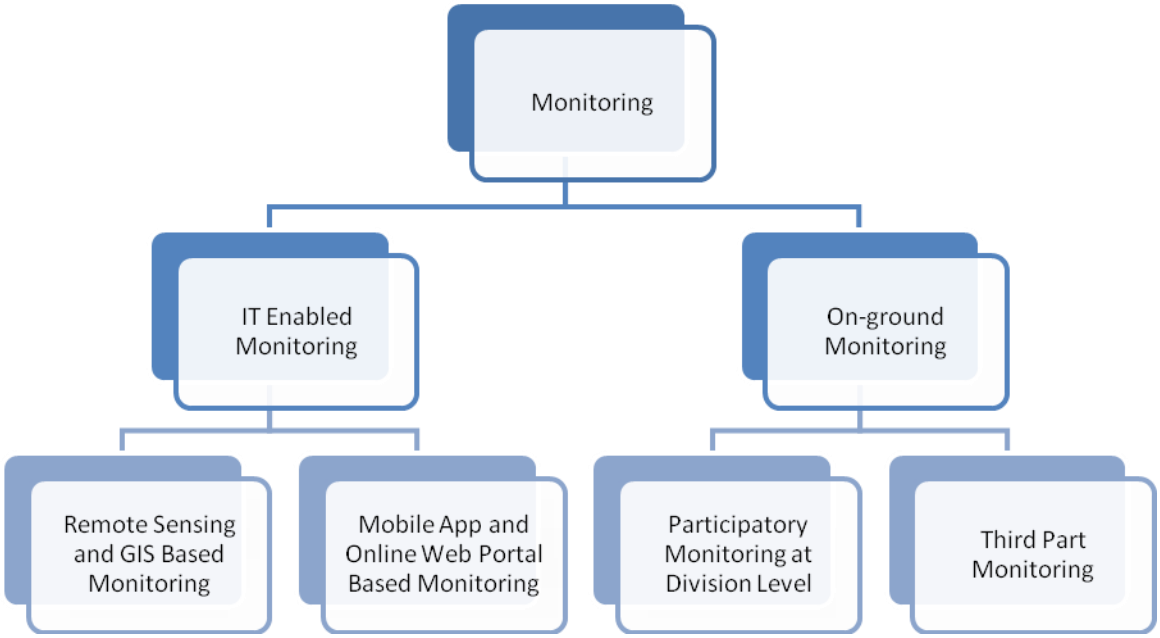


Fig. 5. 44 Multi-Tiered Monitoring Mechanism for Proposed Forestry Interventions in Sutlej Riverscape

In short, the implementation plan envisaged multi-tiered monitoring mechanism for monitoring progress of the project as well as achievements of objectives. The National Level Partner Organization (most likely HFRI, Shimla) selected by the Central Nodal Ministry implementing the project will be responsible for comprehensive monitoring besides State/ Local Site Specific Monitoring would be undertaken by the concerned SFD. The monitoring and evaluation of the program will be carried out as per the existing State norms. However, a budgetary provision for developing a comprehensive monitoring programme as well as its implementation has been made which accounts for about 2 2.5% of the total cost of the project.

e) Capacity Development

The world over, the development agenda is being implemented for past several decades by various International/ National/ State/ Local Governments with mixed success. Often, developmental projects are not yielding desired results and a reasonably high number of projects even fail. One of the primary reasons of failures of major developmental projects in spite elaborate planning and huge investments is the inadequate capacity.

Capacity Development: Capacity has been defined as the ability of people, organizations and society as a whole to manage their affairs successfully; whereas the *Capacity Development* has been defined as the process whereby people, organizations and society as a whole unleash, strengthen, create, adapt and maintain capacity over time (UNDG, 2008).Further, National and International Agencies engage in addressing global challenges (e.g., land degradation; water

crisis; food insecurity; depleting 'Natural Capital' and loss of biodiversity; poverty; hunger; malnutrition; social issues – gender, equity and peace; and climate change) or contributing towards specific sector or the agenda of development increasingly emphasize on decentralized, bottom up, participatory, science based, integrated approaches, essentially seeking building alliances, interagency cooperation and sectoral convergence. There is now emerging agreement in the community development that capacity development at all levels is of utmost importance and is the engine of human development. Capacity development starts from the principle that are best empowered to realize their full potential when the means of development are sustainable – homegrown, long term, generated, and managed collectively by those who stand to benefit.

According to UNDP (2009), the 'Capacity is Development' and the capacity development is about transformations that empower individuals, leaders, organizations and societies. Capacity development is aimed at effective and informed participation in decision making for implementation of any programme towards sustainable development. Capacity development initiatives go much beyond raising awareness of stakeholders and aim at developing the capacity of diverse stakeholder groups to appreciate the multifaceted issues, and their own role within a complex set of actors and dynamic environment. Most agencies aim to bring desired change in policy framework, mindsets, attitudes, perceptions, functional approaches, and foster an enabling environment in view of the emerging requirements. Diverse stakeholder groups at various hierarchical levels depending upon their interests, roles and responsibilities, needs, and expectations require different knowledge, ability, and skills for taking active part and to make meaningful contributions in the participatory processes. In recent time, the concept of capacity development has undergone notable transformations conceptually, operationally, and institutionally. Conceptually, efforts of capacity development seek an enlarged and broader scope beyond the capacity enhancement of individuals, instead now it also focuses on societal and organizational transformation. Thereby, creating appropriate space for and management of dialogues, relationships, collaborations, partnership, knowledge networks, and incentives for efficiency, performance, transparency, accountability, and sustainability.

In past, the sole emphasize was on physical targets and outputs. However, in the change scenario, the operational transformation of capacity development emphasizes on processes and mechanisms that lead to desired outcomes, and impact. Institutionally, capacity development initiatives are at the core of the work of the countries and National Governments and they are embedded in the National development strategies as well as Sub National Developmental Plans. Capacity development is central for ensuring ownership of any development plan for effective resource management, empowering communities and civil society, scaling up, sustaining progress overtime.

River Conservation–Intricate Nature: Certainly, the agenda of River conservation and restoration for India is relatively new. Proposed Forestry Interventions for River restoration aiming *Aviral Dhara, Nirmal Dhara* and ecological integrity of the River lays emphasis on a holistic and integrated approach for achieving goals of Sustainable land and River ecosystem

management, increased forest/ vegetation cover, improved livelihoods and build resilience for climate change. The envisaged thrust of the project is on 'Multidisciplinary', 'Multisectoral', 'Multistakeholder' and 'Multiscale'approach. In order to achieve project goals and objectives, SFDs of Himachal Pradesh and Punjab as Implementing Agencies would need cooperation and collaboration of various Line Agencies and Local Communities. Various measures *viz*., plantations in different types of Landscapes (i.e., Natural, Agriculture and Urban), Conservation Interventions (i.e., Soil and Moisture Conservation, Riparian and Riverine Wildlife Management, and Wetland Management) and Supporting Activities (i.e., policy level interventions, strategic adaptive research and development, participatory monitoring, capacity development, awareness, evaluation and project management) have been planned. The project implementation would require partnering, collaboration and convergence. The intricate nature of River and of the above stated holistic approach towards river Conservation and Restoration essentially requires capacity development of various target groups.

Objectives of Capacity Development: The Logical Framework Analysis has summarized the vision, goals, and objectives of river Conservation and Restoration along with envisioned outputs and outcomes. Accordingly, objectives of capacity development lay emphasize on participatory planning involving various line agencies and engaging communities at the grass roots level. Development of soft skills relevant to communication, advocacy, negotiation, conflict resolution, etc. is a prerequisite for varied stakeholders, particularly in case of professionals representing different Line Agencies, and Local Communities. Considering the intricate nature of river and associated measures for River restoration, it is proposed to build professional competence and develop skills for science and technology based backstopping. The agenda of capacity development would need to focus on sustainable livelihoods alongside effectively managing and maintaining natural resources as the natural capital. Enhanced capacity for monitoring and evaluation is also proposed. A wide range of stakeholders are expected to be involved in proposed plantation activities in three types of Landscapes besides implementation of different Conservation Interventions. Hence, one of the objectives of capacity development would be to enhance capacity in the field of Forestry Interventions. The holistic approach to River conservation essentially requires sectoral integration, convergence and sustainability. Thus, developing appropriate capacity in these specialized fields is envisaged as one of the objectives. Various objectives for capacity development are presented in Fig. 5.45.



Fig. 5. 45 Objectives of Capacity Development

Core Modules: The newer generation approaches towards River Conservation and Restoration emphasize on the river basin or Riverscape approach wherein the linkages between the upstream and downstream, Riverine *Lotic* System and the adjacent Riparian zone, surface water and groundwater, and environmental flow and aquatic biota matter. The River ecosystem management efforts are regardless of administrative and legal boundaries and require application of different scales.

In view of the above, the capacity development efforts for River Conservation and Restoration envisage various core modules on: (a) River ecology and ecosystem management, (b) Organizations and project management, (c) Participatory approaches and sustainable livelihoods, (d)Science and technology based backstopping, (e) Crosscutting issues, convergence and synergies,(f) Climate change mitigation and adaptation, (g) Forestry Interventions, (h) Monitoring, evaluation and learning documentation, and (i) Sustainability (Fig. 5.46)

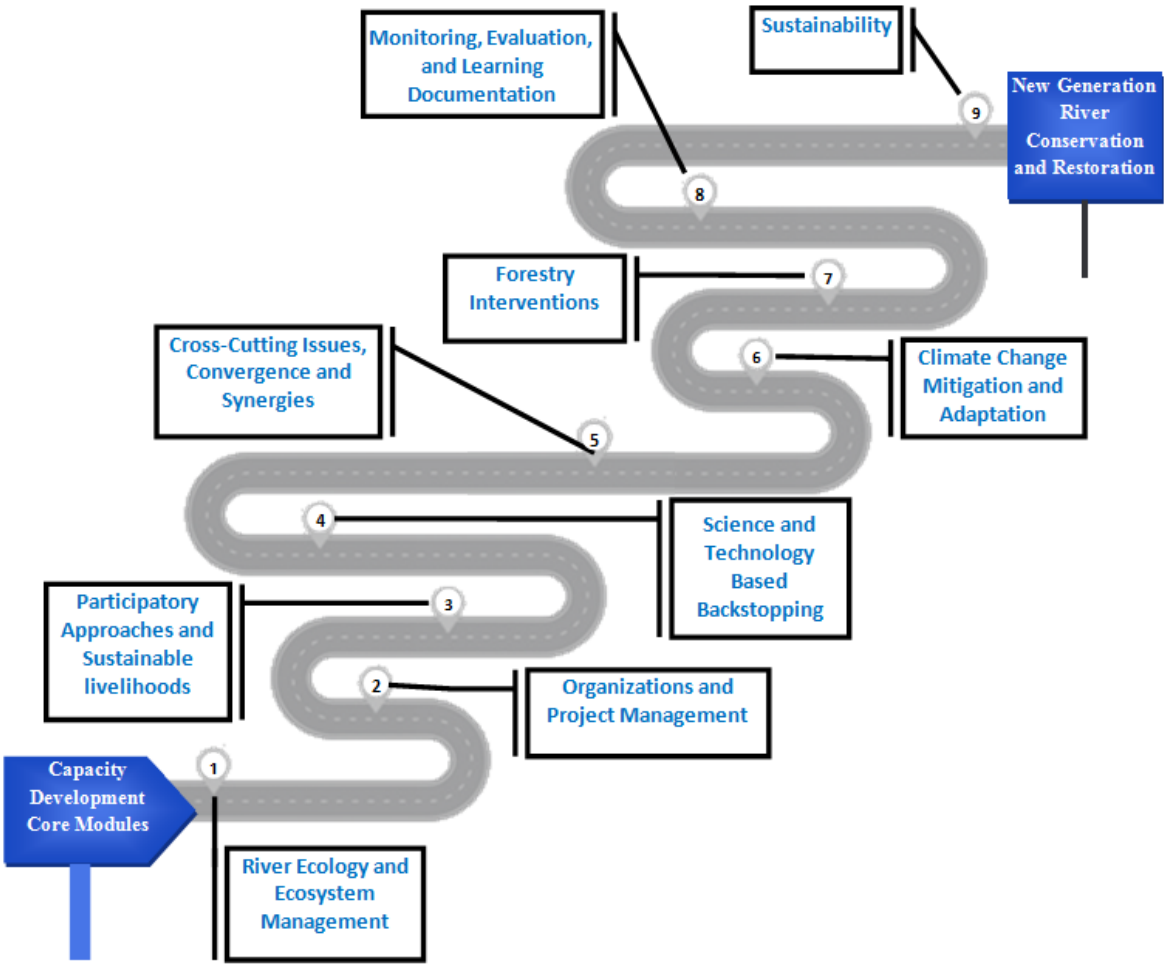


Fig. 5. 46 Capacity Development –Core Modules for River Conservation and Restoration

Target Groups: Broadly, the Target Groups for capacity development can be grouped at four hierarchical levels *viz*., National, State, Division and Community (Fig. 5.47). It is essential to target the right people for specific inputs towards capacity development. Potential target audience at different hierarchical levels includes:

a. **National Level** –Policy and decision makers and professionals of Partner Organizations
b. **State Level** Forest officials and professionals of various Line agencies and Partner Institutions.
c. **District/ Division Level** Forest frontline staff and NGOs
d. **Community Level** – CBOs, Local communities, Farmers, Graziers, Fishermen, etc.

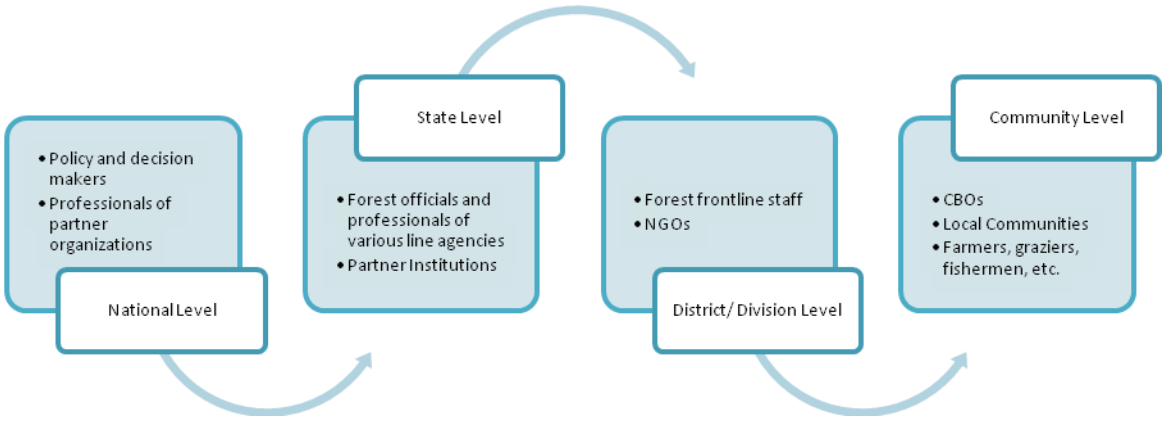


Fig. 5. 47 Capacity Development at Various Hierarchical Levels and Target Groups

Proposed capacity development is expected to improve the knowledge and skills of the professionals, partners, frontline staff of SFDs, local communities and specialized occupational groups.

Trainings, Workshops, Scientific Exchange and Engagement of National/ International Experts: The knowledge and skill development of various target groups can be enhanced through Trainings, Seminars, Workshops, Scientific Exchange, Exposure Visits, Demonstrations and Resource Inputs by National and International Experts. Theme based short duration trainings (23 days) have been planned. Seminar/ Workshops have also been planned. Exposure visits for professionals, frontline staff, local communities and other occupational groups have also been provisioned. The National Level Partner Organization (HFRI) responsible for capacity development would plan and organize for the National Level Capacity Enhancement by organizing trainings and orientation seminar/ meetings, scientific exchange, field tours and overseas visits for professionals and decision makers. Considering the fact that the discipline of River restoration is relatively new for the country, the National Level Partner Organization also plans to involve select reputed National and International Experts, especially in the fields of River conservation and Ecological restoration, Bioremediation and Bioengineering methods, climate change mitigation and adaptation, conservation breeding, policy interventions, and advanced technologies relevant to rivercape management so as to avail their resource inputs in endevaous towards knowledge management and National Level Capacity Development. Necessary budget provisions for such activities have been made in the budget outlay meant for the purpose of capacity development, scientific exchange and management of National and International Experts. The proposed expenditure norms include costs towards payment of honorarium to Resource Persons, training and learning material, travel and transportation, lodging and board, venue charges, and other contingent expenses. The Trainings, Workshops,

Meetings, Exposure Visits, etc. at the State, Division and Community levels will be either conducted in house by the SFDs or outsourced to other relevant specialized organizations or technical agencies having expertise in the relevant field. The cost details towards various activities of capacity development by the National Partner Organization are provided in Chapter 7.

The Trainings and Workshops at different levels to be organized by Himachal Pradesh and Punjab IAs at the State level are also proposed to be conducted as per details given in Tables 5.44 and 5.45.

Table 5. 44 Cost of Capacity Building (Training, Workshops, Seminars and Exposure Trips) in Himachal Pradesh

Sr.No.	Activity	Norms Rs. in lakh	Phase I					Grand Total
			Year					(Cost Rs. in lakh)
			(Cost Rs. in lakh)					
			I	II	III	IV	V	
1	Local Level Training for Communities (16 no. Trainings; 23 days) 25 trainees	3	48	50.40	52.92	55.57	58.34	265.23
2	Division Level Trainings for SFD Personnel, Line Departments and Other Partner Agencies (One Training/ Division/ 23 days) 25 trainees	3	48	50.40	52.92	55.57	58.34	265.23
3	State Level Inception Workshop (23 days) 1	15	15	0	0	0	0	15.00
4	State Level Seminar – Mid Term (23 days) 1	20	0	0	20	0	0	20
5	Exposure Trip Within State (30 participants; two per year)	10	20	21.00	22.05	23.15	24.31	110.51
6	Exposure Trip Outside State (15 participants; One per year)	20	20	21.00	22.05	23.15	24.31	110.51
Grand Total			**151.00**	**142.80**	**169.94**	**157.44**	**165.31**	**786.49**

Table 5. 45 Cost of Capacity Building (Training, Workshops, Seminars and Exposure Trips) in Punjab

Sr.No.	Activity	Norms Rs. in lakh	Phase I					Grand Total (Cost Rs. in lakh)
			Year (Cost Rs. in lakh)					
			I	II	III	IV	V	
1	Local Level Training for Communities (7 no. Trainings; 23 days) 25 trainees	3	21	22.05	23.15	24.31	0.00	90.51
2	Division Level Trainings for SFD Personnel, Line Departments and Other Partner Agencies (1 Training/ Division/ 23 days) 25 trainees	3	21	22.05	23.15	24.31	0.00	90.51
3	State Level Inception Workshop (23 days) One no.	15	15	15.75	16.54	17.36	0.00	64.65
4	State Level Seminar – Mid Term (23 days) 1 and Final year (1)	20	0	0.00	20.00	0	22.05	42.05
5	Exposure Trip Within State (30 participants; two per year)	10	20	21.00	22.05	23.15	24.31	110.51
6	Exposure Trip Outside State (15 participants; 1 per year)	20	20	21.00	22.05	23.15	24.31	110.51
Grand Total			**97.00**	**101.85**	**126.94**	**112.29**	**70.67**	**508.75**

Capacity Enhancement through Technology Adoption: It is essential to incorporate appropriate modern technologies and innovations in the endevour towards River restoration. Thus, capacity enhancement at the National Level, National Level Partner Organizations, and capabilities of field personnel of concerned State Forest Departments (SFDs) is proposed by adopting innovations and modern technologies so as to facilitate efficient implementation of activities envisaged in the DPR. For facilitation of smooth field level operations, the concerned SFDs will require support of physical infrastructure. Accordingly, necessary budget provision has been made to augment and strengthen physical infrastructure including office, computer, RS and GIS, IT and communication, and field equipment. The field staff of SFDs will be provided proper training in the use of GPS, Mobile app, and other modern field tools relevant to analysis of water quality, sedimentation and runoff, plant and animal monitoring, etc.

f) Awareness

All prominent rivers in the country and their tributaries are in the state of degradation due to the fact that the rural and urban populations living along the river course continue to exploit its resources, contaminate and neglect the ecological concerns of the river and contribute in some form of the disturbance or pollution. Thus, it has been lately realized that the public awareness campaign is a prerequisite for any planned efforts towards River restoration. In absence of such efforts, any amount of investments and diversity of interventions would not help in the restoration process of degraded rivers.

A public awareness campaign is an effort to build public recognition of a problem through media, messaging, and an organized set of communication tactics. These campaigns target masses and specific groups of people over a period of time so as to try and generate explicit outcomes or achieve predetermined goals. Public awareness campaigns are important as they can help to facilitate policy change and encourage the community to take action. Campaigns also help to inform the community about the declining condition of the river, factors responsible for the current state, and how they affect the overall environment, economy, livelihoods, ecological integrity of the river, and even the human health. Awareness campaigns can also help in drawing attention of the community in such a way that the information and education provided can elicit their support for river restoration and solicit actions to make changes in current use patterns of river resources, lifestyle and behavior those have been adversely impacting the river and its ecological functioning.

In view of the above, creating awareness and sensitizing the masses on the importance of river restoration and the role public has to play in such efforts are the priority agenda envisaged as a part of the proposed Forestry Interventions. Awareness campaigns are proposed to be directed primarily towards two broad groups i.e., the general public, and the educational institutions, particularly targeting the youth. The SFDs as IAs in Himachal Pradesh and Punjab can adopt different approaches and tools for awareness campaigns and sensitizing the masses. These are: use of multimedia, awareness camps and rallies, posters, brochures, pamphlets, booklets, hoardings, mobile vans, audio visual shows, and celebration of important days (e.g., Water Day,

Wetlands Day, Wildlife Week, International Day for Biological Diversity, Mountain Day, World Environment Day, World Forestry Day, etc.). It is proposed that H.P. and Punjab Forest Departments can organize awareness campaigns in R & D and educational institutions (i.e., Schools, Colleges, and Universities) through the NYKs, Eco-clubs, NSS, NCC, Scout and Guide and other appropriate mechanisms approved by the authorities both in government and private institutions. The Civil Society Organizations (CSOs), NGOs and religious organizations are expected to play pivotal role in this priority endeavor. SFDs can prepare video documentaries highlighting ecosystem services offered by the River; declining state and its reasons; and how public can meaningfully contribute towards River Restoration by way of planting trees, reducing biotic pressure and various contaminants and widely use them for awareness campaigns. Necessary budget provisions for carrying out various activities by SFDs for awareness have been made. Likewise, budgetary provisions have also been made for various envisaged activities relevant to this priority agenda by the National Level Partner Organization. The activities to be carried out by Himachal Pradesh and Punjab Implementing Agencies for effective awareness creation over five years as per the details given in Tables 5.46 and 5.47.

Table 5. 46 Projected Costs of Awareness Programmes for Himachal Pradesh

Sr.No.	Activity	Phase I					Grand Total
		Year					(Cost Rs. in lakh)
		(Cost Rs. in lakh)					
		I	II	III	IV	V	
1	Awareness Campaigns@Rs One lakh/Year/Division	16.00	16.80	17.64	18.52	19.45	**88**
2	Awareness Activities for General Public@ Two lakh/Year/Division	32.00	33.60	35.28	37.04	38.90	**177**
3	Awareness Material – Pamphlets, Brochures, Booklets, Signages, Boards and Hoardings @ Two lakh/Year/Division	32.00	33.60	35.28	37.04	38.90	**177**
4	Publicity Through Mass Media@ Three lakh/Year/Division	48.00	50.40	52.92	55.57	58.34	**265**
Grand Total		**128.00**	**134.00**	**141.00**	**148.00**	**156.00**	**707.00**

Table 5. 47 Projected Costs of Awareness Programmes for Punjab

Sr.No.	Activity	Phase I					Grand Total
		Year					(Cost Rs. in lakh)
		(Cost Rs. in lakh)					
		I	II	III	IV	V	
1	Awareness Campaigns@1	7	7.35	7.72	8.10	8.51	**38.68**
2	Awareness Activities for General Public@2	14	14.70	15.44	16.21	17.02	**77.36**
3	Awareness Material – Pamphlets, Brochures, Booklets, Signages, Boards and Hoardings @2	14	14.70	15.44	16.21	17.02	**77.36**
4	Publicity Through Mass Media@3	21	22.05	23.15	24.31	25.53	**116.04**
Grand Total		**56.00**	**58.80**	**61.74**	**64.83**	**68.07**	**309.44**

g) Evaluation

A strong evaluation mechanism is a core element of a major, multifaceted project on Proposed Forestry Interventions for river Restoration so as to assess the project performance, collect evidence that indicates the extent to which the envisaged outcomes have been achieved, and document what has been the impact of the project to bring desired change. The Logical Framework Matrix has earlier provided details on the range of activities, expected outputs and outcomes, performance and impact indicators along with their means of verification. This information forms the basis to assess the project's impact. The project envisages project evaluation, particularly appraisal of annual progress, Mid Term Review (MTR), and the Terminal Evaluation (TE).

Third Party External Evaluation: Third party or External Evaluation is essential so as to get an independent view of the project activities, performance and impact. The MTR and TE are proposed as independent evaluation involving External Experts other than those who have been neither the part of the project design and development nor of implementation. The independent evaluations would rely on the criteria developed by the third party involved in the process. However, they would also review the monitoring efforts made by the Implementing Agencies at the State and Division levels, the National Partner Organization, and the Central Nodal Ministry at different stages of the project implementation. The MTR would specifically focus on midcourse corrections so as to accomplish the project goals while the TE is expected not only to focus on documentation of project performance, accomplished outcomes and impact, but also provide recommendations for future projects based on learning's. The aim of evaluation is also

to share the knowledge gained in project implementation. The National Level Partner Organization is expected to facilitate project evaluation and would require an amount of Rs. 44.86 Crores, while Rs. 60.61Crores has been provisioned for carrying out various activities related to field evaluation by Himachal Pradesh and Punjab SFDs. State wise cost of monitoring and evaluation has been discussed in detail in Chapter 7, Table 7.4a.

h) Project Management

Proficient administration of project activities is of most extreme significance in accomplishing desired objectives and goals. This requires suitable institutional plans at different progressive levels and a very much structured system for viable usage of the task, especially smooth progression of expected assets to state level execution offices, particularly taking into account the occasional and time bound nature of majority proposed works. Appropriately, Project Steering Committees (PSCs) at two hierarchical levels (National and State) have been proposed. The details on institutional courses of action and system for program usage are given in the DPR. In view of the much desired transparency and efficiency, the optimum use of IT based Mobile app is envisaged.

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CHAPTER-6

PROJECT IMPLEMENTATION – MECHANISM AND SUSTAINABILITY

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6.1 Project Implementation – The Components and Partnership Arrangements

In India, there is a need to ensure water security for the environmental stability and economic prosperity through sustainable management of available water resources. Accordingly, the country's 'Strategy for New India @75' envisages that by 2022–23, India's strategy on management of water resources should facilitate and ensure water security by way of adequate availability of water for life, agriculture, economic development, ecology and environment (NITI Aayog, 2018). The broader vision is aimed to be achieved by attaining the various sectoral goals including a focus on *Aviral* and *Nirmal Dhara* of the National River as well as other major rivers along with their tributaries. Further, the commitment of the Government of India to realize its vision is amply evident from the D.O. Letter No. 11(1)/ 2017 – WR Vol. I, dated 06 June, 2018 issued by the CEO, NITI Aayog, New Delhi to all the Chief Secretaries/ Administrators of all States/ UTs conveying the GoI's decision to launch of a major mission which details how the revitalization of India's River Programme will be implemented on the ground utilizing the existing schemes and programmes of the government with community led efforts. The above mentioned letter stated that 'the programme would be led by the Department of Rural Development (DoRD) under the guidance of NITI Aayog and would target convergence of MGNREGS with other programmes of Central Ministries *viz.*, MoEF&CC, DoAC, MoWR, MoPR, DoLR, and the State Governments.

Considering the significance of revitalization of major Indian rivers and their tributaries from the perspective of environmental stability and economic prosperity and also in the view of the above directives by the NITI Aayog, the National Afforestation and Eco development Board (NAEB) under the MoEF&CC has entrusted the major task to ICFRE and its institutes to prepare the DPRs of nine (09) major rivers of the country including five Indus Rivers Basin. NAEB has not only provided full financial support for the purpose (project formulation) but also advised to follow the pathway earlier adopted in the preparation of DPR on forestry interventions in the context of rejuvenation of River Ganga. In the case of Ganga, the *Namami Gange* Programme of the NMCG has provided the financial support for implementation of the programme. However, in the present case, the MoEF&CC may either decide to implement the project formulated in the present DPR at its own or request the MoJS to provide required funds for execution or implement as a joint venture in collaboration with any other central ministry/ national or international agency. Alternatively, the MoEF&CC may decide to implement the specific component(s) of the project and implement the whole programme in partnership with other Ministries/ Agencies. The Project envisages the following four Components of programme implementation (Fig. 6.1):

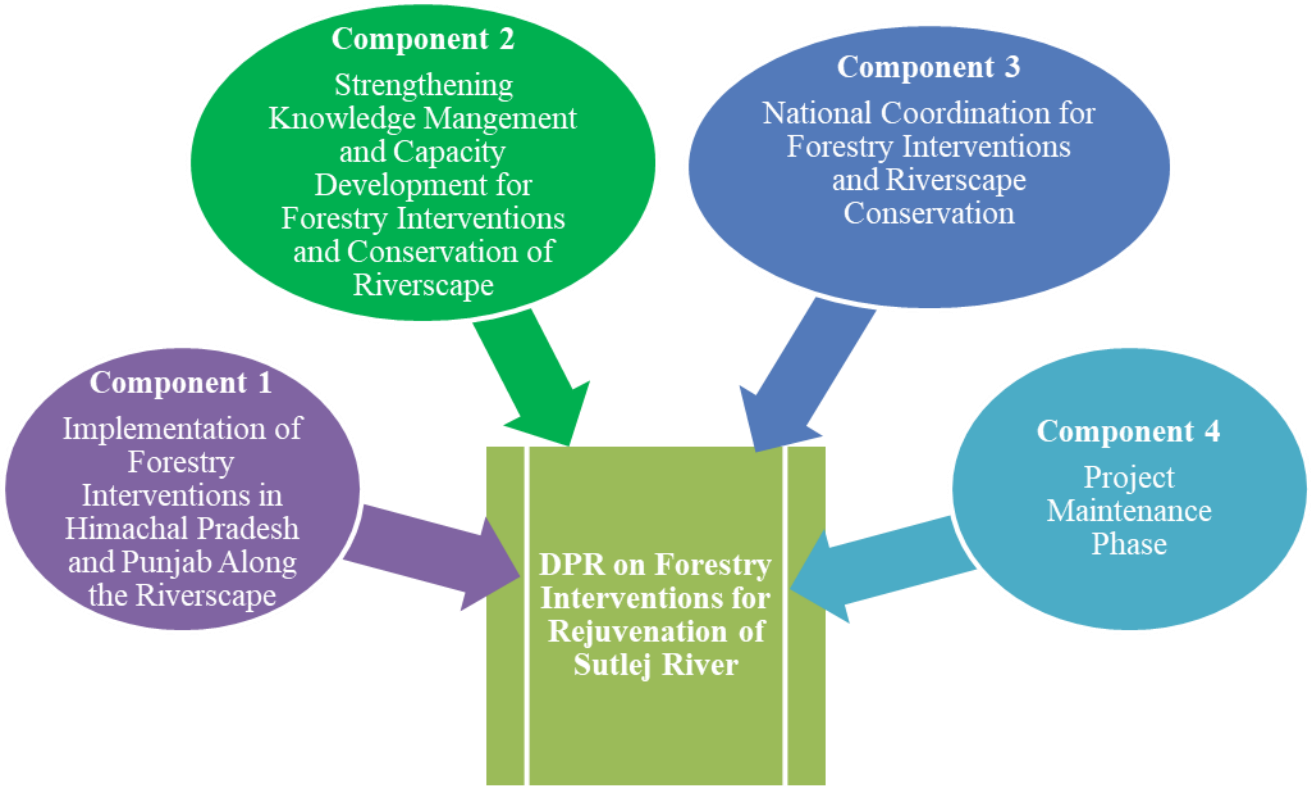


Fig.6. 1 Four Components of the Project

Component 1: Implementation of Forestry Interventions in Himachal Pradesh and Punjab of Sutlej Riverscape

The Component 1 of the Project specifically deals with the proposed forestry interventions in Himachal Pradesh and Punjab, along the course of Sutlej River. The Component 1 includes three subcomponents: (i) the proposed 'Forestry Interventions in three lower order subzones' delineated within the riverscape *viz*., (a) Natural Landscape (NL), (b) Agriculture Landscape (AL.), and (c) Urban Landscape (UL) adopting appropriate plantation treatment models; (ii) 'Conservation Interventions'; and (iii) 'Supporting Activities'. Besides proposed extensive plantation in three types of landscapes within the riverscape, the significant inputs under the subcomponents on Conservation Interventions by way of soil and water conservation, Riparian and riverine wildlife management, and wetland management have been envisaged. In addition, concerned participating States will carry out 'Supporting Activities' referred as 'Themes' at the State and local levels those are critical and supportive in nature for the overall success of major project on forestry interventions. Prominent proposed supporting activities include: (a) policy level interventions; (b) concurrent research and development; (c) participatory monitoring; (d) capacity development; (e) awareness; and (f) evaluation. Further, in order to ensure effective implementation, coordination, and monitoring of the State wise project activities, supports for the establishment and smooth running of the State level Project Management Units (SPMUs) one

each in Himachal Pradesh and Punjab is also provisioned as a part of this Component. The subcomponents and various anticipated activities are summarized in Fig. 6.2.

The Project expects that the State Forest Departments (SFD) of Himachal Pradesh and Punjab will be responsible for implementation of the Component 1 that primarily includes plantation activities in three types of landscapes. Hence, the SFDs of Himachal Pradesh and Punjab would be the Implementing Agencies (IAs) for this major component. The Chapter 4 has already provided an insight on the organizational structure, mandate, functions and activities, schemes, past experiences of SFDs in afforestation, forest management, protected area management, biodiversity conservation and improvement of rural livelihoods. Obviously, the SFDs is the relevant department related to proposed activities under the Component 1 as SFDs offer most suitable organizational setup and institutional framework for execution of a major Project of this nature. The hierarchical organizational structure; well laid physical infrastructure and procedures for programme execution, communication, expenditure, accounting, auditing; and monitoring are added characteristics of SFDs and thus, they make the right choice for effective implementation of the proposed programme. Often, the management units in the SFDs have been carved out on the basis of natural micro -watershed boundaries and such mechanism makes it convenient for planning, implementation, monitoring, and evaluation of the likely impacts of proposed activities at the micro- watershed levels. The Project also predicts that the SFDs may like to involve the Eco-Task Force Battalion(s) of the Territorial Army and Civil Society Organizations i.e., *NYKS*, NSS, Youth and Eco Clubs, *Mahila Mandals*, NGOs, etc. as important partners in execution of proposed mammoth plantation activities as planned in the DPR. Further, SFDs may like to involve the Agriculture Department, Pollution Control Board and Municipal Corporation/ Municipal Board for specific activities related to agriculture landscape and urban landscape, respectively.

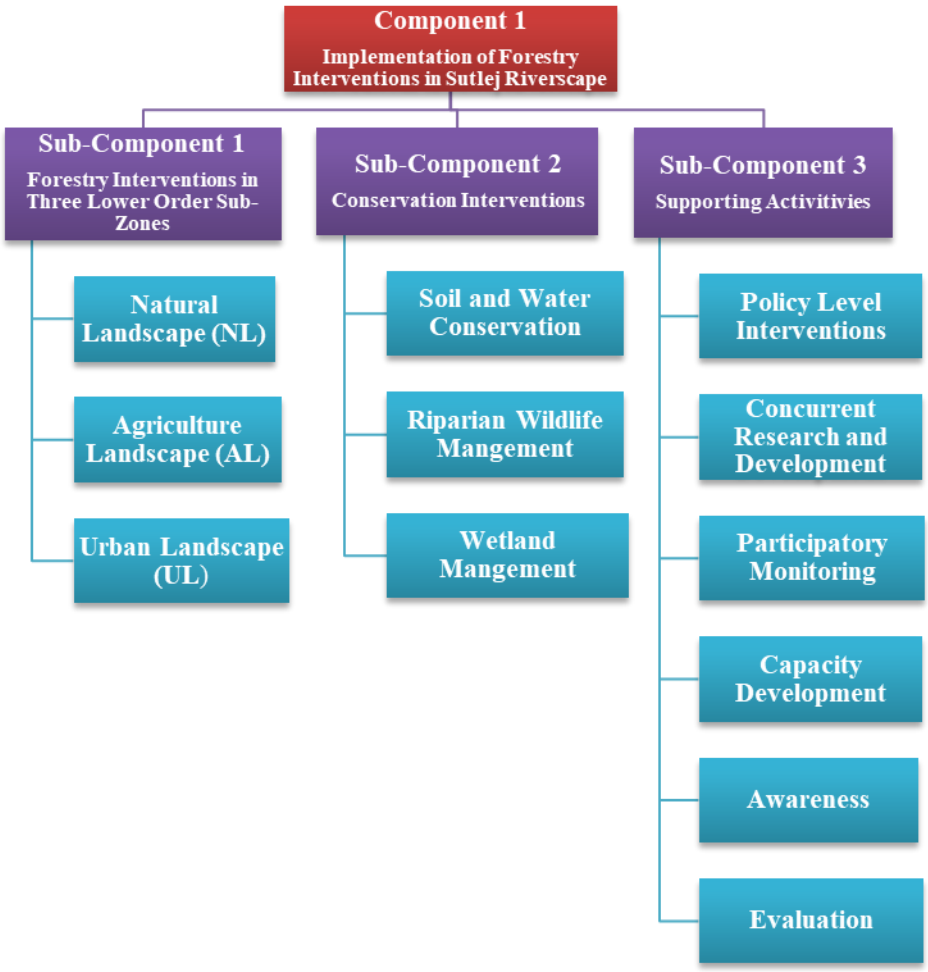


Fig.6. 2 Project Component on Forestry Interventions and Proposed Activities

Component 2: Strengthening Knowledge Management and Capacity Development for Forestry Interventions and Conservation of Riverscape

The preceding Chapters have highlighted the significance of rivers for human wellbeing, environmental stability and prosperity in the region/ country as well as elaborated on the complex and dynamic nature of rivers. The appropriate reviews also described strong linkages between forests and rivers, and four types of connectivity in the context of a river, and at the same time provided much desired clue that how enhanced biotic activities in a river basin have degraded the river ecosystem. Owing to degradation of the river environment and deterioration of water quality in the most rivers of the world, these natural renewable freshwater ecosystems now not only offer much reduced ecosystem services but are also a major concern for poor health of human as well as his livestock. Such poor situation of river health is quite pertinent in human dominated country like India where all major rivers are facing enormous challenges for their sustainable management. As streams and rivers are among the most endangered ecosystems, there is a priority need for comprehensive approaches to evaluate the historic and current state of rivers and their environment, appreciate causative factors responsible for their

present state and concerted efforts to restore them. There is an evident paradigm shift in management approaches of river ecosystems and it is fast changing. This has rapidly moved from the 'River development' to 'River conservation' and now to 'River Restoration'. Obviously, India lacks desired experience in restoration of rivers as relatively it is a new discipline for the country. However, efforts are on in this direction. Positive outcomes from any such effort aiming towards river restoration or river conservation are unlikely unless evidence and science based holistic strategies are actively involved in planning, assessment, management and development of rivers and policies relevant to river conservation and restoration. Moreover, in the emerging scenario of transparency in public policy, and essential requirements of comprehensive environmental impact assessment, and integrated planning for conservation of water resources, there are several expectations from multidisciplinary sciences. The expected best available science in efforts towards river restoration should be based on six broad criteria: (a) relevance, (b) inclusiveness, (c) objectivity, (d) transparency and openness, (e) timeliness, and (f) peer review. In view of the above stated facts, the component two of the Project aims to incorporate science into policy, planning and management for informed decision making that can facilitate positive outcomes of concerted efforts towards sustainable management of rivers and river restoration in particular in India.

The HFRI, Shimla has taken a lead in the preparation of present DPR adopting a multistep approach involving active participation of stakeholders, exhaustive consultations, and following a scientific planning process using RS and GIS based geospatial analysis for the riverscape, multidisciplinary review on the riverscape environment, and extensive field level data collection by the concerned SFDs in the data formats developed by the institute. HFRI is a reputed and established learning seat in the fields of natural resource management, Forestry Research and Education, particularly relevant to the Himalayan environment; those have direct relevance to the river ecosystems. Thus, it is of utmost importance that HFRI is not only involved as a National Level Partner Organization for facilitating monitoring, evaluation, and capacity development as proposed in the present DPR, but also be entrusted the responsibility of major task to serve as the Knowledge Management/ Learning Center and to undertake concurrent research related activities essential for conservation and restoration of the Himalayan Rivers. HFRI will also play a pivotal role in building desired national capacity for demonstrating the strong linkages between diverse forests in the Himalaya and river ecosystems. The Component 2 specifically seeks to support the dissemination of improved knowledge by strengthening the Knowledge Management Center and capacity development required for conservation of Himalayan Riverscapes within the country by offering best practices for forestry interventions and varied conservation measures as envisioned in the DPR. In addition, the Knowledge Management Center (HFRI) is expected to contribute intended intervention and activities relevant to policy, advocacy, outreach, monitoring, evaluation, and capacity development. In order to accomplish this, the National Level partner organization meant for the knowledge management and capacity development would need to establish a Project Facilitation Unit (PFU) for effective coordination with

participating States and the Central Nodal Ministry supporting the implementation of the programme.

The knowledge management would require a range of strategies and practices so as to identify, create, represent, distribute, and enable adoption of insights and experiences. Such insight and experiences comprise knowledge, either embodied in individuals or embedded in organisational processes or practices. An organisation seeking to become a Knowledge Management Center would primarily require: People, Processes, Innovations and Technologies (Fig. 6.3). People are the key to the success of a Knowledge Management Programme in an organisation. The collective multidisciplinary knowledge in the organisation would play an important role in dealing with the complexities of Himalayan Rivers. The 'institution building' is complex and continuum process. It has to be holistic – have to go beyond organisation management and development, and involves the process of developing people, and streamlining various systems, improving style of functioning, developing a positive climate, and promote organizational culture of professional and nonhierarchical relationships. Remote Sensing and GIS tools, information technology i.e., mobile apps, and web portals, automatic meteorological and hydrological equipment for measurement of River flow and rate of sedimentation, camera traps, satellite telemetry, etc. are some of the emerging technologies. These can be used for various proposes *viz*., planning, management and monitoring. The internet and World Wide Web would not only connect people, but also connect them to various databases being maintained across the globe.

Component 3: Scaling Up, Replication in Additional Sites and Maintenance Phase

The present DPR focuses on the programme implementation on the selected tributaries, particularly once the river descends in the Punjab plains. The Component 3 plans to support the scaling up and replication of planned efforts in additional sites / tributaries besides primarily, supporting the maintenance phase of various types of plantations raised in later years (3^{rd}, 4^{th} and 5^{th} years) of the Phase -I i.e., Implementation Phase.

Component 4: National Coordination for Forestry Interventions and Riverscape Conservations

In general, major Indian River Systems involve two or more states as the basin of the river and its tributaries are spread over multiple states. Thus, programmes related to river management and restoration requires National Level coordination for proposed forestry interventions and various conservation efforts among the participating states that are located along the course of main channel and its tributaries. As such, the Ministry of Jal Shakti (MoJS) is the Central Nodal Ministry for all aspects of management of water resources including river development and restoration of rivers. However, several other ministries are also involved for specific components/ needs. Thus, the Component 4 predicted National Level coordination for forestry interventions and river restoration and visualizes varied activities *viz*., (a) establishment of the River Decision Support and Management Information System (RDS & MIS); (b) facilitating

activities relevant to policy and legal interventions, riverscape level coordination, monitoring and impact evaluation; and (c) administering the implementation of major project on forestry interventions. In order to accomplish this, the Component 4 specifically envisages the establishment of a Project Management Unit (PMU) at the Nodal Ministry Level. The PMU at the Nodal Ministry would handle the programme implementation, coordination among participatory states, partner organisations at the National and state level besides extending support for the finances required for the project execution.

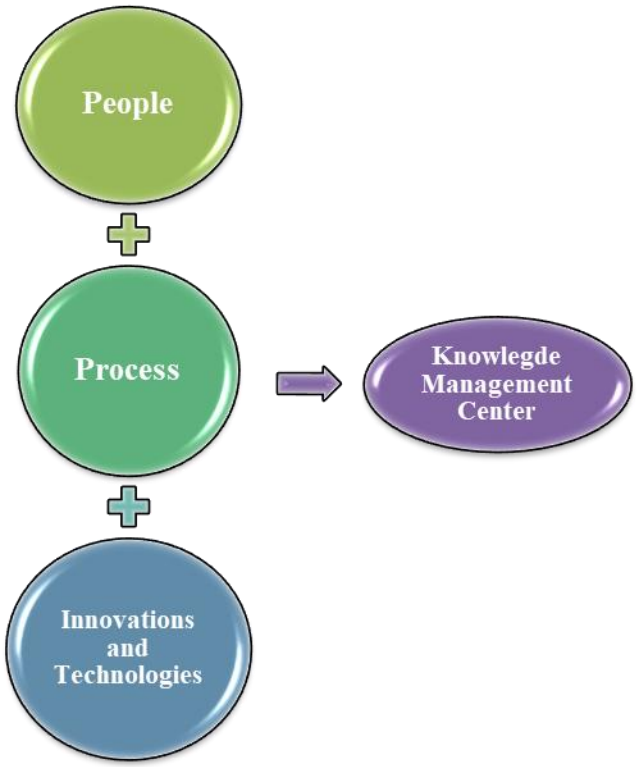


Fig.6. 3 Three Essential Elements for the Knowledge Management Center

6.2 Institutional and Implementation Arrangements

Basically, the project is proposed to be implemented at three hierarchical levels *viz*., the National, State and Division. Accordingly, institutional arrangements at these levels are envisioned for the effective and successful implementation of a major project of this kind. At the apex level, the identified Central Nodal Ministry will provide the overall policy guidance and the supervision of the project at the national or the riverscape level. The PMU established at the Central Nodal Ministry will not only ensure timely release of funds, but would also be responsible for overseeing and coordinating the efforts at the national or Riverscape level. The concerned SFDs of involved States within the riverscape will be the primary Implementing Agencies (IAs) at the State, Division, and local levels. However, SFDs would be able to involve other partners (i.e., the Agriculture/ Urban Development Departments, Eco-Task Force, NYKs, NSS, select NGOs, etc.) for programme implementation in different landscapes. Each SFD at the

State level will establish the PMU for effective implementation of the project across the State/ Divisions/ Ranges and even at the *Panchayat*/ Community levels. In addition, the National Level Partner Organisation (HFRI, Shimla) responsible for facilitation, concurrent research, monitoring, evaluation, and capacity development would also be functioning and will have the support of Project Facilitation Unit (PFU). Details of institutional arrangements at different hierarchical levels are provided below:

6.2.1 Project Management Unit (PMU) at the Central Nodal Ministry

The MoEF&CC is expected to be the Central Nodal Ministry for implementation of project. However, other related ministries (e.g., MoJS and MoRD) may also join and collaborate with the Central Nodal Ministry for the purpose and provide/ arrange required financial resources. Once the GoI decides about the Central Nodal Ministry and entrusts the task to implement the project planned in the present DPR, then designated Central Nodal Ministry would require to establish the PMU, specifically for performing various functions relevant to project overseeing, advice, steering, coordination, programme approval, policy level interventions, budget allocations, fund flow, monitoring, and evaluation.

The PMU at the Central Nodal Ministry will be headed by an Addl. Secretary/ Joint Secretary level officer who will be designated as the Project Director (PD). The PD will be supported by a small project management team of existing and project staff on contract to support various activities related to coordination, technical supervision, communication, project administration, procurement, financial control and management, report preparation, monitoring, and evaluation. The PD will be assisted by a Joint Secretary/ Director level officer designated as the Project Coordinator (PC). The PC will be supported by three Senior Project Scientists (one each for Policy Intervention/ Riverscape Conservation/ Communication), three Junior Project Scientists (one each for Forestry/ Riverscape Conservation/ Monitoring and Evaluation), four Project Managers (one each for RDS & MIS/ Administration / Procurement/ Finance and Audit), four Project Assistants, four Office Assistants, and three Multi Tasking Staff (MTS) (Fig. 6.4). The PMU will carry out the following tasks relevant to the financial control and management:

a. Annual budgetary provision for the project and monitoring of project expenditure against allocated budget
b. Approval of Annual Plan of Operations (APOs)/ Work Plan and budgets.
c. Coordination and ensuring sufficient and timely fund flow to concerned State IAs and national partner organisation for activities at the riverscape level and for national capacity development activities, respectively.
d. Regular financial reporting of the project at all levels and compilation of quarterly financial reports and annual financial statements of the project
e. Ensuring internal audits and annual external audit of the project by the CAG

In order to make the PMU fully functional, necessary budget provisions for its establishment, office equipment beside recurring costs on salary and wages, office expenses, travel, workshops/

seminars, meetings, publications, dissemination, and miscellaneous expenditures and contingency have been made. Further, adequate budget provisions for capacity development, planning and conduct of National Level seminars/ workshops, and coordination, review meetings, etc. have also been made so as to make the working of PMU effective in its mandate.

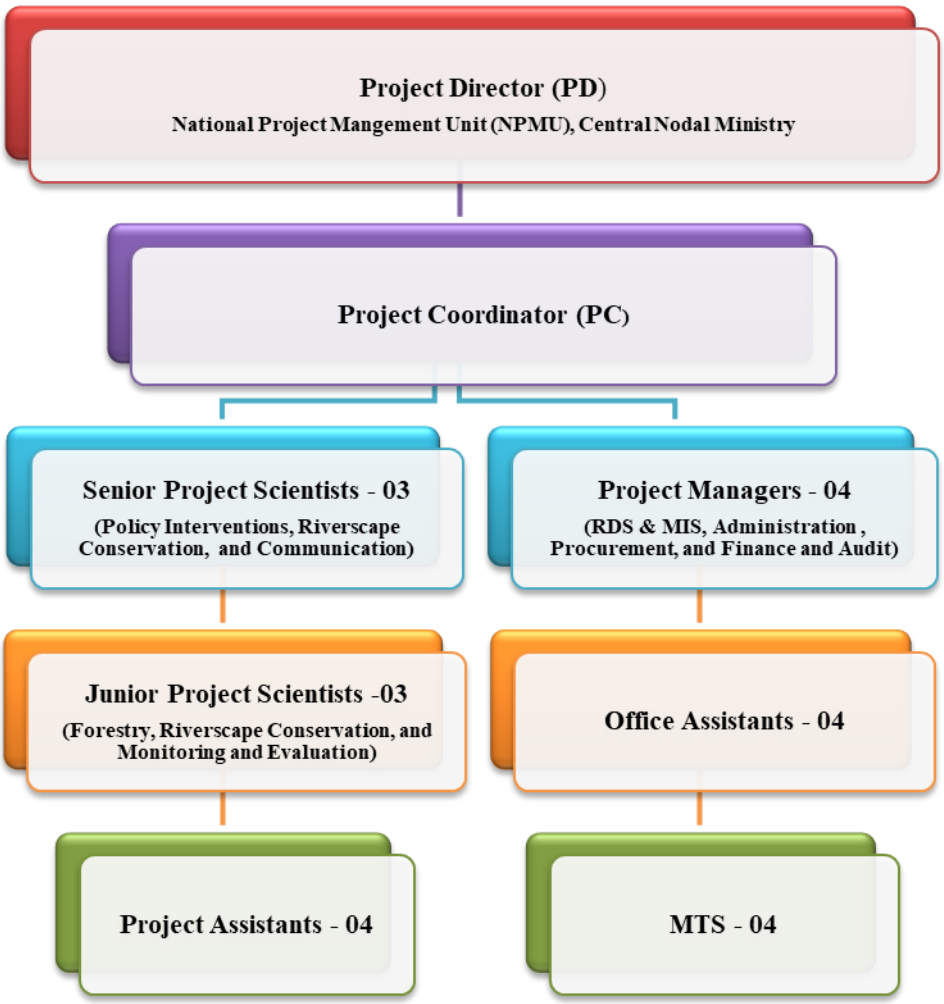


Fig.6. 4 Proposed Organisation Structure of the Project Management Unit at the Central Nodal Ministry

6.2.2 Project Facilitation Unit at the National Level Partner Organization (HFRI, Shimla) for Knowledge Management and Enhancement of National Capacity for Forestry Interventions and Riverscape Conservation

The HFRI, Shimla, as one of the institutes of ICFRE owing to its expertise in the ecology of the Himalayan environment, natural resource management, and the Himalayan forestry besides its strategic location, multidisciplinary team, having long experience in dealing with cumulative environmental impact assessments of Himalayan Rivers, and well aid infrastructure, has been proposed to undertake the major responsibility as the National Level Partner Organisation for

effective implementation of this priority project on river restoration i.e., forestry and conservation interventions aiming for *aviral dhara* and *nirmal dhara*, ecological integrity and restoration of river health, liaisoning with Central Nodal Ministry and Implementing Agencies at the State level, concurrent research and development, science and technology based backstopping, capacity development, monitoring, and evaluation. For this purpose, the HFRI would need to establish a Project Facilitation Unit (PFU), headed by the Nodal Officer (NO) of the project at a senior level (Scientist – G or CCF level officer). He/ she will be supported by River Coordinator (RC). The NO and RC will be assisted in their functions by six Senior Project Scientists (one each for Forest Policy and Law/ Forest Ecology/ Forest Hydrology/ River Ecology and Conservation/ Ecosystem Services/ Climate Change), six Junior Project Scientists (one each for Forest Biodiversity/ Bio-remediation and Bio-filtration/ Aquatic Ecology/ Remote Sensing and GIS/ Agroforestry/ SMC and Bioengineering), four Project Associate (one each for Forestry Research/ Communication and Conservation Education/ Ecosystem Monitoring/ Forestry Training), four Project Managers (one each for IT and National River Database/ Administration/ Procurement/ Finance and Audit),six Project Assistants, four Office Assistants, and three MTS(Fig. 6.5). In order to make the PFU effective and fully functional, provisions for its establishment, engagement of contractual technical and office staff, recurrent expenses towards salary and wages, travel, procurement of office/ computer, IT, and RS and GIS/ laboratory/ field equipment, research and monitoring, capacity development, development of learning material and dissemination, advocacy and outreach, and evaluation. In addition, budget provisions for institutional charges and contingent expenses have also been made. Further, adequate budgetary provisions for organisation and conduct of activities related to seminar/ workshops/ meetings, exposure visits to demonstration sites, scientific exchange and overseas visits, engagement of national and International Experts on specific themes, impact evaluation, etc. have also been incorporated in the proposed budget of the project so as to make the PFU, Knowledge Management Center at the National Partner Organisation fully functional and effective for the predicted purpose.

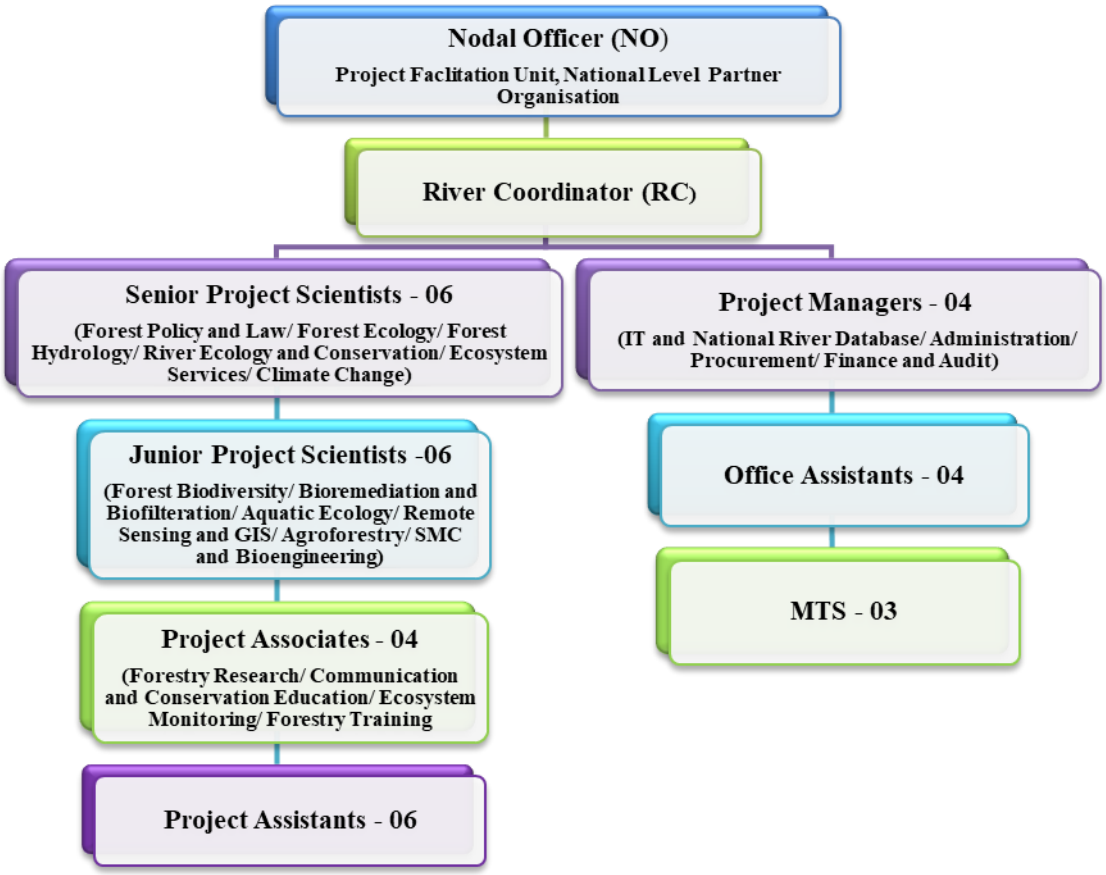


Fig.6. 5 The Proposed Organisational Structure of the Project Facilitation Unit (PFU) at the National Level Partner Organisation on Knowledge Management and Capacity Development

6.2.3 Project Management Unit(s) at SFDs in Himachal Pradesh and Punjab

The SFDs in Himachal Pradesh and Punjab along the course of Sutlej River would be the primary IAs for proposed forestry interventions in the riverscape and they are expected to carry out extensive activities i.e., plantations, conservation interventions, and supporting activities at three hierarchical levels *viz*., State, Division, and Local Communities. Thus, a provision of Project Management Unit (PMU) at each SFD has been made so as to facilitate, coordinate, and manage foreseen project activities through 25 Territorial Forest Divisions and 8 Wildlife Divisions within the two States. The PMU in each of the participating State will be headed by the Addl. PCCF/ CCF level officer and designated as the Project Executive Director (PED) while the CF level officer designated as Project Executive Officer (PEO) would assist the PED. The DFOs/ DCFs of all 33 Divisions will be responsible for actual implementation of proposed forestry interventions and other allied activities anticipated in the DPR. The existing Forest Development Agencies (FDAs) operating at Divisions/ District level or any other appropriate suitable State specific mechanism could be utilized for implementation of the project at the field level while *Joint Forest Management Committees* (JFMCs)/ Eco-development Committees (ECs)/ Biodiversity Management Committees (BMCs) / *Gram Panchayats* or other relevant

bodies need to be involved in field level execution at the local/ community level. Each State specific PMU will avail the existing Government Officers/ staff besides select contractual employees for the project tenure. The contractual staff will include three Project Managers (one each for Project Administration and Procurement/ Project Finance/ Project Audit), two Senior Project Associates (Forestry/ River Conservation), four Junior Project Associates (Forestry/ River Conservation/ Capacity Development/ Awareness and Outreach), three Project Assistants (Forest Management/ RS and GIS/ IT, Communication and Database), and three Office Assistants would be engaged for the project duration (Fig. 6.6).

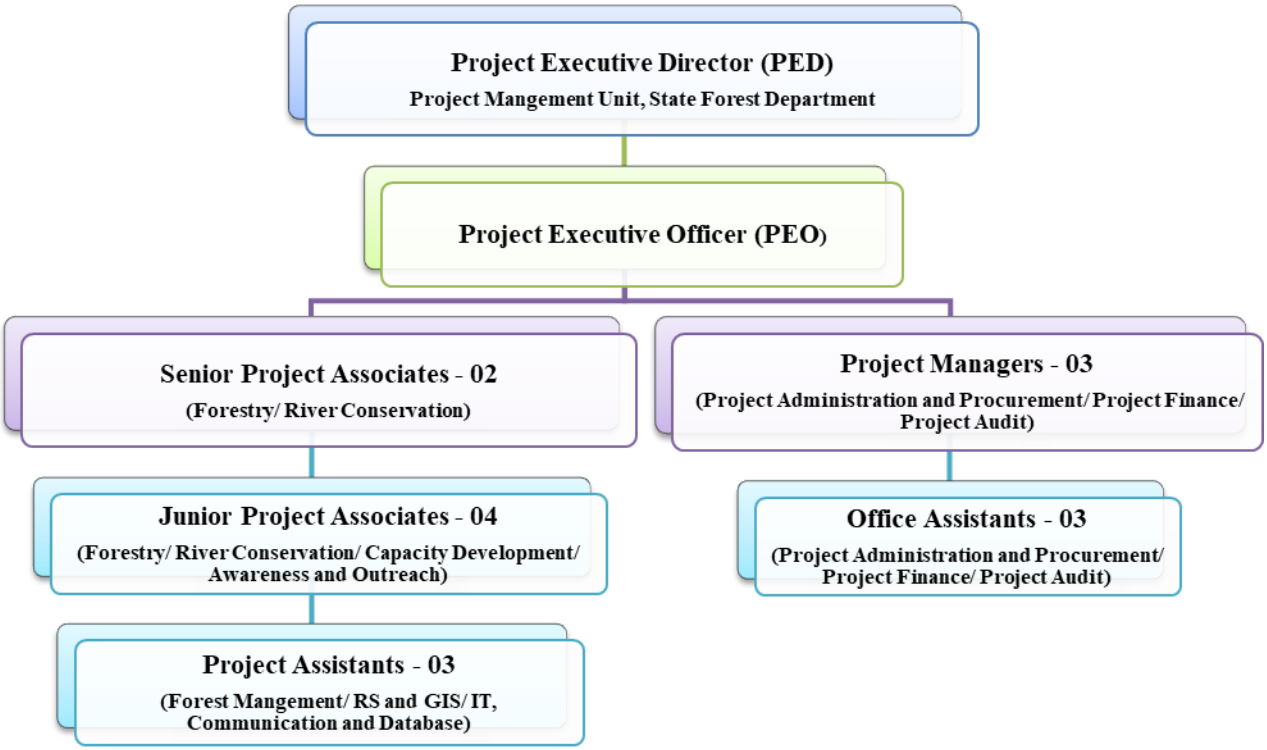


Fig.6. 6 Proposed Organizational Structure of Project Management Unit at the State Forest Department in the Himachal Pradesh and Punjab

6.3 Implementation and Fund Flow Mechanism

Considering the conservation significance of the River, multifaceted nature of the project design, diverse proposed activities, multiple agencies involved, and in order to ensure effective execution of the programme across the vast extent of riverscape. Efficient implementation mechanism is desirable. Thus, the project envisions constitution of two high level Project Steering Committees, one at the National Level in the Central Nodal Ministry and referred as the 'National Programme Steering Committee' (NPSC). While other at the State level in concerned SFDs of the involved States within the riverscape, to be named as the 'State Programme Steering Committee (SPSC)'.

(i) National Level Programme Steering Committee (NPSC): The NPSC will be chaired by the Secretary of the concerned Central Nodal Ministry and the Member Secretary would be the NPD. The NPSC is expected to have multiple members represented by senior officials of the MoEF&CC; Ministries of Jal Shakti, Agriculture, AYUSH, Youth Affairs and Sports, Tribal Development, Rural Development, Urban Development, Panchayati Raj, and Tourism; PCCFs and HoFFs of Himachal Pradesh and Punjab or their representatives; Director/Nodal Officer of the National Partner Organisation (HFRI); and one representative each from ITBP and Eco-Task Force. Thus, the NPSC is expected to have about 20 members or so. The NPSC shall meet at least once in a year at appropriate time for considering and approving the APOs submitted by the concerned SFDs. The funds against the approved APOs of the States shall be transferred by the NPMU to respective SFDs. The National Level PFU will follow its own mechanism of governance and if required will have its Monitoring and Steering Committee for overseeing the project. Details on proposed institutional arrangements, implementation mechanism at the State and field levels, and constitution of SPSC in Himachal Pradesh and Punjab are presented in Fig. 6.7.

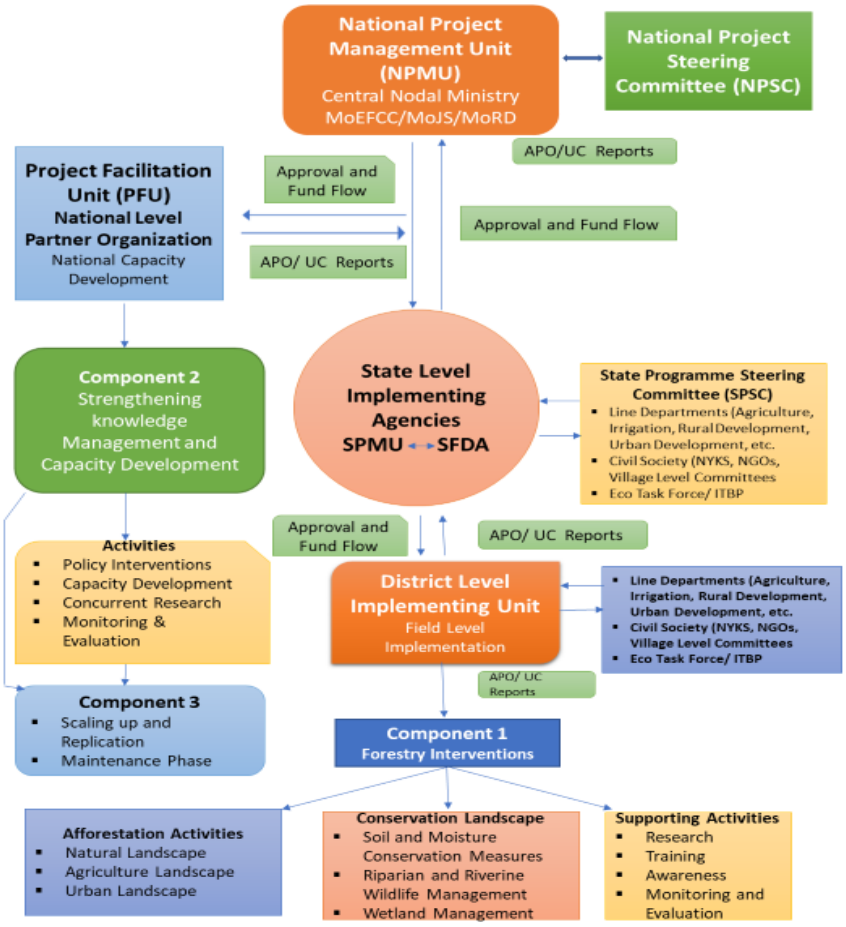


Fig.6. 7 Proposed Hierarchical Institutional Arrangement and Mechanism for Project implementation

(ii) State Level Programme Steering Committee (SPSC): On the lines of National Level NPSC, each concerned SFD will also have the State Level SPSC. The existing framework of the State Forest Development Agency (SFDA) at the State Level or any other similar/ equivalent agency will be used for transferring and parking of funds at the State Level and to be released on the approval of the SPSCs. On approval by the SPSC, the matching funds will be transferred to SPMU, an exclusive State Level PMU for further allocation to concerned Divisions as per the respective APOs, duly approved by the SPSC. At the Circle/ District Level, a Circle Project Implementation Committee (CPIC) will be constituted under the Chairpersonship of the Conservator of Forests (CF) with concerned DFO as the Member Secretary so as to ensure a transparent and accountable mechanism for implementation of activities as proposed in present DPR. Various works related to proposed forestry interventions in the riverscape could be implemented in close association and involvement of the *Village Panchayat/*JFMC level setup. SPMU is proposed to perform in each of the implementing States. The SPMUs shall be responsible for all the directions, operations, and control of forestry interventions at the State level through SPSC. The SPSC shall be chaired the Principle Secretary (Forests)/ PCCF (HoFF) while at the State level Project Executive Director (PED) shall be the Member Secretary. The SPSC shall have equal level representative of various Line Agencies/ Departments, Civil Society, NGOs, Eco-Task Force, ITBP, etc. The SPSC shall meet at least twice a year at appropriate times for approving the APOs submitted by Divisions and steering the project implementation activities across the State.

(iii) Implementation at District/ Division Level: A Civil Society Organisation at the Division/ District Level shall be involved for programme execution at the field level. The District Level Implementing Committee (DIC) shall be constituted for programme execution while having the CF as the Chairperson and the concerned DCF/ DFO as the Member Secretary along with the representation of District level Line Agencies/ Departments as well as the Civil Society. The concerned DFO as the Member Secretary who is also the Chief Executive Officer of this FDA wherever in existence and functional shall submit APOs for forestry interventions as predicted in the project in consultations with the representatives of Line Departments, NGOs, Eco-Task Force, and other Civil Societies who shall be invited by DFO and involve every time in the consultation process. The SPMU will scrutinise the APOs received from concerned DFOs and ensure timely approval by the SPSC, with or without necessary changes, for further submission to the NPSC at the Central Nodal Ministry. Upon approval of the APO by the NPSC, the funds shall be transferred against the APO to an account separately maintained by the respective SFDs for implementation of the project anticipated in the present DPR. Likewise, separate accounts shall be opened by each of the DFOs at the Division Level so as to exclusively operate planned forestry interventions as proposed/ predicted in the DPR. DFOs will ensure that there is no mixing up of expenses/ accounts of any other nature with the account specifically opened for the purpose of present project. The SPSC shall authorise SFDA to transfer funds against approved APOs to accounts opened by Divisions specifically for the purpose. Financial

expenses, creation and management of assets, incurring overhead expenditures, etc. shall be as per the provisions of GFR2005 and/ or any rules/ guidelines framed by the Central and State Governments in this regard from time to time. The SFD or any other Implementing Partner department/ Agency as well as the Civil Societies shall be responsible for achieving the objectives, targets while maintaining proper documents and accounts, besides accountability and transparency. The Himalayan State will ensure active involvement of the Eco-Task Force/ ITBP in plantation and other related soil and water conservation measures, control of forest fires and protection of Rare, Endemic and Threatened (RET) faunal species in the terrestrial as well as the riverine environments and other relevant project activities. It is proposed that at least 10% plantation activities in Himachal Pradesh will be entrusted to the Eco-Task Force and/ or ITBP. The PMUs of concerned SFDs will allocate funds to these agencies for actual implementation of areas under their command or arrange to allocate new areas. Further, setup under the Ministry of AYUSH will be involved for works related to afforestation/plantation, conservation and sustainable harvest of Medicinal and Aromatic Plants (MAPs). The State/ District and Field Level formations under the NYKS of the Ministry of Youth Affairs and Sports, such as Youth Clubs/ Eco-Clubs/ *Mahila Mandals* and other leading CSOs (e.g., Seechewal initiative, etc.) will also be actively involved not only in plantation works, but also in awareness campaign and other activities relevant to this project. The concerned SFD/ SPMU will work out the detailed mechanism as per the specific requirements and prevailing conditions and duly signed MoUs on record. Nearly, 30% to 40% budget on awareness provisioned in the project for each of the State will be utilised through above stated State level and local level organisations/ formations. The SPMUs will invite proposal and APOs from AYUSH, NYKS, ITBP, Eco-Task Force, and other CSOs for consideration by the concerned SPSC. On approval, signing of MoU and timely funds will be released to the concerned agency for the specific/set of activities.

(iv) Execution at Field Level: Once the APO submitted by the Division approved and works allotted, the respective work shall be executed with active involvement of JFMCs and/ or other CSOs in the area. In case, the works are entrusted to JFMCs/ CSOs for execution, the cashbook and account so maintained by them in turn shall be submitted to the concerned DFO who will ensure that the works have been done in accordance with the physical and financial parameters prescribed. The accounts as well as the bank account for the purpose of execution of project as per the present DPR shall be maintained separately. The Measurement Books (MBs) for such activities recorded through JFMCs or CSOs of the SFDs shall be maintained by the concerned officials of the SFDs while the JFMCs shall submit Utilization Certificate (UC) dully verified by RFOs and Completion Certificates (CCs) to the concerned DFO.

For the works to be executed by the other Line Departments, Eco-Task Force, ITBP, NGOs, and other Community Based Organisations (CBOs), the DFOs shall convey the approved APOs to concerned officials of the respective Department/ Agency, and also release corresponding funds to them. The responsibility of execution shall completely rest with the Line Department/ Agency and they shall be maintaining MBs at their own level and submit account for the same to the

DFO. These works shall be inspected jointly by the concerned field staff of SFDs with the executing Department/ Agency and inspection report submitted to DFO. DFO who is the Member Secretary of District Level Implementing Agency (DIC) specifically constituted for implementation of the present project, shall make electronic fund transfer to the executing agency to facilitate timely implementation of envisaged works. SFDs will maintain records for individual site with all the activities logged in immediately as and when carried out along with the expenditure incurred on the standard forms being used by respective SFD. The UCs and CCs compiled at State Level PMU shall be submitted to the NPMU at the Central Nodal Ministry for monitoring.

The SFD will form new JFMCs for programme implementation, if required and deemed fit. Concerned SPSCs, SPMUs and DFOs will ensure adequate involvement and participation of other recognized CSOs like, *NYKS*, NSS, NCC, NGOs, *Mahila Mandals*, Self Help Groups, (SSFs), etc. In areas where none of these CSOs exists or are not feasible for any justifiable reason, the DFO may opt for executing the works departmentally with the help of any other active Civil Society in the area.

The expenditure incurred is auditable as per the Government of India Rules/ Procedures and/ or as per the specifications provided by the Central Nodal Ministry or even the prominent financial agency supporting the project.

(v) Budget: The SFDs are mandatorily required to organize and undertake in house/ internal monitoring and necessary budget provisions have been made in this regard. Twenty five per cent of the actual works carried out will have to be essentially monitored. The mechanism of such monitoring shall be finalized by the concerned SPSC which will also lay down the procedure for submission of UCs to the Central Nodal Ministry along with the approved APO for various works during the next year. Based on APO as well as UC for the amount released during the previous year, the Central Nodal Ministry/ NPMU shall release the funds after obtaining the approval of the NPSC.

6.4 Risk Assessment

There is a strong linkage between forests and rivers and also described intricate nature of both, forest ecosystem and river ecosystem. Likewise, two associated disciplines *viz*., forestry and River conservation are likely to be influenced by a wide range of driving variables (i.e., solar radiation, precipitation, temperature, humidity, wind, etc.), biotic (human disturbances – deforestation, fragmentation and habitat loss, livestock grazing, forest fires, invasive and alien species, pests, agriculture expansion, developmental activities, etc.) and abiotic factors (i.e., soil erosion, landslides, etc.). While some of these factors (biotic and abiotic) can be managed to an extent, others (driving variables) are beyond the scope of human interventions. Hence, a degree of risks is involved in the implementation of planned activities of forestry interventions with the aim to restore the River from the perspective of water flow, water quality, ecological integrity, and

sustainability of ecosystem services. Potential risks broadly grouped into biotic and abiotic categories based on the likely causes are summarized below in below (Table 6.1):

Table 6. 1 Potential Risk Factors Relevant to Forestry Interventions and River Conservation

Sr. No.	Risk Factors	Risk Reduction Measures
A.	**Biotic Risks**	
1.	Illicit cutting of plantations- Plantations in remote areas as well as high human population areas are prone to illegal cutting of plantations or any other type of damage by human activities.	Effective fencing and protection measures (watch and ward and social fencing) so as to prevent any illegal activities and damage to plantations
2.	Grazing of plantations by domestic livestock and wild herbivores – livestock grazing, particularly by migratory sheep and goat in harsh climatic conditions and upper reaches can adversely impact plantation efforts at any stage.	Proper fencing of plantation areas, watch and ward, social fencing, and awareness.
3.	Human induced forest fires – recurrent manmade annual forest fires are widespread and they can damage young plantations.	Adoption of comprehensive strategy towards prevention of forest fires. This would include awareness campaign, creation and maintenance of fire lines, watch and ward and efforts to control the fire in case it outbreaks.
4.	Pest and disease attacks	Little scope of management as use of chemical pesticides is discouraged due to toxic effect on water sources.
5.	Reduced environmental flow and declining aquatic biota.	Ensure minimum environmental flow and four dimensions of river connectivity; maintenance of Riparian forests/ buffer.
6.	Reduced water quality in streams, rivers and other wetlands owing to enhanced pollution.	Adoption of comprehensive strategy to deal with issues of water pollution including awareness, treatment of sewage prior to its flow to river/ wetlands, bio-remediation and bio-filters, etc.
B.	**Abiotic Risks**	
1.	Scarce and erratic rainfall –delayed rainfall, long dry spells and excessive rains can adversely impact planting activities	Timing of planting activities in consonance with rainfall is important for survival. Success of plantation depends on timely and optimum rainfall. Hence, prepare exigency plan – select hardy species

		those can withstand erratic rainfall pattern, ensure alternate methods for watering in the event of dry spells, select plant species those can also withstand impact of excessive rains/ flooding.
2.	Climatic factors – Temperature: High temperature may lead to drying up of seedlings and young plantation. Irrigation can be done in very few select areas especially in the riverfront development component, river parks and eco - parks and agroforestry models; Low temperatures and frost in the alluvial plains are likely to cause mortality among plantations due to frost injury and desiccation.	The risk factor can be minimized by adopting planned adaptation in forest management practices. At the community level, planned adaptation may include diversification of forest based and non forest based income sources, better local governance of forest resources and capacity development for monitoring. Industrial forest sector may involve the inclusion of bioenergy. At the stands level, planned adaptation may include planting a larger diversity of species or provenances, or trees bread for resistance to accepted stresses. At the landscape level, planed adaptation may include measures to minimize the potential impact of fire, pests and diseases, increased afforestation and reforestation, and creation of biodiversity corridors. Science is essential to support planned adaptation. The development of planting stock with desirable genetic traits may be a promising avenue to counter changes in the local climate. Intensive forest monitoring is key component of planned adaptation. The impetus for change in the forest sector and society primarily comes from socioeconomic situation, not ecological crisis. Planned adaptation needs to link to local adaptation policies focussing on the importance of the social and behavioural sciences in the forest management. Awareness of actual and potential impacts from climate change is crucial.
3.	Edaphic factors – soil erosion and landslides: the Himalayan mountainous tract is prone to soil erosion and landslide due to fragility, steep slopes and enhanced human disturbances.	Adopt appropriate soil and water conservation measures (bioengineering and mechanical); species selection and use of tall nursery material is important to reduce the risk factor for better survival and establishment.

Anyone or a combination of above stated potential risk factors can influence establishment, survival and desired growth of various proposed plantations as well as impact different conservation activities pictured in the DPR. Hence, concerned SFDs, DFOs and other involved Implementing Agencies shall consider the following possible mechanisms to reduce above risks:

a. The quality of planting stock, particularly age and size is an important aspect. In order to reduce above stated risks, IAs must ensure to use the quality planting stock. Tall nursery plants have proven to minimize several risk factors to a great extent.
b. Time is essence for successful operation of plantation activities. Thus, timely establishment of nursery and supply of high quality planting materials well before the planting season are essential to minimize risk factors. Damage to planting materials in transit also needs to be prevented. Early plantation is key to success.
c. Timely completion of planned advance works (fencing, cleaning of site, pit digging, etc.) and execution of actual plantation activities supplemented by use of bio-fertilizers, organic manure and composed, mulching, etc. can reduce risk levels drastically.
d. Establishment of required fencing and protection of plantations from livestock and wild herbivores will ensure from the risk of grazing and trampling. Thus, awareness, sensitization, and involvement of local communities are essential so as to reduce the above stated biotic risks. Near habitation multipurpose species need to be planted for the benefit of communities and their whole hearted involvement.

In spite of all possible attempts have been made to minimize the risk involved, much of the progress, growth and success of the plantations are left to nature. Vagaries of nature in the form of climatic and edaphic extremities pose the greatest threat to proposed forestry interventions.

6.5 Mid Course Learning and Adaptation

Proposed forestry interventions for restoration of a River by way of enhanced environmental flow and water quality are definitely an innovative and integrated approach. The preceding section has highlighted the potential risks and vulnerability. Erratic climatic conditions and unpredictable external forces of nature tend to impact the field level activities as predicted in the DPR. In view of the local conditions, activities and treatment models proposed in the DPR might need certain modifications to make them adaptable to micro level conditions. The periodic monitoring, particularly the midterm review would allow the midcourse corrections and adaptation of new ideas and design suitable under changing environment conditions. Such adaptive modifications in the design, criteria, specifications, timing of a particular activity, selection of sites and species, if any will have to be specifically mentioned in the APOs and executed by the DFOs/ Partner Organizations only after obtaining approval from the SPMU. If needed, special approval may be accorded by the State Level Project Executive Director in order to ensure timely execution keeping in view the seasonal nature of proposed works.

6.6 Monitoring and Evaluation of Outcomes/ Results

Monitoring of activities and periodic evaluation are integral part of the project implementation. Broadly, two types of monitoring have been proposed during the project execution phase: (a) monitoring of project performance in terms of project goals/ objectives, activities, targets, outputs, outcomes and impact; and (b) ecological and socio economic monitoring in terrestrial as well as aquatic ecosystems. The set of measurable indicators elucidated will be monitored on a given timeline (Table 6.2 & 6.3).

Table 6. 2 Measurable Ecological Indicators for Monitoring and Review Mechanism

Sr. No.	Ecological Indicators
1	Area covered under plantations in different landscapes
2	Stock quality of planting materials
3	Survival rates of plants
4	Growth performance of plants *viz*., height and girth
5	Biomass and productivity
6	Forest cover and tree cover
7	Area under invasive and alien species and fire incidences
8	Extent of soil and moisture conservation works
9	Silt load/ rate of sedimentation in select locations in the implementation area
10	Water quality in the select locations
11	Population estimates of select RET faunal species

Table 6. 3 Measurable Socio Economic Indicators

Socio Economic Indicators
Extent of employment generation
Per capita income of the impacted population
Forest based livelihood generation activities
Dependency of local population on forest resources
Biotic pressure on forests/ grasslands/ wetlands and protected areas
Availability of fodder to the affected population
Availability of medicinal plants or raw material for industries
Number of awareness campaigns, development of publicity material (i.e., pamphlets, brochures, etc.)
Access to safe drinking water
Health of people, enhanced crop productivity, improved wellbeing, and improved livelihood
Increased population and abundance of RET species

Plantation activities make the core activity of the proposed forestry interventions by adopting varied plantation/ treatment models in natural, agriculture and urban landscapes within the riverscape in Himachal Pradesh and Punjab. Accordingly, a bulk amount of the total budget outlay has been provisioned for this important activity. Considering the significance of plantation activities for the overall success of the project, in house monitoring has been anticipated and to be carried out by the IAs i.e., the concerned SFDs. Thus, 25% of the actual works carried out will have to be mandatorily monitored. The DPR has made adequate provisions for the required budget for monitoring of plantations as well as other interventions proposed in the project. Further, in order to ensure optimal success of the plantations, necessary budgetary provisions

have also been made for replacement of failed plants in the establishment year and gap filling (15% cost for first year, and 10% cost for second year) in subsequent years of maintenance. This is reflected in Table 5.2 and Table 5.4 under Chapter 5 of DPR. The DPR also envisions actual field level, and annual monitoring at three hierarchical levels of SFDs/ IAs by way of monitoring of 40-50% plantation sites by the concerned ACFs, 20-25% sites by DFOs, and 10-12% by CFs. The SPMU in consultation with the SPSC shall finalize the mechanism for proposed 25% in house monitoring. The SPSC will also lay down the procedure for submission of UCs to the NPMU based at the Central Nodal Ministry along with the approved APO for the proposed works in the next year and the budget estimates. The NPMU would release the funds for the next year after the NPSC has considered the UCs and APO and approved release of funds.

SFDs have provided preliminary information regarding proposed sites for plantations in field data formats submitted to HFRI, Shimla along with GPS locations for the preparation of present DPR. Site details have been incorporated in GIS/ Google Earth maps. As per the old and well established traditional practice of documentation, SFDs are required to maintain 'Nursery Journal', 'Plantation Journals' and 'Journals for Other Interventions' meticulously. As per the existing system and laid procedures, these journals contain all requisite information on plantations, selected sites, geographical coordinates, site sketch and map, details of activities carried out and expenditure on plantations, weeding, tending, gap filling, and maintenance activities. Besides these also includes the chronology of natural (i.e., flood, drought, etc.) and manmade (i.e., fire) events, if any impacting plantations adversely. As already stated, the DPR envisages actual monitoring of plantations at three hierarchical levels and proper recording of site level observations in the Plantation Journals. As a first step, SFDs are required to place a sign board at the plantation site indicating the name of the scheme, area covered, and other details on planted species and their numbers. Necessary budget provisions for this purpose have been made in the cost norms under the head of contingency of various proposed forestry interventions.

The Logical Framework Analysis earlier presented incorporates important aspects of project monitoring and provides an insight on monitoring of project performance at three hierarchical levels i.e., National/ State/ Local Levels. The logical framework has also provided details of verifiable indicators and appropriate means. The proposed project outcomes (i.e., biological, socio economic and institutional) will assess the impact of project interventions against the baseline developed during the Year-1 of implementation. The National Level Partner Organization (Himalayan Forest Research Institute, Shimla) will facilitate project monitoring and evaluation of outcomes/ results through consultative process with leading scientific organizations and effective coordination with the Nodal Ministry, State level IAs and CSOs. Outcome indicators include: (a) creation of an enabling environment for climate resilient, sustainable terrestrial, aquatic (river and wetlands), and floodplain ecosystem management; (b) enhanced levels for multi sector convergence, alliances, integration, favourable national and state level policies.

The National Level Partner Organization in collaboration with concerned SFDs would involve concerned experts and organizations to develop an integrated, long term ecological and socio economic monitoring programme during the first year of project implementation and generate the base line information for evaluation of project impact in future. The ecological and socio economic monitoring programme, thus, developed will be executed periodically as per the plan developed for the purpose. Additional priority researches and theme based studies would be supported for each of the landscape category, river and its tributaries so as to supplement the participatory impact monitoring programme. Local Universities, Expert Scientific Organizations, and CSOs will be involved in monitoring programme proposed for the project.

In addition to the above stated project as well as ecological and socio economic monitoring, HFRI, Shimla (National Partner Organization) will undertake and facilitate supervision missions in consultation and coordination with the NPMU based at the Central Nodal Ministry so as to review the progress made in execution of the Project besides the well-structured and designed Mid Term Review (in third year) and the Terminal Evaluation (last quarter of fifth year of project implementation) by the Third Party/ External Experts selected by the PMU of the Nodal Ministry.

6.7 Sustainability, Replication and Cost Effectiveness

For a multifaceted project on forestry interventions for restoration of river, three aspects *viz*., sustainability, replication and cost effectiveness are of immense significance. These aspects are briefly described below:

6.7.1 Sustainability

The geospatial analysis of the riverscape was an important step towards the preparation of present DPR and that provided a valuable insight on priority sites (high, moderate and low) for proposed forestry interventions and execution of other conservation interventions etc. Availing this insight, forestry interventions have been proposed mainly in high and moderately priority sites identified on the basis of geospatial analysis. Hence, majority targeted sites are of great significance for protection, conservation and restoration. Proposed interventions in such sites are likely to generate global biodiversity benefits i.e., enhanced forest cover and tree cover and diversity of species, carbon sequestration, and improved ecosystem services, besides improved rural livelihoods. The project relies on the ecosystem based approach to river conservation and targets towards forest – river linkages, conservation and development interventions at the riverscape level so as to contribute in a meaningful way towards three important goals i.e., *Aviral Dhara*, *Nirmal Dhara* and ecological integrity. Hence, project itself aims to achieve the ecological sustainability. The project also lays emphasis on social sustainability as the project approach focuses on community driven strategy for forestry interventions and ecosystem management while ensures active involvement of CBOs/ CSOs, line departments and various agencies. Project seeks to achieve objectives of empowerment of local communities, livelihood support and plans to disseminate best practices for optimal use at elsewhere. The project is of

utmost importance for the Himachal Pradesh and Punjab and the country, as the river contributes significantly towards water availability, agricultural sustainability particularly in the plains, economic development, biodiversity conservation, and the overall prosperity in the region.

6.7.2 Replication

The present project is yet another pilot effort after the first project of similar nature in the context of Ganga River which is being presently implemented in five States. Hence, the country has very little experience in implementing a major project in the entire riverscape on river restoration while specifically focusing on the theme of forestry intervention. Thus, the success of this yet another pilot project will help in developing capacity for replication of such efforts within the country and elsewhere. The project has an integral component to enhance the national capacity on river conservation and restoration. The project fits into the national priorities and is expected to contribute towards the wider goals of sustainable development. Since, it is the beginning of implementation of project of this nature in a vast country like India having nine major river systems, experiences and learning in execution shall have enormous scope for their replication.

6.7.3 Cost Effectiveness

The project adopts newer, holistic, and participatory approaches towards river conservation and restoration and aims to develop best practices. The project promotes to enhance ecological integrity of the complex and dynamic river ecosystem. The cost norms for various proposed interventions have been computed on the basis of acceptable cost on the establishment of plantations in natural, agriculture and urban landscapes and the reasonable maintenance costs in the subsequent years. The project has also considered the norms of success rates of plantation in different States as well as the country as a whole. The project is expected to contribute a wide array of tangible and intangible values besides helping in the restoration of an important river ecosystem for the country. In general, cost effective norms and scientific basis to planning, management and conservation have been adopted. Project will be highly cost effective since it is not only expected to meaningfully contribute towards river conservation and restoration but also would help in development of national capacity in such endeavors and enhanced ecosystem services.

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CHAPTER-7

PROJECT BUDGET AND SCHEDULE

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7.1 Project Budget

The DPR envisages two Phases: (a) Phase 1 – Project Implementation, and (b) Phase II – Maintenance Phase. Each Phase is of 5 years duration. Thus, the project activities planned and incorporated in the DPR spread over a period of 10 years. Total projected financial outlay of the overall project is Rs. 996 Crore (Table 7.1). The Government of India is required to consider this priority conservation project on the proposed forestry interventions aiming a significant contribution towards restoration of Sutlej River and take a decision about the Central Nodal Ministry which will be responsible for project execution, coordination, steering and providing required finances as envisaged in the DPR. The MoEF&CC had assigned the task on the preparation of the DPR on forestry interventions in the context of restoration of nine major Indian River Systems to ICFRE and its institutes in April, 2019. Accordingly, the present DPR for the Sutlej River, a principal River of the Indus River System has been prepared by HFRI, Shimla. Considering the priority and specific focus on forestry interventions, the MoEF&CC may decide to lead the project and provide required finances from its own resources or request other concerned Ministry like MoJS to extend the desired financial support for execution of the DPR. Alternatively, MoEF&CC may decide to implement the project as a joint venture in collaboration with other concerned Ministries.

Cost Indexing: The project costs have been worked out on the basis of rate prevalent during year 2019-20 in the respective States and 7% escalation in the project cost during the subsequent years has been incorporated in anticipation of the cost escalation in future. However, actual project cost at the time of implementation on yearly basis shall need revision as per the change in Wholesale Price Index (WPI) on year to year basis. The Conservator of Forest may be empowered to revise the project cost accordingly for the quality desired output of the project.

The Overall Project Outlay along with the Component and/ or Activity wise cost breakup is summarized in Table 7.1.

The Component-A {**(A1+A2)+(C1+C3)**} on **'Implementations of Forestry Interventions in Two States of Riverscape'** is the principal Component considering the extent covered and projected budget outlay. This component would require a budget of Rs. 851.84 Crore or 85.53 % of the overall budget outlay. The Sub-Component A.3 on Supporting Activities would require a budget of Rs. 46.62 Crore or 4.68 % of the overall budget outlay The Component-B on 'Strengthening Knowledge Management and Enhancement Capacity for Forestry Interventions and Conservation of Riverscape' would require a sum of Rs. 29.52 Crore or 2.96% share of the overall project budget outlay. The Component-C primarily pertains to the Maintenance Phase of plantation activities undertaken during the Phase I. This Component also has a small Sub-Component that relates to replication and up scaling of successful models in remaining tributaries. The Sub-Component-C.2 seeks an overall amount of Rs. 42.20 Crore or 4.24% of the

total project cost. The designated Central Nodal Ministry responsible for project implementation, coordination and steering would require setting up a National Project Management Unit (NPMU). The NPMU would need an amount of Rs. 25.82 Crore for efficient execution of various activities envisaged in the Phase I and Phase II of the project and this represents 2.59% of the total project financial outlay. Hence, from Table 7.1, it is amply clear that the major chunk (~85.53 %) of the budget outlay is planned for field level activities concerning proposed forestry interventions, Conservation Interventions, and supporting activities to be executed by two Implementing Agencies (IAs) i.e., the State Forest Departments of Himachal Pradesh and Punjab. The consent for availability of land for proposed Forestry Interventions have been obtained from PCCF (HoFF), Himachal Pradesh Forest Department and PCCF (HoFF), Punjab Forest Department (*Annexure at page No. 256 and 282 of Vol.II for Himachal Pradesh and Punjab respectively*)

Table 7. 1 Component/ Activity Wise Budget Allocation for Sutlej Riverscape

Sr. No.	Component/ Activity	Amount	Allocation Total	Allocation Phase I
		(Rs. in Crore)	(%)	(%)
A.	**Implementation of Forestry Interventions in Sutlej Riverscape, in two States (A1+A2)+(C1+C3)**	**851.84**	**85.53**	**87.64**
A.1	**Plantations and Treatment Models in Three Categories of Landscape**	**525.17**	52.73	63.68
A.1.1	Natural Landscapes	324.03		
A.1.2	Eco Task Force	44.86		
A.1.3	Agriculture Landscapes	47.68		
A.1.4	Urban Landscapes	108.60		
A.2	**Conservation Interventions**	**197.51**	19.83	23.95
A.2.1	Soil and Moisture Conservation	144.38		
A.2.2	Riverine and Riparian Wildlife Management	45.93		
A.2.3	Wetland Management (Natural and Artificial)	7.20		
A.3	**Supporting Activities**	**46.62**	**4.68**	**5.65**
A.3.1	Policy Level Interventions	0.36		
A.3.2	Research Activities	3.31		
A.3.3	Capacity Development	12.95		
A.3.4	Awareness	10.17		
A.3.5	Participatory Monitoring	1.63		
A.3.6	Cost of PMUs of UT Level Implementing Agencies	17.09		
A.3.7	Evaluation	1.02		
A.3.8	Contingency and Miscellaneous Activities	0.09		

B.	**Strengthening Knowledge Management and National Capacity for Forestry Interventions and Conservation of Riverscapes**	**29.52**	**2.96**	**3.58**
C.	**DPR – Phase II (Maintenance phase) Including Scaling Up and Replication of Successful Models of Forestry Interventions**	**42.20**		
C.1	Maintenance Cost of A.1 and A.2 (Cost of Phase II)	93.03		
C.2	Maintenance Cost of A.3, B and D	42.20	**4.24**	
C.3	Scaling Up and Replication of Successful Models of Forestry Interventions (5% of A.1 & A.2)	36.13		
D.	**National Coordination for Forestry Interventions and Riverscape Conservation**	**25.82**	**2.59**	**3.13**
	Total Phase I (A+B+D)	**824.64**		
	Total Project Cost (Phase I+II) (A+B+C+D)	**996.00**	**100.00**	**100.00**

7.2 Project Outlay – Component and ActivityWise

The following section elaborates on the proposed budget allocation for Sub-Components and activitywise details under broad four Components of the Project.

7.2.1 Component A – Implementation of Forestry Interventions

The Component A, being the predominant Component of the overall Project has envisaged three SubComponents. Projected budget outlays for these three SubComponents are summarized below:

a) Sub-Component (A.1) on Plantations and Treatment Models in Three Types of Landscapes

The ComponentA includes three broad SubComponents and they relate to plantations and treatment models, Conservation Interventions and supporting activities. The predominant SubComponent (A.1) emphasizes on extensive plantations in three types of landscapes (Natural, Agriculture, and Urban) within the riverscape (Table 7.2). Among three landscapes, the highest prominence of proposed activities is in Natural Landscapes within the riverscape. An amount of Rs 480.31 Crore has been budgeted (Except Eco Task Force) for afforestation/ reforestation activities adopting a wide range of plantation/ treatment models. The budget allocation for plantations in Natural Landscapes alone accounts for Rs 324.03 or 61.70% of the SubComponent (A.1) on plantation and treatment models which represent 52.73% of the overall project budget outlay. One Battalion of Eco-Task Force with two Companies/ Units will also carry out plantation (2,000 ha) activities in the Natural Landscapes in the mountainous State of Himachal Pradesh at a projected cost of Rs. 44.86 Crore. Accordingly, necessary budget provision of Rs. 14 Crore has been made for the establishment of two units of ETF. Plantations and other

appropriate treatment models have been planned for Agriculture Landscapes and Urban Landscapes within the riverscape and budget provisions to the tune of Rs. 47.68 Crore and Rs. 108.60 Crore or 9.08% and 20.68 %, respectively of the SubComponent (A.1) have been made. The thrust of plantation models in Agriculture Landscapes is primarily on plantations of economic and fruit trees on privately owned farmlands and high density block plantations, particularly in the alluvial plains of Punjab. The focus of proposed activities in the Urban Landscapes would be on: (a) Bioremediation and biofiltration, (b) Institutional and industrial estate plantations, (c) Riverfront development, (d) Eco-Parks, and (e) Roadside avenue plantations.

Table 7.2 Proposed Budget Allocation for Various Plantation and Treatment Models in Three Types of Landscapes of Sutlej Riverscape

A. Natural Landscape					
State	**No. of Sites**	**Area (ha)**	**Cost of Establishment (Rs. in Crore)**	**Cost of Maintenance (Rs. in Crore)**	**Total Cost (Rs. in Crore)**
Himachal Pradesh	293	15,668	234.22	114.06	348.29
Punjab	46	1,271	16.35	10.07	26.42
Total	**339**	**16,939**	**250.57**	**124.13**	**374.7**
B. Agriculture Landscape					
State	**No. of Sites**	**Area (ha)**	**Cost of Establishment (Rs. in Crore)**	**Cost of Maintenance (Rs. in Crore)**	**Total Cost (Rs. in Crore)**
Himachal Pradesh	90	2,264	3.99	6.87	10.86
Punjab	42	8,203	14.41	25.28	39.69
Total	**132**	**10,467**	**18.40**	**32.15**	**50.55**
C. Urban Landscape					
State	**No. of Sites**	**Area (ha)**	**Cost of Establishment (Rs. in Crore)**	**Cost of Maintenance (Rs. in Crore)**	**Total Cost (Rs. in Crore)**
Himachal Pradesh	90	940.52	40.26	26.17	66.43
Punjab	43	311.80	26.51	17.22	43.73
Total	**133**	**1,252.32**	**66.71**	**43.39**	**110.16**
Grand total of Cost: 535.41					
D. Eco-Task Force					
State	**No. of Sites**	**Area (ha)**	**Cost of Establishment (Rs. in Crore)**	**Cost of Maintenance (Rs. in Crore)**	**Total Cost (Rs. in Crore)**

Himachal Pradesh	2	2,000	21.36	61.18	82.54
Total	**2**	**2,000**	**21.36**	**61.18**	**82.54**

b) Sub Component (A.2) on Conservation Interventions

The second Sub Component (A.2) pertains to various 'Conservation Interventions' including three types of activities *viz*., (a) soil and water conservation measures, (b) riverine and Riparian wildlife management, and (c) wetland management. In all, the projected budget outlay for the second Sub Component (Conservation Interventions) is Rs. 197.51 Crores and this is 19.83% allocation of the total project cost (Table 7.3).

Table 7.3: Budget Allocation for Proposed Activities under the Sub Component (A.2) on Conservation Interventions in Sutlej Riverscape

A. Soil and Moisture Conservation (Extent in m^3)					
State	**No. of Sites**	**Area (m^3)**	**Cost of Establishment (Rs. in Crore)**	**Cost of Maintenance (Rs. in Crore)**	**Total Cost (Rs. in Crore)**
Himachal Pradesh	588	5,80,523	113.05	0	113.05
Punjab	31	1,70,305	31.33	0	31.33
Total	**619**	**7,50,828**	**144.38**	**0**	**144.38**
B. Riverine and Riparian Wildlife Management (Extent in ha)					
State	**No. of Sites**	**Area (ha)**	**Cost of Establishment (Rs. in Crore)**	**Cost of Maintenance (Rs. in Crore)**	**Total Cost (Rs. in Crore)**
Himachal Pradesh	5	277	8.86	18.84	27.70
Punjab	3	185	5.92	12.58	18.50
Total	**8**	**462**	**14.78**	**31.42**	**46.20**
C. Wetland Management (Extent in ha)					
State	**No. of Sites**	**Area (ha)**	**Cost of Establishment (Rs. in Crore)**	**Cost of Maintenance (Rs. in Crore)**	**Total Cost (Rs. in Crore)**
Himachal Pradesh	3	40	1.12	2.48	3.60
Punjab	1	40	1.12	2.48	3.60
Total	**4**	**80**	**2.24**	**4.96**	**7.20**
Grand total of Cost: 197.78					

c) SubComponent (A.3) on Supporting Activities

The third SubComponent (A.3) relates to supporting activities including: (a) policy level interventions, (b) strategic adaptive research and development, (c) capacity development, (d) participatory monitoring, (e) awareness (f) evaluation, (g) cost of SPMUs in two IAs of involved

States, and (h) contingency and miscellaneous activities. The overall budget provisions for various supporting activities during Phase I and Phase II would be Rs. 60.61 Crore or 6.09% of the overall project budget outlay (Table 7.4a & 7.4b).

Table 7.4 (a) Budget Allocation for Proposed Activities under the Sub Component (A.3) on Supporting Activities in Sutlej Riverscape

Sr. No.	Activity	States		Total	States		Total	Grand Total
				(Rs. in Crore)			(Rs. in Crore)	(Rs. in Crore)
		Himachal Pradesh	Punjab	Phase I	Himachal Pradesh	Punjab	Phase II	Phase I+II
		(Rs. in Crore)	(Rs. in Crore)	(Rs. in Crore)	(Rs. in Crore)	(Rs. in Crore)	(Rs. in Crore)	(Rs. in Crore)
1	**Policy Level Interventions**	0.21	0.15	**0.36**	0.02	0.00	**0.02**	**0.38**
2	**Research**	2.66	0.64	**3.31**	1.70	0.38	**2.08**	**5.39**
3	**Capacity Development**	7.86	5.09	**12.95**	0.00	0.00	**0.00**	**12.95**
4	**Awareness**	7.07	3.09	**10.17**	0.00	0.00	**0.00**	**10.17**
5	**Participatory Monitoring**	0.99	0.64	**1.63**	0.58	0.38	**0.96**	**2.59**
6	**Project Management**	10.51	6.57	**17.09**	5.04	1.76	**6.80**	**23.89**
7	**Evaluation**	0.63	0.40	**1.02**	2.61	1.49	**4.10**	**5.12**
8	**Contingency and other Expenses**	0.05	0.03	**0.09**	0.03	0.01	**0.03**	**0.12**
Total Cost – Supporting Activities		29.99	16.62	**46.61**	9.98	4.02	**14.00**	**60.61**

Table 7.4 (b.1) Year-Wise Breakup Budget Allocation of Projected Cost on Supporting Activities in Sutlej riverscape

Sr. No.	Activity	Year					
		(Rs. in lakh)					
		Phase I					Total
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Phase-I
1	**Policy Level Interventions**	12.68	7.70	5.92	5.13	4.35	**35.77**
2	**Research Activities**	63.91	64.75	65.87	67.25	68.89	**330.67**
3	**Capacity Development**	248.00	244.65	296.88	269.73	235.98	**1295.24**
4	**Awareness**	184.00	193.20	202.86	213.00	223.65	**1016.72**
5	**Participatory Monitoring**	39.82	35.84	32.25	29.03	26.12	**163.06**
6	**Cost of PMUs of Two State Level Implementing Agencies**	398.17	304.54	319.44	335.09	351.52	**1708.76**

7	**Evaluation**	0.00	0.00	102.22	0.00	0.00	**102.22**
8	**Contingency and Miscellaneous Activities**	1.99	1.52	1.60	1.68	1.76	**8.54**
Grand Total of Riverscape		**948.57**	**852.19**	**1027.03**	**920.90**	**912.27**	**4660.96**

Table 7.4 (b.2) Year-Wise Breakup Budget Allocation of Projected Cost on Supporting Activities in Sutlej riverscape

Sr. No.	**Activity**	**Year**					**Total**	**Grand Total**
		(Rs. in lakh)					**(Rs. in lakh)**	**(Rs. in lakh)**
		Phase II					**Phase II**	**Phase I+II**
		6th Year	**7th Year**	**8th Year**	**9th Year**	**10th Year**		
1	**Policy Level Interventions**	2.26	0.00	0.00	0.00	0.00	2.26	**38.02**
2	**Research Activities**	40.04	40.65	41.42	42.37	43.47	207.95	**538.62**
3	**Capacity Development**	0.00	0.00	0.00	0.00	0.00	0.00	**1295.24**
4	**Awareness**	0.00	0.00	0.00	0.00	0.00	0.00	**1016.72**
5	**Participatory Monitoring**	23.51	21.16	19.04	17.14	15.43	96.28	**259.34**
6	**Cost of PMUs of Two State Level Implementing Agencies**	154.24	143.60	135.18	127.26	119.80	680.07	**2388.83**
7	**Evaluation**	170.88	0.00	0.00	0.00	238.88	409.76	**511.97**
8	**Contingency and Miscellaneous Activities**	0.77	0.72	0.68	0.64	0.60	3.40	**11.94**
Grand Total of Riverscape		**391.69**	**206.13**	**196.33**	**187.40**	**418.18**	**1399.72**	**6060.68**

7.2.2 Component B – Strengthening Knowledge Management, Enhancing Capacity for Forestry Interventions and Conservation of Riverscape

The Component B specifically pertains to the National Partner Organization (NPO) responsible for carrying out priority activities relevant to the strengthening of knowledge management, enhancement of capacity for forestry interventions and River conservation. Activitywise projected budget for the NPO (HFRI, Shimla) is presented in Table 7.5. The budget allocation amounting Rs. 10.07 Crore is for the purpose of strategic adaptive research and development on priority thrust areas for strengthening knowledge management and capacity enhancement for river conservation. Necessary budget provisions for three other important activities *viz*., (a) policy level interventions, (b) capacity development, (c) awareness (d) monitoring, and (e) evaluation have also been made and projected budget outlays for these activities are: Rs. 2.68 Crore, Rs. 4.32 Crore, Rs. 1.54 Crore, Rs. 1.06 Crore, and Rs. 2.26 Crore, respectively. In all, the projected budget outlay for the NPO is Rs. 44.86 Crore or 4.50% of the total project cost.

Table 7.5 Budget Allocations for Proposed Activities under the Component B on Strengthening Knowledge Management, Enhancing Capacity for Forestry Interventions and Conservation of Riverscape

Sr. No.	Item	Year											Total (Rs. in Crore)	Cost (Rs. in Crore)
		Phase I					Total	Phase II						
		I	II	III	IV	V	Phase I	VI	VII	VIII	IX	X	Phase II	Phase I+II
A.	**Recurring Cost**													
A.1	Cost of PFU Salary and Wages, Equipment, Office Expenses and Management, Travel, Vehicle and POL, Audits, etc.,	1.62	1.45	1.51	1.57	1.64	**7.79**	0.55	0.52	0.49	0.46	0.43	**2.45**	**10.24**
A.2	Inputs for Policy Level Interventions	0.32	0.34	0.36	0.38	0.39	**1.79**	0.41	0.000	0.000	0.000	0.48	**0.89**	**2.68**
A.3	Strategic Adaptive Research and Development	1.13	1.19	1.25	1.31	1.38	**6.27**	0.69	0.72	0.76	0.80	0.84	**3.81**	**10.07**
A.4	Knowledge Management and Capacity Development	0.49	0.51	0.54	0.56	0.59	**2.69**	0.30	0.31	0.33	0.34	0.36	**1.63**	**4.32**
A. 5	Scientific Exchange, Exposure Visits, and Engagement of International and National Consultants	0.65	0.68	0.71	0.75	0.79	**3.58**	0.39	0.41	0.43	0.46	0.48	**2.18**	**5.76**
A. 6	Inputs for Awareness	0.49	0.24	0.24	0.24	0.24	**1.46**	0.06	0.00	0.02	0.00	0.00	**0.08**	**1.54**
A.7	Monitoring Project, and Ecological and Socioeconomic	0.16	0.15	0.13	0.12	0.11	**0.66**	0.10	0.09	0.08	0.07	0.06	**0.39**	**1.06**
A. 8	Project Evaluation			0.46			**0.46**	0.78				1.02	**1.80**	**2.26**
	Sub Total Recurring Cost (A)	**4.86**	**4.56**	**5.20**	**4.94**	**5.14**	**24.70**	**3.28**	**2.05**	**2.10**	**2.13**	**3.67**	**13.23**	**37.93**
B.	**NonRecurring Cost**													
B.1	Incorporation	0.16	0.15	0.13	0.12	0.11	0.66	0.05	0.00	0.00	0.00	0.00	**0.05**	**0.72**

	of Advance Technology													
B.2	Permanent Equipment and Maint.	0.16	0.08	0.04	0.02	0.01	0.31	0.01	0.01	0.01	0.01	0.01	**0.05**	**0.36**
	Sub Total NonRecurring Cost (B)	**0.32**	**0.23**	**0.17**	**0.14**	**0.12**	**0.98**	**0.06**	**0.01**	**0.01**	**0.01**	**0.01**	**0.10**	**1.08**
C.	**Total (Recurring and Non Recurring Costs) A+B**	**5.18**	**4.78**	**5.37**	**5.07**	**5.26**	**25.67**	**3.34**	**2.06**	**2.11**	**2.14**	**3.68**	**13.33**	**39.01**
D.	**Institutional Charge @ 15%**	0.78	0.72	0.81	0.76	0.79	3.85	0.50	0.31	0.32	0.32	0.55	**2.00**	**5.85**
E.	**Grand Total (C+D)**	**5.96**	**5.50**	**6.18**	**5.84**	**6.05**	**29.52**	**3.84**	**2.37**	**2.43**	**2.46**	**4.24**	**15.33**	**44.86**

7.2.3 Component C – Maintenance Phase Including Replication/ Scaling up

The proposed forestry interventions, particularly plantations in the Natural Landscapes within the temperate zone envisages 7 to 8 years of plantation activities including the establishment of nurseries, preparatory works, three to four years for developing planting material, actual planting activities, and the management phase. The Sub-Component C.2 specifically pertains to the Maintenance Phase of Plantations (Phase II) including contingent provisions for planning replication and scaling up of activities in left over tributaries. A budget of Rs. 42.20 Crore or representing 4.24% (Table. 7.1) allocation of the overall project budget outlay has been provisioned for the Sub-Component C.2.

7.2.4 Component D – National Coordination for Project Implementation

The fourth Component D of the Project relates to National Level Project Coordination and Management by the Central Nodal Ministry. A sum of Rs. 25.82 Crore during Phase I and Phase II would be necessary for the establishment of NPU at the Central Nodal Ministry and for undertaking various envisaged activities for efficient project implementation, coordination, management, steering, evaluation, etc (Table 7.6). The projected budget for the Component D represents 2.59% for the overall project budget outlay.

Table 7.6 Proposed Budgets for Project Management Unit at the Central Nodal Ministry

Sr. No.	**Item**	**Year**												**Grand Total Cost**
		Phase I					**Total**	**Phase II**					**Total**	**(Rs. in Crore)**
		I	**II**	**III**	**IV**	**V**	**Phase I**	**VI**	**VII**	**VIII**	**IX**	**X**	**Phase- II**	**Phase I+II**
A. Recurring Cost														
A.1	Cost of PMU Salary and Wages, Equipment, Office	1.76	1.36	1.41	1.48	1.55	**7.57**	0.49	0.46	0.44	0.41	0.39	**2.19**	**9.76**

	Expenses and Management, Travel, Vehicle and POL, Audits, etc.,													
A.2	Inputs for Policy Level Interventions	0.53	0.56	0.58	0.61	0.64	**2.92**	0.64	0.00	0.00	0.00	0.74	**1.39**	**4.31**
A.3	National Decision Support and Management Information System	0.70	0.74	0.78	0.82	0.86	**3.89**	0.45	0.40	0.36	0.33	0.30	**1.84**	**5.74**
A.4	Scientific Exchange, Exposure Visits, and Engagement of International and National Consultants	0.88	0.93	0.97	1.02	1.07	**4.87**	0.96	0.44	0.44	0.44	0.44	**2.73**	**7.59**
A.5	Inputs for National Level Awareness	0.53	0.56	0.58	0.61	0.64	**2.92**	0.58	0.55	0.52	0.49	0.46	**2.59**	**5.51**
A.6	Project Monitoring and Evaluation			0.45			**0.45**	0.76				0.98	**1.73**	**2.19**
Sub Total Recurring Cost (A)		4.41	4.14	4.78	4.54	4.77	**22.63**	3.88	1.85	1.76	1.67	3.31	**12.47**	**35.10**
B. NonRecurring Cost														
B.1	Incorporation of Advance Technology	0.53	0.48	0.43	0.39	0.35	**2.16**	0.35	0.00	0.00	0.00	0.00	**0.35**	**2.51**
B.2	Permanent Equipment	0.53	0.26	0.13	0.07	0.03	**1.02**	0.01	0.01	0.01	0.01	0.01	**0.05**	**1.07**
Sub Total NonRecurring Cost (B)		1.06	0.74	0.56	0.45	0.38	**3.19**	0.36	0.01	0.01	0.01	0.01	**0.40**	**3.59**
C.	**Grand Total (Recurring and NonRecurring Costs) A+B**	**5.46**	**4.88**	**5.34**	**4.99**	**5.15**	**25.82**	**4.24**	**1.86**	**1.77**	**1.68**	**3.32**	**12.87**	**38.69**

7.3 Budget Outlays – States/ Implementing AgencyWise

The Project envisages involvement of two States located along the course of the Sutlej River and their respective Forest Department as the Implementing Agency. The budget outlay for each of the two participating States in the Project is summarized in Table 7.7. and it reveals that the highest amount of Rs. 692.43 Crore or 78.42% of total budget (Rs. 883.03 Crore) allocation to two State IAs is to be provided to the mountainous State of Himachal Pradesh so as to ensure extensive as well as intensive inputs in the prominent part of the catchment of the River. The budget outlay for Punjab is Rs 183.91 Crore or 20.83% of the overall proposed budget allocation to two State IAs (Table 7.7). Thus, proposed financial allocation for the States of Himachal Pradesh and Punjab are to the tune of Rs. 692.37 Crore and Rs. 183.91 Crore, respectively.

Table 7.7 Budget outlay (in Crore) for each of the two participating States in the Project

States	Natural	Eco-Task Force	Agriculture	Urban	Conservation	Supporting Activities	Total
Himachal Pradesh	348.29	82.54	10.86	66.43	144.35	39.97	692.43
Punjab	26.42	0	39.69	43.73	53.43	20.64	183.91
Total	**374.71**	**82.54**	**50.55**	**110.15**	**197.78**	**60.61**	**883.03**

7.4 Budget Outlays – Intervention/ Activity Wise

Table 7.8 provides an overall summary of the proposed budget allocations to State IAs for carrying out various forestry interventions. The proposed budget outlay to SFDs/ IAs includes cost towards plantation activities in three types of landscapes and other treatment models besides carrying out various Conservation Interventions and supporting activities.

Table 7.8: Overall summary of the proposed budget allocations in various forestry interventions

State	Landscape	Model/ Activity	Area (ha)	Cost (Rs. in Lakhs)
Himachal Pradesh	**Natural**	SL/HP/NL/01 Cold Desert Greening	100	386.78
		SL/HP/NL/02 Cold Desert Conservation	100	255.09
		SL/HP/NL/03 Alpine Conservation	60	144.46
		SL/NL/H/04 SubAlpine Enrichment	315	600.97
		SL/NL/H/05 Dry Temperate Conifer Forest Enrichment	10	35.75
		SL/NL/H/06 Temperate Conifer Forest	681	2070.12
		SL/NL/H/07 Temperate Mixed Forest	665	2026.54
		SL/HP/NL/08 Pasture and Grazing Land Development	185	420.97
		SL/HP/NL/09 Himalayan Chir Pine Forest	1442	4375.86
		SL/HP/NL/10 Himalayan Mixed Forest	820	2238.19
		SL/HP/NL/11 Sub Tropical Dry Deciduous Forest	2039	5471.16
		SL/HP/NL/12 Eradication of *Lantana* (> 50%)	576	1822.03
		SL/HP/NL/13 Control/	60	184.21

		Removal of Invasive Species or <50% *Lantana*		
		SL/HP/NL/14 Protection Model for Natural Regeneration	7030	12649.30
		SL/HP/NL/15 Fire Protection Model	1585	2043.4
	Eco-Task Force	SL/HP/NL/16 Eco-Task Force	2000	8254
	Agriculture	SL/HP/AL/01 Boundary Plantation Model	1764	432.15
		SL/HP/AL/02 Block Plantation Model	500	652.91
	Urban	SL/HP/UL/01 Bioremediation and Bio filtration	17.25	426.95
		SL/HP/UL/02 Riverfront Development	4.75	1175.64
		SL/HP/UL/03 Institution Plantation	914	3921.06
		SL/HP/UL/04 Eco-Park Development	4.52	1118.71
	Conservation Interventions (area in m^3)	SL/HP/CI/01 Brushwood Interventions	126990	380.99
		SL/HP/CI/02 Dry Stone Activities	181641	3269.538
		SL/HP/CI/03 Crate Wire Activity	122031	5491.41
		SL/HP/CI/04 Water Pond	120865	423.0275
		SL/HP/CI/05 Silt Detention Dam Type Activity	28996	1739.76
	Other Interventions	SL/HP/CI/06 Riverine and Riparian Management	277	2770
		SL/HP/CI/07 Wetland Management	40	360
Punjab	**Natural**	SL/PB/NL/01 Shivalik Hills Forest Enrichment	694	1513.27
		SL/PB/NL/02 Degraded Model with Staggered Trench & Pits	135	264.41
		SL/PB/NL/03 – Control/ Removal of Invasive Species and *Lantana*	145	94.61
		SL/PB/NL/04 Restoration of Degraded Forests	260	602.97
		SL/PB/NL/05 Road Side Plantation	37	166.37
	Agriculture	SL/PB/AL./01 Boundary	6400	1614.58

		Plantation Model		
		SL/PB/AL./02 Block Plantation Model	1803	2353.96
	Urban	SL/PB/UL/01 Bioremediation and Bio filtration	20	495
		SL/PB/UL/02 Riverfront Development	0.3	74.25
		SL/PB/UL/03 Institution Plantation	281	1205.49
		SL/PB/UL/04 Eco-Park Development	10.5	2598.75
	Conservation Interventions (area in m^3)	SL/PB/CI/01 Brushwood Interventions	57785	173.355
		SL/PB/CI/02 Dry Stone Activities	50280	905.04
		SL/PB/CI/03 Crate Wire Activities	37110	1669.95
		SL/PB/CI/04 Water Ponds	19870	69.57
		SL/PB/CI/05 Silt Detention Dam Type Activities	5260	315.6
	Other Interventions	SL/PB/CI/06 Riverine and Riparian Management	185	1850
		SL/PB/CI/07 Wetland Management	40	360

7.5 Project Budget Outlays – Forest Division Wise

In all, 32 Forest Divisions in two implementing States will participate and carry out proposed activities relevant to forestry interventions including plantations, Conservation Interventions, and supporting activities. The overall projected budget outlay for 32 Forest Divisions in two States is provided in respective State Summaries incorporated in Vol. II of DPR. The total projected cost of Phase-I is 824.64 Crore and total project cost is 996 Crore (Table 7.1).

7.6 Project Schedule

As stated earlier, the project has been planned in two Phases of 5years each. The first five year period during Phase I focus on actual project implementation while the Phase II primarily focuses on the maintenance Phase, particularly plantations. At the time of finalization of the present DPR, it was not certain which would be the project commencement year as project is yet to seek funding as envisage in the DPR. However, various project activities planned under the proposed four components and different Sub-Components have been suitably staggered during the Phase I. The extent (ha) of proposed plantations and other Conservation Interventions and corresponding costs have been summarized in Table 7.9 to 7.12.

Table 7.9: Extent (ha) of proposed plantations and other Conservation Interventions in Sutlej Riverscape Phase-I

PHASE –I											
Landscape/ Activity	**1st Year**	**2nd Year**		**3rd Year**		**4th Year**		**5th Year**		**Total Phase-I**	
	Estb.	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**
Natural	3725	3900	3725	3764	7625	2740	11389	2810	14129	16939	14129
Eco-Task Force	0	400	0	400	400	400	800	400	1200	1600	1200
Agriculture	4159	3600	4159	2708	7759	0	10467	0	6308	10467	10467
Urban	439.57	415.75	439.57	397	855.32	0	1252.32	0	812.75	1252.32	1252.32
Conservation Interventions	161683	187734	367	163303	397	133665	397	104840	397	751225	397
Total	**170006.57**	**196049.75**	**8690.57**	**170572**	**17036.32**	**136805**	**24305.32**	**108050**	**22846.75**	**781483.32**	**27445.32**

Table 7.10 Extent (ha) of proposed plantations and other Conservation Interventions in Sutlej Riverscape – Phase-II

PHASE –II											
Landscape/ Activity	**6th Year**		**7th Year**		**8th Year**		**9th Year**		**10th Year**		**Total Phase-II**	
	Estb	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**
Natural	0	13214	0	8737	0	5155	0	20860	0	0	0	14204
Eco-Task Force	400	1600	0	1600	0	1200	0	800	0	400	400	2000
Agriculture	0	2708	0	0	0	0	0	0	0	0	0	2708
Urban	0	397	0	0	0	0	0	0	0	0	0	397
Conservation Interventions	0	30	0	0	0	0	0	0	0	0	0	30
Total	**400**	**17949**	**0**	**10337**	**0**	**6355**	**0**	**21660**	**0**	**400**	**400**	**19339**

Table 7.11 Proposed Budget (Crore) for plantations and other Conservation Interventions in Sutlej Riverscape – Phase-I

PHASE –I											
Landscape/ Activity	**1st Year**	**2nd Year**		**3rd Year**		**4th Year**		**5th Year**		**Total Phase-I**	
	Estb.	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**
Natural	36.80	84.55	7.17	66.15	12.89	45.13	24.35	17.94	29.05	250.57	73.46
Eco-Task Force	14	1.20	6	1.32	6.30	1.44	6.40	1.60	6.60	19.56	25.30
Agriculture	7.57	6.27	4.05	4.55	7.79	0	10.85	0	6.60	18.40	29.28
Urban	37.16	19.28	11.15	10.32	13.22	0	12.53	0	4.96	66.76	41.85
Conservation Interventions	44.99	38.80	14.10	38.48	10.33	21.67	6.71	17.46	4.97	161.40	36.11
Total	**140.52**	**150.1**	**42.47**	**120.82**	**50.53**	**68.24**	**60.84**	**37**	**52.18**	**516.69**	**206.00**

Table 7.12 Proposed Budget (Crore) for plantations and other Conservation Interventions in Sutlej Riverscape – Phase-II

PHASE –II												
Landscape/ Activity	**6th Year**		**7th Year**		**8th Year**		**9th Year**		**10th Year**		**Total PhaseII**	
	Estb.	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**	**Estb.**	**Maint.**
Natural	0	27.48	0	15.37	0	6.42	0	1.39	0	0	0	50.67
Eco-Task Force	1.80	6.80	0	7.48	0	7.36	0	7.16	0	7.08	1.80	35.88
Agriculture	0	2.85	0	0	0	0	0	0	0	0	0	2.85
Urban	0	1.55	0	0	0	0	0	0	0	0	0	1.55
Conservation Interventions	0	0.27	0	0	0	0	0	0	0	0	0	0.27
Total	**1.8**	**38.95**	**0**	**22.85**	**0**	**13.78**	**0**	**8.55**	**0**	**7.08**	**1.8**	**91.22**

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CHAPTER-8

POTENTIAL BENEFITS OF PROPOSED FORESTRY INTERVENTIONS

CHAPTER 8

POTENTIAL BENEFITS OF PROPOSED FORESTRY INTERVENTIONS

8.1 Benefits of River Restoration

Healthy rivers perform various ecological functions which in turn provide a wide range of social and economic benefits. These benefits derived from the rivers can be expressed in terms of provisioning, regulatory, cultural or supporting ecosystem services (MEA, 2005). River restoration has become essential where river systems have degraded to the point that can no longer provide the ecological services required of them. Increasingly, river restoration is now a common response to declining river health and its importance can only be expected to grow in future. Restoration of river is often triggered on account of ecological concerns, social and cultural factors, economic drivers, the need to protect infrastructure and assets from water related risks, and increasing water security concerns (Speed *et al.*, 2016). Restoration includes any action aimed at improving the health of the River, including improving ecosystem functions and any related ecosystem service. The benefits of well designed river restoration projects will mainly be felt from the return of at least some ecological and social services as a result of improvements in river health.

8.2 The Need for River Restoration in the Context of Sutlej River

The need for river restoration in the context of Sutlej River has arisen as a consequence of primarily two main reasons i.e., (a) Degradation of river ecosystem because of deforestation in past, enhanced dependence on forest resources resulting into forest degradation, expansion of agriculture and horticulture, increased developmental activities (i.e., road network, HEPs, urbanization and industrialization along the course of river and its tributaries), over abstraction, diversion of water, pollution, and climate change; and (b) Loss of ecological services historically provided by River are indicated by decreased water availability; decline of water quality; loss of biodiversity; reduced aesthetics; reduction in recreational and tourism values; increased floods; and the growing risks.

Based on the exhaustive review on the river and its environment, it can be safely stated that the current degraded state of the Sutlej River is a cumulative reflection of a number of anthropogenic activities occurred gradually in past one and a half centuries or so in its basin area (Fig. 8.1). Resultant major environmental concerns or evident broad based symptoms of river deterioration are: (i) Degraded catchment area and river ecosystems; (ii) Excessive soil erosion, landslides and sedimentation in dams and flood plains; (iii) Non availability of water in dry period and reduced environmental flow; and (iv) Unhygienic and poor quality of water.

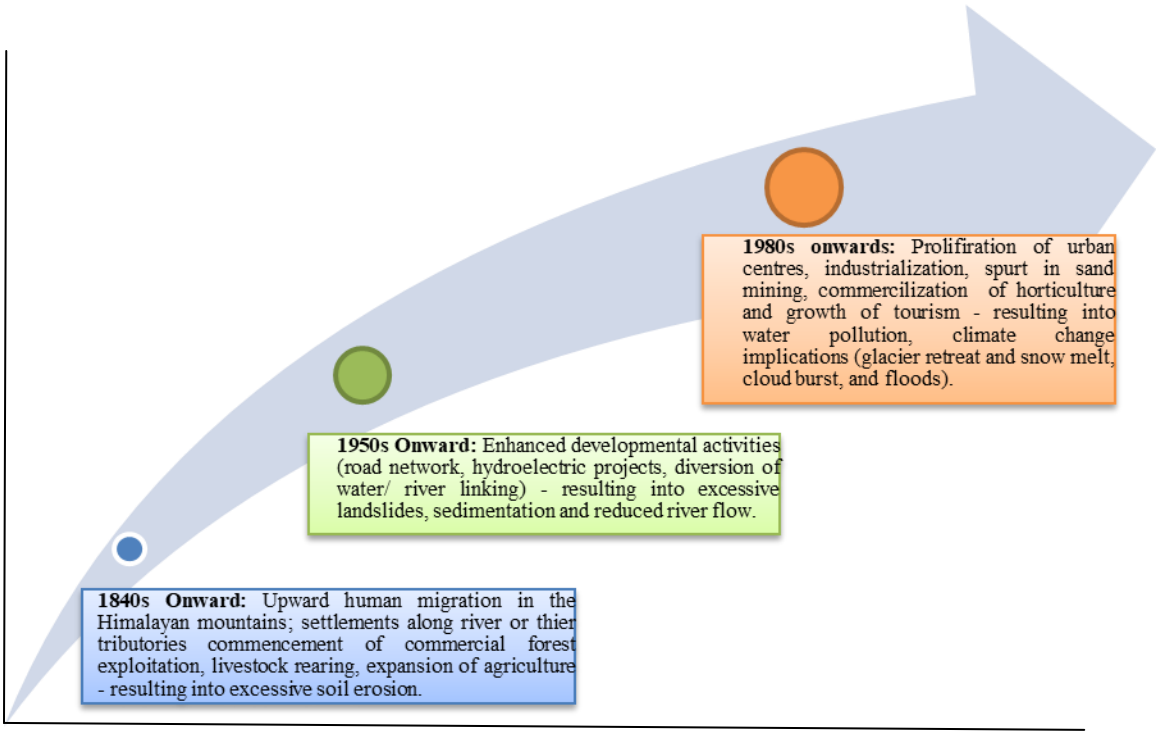


Fig.8. 1 Gradual Process of Degradation and Cumulative Impact on the River Ecosystem

8.3 Strategy and Measures for River Restoration

The present DPR has adopted a comprehensive, multipronged strategy for implementing various Forestry Interventions to address above stated four broad based symptoms of river degradation. Several potential measures have been planned for concurrent implementation for restoration of Sutlej River. The proposed restoration strategy includes extensive plantation activities in Natural, Agriculture and Urban Landscapes within the Riverscape along with appropriate bioengineering and mechanical measures for Soil and Water Conservation besides Riparian and Riverine Wildlife Management, and Wetland Conservation for overall improvement in river ecosystem. Several Supporting Activities *viz*., policy level interventions, concurrent research and development, awareness, capacity development, participatory monitoring, and evaluation vital for effective and successful execution of the implementation plan of various Forestry Interventions have also been envisaged.

8.4 Potential Benefits of Proposed Forestry Interventions

The proposed efforts towards river restoration are confined exclusively to Forestry Interventions aiming for enhancement of forest cover, intervention in grassland and wetland management, reduction in soil erosion, Riparian management, and in stream/ aquatic habitat and species management. Certainly, several other measures of engineering, hydrological, mechanical, agricultural and biotechnological nature aiming channel and flow modification, dam removal or retrofitting, bank stabilization, storm water management and flood control, spring/ aquifer

management, floodplain reconnection and channelization, channel reconfiguration, management of industrial effluents and urban waste and sewage, climate smart agriculture, management of toxins, etc. are out of purview of the present DPR.

In view of the above, various potential socio-economic benefits and improved ecological function expected as a result of proposed wide ranging Forestry Interventions for restoration of Sutlej River are summarized in Table 8.1.

Table 8. 1 Potential Socio-economic Benefits and Improved Ecological Functions as a result of Proposed Forestry Interventions

Element	Approach to Restoration	Ecosystem Services			
		Provisioning	**Regulating**	**Cultural**	**Supporting**
Catchment	Protection and conservation of natural forests; forest plantations in Natural Landscapes, agroforestry practices in Agriculture Landscapes, and development of Eco-Parks/ avenue plantations in Urban Landscapes; and various other conservation intervention	Wood, NTFPs – fuel wood, fiber, fruits, medicinal and aromatic plants for human consumption; grass, fodder, and grazing for livestock; increased population and enhanced abundance of native flora and fauna including Rare, Endemic and Threatened (RET) species	Carbon sequestration by forest/ plantation and other vegetation and carbon storage in soils; water storage by forests/ plantations function of 'sponge' and water purification; control water temperature; lessens soil erosion, sediment and nutrient runoff; control of Invasive and Alien Species; enhanced fluvial processes, lateral connectivity; and environmental amelioration	Aesthetic value of natural forests and Riparian zones; benefit to tourism, employment generation, and areas for public recreation	Increased and improved habitat for biodiversity on land and in stream/ rivers; checking soil erosion, water conservation; and sediment changes
Flow regime	Water availability	Increased availability of	Alter the timing and	Increased ecotourism	Important fish spawning

Element	Approach to Restoration	Ecosystem Services			
		Provisioning	**Regulating**	**Cultural**	**Supporting**
	and environmental flow	water and enhanced environmental flow; affect fish diversity and population and other services that rely on presence and abundance of migratory fishes	delivery of water; and improvement in water quality; enhanced longitudinal and vertical connectivity	and recreation	habitat and benthic invertebrates
Habitat	Instream habitat improvement and bank stability	Increase in availability of key fish and other featured aquatic fauna; improved fisheries, and conserve native species	Increased oxygenation and sediment flushing of water; reduced diffuse and point source pollution	Improved aesthetics and environment for recreation	Physical habitat heterogeneity; enhanced biodiversity; Improves and stabilizes physical habitats for breeding; increased richness and abundance of macro invertebrates; enhanced spawning, feeding and refugia habitats for native fishes
Water Quality	Improvement in water quality	Supports aquatic fauna and enhancement in native fish diversity	Improvement in stream water quality and reduces competition of native fish species for resources	Enhances the economic and social amenity value; improves the quality of life	Reduces habitat inhabitance by invasive species and increase in population and abundance of RET species
Biodiversity	Species management	Increase in availability of	Improves water quality and	Improves river health and	Alter aquatic native species

Element	Approach to Restoration	Ecosystem Services			
		Provisioning	**Regulating**	**Cultural**	**Supporting**
		native fish and other aquatic fauna	resource competition among native fish species	recreational activities	distribution and abundance

(Source: Adopted and Modified from Speed *et al.*, 2016)

8.5 Forest Plantation

Forests like any other natural ecosystem provide multiple environmental benefits, and this recognition is not new because as early as in 400 BC Plato has recognized that the loss of forests could lead to soil erosion and the drying up of springs and other water bodies (Bauhus *et al.*, 2010; Soman and Anitha, 2019). Traditionally, several goods and services from forest ecosystems have been viewed as free benefits to society. Several ecosystem services provided by forests are difficult to quantify and thus, neither market exists for many of them nor have their values seldom been reflected in market prices. In spite of multiple environmental benefits obtained by the human society, mankind has altered and transformed 40% to 50% of the ice free terrestrial surface of the Earth and appropriates about 20% of the global net primary production. The projections also stress that natural ecosystems are being replaced that provide enormous benefits to human society by plantation forests.

Tree plantations are artificial forests that differ greatly from natural forest ecosystems in terms of their structure, composition and functions. While the area of natural forests is shrinking, tree plantations are expanding at a rapid rate and dominate the Landscapes in some regions of the world (Kanninen, 2010). Forest plantation is defined as 'Forest or other wooded land of introduced species and in some cases native species, established through planting or seeding'. Forest plantations are divided into two sub groups: 'Productive Plantations' and 'Protective Plantations' (FAO, 2005). Forest plantations mainly intended for the provision of wood, fiber and non wood products are referred as productive plantations while forest plantations meant for the provision of services such as the protection of soil and water, rehabilitation of degraded lands, combating desertification, etc. are being referred as protective plantations. As per FAO (2005), forests plantations cover about 140 million hectares (Mha) globally, representing about 4% of the global forest area. In 2000, plantations supplied one third of the total demand for industrial round wood. CIFOR (2001) has provided the typology of planted forests as they are not only distinguished by their different purposes, but also by their spatial scale, management intensity, structure and ownership. Accordingly, planted forests based on type and purposes have been named as: (a) Industrial plantations (i.e., timber, biomass, food); (b) Home and farm plantations (i.e., fuel wood, timber, fodder, orchards, forest gardens, etc.); (c) Agroforestry plantations (i.e., fuel wood, timber, fodder); and (d) Environmental plantations (i.e., windbreaks, soil protection and erosion control, wildlife management and site reclamation or amenity). In

addition, the 'Managed Secondary Forests', where forest composition and productivity is maintained through additional planting or/ and seeding are regarded as a transitional type between plantations and other forest types. This broadening of the definition almost doubles the area of planted forests and estimated to be around 270 Mha, compared to around 140 Mha reported earlier as forest plantations (Kanninen, 2010; Bauhus *et al.*, 2010).

In view of the above, proposed forest plantations in Natural Landscapes would fall in the category of 'Protective Plantations', particularly 'Environmental Plantations' as defined by CIFOR, (2001) for obtaining various ecosystem service. Some of these plantations are specifically intended as 'Enrichment Plantations' in managed forests through additional planting or/ and seeding. Beside these, in fire prone areas fire protection model and in good natural regeneration areas only protection models are being proposed for enhancing economic viability and effectiveness of this DPR. Proposed plantations in Agriculture Landscapes are mainly aimed for the purpose of increase in tree cover in TOFs and subsistence or local sale for some additional income and for their benefits alongside agricultural production and thus, would fall under the category of agroforestry plantations. Proposed plantations in the Urban Landscapes along roads, railway lines, canals, and in educational and industrial estates would also fall in the category of environmental plantations. Thus, it is amply clear that majority of proposed plantations in three types of landscapes within the riverscape are neither 'Productive' nor 'Commercial' in nature, except a small extent of agroforestry plantations proposed on private lands. Even agroforestry plantations would also immensely help in increasing the tree cover in TOFs providing some additional income to farming communities.

8.5.1 Forest Plantations - Myths and Reality

Several myths abound about plantation forests or fast wood forestry. Many believe that fastwood forestry/ short rotation forestry is an environmental and social menace. Cossalter and PyeSmith, (2003) have attempted to sort facts from fiction, truth from misinformation, as far as fastwood forestry is concerned. In some situations, short rotation plantations have caused environmental and social problems and it is a truth that such plantations are a bad thing by exploiting resources. Thus, undesirable to some extent; while in other situations, they can yield benefits not just for the economy, but for the environment, and local communities. Growing fastwood can be an efficient way of producing timber and pulpwood and such plantations can be a profitable investment for the involved companies as well as for the society. However, environmentalists dislike all large scale monocultures, particularly of exotic species as they not only adversely impact the local environment, but offer much reduced ecosystem services than natural forests. Nevertheless, in certain situations, plantations may help to enrich biodiversity (Cossalter and Pye Smith, 2003) and moderate local climate conditions to some extent. Therefore, in this DPR more emphasis is given on plantation of native species and only in Agricultural Landscape short rotation economically viable exotics are suggested for plantation.

8.5.2 Plantations for Carbon Sequestration

Climate change has been recognized as the most important global environmental challenge humanity is facing with implications for fresh water supply, natural ecosystems, food production, health, biodiversity, etc. Certainly, since the pre-industrial era, the Earth's climate system has drastically changed on both global and regional scales. The environmental security has become a global concern. The Intergovernmental Panel on Climate Change (IPCC) has estimated that 20% to 30% of plants and animals could be at risk of extinction, if average global temperatures reach the projected levels (Hawkes *et al.*, 2007; Chauhan *et al.*, 2016). The concentration of carbon dioxide (CO_2) and other Green House Gases (GHGs) in the atmosphere has considerably increased over the last century and is set to increase further, the larger proportion of which is resulting from the burning of fossil fuels and the conversion of tropical forests especially in Amazon basin to agriculture (Paustian *et al.*, 2000).

Presently, there are global efforts to manage carbon by different means. One way is to manage carbon is through carbon sequestration. The investment in forestry sector has been recognized as an effective means as trees not only can sequester relatively a large quantity of carbon for a longer period but also capable to store carbon for long time in finished wood products. Likewise, other vegetation in forests and forest soils can also accumulate considerable amount of carbon in biomass and soil. Thus, protecting the existing forest woodlands and establishing the new ones, will definitely help the priority agenda to limit GHS emissions (Jose and Bardhan, 2012; Chauhan *et al.*, 2016). Tree plantations feature prominently among the tools for carbon sequestration. However, Jackson *et al.* (2005) stated that carbon sequestration strategies emphasize tree plantations without considering their full environmental consequences. Based on combined field research, synthesis of more than 600 observations, and climate and economic modeling, they documented substantial losses in stream flow, and increase soil salinization and acidification, with afforestation. They further described that plantations decreased stream flow globally by 52%, with 13% of streams drying completely for at least one year and concluded that plantations can help control groundwater recharge and upwelling but reduced stream flow and salinize and acidify some soils. At the same time, they also observed that a different situation is found in some other regions, where reforestation and afforestation can improve water quality.

Böttcher and Lindner (2010) described five strategies for the contribution of the forestry sector to combat climate change. These are: (a) Increase forest area, (b) Increase carbon stock in existing forest, (c) Protect existing stocks, (d) Increase carbon stored in products, (e) Substitute fossil fuels with bioenergy derived from forest biomass and wood. There is great theoretical potential for plantation forestry to contribute towards increase in forest area and enhancement of carbon stock in existing forests through afforestation. According to Böttcher and Lindner (2010), carbon sequestration in the forest based sector is, to a large degree a non permanent strategy as tree plantations that are established, harvested yet not reestablished do not contribute further to carbon sequestration. Thus, sequestration phase is finite, lasting for some decades and gained carbon stocks need to be protected thereafter to keep carbon withdrawn from the atmosphere.

Hence, sequestration always needs to be guarded by conservation measures so as to make mitigation strategies effective. Further, as predictable impacts of climate change on forests goods and services including carbon sequestration are not fully appreciated. Hence, this is another challenge, requiring adaptive management strategy. Moreover, the anticipated impact of climate change will differ strongly between bioclimatic zones, site conditions and forest types (Böttcher and Lindner, 2010). Hence, future management strategies need to be region and site specific for perpetually harnessing the Forestry Intervention for ecological and economic gains.

In India, broad based studies on carbon sequestration and carbon stock in forests and forests soils have been carried out. The FSI, Dehra Dun also provides an insight on carbon stock in various components of trees/ forests including soils. The HFRI, Shimla has carried out a study on the assessment of carbon stock in biomass and soils in prominent forest types of Shimla Forest Circle (Verma *et al*., 2015).The values of carbon stock in biomass and soils showed high variability on account of the varied forest composition, tree density, growth class, and site characteristics. The values of carbon stock in total biomass in various forest types at different field sites ranged from 1.65 t/ ha (Alpine pastures) to 522.2 t/ ha (Kharsu Oak – *Quercus semecarpifolia* forest). Likewise, carbon stock in soils in different forests varied from 39.2 t/ ha (Alder – *Alnus nitida* forest) to 163.2 t/ ha in soils of Alpine pastures. Moreover, there is no precise insight available on the carbon stock in biomass and soils of varied aged forest plantations that too in different agro- climatic and edaphic conditions. Thus, it is difficult to estimate exact information on carbon stock in proposed forest plantations under different treatment models prescribed in various agro- climatic zones and site conditions.

a) Projected Reduction of CO_2 by Forestry Intervention in the Sutlej Riverscape

Rejuvenation efforts of the Sutlej River through Forestry Interventions in the river basin in Himachal Pradesh and Punjab will be done by planting trees on 29,016 ha of identified diverse landscapes on either side of the river. The expected CO_2 mitigation benefits from the proposed Forestry Interventions have been estimated following the IPCC (2003) Good Practice Guidance by using following formula:

$$C= [V \times D \times BEF] \times (1+R) \times CF]$$

Where:

C= Carbon stock in Biomass (tonnes C)
V= Stand volume (m^3 ha^1)
D= Basic wood density (tonnes d.m m^3). (Kaul *et al.,* 2009)
BEF= Biomass expansion factor (Default). (Kaul *et al.,* 2009)
R= Root shoot ratio (Default) (Kaul *et al.,* 2009)
CF= Carbon Fraction (Default value of 0.47 has been considered (IPCC, 2006)
Carbon in the biomass has been converted into CO_2 eq by multiplying with 44/12

The estimated Carbon dioxide capture by the plantations raised under Forestry Interventions in the Sutlej Riverscape are presented in Table 8.2:

Table 8. 2 Estimated Carbon dioxide capture by the plantations raised under Forestry Interventions in the Sutlej Riverscape

S.No.	River Basin State	Landscape	Proposed area under Plantations (ha)	Mean Wood density (mg/cum)*	Estimated Biomass assuming productivity of 5 m^3/ha/yr**	BEF***	Ratio of below ground biomass to above ground biomass*	Estimated CO_2Reduction (metric tonnes CO_2 Eq/ha/yr)	Estimated CO_2Reduction (metric tonnes CO_2 Eq/ year)	Estimated CO_2Reduction (metric tonnes CO_2 Eq/ year) in 20 Years	Estimated CO_2Reduction (metric tonnes CO_2 Eq/ year) in 10 Years
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1.	Himachal Pradesh	Natural	7,053	0.47	2.35	1.52	0.28	7.879356	55573.1	1111462.92	889169.54
		Agriculture	2,264	0.47	2.35	1.52	0.28	7.879356	17838.86	356777.23	285421.78
		Natural Regeneration	7,030	0.47	2.35	1.52	0.28	2.6264**	18463.67**	369273.4**	295418.72**
		ETF HP	2,000	0.47	2.35	1.52	0.28	7.879356	15758.71	315174.23	252139.38
		Urban Institution Plantation	914	0.47	2.35	1.52	0.28	7.879356	7201.73	144034.62	115227.7
	Total		**19,261**					**34.143824**	**114836.07**	**2296722.4**	**1837377.12**
2.	Punjab	Natural	1,271	0.7	3.5	1.57	0.27	12.02654	15285.73	305714.65	244571.72
		Agriculture	8,203	0.7	3.5	1.57	0.27	12.02654	98653.71	1973074.18	1578459.34
		Urban Institution Plantation	281	0.7	3.5	1.57	0.27	12.02654	3379.46	67589.16	54071.32
	Total		**9,755**					**36.07962**	**117318.9**	**2346377.99**	**1877102.38**
Total for Riverscape			**29,016**					**70.223444**	**232154.97**	**4643100.39**	**3714479.5**

Note:

A conservative productivity rate of 5m3/ha/year has been considered assuming that the plantations will be maintained for at least 20 years with usual harvesting/rotation schedule.

Basic Wood Density (D) for Himachal Pradesh: 0.47 and for Punjab: 0.7, Biomass Expansion Factor (BEF) for Himachal Pradesh-1.52 and for Punjab:1.57, Root:Shoot Ratio for Himachal Pradesh: 0.28 and for Punjab:0.27 has been used (Source: Kaul et al. (2009)

*assuming that plantation will attain 80% of its productivity in 10 years period

**Assisted Natural Regeneration (ANR) will be promoted in existing forests where standing crop is of heterogeneous age and composition. It is assumed that ANR efforts could contribute to adding additional carbon sink of 1/3rd of the expected productivity of the ecosystem.

Assuming a modest productivity of plantations at $5m^3$/ha/ year, the carbon dioxide captured by the plantations raised under the project will be capable of capturing **70.22** metric tonnes of CO_2 eq /ha/year, which will be equal to **232154.97** metric tonnes of CO_2Eq/year for the entire project area. The expected CO_2 reduction for 20 & 10 Years period will be **4.6431** and **3.7144** million tonnes of CO_2eq/Year. Thus, Forestry Intervention for enhancing tree cover in the Sutlej Riverscape will also serve a major mode of CO_2 mitigation and will continue to make positive contribution towards climate change mitigation at local and regional scale. The estimate has been given based on the assumption that the plantation shall be maintained for a minimum of 20 years with usual harvesting at scheduled intervals.

The proposed plantation raised under the Forestry Interventions will also contribute in capturing significant amount of carbon dioxide, the GHG mainly responsible for global warming, which will contribute towards climate change mitigation among other co benefits of the proposed plantations. At the time of conceiving the projects, DPR must also indicate that it intends to develop these plantations for seeking carbon credits under available market or nonmarket mechanisms. The agency executing the interventions shall explore the possibility of registering these plantations for the purpose of carbon credits under existing market/ nonmarket mechanisms under UNFCCC or any other robust carbon standard such as Verified Carbon Standards (VCS). This will help in facilitating determining the additionality of the project. One tonne of CO_2 equivalent will generate one carbon credit. Thus, the programme has a potential to generate 6.6 million tonnes of carbon credits as well over a span of 20 years.

b) Carbon Sequestration in Agroforestry Systems

Agroforestry is a combination of perennials and annuals providing multiple/ direct benefits such as fuel, fodder, timber, etc. Agroforestry is widely practiced, and is a way to prosperity in many Indian States like Punjab, Haryana, etc. (Chauhan and Manget, 2006; Chauhan and Chauhan, 2009). Agroforestry focus on tree species managed and planted with other crops in the agricultural fields, which act as important carbon sink by storing large amount of atmospheric carbon by accumulating biomass and harvesting, followed by long term locking as timber and other byproducts. Watson *et al.*(2000) reported that 630 million hectare area would be available for agroforestry by 2040 which has a carbon sequestration potential (CSP) of 586 mt C/year.

In India, average CSP in agroforestry has been estimated to be 25 Mg C ha^{-1} over 96 million ha (Sathaye and Ravindranath, 1998), but there is a considerable variation in Carbon Sequestration Potential in different regions depending upon the biomass production (Dhyani *et al.,* 2009) and method of estimation. Average carbon storage by agroforestry practices has been estimated as 9, 20, 50 and 63 Mg C ha^{-1} in semiarid, sub humid, humid and temperate regions, respectively. For small holder AFS in tropics, potential carbon sequestration rate ranges from 1.5 to 3.5 Mg C ha^{-1} yr^{-1} (Montagnini and Nair, 2004). In another study by Singh and Gill, 2013 about the carbon sequestration by five fast growing species in the Punjab region the carbon sequestration was found to be highest in *Populus deltoids,* followed by *Eucalyptus tereticornis, Melia azedarach, Ailanthus excelsa* and *Toona ciliata* (i.e.,54.9, 48.0, 43.3. 20.8 and 19.1 t/ha) in seven year old plantations.

8.5.3 Planted Forests River Flow and Water Conservation

The availability and especially the quality of water are strongly influenced by forests (Ekhuemelo *et al.,* 2016). According to Carina (2008), forested catchments served as guarantors of high value surface and drinking water. The importance of forests and trees to rainfall and water supply include: improvement of water cycle, reduction of runoff, improving the

replenishment of the water table, filtration of water pollutants, control of floods, and regulation of storm water (Ekhuemelo *et al.*, 2016).

Trees have been around for more than 370 million years, and presently there are about 80,000 species, of them covering 3.5 billion ha area worldwide, including 250 million ha of commercial plantations. While forests provide enormous environmental, social and economic benefits to the society as well as to Nations, they affect the hydrological cycle in various ways (UNESCO, 2017). Calder (2002) noted that there is a significant disparity between public and scientific perceptions of the hydrological role of forests and plantations. Some old myths such as 'Forests generate rainfall' and 'Forests increase runoff' abound, and do some more contentious assertions such as 'Forest regulates flows'. The paper by Vertessy *et al.* (2002) recapitulates the state of knowledge and discusses the development in human understanding of how plantation development affects the water and salt balances of catchment. The study concluded that large scale plantation development will exert additional pressure on a water resource system that is already under considerable stress and also stated that tree planting will reduce river flows and recharge to groundwater. They argued that water used by plantation should be factored into water economy and catchment. Vertessy *et al.* (2002) also stated that the phasing of afforestation is an important factor that would mitigate against the maximal hydrologic impacts being realized. Plantings within a catchment are usually made over a period of years, leading to a mixture of stand ages. In most situations, the full hydrological effect of plantations is not attained until the stand has reached about 815 years of age. Thus, in their opinion, any catchment containing a significant portion of young stands will not exhibit the maximum hydrological effects of afforestation. Further, they documented that there is also some evidence to indicate that evapotranspiration rates in mature forest stands are lower than in vigorously growing ones, with decreases starting to become apparent after 30-35 years of age of plantation. UNESCO (2017) stated that it is now well documented that at local scales of several thousands of hectares, replacement of shallow rooted vegetation with forest usually reduces stream flow, but may improve water quality. Various comparative studies undertaken in South Africa as well as in Australia have amply revealed that different plantation species respond differently in use of water as some use more water than others. Selection of species is critical for improving hydrological functions of Forestry Intervention through plantations. It is well documented that exotic species like *Eucalyptus* use more water than pine plantations (Scott *et al.*, 2005).

The overall impact on water yield largely depends upon the extent of the catchment planted and the spatial configuration of the trees. It is difficult to reliably detect the effects of runoff if the proportion of the catchment reforested is below a certain threshold because rainfall and the hydrological effect of the catchment surface, soil profile and vegetation vary across catchments (Keenan *et al.*, 2010). Vertessy *et al.*, (2003) suggested that planting trees on upper slopes will potentially have much less impact on stream flow than planting same area on lower slopes, at least in water limited environments. Afforestation and catchment has long been promoted to reduce soil erosion, nutrient and sediment input to streams. Surface runoff is a major driver of

soil erosion and river pollution. Afforestation/Reforestation can reduce surface runoff and soil erosion (Bruijnzeel, 2004; Sidle *et al.*, 2006). Tree cover alone affords some protection by reducing the direct impact of rainfall, but maximum erosion protection is provided with development of litter layer, under storey growth and the surface roughness provided by tree roots. Belts of trees can act as 'Filter strips', intercepting and transpiring surface runoff and nutrients before they reach the stream (Ellis, 2006). A variety of analytical tools have been developed to assess the potential impact of planted forests on water yield or quality. However, the accuracy and reliability of these models is also constrained by data availability, particularly for soil properties (Scott *et al.*, 2005).

The growing literature on the theme of planted forests and water has enhanced the understanding of the interactions between planted forests and water. Certainly, trees tend to use more water than shallow rooted forms of vegetation such as crops, pastures, grasslands or shrub lands. However, it is difficult to detect the effect of afforestation on hydrology, if less than 20% of the catchment is planted (Zhang *et al.*, 2006). There are some obvious differences between species in these effects, and impacts can be mitigated through plantation activities such as belt and strip plantings, thinning and managing rotation lengths. In catchments with degraded soils, afforestation may increase infiltration, water storage and stream flow. The impact of afforestation and development of planted forest on minimizing the impact of flooding is likely to be limited to smaller catchments. Planted forest may reduce the frequency of shallow earth movements and landslides but are not likely to impact on large scale debris flows and earth movements, which are primarily a result of the combination of extreme rainfall and catchment hydrology (Keenan and Van Dijk, 2010).

Assessing the impact of planted forests on water yield and availability will primarily depend on the nature of the catchments, impoundment and water management system and losses due to evaporation and other impacts. Simplistic calculations based on forest evaporation may give a misleading picture of the impacts of plantations on water availability downstream. Thus, Keenan and Van Dijk (2010) and Bauhus *et al.* (2010) concluded that sophisticated decision support tools integrating a process based understanding on forest physiology, geological and hydrological processes and climatic variables can provide more realistic assessments and insight of the potential impact of planted forest on water.

Despite growing literature on the above stated theme of plantations and water, there is evident acute deficiency of relevant literature from a vast country like India. Much of the available insight comes from different parts of the world and may not be relevant considering the complex and violent nature of Himalayan Rivers and the fact that the mountainous tract of the Himalaya was once well covered by diverse and dense forests, except the Trans Himalayan region. It is only in the past 150 years or so that the forested tract was severely influenced by enhanced anthropogenic activities especially during last 3-4 decades.

8.5.4 Plantations, SMC Works and Water Conservation

The rivers originating from the Himalayan Region are an important water resource for millions of people in South Asia. However, due to increasing anthropogenic activities and land use changes, the quality of water is continuously decreasing. In addition, these rivers also carry the highest sediment loads of all world rivers. Furthermore, climate change is also altering hydrology regimes and posing greater threat to this fragile ecosystem. In this scenario, forest catchments can play important role in regulating water flow, influencing the availability of water resources and maintaining the water quality (Bergkamp *et al.*, 2003). Therefore, the relationship between forests and water is a significant issue that must be given high priority.

Watershed service provided by Forest ecosystems is gaining acceptance with increased understanding of biophysical modelling in the research and policy area. These forest catchments provide a high proportion supply of the water for domestic, agricultural, industrial and ecological needs in both upstream and downstream areas. In addition, it also addresses many environmental problems caused by changes in aspects of the hydrological cycle in terms of water demand and quality. However, forest managers are facing challenges in implementing scientific management of forest catchment areas due to lack of recognition of the multi sectoral forest benefits including regulation provision of water resources. It is also important to understand the "Green Water **(**Green water is a picturesque name for the water available in the soil for plants and the soil biota (i.e., microbes, earthworms, soil insects, etc.) to use. It's the water absorbed by roots, used by plants, and released to the atmosphere through a process called transpiration role in the hydrological cycle.

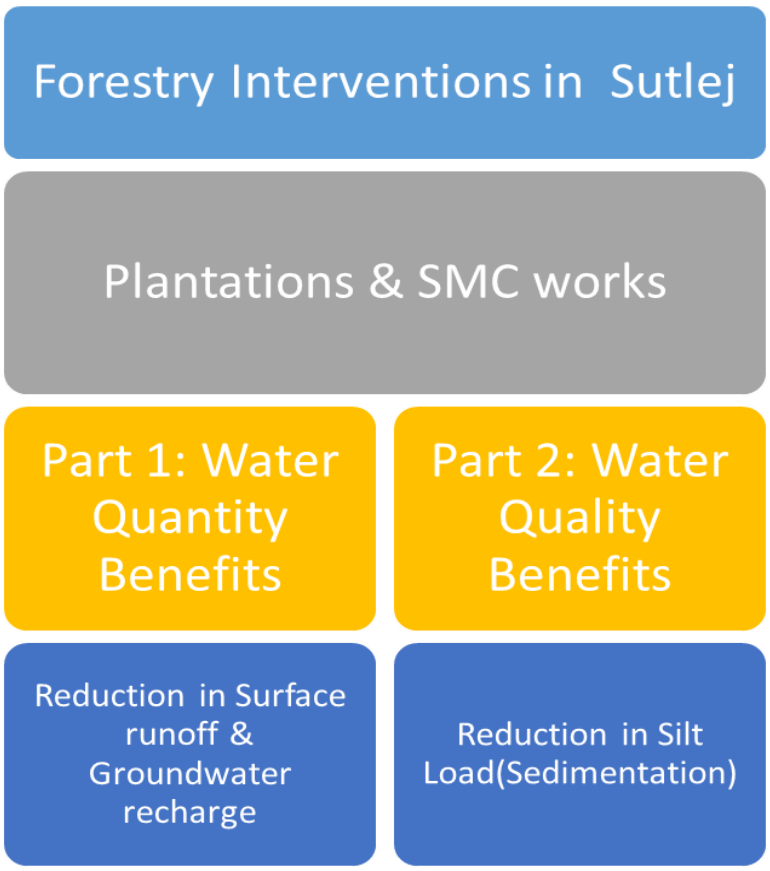


Fig.8. 2 Potential Benefit from Assessment Framework

To address this challenge, there is an urgent need for formulating an effective plan for restoration and rejuvenation of the forest catchments of major rivers in India. Present DPR is one of the important steps of the Ministry of Environment, Forest & Climate Change (MoEF&CC), Government of India (GoI) towards addressing these issues. The overall benefit assessment framework of the Forestry Intervention plan proposed in the Sutlej Catchment area will have two components *viz*., Water Quantity and Water Quality (Fig. 8.2).

a. The first component will conservatively estimate the green water benefits of the proposed plantation and SMC works in the Sutlej Sub Basin using SCS Curve Number Method and Groundwater Estimation Committee Methodology, 2015, respectively.

b. Second component will quantify the reduction of Silt load (Sedimentation reduction) in the Sutlej Sub Basin from the Forestry Interventions.

Component 1: Water Quantity Benefit Assessment

Under component 1, the Proposed Forestry Interventions in Sutlej Riverscape area has two major parts *viz.*, 1) Plantations, and 2) SMC Activities (Table 8.3). The quantitative benefits of the activities are assessed under the following sections.

Table 8. 3 Proposed Forestry Intervention Activities in the Sutlej River Sub basin

State	Riverscape Area (ha)	Plantation Area (ha)	Estimated Excavation (m^3)
Himachal Pradesh	20,15,461	19,261	5,80,523
Punjab	3,95,622	9,755	1,70,305
Total	24,11,083	29,016	7,50,828

Part A: Reduction of Surface runoff and recharge from the Plantation Activities

Conceptual Model for Assessment: Water Balance Model

The Water balance is based on the law of conservation of mass which states that any change in the water content of a given soil volume during a specified period must equal the difference between the amount of water added to the soil volume and the amount of water withdrawn from it. It helps to quantify the relationships between precipitation, surface and groundwater runoff, evaporation, transpiration, and aquifer drafts, and provides a framework for future planning of sustainable exploitation of the available water resources.

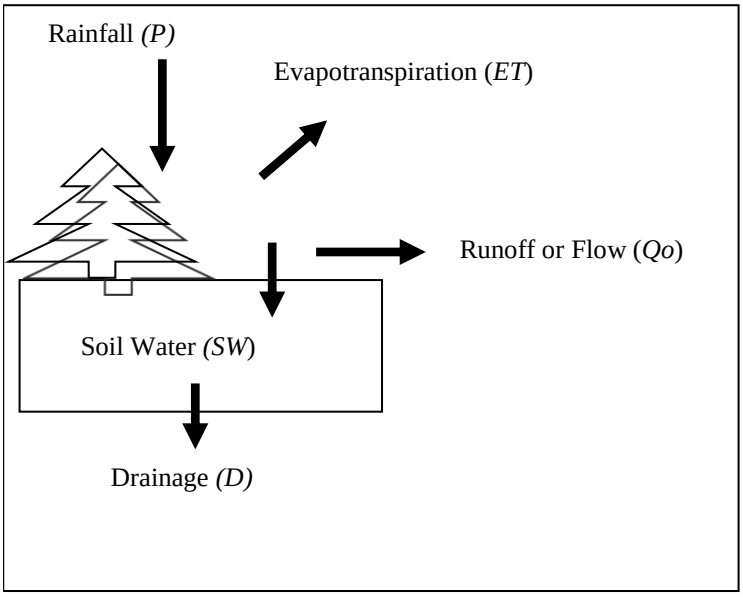


Fig.8. 3 Diagrammatic representation of Water Balance Model

The water balance of a forest basin can be determined by calculating the input, output, and storage changes of water. The major input of water is from precipitation and major output is runoff. A complete water balance model (Kannan, *et al*., 2017) (Fig. 8.3) may contain four sub modeling systems describing the hydrologic cycle, namely, atmospheric water balance

subsystem; a surface water balance sub-system; a soil water balance sub-system; and a groundwater balance sub-system (Equation 1). Depending upon the focus of the analysis, each subsystem can be modeled separately.

The general water balance equation is of the following form:

Equation 1

G+P = Qdsro +Qb + ET+ ΔSg

Where, P = Precipitation; Glacial Inflow; Q_{dsro}*= direct surface runoff;* Q_b *= base flow;* E_t *= ET = evapo-transpiration;* and ΔS_g *= change in groundwater storage (in soil or the bedrock / ground water)*

Assumptions

1. Inflows from Precipitation and Glacial inflows would remain same for both scenarios.

2. Evapo-Transpiration (ET) is the sum of evaporation and plant transpiration from the surface to the atmosphere. Evapotranspiration is an important part of the water cycle. However, for understanding benefits as forests act as giant sponges, soaking up rainfall during wet seasons and releasing it slowly during drier times supporting crucial ecological services. Forests can also help reduce the severity of flash floods downstream through the sponge effect and by blocking the path of the water with tree trunks, branches and other forest litter, it is excluded from the calculations showing casing how Forestry Interventions can reduce surface runoff and improve recharge. In addition, it is also important to note that the ET values in the forests are much higher than that of other land uses, but provides ecological functions such as carbon storage, nutrient cycling, water and air purification, soil protection, microclimatic benefits and maintenance of habitat.

3. From the hydrogeological point of view, it is observed that the groundwater occurs in setting in joints, cracks, fissures, and fractures moving to deeper levels in the weathered zones. As the eastern and southeast part of the basin has already been over exploited in terms of CGWB classification and very low inter aquifers transfers between complex Basaltic Zones and Alluvial Plains, the changes in groundwater storage (ΔSg) is considered zero for computational purposes

Equation 2

Changes in Water Balance = Without Forestry Interventions – With Forestry Interventions

i. Changes in surface runoff (Without Forestry Interventions Q_{dsro} With Forestry Interventions Q_{dsro}) = Changes in base flow (With Forestry Interventions Q_b Without Forestry Interventions Q_b)

Estimating Changes in Surface runoff (Without Forestry Interventions Q_{dsro} with Forestry Interventions Q_{dsro})

There are many methods offered for rainfall runoff modeling. Soil Conservation Services and Curve Number (SCS–CN) technique is one of the primogenital and simplest method for rainfall runoff modeling (Kumar *et al.,* 2017). The surface water outflow from the Riverscape area will be estimated by the Soil Conservation Service Curve Number (SCSCN) model. The SCSCN model (Kannan, *et al*., 2017) is based on the single parameter Curve Number (CN) which depends on the land use, land cover, soil type and the antecedent moisture conditions prevailing in the catchment. The direct surface runoff has been estimated using the SCSCN model given in Equation 3 and 4 (Raynold, 2014)

Equation 3

$$Q = \frac{(P - I_a)^2}{(P - I_a + S)} \; for P > I_a \; ; and \; Q = 0, \; for P \le I_a$$

Equation 4

$$S = \frac{25400}{CN} - 254$$

where, P = rainfall; Q = direct surface runoff (mm); S = potential retention (mm); CN = curve number; and I_a= initial abstraction.

Step 1: Annual Rainfall (P)

The annual rainfall varies from 1000-1600 mm in Himachal Pradesh Region and 800-1000 mm in Punjab Region of Sutlej River Sub Basin. In this study, we have taken the average rainfall in Sutlej River Sub Basin between years 1971-2004 (Table 8.4).

Table 8. 4 Annual Rainfall in Sutlej River Sub Basin

Name of state	**Riverscape Area (ha)**	**Plantation Area (ha)**	**Rainfall (mm)**
Himachal Pradesh	20,15,461	19,261	1157
Punjab	3,95,622	9,755	
Total	**24,11,083**	**29,016**	

P= 1,157 mm,

Step 2: Assessing CN = curve number

CN value for soils (Hawkins *et al*., 2002) having high infiltration rates and for more than 58 mm precipitation conditions Antecedent Moisture Conditions (AMCIII Considering the high altitude of the basin, AMC III wet conditions are assumed for the calculations) are provided in Table 8.9.

Table 8. 5 CN value

Land use	AMC	CN Value
Forest	AMC III	45
Barren/Waste/Agriculture	AMC III	77

Step 3: Calculation of (S) Potential retention (mm)

It is defined as the potential maximum retention after runoff begins. "S" aggregates all variation in the runoff response because of land use, soils, soil moisture, or rainfall pattern, duration, or intensity, plus any other variation into one variable (Table 8.6).

Table 8. 6 Potential Retention

S = Potential retention (mm)	With Forestry Interventions	Without Forestry Interventions
$S = \frac{25400}{CN} - 254$	310.4 mm	75.87mm

Step 4 Initial Abstraction (I_a)

The initial abstraction consists mainly of interception, infiltration during early parts of the storm, and surface depression storage. The initial abstraction (Ia) is some fraction of the potential maximum retention (.S) where in $\lambda = 0.2$ adopted as a standard value (Mullem, *et al*., 2002) for general soils (Table 8.7).

Table 8. 7 Initial Abstraction

Land use	With Forestry Interventions	Without Forestry Interventions
$Ia = \lambda S$	62 mm	15.174 mm

Step 5: Direct Surface Runoff (DSRO)

Direct Surface Runoff is the rain that runs off during the rain event as overland flow or in the vegetation cover above a soil (Table 8.8).

Table 8. 8 Direct Surface Runoff

DSRO	With Forestry Interventions	Without Forestry Interventions

$Q_{dsro} = \frac{(P - Ia)^2}{P - Ia + S}$	853.15	1,070.68

Q = Direct Surface Runoff (mm).

Step 6: Reduction in Surface Runoff and Changes in Base Flow

Base flow consists of water that infiltrates into the soil and travels laterally down slope through upper soil layers, and groundwater flow that infiltrates and travels through the aquifer. The Proposed Forestry Interventions will reduce surface runoff and increase groundwater recharge, which in turn increase the base flow. The changes in the base flow caused by plantation activity can also be called as "Green Water (Green water is the amount of rainfall that is either intercepted by the vegetation, or enters the soil and is picked up by plants and evapo-transpired back into the atmosphere)".

Changes in Base Flow Qb (Green Water /Reduction in Runoff)

= Area * (Without Forestry Interventions Qdsro With Forestry Interventions Qdsro)

= 29,016 ha (1,070.68 mm 853.15 mm) =4,793.05ham= 47.93 MCM

Part B: Groundwater Recharge from SMC Measures

Estimating groundwater recharge is important to measure effectiveness for water conservation measures. However, a site specific modeling approaches to forecast groundwater recharge typically requires observed historic data to assist calibration. It is generally not possible to physically observe groundwater recharge activities spreading over large areas. However, the Ground Water Resource Estimation Committee (CGWB GEC2015) Methodology provides a simple assessment framework for the estimation of ground water recharge due to Soil Moisture Conservation (SMC) works. In the present study, this methodology will be employed to project groundwater recharge from the proposed SMC activities.

Assessment Framework

Recharge due to Water Conservation Structures is estimated based on the following formula (GEC, 2015) (Equation 5) (Kumar C.P., 1977):

Equation 5:

RWCS =GS*RF

Where:

i. RWCS = Recharge due to Water Conservation Structures

ii. RF =Recharge Factor

iii. GS= Gross Storage= Storage Capacity x No. of Fillings

Step1: Estimating Gross Storage

Storage Capacity: AWSA* H *Efficiency* Number of fillings

AWSA = Storage potential created through excavation

i. Efficiency of the structures

ii. Number of Fillings= Number of fillings during the rainfall season

iii. H= Height

Conservative Assumptions

i. SMC Activities proposed (Table 8. 9) in the Riverscape Plan

ii. Efficiency = 50%; *Recharge due to Check Dams and Nallah Bunds can be taken as 50% of gross storage (assuming annual desilting maintenance exists) considering leakages & other factors*

iii. Number of filling assumed to be considering 30 to 50 rainy days in the Sutlej River Basin

iv. AWSA x Height = SMC Excavation Quantity

v. Multiplier factor of 2 applied for calculating the Storage Potential from Area under SMC

Table 8. 9 Soil and Moisture Conservation (SMC) activities under Forestry Interventions

State	**Area under SMC works ('000 Cubic Meter)**	**Storage potential created through excavation ('000 Cubic Meter)**	**Number of Fillings**	**Efficiency**	**Gross Storage ('000 Cubic Meter)**
Himachal Pradesh	580.52	1,161.04	8	50%	4,644.16
Punjab	170.30	340.61	8	50%	1,362.44
Total	**750.82**	**1501.65**	**16**	**100%**	**6,006.60**

Step 2: Recharge Factor

Expected Groundwater recharge= Gross storage * Recharge Factor

RF = Recharge Factor as per GEC, 2015 norms (Table 8.10)

Table 8.10 Recharge Factor as per GEC, 2015 norms

State	Gross Storage ('000 Cubic Meter)	Recharge Factor (%)	Expected Groundwater Recharge ('000 Cubic Meter)
Himachal Pradesh	4,644.16	10%	464.40
Punjab	1,362.44	10%	136.20
Total	6,006.6	20%	600.60

Step 3: Expected Groundwater Recharge

Changes in Base Flow Qb (Green Water / Reduction in Runoff)

= Area * (Without Forestry Interventions Qdsro - With Forestry Interventions Qdsro)

= 29,016 ha (1,070.68 mm- 853.15 mm) = 4,793.05 ham = 47.93 MCM

The Forestry Interventions activities will conserve 48.53MCM water annually. Summary of Potential Benefit of Component 1 is presented in Table 8.11:

Table 8. 11 Summery of Potential benefits of Component 1

Benefits of CAT activities	**Component 1: Water Quantity**	Plantations	47.93 MCM Water Savings
		SMC works	0.6 MCM Groundwater Recharge
		Total	**48.53 MCM**

Component 2: Water Quality

Water quality of Sutlej River Sub Basin is excellent. It deteriorates slightly towards downstream, due to heavy abstraction and discharge of pollutants, but remains very much within permissible limits. Below figure shows schematic representation of some of the main influences on water quality within a river basin (Owens *et al.*, 1966), Water and sediment of the river exhibit seasonal as well as spatial variability, which is contributed by geological, climatologically, and anthropogenic factors. However, many a times, it is difficult to assess the contribution from different sources because of different geological terrain and complex variation in weathering, erosion, transport and anthropogenic activities operating in the river catchment. The legacy data of silt rate provides a realistic estimate for the sediment rates from the Basin.

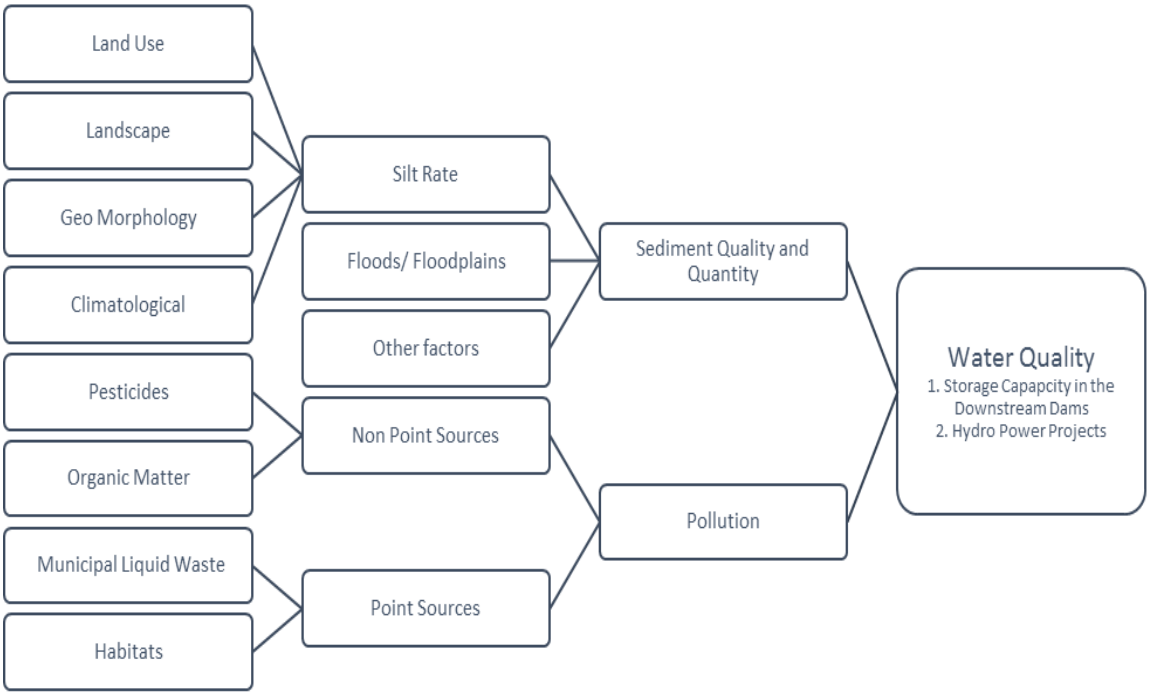


Fig.8. 4 Main influences on water quality

As per India WRIS database, there are 9 surface water quality observation stations installed in the Sutlej River Basin. These stations provide surface water quality in the basin. As per the monitoring results of 2009, the water quality is excellent; however, organic pollution is the predominant reason of pollution in these water resources. Biochemical Oxygen Demand (BOD) and Coliform bacterial Count are the major indicators (Fig. 8.4) of extent of water quality degradation.

Role of Forest Catchments

Forest catchments have often been described as 'Sponges' storing rain water and slowly releasing it to maintain groundwater and streams during dry periods (Hamilton and King, 1983). Despite the recognition that trees can improve soil hydraulic conductivity and reduce overland water flow (Sandström, 1998), their contribution towards groundwater recharge and improvement of water quality is often understated. In the long term, one of the most important ways in which forest catchments can influence water quality is through their effect on absorbing rainfall variability and seasonal climate variations. It is one of the key factors that influence sediment yield from a given basin. If lands are degraded and soils are unstable, rainstorms can lead to heavy sedimentation from river sheds. Under any given condition, forest catchments have an important impact in reducing sediment yield from watersheds (Conroy *et al.*, 2001).

The Sutlej River Basin is one of the most depleted basins in the world (Sharma *et al.*, 2010). During certain periods of the year, water even does not really reach the sea any more, making it a

closed basin (Molle *et al.,* 2010). Rapid population growth, increasing urbanization and industrialization, environmental degradation, inefficient water use and poverty (economic water shortage) are the prominent challenges in sustainable water resource management in the said region.

Flooding, erosion and high sedimentation in the region lead to rise of riverbeds between their embankments and also impacting the capacity of reservoirs. The rehabilitation of some forest watersheds can dramatically reduce the rate at which sediments are delivered to a reservoir. These sediment yields will be calculated by standard extrapolation techniques from previous measurements (Trimble, 1999) (Equation 6) (Owens, P., *et al*, 2007).

Equation 6 :

Sediment load = Catchment area X Sediment factor X Trap Efficiency

Step 1: Catchment Area

The Sutlej River Sub-Basin covers an area of 48,32,162 ha. Out of this, 24, 11, 083 ha area is selected for the Riverscape management under the proposed project, and Intervention through afforestation (Plantation Area in ha) will be 19,261 in H.P. and 9,755 in Punjab respectively

Step 2: Sediment Factor

The evaluation of sediment inflow has been always difficult because the sediment content varies considerably for a same river according to the flow and the season. In addition, it also requires complex sediment modeling based on the land use assumptions; besides requires huge time and resources for measurement. Further, the results cannot be very precise and there would be associated uncertainties. However, based on the sedimentation legacy data at the project locations, most reliable sedimentation assessments may be provided (Table 8. 12).

Table 8. 12 Average silt rate in Sutlej River Sub Basin

State	**Major Reservoir**	**Observed Sediment Rate(000' m^3/ km^2/yr)**
Himachal Pradesh	Bhakra Reservoir	0.682
Punjab		

Source: CWC Compendium on Silting of Reservoirs in India, 2015

Step 3: Trap Efficiency

The rate of sediment production in the catchment area and the actual rate of silting depend on many other factors *viz.*, gradation of silt, maintenance of structures, etc. Therefore, we conservatively estimate 90% efficiency of the CAT activities.

Step 4: Sediment Reduction Due to Forestry Interventions

Table 8. 13 Sedimentation Estimation

State	Sedimentation factor (000' m^3/ km^2/yr)	Trap Efficiency	Total CAT Intervention Area km^2	Sedimentation ('000 m^3/yr)
Himachal Pradesh	0.682	0.9	192.61	118.24
Punjab	0.682	0.9	27.73	17.02
Total	**0.682**	**0.9**	**220.34**	**135.24**

*Assumption: *Plantation area has been considered as Intervention Area for the above calculations.*

The Forestry Interventions will reduce **1,35,244** m^3 of sedimentation annually(Table 8. 18)**.**

Summary of Component 2 Activities

Annually, the proposed activities will reduce 135.24 Thousand Cubic Meters sedimentation in the Sutlej River Sub Basin (Table 8.14).

Table 8. 14 Summary of Potential benefits from Component 2 Activities

Benefits of Forestry Interventions	Part 2: Water Quality	Sedimentation	1,35,244 m^3 sedimentation reduction annually

Monitoring Framework

Summary of the Monitoring Framework has been presented in Table 8.15:

Table 8. 15 Summery of Monitoring Framework

Component	Parameters	Indicators	Timeframe	Rationale
Water Quantity	Water Augmentation through Plantation Activities	Normalized Difference Vegetation Index (NDVI)	Annual	Precise monitoring of improvement in the recharge rates from the Forestry Interventions is only possible with the availability of historical hydrographs from the Piezometers, recordings from the River Gauzing Stations and Forestry Interventions implemented at the Landscape level. Therefore, it is not
	Groundwater Recharge from SMC Measures	Normalized Difference Water Index (NDWI)	Pre & Post	

			Monsoon	possible to directly measure these indicators in the present context. However, for all practical purposes, NDVI and NDWI can be used as proxy indicators for monitoring the benefits of the Forestry Interventions
Water Quality	Silt Rates	NDVI & NDWI		

Note:

a) The Normalized Difference Vegetation Index (NDVI) quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs).

b) The Normalized Difference Water Index (NDWI) is known to be strongly related to the plant water content. It is therefore a very good proxy for plant water stress. The Normalized Difference Water Index (NDWI) is a Satellite-Derived Index from the Near-Infrared (NIR) and Short Wave Infrared (SWIR) channels.

8.5.5 Livelihood Generation through NTFP Interventions in Sutlej Riverscape

North Western Himalaya is having the distinction of being one of the richest repositories of MAPs in the country. Himalayan herbs in fact have received unprecedented attention the world over mainly to their uniqueness and high medicinal value. The MAPs sector has traditionally occupied an important position in the socio cultural, spiritual and medicinal arena of rural and tribal lives in the region. Local communities have traditional rights to collect medicinal herbs as Minor Forest Produce (MFP) in designated forestland (Anderson, 1886) and have been an important source of income to the natives (Dobriyal *et al.*, 1997; Tondon, 1997; Badola, 1998, 2002).

NTFP or Minor Forest Products cover all forest products other than major forest products. For the sake of convenience in dealing with the subject, minor forest products of commercial importance in India may be divided into the following classes: (1) Fibers and flosses; (2) Grasses (Other than oil producing grasses), bamboos and canes; (3) Essential oils (including oil yielding grasses); (4) Oil seeds; (5) Tans and dyes; (6) Gums, resins, and oleoresins; (7) Drugs, spices, poisons and insecticides; (8) Edible products; and (9) Minerals and miscellaneous products (FRIC,1972).

The natural resources in forest provide food, fodder, medicine, clothes, house building materials to human civilization. It is estimated that 275 million poor rural people in India about 27 % of

the total population depend on NTFPs for at least part of their subsistence and cash livelihoods (Malhotra and Bhattacharya, 2010; Bhattacharya and Hayat, 2009). This dependency is particularly intense for half of India's 89 million tribal people, who live in forest fringe areas. According to an estimate the NTFP sector alone is able to create about 10 million mandays annually in the country (Anonymous, 2011). NTFP contributes to about 20% to 40% of the annual income of forest dwellers who are mostly disadvantageous and landless communities with a dominant population of tribals. It provides critical subsistence during lean seasons, particularly for primitive tribal groups such as hunter gatherers and the landless. Most of the NTFPs are collected and used/sold by women, so it has a strong linkage to women's financial empowerment in the forest fringe areas (Anonymous, 2011). In view of their ever increasing demand there is urgent need to grow and propagate the species in *ex-situ* and *in-situ* conditions. It will help not only in fulfilling the demands but wlll eventually conserve the resource from biodiversity point of view. For calculating the estimated values of medicinal plants, average value per hectare from various publications (Singh, *et al.*, 2013; Meena, 2003; NMPB, 2004; Samant *et al.*, 2007, 2008) were consulted. In Temperate to Alpine zone, the average value per hectare assumed after taking survival rate as 60%. The harvesting of plants is taken as 50% after rotation period of 3.5 years, in 7^{th} year 50% of the remaining part of 3.5 year and in 10^{th} year 40% of the remaining part of 7^{th} year. In Tropical and Subtropical areas, the crop harvesting has to be done after rotation period of 1.5 year.

The different Proposed Forestry/Plantation treatment Models in Sutlej River DPR envisaged including traditional/ native species of trees, grasses and NTFP's for rejuvenating river and its tributary in different stakeholders of Sutlej River Basin through Forestry Interventions.

Since most of the high temperate medicinal plants rotation period is 3.5 years. If sustainable harvest practices and beating up of medicinal plants in the intervention areas are followed, two more harvesting i.e., on 7^{th} year and 10^{th} year can be obtained. The estimated income from growing, selling and extracting NTFP from plantation forests in Sutlej basin is given in Table 8.16 for Himachal Pradesh and Table 8.17 for Punjab. Further Generation of Employment from Plantation Activities and Other Conservation Interventions (Total man days in Phase I and Phase II) will be **3,69,89,136 (Table 8.18)**

Table 8. 16 Estimated Income generated through NTFPs in Himachal Pradesh

Sr. No.	Model Name	Model No.	No. of Herbaceous medicinal plant	Area in Hectare	Rate Per Hectare	Estimated income after 3.5 years (Rs in Lakhs)	Estimated income after 7 years (Rs in Lakhs)	Estimated income after 10 years (Rs in Lakhs)	G. Total of Income (Rs in Lakhs)
1	Cold Desert Conservation	SL/HP/NL/02	2,400	100	9,600	9.60	4.80	3.84	18.24

2	Alpine Conservation	SL/HP/NL/03	2,400	60	9,600	5.76	2.88	2.30	10.94
3	Sub-Alpine Enrichment	SL/HP/NL/04	800	315	3,200	10.08	5.04	4.03	19.15
4	Dry Temperate Conifer Forest Enrichment	SL/HP/NL/05	1,600	10	6,400	0.64	0.32	0.26	1.22
5	Temperate Conifer Forest	SL/HP/NL/06	1,200	681	4,800	32.69	16.34	13.08	62.11
6	Temperate Mixed Forest	SL/HP/NL/07	1,200	665	4,800	31.92	15.96	12.77	60.65
Total			**9,600**	**1,831**	**38,400**	**90.69**	**45.34**	**36.28**	**172.31**

Table 8. 17 Estimated Income generated through NTFPs in Punjab

Sr. No.	Model Name	Model No.	No. of Herbaceous medicinal plant	Area in Hectare	Rate Per Hectare	Estimated income after 1.5 years (Rs in Lakhs)
1	Plantation Design of Shivalik Hills Forest Enrichment model	SL/PB/NL/01	1,600	694	4,000	27.76
Total				**694**	**4,000**	27.76

8.6 Plantations – Key for Sustainable Ecosystem Goods and Services

There is a growing body of knowledge and experience illustrating that plantation forests in a crowded world can play varied roles, if appropriately planned, designed and managed. Plantations can offer a wide range of ecosystem goods and services on both landscape and stand scales. However, there is a need to realize that the benefits and impacts of plantations are highly context specific. Thus, the range of impacts and benefits associated with plantation forests which typically differ from those of other landscape components such as native forests or agricultural lands need to be carefully considered, assessed, agreed upon and managed in a landscape context. One of the major environmental benefits of plantations well documented is the fact that they help in reducing the harvesting pressure on native and semi-natural forests. Societies have the right to expect that plantations will deliver more benefits than costs. Thus, enhancing the ecosystem goods and services, plantations can offer to the society is an important facet of plantation forestry (Bauhus *et al.*, 2010).

Despite simplicity in structure and shape, and high intensity of management inputs needed, tree plantations can play an important role in addressing and mitigating some of the pressing current global challenges *viz*., land degradation, increasing demands for forest based resources, water availability and conservation, energy, poverty, climate change, or even the loss of biodiversity. Cossalter and PyeSmith (2003) have documented that many ecosystem services were improved by the plantation raised on degraded lands. Livelihoods of a considerable population in rural

areas depend on the use of degraded land. Thus, restoration through appropriate afforestation measures would provide higher returns (Hunter *et al.*, 1998). Ignoring the immediate needs of local communities and replacing their use of land with plantations that could not support and maintain their livelihoods has often lead to the failure of many of such projects in the past. Thus, it is essential that local communities are involved right from the planning stage, engaged in various works and their livelihoods are being maintained.

There is a growing evidence that plantations can effectively assume the role of mandating water and nutrient cycles, soil protection and provision of habitat for biodiversity (Böttcher and Lindner, 2010; Keenan and Van Dijk, 2010; Bauhus and Schmerbeck, 2010). In addition, the focus on ecosystem services in restoration efforts does not contradict instead but may compliment various socio-economic objectives (Lamb *et al.*, 2005). According to FAO (2007), the maintenance and enhancement of ecosystem goods and services of planted forests is central to all principles. Explicitly, intelligent solutions for plantations should feature ecological restoration and aim to achieve optimal productivity of multiple products and services besides they have to be economically beneficial to local communities. Increasingly, there is a growing emphasis that plantations must not be simple or have a narrow focus or the design may not just be concerned with the choice of tree/ planting species and the arrangement of trees, but with the creation of entire ecological communities and functioning landscapes to meet specific services (Shiyomi and Koizumi, 2001; Kirschenmann, 2007). Options to improve water services from plantations at the landscape scale are largely related to the percentage area under plantation, the specific location of plantations and the protection of soil and waterways. At the landscape level, interspersing plantations with buffer strips and reserves of native vegetation creates patches with more long term carbon storage than in the plantation stands and helps in conservation of native biodiversity.

The above description has briefly summarized the necessity of restoration of river ecosystem, potential benefits of river restoration, particularly of the proposed Forestry Interventions and more specifically of planted forests, myths and reality, and how restoration measures can help in obtaining enhanced ecosystem goods and services with the implementation of planned strategies towards restoration. In India, scientific community and field practitioners are working in the fields of natural resource management, forestry, watershed management, agriculture, etc., and have gained considerable experience through execution of various programmes/ projects relevant to eco-restoration of degraded lands. They adopted strategies focusing on soil and moisture conservation works, forest and agroforestry plantations, and other measures related to water conservation, rural livelihoods, and biodiversity conservation.

8.7 Projected Potential of Benefits of Proposed Forestry Interventions

India has been unique in pursuing a visionary goal of having 33% of its geographical area under forests and tree cover despite growing pressure to part away with forestlands in the interest of various developmental activities (MoEF&CC, 2018). Further, the country's global commitment

to create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forests and tree cover by 2030 under the Paris Agreement of UNFCCC has attained added significance in view of the Nationally Determined Contribution (NDC) targets. The preceding Chapters and foregoing description have amply highlighted the strong interconnectedness between forests and rivers and how both these natural ecosystems have been impacted by humanity in spite both ecosystems offer a wide range of ecosystem services for human well being, prosperity and sustainable development. Proposed Forestry Interventions involving extensive plantation activities in three Landscapes (Natural, Agriculture and Urban) within the Sutlej Riverscape besides execution of planned Conservation Interventions and Supporting Activities.

Table 8. 18 Accrued Potential Benefits from Proposed Forestry Interventions

Sr. No.	Potential Benefits	Quantity	
A.	**Biomass, Carbon Stock, CO_2 Reduction and Carbon Credit**	**After 20 Years**	**After 10 Years**
1	Biomass Production in Natural, Agriculture and Urban Landscapes (assuming productivity of $5m^3$/ha/year)	2.925*	
2	Total Biomass Production from 29,016 ha areas of Landscapes after 20 years (Tonnes)	84871.80	67897.44
3	Contribution to Carbon Stock from 29,016 ha areas of Landscapes (Tonnes)	39889.75**	31911.80
4	Estimated CO_2Reduction from Forestry Interventions in Landscapes (29,016 ha) (metric tonnes CO_2 eq/ha/year)	70.223444	56.1787552
5	Estimated CO_2 Reduction from Forestry Interventions in Landscapes (29,016 ha) (metric tonnes CO_2 eq/ year)	232154.97	185723.976
6	The expected CO_2 reduction (million tonnes of CO_2eq./Year)	4.6431	3.71448
7	Potential to generate carbon credit from plantation in three Landscapes (million Carbon Credits)	4.6431	3.71448
B.	**Water Quality and Quantity**		
8	Water Quantity: Conservation of water through Forestry Interventions (Million Cubic Meter/year)	15.45	
9	Water Quality: Estimated sediment reduction through Forestry Interventions (‘000 m^3/Year)	10.20	
C.	**NTFPs’s**		
10	Income generated through NTFP’s (1831 ha) in Himachal Pradesh after 10 years (in Lakhs)	172.31	
11	Income generated through NTFP’s (694 ha) in Punjab after 1.5 years (in Lakhs)	27.76	
D.	**Man Days to be Generated**		

12	Generation of Employment from Plantation Activities and Other Conservation Interventions (Total man days in Phase I and Phase II)	**3,69,89,136**

(*Projection as per Table 8.2*)

One tones of CO_2 eq is one credit or 1CER. Therefore, the estimates Carbon Credit Potential for 20 Years will be 4643100.39 CER (CER= Certified Emission Reduction) ** Assuming 80% of the Potential Productivity in 10 Years

*** Average of 2.35(Himchal Pradesh) +3.5(Punjab) is taken for calculation of total biomass production in Sutlej riverscape**

**** 47% of 84871.80.**

Table 8. 19 Generation of Employment from Plantation Activities and Other Conservation Interventions (Total Man days in Phase I and Phase II)

Sr. No.	Landscape/ Activity	Phase I Year wise Man Days					Total of Phase I	Phase II Year wise Man Days				Total of Phase II	G Total
		I	II	III	IV	V		VI	VII	VIII	IX		
1	Natural	1012565	2213434	2098602	1916867	1413800	8655268	774979	405848	175733	38016	1394576	**20099688**
2	Agricultural	236132	314602	364550	293962	174936	1384182	74428	0	0	0	35088	**2877880**
3	Urban	374653	335988	259405	136158	56955	1163159	17658	0	0	0	17658	**2361634**
4	SMC	1066983	1363908	1316906	777285	565160	5090242	0	0	0	0	0	**10180484**
5	Riparian Wildlife& Wetland Management	226654	209546	141178	90099	65088	732565	4320	0	0	0	0	**1469450**
Total Number of Man Days		**2916987**	**4437478**	**4180641**	**3214371**	**2275939**	**17025416**	**871385**	**405848**	**175733**	**38016**	**1447322**	**36989136**

Likely potential benefits of proposed interventions in terms of increased availability of water; enhanced environmental flow; reduced soil erosion and sedimentation; augmented forest cover; and improved water quality, terrestrial and aquatic biota, ecosystem services and rural livelihoods besides significant contribution towards climate change mitigation by way of sequestration and storage of carbon. However, potential benefits in quantitative terms computed based on above stated norms in Table 8.18. It is pertinent to mention here that the plantations produce range of direct and indirect environmental benefits, which when taken into account, would lead to much higher estimates. Monetization of such benefits would need the application of more precise indirect methods, which is another area of research. The results derived here in Table 8.18 and 8.19 are highly conservative estimates of the benefit of proposed plantations.

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ANNEXURES

Annexure 1: Logical Framework Analysis

Project Strategy	**Objectively Verifiable Indicators**				
Project Objectives and Outcomes	**Project Output**	**Target**	**Indicator**	**Source of Verification**	**Risks and Assumptions**
Project Goal 1	**Riverscape Management:** Aiming a holistic riverine landscape (riverscape) approach for sustainable management of Sutlej River, its banks, or its Riparian areas, within its fluvial system.				
Outcome 1: Creation of an enabling environment for climate resilient, sustainable terrestrial, aquatic (River and wetlands), and floodplain ecosystem management.	**Project Objective 1:** To promote an enabling environment for sustainable land and River ecosystembased management approaches focusing on reduced soil erosion, enhanced forest/ vegetation cover in the buffer zone, enhanced connectivity and eflow, and ecological rejuvenation of Sutlej River and its tributaries.				
	Output1.1 Enhanced levels and enabling environment created for: (a) multisector convergence, alliances, and integration; (b) favourable national and state level policies (forests, agriculture, animal husbandry, watershed management, River management, tribal welfare, infrastructure development, and tourism) those reflect principles of climate resilience, sustainable land and ecosystem management, and mainstreaming biodiversity concerns in production sectors.	The target is to create an enabling environment wherein multiple agencies/ sectors working for various production sectors converge and adopt climate resilient and sustainable approaches of land and ecosystem management by mainstreaming biodiversity concerns. Various concerned sectors also work together so as to address gaps and inadequacies in realizing global and national policy objectives relevant to environment, biodiversity, water resources, climate change, and sustainable development.	Integration and convergence of line agencies and various production sectors initiated and notable progress made. Communities mobilized and their active engagement ensured. Biodiversity concerns mainstreamed in production sectors. Gaps and inadequacies in various policies reviewed and actions initiated to address them.	Periodic reports, proceedings of consultative process (workshops, meetings, seminars, etc). Midterm and final independent evaluations.	Lack of enthusiasm on the part of stakeholders, inadequate sectoral integration, and lack of community participation in the implementation of existing and proposed policies and laws relating to conservation might hinder the promotion of local decision making and also their active engagement in the conservation agenda. Participation of communities particularly marginalized groups is weak due to a fear that their access to natural resources is going to be curtailed or restricted in ways that reduce the income they can derive. Conflict between conservation and local community needs might create difficulty in achievement of

Project Strategy	Objectively Verifiable Indicators				
Project Objectives and Outcomes	**Project Output**	**Target**	**Indicator**	**Source of Verification**	**Risks and Assumptions**
					intended outcomes. Sectoral departments/ agencies are reluctant, not open to integrate/ cooperate for climate resilient and sustainable land and ecosystem management approaches. Project benefits are not captured by intended beneficiaries due to lack of adequate measures, transparency, and appropriate compensation measures. Inadequate and inaccurate flow of information may result in misconceptions about the project and hence lead to opposition/ nonparticipation by some agencies and CSOs. Sectors/ agencies primarily responsible for reduced eflows are rigid, and continue with conventional approaches resulting into fragmentation of rivers, reduced eflows, and decline in water quality.
	Output 1.2 Capacity of government officials and civil society organizations is developed in promoting	Capacity of agencies, government officials and CSOs for sustainable land and ecosystem management,	Training need assessment carried out. Appropriate training learning material developed.	Periodic reports, appraisal of training schedules, learning material and feedback obtained from trainee	The concept and need of sustainable land and ecosystem management, and climate and its likely impact are not well appreciated by CBOs/ different sectors and

Project Strategy	Objectively Verifiable Indicators				
Project Objectives and Outcomes	**Project Output**	**Target**	**Indicator**	**Source of Verification**	**Risks and Assumptions**
	community driven, climate resilient, sustainable land and ecosystem approaches, and holistic approach to management of River ecosystem.	ecological rejuvenation and ecological integrity of River ecosystem is built.	Planned awareness and specialized training programmes on priority themes for various target groups successfully organized. Number of government staff and CSO representatives trained in climate resilient ecosystem management approaches.	participants. Midterm and final independent evaluations.	agencies. The Implementing Agencies are new to the subject and expected outputs and outcomes and also widespread with limited financial management and technical capacity. Lack of interest and support for conservation might result in limited use of training facilities and opportunities. There are flaws in training need assessment and designing appropriate training programmes. Thus, trainings are not appealing and having desired impact.
Project Goal2	***Aviral Dhara, Nirmal Dhara,* Ecological Rejuvenation and Biodiversity Conservation:** Aim to address the drivers and stressors of River ecosystem and promote sustainable use by balancing ecological needs with livelihood needs.				
Outcome 2: Interagency and civil society driven, climate resilient approaches for appropriate forestry and other interventions demonstrated in adequate extents of natural, agriculture, and urban landscapes of	**Project Objective 2:** To carry out appropriate Forestry Interventions to restore River connectivity, enhance eflow, improve water quality, and conserve the terrestrial and aquatic biota within the Sutlej riverscape.				
	Output 2.1 Plans to reduce/ check erosion in the mountainous region and floodplains of Sutlej and its tributaries by appropriate soil and moisture conservation works and development of optimal strategy for riverbed mining. Sites of	Various soil and moisture conservation strategies and works in target area of 750828 m^3 proposed to be implemented.	Reduced erosion in the hilly tract, reduced and stabilized landslides, decreased bank erosion, and reduced sedimentation rate. Enhanced moisture regime and flow in streams and rivers.	Appraisal of reports on soil and moisture conservation works undertaken, site visits and field observations and assessments, monitoring reports on sedimentation.	Occurrence of natural calamities (e.g. cloudburst, flood, drought, eartHeadquatersuake, landslides, etc). Increase in biotic pressure and enhanced developmental activities (hydropower and road networks) in upstream area without adequate catchment area

Project Strategy	Objectively Verifiable Indicators				
Project Objectives and Outcomes	**Project Output**	**Target**	**Indicator**	**Source of Verification**	**Risks and Assumptions**
the riverscape.	landslides are adequately treated and stabilized				treatment.
	Output 2.2 Plans for restored and sustainably managed forest lands, agriculture lands in targeted villages and Forestry Interventions in urban environment for improved forest/ vegetation cover achieved. Enhanced assisted natural regeneration through improved protection and other measures.	Forestry Interventions by way of various plantations under different treatment models to be undertaken. Plantations in 17,354 ha natural landscapes, 10,467 ha in agriculture landscapes, and 1,195 ha in urban landscapes (Institutional plantation) are established and maintained.	Reduced biotic pressure on forests and improved regeneration. Improved forest cover in forest lands and TOFs in two States. Reduction in fuel wood extraction pressure on surrounding forests. Increase in average fodder yields, livestock grazing pressure reduced. Perennial vegetation cover increased on degraded lands. Private/community lands mobilized for reviving forest cover, enhancement of ecosystem health and services. Rejuvenation and renovation of existing communitybased watershed structures.	Field level assessments and verification. Periodic reports on plantation works carried out. Biennial assessment on forest cover by FSI for two States.	Nonavailability of suitable nursery techniques, planting material, inadequacies in plantation works i.e. preparation of plantation site, excavation of pits, poor quality of planting material, inadequate protection and constraints of watering, damage by livestock/ wildlife, etc. Nonavailability of lands (natural/ agriculture/ urban) for plantations and noncommittal and inadequate support of local communities/ farmers/ urban agencies. Occurrence of natural calamities (e.g. cloudburst, flood, drought, etc.).
	Output 2.3 Plans for improved protected area management by implementing appropriate protection strategies, habitat management (e.g.	Strategies for improved PA management implemented, weed control works undertaken, research on priority themes planned and undertaken. Periodic	Improved protected area management and enhanced management effectiveness. Increased diversity and abundance of species. Enhanced conservation values	Appraisal of periodic reports and reports of midterm and terminal evaluation. Report on Management Effectiveness Evaluation	Increased biotic pressure and adverse impact of developmental projects. Increased humanwildlife conflict and noncompatible land use in surrounding lands.

Project Strategy	Objectively Verifiable Indicators				
Project Objectives and Outcomes	**Project Output**	**Target**	**Indicator**	**Source of Verification**	**Risks and Assumptions**
	weed control and water management), research and monitoring inputs, and enhanced capacity.	ecological and socioeconomic monitoring carried out. Training of frontline/ PA staff and other stakeholders planned and implemented.	(e.g. catchment value, carbon sequestration, environmental amelioration, etc). Reduced humanwildlife conflict.	(MEE) for respective PAs. Reports on ecological and socioeconomic monitoring.	Inadequate support of local communities and their engagement. Occurrence of natural calamities (e.g. cloudburst, flood, drought, eartHeadquatersuake, landslides, etc).
	Output 2.4 Plans for improved management of prominent wetlands in the riverscape by protection, restoration, zoning, habitat management, and wise use of wetland resources.	Improved wetland management and sustainable use of wetland resources implemented.	Improved and effective management of wetlands accomplished. Wetland habitats restored, effective zone planning accomplished and sustainable wise use of wetland resources promoted.	Periodic reports, appraisal of conservation/ management plans. Site visits and field level assessments. Questionnaire survey and stakeholder consultations.	Enhanced biotic pressure, waste disposal, and more effluents, unsustainable harvests, natural calamity (flood and heavy siltation). Inadequate support of local communities.
	Output 2.5 Plans for improved riverfronts and development of eco-parks.	Riverfronts and eco-parks to be developed.	Improved riverfronts, effective eco-parks, reduced erosion.	Site visits and observations, periodic reports.	Noncompatible land use in surrounds of riverfronts/ River, enhanced biotic pressure on eco-parks, damage of riverfronts by excessive floods and mass congregation.
	Output 2.6 Plans for development of forest and Riverbased ecotourism.	Forest and River/ water resourcebased ecotourism.	Healthy forests and rivers/ water resources are maintained. Reduced biotic pressure, ecologically sustainable, and socioeconomically viable tourism developed.	Appraisal of periodic reports and ecotourism plans. Site visits and field assessments. Feedback from tourists.	Natural resources are depleted and degraded. Uncontrolled and unregulated mass congregation and adverse impacts.
Project Goal 3	**Improved Ecosystem Services and Sustainable Livelihoods**: This goal aims to specifically seek enhanced ecosystem services and sustainable livelihoods.				

Project Strategy	**Objectively Verifiable Indicators**				
Project Objectives and Outcomes	**Project Output**	**Target**	**Indicator**	**Source of Verification**	**Risks and Assumptions**
	Project Objective 3: To promote improved ecosystem services and support sustainable livelihood opportunities for local communities, particularly forest dwellers and fishermen.				
Outcome 3: Enhanced ecosystem services from natural (forest, River, and wetland ecosystems), agroecosystem and urban landscapes *Outcome 4*: Sustainable livelihoods, particularly of forest dwellers and fishermen	*Output 3.1* Plans for reduced traditional forest dependence, developed alternate income generation activities, improved livelihoods, and facilitate establishment of viable Small and MicroEnterprises (SMEs).	Reduced traditional forest dependence and alternate income generation options developed. Improved livelihoods and wellestablished small and microenterprises.	Sustainable livelihoods by way of improved/ enhanced natural resources, effective social institutions, better physical assets, enhanced incomes, improved and skilled human resource, reduced vulnerability, well established SMEs. Change in proportion of project participants who are living above the poverty line. Increase in earnings of families from involvement in sustainable management of degraded forest lands. Number of women participants in SMEs increased. Curtailment of distressed migrations. Number of SMEs operationalized.	Household surveys, periodic reports, field level assessments, evidences on reduced conflicts, etc.	Enhanced and frequent natural calamities, external market forces and impact of globalization, neglect and over exploitation of natural resources by local communities.
	Output 3.2 Plans for enhanced levels of protection, conservation, and sustainable harvests of medicinal and aromatic plants	Conservation and sustainable harvests practices implemented for *in situ* and *ex situ* conservation of medicinal and aromatic plants.	Diversity, abundance, and productivity of medicinal and aromatic plants in wild are enhanced. Herbal gardens developed.	Appraisal of periodic reports, site visits, and field level assessments.	Inadequate marketing strategies and mechanisms. Fluctuating market demands, supply, and market rates.

Project Strategy	Objectively Verifiable Indicators				
Project Objectives and Outcomes	**Project Output**	**Target**	**Indicator**	**Source of Verification**	**Risks and Assumptions**
	and development of herbal gardens.				
Project Goal 4	**Effective Implementation, Knowledge Management, and Innovative Approaches:** This goal aims to ensure effective implementation of the project, knowledge management, development of innovative approaches (nursery techniques, afforestation, bio-filters and bio-remediation), and adopt modern technology.				
Outcome 5 Capacities for adaptive management, learning, and replication of project lessons are developed.	**Project Objective 4:** To adopt, integrate and implement innovative approaches and modern technology for rejuvenation of Sutlej and its tributaries, knowledge management, enhanced capacity, and monitoring and evaluation.				
	Output 4.1 Plans developed for integrated, science based, and communitybased monitoring and assessment of impacts, as well as periodic evaluation of the project.	Improved research and monitoring capacity targeted. Adaptive management approach being implemented.	Improved research infrastructure, well designed monitoring system, enhanced scientific capacity, and effective documentation and dissemination of research and monitoring findings. Local level monitoring mechanisms setup. Learning on best practices and models disseminated within and outside project villages.	Project/ research and monitoring reports. Peer reviewed publications, databases, improved natural resource management.	Inadequate support for research and monitoring, lack of incentives, inordinate delays in research permissions, isolationist approach of research and monitoring, inadequate management oriented research.
	Output 4.2 Plans for documentation of lessons learned and preparation of information dissemination products for wider audiences and applicability.	Innovative approaches for adaptive management of natural resources, particularly River ecosystem targeted. Successful implementation of community driven management of natural resources and River ecosystems	Successful and effective NRM and River management. Documentation of successful approaches in project design, development, and implementation. Case study on best practices developed.	Reports and periodic evaluation. Case studies and lessons learned, publications, and other documents.	Ineffective research and monitoring and adaptive management approaches. Lack of support for scaling up of riverscape conservation approaches. State level Implementing Agencies and partner organizations lack

Project Strategy	Objectively Verifiable Indicators				
Project Objectives and Outcomes	**Project Output**	**Target**	**Indicator**	**Source of Verification**	**Risks and Assumptions**
		implemented.			capacity to coordinate and monitor project effectively and ensure timely fund flows to landscape/ plantation/ treatment sites.

Annexure 2: Field Data Formats

2.1 Field Data collection format under Natural Landscape

Set - 1

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PREPARATION OF DETAIED PROJECT REPORT (DPR) FOR REJUVENATION OF INDUS RIVER BASIN THROUGH FORESTRY INTERVENTIONS

PROFORMA OF DATA COLLECTION FOR PROPOSED SITE

HIMALAYAN FOREST RESEARCH INSTITUTE, SHIMLA, HIMACHAL PRADESH

(INDIAN COUNCIL OF FORESTRY RESEARCH & EDUCATION, DEHRADUN-248006)

A. FORESTRY INTERVENTIONS	**NATURAL LANDSCAPE**
B. MODEL NO.	*To be proposed* SL/PB/NL/01

C. TREATMENT SITE (DETAILS)		
1.	NAME OF SITE	Lakhowal Drain
2.	AREA (IN HECTARE)	5 Hect.
D. GEOGRAPHICAL DETAILS		
1.	Name of River	Satluj ✓ Chenab Ravi Beas Jhelum
2.	State	Himachal Pradesh Punjab ✓ Jammu & Kashmir
3.	District	Ludhiana
4	Forest Circle	South circle, Punjab, Patiala.
5.	Forest Division	Ludhiana.
6.	Forest Range	Samrala.
7.	Forest Block	Machhiwara.
8.	Forest Beat	Machhiwara.
9.	Development Block Name	Machhiwara.
10.	Tehsil	Samrala
11.	Panchayat	—
E. BASELINE DATA		
1.	Current Status of Flora and Fauna	Protected Forest.
2.	Current land use	— " — " "
3.	Legal Status of land	— " —
4.	Geology and Soil type	medium.
5.	Slope	20 %.
6.	Aspect	—

7.	Average Annual Rainfall (in mm)	Medium.
8.	Special features of the site e.g. fire prone / landslides / mining areas / avalanche etc.	Polluted water.
9.	Distance from Road (Approximate)	01 k.m.
10.	Distance from Main River with Name of the river (Approximate)	5 k.m.
11.	Distance from Main Tributary with name of tributary (Approximate)	—
12.	Suggestive species for plantation	Shisham, Drak Toot.
13.	Pit Size	.50 x .50 x .40
14.	Details of Fencing works, if required before plantation	
15.	Details of Soil Moisture and Conservation works, if required before plantation	Nursery -
16.	Planting Cost including nursery cost (Approximate)	Nursery Cost = 125000 —
17	Maintenance Cost of plantation with years (Approximate)	= 75000 —
18.	Remarks, if any	Forest.
19.	GPS coordinates of the site at all the corners (As per the shape of site, minimum 4 points are required)	1. N: 30°55'53.4" E: 76°14'10.8" Ele (m): / 2. N: 30°57'48.7" E: 76°08'07.8" Ele (m): / 3. N: E: Ele (m): / 4. N: E: Ele (m): / 5. N: E: Ele (m): / 6. N: E: Ele (m): / 7. N: E: Ele (m): / 8. N: E: Ele (m):
F. ROUGH SKETCH OF TREATMENT SITE / MAP (AS AN ATTACHMENT)		
G. CURRENT PHOTOGRAPH (AS AN ATTACHMENT)		
Name and Designation: Sukhpal Singh, Forest Range officer, Samrala	Contact Number: 95016-89123	Signature of Forest Officer / Official

PREPARATION OF DETAIED PROJECT REPORT (DPR) FOR REJUVENATION OF INDUS RIVER BASIN THROUGH FORESTRY INTERVENTIONS

DIVISION LEVEL PROFORMA OF DATA COLLECTION

HIMALAYAN FOREST RESEARCH INSTITUTE, SHIMLA, HIMACHAL PRADESH

(INDIAN COUNCIL OF FORESTRY RESEARCH & EDUCATION, DEHRADUN-248006)

FORESTRY INTERVENTIONS	NATURAL LANDSCAPE
Name of River	Sutlej ✓ Chenab Ravi Beas Jhelum
State	Himachal Pradesh Punjab ✓ Jammu & Kashmir
District	Ludhiana
Forest Division	Ludhiana.
MODEL NO.	

Treatment Site Name	Year 2021-22		Year 2022-23		Year 2023-24		Year 2024-25		Year 2025-26												Total Area	Total Cost
	Area	Cost	Area	Cost	Area	Cost	Area	Cost	Area	Cost												
Ludhiana Drain	5 Ha	35000	5 Ha.	75000	5 Ha.	75000																
GRAND TOTAL																						

Name and Designation	Contact Number	
SUKHPAL SINGH FOREST RANGE OFFICER SAMRALA	95016-89123	Sukhpal Singh Signature of Forest Officer / Official

Note: 1. one sheet must be used for only one model.
2. Creation and subsequent maintenance year wise have to be filled up for one site.
3. The Grand Total in Area column should be only for newly created areas. However costs should be added for newly created areas and maintenance, both.
4. Area must be in Hectare and cost must be in Rs. (Lakh) only.

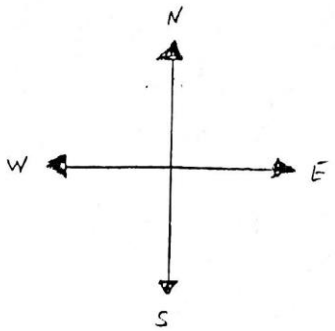
67

Lokhowal Drain
Block Machhiwara
RANGE SAMRALA



30° 55' 53.4" N
76° 14' 10.8" E

30° 57' 48.7" N
76° 08' 07.8 E



Skipped such R.O.S

Scanned by CamScanner





2.2 Field Data Collection Format under Urban Landscape

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Set - III

PREPARATION OF DETAIED PROJECT REPORT (DPR) FOR REJUVENATION OF INDUS RIVER BASIN THROUGH FORESTRY INTERVENTIONS

PROFORMA OF DATA COLLECTION FOR PROPOSED SITE

HIMALAYAN FOREST RESEARCH INSTITUTE, SHIMLA, HIMACHAL PRADESH

(INDIAN COUNCIL OF FORESTRY RESEARCH & EDUCATION, DEHRADUN-248006)

A. FORESTRY INTERVENTIONS	**NATURAL LANDSCAPE** / Urban landscape
B. MODEL NO.	***To be proposed*** SL/PB/UL/01

C. TREATMENT SITE (DETAILS)		
1.	NAME OF SITE	Lassara Drain RD 260 - 303 B/S
2.	AREA (IN HECTARE)	5
D. GEOGRAPHICAL DETAILS		
1.	Name of River	Satluj Chenab Ravi Beas Jhelum
2.	State	Himachal Pradesh Punjab Jammu & Kashmir
3.	District	Ludhiana
4.	Forest Circle	Patiala
5.	Forest Division	Ludhiana
6.	Forest Range	Doraha
7.	Forest Block	Dhamot
8.	Forest Beat	Sirthla
9.	Development Block Name	Dhamot
10.	Tehsil	Payal
11.	Panchayat	Sirthla

E. BASELINE DATA		
1.	Current Status of Flora and Fauna	Kikar, Arjun, Suckchain / Neel gau
2.	Current land use	Protected forest
3	Legal Status of land	Protected forest
4.	Geology and Soil type	Loamy Sand
5.	Slope	
6.	Aspect	

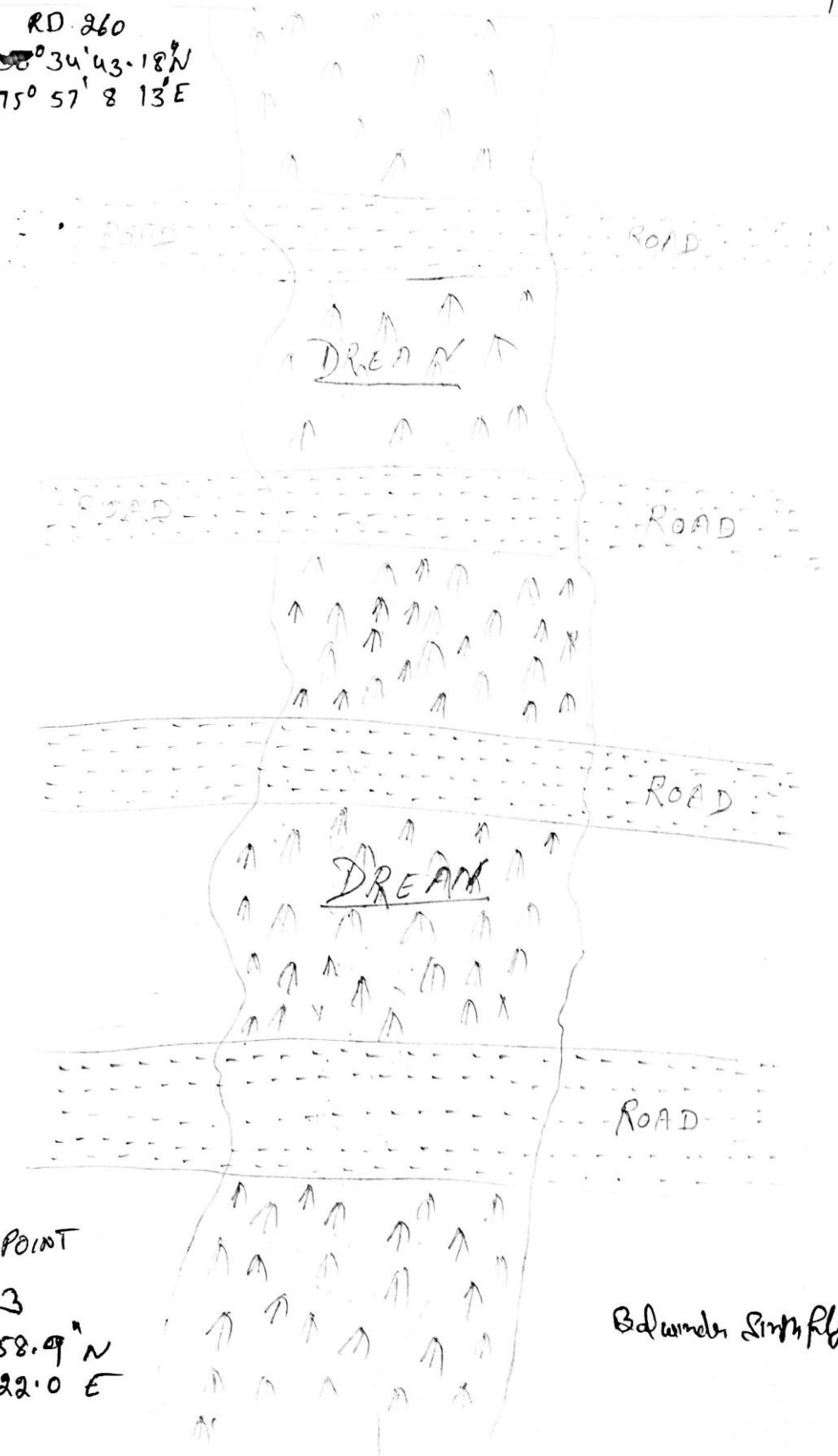
7.	Average Annual Rainfall (in mm)				
8.	Special features of the site e.g. fire prone / landslides / mining areas / avalanche etc.	Shrubs, Fire prone area			
9.	Distance from Road (Approximate)	3 km from main Road			
10.	Distance from Main River with Name of the river (Approximate)				
11.	Distance from Main Tributary with name of tributary (Approximate)				
12.	Suggestive species for plantation	Kikar / Arjun, Shisham			
13.	Pit Size	0.50 x .50 x .40			
14.	Details of Fencing works, if required before plantation	NO			
15.	Details of Soil Moisture and Conservation works, if required before plantation	No Moisture			
16.	Planting Cost including nursery cost (Approximate)				
17	Maintenance Cost of plantation with years (Approximate)				
18.	Remarks, if any				
19.	GPS coordinates of the site at all the corners (As per the shape of site, minimum 4 points are required)	1. N : 30° 34' 43.18" E: 75° 57' 08.13" Ele (m) :	2. N : 30° 37' 58.9" E: 76° 02' 22.0" Ele (m) :	3. N : E: Ele (m) :	4. N : E: Ele (m) :
		5. N : E: Ele (m) :	6. N : E: Ele (m) :	7. N : E: Ele (m) :	8. N : E: Ele (m) :
F. ROUGH SKETCH OF TREATMENT SITE / MAP (AS AN ATTACHMENT)					
G. CURRENT PHOTOGRAPH (AS AN ATTACHMENT)					
Name and Designation Balwinder Singh Forest Guard		**Contact Number** 9872442551 9878837364		Forest Range Officer Doraha **Signature of Forest Officer / Official**	

ਸਮਾਰਕ ਭਵਨ ਦੇ ਪੱਛੋਂ

Balwinder Singh Gill

समाना हेड RD 260 - 303 BLS

START POINT
RD 260
30° 34' 43.18" N
75° 57' 8.13" E



END POINT
RD 303
30° 37' 58.49" N
76° 02' 22.0" E

Balwinder Singh Rly

2.3 Field Data Collection Format under Conservation Inyerventions (SMC)

Set - IV

PREPARATION OF DETAIED PROJECT REPORT (DPR) FOR REJUVENATION OF INDUS RIVER BASIN THROUGH FORESTRY INTERVENTIONS

PROFORMA OF DATA COLLECTION FOR PROPOSED SITE

HIMALAYAN FOREST RESEARCH INSTITUTE, SHIMLA, HIMACHAL PRADESH

(INDIAN COUNCIL OF FORESTRY RESEARCH & EDUCATION, DEHRADUN-248006)

A. OTHER INTERVENTIONS	**a. Wetland Management (Natural and Artificial)** **b. Wildlife Management** **c. Riparian Wildlife Management** **d. Soil and Water Conservation** ✓ **e. Moraine Management** **f. Others (Specify please).....**

B. SITE DETAILS						
1.	NAME OF SITE	Dff Ramgarh Shoola (CTb)				
2.	AREA (IN HECTARE)	40 hect				
C. GEOGRAPHICAL DETAILS						
1.	Name of River	Sutlej	Chenab	Ravi	Beas	Jhelum
2.	State	Himachal Pradesh		Punjab		Jammu & Kashmir
3.	District	UNA				
4.	Forest Circle	Hamirpur				
5.	Forest Division	UNA				
6.	Forest Range	Ramgarh				
7.	Forest Block	Thanakalan				
8.	Forest Beat	Mandli				
9.	Development Block Name	Bangana				
10.	Tehsil	Bangana				
11.	Panchayat	Mandli				
D. BASELINE DATA						
1.	Current land use	Demarcated Protected forest				
2.	Land Use Status five year ago	— " —				
3.	Legal Status of land	— " — Forest				
4.	Soil Type	Sandy loamy				
5.	Average Annual Rainfall (in mm)	105 – 110 mm				

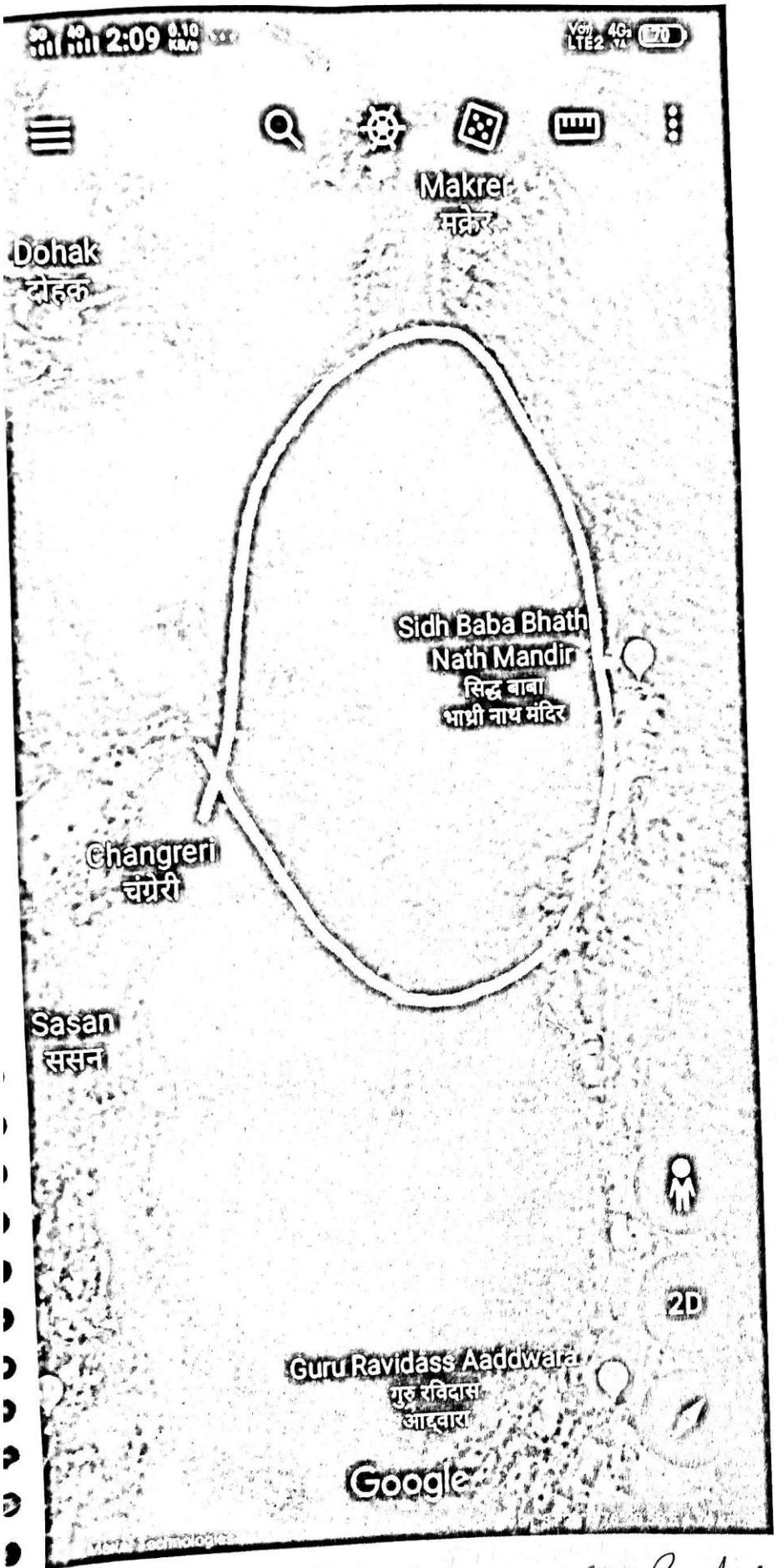
6.	Special features of the site	Fire Proone			
7.	Distance from Road (Approximate)	1.25 km			
8.	Distance from Main River with Name of the river (Approximate)	Dobale Nala (Cho) 1.25 km			
9.	Distance from Main Tributary with name of tributary (Approximate)	2 Km			
10.	Remarks, if any	—			
11.	GPS coordinates of the site at all the corners (As per the shape of site, minimum 3 points are required)	1. N : 31°30'44.3 E: 076°22.063 Ele (m) :	2. N : 31°30'44.3 E: 076.22'19.0 Ele (m) :	3. N : 31°29'190 E: 076°22'13.2 Ele (m) :	4. N :31°23.423 E: 076°22'2.03 Ele (m) :
		5. N : E: Ele (m) :	6. N : E: Ele (m) :	7. N : E: Ele (m) :	8. N : E: Ele (m) :
F. ROUGH SKETCH OF TREATMENT SITE (AS AN ATTACHMENT)		Attached			
G. CURRENT PHOTOGRAPH (GEOREFRENCED FROM ONE CORNER AS PER POINT No. 11. (AS AN ATTACHMENT)		Attached.			

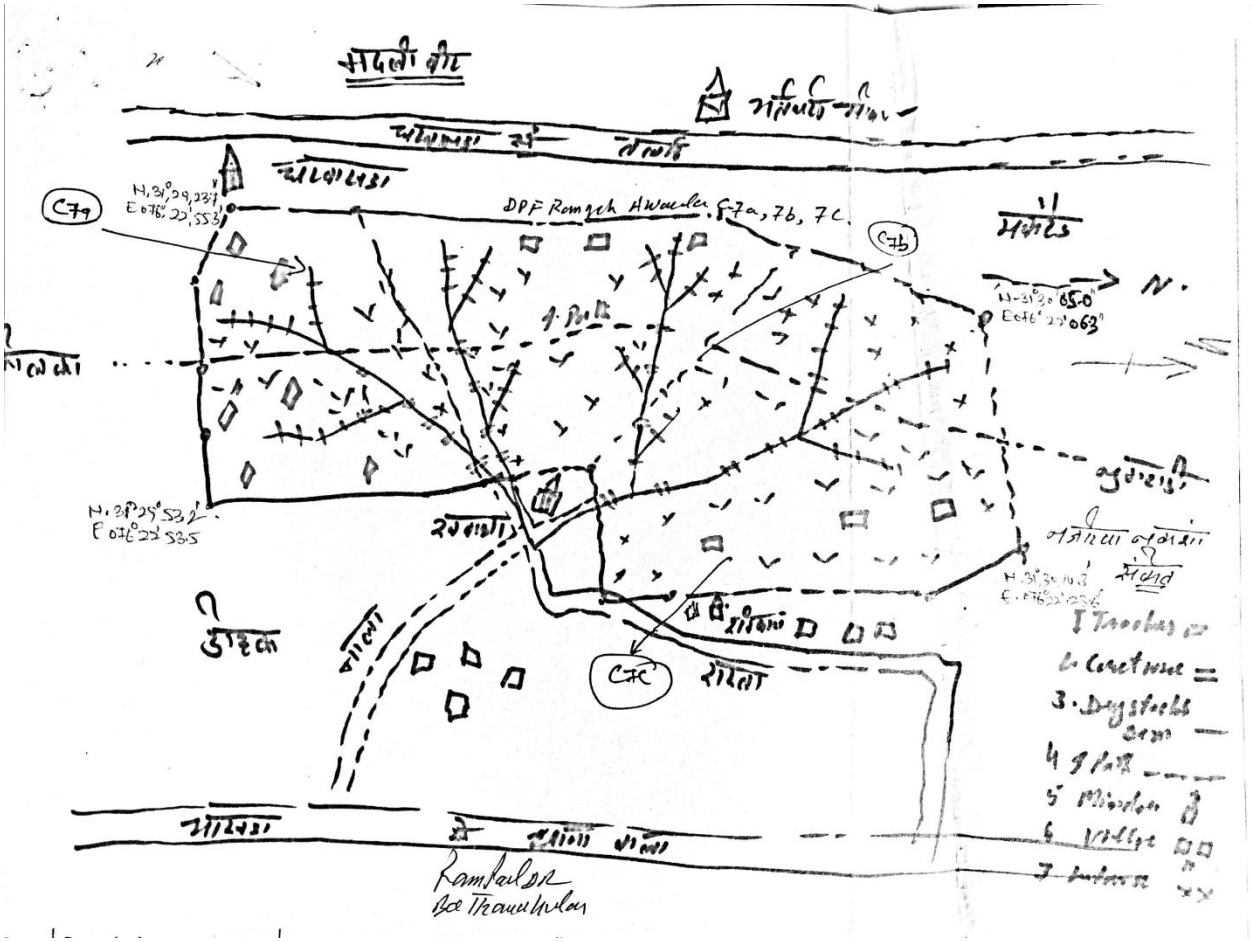
H. SITE SPECIFIC ACTIVITIES

S. NO.	YEAR	NAME OF ACTIVITIES	UNIT (AREA/ NO.)	FINANCIAL OUTLAY (IN RS.)
1	2021-22	(a) Construction of Pitpody (b) C/o Trenches.	3800 Rmt	75400.00
2.	2022-23	C/O Dry Stone Check dam (2)	50 MO 150 Cum	4,50,000.00
3.	2023-24	C/O Dry Stone Check dam (2)	2540 (75 Cu)	2,25,000.00
4.	—	C/o Trenches in Plantin area	2200 Rmt	64000.00
		GRAND TOTAL		8,14,400.00

Name and Designation	Contact Number	Signature of Forest Officer / Official
Ajay Kumar	82196-30075	

Ram Paul DR 8629095743 Ram Paul DR Tizoma Kohima


2:09
Makrer
मक्रेर
Dohak
दोहक
Sidh Baba Bhath
Nath Mandir
सिद्ध बाबा
भाथ्री नाथ मंदिर
Changreri
चंगेरी
Sasan
ससन
2D
Guru Ravidass Aaddwara
गुरु रविदास
आद्वार
Google


C79
C7b
C7c
DPF Ramgarh Haveli 57a, 76, 7c.
N. 31°29'28.3"
E 076° 22' 55.3"
N. 31°29'25.53.2"
E 076°22'53.5
N. 31°29'65.0
E 076°22'063°
N. 31°30'10.3"
E 076°22'03.4"
Ramgarh
See Tehsil Office

2.3 Field Data Collection Format under Awareness and Participatory Monitoring Activity

Set - V

PREPARATION OF DETAIED PROJECT REPORT (DPR) FOR REJUVENATION OF INDUS RIVER BASIN THROUGH FORESTRY INTERVENTIONS

PROFORMA OF DATA COLLECTION FOR PROPOSED SITE

HIMALAYAN FOREST RESEARCH INSTITUTE, SHIMLA, HIMACHAL PRADESH

(INDIAN COUNCIL OF FORESTRY RESEARCH & EDUCATION, DEHRADUN-248006)

A. OTHER ACTIVITIES				
NAME OF ACTIVITY	Civil society involvement (like Nehru Yuva Kendra, Eco clubs, Street play, community meeting, advertisement and publication etc.	Baseline data w.r.t. water discharge and sediment load (SOP) data collection; on field research etc .	Capacity building	Participatory monitoring

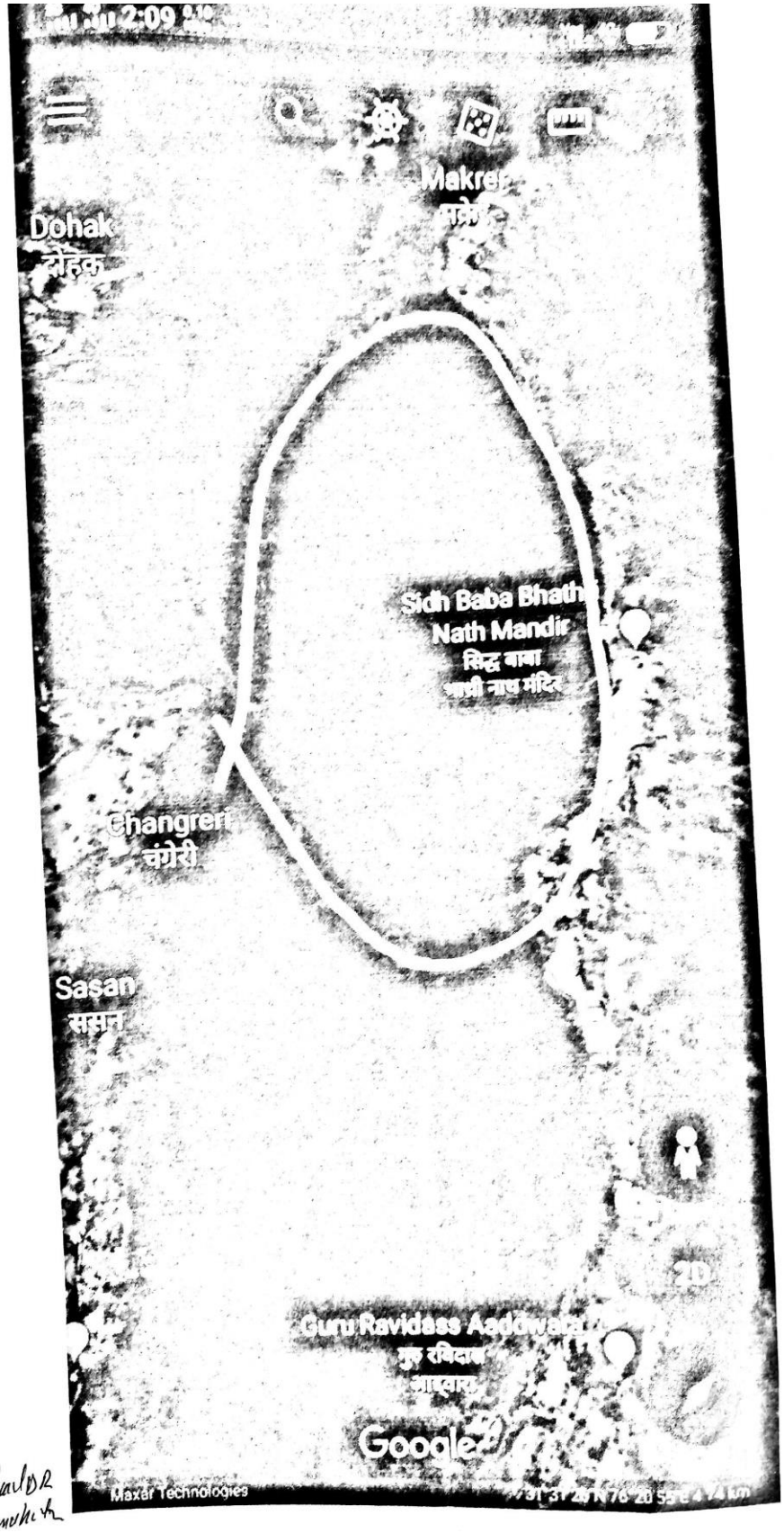
B. SITE DETAILS		
1.	NAME OF STATE	H.P.
2.	NAME OF SITE	DPF Rampur Awasta (CTa)1
3.	AREA (IN HECTARE)	45 hect
4.	FOREST IVISION	UHA

C. ACTIVITIES			
1.	YEAR	NAME OF ACTIVITY	FINANCIAL OUTLAY
2.	2020-21	Public Awareness. @ Publication	50,000/-
3.	2021-22		20,000/-
4.	2022-23	— D	25000/-
5.			
6.			
7.			
8.			95000.

Name and Designation	Contact Number	Signature of Officer
Ajay Kumar Forest Guard.	82196-30275	

Ram Paul Deputy Ranger 8629098743

Ram Paul DR
Bc Tirona Kulu



Ramdas DR
Panchayat

Annexure 3 : Description of Soil Type within Sutlej Riverscape

Sr.No.	Soil type	Description
1	**Dystric Eutrochrepts**	Deep, well drained, thermic, fineloamy soils on very steep slopes with loamy surface and severe erosion
2	**Fluventic Ustochrepts**	Very deep, moderately well drained coarse loamy soils, occurring on very gentle slopes in active alluvial plains with fluvial parent material
3	**Lithic Cryorthents**	Poorely developed soils, semipermanent snow, bank is simply a thin sandy Ahorizon over a Chorizon
4	**Typic Cryochrepts**	Soils of glaciogluvial valley with moderate slopes occupied with moderately shallow
5	**Typic Cryorthents**	Soils of glaciogluvial valley with moderate slopes occupied with moderately shallow, excessively drained, sandyskeletal, neutral to slightly acidic, moderately eroded, and strongly stony.
6	**Typic Eutrochrepts**	Deep, well drained, thermic, fineloamy, calcareous soils on moderately steep slopes with loamy surface and severe erosion
7	**Typic Udifluvents**	Have moderately good or good drainage, occur in relatively high areas on flood plains, and the water table is deeper than 50 cm all of the time
8	**Typic Udorthents**	Found on moderate to steep slopes, are slightly to moderately acidic, moderately eroded, and moderate to strong stony
9	**Typic Ustifluvents**	Very deep imperfectly drained fine soils occurring on flat to nearly level active alluvial plain.
10	**Typic Ustipsamments**	Sand that have deep ground water and a thick regolith
11	**Typic Ustochrepts**	Coarseloamy soils derived from mixed alluviam or residium weathered from sand stone and shale
12	**Typic Ustorthents**	Soils those are deep or moderately deep to hard rock and those do not have ground water within 150 cm
13	**Udic Ustochrepts**	Coarseloamy soils derived from mixed allluviam or residium weathered from sand stone and shale
14	**Non Soil**	Areas that do not support plant growth are not considered but mapped. These may be glaciers, bedrock outcrops, urban land, active quarries, etc.

Annexure 4: List of Suggested Plant Species with Uses for Planting in Natural, Agriculture, Urban Landscape

Sr. No.	Botanical Name	Common Name	Habit	Special Attributes
1.	*Abies pindrow* (Royle ex D.Don) Royle	Tosh, Chilla, Talish, Raga	Tree	Construction, Used in some of the local medicines
2.	*Abies spectabilis* (D.Don) Mirb.	East Himalayan Fir	Tree	Rheumatic disorders, Nasal Blockage and Cold
3.	*Senegalia catechu* (L.f.) Willd.	Khair	Tree	Nitrogen fixer, fuel, fodder, timber, tannin, lac insect host, medicinal (cough and sore throats)
4.	*Acacia nilotica* (L.) Delile	Babul, Kikar	Tree	Nitrogen fixer, fuel, timber, fodder, tannin, gum
5.	*Acer caesium* Wall. ex Brandis	Kainju, Tilpatra	Tree	Burrs sometimes made into cups
6.	*Acer cappadocicum* Gled.	Caucasian Maple	Tree	Soil Stabilizer
7.	*Acer pictum* Thunb.	Yellow Paint Maple	Tree	Ornamental, Source of Wood
8.	*Aconitum heterophyllum* Wall. ex Royle	Atish	Herb	Medicinal (analgesic, antiinflammatory, antipyretic, aphrodisiac, astringent)
9.	*Acorus calamus* L.	Vacha	Herb	Roots are used for gastrointestinal (GI) problems including ulcers, inflammation of the stomach lining (gastritis), intestinal gas (flatulence), upset stomach and loss of appetite (anorexia)
10.	*Adina cordifolia* (Roxb.) Benth. & Hook.f. ex B.D.Jacks. (Syn: *Haldina cordifolia* (Roxb.) Ridsdale)	Haldu, Karam	Tree	Bark as Antiseptic
11.	*Aegle marmelos* (L.) Corrêa	Bil	Tree	Fuel wood, fencing, medicinal (laxative, heart and brain tonic, diarrhoea, dysentery etc.)
12.	*Aesculus indica* (Wall. ex Cambess.) Hook.	Pangar, Bankhor, Kandur	Tree	Wooden dishes to hold milk, ghee etc., seed embryo ground in to flour
13.	*Agropyron* spp.	Wheat grass	Grass	Used as forage and in erosion control.
14.	*Agropyron* spp.	Wheat grass	Grass	Used as forage and in erosion control.
15.	*Agrostis gigantea* Roth	Black bent grass	Grass	Used as a fodder and forage species. Also used as a lawn/turf grass for revegetation purposes and for erosion control.
16.	*Agrostis munroana* Aitch. & Hemsl.	Velvet bent grass	Herb/ Grass	Soil Stabilizer
17.	*Agrostis pilosula* Trin.	Grass	Grass	Soil Stabilizer
18.	*Ainsliaea* spp.		Grasses/ Forbs	
19.	*Ainsliaea aptera* DC.	Sathjalori	Herb/MP	Soil Stabilizer, Medicinal
20.	*Albizia* spp.		Tree	Timber

21.	*Albizia chinensis* (Osbeck) Merr.	Chuili	Tree	Medicinal, fodder, Fuel, Timber
22.	*Albizia lebbeck* (L.) Benth	Siris, Siras	Tree	Medicine (antipoisoning herb), Timber
23.	*Albizia procera* (Roxb.) Benth.	Kala Siris	Tree	Fodder, Timber
24.	*Allium carolinianum* DC.	Jangli Pyaz	Herb	Neutraceutical properties
25.	*Allium humile* Kunth	JangliPyaz	Herb	Medicinal uses
26.	*Alnus nitida* (Spach.) Endl.	Alder, Kunish	Tree	Soil Binder, Fodder
27.	*Alopecurus aequalis* Sobol.	orange foxtail	Grass	Soil stabilizer
28.	*Alopecurus nepalensis* Trin. ex Steud.	Nepal foxtail grass	Grass	Used as food, fodder and for soil conservation.
29.	*Alstonia scholaris* (L.) R. Br.	Scholar's tree	Tree	Shade, wood for slateframe, pencil, packing Chatiun, Satwincase, medicine (malarial fever, dysentery)
30.	*Andrographis paniculata* (Burm.f.) Nees	Green Chiretta	Herb	It is used traditionally for the treatment of array of diseases such as diabetes, high blood pressure etc
31.	*Angelica glauca* Edgew.	Choura	Herb	Medicinal (Carminative, improve digestion)
32.	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guillem. & Perr.	Dhau	Tree	Fodder, fuel, medicine, timber
33.	*Anthocephalus cadamba* (Roxb.) Miq. (Syn: *Neolamarckia cadamba* (Roxb.) Bosser)	Kadam	Tree	Medicinal (Secondary Metabolites)
34.	*Apluda mutica* L.	Tachula, Tachhila, Pongta,	Grass/ Forb	Soil stabilizer, Fodder
35.	*Araucaria araucana* (Molina) K.Koch	Monkey Puzzle Tree	Tree	Ornamental, Medicinal
36.	*Arnebia euchroma* (Royle) I.M.Johnst.	Ratanjot	Herb	It is used in the treatment of measles, mild constipation, burns,
37.	*Arnebia benthamii* (Wall. ex G.Don) I.M.Johnst.	Ratanjot	Herb MP	Medicinal (Cardiac, febrifuge, diseases of the tongue and Throat)
38.	*Arnebia guttata* Bunge	Ratanjot	Herb	Traditional medicinal uses
39.	*Artemisia maritima* L.	Sea Wormwood	Shrub	It is used mainly as a tonic to the digestive system and in treating intermittent fevers
40.	*Artemisia* spp.	Sea Wormwood	Shrub	Aromatic, insect repellent
41.	*Arundinella nepalensis* Trin.	Dundi	Grass	Soil stabilizer
42.	*Arundinella pumila* (Hochst.) Steud.	Dwarf Reed Grass	Grass	Soil stabilizer
43.	*Arundo donax* L.	Barana, Nal	Grass	Soil stabilizer
44.	*Azadirachta indica* A.Juss.	Neem	Tree	Medicinal (skin diseases, leprosy, intestinal helminthiasis, respiratory disorders, etc.), timber, fodder, oil, oilcake as manure
45.	*Bacopa monnieri* (L.) Wettst.	Brahmi	Herb	It has been used by Ayurvedic medical practitioners for centuries for a variety of purposes, including

				improving memory, reducing anxiety,
46.	*Bambusa bambos* (L.) Voss	Giant thorny bamboo	Tree	Making bridges, furniture, ladders, thatching, etc.
47.	*Bambusa* spp.	Bamboo	Tree	Making bridges, furniture, ladders, thatching, etc.
48.	*Bauhinia* spp.	Kachnar	Tree	Food, fodder, fuel, fibre, gum, tannin, medicinal (diarrhoea, astringent, skin disease), nitrogen fixer
49.	*Bauhinia variegata* L.	Kachnar	Tree	It is used in several traditional medicine systems to cure various diseases. This plant has been known to possess antibacterial, antidiabetic, analgesic, anti-inflammatory, anti-diarrheal
50.	*Bauhinia vahlii* Wight & Arn.	Torreya	Shrub	The leaves as biodegradable plates Medicinal (Inflammation, tuberculosis, dysentery, fever, toothbrush, skin disease, diarrhea, pimples, indigestion)
51.	*Berberis lycium* Royle	Kashmal	Shrub	Its ethnomedicinal uses include its use for treatment of jaundice, diabetes, eye infections, fractured bones, internal wounds, diarrhea, rheumatism, stomachache
52.	*Berberis* spp.	Kashmal	Shrub	Medicinal uses
53.	*Berberis aristata* DC.	Kingora, Kashmoi, Kashmal	Shrub	Stem and root extracts used in medicine
54.	*Bergenia ciliata* (Haw.) Sternb.	Winter begonia	Herb	Rhizome, Whole Plant, Leaves. Urinary Troubles, Earaches, Diarrhea, Stomach And Duodenal Ulcers,
55.	*Bergenia stracheyi* (Hook.f. & Thom.) Engl.	Pashanbeda	Herb	Medicinal (Diuretic, aphrodisiac, tonic)
56.	*Betula alnoides* Buch.-Ham. ex D.Don	Kath bhuj	Tree	Fodder, peeling of bark stiffer than *B.utilis*
57.	Betula utilis D.Don	Bhojpatra	Tree	Bark in ancient times used for writing scriptures, afforestation, medicinal (ear ache, antiseptic, carminative)
58.	*Blumea* sp.	Ngai camphor	Herb	acrid, thermogenic, errhine, anti-inflammatory, styptic, opthalmic, digestive, anthelmintic, liver tonic, expectorant, febrifuge, antipyretic,
59.	*Boehmeria rugulosa* Wedd.	false nettles	Tree	Used as food plants by the larvae of some Lepidoptera species
60.	*Boerhavia diffusa* L.	Punarnava, Satha	Grass/ Forb	Soil Stabilizer, Medicinal (antiinflammatory and analgesic)
61.	*Bombax ceiba* L.	Semal	Tree	Wood, floss, medicinal (antioxidant, antimicrobial)
62.	*Bothriochloa intermedia* (R.Br.) A.Camus (Syn: *Bothriochloa bladhii* (Retz.)	Indian couch grass	Grass	Soil stabilizer, Fodder

	S.T.Blake)			
63.	*Bothriochloa parviflora* (R.Br.) Ohwi (Syn: *Capillipedium parviflorum* (R.Br.) Stapf)	Blue grass	Grass	Soil stabilizer, Fodder
64.	*Bothriochloa pertusa* (L.) A.Camus	Indian Bluegrass	Grass	Soil stabilizer, Fodder
65.	*Bougainvillea* spp.	Great bougainvillea	Shrub	Ornamental, Medicinal
66.	*Brachypodium sylvaticum* (Huds.) P.Beauv.	purple false brome, purple falsebrome	Herb	Soil stabilizer
67.	*Bromus ramosus* Huds.	Cheat grass	Grass	Soil stabilizer
68.	Bromus himalaicus Stapf	Cheat grass	Grass	Soil stabilizer
69.	*Buddleja* spp.	Butterfly bushes	Shrub	Soil stabilizer
70.	*Butea monosperma* (Lam.) Taub.	Dhak, Plash, Teshu	Tree	Nitrogen fixer, dye, fuel, fodder, medicinal (diarrhoea, diabetes)
71.	*Cactus* spp.	Cactus	Shrub	Soil stabilizer
72.	*Calamagrostis montanus* Host.	Bunch grass	Grass	Soil stabilizer
73.	*Calamograstis* spp.	Bunch grass	Grass	Soil stabilizer
74.	*Callistemon citrinus* (Curtis) Skeels	Bottle Brush	Tree	Ornamental, Medicinal
75.	*Capparis spinosa* L.	Caper	Shrub	Flower Buds Edible, Medicinal uses
76.	*Capparis decidua* (Forssk.) Edgew.	Kair, Kairiya	Shrub	Medicinal (Antooxidant)
77.	*Caragana brevifolia* Kom.		Shrub	Fuel, Biofencing
78.	*Caragana versicolor* Benth.		Shrub	Fuel, Biofencing
79.	*Carex* spp.	Brown sedge	Grasses/ Forbs	Bio fencing
80.	*Carissa spinarum* L.	Karonda	Shrub	Edible, Medicinal
81.	*Carpinus viminea* Wall. ex Lindl.	Himalayan Hornbeam.	Tree	Timber
82.	*Cassia fistula* L.	Amaltas	Tree	Shade/ornamental
83.	*Cedrus deodara* (Roxb. ex D.Don) G.Don	Deodar, Kelon	Tree	Timber, oil used against ulcers and eruptions
84.	*Celtis australis* L.	Kharik, kharakchena	Tree	Oars, whip handles, churn sticks, leaves as fodder
85.	*Chrysopogon serrulatus* Trin.	Grass	Grass	Fodder, Soil stabilizer
86.	*Chrysopogon zizanioides* (L.) Roberty	Khas	Grass	Soil binder, medicine, perfumery, scented mats, curtains
87.	*Chrysopogon fulvus* (Spreng.) Chiov.	Dhaulu	Grass	Fodder, Soil stabilizer
88.	*Chrysopogon gryllus* (L.) Trin.	Grass	Grass	Fodder, Soil stabilizer
89.	*Cicer songaricum* DC.	Chickpea	Herb	Aphrodisiac, antioxidant and antidiabetic
90.	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Tejpata	Tree	Medicinal (Colic diarrheoa)
91.	*Clerodendrum* spp.	glorybower, bagflowe	Shrubs	Use in Siddha medicinal for against diarrheoa
92.	*Colutea nepalensis* Sims.	Bladder Senna	Shrub	Medicinal uses
93.	*Cordia myxa* L.	Sapistan Plum	Tree	Fruits edible, Medicinal Use
94.	*Cornus capitata* Wall.	Himalayan Strawberry Tree	Tree	Fruits edible, Bark as source of Tannins
95.	*Cornus macrophylla* Wall.	LargeLeaf Dogwood	Tree	food, medicine and source of

				materials
96.	*Cornus oblonga*	Petal dogwood	Tree	Fuel wood and timber
97.	*Corylus jacquemontii* Decne.	Shalodi	Tree	Nuts edible, Leaves used as fodder.
98.	*Cotoneaster bacillaris* Wall. *ex.* Lindl.	Riyuns, Rockspray cotoneaster, Khareto	Shrub	Fruit edible, wood used for making walking sticks and agriculture tools, used as fodder.
99.	*Crotalaria* spp.	Sun hemp	Grasses	Soil stabilizer
100.	*Cryptomeria japonica* (Thunb. ex L.f.) D.Don	Japanese cedar or sugi	Tree	Timber sp.
101.	*Cupressus torulosa* D.Don.	Himalayan cypress, Surai	Tree	Ornamental, fuelwood, timber, essential oil for cosmetics
102.	*Cymbopogon martini* (Roxb.) W.Watson	Lemon Grass	Grass	
103.	*Cymbopogon* spp.	Lemon Grass	Grass	Soil stabilizer
104.	Cymbopogon citratus (DC.) Stapf.	Lemon Grass	Grass	Medicinal , Yield Oil, Soil stabilizer
105.	*Cymbopogon distans* (Nees ex Steud.) W.Watson	Lemon Grass	Grass	Soil stabilizer
106.	*Cymbopogon jwarancusa* (Jones) Schult.	Lemon Grass	Grass	Soil stabilizer
107.	C*yperus* spp.	Sedge	Grasses	Soil stabilizer
108.	*Dactylis glomerata* L.	Cock's Foot	Herb	Soil stabilizer
109.	*Dactylorhiza hatagirea* (D.Don) Soó	Salam Panja	Herb	Medicinal Plant
110.	*Dalbergia sissoo* DC.	Shisham	Tree	Furniture making
111.	*Danthonia* spp	Oatgrass	Grass	Soil stabilizer
112.	*Daphne papyracea* Wall. ex G. Don	Satpura	Shrub	Medicinal use
113.	*Debregeasia saeneb* (Forssk.) Hepper & J.R.I.Wood	Seru	Shrub	fibre is obtained from the bark, used for making twine and rope
114.	*Delonix regia* (Hook.) Raf.	Gulmohar	Tree	Ornamental uses
115.	*Dendrocalamus* spp.	Bamboo	Grass /bamboo	Timber, furniture and roots are used for pickle
116.	*Dendrocalamus hamiltonii* Nees & Arn. ex Munro	Kako, Choya bans	Bamboo	Timber, fodder, paper pulp
117.	*Dendrocalamus strictus* (Roxb.) Nees	Lathibaans	Bamboo	Fodder, edible young shoots, agricultural implements, construction
118.	*Deschamsia* spp.	Hair grass	Grass	Soil stabilizer
119.	*Desmodium elegans* DC.	Chamlai	Shrub	Medicinal Use
120.	*Desmodium gangeticum* (L.) DC.	Dirghamuli	Herb	Nitrogen fixer
121.	*Desmodium oojeinense* (Roxb.) H.Ohashi	Sandan	Tree	Medicinal Use
122.	*Desmodium triquetrum* (L.) DC.	Chamlai ,Elegant desmodium	Shrub	The roots are carminative, diuretic and tonic. The juice of the root, sometimes combined with the bark juice of *Bauhinia malabarica*, is used in the treatment of cholera.
123.	*Deutzia corymbosa* R.Br. ex G.Don		Shrub	Used as an ornamental plant, fuel and fodder.
124.	*Deutzia staminea* R.Br. ex Wall.		Shrub	Medicinal uses
125.	*Dichanthium annulatum* (Forssk.) Stapf	Marvel grass	Grass/ Forb	Soil stabilizer

126.	*Digitaria* spp.	hairy crabgrass	Grasses/ Forbs	Soil stabilizer
127.	*Diospyros kaki* L.f.	Japani Phal, Halwatendu	Tree	Wild Fruit
128.	*Diospyros lotus* L.	Japani Phal	Tree	Friuts edible, Medicinal use
129.	*Diospyros montana* Roxb.	Japani Phal	Tree	Friuts edible, Medicinal use
130.	*Diospyros nigra* (J.F.Gmel.) Perrier	Japani Phal	Tree	Friuts edible, Medicinal use
131.	*Dracocephalus* spp.	dragonhead	Herb/ MP	Soil stabilizer
132.	*Drepanostachyum falcatum* (Nees) Keng f.	Pahari Bans	Hill bamboo	Craft, Basket making, Fodder, Soil Binder
133.	*Eclipta alba* (L.) Hassk.	Bhringraj	Grasses	Soil stabilizer
134.	*Eichhornia crassipes* (Mart.) Solms	water hyacinth	Aquatic Plant	Bioremediation
135.	*Elaeagnus conferta* Roxb.	Wild Olive	Shrub	Fruits seeds edible, Medicinal Use
136.	*Ephedra gerardiana* Wall. ex Stapf	Somlata	Herb	Yield 'Ephidrin', Medicinal Use
137.	*Eragrostis* spp.	Cane grass	Herb	Soil stabilizer
138.	*Eragrostis nigra* Nees ex Steud.	Cane grass	Grass	Soil stabilizer
139.	*Erianthus filifolius* *(Syn: Saccharum filifolium* Steud)	Grass	Grass	Soil stabilizer
140.	*Erianthus rufipilus* *(Syn: Saccharum rufipilum* Steud.)	Grass	Grass	Soil stabilizer
141.	*Erianthus* spp.	Grass	Grass	Soil stabilizer
142.	*Eulaliopsis binate* (Retz.) C.E.Hubb.	Grass	Grass	Soil stabilizer
143.	*Euphorbia* spp.	Spurge	Shrub	Soil stabilizer
144.	*Euphorbia pulcherrima* Willd. ex Klotzsch	Spurge	Shrub	Soil stabilizer
145.	*Festuca arundinacea* Schreb.	Tall fescue	Grass	It is used as an ornamental grass and used for polluted soil remediation.
146.	*Festuca pratensis* Huds.	Tall fescue	Grass	It is used as an ornamental grass and used for polluted soil remediation.
147.	*Festuca valesiaca* Schleich. ex Gaudin	Tall fescue	Grass	It is used as an ornamental grass and used for polluted soil remediation.
148.	*Ficus benghalensis* L.	Bad	Tree	Religious significance, shade
149.	*Ficus benjamina* L.	Bad	Tree	Religious significance, shade
150.	*Ficus hispida* L.f.	Daduri, Jogdumur	Tree	Medicinal (leucoderma, psoriasis, haemorrhoids), fuel wood.
151.	*Ficus racemosa* L.	Goolar	Tree	Fodder, medicinal (astringent, dysentery, stomachache, piles)
152.	*Ficus religiosa* L.	Peepal	Tree	Religious significance, shade
153.	*Ficus rumphii* Blume	Kabaipipal, Bettaarli	Tree	It is useful in burning sensations, leucoderma, ulcers, leprosy, itching, biliousness and diseases of blood.
154.	*Flacourtia indica* (Burm.f.) Merr.	Bilangada, Governor's' Pulm	Tree	Medicinal Uses
155.	*Flemingia semialata* Roxb.	Bara solpan, Ban chola	Shrub	Fodder, dyes and for various therapeutic purposes.

156.	*Fraxinus xanthoxyloides* (G.Don) Wall. ex A.DC.	Ash Tree	Tree	Making bows, tool handles, baseball bats
157.	*Geranium wallichianum* D.Don ex Sweet	Himalayan Geranium	Shrub	Soil stabilizer, Ornamental, Dye
158.	*Gmelina arborea* Roxb.	Gamhar	Tree	Timber, medicinal (stomachic, galactagogue laxative and anthelmintic)
159.	*Grevillea robusta* A.Cunn. ex R.Br.	Silver Oak	Tree	Ornamental, Furniture, Timber
160.	*Grewia eriocarpa* Juss.		Tree	Fuel wood and fodder
161.	*Grewia optiva* J.R.Drumm. ex Burret	Beul	Tree	Leaves as excellent fodder used to make rope
162.	*Grewia* spp.		Tree	Used as Fuel wood and Fodder
163.	*Hedychium spicatum* Sm.	Spiked Ginger Lily	Herb	Medicinal
164.	*Heracleum candicans* Wall. ex DC.	Padra, Patrala, Hogweed	Herb	Sunscreen creams/lotions, Medicinal Properties
165.	*Heracleum wallichii* DC.	Krandel,Chitra	Herb	It exhibit medicinal properties and used for the treatment of leucoderma.
166.	*Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult.	Black speargrass	Grass	Soil stabilizer
167.	*Hierochloe laxa* Hook.f.	Sweet grass	Grass	Used as fodder and soil conservation.
168.	*Hippophae rhamnoides* L. spp.turkestanica	Chharma	Shrub	Fruits edible rich in vitamins C and minerals
169.	*Hippophae salicifolia* D. Don	Chuk, Tarwa	Tree	Firewood, fodder, windbreaks, shelterbelts
170.	*Holarrhena pubescens* Wall. ex G.Don	karvaindrajau	Tree	Medicinal Use
171.	*Holoptelea integrifolia* Planch.	Kanju	Tree	Timber, medicinal (antioxidant)
172.	*Hymenodictyon orixense* (Roxb.) Mabb.	Kala Bachnag	Tree	Fuelwood
173.	*Hymenodictyon sauveolens*	Bhurkur	Tree	Medicinal Use
174.	*Hyoscyamus niger* L.	Khurasani ajwain	Herb	Henbane is used in Homoepathic medicine.
175.	*Hypericum oblongifolium* Choisy	Basant	Shrub	Fodder, Fuel wood
176.	*Hyssopus officinalis* L.	Jupha	Herb	Soil stabilizer
177.	*Indigofera heterantha* Brandis	Kathi, sakina	Shrub	Twigs used for basket work, fuel
178.	*Inula racemosa* Hook.f.	Pushkarmool	Shrubs	Soil stabilizer
179.	*Inula* spp.	Pokharmol	Shrubs	Soil stabilizer
180.	*Isodon rugosus* (Wall. Ex Benth.) Codd.	Merati	Shrub	Medicinal uses
181.	*Jacaranda mimosifolia* D.Don.	NeeliGulmohar	Tree	Furniture and Cultural use
182.	*Jasminum* spp.	Chameli	Shrub	Medicinal and Cultural Use
183.	*Juniperus polycarpos* K.Koch	Juniper	Tree	Medicinal and Cultural Use
184.	*Justicia adhatoda* L.	Basak, Arusa	Shrub	Medicinal (relieve cough, cold, whooping cough, asthma)
185.	*Kigelia africana* (Lam.) Benth.	BalamKhira	Tree	Traditional Uses
186.	*Koeleria* spp.	Grass	Grass	Fodder, astringent and apllied externally to the skin in the form of poultice to heal the wounds.
187.	*Lannea coromandelica* (Houtt.)	Mohin	Tree	Boundary, barrier or support;

	Merr.			Charcoal, Fodder
188.	*Litsea glutinosa* (Lour.) C.B.Rob.	MedaLadaki	Tree	Medicinal Use
189.	*Lonicera hypoleuca* Decne.	Yellow Himalayan Honeysuckle	Shrub	Medicinal Use
190.	*Lyonia ovalifolia* (Wall.) Drude	Ayar	Tree	Mature leaves of is a used as fodder, leaf juice is applied to treat scabies and itching
191.	*Maesa indica* (Roxb.) A. DC.	kramighnaphal	Shrub	Antioxidant and medicinal properties
192.	*Mallotus philippensis* (Lam.) Müll. Arg.	Kambal	Tree	Firewood, Red dye obtained from the fruits; the powder also used as anthelmintic and purgative
193.	*Malva* spp.	Least mallow	Shrub	Fodder and soil stabilization
194.	*Malvastrum* spp.	False Mallow	Grasses	Fodder and soil stabilization
195.	*Mangifera indica* L.	Mango	Tree	Fruit tree (horticultural plant)
196.	*Medicago* spp.	Sickle Medick	Shrubs	Soil stabilization
197.	*Melia azedarach* L.	Drek	Tree	agricultural implements, like ploughs; Ethnomedicinal(Malaria, skin diseases, indigestion, headache) Fruit—anthelmintic; used in skin diseases
198.	*Melilotus* spp.	White Sweet Clover	Herb	Medicinal uses
199.	*Mentha* spp	Puddina	Herb	Traditional Cultural dish and Medicinal uses
200.	*Michelia* spp.		Tree	Diabetes, quick wound healing, cardiac disorders, gout
201.	*Mitragyna parvifolia* (Roxb.) Korth.	Kadamb	Tree	Roots, Bark and Leaves have medicinal Properties
202.	*Morus alba* L.	Sehtoot	Tree	Fruits edible, Timber wood
203.	*Murraya koenigii* (L.) Spreng.	Gandhala	Shrub	The leaves are used as coolant and also used in flavor "Kaddi'. Used as Fodder Ethnomedicinal (Dysentery, renal pain, control blood pressure, lower cholesterol level)
204.	*Murraya paniculata* (L.) Jack.	Kamini	Shrub	Ethnomedicinal Uses
205.	*Myrica esculenta* Buch.-Ham. ex D. Don	Kaphal	Tree	Medicinal Plant
206.	*Myricaria elegans* Royle	Elegant False Tamarisk	Shrub	Medicinal uses
207.	*Myricaria germanica* (L.) Desv.	Scaly False Tamarisk	Shrub	Bark as Astringent
208.	*Nerium oleander* L.	Kaner	Shrub	Ornamental, Medicinal Uses
209.	*Nyctanthes arbor-tristis* L.	HarSingar	Shrub	Ornamental, Cultural use
210.	*Olea cuspidata* *(Syn: Olea europaea* subsp. cuspidata (Wall. & G.Don) Cif.)	Brown Olive	Tree	Fuelwood
211.	*Oroxylum indicum* (L.) Kurz	Tatplanga	Tree	Cultural Use, Medicinal Use
212.	*Panicum maximum* Jacq.	Buffalo grass	Grass	Used as Soil stabilizer and Fodder.
213.	*Parietaria debilis* G.Forst.	Pellitory	Grass	Soil stabilizer
214.	*Pennisetum glaucum* (L.) R.Br.	Bajra	Grass	Soil stabilizer
215.	*Phleum pretense* L.	Alpine Cat Tail	Grass	Soil stabilizer
216.	*Phragmites karka* (Retz.) Trin. ex Steud.	Tall reed, Khagra	Grass	Soil stabilizer, culms for making baskets, mats, pipe, paper

217.	*Phragmites* spp.	Khagra	Grass	Soil stabilizer, culms for making baskets
218.	*Phyllanthus emblica* L.	Amla	Tree	Edible, fodder, fuel, religious, medicinal
219.	*Phytolacca acinosa* Roxb.	Indian pokeweed	Herb	Leaves edible like spinach, medicinal (roots have contraceptive properties)
220.	*Picea smithiana* (Wall.) Boiss.	Rai	Tree	Timber, railway sleeper
221.	*Picrorhiza kurrooa* Royle	Kutaki	Herb	Medicinal (hepatoprotective, antipyretic and to treat dyspepsia, respiratory disorders, chronic diarrhoea, and scorpion sting)
222.	*Pinus gerardiana* Wall. ex D.Don	Chilgoza/ Neoza	Tree	Seeds highly nutritious and edible
223.	*Pinus roxburghii* Sarg.	Chir	Tree	Timber, source of an oleoresin which yields turpentine oil
224.	*Pinus wallichiana* A.B.Jacks.	Kail	Tree	Timber, stumps as torch
225.	*Pistacia chinensis* subsp. integerrima (J. L. Stewart ex Brandis) Rech. F.	Kakarsingi	Tree	Medicinal Use
226.	*Platanus orientalis* L.	Chenar	Tree	Soil stabilizer
227.	*Poa alpina* L.	Grass	Grass	Soil stabilizer
228.	*Poa annua*	Grass	Grass	Soil stabilizer
229.	*Poa pratensis* L.	Grass	Grass/ Forb	Soil stabilizer
230.	*Polyalthia longifolia* (Sonn.) Thwaites	Ashok	Tree	Ornamental, Fiber yielding
231.	*Polygonatum cirrhifolium* (Wall.) Royle	Medha, Coiling leaf	Herb	Medicinal uses
232.	*Polygonatum verticillatum* (L.) All.	Khinraula	Herb	Medicinal
233.	*Polypogon fugax* Nees ex Steud.	Beard Grass	Grasses	Soil stabilizer
234.	*Pongamia pinnata* (L.) Pierre	Karanj, Pongam	Tree	Nitrogen fixer, Fodder, insecticidal, fish poison, Medicinal (Antidiarrhoeal, Anti ulcerogenic, antiinflammatory)
235.	*Populus deltoides* Marshall	Poplar	Tree	Timber, fuel wood
236.	*Populus* spp.	Poplar	Tree	Timber, fuel wood
237.	*Populus alba* L.	Poplar	Tree	Ornamental, Timber
238.	*Populus ciliata* Wall. ex Royle	Himalayan Poplar	Tree	Timber, fuel wood and religious purposes
239.	*Potentilla* spp.	Silverweed Cinquefoil	Herb	Traditonal Medicinal
240.	*Prinsepia utilis* Royle	Bhekal, Bhekoi	Shrub	Seed oil extract used for burning
241.	*Prosopis cineraria* (L.) Druce	Khejri Tree	Tree	Fuel wood
242.	*Prunus armeniaca* L.	Chulti, Shadi. Apricot, wild apricot	Tree	Fruit tree (horticultural plant), wild form gives medicinal oil
243.	*Prunus cerasifera* Ehrh.	Padam	Tree	Ornamental tree
244.	*Prunus cerasoides* Buch.-Ham. ex D.Don	Pajja	Tree	Walking sticks, fruit edible, stones used to make roseries
245.	*Prunus cornuta* (Wall. ex Royle) Steud.	Himalayan Bird Cherry	Tree	Fruits edible, leaves as fodder
246.	*Prunus domestica* L.	Plum	Tree	Edible

247.	*Prunus mira* Koehne	Behmi	Tree	Fruit and oil edible. Oil used for body massaging.
248.	*Prunus persica* (L.) Batsch	Auru	Tree	Fruit edible, kernel paste is applied in forehead for headache, twigs used toothbrush, leaves for fodder
249.	*Pterocarpus marsupium* Roxb.	Fruits edible, leaves as fodder	Tree	Nitrogen fixer
250.	*Punica granatum* L.	Daru, Anar	Tree	Fruit tree
251.	*Pyrus pashia* Buch.-Ham. ex D.Don	Mohal, Kainth	Tree	Walking sticks, combs, half rotten fruit eaten, leaves as fodder
252.	*Quercus floribunda* Lindl. ex A.Camus	Moru	Tree	Building, agricultural implements, sole of sledges, leaves for fodder
253.	*Quercus glauca* Thunb.	Banni	Tree	Fuel wood
254.	*Quercus oblongata* D. Don	Ban Oak	Tree	Wood for construction, ploughs, major source of fodder, good fuel
255.	*Quercus semecarpifolia* Sm.	Kharsu Oak	Tree	Fuel wood, fodder and medicinal uses
256.	*Rauvolfia serpentina* (L.) Benth. ex Kurz	Sarpagandha	Shrub	Medicinal uses
257.	*Rheum australe* D. Don	Himalayan Rhubarb	Herb	Medicinal uses
258.	*Rheum moorcroftianum* Royle	Himalayan Rhubarb	Herb	Medicinal Plant
259.	*Rheum* spp.	Himalayan Rhubarb	Herb	Medicinal uses
260.	*Ribes alpestre* Wall. ex Decne.	Asian Gooseberry	Shrub	Ornamental uses
261.	*Ribes himalense* Royle ex Decne.	Himalayan Goosberry	Shrub	Berries edible, used in jams and jelly
262.	*Ribes orientale* Desf.	Oriental Gooseberry	Shrub	Food, Medicinal use
263.	*Ricinus communis* L.	Arandi	Shrub	Oil , Medicinal Use
264.	*Rosa macrophylla* Lindl.	Himalayan Rose	Shrub	Ornamental
265.	*Rosa moschata* Herrm.	Ban Gulab	Shrub	Ornamental, Medicinal use
266.	*Rosa sericea* Wall. ex Lindl.	Silky Rose	Shrub	Ornamental, Medicinal use
267.	*Rosa* spp.	Rose	Shrub	Ornamental
268.	*Rosa webbiana* Wall. ex Royle	JangliGulab	Shrub	Edible and Medicinal use
269.	*Rubus biflorus* Buch.-Ham. ex Sm.	Raspberry	Shrub	Fruits edible, Ornamental
270.	*Rubus ellipticus* Sm.	Hinsur	Shrub	Fruits, fodder & fencing.
271.	*Rubus foliosus* Weihe	Roseleaf Bramble	Shrub	Fruits, fodder & fencing.
272.	*Rubus niveus* Thunb.	Kalka	Shrub	Fruits, fodder & fencing.
273.	*Rubus* spp.	Roseleaf Bramble	Shrub	Fruits and fodder
274.	*Saccaharum munja*	Sugarcane grass	Grass	Soil stabilizer
275.	*Saccharum bengalense* Retz.	Sarkanda	Grass	Soil stabilizer
276.	*Saccharum filifolium* Steud.	Sarkanda	Grass	Soil stabilizer
277.	*Saccharum spontaneum* L.	Kans	Grass	Soil stabilizer
278.	*Salix alba* L.	White Willow	Tree	Medicinal uses
279.	*Salix daphnoides* Vill.	Daphne Willow, Biuns	Tree	used as timber, as fuel and making baskets
280.	*Salix flabellaris* Anders.	Willow	Tree	used as timber
281.	*Salix fragilis* L.	Crack Willow	Tree	Ornamental
282.	*Salix* spp.	Salix	Tree	Medicinal uses
283.	*Salix tetrasperma* Roxb.	Lai la	Tree	Erosion control, soil binding, stream bank stabilisation
284.	*Santalum album* L.	Indian Sandal wood, Chandan	Tree	treat skin diseases, acne, dysentery, gonorrhea
285.	*Sapindus mukorossi* Gaertn.	Ritha, Soap Nut, Soap	Tree	ingredient in soaps and shampoos,

		Berry		Medicinal Uses
286.	*Saraca asoca* (Roxb.) Willd.	Ashoka	Tree	Bark Flower and seeds used as Medicine
287.	*Saussurea costus* (Falc.) Lipsch.	Kuth	Herb	Medicinal plant
288.	*Saussurea* spp.	Kuth	Herb	Medicinal plant
289.	*Scirpus grossus* L.f.	Kaseru	Herb	Ayurvedic /Medicinal uses
290.	*Scirpus* spp.	Coastal Plain Spike-Rush	Grasses	Soil stabilizer
291.	*Scrophularia* spp.	Leaf Figwort	Grass	Soil stabilizer
292.	*Selinum vaginatum* C.B. Clarke	Bhutkeshi	Herb	Medicinal uses
293.	*Selinum wallichianum* (DC.) Raizada & H.O. Saxena	Bhutkeshi	Herb	Ayurvedic /Medicinal uses
294.	*Sesbania sesban* (L.) Merr.	Jayanti	Tree	Excellent Fodder
295.	*Sinopodophyllum hexandrum* (Royle) T.S.Ying	Bankakri	Herb	Yield Podophyllotoxin, Medicinal Use
296.	*Spiraea canescens D.Don*	JharMirala	Shrub	Fodder, Basket Making
297.	*Spiraea* spp.	Spirea	Shrub	Soil stabilizer
298.	*Spirodela polyrrhiza* (L.) Schleid.	Duckweed	Tree	Fodder
299.	*Sporobolus diandrus* (Retz.) P.Beauv.	Grass	Grass	Soil stabilizer
300.	*Stipa roylei* (Nees) Duthie	Stipa	Herb	Traditional medicinal uses
301.	*Strobilanthus* spp.	Maruadona	Grass	Soil stabilizer
302.	*Symplocos paniculata* (Thunb.) Miq.	sapphire berry	Tree	Ornamental
303.	*Syringa emodi* Wall. ex Royle	Himalayan lilac.	Shrub	Soil stabilizer
304.	*Syzygium venosum* (L.) Skeels	Jamun	Tree	Ornamental, edible fruit, medicinal (treatment of various disease particularly diabetes)
305.	*Tamarindus indica* L.	Imli	Tree	Fruit tree, culinary
306.	*Taxus wallichiana* Zucc.	Rakhal	Tree	Leaves contain an alkaloid ‘Taxol’ used for treatment of Cancer. Bark as alternative to tea. Wood used as furniture.
307.	*Tecoma stans* (L.) Juss. ex Kunth	Piliya	Shrub	Construction and Medicinal Uses
308.	*Tecomella undulata* (Sm.) Seem.	Roheda	Tree	Timber sp.
309.	*Tectona grandis* L.f.	Teak	Tree	Premium quality timber
310.	*Tephrosia hamiltonii* (Syn. *T. purpurea* (L.) Pers.)	Sarphonka, Bannil	Herb	Medicinal (asthma, cough), rutin, dye, green manure
311.	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	Arjun	Tree	Tassar cultivation, timber, fencing, fuel wood, medicinal (heart tonic), shade
312.	*Terminalia bellirica* (Gaertn.) Roxb.	Bahera	Tree	Fodder, fuel, fruit (myrobalan), timber, medicinal, ingredient of 'triphala'
313.	*Terminalia chebula* Retz.	Harar	Tree	Fodder, fuel, fruit (myrobalan), timber, medicinal, ingredient of 'triphala'
314.	*Terminalia* spp	East-Indian Almond	Tree	Fodder, fuel, fruit (myrobalan), timber, medicinal, ingredient of 'triphala'
315.	*Thamnocalamus spathiflorus* (Trin.) Munro	Grass	Bamboo	Seeds and Young shots edible
316.	*Themeda anathera* (Nees ex Steud.) Hack.	Loonder	Grass/ Forb	Soil stabilizer

317.	*Themeda arundinacea* (Roxb.) A.Camus	Kangaroo Grass	Grass/ Forb	Soil stabilizer
318.	*Thuja orientalis* L	White Cedar	Tree	Ornamental, Medicinal
319.	*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda	Naktura, Nastura	Grass/ Forb	Soil stabilizer
320.	*Tinospora sinensis* (Lour.) Merr.	Giloe, Gulaje	Shrub	Medicinal (Joints pain, tonic, antiperiodic)
321.	*Toona ciliata* M.Roem.	Tooni	Tree	Timber, Medicinal,Furniture making, building and ornamental woodwork (Dysentery, ulcers)
322.	*Trema politoria* (Planch.) Blume	Indian Charcoal Tree	Tree	Fuelwood and fencing
323.	*Trifolium pretense* L.	Clover	Grasses/ Forbs	Soil stabilizer
324.	*Trifolium repens* L.	White Clover	Grass/ Forb	Flowers edible, Soil stabilizer
325.	*Trillium govanianum* Wall. ex D.Don	Nag chhatri	Herb	Medicinal (active ingredient diosgenin)
326.	*Typha* spp.	Bulrush	Herb	Fireworks; stuffing pillows, insulation, crude floatation devices,
327.	*Ulmus wallichiana* Planch.	Emroi, Imroi	Tree	Plant is used as fodder, fuel and timber. A strong fibre is obtained from the inner bark and used for cordage, slow matches and sandals.
328.	*Valeriana jatamansii* Wall. (Syn. Valeriana wallichii)	Balchhari, mushkbala	Herb	Medicinal (hysteria, nervous disorders), hair oil, perfumery
329.	*Viburnum cotinifolium* D Don.	Talanj	Shrub	Plant is used as fodder, fuel and it is edible. It is used to treat menstrual pain, morning sickness and cramps of the digestive tract or the bile ducts. Black haw's primary use was to prevent miscarriages.
330.	*Viburnum grandiflorum* Wall. ex DC.	Thaline	Shrub	Fruits & fodder
331.	*Viburnum mullaha* Buch.-Ham. ex D. Don	Talanj	Shrub	Plant is used as fodder, fuel and it is edible. It is used to treat menstrual pain, morning sickness and cramps of the digestive tract or the bile ducts. Black haw's primary use was to prevent miscarriages.
332.	*Vigna* spp.	Moth Bean	Grass	Medicinal uses
333.	*Viola canescens* Wall.	Himalayan White Violet	Herb	Medicinal uses
334.	*Viola pilosa* Blume	Banfsha	Herb	Medicinal (Relives cold and cough)
335.	*Viola* spp.	Indian Violet	Herb	Medicinal
336.	*Vitex negundo* L.	Nirgundi, Banna	Shrub	Soil stabilization
337.	*Withania somnifera* (L.) Dunal	Ashwagandha	Shrub	Medicinal (diuretic, arthritis, insomnia, asthma, sedative etc.)
338.	*Woodfordia fruiticosa* (L.) Kurz	Dhaula	Shrub	Fodder, fuel, soil conservation
339.	*Zanthoxylum armatum* DC.	Tirmira	Shrub	Medicinal (Toothache, fever, carminative, tonic, remove bad smell from teeth)

340.	*Ziziphus jujuba* Mill.	Ber	Tree	Fruits edible, Fodder for Goats, Ethnomedicinal (Sedative, astringent, diuretic, stomachic, fever, increase immune system)
341.	*Ziziphus* spp.	Ber	Shrub	Fruit

Annexure 5.1 : Model Wise List of Plant Species for Planting in Natural Landscape

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Abies pindrow							*											
Abies spectabilis							*											
Senegalia catechu											*	*	*	*	*	*	*	
Acacia nilotica															*		*	*
Acer caesium				*			*											
Acer cappadocicum							*											
Acer Pictum				*			*											
Aconitum heterophyllum			*	*		*	*											

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Acorus calamus														*				
Adina cordifolia											*	*	*	*		*		
Aegle marmelos									*		*	*	*	*		*	*	
Aesculus indica							*											
Agropyron spp.			*					*	*	*								
Agrostis gigantean			*						*	*	*							
Agrostis Munroana			*															
Agrostis pilosula			*															
Agrostis spp.		*						*			*							

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Ailanthus excelsa																	*	*
Ainsliaea aptera			*															
Ainsliaea spp.			*															
Albizia spp																*		
Albizia chinensis																		
Albizia lebbeck											*			*	*	*		*
Albizia procera											*			*	*	*		*
Albizia spp.									*	*		*	*					
Allium carolinianum		*																
Allium			*	*														

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
humile																		
Alnus nitida					*		*											
Alopecurus nepalensis								*										
Alopecuru saequalis								*										
Alstonia scholaris										*	*	*	*	*	*	*		*
Andrographis paniculata														*				
Angelica glauca			*	*	*	*	*											
Anogeissus latifolia														*	*	*		

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Anthocephalus cadamba																		*
Apluda mutica												*	*		*	*		
Arnebia benthamii			*	*														
Arnebia guttata		*																
Arnebia guttata		*																
Arnebia euchroma		*																
Artemisia maritima		*			*													
Artemisia spp		*	*															
Arundinella								*										

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
pumila																		
Arundinella nepalensis								*				*	*		*	*		
Arundo donax									*	*	*	*	*		*	*		
Azadirachta indica									*		*			*	*	*	*	*
Bacopa monnieri														*	*			
Bambusa bambos														*	*	*		
Bambusa spp.									*		*	*	*			*		
Bauhinia vahlii														*				
Bauhinia variegata									*	*	*	*	*					
Berberis aristata									*	*								

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Bergenia ciliata						*	*											
Bergenia stracheyi				*		*												
Betula alnoides							*											
Betula utilis				*														
Blumea spp.													*					
Boehmeria rugulosa										*								
Boerhavia diffusa									*	*	*	*	*	*	*			
Bombax ceiba,														*	*		*	
Bothriochloapertus								*	*	*	*							

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
a																		
Bougainvillea spp.																		*
Brachypodioum sylvaticum			*															
Bromus himalaicus			*															
Bromus Ramosus			*															
Butea monosperma																		*
Calamagrosis montanus			*															
Calamagrostis spp.								*										
Calamograstis spp.									*	*	*							

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Capparis decidua																	*	
Capparis spinosa	*	*																
Caragana versicolor	*	*																
Caragana brevifolia	*	*																
Carex spp.											*	*	*		*			
Carissa opaca									*	*	*							
Carpinus viminea							*											
Cassia fistula																	*	
Cedrus deodara					*	*	*											
Celtis australis					*						*	*	*					
Chrysopo								*										

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
gon serrulatus																		
Chrysopogon fulvus									*	*	*	*	*		*	*		
Chrysopogon gryllus								*										
Cicer songaricum		*																
Cinnamomum tamala									*	*	*							
Clerodendrum spp.														*				
Colutea nepalensis	*	*																
Cordia myxa																	*	
Cornus capitate							*											
Cornus							*											

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
macrophylla																		
Cornus oblonga						*												
Corylus jacquemontii				*														
Cotoneaster bacillaris						*	*											
Crotalaria spp.										*	*	*	*					
Cupressus torulosa						*												
Cymbopogon citratus													*		*	*		
Cymbopogon distans								*										
Cymbopo									*									

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
gon jwarancusa																		
Cymbopogon martini									*	*	*							
Cymbopogon spp.												*						
Cyperus spp.												*	*		*			
Dactylis glomerata		*	*					*										
Dactylorhiza hatagirea			*	*														
Dalbergia sissoo											*		*	*	*	*	*	*
Danthonia spp.		*	*															
Daphne papyracea						*	*											
Debregea						*	*			*	*							

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
sia hypoleuca																		
Debregeasia saeneb						*	*			*	*							
Delonix regia																		*
Dendrocalamus hamiltonii									*		*	*		*	*	*		
Dendrocalamus spp.													*					
Dendrocalamus strictus									*		*	*		*	*	*		
Deschamsia spp.												*	*		*	*		
Desmodium gangeticum										*	*			*				
Desmodiu						*			*									

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
m elegans																		
Desmodium oojeinense														*	*	*		
Desmodium triquetrum									*									
Deutzia corymbosa							*											
Deutzia staminea							*											
Dichanthium annulatum								*				*	*		*	*		
Digitaria spp.								*										
Diospyros montana									*		*	*	*	*	*	*		
Dracocephalus spp.				*														
Drepanostachyum						*	*	*										

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
falcatum																		
Eclipta alba														*	*			
Elaeagnus conferta							*			*								
Ephedra gerardiana	*	*																
Eragrostis nigra												*	*		*	*		
Eragrostis spp.		*																
Erianthus filifolius									*									
Erianthus rufipilus									*	*	*							
Erianthus spp.								*										
Eulaliopsi									*	*	*	*	*		*	*		

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
s binata																		
Euphorbia spp.											*							
Fastuca Valesiaca			*															
Festuca pratensis		*	*					*	*	*	*							
Festuca arundinacea									*	*	*							
Festuca valesiaca			*															
Ficus bengalensis									*	*	*	*		*	*	*		
Ficus benjamina																		*
Ficus hispida																*		

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Ficus racemosa									*	*	*	*		*	*	*		
Ficus religiosa														*	*			
Ficus rumphii									*	*	*	*						*
Flacourtia indica														*				
Flemingia semialata									*									
Fraxinus xanthoxyloides					*													
Geranium wallichianum			*	*	*	*	*											
Grevillea robusta																		*
Grewia												*					*	

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
elastica																		
Grewia eriocarpa																	*	
Grewia optiva									*	*	*	*	*			*		
Hedychium spicatum							*											
Heracleum candicans		*	*	*	*	*	*											
Heracleum wallichii		*	*		*													
Heteropogon contortus									*	*	*	*	*		*	*		
Hierochloe laxa												*	*		*	*		
Hippophae rhamnoid	*																	

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
es ssp. Turkestanica																		
Hippophae salicifolia	*																	
Holopteleа integrifolia									*	*	*	*	*	*	*	*		
Hymenodictyon excelsum															*			
Hymenodictyon orixense															*			
Hymenodictyon sauveolens															*			
Hyoscyamus niger		*			*													

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Hypericum oblongifolium						*	*											
Hyssopus officinalis		*																
Indigofera heteranth a						*												
Inula racemosa		*																
Inula spp.									*	*								
Isodon rugosus									*									
Jacaranda mimosifolia																		*
Jasminum spp.									*									
Juniperus	*	*																

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
polycarpos																		
Justicia adhatoda									*	*	*							
Kigelia africana																		*
Kigelia pinnata																		*
Koeleria spp		*	*					*										
Lannea coromandelica														*				
Litsea chinensis												*						
Litsea glutinosa												*						
Lonicera hypoleuca	*																	
Lyonia ovalifolia									*	*								

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Maesa indica									*	*	*			*				
Mallotus philippensis									*		*	*	*	*	*	*		
Malva spp.									*									
Malvastrum spp.													*					
Mangifera indica														*	*	*		
Medicago spp.		*																
Melia azedarach														*	*	*	*	*
Melilotus spp.		*	*															
Mentha spp														*				

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Mitragyna parvifolia														*	*	*		
Morus alba										*	*		*				*	*
Murraya paniculata									*	*	*			*				
Murraya koenigii									*	*	*			*				
Myrica esculenta							*		*		*							
Myricaria elegans	*																	
Myricaria germanica	*																	
Nerium oleander																		*
Nyctanthes arbortristris									*	*	*			*				*
Olea					*													

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
cuspidata																		
Oroxylum indicum											*	*		*	*	*		
Ougenia oogeinensis														*	*			
Panicum maximum												*	*		*	*		
Pao alpina		*																
Parietaria debilis									*	*		*						
Pennisetum glaucum								*										
Phleum pratense									*	*	*	*	*		*	*		
Phragmites karka									*	*	*	*	*		*	*		

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Phyllanthus emblica									*	*	*	*	*	*	*	*		
Phytolacca acinosa				*		*												
Picea smithiana				*		*	*											
Picrorhiza kurrooa				*		*												
Pinus gerardiana					*													
Pinus roxburghii									*									
Pinus wallichiana				*	*	*	*											

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Pistacia chinensis										*								
Plectranthus rugosus									*									
Poa pratensis		*	*					*	*	*	*							
Poa annua			*					*										
Poa alpina		*																
Polygonatum cirrhifolium						*	*											
Polygonatum verticillatum			*	*	*	*	*											
Polygonatumverticillatum			*	*	*		*											

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Polypogon fugax								*										
Pongamia pinnata														*	*	*	*	
Populus alba	*																	
Populus ciliata	*																	
Potentilla spp.		*	*															
Prinsepia utilis						*	*											
Prosopis cineraria																	*	
Prunus cornuta				*			*											
Prunus cerasoides							*		*									
Pterocarpus																	*	

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
marsupium																		
Punica granatum										*		*	*			*		
Pyrus pashia									*	*	*	*	*					
Quercus semecarpifolia				*			*											
Quercus oblongata							*		*	*						*		
Quercus floribunda							*											
Quercus glauca							*		*	*								
Rauvolfia serpentina														*				
Rheum australe		*	*															
Rheum moorcroft			*															

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
ianum																		
Rheum racemos		*	*															
Rheum spp.				*														
Ribes alpestre		*																
Ribes himalense		*																
Ribes orientale	*	*																
Ricinus communis									*	*	*							
Rosa macrophylla						*												
Rosa moschata						*	*			*	*							
Rosa sericea						*												
Rosa spp.							*		*									*
Rosa	*	*																*

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
webbiana																		
Rubus niveus							*											
Rubus biflorus							*											
Rubus ellipticus							*											
Rubus foliosus							*											
Rubus niveus							*											
Rubus spp.									*									
Saccharum munja																*		
Saccharum bengalense															*	*		
Saccharum										*	*							

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
filifolium																		
Saccharum spontaneum								*							*	*		
Salix fragilis	*																	
Salix alba	*																	*
Salix daphnoides	*																	
Salix flabillaris	*																	
Salix tetrasperma	*																	
Santalum album														*	*	*		
Sapindus mukorossi											*	*	*	*	*	*		

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Saussurea costus			*															
Saussurea spp.				*														
Scirpus spp.															*			
Scrophularia spp.									*		*							
Selinum wallichianum			*	*	*													
Selinum vaginatum					*													
Sesbania sesban																	*	*
Setaria glauca								*										
Sinopodophyllum hexandrum			*		*	*	*											

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Spiraea canescens							*											*
Spiraea spp.																		*
Sporobolus diandrus												*	*		*	*		
Stipa roylei			*															
Strobilanthus spp										*	*							
Symplocos paniculata										*								
Syringa emodi						*												
Syzygium venosum									*	*	*	*	*	*	*	*		*

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Taxus wallichiana						*	*											
Tecomella undulata																	*	
Tectona grandis																	*	
Tephrosia hamiltonii									*	*	*			*				
Terminalia arjuna											*	*	*	*	*	*		*
Terminalia bellirica											*	*	*	*	*	*		*
Terminalia chebula											*	*	*	*	*	*		*
Terminalia spp.										*								
Themeda anathera								*	*	*	*							
Themeda												*	*		*			

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
arundinacea																		
Thysanolaena latifolia									*	*	*		*		*	*		
Thysanolaena maxima									*	*	*		*		*			
Tinospora cordifolia									*	*	*							
Tinospora sinensis									*	*	*							
Toona ciliata										*		*	*				*	*
Trema politoria										*								
Trifolium repens								*	*			*	*		*	*		
Trifolium pretense		*	*					*	*									
Trillium govanianum						*												

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Ulmus wallichiana							*											
Valeriana jatamansii					*	*	*											
Viburnum cotinifolium						*												
Viburnum grandiflorum						*	*											
Viburnum mullah							*											
Vigna spp.											*							
Viola canescens							*											
Viola pilosa						*	*											
Viola serpens						*	*											

Species Name `	HP/NL/01	HP/NL/02	HP/NL/03	HP/NL/04	HP/NL/05	HP/NL/06	HP/NL/07	HP/NL/08	HP/NL/09	HP/NL/10	HP/NL/11	HP/NL/12	HP/NL/13	PB/NL/01	PB/NL/02	PB/NL/03	PB/NL/04	PB/NL/05
Viola spp.					*													
Vitex negundo									*	*	*			*				
Withania somnifera														*				
Woodfordia fruiticosa									*	*	*			*				
Zanthoxylumarmatum							*			*	*							
Ziziphus spp										*	*							
Ziziphus jujuba														*	*	*		

Annexure5.2 Model Wise List of Suggestive Plant Species for Planting in Agriculture and Urban Landscapes

Species Name	**HP/ AL/ 01**	**HP/ AL/ 02**	**PB/ AL/ 01**	**PB/ AL/ 02**	**HP/ UL/ 01**	**HP/ UL/ 02**	**HP/ UL/ 03**	**HP/ UL/ 04**	**PB/UL/01**	**PB/ UL/ 02**	**PB/ UL/ 03**	**PB/ UL/ 04**	**PB/ UL/ 05**
Senegalia catechu	*	*		*									
Acacia nilotica				*							*		
Acer spp.		*											
Acorus calamus									*				
Aegle marmelos	*	*	*	*									
Aesculus indica							*	*					
Albizia chinensis						*	*	*					
Albizia procera						*	*	*					
Albizia spp.			*							*	*	*	
Anthocephalu							*				*		

Species Name	**HP/ AL/ 01**	**HP/ AL/ 02**	**PB/ AL/ 01**	**PB/ AL/ 02**	**HP/ UL/ 01**	**HP/ UL/ 02**	**HP/ UL/ 03**	**HP/ UL/ 04**	**PB/UL/01**	**PB/ UL/ 02**	**PB/ UL/ 03**	**PB/ UL/ 04**	**PB/ UL/ 05**
s cadamba													
Araucaria araucana							*	*			*	*	
Azadirachta indica			*	*		*							
Bambusa bambos							*						
Bambusa spp.	*	*					*						
Bauhinia spp.	*	*											
Berberis aristata	*												
Bombax ceiba				*									
Bougainvillea spp						*		*		*		*	*
Buddleja spp.	*												
Butea monosperma					*	*		*		*		*	*
Callistemon citrinus					*	*	*	*		*	*	*	*

Species Name	**HP/ AL/ 01**	**HP/ AL/ 02**	**PB/ AL/ 01**	**PB/ AL/ 02**	**HP/ UL/ 01**	**HP/ UL/ 02**	**HP/ UL/ 03**	**HP/ UL/ 04**	**PB/UL/01**	**PB/ UL/ 02**	**PB/ UL/ 03**	**PB/ UL/ 04**	**PB/ UL/ 05**
Cassia fistula						*							
Cedrella toona				*									
Cedrus deodara							*	*					
Celtis australis	*	*											
Cinnamomum tamala												*	
Cryptomeria japonica							*	*			*	*	*
Cupressus sempervirens							*	*					
Cupressus torulosa							*	*					
C*yperus* spp.					*				*				
Dalbergia sissoo	*	*		*	*		*	*		*	*	*	
Delonix regia						*	*	*		*	*	*	
Dendrocalamus spp.	*	*					*						
Diospyros	*	*											

Species Name	**HP/ AL/ 01**	**HP/ AL/ 02**	**PB/ AL/ 01**	**PB/ AL/ 02**	**HP/ UL/ 01**	**HP/ UL/ 02**	**HP/ UL/ 03**	**HP/ UL/ 04**	**PB/UL/01**	**PB/ UL/ 02**	**PB/ UL/ 03**	**PB/ UL/ 04**	**PB/ UL/ 05**
kaki													
Diospyros lotus	*	*											
Diospyros nigra	*	*											
Drepanostachyum falcatum	*												
Eichhornia crassipes (water hyacinth)					*				*				
Eucalyptus territicornis						*							
Eugenia jambolana													
Euphorbia pulcherrima								*					
Ficus racemosa			*										
Ficus rumphii						*							
Gmelina			*	*									

Species Name	**HP/ AL/ 01**	**HP/ AL/ 02**	**PB/ AL/ 01**	**PB/ AL/ 02**	**HP/ UL/ 01**	**HP/ UL/ 02**	**HP/ UL/ 03**	**HP/ UL/ 04**	**PB/UL/01**	**PB/ UL/ 02**	**PB/ UL/ 03**	**PB/ UL/ 04**	**PB/ UL/ 05**
arborea													
Grevillea robusta						*	*	*		*	*	*	
Grewia elastica				*									
Grewia optiva	*	*											
Grewia spp.			*										
Hippophae rhamnoides	*												
Hippophae salicifolia	*	*											
Holarrhena pubescens			*	*									
Holoptelea integrifolia							*				*		
Jacaranda mimosifolia						*	*	*		*	*	*	
Jasminum spp.						*						*	

Species Name	**HP/ AL/ 01**	**HP/ AL/ 02**	**PB/ AL/ 01**	**PB/ AL/ 02**	**HP/ UL/ 01**	**HP/ UL/ 02**	**HP/ UL/ 03**	**HP/ UL/ 04**	**PB/UL/01**	**PB/ UL/ 02**	**PB/ UL/ 03**	**PB/ UL/ 04**	**PB/ UL/ 05**
Kigelia africana						*	*			*	*	*	
Kigelia pinnata					*	*	*			*	*	*	*
Magnolia grandiflora					*	*		*					
Melia azedarach			*	*			*				*		
Michelia spp.						*							
Morus alba	*	*		*									
Murraya koenigii												*	
Myrica esculenta	*	*											
Nerium oleander						*		*		*		*	
Nyctanthes arbortristis					*			*		*		*	
Phragmites spp					*				*				
Phyllanthus emblica	*	*	*	*									

Species Name	**HP/ AL/ 01**	**HP/ AL/ 02**	**PB/ AL/ 01**	**PB/ AL/ 02**	**HP/ UL/ 01**	**HP/ UL/ 02**	**HP/ UL/ 03**	**HP/ UL/ 04**	**PB/UL/01**	**PB/ UL/ 02**	**PB/ UL/ 03**	**PB/ UL/ 04**	**PB/ UL/ 05**
Platanus orientalis								*					
Polyalthia longifolia						*	*	*		*	*	*	
Pongamia pinnata				*						*	*	*	
Populus deltoides			*	*									
Populus spp.	*	*											
Prosopis cineraria				*									
Prunus armeniaca	*	*					*						
Prunus cerasifera	*	*											
Prunus domestica	*	*											
Prunus mira	*	*											
Prunus	*	*											

Species Name	**HP/ AL/ 01**	**HP/ AL/ 02**	**PB/ AL/ 01**	**PB/ AL/ 02**	**HP/ UL/ 01**	**HP/ UL/ 02**	**HP/ UL/ 03**	**HP/ UL/ 04**	**PB/UL/01**	**PB/ UL/ 02**	**PB/ UL/ 03**	**PB/ UL/ 04**	**PB/ UL/ 05**
persica													
Quercus spp.							*						
Rosa spp	*					*		*		*		*	
Salix alba						*	*						
Salix spp.	*	*						*		*	*	*	
Santalum album			*	*									
Sapindus mukorossi	*	*		*									
Saraca asoca						*	*	*		*	*	*	
Scirpus grossus					*								
Scirpus spp.					*				*				
Sesbania sesban				*							*		
Drepanostachyum falcatum	*												

Species Name	**HP/ AL/ 01**	**HP/ AL/ 02**	**PB/ AL/ 01**	**PB/ AL/ 02**	**HP/ UL/ 01**	**HP/ UL/ 02**	**HP/ UL/ 03**	**HP/ UL/ 04**	**PB/UL/01**	**PB/ UL/ 02**	**PB/ UL/ 03**	**PB/ UL/ 04**	**PB/ UL/ 05**
Spiraea spp						*		*		*		*	
Spirodela polyrrhiza					*				*				
Syzygium venosum			*	*	*	*	*	*			*		*
Tamarindus indica			*	*									
Tecoma stans					*				*				
Tectona grandis				*									
Terminalia arjuna	*	*	*	*									
Terminalia bellirica	*	*	*	*									
Terminalia chebula	*	*	*	*									
Terminalia indiaca				*									
Thamnocala mus spathiflorus	*												

Species Name	**HP/ AL/ 01**	**HP/ AL/ 02**	**PB/ AL/ 01**	**PB/ AL/ 02**	**HP/ UL/ 01**	**HP/ UL/ 02**	**HP/ UL/ 03**	**HP/ UL/ 04**	**PB/UL/01**	**PB/ UL/ 02**	**PB/ UL/ 03**	**PB/ UL/ 04**	**PB/ UL/ 05**
Thuja orientalis							*	*			*	*	
Toona ciliata	*	*	*										
Typha spp.					*				*				
Vitex negundo	*												
Zanthoxylum armatum	*												

Annexure 6.1 Model Wise/Activity Wise List of Forest Divisions of Himachal Pradesh for Forestry Interventions

[A]	Natural Landscape		
Sl. No.	**Model**	**Division**	**Area (ha)**
1	SL/HP/NL/01 Cold Desert Greening	Spiti Wildlife	100
2	SL/HP/NL/02 Cold Desert Conservation	Spiti Wildlife	100
3	SL/HP/NL/03 Alpine Conservation	Kinnaur	60
4	SL/HP/NL/04 SubAlpine Enrichment	Karsog	50
		Kinnaur	120
		Rampur	110
5	SL/HP/NL/05 Dry Temperate Conifer Forest Enrichment	Kinnaur	10
6	SL/HP/NL/06 Temperate Conifer Forest	Anni	101
		Kinnaur	40
		Kotgarh	70
		Nachan	180
		Shimla	25
		Theog	265
7	SL/HP/NL/07 Temperate Mixed Forest	Anni	197
		Bilaspur	15
		Karsog	203
		Kotgarh	15
		Kunihar	15
		Nachan	60
		Shimla	70
		Suket	90
8	SL/HP/NL/08 Pasture and Grazing Land Development	Kinnaur	60
		Spiti Wildlife	125
9	SL/HP/NL/09 Himalayan Chir Pine Forest	Anni	35
		Bilaspur	346
		Hamirpur	400
		Karsog	223
		Kinnaur	15
		Kotgarh	100
		Nachan	120
		Nalagarh	105
		Rampur	25
		Suket	23

		Una	50
		Anni	15
		Bilaspur	40
		Kinnaur	25
		Kunihar	15
		Nalagarh	485
		Rampur	75
	SL/HP/NL/10 Himalayan Mixed	Solan	35
10	Forest	Una	130
		Anni	135
		Bilaspur	596
		Hamirpur	20
		Kotgarh	15
		Nalagarh	532
		Shimla	35
	SL/HP/NL/11 SubTropical Dry	Suket	255
11	Deciduous Forest	Una	451
		Bilaspur	246
		Karsog	20
		Kunihar	230
	SL/HP/NL/12 Eradication of	Nalagarh	50
12	*Lantana* (> 50%)	Una	30
	SL/HP/NL/13 Control/ Removal	Bilaspur	30
	of Invasive Species or <50%	Nalagarh	15
13	*Lantana*	Una	15
[B]	**Fire Protection or Natural Regeneration**		
		Anni	350
		Bilaspur	450
		Hamirpur	500
		Karsog	330
		Kinnaur	500
		Kotgarh	380
		Kunihar	330
		Nachan	480
		Nalagarh	500
		Rampur	450
		Shimla	850
		Solan	480
	SL/HP/NL/14 Protection Model	Suket	480
1	for Natural Regeneration	Theog	450

		Una	500
		Anni	100
		Bilaspur	200
		Hamirpur	100
		Karsog	100
		Kinnaur	100
		Kotgarh	105
		Nachan	100
		Nalagarh	100
		Rampur	100
		Shimla	200
		Solan	100
		Suket	80
	SL/HP/NL/15 Fire Protection	Theog	100
2	Model	Una	100
[C]	**Agriculture Landscape**		
1	SL/HP/AL/01 Boundary Plantation Model	Anni	160
		Bilaspur	36
		Hamirpur	95
		Karsog	90
		Kinnaur	125
		Kotgarh	140
		Kunihar	155
		Nachan	120
		Nalagarh	140
		Rampur	140
		Solan	150
		Suket	145
		Theog	130
		Una	138
2	SL/HP/AL/02 Block Plantation Model	Anni	30
		Bilaspur	36
		Hamirpur	53
		Karsog	32
		Kinnaur	22
		Kotgarh	30
		Kunihar	18
		Nachan	38
		Nalagarh	44
		Rampur	30
		Shimla	40

		Solan	30
		Suket	40
		Theog	25
		Una	32
[D]	**Urban Landscape**		
		Anni	1
		Bilaspur	0.75
		Hamirpur	1
		Karsog	1
		Kinnaur	1
		Kotgarh	1
		Kunihar	1
		Nachan	1
		Nalagarh	1
		Rampur	1
		Shimla	2.5
		Shimla Urban	1
		Solan	1
		Suket	1
	SL/HP/UL/01 Bioremediation and	Theog	1
1	Bio filtration	Una	1
		Bilaspur	0.8
		Kinnaur	0.65
		Nalagarh	0.4
		Rampur	0.75
		Solan	0.5
	SL/HP/UL/02 Riverfront	Suket	1
2	Development	Una	0.65
		Anni	53
		Bilaspur	40
		Hamirpur	58
		Karsog	54
		Kinnaur	58
		Kotgarh	51
		Kunihar	60
		Nachan	50
		Nalagarh	60
		Rampur	52
		Shimla	58
	SL/HP/UL/03 Institution	Shimla Urban	60
3	Plantation	Solan	60

		Suket	56
		Theog	92
		Una	52
		Anni	0.12
		Bilaspur	0.5
		Hamirpur	0.2
		Karsog	0.2
		Kinnaur	0.2
		Kotgarh	0.2
		Kunihar	0.1
		Nachan	0.2
		Nalagarh	0.2
		Rampur	0.2
		Shimla	1.2
		Shimla Urban	0.2
		Solan	0.25
		Suket	0.2
		Theog	0.25
4	SL/HP/UL/04 Eco-Park Development	Una	0.3
Sl. No.	**Model**	**Division**	**Area (m^3)**
[E]	**SMC Interventions**		
		Anni	6450
		Bilaspur	8990
		Hamirpur	620
		Karsog	1110
		Kinnaur	24680
		Kotgarh	15210
		Kunihar	8970
		Nachan	770
		Nalagarh	9710
		Rampur	8930
		Shimla	7080
		Shimla Urban	1930
		Solan	13480
		Suket	5070
		Theog	1820
1	SL/HP/CI/01 Brushwood Intervention	Una	12170
		Anni	11950
		Bilaspur	17425
		Hamirpur	3645
2	SL/HP/CI/02 Dry Stone Activities	Karsog	12440

		Kinnaur	6610
		Kotgarh	4120
		Kunihar	19720
		Nachan	2890
		Nalagarh	10131
		Rampur	19030
		Shimla	21600
		Shimla Urban	3300
		Solan	16090
		Suket	13650
		Theog	8150
		Una	10890
		Anni	6600
		Bilaspur	4320
		Hamirpur	700
		Karsog	1480
		Kinnaur	8120
		Kotgarh	2020
		Kunihar	21810
		Nachan	2920
		Nalagarh	7151
		Rampur	20200
		Shimla	13400
		Shimla Urban	3150
		Solan	10560
		Suket	8170
		Theog	2550
3	SL/HP/CI/03 Crate Wire Activities	Una	8880
		Anni	4650
		Bilaspur	10079
		Hamirpur	2100
		Karsog	1865
		Kinnaur	21715
		Kotgarh	13200
		Kunihar	20495
		Nachan	5190
		Nalagarh	5161
		Rampur	4650
		Shimla	7675
		Shimla Urban	1360
4	SL/HP/CI/04 Water Ponds	Solan	9265

		Suket	2600
		Theog	2290
		Una	8570
		Anni	1045
		Bilaspur	1965
		Hamirpur	630
		Karsog	300
		Kinnaur	3990
		Kotgarh	2700
		Kunihar	5890
		Nachan	1375
		Nalagarh	1611
		Rampur	1560
		Shimla	2055
		Shimla Urban	540
		Solan	2830
		Suket	550
	SL/HP/CI/05 Silt Detention Dam	Theog	280
5	Type Activities	Una	1675
[F]	**Other Interventions**		
Sl. No.	**Model**	**Division**	**Area (ha)**
		Hamirpur WLS (Bilaspur)	34
		Sarahan Wildlife	73
		Shimla WL	65
	SL/HP/CI/06 Riverine and	Spiti Wildlife	75
1	Riparian Management	W L Kullu	30
		Sarahan Wildlife	15
	SL/HP/CI/07 Wetland	Shimla WL	10
2	Management	Spiti Wildlife	15

Annexure 6.2 Model Wise/Activity Wise List of Forest Divisions of Punjab for Forestry Interventions

[A]	**Natural Landscape**		
Sl. No.	**Model**	**Division**	**Area (ha)**
1	SL/PB/NL/01 Shivalik Hills Forest Enrichment	Nawanshahr	654
		Rupnagar	40
2	SL/PB/NL/02 Degraded Model with staggered	Ludhiana	20

	trench & Pits	Nawanshahr	115
3	SL/PB/NL/03 – Control/ Removal of Invasive Species and *Lantana*	Ludhiana	15
		Nawanshahr	130
4	SL/PB/NL/04 Restoration of Degraded Forests	Jalandhar	75
		Ludhiana	35
		Nawanshahr	130
		Rupnagar	20
5	SL/PB/NL/05 Road Side Plantation	Jalandhar	37
[B]	**Agriculture Landscape**		
1	SL/PB/AL/01 Boundary Plantation Model	Amritsar	895
		Ferozepur	885
		Jalandhar	885
		Ludhiana	965
		Nawashahr	915
		Rupnagar	915
		SAS Nagar (Mohali)	940
2	SL/PB/AL/02 Block Plantation Model	Amritsar	250
		Ferozepur	251
		Jalandhar	251
		Ludhiana	279
		Nawashahr	254
		Rupnagar	254
		SAS Nagar (Mohali)	254
[C]	**Urban Landscape**		
1	SL/PB/UL/01 Bioremediation and Bio filtration	Amritsar	1
		Ferozepur	1
		Jalandhar	2
		Ludhiana	10
		Nawanshahr	2
		Rupnagar	2
		SAS Nagar (Mohali)	2
2	SL/PB/UL/02 Riverfront Development	Ferozepur	0.1
		Ludhiana	0.1
		Rupnagar	0.1

3	SL/PB/UL/03 Institution Plantation	Amritsar	30
		Ferozepur	55
		Jalandhar	40
		Ludhiana	42
		Nawanshahr	37
		Rupnagar	47
		SAS Nagar (Mohali)	30
4	SL/PB/UL/04 Eco-Park Development	Amritsar	0.5
		Ferozepur	1
		Jalandhar	2
		Ludhiana	3
		Nawanshahr	1
		Rupnagar	1
		SAS Nagar (Mohali)	2
[D]	**SMC Interventions**	**Division**	**Area (m^3)**
1	SL/PB/CI/01 Brushwood Intervention	Ferozepur	3200
		Jalandhar	550
		Ludhiana	9500
		Nawanshahr	38850
		Rupnagar	985
		SAS Nagar	4700
2	SL/PB/CI/02 Dry Stone Activities	Ferozepur	2000
		Jalandhar	1250
		Ludhiana	10100
		Nawanshahr	27500
		Rupnagar	3180
		SAS Nagar	6250
3	SL/PB/CI/03 Crate Wire Activities	Ferozepur	2200
		Jalandhar	1000
		Ludhiana	6200
		Nawanshahr	20900
		Rupnagar	3110
		SAS Nagar	3700
4	SL/PB/CI/04 Water Ponds	Ferozepur	700
		Jalandhar	3020
		Ludhiana	2350
		Nawanshahr	5300
		Rupnagar	6550
		SAS Nagar	1950

5	SL/PB/CI/05 Silt Detention Dam Type Activities	Jalandhar	440
		Ludhiana	1000
		Nawanshahr	2500
		Rupnagar	820
		SAS Nagar	500
[E]	**Other Interventions**	**Division**	**Area (ha)**
1	SL/PB/CI/06 Riverine and Riparian Management	Wild Life Ferozepur	25
		Wildlife Division Roopnagar	60
		wildlife Phillaur	100
2	SL/PB/CI/07 Wetland Management	Wildlife Division Roopnagar	40

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