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Detailed Project Report (DPR) for Rejuvenation of Yamuna River Through Forestry Interventions

Volume I

Approaches and Forestry Interventions



Prepared by

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EXECUTIVE SUMMARY

Water is a priceless renewable natural resource which is required for all life processes. The quantity and quality of water available in the world shows huge spatial and temporal variations. The world is increasingly facing shortages as well as excesses of water, depending upon place and time, and a general deterioration in water quality.

Forest and Water

Forests and forested landscapes regulate the provision of water and water-related ecosystem services. They influence the volume and timing of water flow as well as silt load in the flowing water. Forested landscapes supply a high proportion of surface and ground water for domestic, agricultural, industrial and ecological needs in upstream and downstream areas. Forest conservation and afforestation in upstream watersheds are regarded as the cheapest and most effective measures to enhance water availability for various uses as besides preventing floods in downstream areas.

Forest and Rivers

Most of the rivers and their tributaries originate from forested landscapes. Forests have profound favourable effect on climate, microclimate and water cycle. Root zone in the forest has 'sponge effect' which positively influences the water balance and flow of rivers. Steep slopes with loose soil and poor vegetation cover are erosion prone and, as a result, the water flowing from such a watershed are likely to have greater sediment load than a watershed with gentle slope and dense vegetation cover. Excessive loads of sediment are detrimental as they affect river flow and threaten survival of aquatic fauna. Erosion causes frequent filling up of lakes and ponds, and choking of dams, thereby, increasing the cost of their desiltation. Diversity of flora and fauna in river is also influenced by aquatic and terrestrial biodiversity in the floodplain, wetlands and forests in the catchment.

Concerns for River Conservation

River is a large body of flowing water that traverses long distances and interacts with varied environmental and biotic elements. Alteration of flow regime by landuse changes, construction of water-diversion structures, excessive abstraction of water, degradation and fragmentation of forests are the major factors responsible for degradation in rivers. Large stretches of rivers have turned dry or seasonal in densely populated areas of the world. The flow required in streams and rivers to sustain their ecological integrity and ecosystem services is termed as 'environment flow'. Environmental flow does not relate merely to the total amount of water, it also concerns temporal change in flow and the rate of change itself. Environmental flows simulate the natural flow regime through the year.

Water quality is an important parameter concerning suitability of river water for diverse uses. Organisms greatly differ in their tolerance to different water quality parameters. As water quality deteriorates, most organisms decline in their population and activity, and a few other organisms tend to replace them. Water quantity and quality, therefore, strongly influence biodiversity.

Low dissolved oxygen concentrations are generally detrimental to aquatic life, with the exception of a few organisms adapted to low oxygen or anaerobic conditions. A number of other quality parameters, *viz.*, biochemical oxygen demand, chemical oxygen demand, suspended solids, pH, temperature, ammonia (NH_3), faecal coliform, heavy metals, pesticides, etc. are also considered while assessing quality of river water.

River Rejuvenation

Decreasing water flow and deterioration in water quality in the river is the result of similar negative changes that are taking place in the associated springs, streams, rivulets and tributaries. Degradation of river basin is associated with land use and land cover changes and their cascading effects on water infiltration and quality. Land use land cover changes take place in forest, agricultural as well as urban/peri-urban landscapes. These are the result of intensified landuse for meeting the rising demands of increasing population. High soil erosion rates, release of sewage, waste material, industrial effluents, agrochemicals and muck disposal adversely impact water quality. Diversion of water from natural river course to artificial courses and direct withdrawal from river and aquifer are the major factors of water abstraction. Climate change is another factor that is gradually impacting environmental flow in numerous direct and indirect ways.

Some of the factors stated above are related to increasing needs of the society and cannot be reversed. The domain of a forester is related to forestry activities, hence in the present DPR, the term 'rejuvenation' has been used to imply rehabilitation of the degraded ecosystem through forestry activities with an aim of checking and mitigating adverse impacts taking place in the river system.

Yamuna River Basin

The drainage basin of Yamuna extends over 366,233 km^2 distributed over the states of Uttarakhand, Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh, Uttar Pradesh and Delhi-NCT. It constitutes 42.5% of the total Ganga river basin. Yamuna Basin encompasses varied climatic, physiographic and economic conditions. Glaciers, snow-capped Himalayan mountains, eroded Aravalli slopes, lush green valleys, arid tropical plains, erosion-prone ravines, alpine grasslands, dense temperate to subtropical forests, weed-infested forests, scrub, fertile farmlands, wetlands, national parks, wildlife sanctuaries, urban aggregations, rural areas, industrial, religious, historical and eco-tourism places – a unique and complex mosaic of all such landscapes and features is found in Yamuna basin.

Tributaries

The length of Yamuna is 1,376 km from origin at Yamunotri, Uttarakhand to confluence with Ganga at Prayagraj. The main tributaries of Yamuna are Rishi Ganga, Hanuman Ganga, Tons, Giri, Gambhir, Godar, Hindon, Jalai, Kalisindh, Mej, Pabbar, Parvati, Sind, Chambal, Banas, Betwa, and Ken. Tons, in the hills, is the most important tributary from the standpoint of water discharge. In the plains, the Chambal is the largest tributary of the Yamuna. During dry season, Chambal contributes about 5-10 times more water to Yamuna than by Yamuna itself. Similarly, at Prayagraj, Yamuna contributes more water than Ganga itself at the confluence.

Yamuna Water Usage, Diversion and Deterioration

Yamuna has huge religious and cultural significance. Many important commercial, religious and tourism centres *viz*. Delhi, Agra, Kota, Mathura, Kanpur, Meerut, Jhansi, Saharanpur, Yamunanagar, etc. are located in Yamuna basin close to Yamuna or major tributaries. Since independence, the population in the Yamuna basin has increased by 3.5 times. The river water is used in abstractive and non-abstractive forms. Among abstractive uses, about 96% of the consumption of water in Yamuna basin is for irrigation alone. The irrigated area in the basin has increased to twice as compared to the year 1950. Also, since 1950, the contribution of groundwater resources for irrigation has multiplied more than three-fold. Abstraction for domestic and industrial uses is continuously on the rise. Flow of water has been regulated and diverted through a series of medium or small reservoirs and barrages for water consumption and flood control. More than 470 dams and barrages existed on Yamuna and its tributaries

in 2012. A number of more structures came up afterwards. The diversion of water hampers the continuous flow of the river.

Non-abstractive uses of Yamuna water include hydropower generation, fishery, bathing, washing of human and cattle, burning of dead bodies, recreational uses, navigation, etc. Hydropower generation brings about temporal changes in water flow, while most of other activities impact quality of water.

Quality of Yamuna Water

The Yamuna is one of the most polluted rivers in the country. Several studies have been conducted on biochemical and biological quality of Yamuna water. On the basis of water quality, Yamuna river is differentiated into five segments: (i) Himalayan segment of 172 km length from origin to Hathnikund Barrage, (ii) Upper segment of 224 km length from Hathnikund Barrage to Wazirabad Barrage, (iiii) Delhi segment of 22 km length from Wazirabad Barrage to Okhla Barrage, (iv) Eutrophicated segment of 90 km from Okhla Barrage to Chambal Confluence and (v) Diluted segment of 468 km from Chambal Confluence to Ganga Confluence. The 22 km stretch of the Yamuna in Delhi contributes over 80 % of the pollution load of the entire length of the river. Domestic waste water, including sewage, forms the bulk of contaminants. In Himalayan segment, water quality is excellent. Water quality in Hathnikund Barrage to Delhi segment and in Delhi to Etawah segment is poor to marginal. From Etawah to Ganga confluence, the quality is good to excellent, this is attributed to the dilution effect from the Chambal, Betwa, and Ken rivers.

Forest resources in Yamuna basin

The recorded forest area in the Yamuna Basin states (comprising Yamuna Basin and areas outside) is 1,85,702 km^2 which is 17.75% of the geographical area of the states. Total forest cover of the states is 1,50,452.44 km^2 amounting to 14.38% of the geographical area. Very dense, moderately dense and open forest constitute 17,565.72, 63,201.42 and 69,685.30 km^2 area, respectively. The tree cover is 27,157 km^2 which is 2.60% of geographical area of the seven states. The total carbon stock of the seven states adds up to 2,933.37 Mt.

Forest Vegetation and Wildlife

In the lower Himalayan region, the vegetation is predominantly semi-deciduous tropical forest, while at higher altitude species of *Pinus, Cedrus deodara, Picea smithiana, Abies pindrow, Quercus, Cupressus, Rhododendron* thrive depending upon altitude, aspect and other site factors. Lower down in the upper basin, and towards the east, sal (*Shorea robusta*) is the primary species, while the Malwa plateau supports forest vegetation dominated by teak (*Tectona grandis*) and sal. The large western part of the basin has typical dry deciduous thorn scrub vegetation composed chiefly of species of *Acacia* and *Prosopis*. The southern Kota region has dry deciduous forests.

Terrestrial weeds such as *Lantana camara* and *Prosopis juliflora* are noxious weeds and have invaded large areas in the forest in plains, ravines and low altitudes in hills in Yamuna basin. *Eupatorium, Barleria prionitis, Alternanthera philoxeroides, Cassia uniflora, Chromolaena odorata* are also menace. Attempts to control *Lantana camara* and *Prosopis juliflora* have not been successful so far. Although weeds are harmful, the presence of such plants on difficult fragile slopes helps in checking soil erosion. Efforts need to be made to replace them with more economically and ecologically useful plants.

A number of wildlife national parks and sanctuaries such as National Chambal Ghariyal Sanctuary, Ranthambore National Park, Sariska National Park/Tiger Reserve, Govind National Park, Etawah Lion Safari, Kalesar National Park and Wildlife Sanctuary, etc. are located in Yamuna Basin.

Water Bodies, Aquatic Flora and Fauna

Water bodies are spread over a total area of 4,621.32 km^2 in the seven states. *Eichhornia crassipe* and *Ipomoea batatas* are common aquatic weeds in Yamuna Basin. They impair water bodies, are not of much use and need to be managed. Turtles (*Kachuga tentoria*). Crocodiles (*Crocodilus indicus*), Gangetic dolphins (*Platanista gangetica*) are the common species in water bodies. Fish from the family Cyprinidae dominates the fish divesity found in the river.

Socio-economy

Yamuna basin has a dominant rural economy. People have been dependent on the forests for fuel wood, fodder, timber and bamboo since ages but with the manifold increase in their population in the last 60 to 70 years, pressure on forests has increased**.** Diverse micro-small-and medium-industrial units are located in Yamuna Basin that manufacture medicines, vehicles, engineering goods, electrical items, electronics, glass articles, handicrafts, processed food, etc.

Concerns about Yamuna Water

a) Environmental Flow of Water

The Yamuna exhibits conditions of dryness as well as flood during the year. Unsustainable extraction of ground water and diversion of surface water have reduced water availability in many stretches of Yamuna. During the non-monsoon period (November to May, as defined by Central Water Commission), the flow of Yamuna reduces significantly and some rivers stretches become dry, whereas, during monsoon period (June-October), the rivers receives significant amount of water, which is beyond its conveyance capacity. Floods are frequently experienced during July-September.

b) Quality of Water

Study shows that the upstream Yamuna erodes 1.04 mm yr^{-1} of the basin soil surface while the soil erosion rate decreases downstream to 0.19 mm yr^{-1} at Prayagraj. The average chemical erosion rate (165 t $km^{-2}yr^{-1}$) and total erosion rate (973 t $km^{-2}yr^{-1}$) of the Yamuna are very high which are much greater than those of Ganga. At Prayagraj, the dissolved chemical load and sediment load attributable to the Yamuna were 42 mt and 64 mt, respectively. These rates of erosion increase sediment load in river water. More recent data on sediment load in Yamuna are not available but there is no data to show that situation has improved now. Mining and construction activities have, in fact, accelerated in the last three decades, which along with other factors related to catchment area degradation, might have increased the silt load in the river. Deterioration in water quality due to contaminants from sewage, industries, agricultural run-offs, idol immersions, human ashes, etc. is well-recognised as an area of concern. The high level of pollution has degraded the water quality of the river, rendering it unfit for drinking. Aquatic species dwelling in the river, like the Gangetic dolphin and gharials, are nearly regionally extinct as a result. Besides this, the threat of climate change exists, which has the potential to melt large parts of the Yamunotri Glacier, drastically altering the flow of Yamuna.

Decrease in quantity of water during non-monsoon period and deterioration in water quality have drawn attention of the government and judiciary at the highest level.

Policy Directives

National Water Policy, 2012 provided for determination of ecological needs of the river through scientific studies towards the goal of meeting developmental needs of India while providing economic and ecological goods and services. It recommended that a portion of river flows should be kept aside to

meet ecological requirements, including base flow contribution in the low flow season through regulated ground water use.

The Sustainable Development Goal (SDG) - 6 seeks to ensure availability and sustainable management of water and sanitation for all across the globe. The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, aims to address concerns about rising inequalities, natural resource depletion, environmental degradation and climate change. The International Conference on Water and the Environment through its Dublin Statement (1992) advocated Integrated Water Resources Management that strives to promote coordinated development and management of water, land and related resources to maximise the resultant economic and social welfare in an equitable and sustainable manner.

National Forest Policy, 1988 and National Agroforestry Policy, 2014 aim and suggest measures to promote forest protection and tree plantation for supporting environmental conservation, ecosystem services and socio-economic benefits which have indirect and long-term positive impacts on Yamuna.

Legal Context

In 1986, the Hon'ble Supreme Court passed order to control unauthorised and illegal mining operations in Dehradun-Mussoorie belt that were adversely affecting the ecology of the area, including catchment of Yamuna. The Court held that a balance must be struck between environmental preservation and utilisation, a monitoring agency was accordingly set up which effectively dealt with the problem.

The Supreme Court, on 14 May 1999, while deciding on Writ Petition (Civil) 537 of 1992 directed the governance that a minimum flow of 10 $m^3 s^{-1}$ (or 353 cusec) must be allowed to flow throughout Yamuna. National Green Tribunal (NGT) in its judgement dated 13 January 2015 recommended the maintenance of requisite environmental flow in Yamuna downstream of barrage at Hathnikund, Haryana and at Okhla, Delhi NCT to retain enough fresh water flow till Agra for meeting the river's ecological functions. The minimum environmental flow requirement in Yamuna downstream of Hathnikund Barrage and Okhla Barrage during the leanest month of January were, thus, fixed as 70 $m^3 s^{-1}$ and 42.48 $m^3 s^{-1}$, respectively.

Recently on 29th June 2020, NGT's Yamuna Monitoring Committee recommended releases of water from Hathnikund barrage that would meet the minimum water depth of 0.60 m for indicator fish species, *viz.*, Indian carp (*Raiamas bola*) and Indian trout (*Bangana dero*) at 13 identified locations.

Several orders have been passed by the Supreme Court, NGT and High Courts directing the governance to take steps to address different dimensions of pollution, water flow and other issues to clean Yamuna. Environmental Impact Assessment was made a mandatory requirement for setting up any industry in Himachal Pradesh by judgement in the case of *Baldev Singh and Ors. vs. State of H.P. and Ors., 2006.* In another significant move, the Supreme Court took *suo moto* cognizance of a news report titled *'And Quiet Flows The Maily Yamuna'* published in a newspaper and called for action by all the concerned authorities. This led to execution of *Maily se Nirmal Yamuna Revitalization Plan, 2017* in two phases. An important case is under consideration of the NGT which relates to desilting in river bed for maintaining the environmental flow of rivers passing the forest areas.

Institutional Framework

A strong institutional framework is in existence. Water resources are dealt with by the Ministry of Jalshakti, GoI at the highest level. It is supported by organisations such as River Basin Organizations, Central Water Commission, Central Ground Water Board. Forest resources are under the control of Ministry of Environment, Forest and Climate Change (MoEF&CC), GoI which is assisted by agencies

like National Afforestation and Eco-Development Board, National Afforestation and Eco-Development Board, National River Conservation Directorate, Indian Council of Forestry Research and Education, State Forest Departments, etc. Other organisations and groups such as Ecological Task Force and Civil Society/NGOs *viz. Nehru Yuva Kendra Sangathan*, National Service Scheme are also effectively working in the area of ecorestoration.

Major Schemes of the Past and Their Outcome

Several schemes have been launched in the past by Central and State governments through various departments in Yamuna basin that are expected to have influenced Yamuna and its tributaries. These include Yamuna-specific project *viz.* Yamuna Action Plan, 1993 (three phases), *Maily se Nirmal Yamuna Revitalization Plan*, 2017 (2 phases) and National Mission for Clean Ganga, 2018 initiative on Yamuna. Numerous state-specific projects have been implemented on treatment of watersheds, sanitation, drinking water, pollution, afforestation, etc. Due to efforts of SFDs in conservation and afforestation, forest cover in the seven states has increased from1,46,878 to 1,50,452 km^2 (an increase of 4.48%) during 2003-2019. After adjusting for change in density of forest cover, the forest cover in terms of very dense forest equivalent area increased from 75,216 to 78,956 km^2 (an increase of 4.97%) with respect to assessment year 2003. However, there is no evidence of improvement in e-flow and sediment load of Yamuna and its tributaries.

Significant work has been done in forestry-related activities, yet there is scope for augmenting these efforts. For instance, Rajasthan state in 2019 put on record that 130 lakh ha of watershed in the state is yet to be treated. Hence, while augmenting efforts of the forestry sector, the steps by other sectors and public awareness are also important to achieve the goal of rejuvenation of Yamuna.

Policy issues identified for addressing in the DPR

The key policy issues identified that impact Yamuna and need to be addressed by sectors other than forestry, are as follows:

1. Poor infiltration of water into ground from agricultural and urban/peri-urban areas causing water scarcity during non-monsoon periods.
2. Rapid water runoff due to impervious surfaces leading to floods, damage to landscape, soil erosion and siltation in water bodies.
3. Soil erosion caused by disturbance to ground/soil by way of construction, ploughing, mining and other activities.
4. Unsustainable exploitation of surface water in farming and urban areas.
5. Excessive groundwater abstraction resulting in decline in groundwater status.
6. Discharge of industrial chemicals, agricultural pesticides, fertilisers, sewage and other wastes.

Policy recommendations pertaining to sectors other than forestry

To achieve the goal of rejuvenation of Yamuna, it is suggested that sectors other than forestry, may also undertake time-bound steps in coordination with forestry sector. A plausible way to achieve active involvement of other related sectors towards this goal would be to request them to prepare and implement their sectoral plans in tandem with DPR relying on forestry interventions. Such sectors include:

1. Agriculture and Rural Development
2. Highways, Roads and Railways
3. Urban Development and Public Works

4. Industries
5. Rivers, Water Bodies and Ground Water
6. Mining and Quarrying
7. Other sectors

To some extent, steps have been taken by some sectors, but these efforts may have to be augmented till the goal of river rejuvenated is achieved. A comprehensive list of activities may be worked out by the concerned sectors in consultation with experts and stakeholders. New policies need to mainstream the water and river conservation objectives supported by suitable institutional adaptation.

Issues Pertaining to Forestry Sector Identified for Addressing

The major river water-related concerns from point of view of the forestry sector are (a) declining environmental flow and (b) high sedimentation load in riverbed. These are, in turn, related to the following issues which have been addressed in the DPR:

a) Forest degradation and landuse change
b) Open and barren catchments/river banks
c) Soil erosion in forest areas and sediment load in river water
d) Presence of invasive weeds and their expansion into adjacent areas
e) Biodiversity concerns
f) Trees outside forest
g) Livelihood issues and generation of industrial-level surplus
h) Awareness generation

Strategies were accordingly formulated to resolve the issues while developing this DPR.

DPR on 'Rejuvenation of Yamuna River through Forestry Interventions'

Forestry interventions are low-cost options towards river rejuvenation. They are eco-friendly and redeem the riverscape with minimal maintenance cost. The DPR followed a holistic approach in consultation with various related sectors. Logical Framework Planning was done to identify the logical linkages between the set of means and the set of ends.

Vision

To restore degraded forests of Yamuna basin alongwith tributaries to improve ecological flow and quality of river water

Mission

To establish /develop multi-tier forest of native vegetation and improve ground water recharge in the riverscape of Yamuna and its tributaries

Goals

1. To propose appropriate treatment models (technical prescriptions) for prioritised sites in the riverscape in consultation with SFDs, other stakeholders and experts
2. To enhance capacity of SFDs to undertake the prescribed project activities in natural, agricultural and urban/peri-urban landscapes
3. To propose implementation mechanism to MoEF&CC
4. To suggest measures for upscaling of activities in other suitable sites in catchment area of Yamuna and its tributaries

Process for developing DPR

The term 'forestry intervention' was defined as a set of activities carried out in the forest landscape with a view to improve forest ecosystem and any activity that is carried out in agricultural, urban or peri-urban landscape involving planting or rearing of tree or woody vegetation was categorised as a forestry intervention. The DPR prescribed treatments within the domain of forestry interventions. State Forest Departments (SFDs) of respective states were identified as coordinating agencies for partnership. Project team was formulsted at FRI and Nodal Officers were identified by the SFDs. Discussion were held with SFDs and all other stakeholder departments, NGOs and subject experts in the form of First Consultation Meetings in different states. This was followed by focussed discussions with expert agencies.

The width of treatment zone (called riverscape) was determined in consultation with stakeholders: the width was taken as 5 km on both sides of Yamuna and 2 km on both sides of tributaries in Haryana, Uttar Pradesh and Madhya Pradesh. The entire catchment area of Yamuna was included in the riverscape in Uttarakhand and Himachal Pradesh, and entire watershed area identified by Rajasthan SFD was included in Rajasthan's riverscape. In Delhi NCT, the riverscape included area from Yamuna bank upto eastern side of Aravalli ridge.

Formats were designed in which proposals were prepared by frontline staff of SFDs. Uploading and analysis of Information was done through data portal. A website was developed to provide information to the public about activities performed.

Geospatial modelling of the riverscape was done through remote sensing and GIS tools to understand and quantify the riverscape characteristics. Landsat-8 satellite data for the month of February to April 2019 was used for preparation of maps. The ancillary information was taken from various sources under Government of India. For the identification of the riverscape, the year 2013 was identified as the highest flood level year based on literature review and stakeholder consultation process at various levels. The following layers were prepared: elevation, soil type, soil depth, soil erosion, forest type, forest cover, land use and land cover and patchiness.

Treatment models, budget and implementation mechanism were developed and finalised after Second Consultation Meeting with SFDs.

Strategies

Landscapes

The areas proposed for treatment under the DPR include natural landscape, agriculture landscape and urban/peri-urban landscape present in the riverscape.

Natural landscapes: The proposed forestry interventions in natural ecosystems (forests, grasslands, and wetlands) included models that focused on afforestation/reforestation, enhancement of forest density, improvement of biodiversity, habitat management by way of weed control, plantations, eco-restoration, etc. Soil and moisture conservation works have been applied as adjunct to the above activities where absolutely essential to support these models.

Agriculture landscape: It covered the rural environment and models were prescribed that seek enhanced agroforestry output and fodder availability. The purpose of the models was to sustain productivity of agricultural lands with planting of economic and fruit trees.

Urban/peri-urban landscape: The proposed forestry interventions in this landscape specifically seek to develop eco-park, riverfront, institutional and industrial estate plantations, and avenue plantations to improve environment in these areas and create awareness among masses towards conservation of trees and water.

Conservation interventions: Conservation interventions have been proposed for development of riparian wildlife and wetland in the natural landscape. Independent soil and moisture conservation measures have also been proposed in natural landscape in sites where such measures were required without silvicultural measures.

Models

A model is a treatment prescription consisting of several activities suggested for a number of sites with similar site condition and management objective. A total of 142 models/sub-models comprising 49 in natural landscape, 14 in agriculture landscape, 21 in urban/peri-urban landscape and 58 as conservation interventions have been formulated for the riverscape. The number of models/sub-models for different states is as follows: 17 in Uttarakhand, 15 in Himachal Pradesh, 19 in Haryana, 1 in Delhi, 34 in Uttar Pradesh, 28 in Rajasthan and 28 in Madhya Pradesh. Species recommended in the Working Plan have been prescribed in the models, thereby, not recommending use of exotics in the natural landscape. Flexibility is permissible in application of the models to allow adaptation to unique site conditions and improvements based on local experiences while retaining the essence of the model. Use of species that are believed to draw excessive amounts of water or have other adverse effects on water and general environment must, however, be avoided.

In urban landscape, it has been prescribed that the natural layout of the land will be manoeuvred in such a way that the aesthetic beauty will be enhanced without much investment on civil works. Landscaped area will be designed to afford good soil, moisture and biodiversity conservation. *Nakshatra vatika, Rashi vatika, Nav-grah vatika, Panchvati vatika, Dhanvantri vatika,* etc. will be established within the park for awareness generation, meditation and spiritual fulfilment. In riverfront development, plantation of trees, shrubs and grasses will be done to stabilise the riverbank and control soil erosion. The infrastructure in the riverfront would be simple and integrated with the landscape. Under the Wetland Management model, de-siltation will be carried out in wetlands and in their entry-exit channels. Terrestrial and aquatic weeds will be removed and regeneration of native species of trees, shrubs, grasses and other herbs will be augmented. Need-based measures will also be taken to improve habitat and augment the population of native aquatic fauna and control invasive faunal species. Water ponds may be created or dug deeper for collecting water to prevent runoff or check inundation in surrounding areas. Water-logging tolerant plant species will be planted wherever possible.

Adaptability and General Guidelines for Implementation of Models

1. Site-specific modifications in the models and site finalisation are permitted provided they capture the essence of the respective models. The rates prevailing in SFD at the site and time of operation would be applicable.
2. Species will be selected in consultation with industries /market experts to plant species that would create industry-level surpluses. Seed or other propagules of forest tree species will be sourced from natural forests and plantations, especially seed orchards, plus trees or seed production areas, wherever available in sufficient quantity, aiming at quality seed. Seed would not be purchased from market for plantation in natural landscape.
3. Soil and moisture conservation measures have been prescribed in most of the plantation models to improve soil moisture. Water storage ponds have been prescribed in few models to increase availability of water for irrigation purpose.
4. During site preparation prior to plantation work, seedlings already growing in the site would be retained, nurtured (through soil working, manure, irrigation operations) and protected.

5. Complete removal of ground vegetation would not be done during rehabilitation of weed-infested areas, Partial removal of invasive weeds would be done followed by artificial regeneration to facilitate gradual replacement of the weeds with economically and ecologically useful species.
6. Biofertilizers such as arbuscular mycorrhiza (AM), organic manures will be applied in nurseries and plantations to boost plant growth. Eco-friendly plant protection measures (e.g., physical or mechanical methods, use of natural products, etc.) will be adopted to manage weed and pest without resorting to use of synthetic products. Tall seedlings may be planted to achieve greater survival in areas with high biotic disturbances.

Supporting Activities

Supporting activities, *viz.*, awareness generation, capacity building & value-chain development, entry point activities, nursery improvement & fire protection, research, monitoring & evaluation, other field activities and miscellaneous works have also been prescribed. Monitoring may be IT-enabled or on-ground monitoring. The IT-enabled monitoring may be remote sensing & GIS-based or on-line web-portal or App-based monitoring. On-ground monitoring may comprise participatory monitoring at the forest division level and third-party monitoring by external agency. As a policy recommendation for forest areas, it is recommended to develop effective measures for prevention of encroachment, fragmentation of forest areas and muck disposal on forest land.Project Management Unit (PMU) at the state level for Yamuna basin who would liase with MoEF&CC at the state level and DFOs and other officials responsible for execution of the project.

Implementation Period and Agency

A five-year implementation phase (year 1 to 5 from the date of approval; Phase I) with a five-year maintenance phase (year 6 to 10; Phase II) is envisaged. The total duration of project activities would thus be ten years. The SFDs of the seven stakeholder states will be the primary Implementing Agencies (IAs) for various activities under the DPR.

Implementation mechanism

Project will be implemented at national, river, state and district (i.e., forest division) levels. The existing framework within the MoEF&CC, GoI will broadly be used for implementation of the DPR on Yamuna for its rejuvenation through forestry interventions. National River Conservation Directorate (NRDC) or National Afforestation and Eco-Development Board (NAEB) under MoEF&CC may serve as the National Project Management Unit-Forest (NPMU-Forest) on river rejuvenation. A State Project Management Unit - Forest (SPMU-Forest) will be set up at the headquarters of SFD in each of the seven states. APCCF (Projects) may look after the SPMU-Forest. SPMU-Forest will implement the DPR through its hierarchical structure of CCF → CF → DFO.

A multi-sectoral framework is also proposed to allow coordinated implementation of DPRs of various sectors under the control of a nodal Ministry (Ministry of Jalshakti, MoeF&CC or other suitable Ministry that may be identified by the GoI). Interventions for various sectors will be implemented by respective ministries and departments with coordination and management by National Project Management Group (NPMG), State Project Management Group (SPMG) and District Project Management Group (DPMG) at national, state and district levels, respectively. Yamuna Cell will be created at national level as well as in relevant states and districts to implement the activities related to Yamuna.

A list of potential funding agencies for different landscapes and thematic areas has also been provided.

Budget

The total projected outlay for the implementation phase of project on Forestry Interventions for Yamuna River is Rs. 3,868.89 crore. The Component A on Implementation of Forestry Interventions in Riverscape Area of Seven States is Rs. 3,620.05 crore which accounts for 93.57% of the total project budget outlay. Component B on Strengthening Knowledge Management and National Capacity for Forestry Interventions and Conservation of Riverscapes has been allocated Rs. 197.74 crore which accounts for 5.11% of the overall project outlay. The project also envisages Preparation of Follow-up DPR for scaling up, monitoring and replication of successful models of forestry interventions and riverscape conservation in additional sites provided by the state forest departments, for which a sum of Rs. 2 crore (0.05% of the Project budget outlay) has been provisioned as Component C**.** In order to oversee, steer and manage this important project by the Central Nodal Ministry (MoEF&CC), an amount of Rs. 49.10 has been allocated as Component D which is 1.27% of the projected budget outlay. Thus, it is evident that about 94 % of the budget outlay is meant for field activities on Plantations, Treatment Models, Conservation Interventions and Supporting activities to be implemented by the seven Implementing Agencies (IAs). The financial allocations for Uttarakhand, Himachal Pradesh, Haryana, Delhi, Uttar Pradesh, Rajasthan and Madhya Pradesh are Rs. 123.71 crore, Rs. 105.21 crore, Rs. 67.28 crore, Rs. 10.73 crore, Rs. 451.78 crore, Rs. 2,268.26 crore and Rs. 593.08 crore, respectively.

Potential Benefits

The potential benefits *ceteris paribus* expected from the implementation of the DPR are as follows:

Benefits	**Quantity**
Estimated CO_2 capture:	a) 10 Years: 1.69 Mt yr^{-1} b) 20 Years: 2.12 Mt yr^{-1}
Water recharge/ground water recharge:	452.38 MCM yr^{-1}
Sedimentation-reduction:	1,373.98 thousand m^3 yr^{-1}
Non-timber and other forest produce:	Rs. 6,682.98 lakh yr^{-1}
Man-days to be generated over the project period:	74.69 million

LIST OF ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
AGB	Above Ground Biomass
AL	Agriculture Landscape
APO	Annual Plan of Operations
B	Billion
BBMB	Bhakra-Beas Management Board
BCM	Billion Cubic Metre
BGB	Below Ground Biomass
BIS.	Bureau of Indian Standards
BOD	Biological Oxygen Demand
BPL	Below Poverty Line
BUR	Biennial Update Report
CAMPA	Compensatory Afforestation Fund Management and Planning Authority
CBD	Convention on Biological Diversity
CBO	Community Based organization
CC	Completion Certificate
CCF	Chief Conservator of Forests
CCME	Canadian Council of Ministers of the Environment
CCTV	Close Circuit Tele Vision
CETP	Common Effluent Treatment Plant
CGWB	Central Ground Water Board
CIFOR	Centre for International Forestry Research
CITES	Convention on the international Trade is Endangered Species of Wild Flora and Fauna
CMS	Convention on Migratory Species
COD.	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPIC	Circle Project Implementation Committee
CRA	Cauvery River Authority
CSO	Civil Society Organization
CSR	Corporate social responsibility
CSS	Centrally Sponsored Schemes
CWC	Central Water Commission
CWPRS	Central Water and Power Research Station
DDT	Dichloro Diphenyl Trichloroethane
DEM	Digital Elevation Model
DFO	Division Forest Officer
DIC	District Level Implementing Committee
Div.	Division
DPIIT	Department for Promotion of Industry and Internal Trade
DPR	Detailed Project Report
DO	Dissolved Oxygen

DOM	Dead Organic Matter
DSMIS	Decision Support and Management Information System
EAC	Environment Appraisal Committee
EAP	Externally Aided Project
EC	Electrical Conductivity
EFR	Environment Flow Requirement
EIA	Environmental Impact Assessment
EPA	Environment Protection Act
EQI	Ecological Quality Index
ESA	Environment and Social Analysis
ESMF	Environment and Social Management Framework
ESZ	Eco-Sensitive Zone
ETC	Eco Task Force
ETP	Effluent Treatment Plant
EYC	Eastern Yamuna Canal
FAO	Food and Agriculture Organization
FBR	Aerobic Fluidized Bed Reactor
FDA	Forest Development Agency
FDI	Foreign Direct Investment
FFV	Forest Fringe Village
FPC	Flow Pulse Concept
FRI	Forest Research Institute, Dehradun
FSI	Forest Survey of India
FSSM	Faecal Sludge and Septage Management
gal	Gallon
GDP	Gross Domestic Products
GEF	Global Environment Facility
GIM	Green India Mission
GLOF	Glacial Lake Outburst Floods
GoI	Government of India
GPC	Good Practices Guidance
GSDP.	Gross State Domestic Products
GSI	Geological Survey of India
GSVA	Gross State Value Added
GWP	Global Water Partnership
HCC	Hyportheic Corridor Concept
HDI	Human Development Index
HKB	Hathini Kund Barrage
HP	Himachal Pradesh
IA	Implementing Agency
ICAR	Indian Council for Agricultural Research
ICFRE	Indian Council of Forestry Research and Education
INBO	International Network of Basin Organizations
IP	Implementation Plan
IPCC	Intergovernmental Panel on Climate Change

IS	Indian Standards
ISFR	India State of Forest Report
ISP	Interceptor Sewage Project
ITO	Income Tax Office
IUCN	International Union for the Conservation of Nature and Natural Resources
IRBM	Integrated River Basin Management
IWDP	Integrated Watershed Development Project
IWMP	Integrated Watershed Management Programme
IWRM	Integrated Water Resources Management
JBIC	Japanese Bank for International Cooperation
JFMC	Joint Forest Management Committee
JICA	Japan International Cooperation Agency
L	Litre
LFA	Logical Framework Approach
LULC	Land Use and Land Cover
LULUCF	Land Use, Land Use Change and Forestry
MAP	Medicinal and Aromatic Plant
MAR	Mean Annual Runoff
MB	Measurement Book
MBT	Main Boundary Thrust
MDF	Moderately Dense Forest
MGD	Million Gallons Per Day
MMT	Million Metric Tons
MSME	Micro, Small and Medium Enterprises
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
M	Million
MCM	Million Cubic Metre
MoEF&CC	Ministry of Environment, Forest and Climate Change
MoWR	Ministry of Water Resources
MoWR,RD&GR	Ministry of Water Resources, River Development and Ganga Rejuvenation
MP	Madhya Pradesh
MSL	Mean Sea Level
MSR	Mean Seasonal Runoff
MW	MegaWatt
NABARD	National Bank for Agriculture & Rural Development
NAEB	National Afforestation and Eco-Development Board
NAP	National Afforestation Programme
NAP	National Agroforestry Policy
NAPCC	National Action Plan on Climate Change
NATCOM	National Communication
NBM	National Bamboo Mission
NBSS&LUP	National Bureau of Soil Survey and Land Use Planning

NCR	National Capital Region
NCS	National Chambal Sanctuary
NCT	National Capital Territory
NFP	National Forest Policy
NGO	Non-Government Organization
NGT	National Green Tribunal
NIH	National Institute of Hydrology
NL	Natural Landscape
NM	Nodal Ministry
NMCG	National Mission for Clean Ganga
NMPB	National Medicinal Plants Board
NP	National Park
NPCA	National Plan for Conservation of Aquatic Ecosystems
NPSC	National Programme Steering committee
NRCD	National River Conservation Directorate
NRCP	National River Conservation Plan
NSS	National Service Scheme
NTCA	National Tiger Conservation Authority
NTFP	Non-Timber Forest Produce
NWB	National Water Board
NWCP	National Wetlands Conservation Programme
NWDA	National Water Development Agency
NWIA	National Wetlands Inventory and Assessment
NWP	National Water Policy
NWRC	National Water Resource Council
NYKS	Nehru Yuva Kendra Sangathan
OA	Original Application
OF	Open Forest
OIP	Overall Index of Pollution
OMD	Online Monitoring Devices
PA	Protected Area
PC	Project Coordinator
PCCF	Principal Chief Conservator of Forests
PD	Project Director
PET.	Potential Evapotranspiration
PF	Project Facilitator
PFU	Project Facilitation Unit
PIB	Press Information Bureau
PMU	Project Management Unit
PSC	Programme Steering Committees
PTI	Press Trust of India
RBC	Rotating Biological Contactor
RCC	River Continuum Concept
RBO	River Basin Organization
RFA	Recorded Forest Area

RFO	Range Forest Officer
RPI	River Pollution Index
SAR	Species Area Relationship
SDC	Serial Discontinuity Concept
SDG	Sustainable Development Goal
SEZ	Special Economic Zone
SF	Scrub Forest
SFD	State Forest Department
SFDA	State Forest Development Agency
SFM	Sustainable Forest Management
SIWI	Stockholm International Water Institute
SMC	Soil and Water Conservation
SOM	Soil Organic Matter
SOP	Standard Operating Procedure
SPMU	State Level Project Management Unit
SPMG	State Project Management Group
SPSC	State Programme Steering Committee
SS	Suspended Solids
STP	Sewage Treatment Plant
TA	Total Alkalinity
TDS	Total Dissolved Solids
TERI	The Energy and Resources Institute
TH	Total Hardness
TOF	Trees Outside Forest
TR	Tiger Reserve
UASB	Up Flow Anaerobic Sludge Blanket
UC	Utilization Certificate
UL	Urban Landscape
UK	Uttarakhand
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNDP	United National Development Programme
UNEP.	United Nation Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UP	Uttar Pradesh
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
US-EPA	United States Environment Protection Agency
USGS	United States Geological Society
UYRB	Upper Yamuna River Board
VDF	Very Dense Forest
VFDC	Village Forest Development Committee
VSS	*Van Sanrakshan Samiti*

WBD	Wazirabad Barrage, Delhi
WL	Wetland Management
WLS	Wildlife Sanctuary
WPA	Wildlife Protection Act
WQI	Water Quality Index
WSSD	World Summit on Sustainable Development
WWF	World Wide Fund
WYC	Western Yamuna Canal
YAP	Yamuna Action Plan

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Chapter 1
INTRODUCTION

Water is one of the most important natural resources on the earth. It is essential for the survival and growth of all living beings and functioning of various ecosystem processes. Water is a renewable resource, however its availability is variable. The quantity and quality of water has huge spatial and temporal variation. The world is increasingly facing shortages as well as excesses of water, depending upon time and place, and a general deterioration in water quality. It has been estimated that nearly two-thirds of the human population in the world is facing severe water scarcity at least during one month of the year (Mekonnen and Hoekstra, 2016). This scarcity is largely human-induced and is impacting all living organisms directly and indirectly.

According to one of the reports on Composite Water Management Index of the *NITI Aayog* (2019), India has 17% of world's population and only 4% of water. About 2 lakh people die every year due to inadequate water, hygiene and sanitation issues. Some regions of India such as western Rajasthan, Saurashtra, north Gujarat, Vidarbha, Bundelkhand etc. face the onslaught of drought and water scarcity very frequently. The phenomenon of climate change is gradually deteriorating the situation all over the world. Surface and ground water resources in many parts of India are under stress. The water requirement is rising and meeting the widening demand-supply gap presents a mammoth task. The water crisis requires a timely resolution. However, before advocating a water management plan, understanding of rivers in ecosystem context is a prerequisite. River, pond, lake, etc. are aquatic ecosystems and are different from terrestrial ecosystems such as desert, forest or meadow.

1.1. AQUATIC ECOSYSTEM: RIVER

An aquatic ecosystem is a community of organisms that live together, interact, and depend on each other in a water-based environment. Rivers and streams are lotic (i.e., flowing) freshwater environments and their waters flow in one direction. The term river is used for larger, deeper and longer bodies of flowing water than streams. River and streams begin at a source, which could be a spring, lake, or snowmelt and travel to their mouths, which may be the sea or another river. Rivers link terrestrial, freshwater, and coastal marine systems and nearly all aspects of human culture as they act as integrators and centres of civilization within the landscape (Naiman and Bilby, 1998; Combes, 2003). Rivers possess five essential characteristics, *viz.*, (i) unidirectional flow, (ii) gradual physical change, (iii) large spatial and temporal heterogeneity, (iv) large variation between lotic systems and (v) varied biotic elements (van der Velde *et al.*, 2004). Rivers are a major source of surface water on the earth. They carry water and nutrients to downstream areas and play a very important role in the water cycle. They act as drainage channels for surface water and provide habitat and food for many aquatic and terrestrial organisms. They also provide fertile valleys and plains for agriculture and kinetic energy for hydropower generation.

India is blessed with many river systems that have a history of sustaining civilizations as old as the Harappan and Indus Valley civilizations. The country has been divided into 20 river basins (CWC, 2010). The rivers may be classed into four groups according to their origin and flow pattern: (a) The Himalayan rivers (Ganga, Brahmaputra, Indus) that originate from high altitude glaciers and are perennial (Fig. 1.1 and 1.2), (b) Rivers of Indian craton (Mahanadi, Godavari, Krishna, Pennar, Cauvery, Narmada, Tapi) are mostly rain-fed and strive on base-flow, (c) Coastal rivers (Subaranrekha, Nagavalli, etc.) are mostly non-perennial, and (d) Rivers of western Desert (Luni, etc.) originate within small fluvio-aeolian basins and are rain-fed, ephemeral and disconnected from the ground water systems (FAO, 2015).



Fig. 1.1. Origin of River Yamuna: Yamunotri, Uttarakhand
(*Source:* Project Team**)**



Fig. 1.2. River Yamuna in the Shiwalik Himalayas, Uttarakhand
(*Source:* Project Team**)**

1.2. TERRESTRIAL ECOSYSTEM: FORESTS

More than seven billion humans live on the earth. The forest area on the earth is gradually decreasing. There is wide variation among countries in per capita forest area on the earth, however, the majority of the people facing severe water scarcity live in areas where green cover is scarce (Oki and Kanae, 2006; Rockström *et al.*, 2014; Mekonnen and Hoekstra, 2016).

Since time immemorial, forests have been grazed by livestock and cleared in the river basins for promoting cultivation and other needs. Biotic disturbances in the upstream forested tract and forests along river courses have fragmented and degraded the forest ecosystem and impaired their functioning. Forests provide multiple goods and services and play an important role in cycling of carbon, oxygen and other gases in the earth's atmosphere. Forests provide diverse produce such as wood, fodder, fuel, fruit, medicines, gum, resin, tannin, dye, fibre, floss, etc. Forests conserve soil and biodiversity and ameliorate environment. They purify air and water. Forests contribute to the reduction of water-related risks such as local floods, droughts and help prevent desertification and salinization. Forests have huge aesthetic value. They are the habitat of diverse plant life and wild animals of varied sizes. They are abode of several tribal communities, provide raw material for industries and are deeply intertwined with life and livelihood. Due to their multiple and varied goods and services, it has not been possible so far to assign an economic value to the benefits accrued from forests, thus, their role in GDP is grossly undervalued.

1.3. FOREST AND WATER

Forests and trees are important factors that regulate water flows (Vörösmarty *et al.*, 2000; Bruijnzeel, 2004; Bonell and Bruijnzeel, 2005; Calder *et al.*, 2007). Due to their strong relationship with water, the forests are prominent determinants of health and wellbeing of living organisms (Sullivan, 2002; Falkenmark and Rockström, 2004; Kummu *et al.*, 2010). Water availability is likely to decrease in the future, as climate variability and change create uncertainties in water supply. At the same time, demand for water is rising due to increasing population. Forests and forested landscapes regulate the provision of water and water-related ecosystem services. They predominantly affect the volume and timing of water flow as well as rates of soil formation or erosion. Forests absorb rainfall and snow melt and also check runoff, decrease soil erosion, improve water infiltration rates and recharge aquifers. Thus, they have 'sponge effect'. Stream-side forests filter pollutants. Forested basins and catchments supply a high proportion of freshwater for domestic, agricultural, industrial and ecological needs in both upstream and downstream areas (Calder *et al.*, 2007). They influence the amount of water available and regulate surface and groundwater flows with maintaining water quality.

Forested landscapes supply a high proportion of fresh water for domestic, agricultural, industrial and ecological needs in both upstream and downstream areas (Fig. 1.3). A meta-study conducted in 2003 by the World Wildlife Fund for Nature (WWF) showed that about one-third (33 out of 105) of the world's biggest cities including New York, Mumbai, and Bogota obtained a significant proportion of their drinking water supplies from forested watersheds and protected areas (FAO, 2013). Effective forest and watershed management are valuable for long term sustainability of water resources. Government and other stakeholders need to develop policies and implement programmes that promote a holistic, multidisciplinary and stakeholder approach that links forests, water, watersheds, the environment and people.

A good forest cover is the most effective land cover to keep the sediment load in flowing water at a low level. Forest is certainly the best cover for drinking-water supply watersheds, because forestry activities do not involve use of fertilizer, pesticide and fossil fuel, or flow of domestic sewage and industrial processes (Hamilton *et al.*, 2008). Riparian forests act as buffers to reduce the impact of

anthropogenic disturbances on rivers. The riparian forest buffer in the form of grass, shrubs and/or trees along the banks of rivers and streams filter polluted runoff and provide a transition zone between water and human use.

Forest conservation and afforestation in upstream watersheds are regarded as the most effective measures to enhance water availability for agriculture, industrial and domestic uses, as well as for preventing floods in downstream areas. Forest hydrology research conducted during the 1980s and 1990s confirmed the important role of upstream forest cover in ensuring the delivery of high-quality water, however, some generalisations may not be true in some environments (Bruijnzeel, 2004; Calder, 2005, 2007; van Dijk and Keenan, 2007; FAO and CIFOR, 2005).

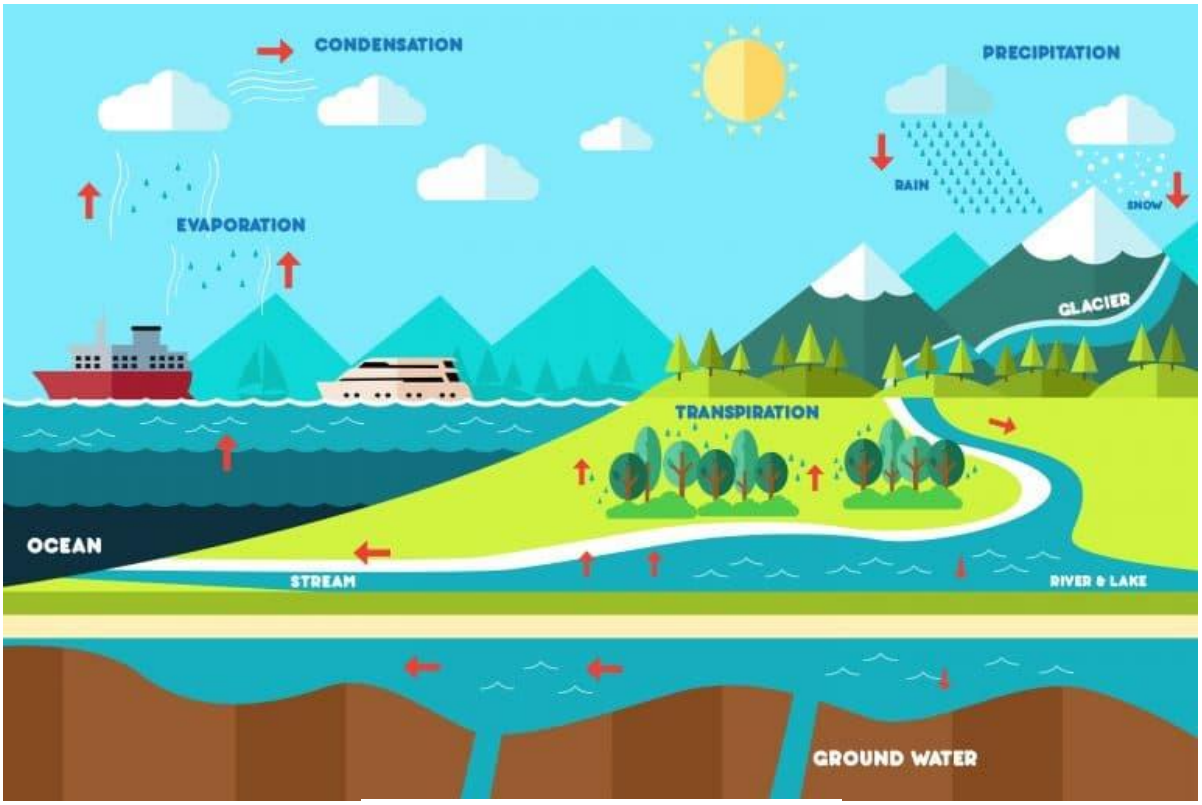


Fig. 1.3. The hydrological cycle

Source: https://www.sciencedirect.com/topics/earth-and- planetary-sciences/hydrological-cycle.

A key challenge for land, forest and water managers is to enhance the wide range of forest benefits without detriment to water resources and ecosystem function. To address this, there is a need for better understanding of the interactions between forests/trees and water. There is also a strong need for awareness generation and capacity building in forest management and hydrology, and for embedding this knowledge in policies. There is an urgency to develop institutional mechanisms to enhance synergies in forests and water issues (Calder *et al.*, 2007).

1.4. RIVER BASIN

Land and river water are ecologically connected in a landscape called a river basin. A river basin is the geographical area which is drained by a river and all its tributaries. The term ‘catchment area’ has similar connotation, but is used for smaller area (hence smaller rivers or tributaries). A watershed is the dividing line between two drainage areas, the term is used for a smaller division of catchment area.

Watershed is also used to refer to an area of land that catches all the rain and directs it to a stream or rivulet (Fig. 1.4). Water carries with it sediments and dissolved materials from the drainage area. Every action affects watershed – from washing clothes or growing plants to mining, building roads or dams. The reverse is also true: the condition of watershed determines what can be sustainably carried out in the watershed.

1.4.1. Physical Features

A watershed usually starts at the top of a hill, mountain or ridge. Flowing down, the water within a part of the watershed joins more water of the same watershed to form a stream. Water of different streams and watersheds join to form a river. Water of different smaller rivers merge to form a bigger river. Merging in this fashion, a major river is formed which may often flow into the sea or oceans. Water may also flow under the ground for some part of its journey. A watershed's floodplain is the flat area that starts at river's edge and continues to the beginning of surrounding highlands. Floodplains are particularly rich zones of biodiversity and have fertile soil suitable for farming. Soil moisture is usually less on steep slopes and sun-facing aspects. Slopes exposed to the sun usually support plants different from those facing away from the sun. Orientation about the prevailing winds has similar effects.

Depending on periodicity of water, streams are of three types:

a. *Ephemeral streams* are small and flow during a rainstorm often lasting for a short period of time after the rainstorm. An ephemeral stream does not have fixed, well-defined course on the ground, and the same place may witness an ephemeral stream with a different course in the next storm.

b. *Intermittent streams* generally flow only during the wet season of the year.

c. *Perennial streams* flow throughout the year, their channels are usually well-defined.

The physical, chemical and biological characteristics of a stream are greatly influenced by physical features of the watershed.

1.4.2. Climate

Land and water are closely linked through the water cycle. Solar energy drives the water cycle and other natural cycles in the river basin. Climate determines how much water comes to the watershed through seasonal cycles. The seasonal pattern of precipitation and temperature variation control stream flow and water production. The amount of precipitation can vary from year to year.

Climate also affects water loss from a watershed. In hot, dry, or windy weather, evaporation loss from bare soil and from water surfaces is high. Transpirational loss of water from plants is also high in such conditions. Transpiration removes soil moisture from a greater depth than evaporation. Transpiration is greater during warm growing season and less during cold weather, when most plants are relatively dormant.

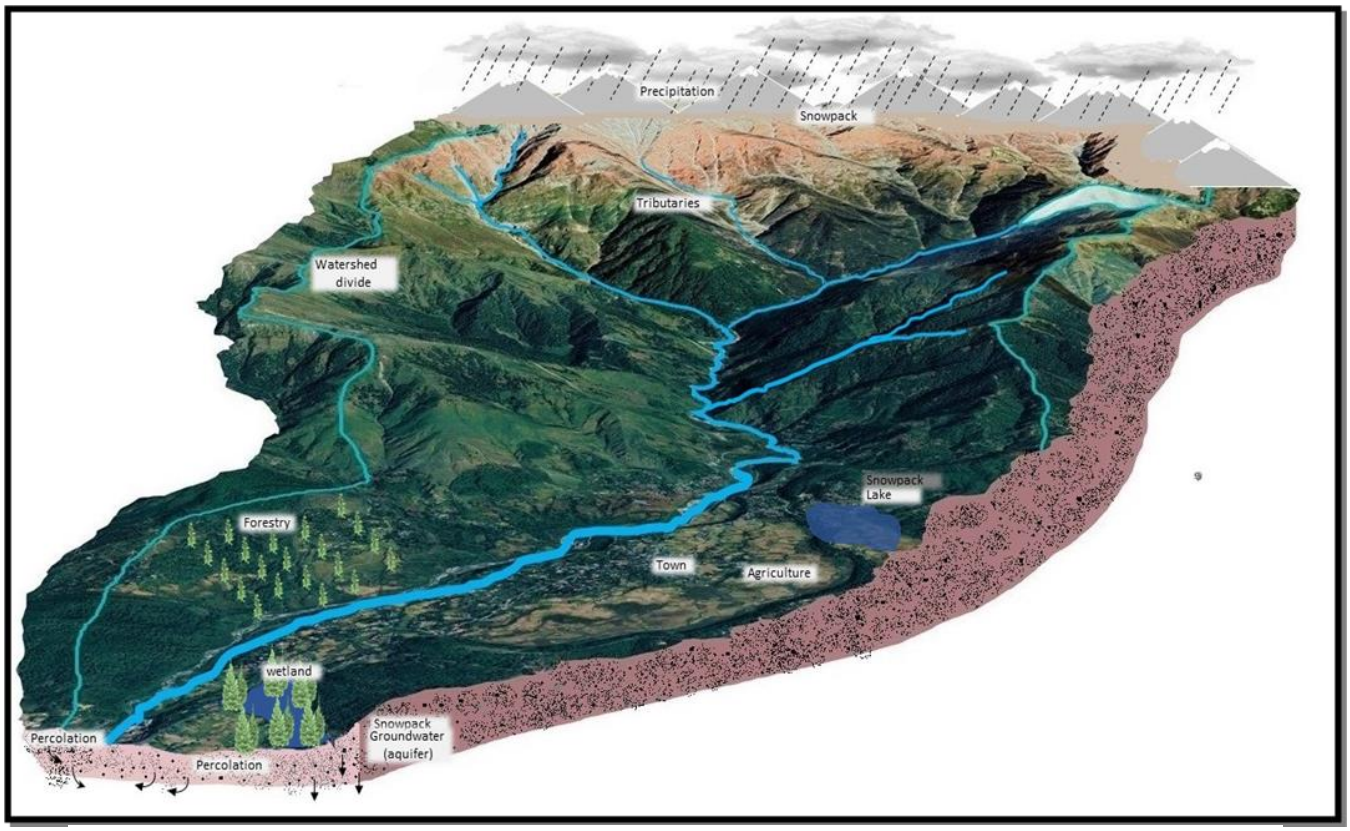


Fig. 1.4. A river basin showing its major components *viz*., mountains, lakes, rivers, forest, agricultural land, wetlands, habitation, etc.
(*Source:* Project Team**)**

1.4.3. Geology and Soil

Soil is a basic watershed resource that, except over a long period of time, is non-renewable. It may take more than a century to produce a single centimetre of soil and thousands of years to produce enough soil to support a high-quality forest, grassland or agricultural crop. Careful management and protection of soil is necessary to preserve its function and productivity. Soil carries plant nutrients and holds water; it is a key element in a watershed's health.

Soil formation is greatly influenced by climate and geology. Hard rocks weather slowly and are associated with poor and shallow soil. Rainfall causes leaching and transports soils, through the erosive power of runoff. Soil plays a major role in determining the type and quality of vegetation. Plants also modify and develop the soil. Plant roots create soil spaces, which help increase a soil's ability to store water. Litter from plants adds organic matter to soil which also increases water-holding capacity. Plant debris slow down surface runoff and protect the soil surface from water erosion.

1.4.4. Vegetative Cover

Plant cover has positive effect on river basin. The canopy intercepts rain, decreases the impact of water on the ground and reduces soil erosion. Canopy also reduces wind velocity. Litter, organic matter and humus from the vegetation improve the quality of soil, enhance infiltration of water, decelerate surface runoff and increase water-holding capacity. Stem and roots create gaps in the soil, thereby promoting

water infiltration and retention. Tree roots hold soil particles and check soil erosion. Roots of some plants remove harmful chemicals from soil and water and store them in plant biomass.

The forest vegetation comprises not only trees, but also shrubs, herbs and lower plant forms. The number of smaller plants is usually several times more than the trees. The individual effect of those plants is smaller than trees, but together they add up to a substantial quantity and contribute significantly. Though all plants in a forest have some effect on water, trees are the most important in many ecosystems (Fig. 1.5). Native vegetation that naturally develops in an ecosystem is well adapted to the site conditions of the area, therefore removing native trees from catchments can adversely impact ecological health - the losses from which may be realised after several decades.

1.4.5. People

Humans make major changes to river basins individually and collectively – some of which are beneficial but others can do serious harm. Some watersheds have been modified so much that they are no longer able to perform many of the useful functions that protect and support communities. Deforestation reduces the soil's ability to hold water, greatly increasing runoff. Encroachment of wetlands and flood plains, and land use change remove the watershed's natural sponges which absorb run-off and rain. Developmental activities and urbanization lead to fragmentation of forest landscape, construction of impervious ground surface, roads, buildings, etc. thus leaving less natural space. The result is a dramatic increase in runoff. Diversion of water for agriculture, domestic and industrial uses, discharge of sewage and pollutants from industry, pesticides and other chemicals, as point and non-point source pollutions, seriously affect the flow and quality of water. It takes lots of actions by several people to do this much damage, but unfortunately it is widely done in all civil societies. Humans can also be great caretakers of their watersheds, their positive actions need to be synergised and augmented to reverse the damage.



Fig. 1.5. Forests and water
(*Source:* Project Team**)**

1.5. RIVER – ECOLOGICAL INTEGRITY

Apart from physical environment, the biological environment also plays an important role in river function (Fig. 1.6). River is a large body of flowing water that traverses long distances and thus interacts with varied environmental and biotic elements. The structure and function of stream communities are influenced by food web comprising water, nutrients and organisms which are dependent on (a) longitudinal distribution of particulate organic matter along streams and rivers based on minimum energy loss (river continuum concept proposed by Vannote *et al.,* 1980) (b) instream impediments such as dam, barrage and weir that disrupt the flow and affect riverine geomorphology and biotic communities (serial discontinuity concept proposed by Ward and Stanford, 1983), (c) interaction between the hydrographic basin and the hyporheic zone, i.e. the ecototone between ground water and surface water (hyporheic corridor concept proposed by Stanford and Ward, 1993) and (d) periodic flood and inundation that influence the lateral exchange of water, nutrients and organisms between the floodplain and the main channel (flood pulse concept, proposed by Junk *et al.,* 1989) .

It is well recognized now that physical, chemical and biological characteristics of rivers depend upon complex interactions between hydrological, geo-morphological and biological processes over a long period of time (Calow and Petts 1991), and are influenced by human activities.

1.6. RIVER MANAGEMENT

The physical structure of the river, the quantity and quality of water, the condition of riparian zone and floodplain and the diversity and populations of plants and animals living in the stream determine the structure and function of river ecosystems (Rutherford *et al.*, 2000). Changes in any of these elements may significantly affect other elements of the river ecosystem.

The modern water management approach adopts the principle of ecological integrity and seeks preservation and re-establishment of functional diversity as an important task. The ecosystem approach seeks an insight through interdisciplinary researches at all stages of the planning, implementation and evaluation process. Interrelated disciplines *viz*., geomorphology, hydrology, landscape ecology and planning, hydraulic engineering, forestry, and aquatic and terrestrial ecology contribute in a significant manner towards inter-disciplinary researches and have important roles to play in planning and management of rivers.

1.7. RIVER – CONCERNS FOR CONSERVATION

The world over, concerns for river systems have emerged in response to rising pollution, but increasingly a broader concern for ecosystem sustainability has arisen both due to issues of socio-economic development and climate change (Roberts, 1993). The global freshwater crisis needs practical solutions to address the problems concerning water availability and quality for which conservation/restoration/rejuvenation of rivers is the need of the hour. The knowledge about river ecology is growing coupled with technological advances in the field of water management, together these may provide efficient tools to overcome the global water crisis. Over the past years, increasing efforts have been directed to the application of scientific principles for development of environmentally-sensitive approaches for managing rivers (Gore and Petts, 1989; Petts, 1994; Petts and Calow, 1996).

The present situation has arisen because humans have failed to appreciate and recognize rivers as natural ecosystems and forgotten their ecosystem services (Fig. 1.7 and 1.8). For over a century studies have been carried out on stream flows, sediment loads, channel forms and their dynamics over temporal scales varying from hours to millennia. Five broad threats to freshwater biodiversity include overexploitation, water pollution, flow modification, destruction or degradation of habitat, and invasion

by exotic species (Hora, 1928; Illies and Btasaneanu, 1961: Leopold, 1973; Schumm, 1960; Wolman, 1967; Yearke, 1971). Fragmentation, changes in water flow, sedimentation, contamination by chemicals and invasion by non-native plant and animal species are the growing concerns of present times.

1.7.1. Total Volume of Water

The total volume of water passing through the channel per unit time is called the 'flow' or 'discharge' and it is an important consideration in judging the usefulness of a river. Rivers contain about 2 % of surface fresh water on the earth. The flow of water in a river is composed of two pathways: (a) storm flow comprises water that reaches the river over ground surface or through underground routes in a short period of time after precipitation, and (b) base flow comprises water that infiltrates the soil, percolates into deeper layers and finds its way to the river after longer period of time. Base flow sustains the river during dry seasons and is very important from point of view of economic activities, and hence commands huge significance in restoration programme.

1.7.2. Environmental Flow

One of the most important, and often the single largest, causes of degradation in rivers is the alteration of their flow regimes by structures such as dams, barrages and embankments for storage, abstraction and diversion of water to meet the growing human needs. The requirement of flow in rivers and streams to sustain their ecological integrity and ecosystem services is now well recognized and termed as 'environment flow'. The Brisbane Declaration (2007) defined it as the 'quantity, quality and timing of water flows required to sustain freshwater and estuarine ecosystem and the human livelihoods and well-being that depend on these ecosystems.

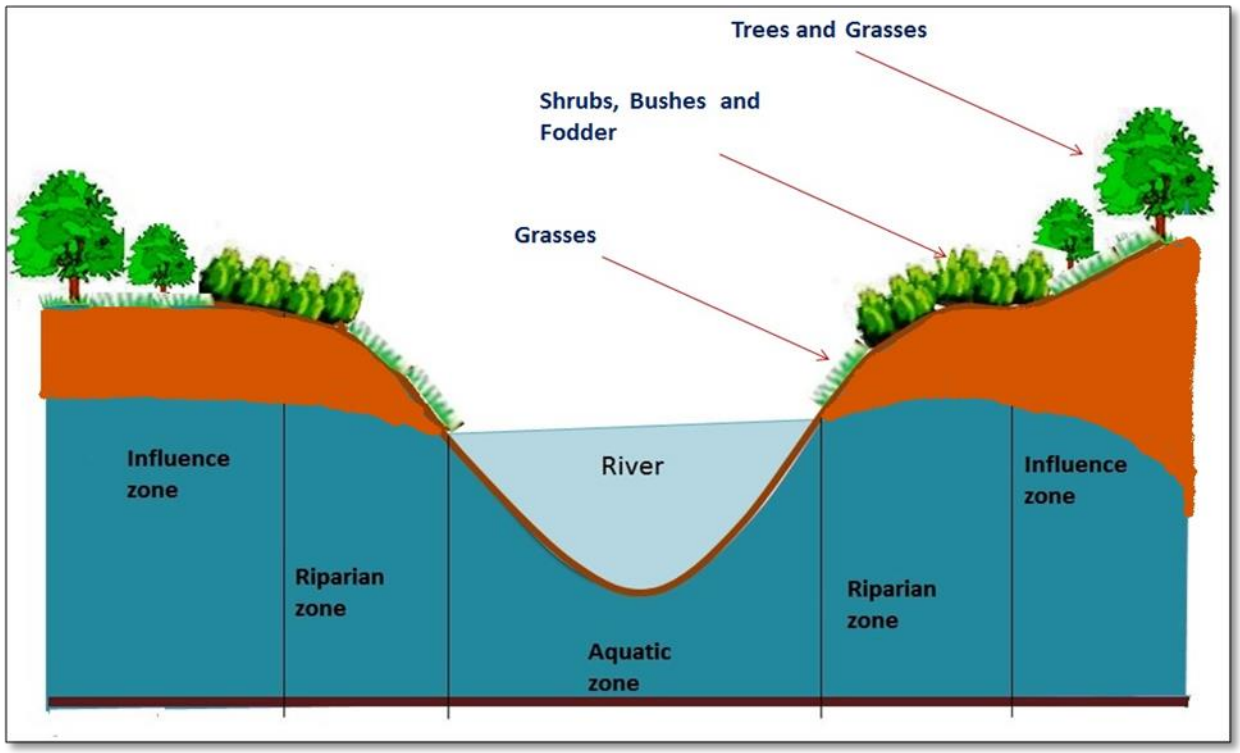


Fig. 1.6. Riparian zone and adjoining landscape
(*Source:* Project Team**)**



Fig. 1.7. Pressures on River Yamuna
(*Source:* Project Team**)**



Fig. 1.8. Pollution in River Yamuna
(*Source:* Project Team**)**

In an aquatic environment, where water is the dominant controlling factor, it is not the total amount of water alone that influences the organisms but also its temporal change and the rate of change itself. Environmental flows simulate the natural flow regime through the year.

Aquatic systems evolve in response to the naturally occurring variability and adapt themselves to major variations occurring periodically except for variations that occur due to extreme events such as cyclones or cloud bursts. Efforts are made to manage the required flows by managing watershed landuse.

1.7.3. Flow and Biodiversity

Biodiversity is greatly influenced by river flow. This is true for plants and animals of all sizes. Species of organisms that are adapted to the quantity, quality and temporal changes in water in the river and river basin survive while those unable to do so die out. The surviving species continuously adapt themselves to the changing environment. Aquatic species tend to grow in the floodplain while xeric species thrive in areas which are not flooded. Dispersal of seeds of some species is aided by water. Many species of plants and animals which were once abundant on river banks in India have disappeared due to changes in flow pattern and water quality. Some species of animals (hyporheic species) require subsurface flows and are able to spend part of their life cycle under the river bed.

1.7.4. Water Quality

Water quality is an important parameter concerning utility of river water and its suitability for diverse uses. Organisms greatly differ in their tolerance to different water quality parameters. As water quality deteriorates, most organisms decline in their population and activity. As water quality declines, sensitive organisms are lost while more tolerant organisms such as blue green algae, etc. tend to dominate. The geological, geochemical and vegetation characteristics of the watershed directly govern the water quality. Water quality is also affected by type and intensity of land use and discharge of domestic and industrial wastewater. The chemical characteristics of water change along the length of the river. Gradually increasing concentration of various nutrients enter the stream with runoff as a variety of dissolved and particulate substances enter river water.

1.7.5. Erosion and Sedimentation

Steep slopes with loose soil and poor vegetation cover are erosion prone and, as a result, the water flowing from those watershed has greater sediment load than that from gentle slopes and dense cover of vegetation. However, in slopes with hard rock and poor soil depth, soil erosion is less. Excessive loads of sediment are detrimental as they affect river flow and threaten survival of aquatic fauna by blocking respiratory systems. Turbidity tends to increase water temperature and suppresses algal photosynthesis. Erosion causes frequent filling up of lakes and ponds, and choking of dams, thereby increasing the cost of their desiltation. Coarse sand accumulates in several stretches of riverbed which is removed by sand mining. Excessive desilting is however, detrimental to the river (Fig. 1.9).

The Himalayan river systems operate in three zones, *viz*., (i) source area in the high mountainous zone, (ii) vast alluvial plains, and (iii) deltaic plain (Sinha, 2004). Thus, from point of view of sediments, the upper zone is source zone, the middle zone is transfer zone and the lower zone is accumulation zone (Schumm, 1977). In the Himalayan rivers, the sediment loads have always been very high (highest among the world's rivers) because of their origin in the geologically young Himalaya.

Wasson (2003) identified the major source regions of erosion in the Himalayas into the Tethyan, High and Lesser. These major source regions are topographically and lithologically distinct and some erosion and transport processes are confined to particular regions. Sedimentary and meta-sedimentary

rocks; steep slopes; moderate to high relief; forested in part; cultivation and grazing etc. are the causes of landslides, sheet and rill erosion and channel erosion in rivers (Fig. 1.10).

1.7.6. Chemicals

Low dissolved oxygen (DO) concentrations are generally detrimental to aquatic life, with the exception of a few organisms adapted to low oxygen or anaerobic conditions. DO concentration in surface waters is determined by many factors including water temperature, salinity, biological respirations, chemical oxygen demand, sediment oxygen demand, photosynthesis, and transfer of oxygen into the water from the atmosphere (i.e. re-aeration).

DO concentrations in streams fluctuate throughout the day, the minimum DO concentrations typically occur at night when aquatic plants do not photosynthesize but respire. Natural re-aeration tends to maintain adequate DO concentrations. Natural re-aeration rates in a stream are influenced by stream properties such as slope, depth, natural drops, turbulence, frequency of rifle areas, etc.

A number of other quality parameters *viz*. biochemical oxygen demand (BOD), faecal coliform, chemical oxygen demand (COD), suspended solids, pH, temperature, dissolved oxygen (DO), ammonia (NH_3), heavy metals, pesticides, etc. are also considered while assessing quality of river water.



Fig. 1.9. Sediment extraction in River Yamuna
(*Source:* Project Team**)**



Fig. 1.10. Soil erosion along river
(*Source:* Project Team**)**

1.8. RIVER REJUVENATION

1.8.1. Meaning of River Rejuvenation

River rejuvenation means to restore to a pristine or former state. Restoration is generally defined as "the re-establishment of pre-disturbance natural functions and related physical, chemical and biological characteristics" (Lewis, 1990). For many reasons, it is practically difficult, if not impossible, to return to some pre-disturbance state. Specifically for aquatic ecosystems, restoration is the re-establishment of chemical, physical and biological components of the ecosystem that have degraded by point or non-point sources of pollution, habitat degradation, modification of hydrological regimes, and other similar human impacts.

The term restoration is used in many ways; however, it normally implies return to an original state. In many situations, true restoration may be unrealistic and exorbitantly expensive; rehabilitation to a better state can be practical in the present context as it may provide an endpoint that may be defined (Bradshaw, 1996). Fig. 1.11 can provide useful guidelines in this context.

In the present DPR, the term 'rejuvenation' has been used to denote rehabilitation, through forestry interventions of the degraded ecosystem of Yamuna due to human interferences over time. However, in geo-morphology terms the river is said to be rejuvenated when it is eroding the landscape in response to a lowering of its base level (Parsons, 2010). The process is often a result of a sudden fall in the sea level or the rise of land. The disturbance enables a rise in the river's potential energy that increases its riverbed erosion rate. The Nile was rejuvenated in geo-morphological context when the Mediterranean Sea dried up and its base level dropped from sea level to over 3 km below the sea level (Gargani *et al.*, 2010). The geo-morphological rejuvenation is not applicable to this DPR.

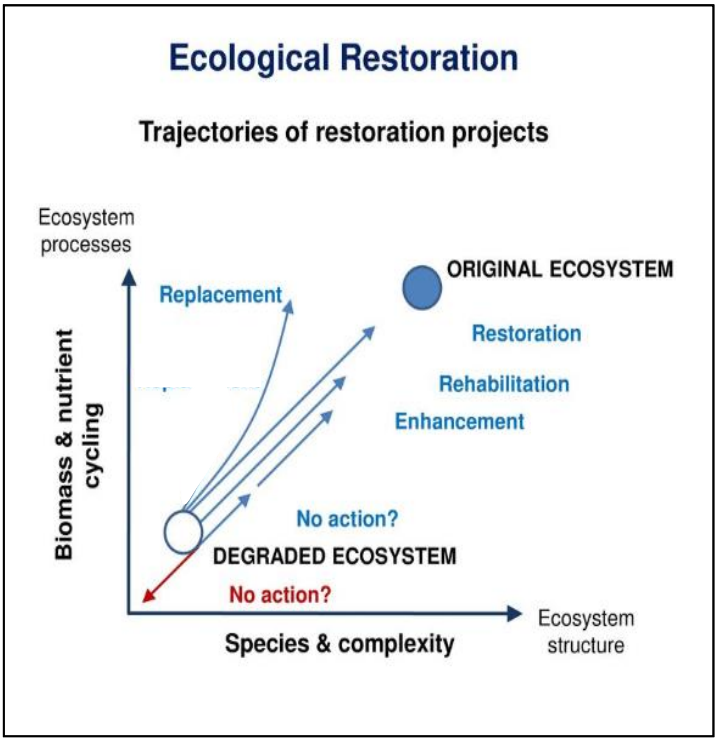


Fig. 1.11. Ecological restoration
(*Source:* Modified from Hudson, 2018)

1.8.2. Principles of River Rejuvenation

The narrative of restoration of wetlands finds a comprehensive expression in the following principles and suggestive actions of river rejuvenation (US-EPA, 2000, http://www.epa.gov/owow/wetlands/restore/, 2018):

1. Preserve and protect the rivers: The streams which are in a relatively good condition should be first protected.
2. Restore ecological integrity: Re-establish as far as possible the ecological integrity of degraded rivers.
3. Restore natural structure: Harmful alteration of channel such as stream channelization, ditching in wetlands, disconnection from adjacent ecosystems, and shoreline modifications should be addressed before improving water quality and rehabilitating native biota.
4. Restore natural functions: Identify the desirable functions and plan for restoring those functions.
5. Work within the watershed (river basin) context: Restoration requires a design based on the entire watershed, not just the part of the river that may be degraded.
6. Understand the natural potential of the watershed: Restoration planning should consider possible irreversible changes in the watershed that may affect the river system.
7. Address ongoing causes of degradation: Identify the direct and indirect causes of degradation and eliminate or remediate ongoing stresses wherever possible.
8. Develop clear, achievable and measurable goals: Different alternatives should be evaluated in consultation with stakeholders and the chosen goals should be ecologically and socio-economically achievable with participation of local communities.

9. Focus on feasibility: The ecological, scientific, technical, financial, social feasibility must also be ensured.
10. Use a reference site: Reference sites, which are not degraded may be used as models or yardstick for restoration.
11. Anticipate future changes: Foreseeable ecological and societal changes such as changes in land use or the climate change should be factored into restoration design.
12. Involve a multi-disciplinary team: Inputs from experts of diverse disciplines (e.g., ecology, aquatic biology, hydrology and hydraulic, geology, geomorphology, soil science, engineering, etc.) should be utilised.
13. Design for self-sustainability: Long-term viability should be ensured to minimise the need for continuous intensive management.
14. Use passive restoration, when appropriate: Assess the potential for passive restoration before taking up active restoration. In some cases, simply reducing or eliminating the sources/causes of degradation and allowing recovery time, can improve the river ecosystem.
15. Use native species and avoid non-native species: Invasive, non-native species should not be used in a restoration project.
16. Use bioengineering techniques, where possible: Bioengineering techniques should be used for erosion control, bank stabilization, flood mitigation, and water treatment (e.g., constructed wetland systems).
17. Monitor and adapt to changes when necessary: Monitoring should be done and mid-course adjustments should be undertaken.

The principles stress to first create the goal, *viz*., restoration of ecological integrity, natural structure and functions; then context, the watershed; thereafter priority, address ongoing causes of degradation; after that approach, develop clear, achievable and measurable goals, develop clear focus on feasibility, use a reference site, involve a multi-disciplinary team, design for self-sustainability, use passive restoration, when appropriate, use native species and avoid non-native species, use bioengineering techniques, where possible, anticipate future changes and, monitor and adapt to changes when necessary.

1.9. RIVER BASINS IN INDIAN CONTEXT

On the basis of the area drained, the river basins of India have been classified into three categories: (i) river basins with catchment area of >20,000 km^2 as large river basins, (ii) river basins having a catchment area between 2,000 to 20,000 km^2 as medium river basins and (iii) the rivers having a catchment area < 2,000 km^2 as minor river basins. There are 12 large and 46 medium river basins covering 25.30 lakh and 2.50 lakh km^2 area, respectively (CWC, 2019). The major river basins of India in descending order of area are: the Ganga, Indus, Godavari, Krishna, Brahmaputra, Luni, Mahanadi, Narmada, Cauveri, Tapi, Pennar, Brahmani, Mahi, Sabarmati, Barak and Subarnarekha (CPCB, 1999).

The water resources potential of the country in the form of natural runoff in the rivers during 2018 was estimated at 1,869 billion m^3 (BCM). Due to topographical constrains and uneven distribution, only 1,123 BCM can be put to beneficial use. This can be achieved through 690 BCM surface water and 433 BCM through ground water (CWC, 2019).

About 58% of the total annual ground water recharge comes from monsoon. The overall contribution of rainfall (both monsoon and non-monsoon seasons) to the country's total annual ground water recharge is 67% and the share of other sources, *viz*., canal seepage, return flow from irrigation, recharge from tanks, ponds and water conservation structures is 33% (CGWB, 2019).

The total annual ground water extraction of the entire country for the year 2017 has been estimated at 248.69 BCM. Agriculture sector is the predominant consumer of ground water resources.

About 89% of total annual ground water extraction, i.e., 221.46 BCM is for irrigation use. Only 27.24 BCM is put to domestic and industrial use, which is about 11% of the total extraction (CGWB, 2019).

1.10. PROBLEMS IN RIVER BASINS IN INDIA

Overexploitation and degradation are major problems in the river basins which are caused by various region-specific reasons. There are three major aspects of problem: degraded river basin, release of undesirable substances in water and excessive water abstraction.

Degradation of river basin is associated with land use and land cover changes and their cascading effects on water infiltration and quality. Land use land cover changes take place in forest, agricultural as well as urban/peri-urban landscapes. These are the result of intensified land use for meeting the rising demands of increasing population. Large soil erosion rates, release of sewage, waste material, industrial effluents, agrochemicals and muck disposal adversely impact water quality.

Largescale diversion of river water has taken place through dams and barrages to meet the needs of agriculture, domestic use and industry. The assessment units of Central Ground Water Board (CGWB) located in the states of Haryana, Himachal Pradesh, Delhi and Uttar Pradesh indicated plenty of replenishable ground water resources but because of the over-extraction beyond the annual ground water recharge, most of the groundwater resources in these areas have become over-exploited. Over-exploited units are also common in the western part of the country, particularly in Rajasthan, where the arid climate results in less recharge of ground water (CGWB, 2017).

The overall stage of ground water development in the country is 63%. The stage of ground water extraction is very high in the states of Delhi, Haryana and Rajasthan, where it is more than 100%, which implies that in these states the annual ground water consumption is more than annual extractable ground water resources. In the states of Himachal Pradesh and Uttar Pradesh, the stage of ground water extraction is between 70-100%. In rest of the states in Yamuna Basin, the stage of ground water development is below 70% (CGWB, 2017). Extraction is high in the states in Yamuna basin.

Climate change is another factor that is gradually impacting environmental flow in numerous direct and indirect ways.

1.11. YAMUNA RIVER BASIN

The extent of Yamuna Basin is 3,66,223 km^2 which is distributed over the states of Uttarakhand, Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh, Uttar Pradesh and Delhi NCT (Fig. 1.12). It constitutes 42.5% of the total Ganga river basin (CPCB, 1980).

In the plains, a significant proportion (10% in Madhya Pradesh and 25% in Rajasthan) is comprised of the Chambal ravines. Mewar plains region, formed by River Banas and its tributaries, is a vast, dry dissected terrain of Archaean gneiss in Rajasthan, with a gradual east- and northeast-ward slope between 500 and 280 m altitude. River Sind originates at Hatoli (District Vidisha, 543 m above msl) on the Malwa plateau. It is 415 km long, with a total catchment of 25,879 km^2 (7.5% of the Yamuna basin). River Betwa rises near Obaidullaganj (District Raisen) at 472 m altitude. After flowing for 564 km north-east and then north in the Bundelkhand region, it joins River Yamuna in the Hamirpur district at 85.5 m above msl. Its drainage basin covers an area of 47,970 km^2 (4.9% of the Yamuna basin).

The 360 km long River Ken, draining a catchment of 24,426 km^2 in the Malwa region, rises in Kaimur hills (district of Satna) and flows northwards before joining River Yamuna at Chilla near Fatehpur, 45 km below the confluence of Betwa. The different segments of Yamuna River are given in Table 1.1.

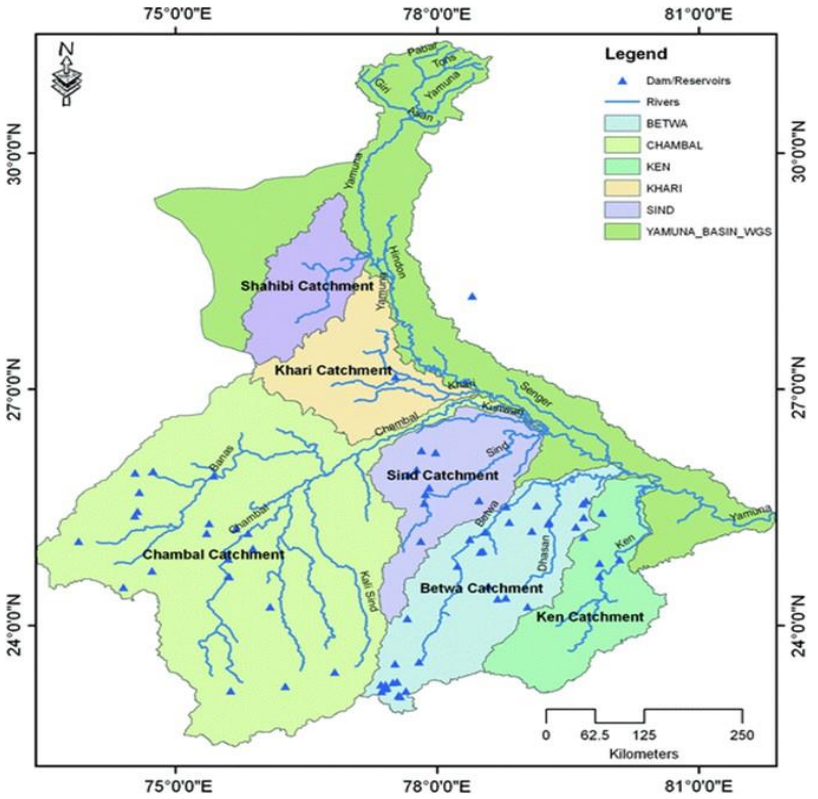


Fig. 1.12. Yamuna Basin
***(Source*:** http://www.yamunariverproject.org/)

Table 1.1. Segments of River Yamuna

Segment	Location	Length (km)
Himalayan	From origin to Hathnikund (earlier Tajewala) Barrage	172
Upper	Hathnikund Barrage to Wazirabad Barrage	224
Delhi	Wazirabad Barrage to Okhla Barrage	22
Eutrophicated	Okhla Barrage to Chambal Confluence	490
Diluted	Chambal Confluence to Ganga Confluence	468
Total		**1,376**

***Source*:** www.nihroorkee.gov.in

1.11.1. Significance of Yamuna Basin

The river water can be used either in abstractive form or non-abstractive form or as *in-situ* water uses, which are:

a) Abstractive Uses

The river water is abstracted at different locations for varied uses. At two places i.e. Hathnikund (earlier called Tajewala) and Okhla, the water abstraction is significant. The major points of abstraction and addition in water of Yamuna and annual abstraction at various locations are given in Table 1.2.

Domestic and Industrial Water Supplies

Significant amount of Yamuna water is used in urban areas like Delhi, Mathura, Agra and Prayagraj.

Table 1.2. Water Abstraction from Yamuna River

Location	River water abstraction (MLD)	Abstraction use
Hathnikund	20,000	Irrigation, drinking water supply and others
Wazirabad	1,100	Drinking water supply
Wazirabad to Okhla Stretch	5,000	Irrigation and others
Okhla to Etawah Stretch	400	Irrigation, drinking water supply and others
Etawah to Prayagraj Stretch	475	Irrigation, drinking water supply

Source: CPCB, 2006.

Irrigation

Irrigation is an important use of Yamuna river water. About 49% of irrigated land in Yamuna basin gets irrigation from surface water (Sharma and Kandal, 2011). Irrigation accounts for about 96% of the water usage of Yamuna (Mishra and Moza, 1997). At present four irrigation canals transport Yamuna water to the command areas (Table 1.3).

Table 1.3. Canals in Yamuna River Basin

Canal	Origin	Capacity (m^3 sec^{-1})	Area (ha.)	State
Western Yamuna Canal (WJC)	Right bank of Yamuna River at Hathnikund/ Tajewala Barrage	163	486,000	Haryana
Eastern Yamuna Canal (EJC)	Left bank of the River Yamuna at Hathnikund/Tajewala Barrage	85	191,000	Uttar Pradesh
Agra Canal	Right bank of Yamuna River at Okhla Barrage	63.5	138,000	Two district of Mathura and Agra in Uttar Pradesh
Gurgaon Canal	Takes off from Agra canal at a distance of around 8 km from its off take at Okhla Barrage	14.15	40,000	Interstate project between Rajasthan, Haryana and Delhi

Source: CPCB, 2006.

b) In-stream Uses

Hydropower: The total hydropower development potential in the Yamuna basin is about 1,300 MW of which one-third is utilised.

Fisheries: Pisciculture is done along the entire river stretch and tributaries on small scale in unorganized way.

Growing of plants: Illegal cultivation of vegetables is done in few areas in river bed when water recedes. Water hyacinth naturally occurs near barrages.

Navigation: Yamuna and its tributaries are not used for navigation except for local movement in areas of poor connectivity. Plans for water transport are being developed by government.

Human bathing and washing: Bathing and washing of human being is one of the most prevalent uses of Yamuna water. Much of this is attributed due to religious rituals and traditions (Fig. 1.13).

Recreational uses: Yamuna River is very rarely used for recreational purpose, though there is potential, subject to cleaning of river water.

Cattle bathing and washing: Water of Yamuna and its tributaries is used for bathing and washing of large population of cattle in areas adjoining these rivers (CPCB, 2006).



Fig. 1.13. Bathing and washing in River Yamuna
(*Source:* Project Team**)**

1.11.2. Yamuna Rivers and its Tributaries

Yamuna is one of the important and sacred rivers of India. It is the largest tributary of Ganga. It originates from Yamunotri glacier in the Mussoorie range of the lower Himalayas and after traversing 1,376 km joins the river Ganga at Prayagraj. At the confluence of the Ganga and Yamuna, the two rivers are visibly different as they merge; here Yamuna is greenish and more calm and deep than Ganga. The Prayagraj confluence is a place of religious importance in Hinduism and is referred to as Triveni-Sangam (confluence of 3 rivers) though the third (Saraswati) is not visible. Major tributaries of Yamuna include Hindon, Chambal, Mej, Kali Sindh, Banas, Sind, Betwa, Ken, etc. (Fig. 1.14 and 1.15).

1.11.3. Uniqueness of the River

Yamuna is the largest tributary of Ganga and constitutes 40.2% of the Ganga basin. Yamuna Basin is spread over 3,66,223 km^2 area and covers parts of seven states, *viz.*, Uttarakhand, Himachal Pradesh, Haryana, Delhi, Uttar Pradesh, Rajasthan and Madhya Pradesh. It originates at Yamunotri at 6,320 m altitude in Uttarakhand and travels 1,376 km before merging into Ganga at Prayagraj. At Prayagraj, Yamuna pours more water in Ganga than Ganga itself. Yamuna basin encompasses varied climatic, physiographic and economic conditions. Glaciers, snow-capped Himalayan mountains, eroded Aravalli slopes, lush green valleys, arid tropical plains, erosion-prone ravines, alpine grasslands, dense temperate to subtropical forests, weed-infested forests, scrub, fertile farmlands, wetlands, national parks, wildlife sanctuaries, urban aggregations, rural areas, industrial, religious, historical and eco-tourism places – a unique and complex mosaic of all such landscapes and features is found in Yamuna basin. Yamuna and its tributaries traverse 7,512.11 km amid such diversities and interact with the environment.

Lives and livelihood of large human population, and varied animals and plants in the Yamuna basin are directly or indirectly dependent on Yamuna and its tributaries.There are major concerns about quantity of water, environmental flow, soil erosion and sediment load, sewage discharge, agro-chemicals, pollution from industries, mining and general degradation of the environment in the Yamuna basin.

Two of the most polluted river stretches in the country – the Wazirabad-Chambal confluence stretch of Yamuna and the Hindon – contrast with the Chambal River which is believed to carry the cleanest water in the country. New Delhi, the national capital, and Agra, one of the most popular destinations among international tourists, are located adjacent to Yamuna. The poor condition of Yamuna at both these places instinctively gives an unwelcome indication about the poor state of river, forest and environment in India.

It is, therefore, imperative to propose forestry interventions to restore Yamuna. Restoration of a river in such varied site conditions presents a tough challenge. The presence of a large number of national-level scientific institutions, experts and administrators in the Yamuna basin, and a multi-stakeholder approach adopted in the preparation of the DPR provided effective support during preparation of the DPR.

1.11.4. Major Issues and Challenges for River Yamuna

Major issues confronting the Yamuna may be categorized as ecological flow and water quality. These indicators are, in turn, the result of several adverse factors. For instance, Yamuna River in Yamunanagar district of Haryana faces severe threat from mechanized and unsustainable stone and sand mining in violation of mining rules and guidelines. There are instances of blockage and change of active course of the river (Rawat, 2019).

a) Environmental Flow of Water

Since independence, the population in the Yamuna basin has increased by 3.5 times. The irrigated area in the basin has become twice as compared to the year 1950. Also, since 1950, the contribution of groundwater resources for irrigation has multiplied more than three-fold. The net share of surface and groundwater for irrigation has now become 37 and 57 % instead of 60 and 20 % in the 1950s (Sharma and Kansal, 2011). Unsustainable extraction of ground water and diversion of surface water have reduced water availability in many stretches of Yamuna River. Concerned at this, National Green Tribunal NGT) has directed Ministry of Jal Shakti to determine environmental flow (E flow) of Yamuna which would be enforced by state governments.



Fig. 1.14. Tons, a tributary of River Yamuna, flowing in Uttarakhand (*Source:* Project Team)



Fig. 1.15. Chambal, a tributary of River Yamuna, flowing in Uttar Pradesh (*Source:* Project Team)

Yamuna can be divided into four segments from the threats point of view (Table 1.4) and every segment faces its own kinds of challenges and threats (Rawat, 2015). During the non-monsoon period (November to May, as defined by Central Water Commission), the flow of Yamuna reduces significantly and some river stretches become dry, whereas, during monsoon period (June-October), the river receives significant amount of water, which is beyond its conveyance capacity resulting in floods. (CPCB, 2006).

b) Quality of Water

Jha *et al.* (1988) estimated sediment runoff in Yamuna. Maximum mass transfer was observed during the monsoon season. The sediment load was 58-86% of the total load carried by the river depending upon site, which was in turn related to lithology. Tributaries are chemically more active than the mainstream. In the upstream areas, physical weathering is more pronounced than chemical weathering. Upstream Yamuna erodes 1.04 mm yr^{-1} of the basin surface; the removal rate decreases downstream to 0.19 mm yr^{-1} at Prayagraj. The average chemical erosion rate (165 t $km^{-2}yr^{-1}$) and total erosion rate (973 t $km^{-2}yr^{-1}$) of the Yamuna are very high which are much greater than those of Ganga. At Prayagraj, the dissolved chemical load and sediment load attributable to the Yamuna were 42 M tonnes and 64 million tonnes, respectively.

More recent data on siltation in the Yamuna at basin scale is not available but there is no reason to believe that situation would have improved now. Mining and construction activities have, in fact, accelerated in the last three decades, which along with other factors related to catchment area degradation, might have increased the silt load in the river.

The Yamuna is one of the most polluted rivers in the country. The 22 km stretch of the Yamuna in Delhi contributes over 80 % of the pollution load of the entire length of the river. Domestic waste water (including sewage) forms the bulk of contaminants (Fig. 1.18). Current sewage generation in Delhi is about 327 crore litres per day against the present treatment capacity of 276 crore litres per day. Wastes from industries, agricultural run-offs, idol immersions and human ashes also pollute the Yamuna. Huge amount of money has been spent by the Government to clean the waters of the Yamuna, but a general lack of public awareness and various issues during implementation have led to poor results. There is little fresh, clean water in the stretch between Delhi and its confluence with the Chambal near Etawah.

Table 1.4. Major challenges faced by River Yamuna

S.no.	Segment	Area	Threat
1	Himalayan	Yamunotri, Uttarakand up to Hathinikund Barrage (HKB), Haryana	Receding glaciers, climate change deforestation, hydro power projects, dams and barrages, stone mining, dumping of debris and solid waste, etc.
2	Upper	HKB to Wazirabad Barrage, Delhi (WBD)	Lack of flow, water intensive and chemical farming, sand mining, industrial pollution, etc.
3	Middle	WBD to Chambal River Etawah, UP	Industrial and sewage pollution, floodplain encroachment, chemical farming, sand mining, etc.
4	Lower	Chambal River to confluence with River Ganga at Prayagraj	Flattening of ravines, sand mining, use of blasting and poison in fishing, etc.



Fig. 1.16. Sewage discharge in River Yamuna in Delhi
(*Source:* Project Team**)**

The high level of pollution has almost completely degraded the water quality of the river, rendering it unfit for human consumption. Aquatic species dwelling in the river, like the Gangetic dolphin and gharials, are nearly regionally extinct as a result. Besides this, the threat of climate change exists, which has the potential to melt large parts of the Yamunotri Glacier, drastically altering the water levels of the Yamuna.

1.11.5 Conservation Initiatives

India has recognized the conservation significance of its 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 was created. Even before this, the Wildlife (Protection) Act, 1972 provided much emphasis on all natural ecosystems (terrestrial, aquatic, and coastal and marine). The 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 protected areas (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 ecosystem/habitats and their associated biota.

a) Yamuna Action Plan

The Yamuna Action Plan (YAP), one of the largest river restoration projects in the country, is a bilateral project between the Government of India and Japan. The Japanese Government provided financial grant of 17.7 billion yen to carry out the project, under the Japanese Bank for International Cooperation (JBIC), and this project is being executed by the Ministry of Environment and Forests, National River Conservation Directorate and the Government of India. Under the Yamuna Action Plan Phase III, the

Delhi stretch is given prime emphasis as it is the most critical stretch of the Yamuna, where most of the city's sewage is dumped.

Yamuna Action Plan was framed to prevent pollution of river Yamuna. Its main objective was to improve the water quality of river and restore it to the desired bathing class. It envisaged pollution abatement schemes in 21 towns of 3 states. In addition, activities such as river front development, plantation along the river and public participation and awareness works have been taken up under the programme.

Yamuna Action Plan (YAP) was launched in 1993. The YAP has so far completed two phases as YAP-I and YAP-II. YAP-I covered Delhi, eight towns in Uttar Pradesh and six towns in Haryana. Under YAP II, emphasis was on the 22-km stretch of the Yamuna in Delhi. Now YAP-III is in operation at an estimated cost of Rs 1,656 crore.

Under the YAP-I and YAP-II, the cleaning of polluted Yamuna was carried out in line with the level of the biological oxygen demand of Yamuna. Under these two phases, 286 schemes, which also included 39 sewage treatment plants (STPs), were completed in 21 towns of Delhi, Uttar Pradesh, and Haryana at a cost of Rs 1,453.17 crore and sewage treatment capacity of 767.25 ML day^{-1} has been created. YAP-III was scheduled to end in April 2020.

A recent report by the Energy and Resources Institute (TERI) has stated that almost 3.46 BLd^{-1} (BLD) of fresh flow of water is needed to support aquatic life and day-to-day activities of the people living on the banks of the river Yamuna. The report also states that the YAPs may not be 100% successful in improving water quality but it is true that the water quality has not deteriorated after its implementation.

b) Afforestation and Conservation Activities

Afforestation activities are routinely undertaken by state forest departments in Yamuna basin every year. Plantation and moisture conservation activities are also carried out under MGNREGA and several other schemes. A 9,770 ha Yamuna Biodiversity Park has been established in Delhi, in phases beginning from year 2005, that harbours a rich diversity of plants, animals and microbes rendering multiple ecological service. A number of conservation and afforestation initiatives have already been taken up in different states, these are discussed in more detail in chapter 2. Forestry interventions with plantations of trees, shrubs and grasses along with conservation of soil, moisture, wetlands, wildlife and biodiversity in the river basin with active participation of the local community can help restore Yamuna.

1.12. LEGISLATIVE, POLICY AND INSTITUTIONAL FRAMEWORK FOR RIVERS IN INDIA

1.12.1. Legislative Framework

Water in India is governed under three different Acts: the Environmental Protection Act (1986), the River Boards Act (1956) and the Inter-State Water Disputes Act (1956). Other Acts and Regulations affect water resources in different ways by addressing its importance for agriculture, biodiversity and conservation and drinking water (Annexure1). These three Acts, however, have the broadest scope in terms of how they affect all aspects of water management in the country.

National Green Tribunal (NGT) is a body set up by the Govt. of India to address cases pertaining to environmental protection and conservation of natural resources in an effective and expeditious manner. The domain of NGT, therefore, covers environmental issues of rivers and natural water resources as well. The Supreme Court (2017) has now ruled that Yamuna and Ganga are not to be considered as living entities; in contrast the Supreme Court had earlier accorded same rights to these rivers as to a person.

1.12.2. Policy Directives

a) National Water Policy, 2012

National Water Policy, 2012 provided for determination of ecological needs of the river through scientific studies towards the goal of meeting developmental needs of India while providing economic and ecological goods and services (Table 1.5). A portion of river flows should be kept aside to meet ecological requirements, including base flow contribution in the low flow season through regulated ground water use. It also emphasised the need to map the aquifers to determine the quantity and quality of ground water resources. It also identified the need to undertake integrated watershed development activities to increase soil moisture and reduce sediment.

It further emphasizes the conservation of river corridors, water bodies and infrastructure in a scientifically planned manner through community participation. Pollution of water and water bodies should not be allowed and third-party periodic inspection should be carried out.

For proper institutional arrangements, the Policy envisaged Integrated Water Resources Management (IWRM) as approach that takes river basin/sub-basin as a unit for planning, development and management of water resources. It further prescribed assessment of surface and ground water status on 10-day basis every year for each river basin. Water budgeting and water accounting should be carried out for each aquifer.

Table 1.5. Water-related ecosystem services promoted through policy directives

Ecological services	Economic goods and services
Climate moderation	Food
Nutrient cycling	Drinking water
Waste treatment	Irrigation water
Flood control	Hydroelectricity
Groundwater recharge	Transportation corridors
Habitats for many species	Recreation
Genetic resources and biodiversity	Employment
Scientific information	

Source: Miller and Spoolman (2009)

b) Sustainable Development Goals

The establishment of Sustainable Development Goal (SDG) - 6 seeks to ensure availability and sustainable management of water and sanitation for all across the globe. The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, aims to address concerns about rising inequalities, natural resource depletion, environmental degradation and climate change. It further highlights the need for collection of detailed data (quantitative, geospatial and qualitative) to demonstrate accurate, contextualized understanding of water-related ecosystems. It seeks to halt/reverse ecosystem degradation and destruction. Targets were set for aquatic ecosystems such as vegetated wetlands, rivers, lakes, reservoirs and groundwater, and also for ecosystems occurring in mountains and forests that play a special role in storing freshwater and maintaining water quality. SDG target 6.6 directly contributes to wider improvements in ecosystem health, both marine (SDG 14) and terrestrial (SDG 15).

c) Integrated Water Resources Management (IWRM)

The International Conference on Water and the Environment through its Dublin Statement (1992) advocated IWRM which is based on the equitable and efficient management and sustainable use of

water. IWRM promotes the coordinated development and management of water, land and related resources to maximize the resultant economic and social welfare in an equitable and sustainable manner (Fig. 1.17).

An IRWM approach focuses on three pillars:

i. An enabling environment of suitable policies, strategies and legislation for sustainable development and management of water resources,
ii. putting in place the institutional framework and
iii. setting up the management instruments to help these institutions to do their job.

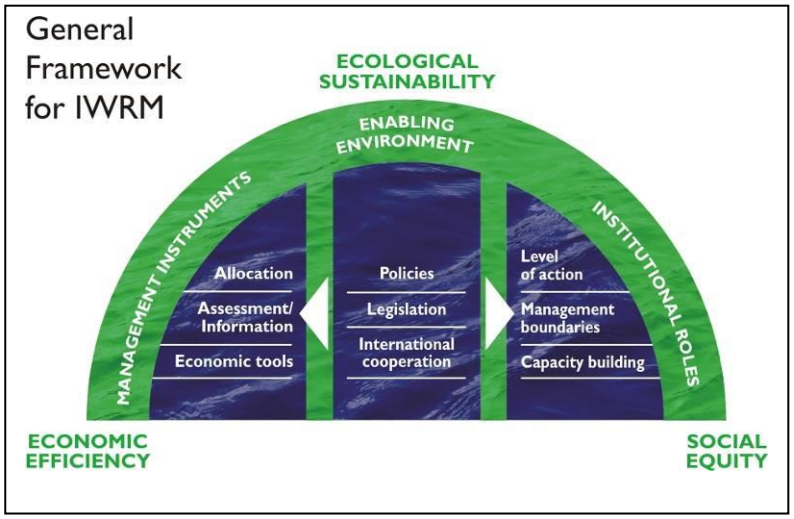


Fig. 1.17. General framework of IWRM.
(***Source:*** www.iwrm.nic.in)

1.12.3. Institutional Framework

a) Administration of Water Resources

Ministry of Jal Shakti is the nodal agency for water resources at the national level. Under it there are many technical agencies, such as the Central Water Commission (CWC) on management of surface water, Central Ground Water Board (CGWB) on ground water resource and National Water Development Agency (NWDA) to assess inter-basin transfer options. Oganisations such as Indian Water Resources Society, Indian National Committee for Irrigation and Drainage, Water and Land Management Institute, Central Water and Power Research Station and National Institute of Hydrology, Roorkee also work under the Ministry.

The *NITI Aayog* (previously known as Planning Commission) at the national level provides project clearance and approves financial allocation to various projects. The implementation at the ground level is done by the public works, irrigation, or water resources departments at the state level.

b) River Basin Management

River Basin Organizations (RBOs) have been created to help bring about IWRM and improve water governance in trans-boundary water basins. They work to achieve inter-state and centre-state coordination. These include various river boards created under the River Boards Act of 1956, the National Water Resources Council (NWRC) set up in 1983, and the National Water Board (NWB) set up in 1990. Ganga Flood Control, Upper Yamuna River Board and Betwa River Board are the major RBOs that work in the Yamuna basin. Their functions include preparation of basin level and regional plans, allocation of water supplies for different uses, generation of hydroelectric power, maintenance of

multi-purpose projects, etc. Many other agencies work on aspects of river basin management such as drinking water and sanitation, wasteland development, soil and water conservation, pollution control, etc.

c) River and Aquatic Resource Conservation in Forest Landscape

While Ministry of Environment, Forest and Climate Change (MoEF&CC) is entrusted with conservation and management of forests, which influence rivers in several ways, the National River Conservation Directorate (NRCD) under this Ministry is implementing the centrally sponsored schemes of National River Conservation Plan (NRCP) and National Plan for Conservation of Aquatic Ecosystems (NPCA) for conservation of rivers, lakes and wetlands in the country. NRCD provides financial assistance under the National River Conservation Plan to the state governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches.

1.13. DPR ON 'REJUVENATION OF YAMUNA RIVER THROUGH FORESTRY INTERVENTIONS

The following section highlights how 'forestry interventions' on scientific basis are pertinent to river conservation, specifically for Yamuna rejuvenation.

1.13.1. From 'Isolationist' to 'Holistic' Approach

Isolationist approaches have been adopted for research on rivers, their management and conservation. The much desired holistic river basin approach has been 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, livelihoods and biodiversity conservation also have been overlooked. Additionally, climate change may also alter the contribution of forests in regulating the water flows and influencing the availability of water resources. Forestry interventions were envisaged for Ganga by FRI in 2016 through a DPR which brought to focus a plan for forestry sector across the states in Ganga riverscape (excluding Yamuna basin) in consultation with various other related sectors (FRI, 2016). The same approach has been adopted in this DPR for rejuvenation of River Yamuna. The availability and quality of water in the Yamuna have been increasingly threatened by poor base water flow, over use, sedimentation and pollution. Base water flow and sedimentation are strongly influenced by the extent and condition of forests in the upstream and downstream areas. Participation of forest departments and various other stakeholders in the consultation and preparation process of this DPR has been ensured to provide a holistic approach.

1.13.2. Funding Agency Initiative

MoEF&CC is the apex nodal agency of the Central Government for the planning, promotion, co-ordination and overseeing the implementation of country's environmental and forestry policies and programmes. It implements policies and programmes relating to conservation of natural resources, including water-bodies. As a part of MoEF&CC, the National Afforestation and Eco-Development Board (NAEB) promotes afforestation, tree planting, eco-restoration and eco-development activities in the country and lays special emphasis on the degraded forest areas and lands adjoining the forest areas. The task of preparing the Detailed Project Reports (DPRs) on rejuvenation of major Indian rivers through forestry interventions has been assigned to ICFRE by NAEB.

1.13.3. Forest Research Institute

The FRI has an impressive history of providing scientific solutions to the issues of forests and forestry relevant to the Indian sub-continent. Since its establishment in 1906, FRI has been providing services

based on sound scientific and technological basis, with a multidisciplinary approach, to various forestry sectors through its scientists and practicing foresters. In addition a Detailed Project Report (DPR) on "Forestry Interventions for Ganga" under *Namami Gange* Programme of Ministry of Water Resources, River Development and Ganga Rejuvenation, GoI was also prepared by Forest Research Institute, Dehradun in 2016. The DPR is now in implementation phase by NMCG, New Delhi and till 2018 about 30,000 ha plantations of different species have been created in the five stakeholder states of Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal since 2017. Now, FRI has prepared this DPR on "Rejuvenation of River Yamuna through Forestry Interventions" under the umbrella of ICFRE, Dehradun on directions of MoEF&CC.

1.13.4. Logical Framework Approach

Since humans interact with water in a wide variety of ways and influence the water environment and river management, the Logical Framework Analysis (LFA) approach was adopted for the preparation of present DPR. Logical Framework Approach is a multi-pronged and multi-stakeholder consultative process. It is an interlocking set of concepts that, when used together, allow project planners to identify the logical linkages between a set of means and a set of ends (Coleman, 1987). The Logical Framework Analysis (LFA) approach offers a systematic and logical approach for designing multifaceted and complex projects for result-based management (FCI, 1970; Ortengren, 2004; Puranik and Dhadwad, 2015). A logical framework or logframe thus developed in the process of preparation of present DPR is presented in Annexure 1.

1.13.5. Vision, Mission, Goals and Objectives

The vision, mission, goals and objectives of DPR preparation on "Rejuvenation of River Yamuna through Forestry Interventions" are listed as under:

a) Vision

To restore degraded forests in catchment of Yamuna and its tributaries to improve ecological flow and quality of river water

b) Mission

To establish /develop multi-tier forest of native vegetation, improve surface water flow and ground water recharge in the catchment of Yamuna and its tributaries

c) Goals

5. To propose appropriate treatment models (technical prescriptions) for prioritised sites in the riverscape in consultation with SFDs, other stakeholders and experts.
6. To enhance capacity of SFDs to undertake the prescribed project activities in natural, agricultural and urban/peri-urban landscapes.
7. To propose implementation mechanism to MoEF&CC.
8. To suggest measures for treatment of necessary sites in the remaining part of the catchment area of Yamuna and its tributaries.

d) Objectives

1. Review and assess the existing situation of river basin, past river management and implications and lessons learned,
2. identify and involve stakeholders and build consensus for design and development of strategies and approaches,
3. assess ongoing forestry activities of the states engaged in the river management programme (s),
4. assess potential and possibilities for regeneration, improvement, and restoration of forest catchments,

5. assess the conditions of riparian forests and potential of biological filters,
6. examine the possibility of allied and other income generation activities,
7. assess the potential of cultivation of medicinal plants and restoration of conservation areas and identify appropriate species and suitable sites,
8. identify research and monitoring needs and develop a strategy for future research and monitoring and
9. formulate strategies, develop approaches, and plan activities for project implementation.

1.13.6. Phases and Organization of DPR

The present DPR preparation phase is of 18 months duration. After the approval and fund allocation process, the DPR will be implemented in two phases: (i) Project Implementation Phase (Phase I) of five years followed by (ii) Maintenance Phase (Phase II) of four years.

The present Detailed Project Report (DPR) has been prepared in two volumes. Volume I deals with the main DPR while the Volume II contains separate DPRs for seven stakeholder states through which the Yamuna and its major tributaries pass.

Chapter 1 entitled 'Introduction' highlights the complexity and dynamic nature of rivers and its linkages with forests, other lands, and human well-being, 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 describes the river basin and its environment, i.e., the existing environment (physical, biological, and socio-economic) in the broader context of the Yamuna basin in stakeholder states. Chapter 3 highlights the approach and methodologies adopted i.e., consultation process, riverscape delineation, data collection, prioritisation of sites, etc. for seven states along the course of River Yamuna. Chapter 4 deals with the legislations, policies and institutional framework pertaining to the theme of the DPR. Chapter 5 describes the goals and objectives of forestry interventions and the adopted strategies, plantation and conservation models. 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 the proposed forestry interventions in respect of water, carbon sequestration, etc. References are provided at the end. As already stated, Volume II incorporates state-wise DPRs concerning the seven states of the Yamuna riverscape for implementation of the project.

1.13.7. Outcome

Forest catchments are regarded as 'sponges' that store rain water and slowly release it to maintain groundwater and streams during dry periods (Hamilton and King, 1983). The benefit assessment framework of the Yamuna DPR will have two major components namely: Water quantity and Water quality.



Fig. 1.18. Betwa, a tributary of River Yamuna, flowing in Uttar Pradesh (*Source:* Project Team)



Fig. 1.19. River Yamuna at Chibro, Uttarakhand (*Source:* Project Team)

The first component will aim at improving ecological flow of water to water availability during lean periods. The second component will focus on checking soil erosion and reducing sediment load in the Yamuna basin. The rehabilitation of forest watersheds can reduce the rate at which sediments detach and move down the slope in the river basin. The initiative of rejuvenation of the Yamuna through forestry interventions will contribute to additional carbon sequestration through afforestation activities. Forestry operations during project implementation as well as afterwards as a sequel to forestry interventions will contribute to livelihood generation. All such potential benefits have been quantified in the DPR.

Chapter 2
YAMUNA BASIN AND ITS ENVIRONMENT

Water is an absolute necessity of all life forms and is required for agricultural, domestic, industrial and other economic activities besides supporting ecological processes. Only 3% of water on the surface of the earth is fresh water. Two-thirds of the fresh water is present in form of ice bodies such as polar ice caps, glaciers and snow-covered mountains. Water in streams, rivers and lakes and groundwater are also part of fresh water resources. Fresh water is a renewable resource, but its availability is decreasing due to overuse and misuse.

The availability of water greatly varies in time and space (Rai *et al*., 2011). Rivers are the most important freshwater resource for man. India has 14 major rivers that contribute to 85% of the total surface flow (Mutiyar *et al.*, 2018), and have huge historical, social, environmental and economic significance (Kumar *et al.,* 2017). Social and economic development has been largely related to the availability and distribution of fresh waters contained in riverine systems. Meybeck *et al.* (1996) listed the following major uses of river water:

1. Sources of drinking water supply
2. Irrigation of agricultural lands
3. Industrial and municipal water supplies
4. Industrial and municipal waste disposal
5. Navigation
6. Fishing, boating and body-contact recreation, and
7. Aesthetic value

The first two sections of this chapter dwell on generalized concept of rivers, their environment and management to build a backdrop to understand various aspects of Yamuna, its tributaries and their confluences. In subsequent sections, the Yamuna Basin and its environment have been described in detail to provide a basis for developing methodology and strategies for rejuvenation of Yamuna.

2.1. RIVER AND RIVER BASIN

The river basin is the entire geographical area drained by a river and its tributaries. All the water of a river basin eventually drains into a larger river. The term watershed is used to describe a smaller area of land that drains to a smaller stream, lake or wetland. There are several smaller watersheds within a basin.

In comparison to small volumes of water in streams, rivers carry relatively large volumes of water moving within a visible channel, including sub-surface water and their associated floodplain and riparian vegetation. The characteristics of a river are related to several features such as the size, form, geological characteristics and climate of the basin (Meybeck *et al.*, 1996).

The course of a river can be divided into three stages: youth, maturity and old stage. Youthful river (a river that has steep gradient, flows fast and erodes deeper than wider) or young parts of a river are usually found in mountainous areas where slopes are steep and water flows rapidly (Centro Civiltà dell'Acqua, 2008). Old-stage river is usually widest and occurs where the terrain is flattest. There is often a river delta in a part of this stage; the delta is a large, silty area where the river splits into many different slow-flowing channels that have muddy banks (Fig. 2.1). Between the above two stages is the mature stage in which the slope becomes gentler and the river becomes much wider than young stage (Centro Civiltà dell'Acqua, 2008).

A river ecosystem consists of interrelated living and non-living physical environment. Flow is the central driving force of river ecology. Geomorphology represents the configuration of the earth's surface, the distribution of the land, water, etc. and is largely determined by topography and geology. Geomorphology considerably governs the water flow across the landscape. 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. These organisms interact with non-living systems. 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.

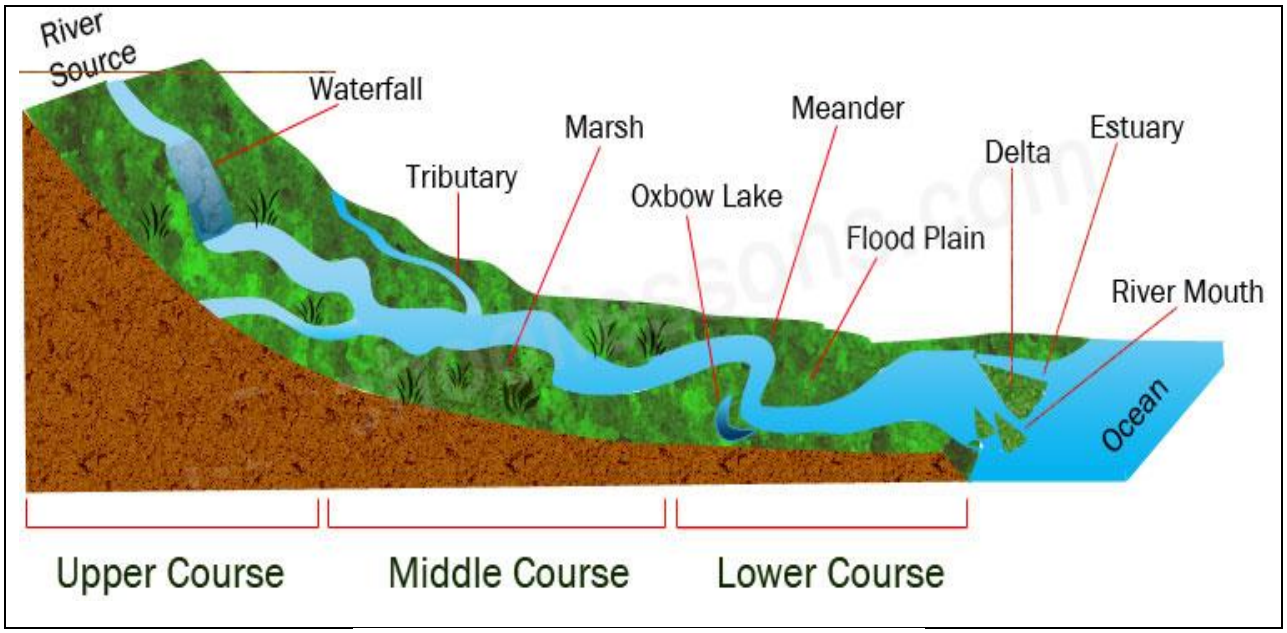


Fig. 2.1. River and its course and stages
(***Source:*** https://k8schoollessons.com/courses-of-a-river)

2.1.1. Human-induced Changes

The basin and, more specifically, the course of a river, alter due to human activities. Construction of dams drastically changes the river's hydrology and connectivity. Flooding disasters always prompt man to adopt more measures to keep water out of habitation and agricultural areas. Such drastic human influences have resulted in the loss of biodiversity, decline in the populations of migratory species including commercial fish, and reduced landscape connectivity and ecological functioning (Nienhuis *et al.*, 1998; Smits *et al*., 2000).

Fig. 2.2. is a representation of two important human impacts, one, water loss on and in the land (underground) and the other, changing habitat; the former leads to stream loss while the latter changes potential vegetation. Problems of stream loss and vegetation change in the basin thus can be addressed by addressing the causative factors. The magnitude of change on temporal scale is still not predictable (Haslam, 2006). The improvement of environmental flow along with water quality can, therefore, be achieved through forestry interventions like afforestation and soil/moisture conservation. The selection of plant species and their planting design (model) should suit local conditions, and should be amalgamated with appropriate soil/moisture conservation measures. It is expected that such measures

while improving the vegetation cover in the basin, will also check soil erosion and reduce siltation in the upstream (Fig. 2.3) and enhance water quality and improve ground water regime downstream.

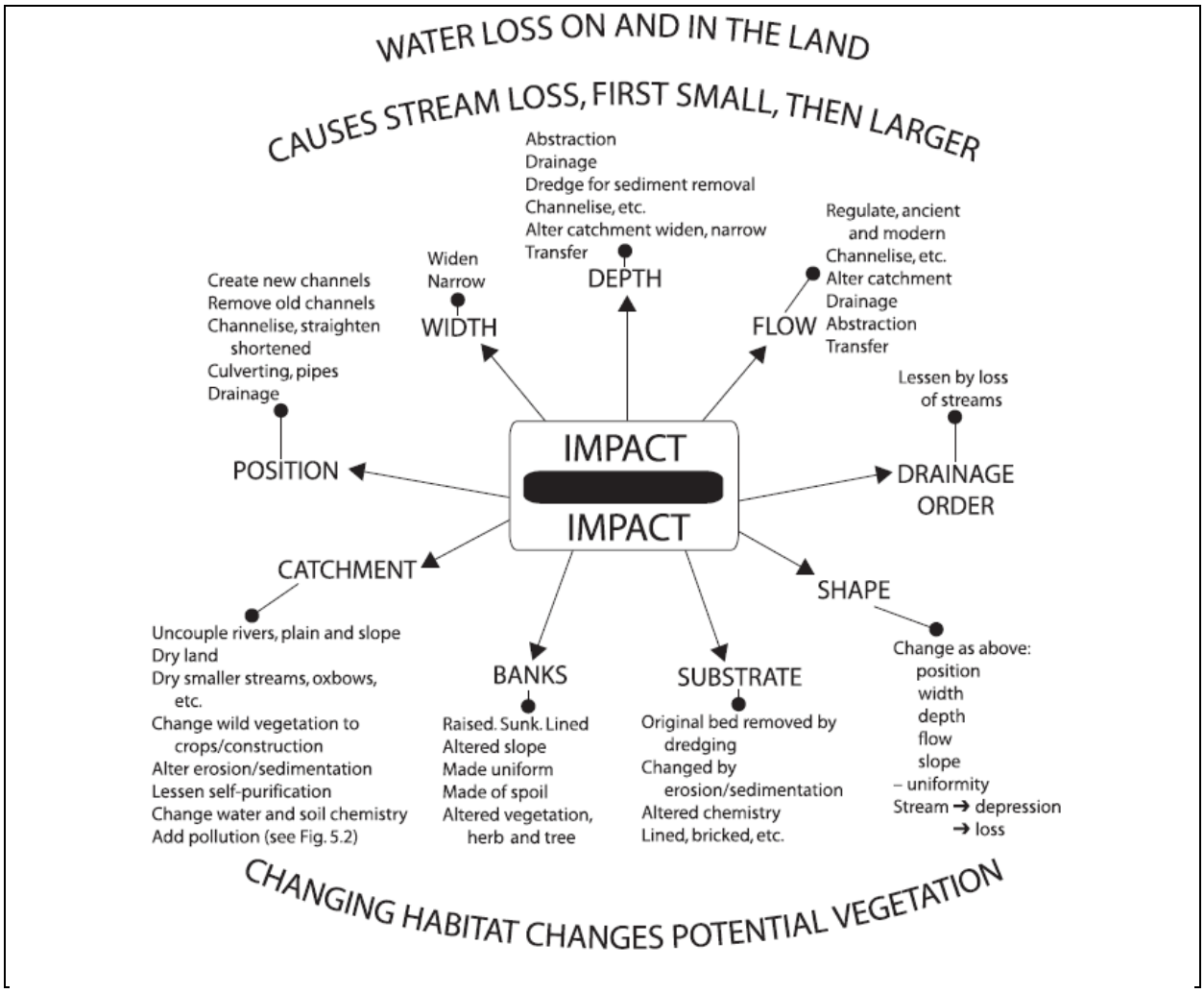


Fig. 2.2. Human impacts: Effects on river size, shape and position. (Representative, not including all types and variations)
(***Source:*** Haslam 2006)

The National Research Council (2007) in the USA identified three topical areas in river science namely, (i) environmental flows and river restoration, (ii) sediment transport and geomorphology and (iii) groundwater-surface water interactions which may need special emphasis globally. There is no denying the fact that human and natural actions have caused the loss or degradation of riverine habitat. The assessment of ecological and sociological impacts of climatic variability is even more challenging. A large-scale change in land use has already taken place in India and many parts are fast getting urbanized. The quantity and quality of river flows are strongly linked to such changes. A complete understanding of the impacts of these changes is necessary for a sustainable water management, flood risk evaluation, and management of erosion and siltation in river basins.

Despite several years of continued efforts and large-scale projects, the river water quality in several stretches of important rivers in India is affected by high pollution load - industrial as well as domestic (Sinha *et al.*, 2013). Any major river rehabilitation project can take a minimum of 25-30 years

to allow the river to return to a desired (but not necessarily pristine) state, hence, sustainability of efforts is essential (Sinha *et al.*, 2013).

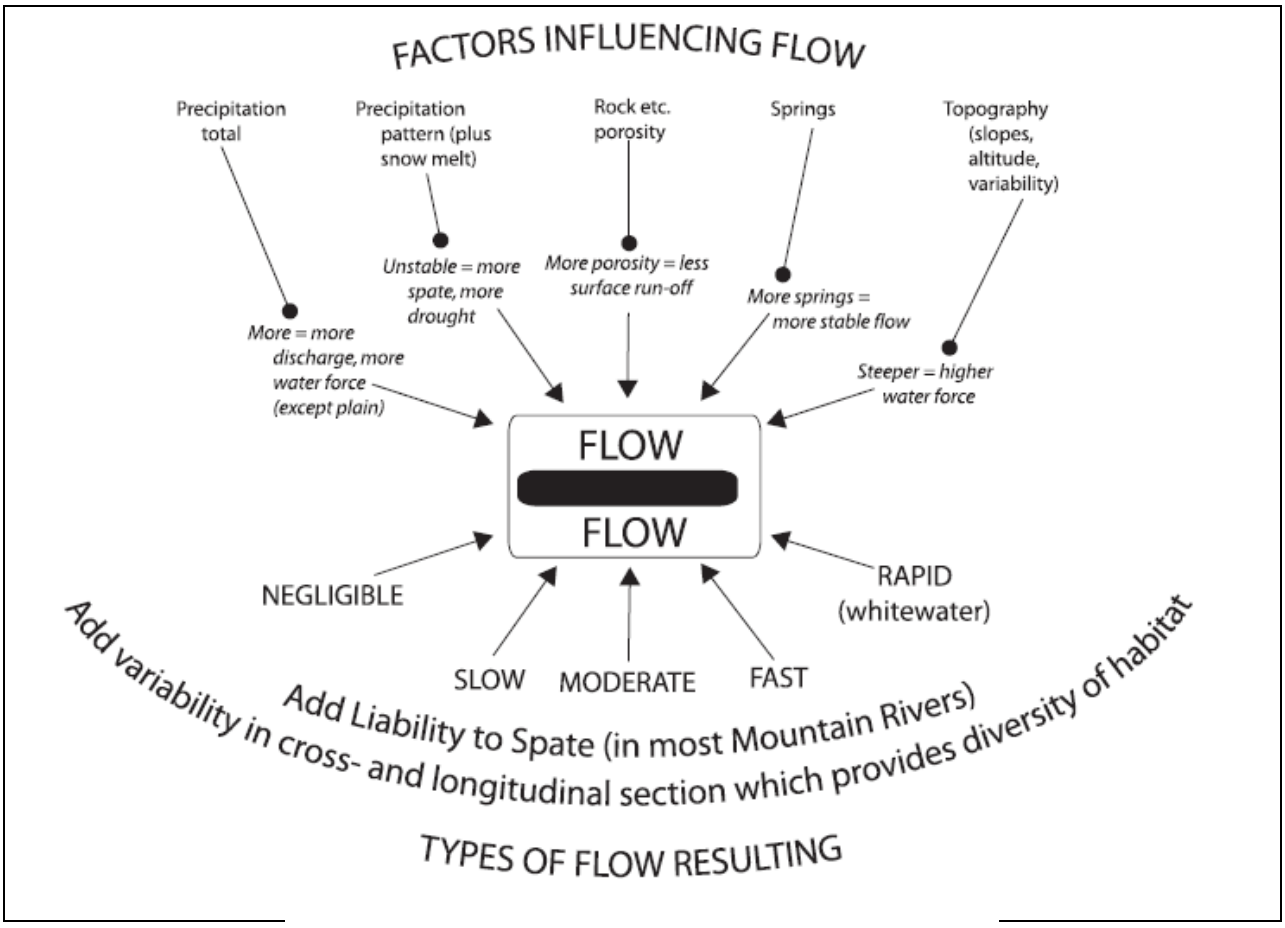


Fig. 2.3. Important factors influencing water flow
(***Source:*** Haslam, 2006)

2.1.2. Himalayan River Systems

The total annual flow availability from the rivers draining from the Himalayas as well as Peninsular India is estimated at about 1,870 km^3 yr^{-1} out of which the Himalayan rivers constitute the major share of 1,180 km^3 yr^{-1} (Fig. 2.4; Kumar *et al.,* 2005). Utilizable water resource is the quantum of water which can be extracted from the place of natural occurrence. Of the total available annual flow from rivers, the 'utilizable' flow is estimated at 690 km^3 yr^{-1} out of it around 320 km^3 yr^{-1} comes from the Himalayan rivers. This data reflects the crucial role of the Himalayan Rivers in freshwater supply.

In view of uncertain availability of water and likely increase in future demands, fresh water is a 'limited' resource. The significant role of Himalayan river systems underscores the need to adopt sustainable river management practices for promoting sustainable flow and river rehabilitation on a long-term basis (Sinha *et al.,* 2013).

2.1.3. Tributaries and Confluences

Confluence is the place where two ricers meet. The quantity and quality of water in the main river downstream of the confluence undergoes marked change vis-à-vis upstream. Two confluences are well

documented in the literature: the confluence of Chambal and Yamuna in district Etawah and the confluence of Yamuna in Prayagraj, both in Uttar Pradesh. The quantity and quality of Yamuna water is tremendously enhanced at Chambal confluence. Sharma and Chaudhary (2010) mentioned that water quality and the very existence of Yamuna downstream of Delhi (NCT) rely on Chambal due to sub-tributaries coming from Rajasthan and Madhya Pradesh. The waters of Yamuna and Ganga at Prayagraj confluence reflect differences in speed of flow and hue: During non-monsoon season the Yamuna water is slower and less clear than Ganga water.

2.2. RIVERSCAPE

The riverscape is the sum total of area adjoining the river comprising features found on or along the river; the features are mostly natural, however, artificial features may also be included. Riverscapes are important as they link terrestrial, freshwater and coastal marine systems and nearly all aspects of human culture in open transport and migration routes.

The riverscape is somewhat like the landscape, but it inhabits a different kind of space, has different kinds of geographical rules and forms, has different human-environmental interactions than do landscapes, and it is essentially unexplored. The river and riverscape have been the places of evolution of civilisation. Haslam (2006) defined riverscape to have the structures and functions stated in the following two sub-sections:

Structure

Passing from centre outwards first, the riverscape is described in terms of size, shape, pattern of:

1. the river and of what grows in it;
2. the riverside, narrow or wide, what grows on it (e.g., wood, flooded wetland, grass, crops) and what has been constructed or installed on it;
3. the land beyond, which may usually rise to well-marked hills or continuing lowland, or even flood plain for the extent of the riverscape view. This also has vegetation and the associated animals. These may be native plants, varying from large, like trees and forests. They may be meadow or pastures of traditional, rather than of native species. They may be agricultural crops Haslam (2006).

The underlying structure of topography and geology, soil and water has on it (and in it) the natural structure of vegetation, and the imposed structures of people, from isolated farms nestling in valleys to towns, transmission lines for mobile telephone masts, from canals to deep abstraction boreholes and sewage treatment works.

Function

The river and riverscape serve as hydrological and physical landscapes which harbour vast amounts of renewable and non-renewable resources, serve as plant and animal habitats (aquatic and terrestrial), sustain ecosystem processes, perform environmental services and support varied economic and societal functions.

2.3. RIVER YAMUNA

The Yamuna is the fifth longest river of India and is the largest tributary of the Ganga. The length of the Yamuna from origin to its confluence with the Ganga at Prayagraj is 1,376 km. The Tons, Giri, Hindon, Chambal, Betwa, Sind and Ken are some of the important tributaries of the Yamuna.

2.3.1. Historical and Cultural Perspective

For the past many centuries, the river has been integral part of Indian culture. The Yamuna is also called Jamuna and Kalindi at different places along its course. It has been sustaining means of livelihoods to

millions. Many people in pursuit of spiritual inspiration venerate it with great hope. But at present, the river is more in the news for its highly polluted state (Rawat, 2015).

The origin point of Yamuna is famously known as *Yamunotri* shrine. It is listed among four prominent pilgrimage places (*Char Dham)* in Uttarakhand. Paonta Sahib, Karnal, Delhi, Agra, Mathura, Prayagraj, etc. are prominent places associated with Yamuna in the historical and religious texts. There are several sites of cultural importance along its numerous tributaries.

2.3.2. Yamuna Basin

The Yamuna River system covers parts of the states of Uttarakhand, Himachal Pradesh, Haryana, Uttar Pradesh, Rajasthan, Madhya Pradesh and the entire state of Delhi. Out of the total catchment area of 8,61,404 km^2 of the Ganga basin, the Yamuna basin is spread over 3,66,223 km^2 area. This is 42.5% of the total Ganga River Basin and 10.7% of the total geographical landmass of the country. The basin area includes catchment area of 3,45,848 km^2 and Yamuna river area of 20,375 km^2). The Chambal is the most important tributary occupying nearly half of the basin area of Yamuna (Table 2.1. and Table 2.2; Fig. 2.4. to 2.6).

GIS-assisted assessment during preparation of the DPR based on Micro-watershed Atlas of India revealed that Yamuna basin is spread over an area of 3,30,372.03 km^2. On the basis of approved project proposal, directions from the Indian Council of Forestry Research and Education (ICFRE) and consensus emerging in the exhaustive consultations with various stakeholders, a riverscape covering an area of 44,070.77 km^2 falling in the seven states in the basin has been selected for the purpose of proposed forestry interventions (Table 2.1 and 2.2).

Table 2.1. Area coverage under the Yamuna basin and the Yamuna Riverscape

S. no.	Consideration unit	Area	Reference
1.	Yamuna Drainage Basin	3,66,223 km^2 drainage basin (3,45,848 km^2 catchment area + 20,375 km^2 water spread area)	Rai *et al*., 2011
		3,30,372.03 km^2 (sum of 44070.77 km^2 riverscape area + 286301.26 km^2 basin beyond riverscape)	Analysis under the DPR based on Micro-watershed Atlas of India, SLUSI
2.	Yamuna Riverscape	44070.77 km^2	Analysis under the DPR based on Micro-watershed Atlas of India, SLUSI

2.3.3. Yamuna - Main Stem and Tributaries

The Yamuna is of glacial origin and originates from the Yamunotri glacier (Saptrishi Kund) near Bandarpoonch peaks (31° 1' 36" N, 78° 34' 19" E) in the lower Himalayas at an elevation of about 6,320 m above mean sea level in Uttarkashi district, Uttarakhand. The river flows south-southwest through narrow and steep valleys until Kalsi, Uttarakhand (45 km west of Dehradun) where it meets River Tons. Along its sojourn through the Himalaya, numerous small tributaries and steams (locally called *gad*) meet it, transforming it into a sixth-order river (Gopal and Chauhan, 2007).

In the upper Himalayan ranges, the main tributaries that join the Yamuna are Rishi Ganga and Hanuman Ganga. Tons, Giri, Bata and Asan join Yamuna in the lower Himalayan ranges. Yamuna flows on Uttarakhand-Himachal Pradesh border and traverses to Haryana.

Table 2.2. Area coverage under important sub-basins

S.no.	State	Area in Yamuna Basin (km^2)	Area in major sub-basin (km^2)					
			Hindon	**Chambal**	**Sind**	**Betwa**	**Ken**	**Others**
1	Uttarakhand	3,771 (1.1%)	-	-	-	-	-	3,771
2	Himachal Pradesh	5,799 (1.7%)	-	-	-	-	-	5,799
3	Uttar Pradesh	70,437 (20.4%)	7,083	452	748	14,438	3,336	44,380
4	Haryana	21,265 (6.1%)	-	-	-	-	-	21,265
5	Rajasthan	1,02,883 (29.7%)	-	79,495	-	-	-	23,388
6	Madhya Pradesh	1,40,208 (40.6%)	-	59,838	25,131	33,502	21,090	647
7	NCT- Delhi	1,485 (0.4%)	-	-	-	-	-	1,485
	Total catchment area	**3,45,848 (100%)**	**7,083 (2.0%)**	**1,39,785 (40.50%)**	**25,879 (7.50%)**	**47,940 (13.90%)**	**24,426 (7.10%)**	**1,00,735 (29.10%)**
	Yamuna water spread area	**20,375**	-	-	-	-	-	-
	Total basin area	**3,66,223**	-	-	-	-	-	-

Note: Figures in parentheses are percentage contribution to catchment. ***Source:*** Rai *et al.* 2011; CPCB 2006

Yamuna River forms a common boundary between Haryana and Uttar Pradesh for nearly 320 km, flows through Delhi (NCT) for about 40 km, and nearly 970 km through Uttar Pradesh (Kumar *et al.*, 2005). The Tons, the largest Himalayan tributary of the Yamuna, joins it downstream of Kalsi. The Giri, another mountainous tributary rises in district Shimla, Himachal Pradesh and joins Yamuna near Paonta Sahib, district Sirmaur, Himachal Pradesh. Hindon River joins Yamuna in Gautam Buddha Nagar district, Uttar Pradesh near border with Delhi (NCT). In Delhi, the Sahibi waters flow into the Yamuna through the Najafgarh drain. Beyond Delhi, Yamuna enters Uttar Pradesh and continues to flow southwards to Mathura for a distance of about 203 km.

From Mathura onwards, Yamuna flows in a south-westerly direction within Uttar Pradesh through Agra, Mainpuri, Etah, Kanpur and Prayagraj districts before joining the Ganga at Sangam near Prayagraj city. Chambal, Sind, Betwa, and Ken rivers join Yamuna River from south/south-west direction. These tributaries originate in the Vindhyas (Chauhan, 1992).

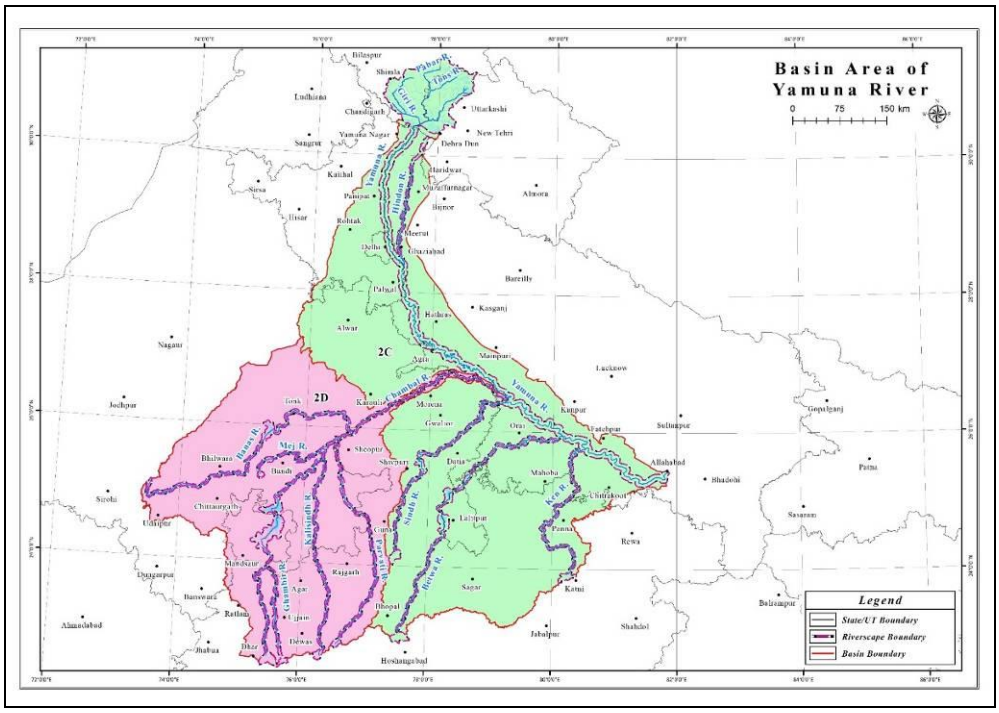


Fig. 2.4. Yamuna basin and riverscape with tributaries. The symbols '2C' and '2D' indicate Yamuna and Chambal basins, respectively
(*Source:* Project Team)



Fig. 2.5. Yamuna in Himalaya, Uttarakhand
(*Source:* Project Team)



Fig. 2.6. Heuglin's gull or Siberian gull at Prayag Triveni Sangam, Prayagraj
Source: https://www.dreamstime.com/heuglin-s-gull-siberian-migrated-bird-ganges-river-allahabad-prayag-triveni-sangam-image140462102.

The main tributaries of Yamuna are Rishi Ganga, Hanuman Ganga, Tons, Giri, Gambhir, Godar, Hindon, Jalai, Kalisindh, Mej, Pabbar, Parvati, Sind, Chambal, Banas, Betwa, and Ken. Tons in the hills and Chambal in the plains are the most important tributaries from standpoint of water discharge. At the point of confluence with Yamuna, Chambal contributes 5-10 times more water than Yamuna itself; however, since 2003 significant reduction has taken place in discharge from Chambal (Rai *et al.*, 2011). The length of the Yamuna main stem and its major tributaries are shown in Table 2.3. A map showing the riverscape and the major tributaries considered in the current DPR of Yamuna basin is given in Fig. 2.5.
A brief description of the tributaries is given hereunder:

Rishiganga
The Rishiganga, is the main tributary of Dhauliganga. It originates from Rishi glacier and takes water from Uttar Nanda Devi, Dakshin Nanda Devi and Uttar Rishi glacier. The river flows almost all in a straight line westward and makes its confluence with Dhauli-Ganga. It has a length of 5.64 km.

Hanuman Ganga
Hanuman Ganga is a tributary of River Yamuna in Uttarakhand and is 8.03 km long.

Tons
The Tons is the longest tributary of Yamuna in Himachal, rises at an elevation of 3,900 m and joins Yamuna downstream of Kalsi. It passes through Shimla and Sirmaur districts and Jaunsar-Bawar

region of district Dehradun. For most of its length, it forms the boundary between the states of Uttarakhand and Himachal Pradesh. It joins Yamuna near Khodar Majri in district Sirmaur, Uttarakhand (State of the Rivers Report for Himachal Pradesh, 2016). It has a total length of 205.66 km.

Giri

Giri or Giriganga rises from Kupar peak near Jubbal town. It flows through the Shimla hills in a South-Eastern direction and divides Sirmaur district into equal parts (known as Cis-Giri and Trans-Giri regions) and joins Yamuna upstream of Paonta Sahib. It flows for 148.66 km in Himachal Pradesh.

Pabbar

Pabbar River flows 67.32 km in Himachal Pradesh and Uttarakhand.

Jalal

It flows in Himachal Pradesh and has a total length of 35.96 km.

Hindon

Hindon originates in the Shiwalik hills in Saharanpur district, Uttar Pradesh and runs parallel to Yamuna along its 286.69 km long route. Hindon joins Yamuna on its left bank upstream of Delhi in district Gautam Buddha Nagar, Uttar Pradesh.

Chambal

It originates at Janapao hill near Mhow, Madhya Pradesh. It enters Rajasthan at Chaurasigarh and Chambal flows along the eastern border of Rajasthan with Madhya Pradesh and enters Uttar Pradesh where it meets Yamuna. The entire Chambal river basin in Madhya Pradesh, Rajasthan and Uttar Pradesh extends to around 93 tehsils and 24 districts (Hussain and Badola, 2001). The Chambal River flows a total length of 1,336.49 km before merging in Yamuna.

Sind

Sind River originates in Vidisha district and travels a length of 484.14 km in Madhya Pradesh and Uttar Pradesh. The major tributaries of Sind are Mahuar, Parbati, Pahuj and Kunwari (Misra, 2016).

Betwa

Betwa originates Bhopal district, Madhya Pradesh and merges into Chambal near Hamirpur district, Uttar Pradesh. The length of the Betwa in the two states is 769.56 km.

Ken

Ken rises in a watershed near Chiruhala in Katni sistrict, Madhya Pradesh (Misra, 2016) and enters Uttar Pradesh in Bundelkhand region. It flows a total length of 445.23 km in Madhya Pradesh and Uttar Pradesh.

Banas

Banas originates in the Aravalli hills near Kumbhalgarh in Rajsamand district, Madhya Pradesh. It drains a large part of Mewar plateau and is 555.24 km in length. It is the major tributary of Chambal River (Dubey *et al.*, 2015).

Gambhir

The total length of the river is 211.41 km in Rajasthan and Madhya Pradesh.

Kalisindh

It originates in the Vindhya hills in Madhya Pradesh and enters Rajasthan in Jhalawar district. After flowing for about 408.16 km, it joins Chambal in Kota district (Jain *et al.*, 2007). The length of Kalisindh in Rajasthan is 273.45 km.

Table 2.3. Length of Yamuna River (main stem) and major tributaries

S. no.	River	Delhi	Haryana	Himachal Pradesh	Madhya Pradesh	Rajasthan	Uttar Pradesh	Uttara-khand	Total
1.	Yamuna	48.53	313.12	18.13	-	22.98	1253.04	147.22	1803.02
2.	Banas	-	-	-	-	555.24	-	-	555.24
3.	Betwa	-	-	-	374.76	-	381.75	-	756.51
4.	Chambal	-	-	-	685.61	497.08	153.8	-	1336.49
5.	Ghambir	-	-	-	189.13	22.28	-	-	211.41
6.	Giri	-	-	148.66	-	-	-	-	148.66
7.	Godar	-	-	-	13.05	-	-	-	13.05
8.	Hanuman Ganga	-	-	-	-	-	-	8.03	8.03
9.	Hindon	-	-	-	-	-	286.69	-	286.69
10.	Jalal	-	-	35.96	-	-	-	-	35.96
11.	Kalisindh	-	-	-	234.71	173.45	-	-	408.16
12.	Ken	-	-	-	303.49	-	141.74	-	445.23
13.	Mej	-	-	-	-	189.66	-	-	189.66
14.	Pabbar	-	-	53.05	-	-	-	14.27	67.32
15.	Parvati	-	-	-	355.43	195.81	-	-	551.24
16.	Rishi Ganga	-	-	-	-	-	-	5.64	5.64
17.	Sind	-	-	-	469.94	-	14.2		484.14
18.	Tons	-	-	62.94	-	-	-	142.72	205.66
	Total	48.53	313.12	318.74	2626.12	1656.5	2231.22	317.88	7512.11

Note: Length of a river or tributary shared by two states is included in both states. Adjusting for the shared length, the length of Yamuna is 1,376 km.

Mej

Mej River originates in Mandalgarh tehsil in Bhilwara district. It joins Chambal River in Kota district (Jain et al., 2007) and flows for 189.66 km in Rajasthan state.

Parvati

Parvati River originates in the Vindhyan hills in Sehore district, Madhya Pradesh and enters Rajasthan in Baran district. It joins Chambal in Sawai Madhopur (Jain *et. al.*, 2007). It has a total length of 551.24 km in Madhya Pradesh and Rajasthan.

2.3.4. Physical Environment

a) Segments of the River

The water flow characteristics of Yamuna during non-monsoon season are different from monsoon. Presence of barrages and less availability of water during lean season hamper the continuity in flow of the river water (Fig. 2.7 and Table 2.4). Thus, in dry season, the river course is distinguishable in four segments (Rai *et al*., 2012):

Segment I (Himalayan Segment): This segment (length 172 km) runs between Yamunotri and Hathnikund barrage (earlier known as Tajewala). The melting of snow forms the major source of water in this segment. A considerable amount of water of this segment is diverted into Eastern Yamuna Canal (EYC) and Western Yamuna Canal (WYC) for irrigation and domestic uses.

Segment II (Upper Segment): This segment (about 224 km) stretches from Hathnikund barrage to Wazirabad barrage. Ground water accrual is the major source of water in this segment while few small tributaries too add water. Water from WYC is discharged into this segment through drain number 2 to meet water requirement of Delhi. Flow of water downstream of Wazirabad barrage is restricted during lean seasons.

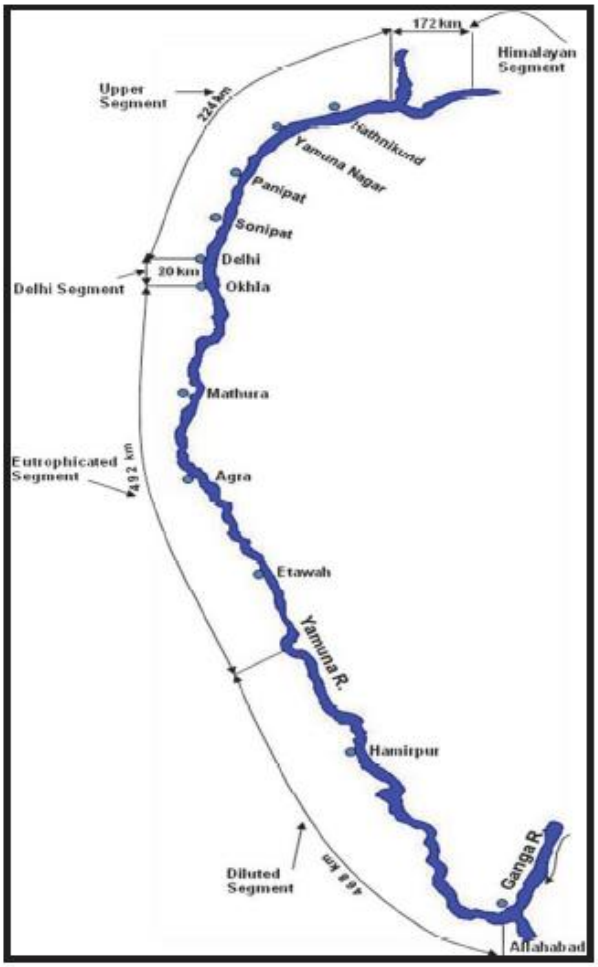


Fig. 2.7. Segments of River Yamuna
(***Source:*** Ecological, Quareshi (2015)

Segment III (Delhi Segment): This segment (22 km length) is located from Wazirabad barrage to Okhla barrage and receives water from 17 sewage drains of Delhi and also from WYC, Upper Ganga Canal via Najafgarh drain and Hindon cut canal. Some quantity of water in this segment is diverted to Surghat where it is mainly used for bathing purposes. This river segment leads to Agra Canal just before Okhla barrage, which is meant primarily for supplying irrigation water to Haryana and Uttar Pradesh.

Segment IV (Mixed Segment): This segment, 958 km in length, begins immediately downstream of Okhla barrage and ends at Prayagraj at confluence with the Ganga. It has two sub-segments, i.e., (a) the eutrophicated segment of about 490 km length, between Okhla barrage and confluence with Chambal, and (b) the diluted segment of about 468 km length from the Chambal confluence to the Ganga confluence at Prayagraj. Water in this segment is contributed by groundwater accrual, from tributaries like Hindon, Chambal, Sindh, Ken, Betwa, etc. and wastewater drains of Delhi, Mathura-Vrindavan,

Agra and Etawah. The water of this segment is used for domestic and industrial uses at Mathura and Agra.

Table 2.4. Major hydraulic structures on Yamuna

Section	State	Length (km)	Tributary/ Drain	Major dams/ Barrages	Canal
Hill (Yamunotri - Hathnikund Barrage)	Uttarakhand, Himachal Pradesh and Uttar Pradesh	172	Kamal, Giri, Tons and Asan	Dakpatthar and Asan Barrage	Dakpatthar and Asan Canal
Upstream Delhi (Hathnikund Barrage - Wazirabad Barrage)	Haryana and Uttar Pradesh	224	Som, Chhoti Yamuna and Drain no. 2 and 8	Hathnikund Barrage	Western and Eastern Yamuna canal
Delhi (Wazirabad Barrage - Yamuna Barrage - Okhla)	Delhi	22	22 drains and Hindon cut	Wazirabad and Yamuna Barrage	Agra Canal
Downstream Delhi (Okhla Barrage confluence with Chambal)	Uttar Pradesh and Haryana	490	Hindon, Bhuria Nalla, Mathura - Vrindavan and Agra Drain	Okhla Barrage	Agra and Gurgaon Canal
Revived Yamuna (Confluence with Chambal and Ganga)	Uttar Pradesh	468	Chambal, Ken, Sind and Betwa		

Source: Sharma *et al.*, 2014.

b) River Characteristics

Width and Depth

The structure and functioning of a lotic ecological complex are characterised by stream channel (shape, size, nature of bed materials, etc.) and stream flow (such as the volume, velocity and its seasonal variation). The average depth of Yamuna is 3 m during the monsoon season. Its channel width ranges from about 30 m in the Himalayan stretch to more than 200 m in the plains (Gopal and Chauhan, 2007). However, at several places within the Himalayan stretch, the river passes through very wide valleys. The river carries large boulders and gravel in its upper reaches which turn to fine gravel and coarse sand as the river enters the plains. Further down between Yamunanagar and Delhi, the bed sediments are sandy being derived chiefly from basaltic rocks, and often have large proportions of silt. The mean floodplain width between the embankments in NCT (Delhi) is 2 km. The active river current during the non-monsoon period is 200-300 m in width.

Diversion and Abstraction

The stream flow of Yamuna and its tributaries varies seasonally. It is nearly negligible between Hathnikund and Etawah during the summer. The glacier area in the Yamuna catchment is small (i.e.,

125 km^2) in comparison with the Indus basin (i.e., 14,043 km^2), this is also one of the reasons behind small stream flow during summer season (Rai *et al*., 2011).

After meandering for about 200 km, Yamuna enters Indo-Gangetic plains at Dakpatthar, district Dehradun, Uttrarakhand. Downstream this place, a significant part of the river water is diverted into canal for hydropower and irrigation purposes. At Hathnikund barrage, Yamunanagar district, Haryana, the major part of the river water is diverted into Western Yamuna Canal and Eastern Yamuna Canal for meeting irrigation requirements of their command areas. According to Rao (1975), the average annual flow of Yamuna at Hathnikund headworks is only 10,750 Mm^3 (MCM). However, the total discharge there often exceeds 14,160 m^3s^{-1} (or 5,00,000 cusec) during the monsoon peak flows, and the Hathnikund Barrage itself has been designed for a 100-year peak discharge of 22,000 m^3s^{-1} (7,76,900 cusec). On the other hand, the flow during the summer decreases to only a few thousand cusec (Gopal and Chauhan, 2007).

During dry season, very little water flows downstream of Hathnikund barrage and the river remains dry in some stretches till Delhi. The river regains water from groundwater recharge and some contributions from feeding canals and streams such as Somnadi (a seasonal stream) upstream of Kalanaur, Yamunanagar district, Haryana. It enters Delhi near Palla village after traversing a distance of about 224 km.

During the monsoon season, the rivers overflow, flooding large areas on both sides. The flow of the Yamuna at Delhi varies between 25 $m^3 s^{-1}$ during summer and 616 m^3s^{-1} during the monsoon season. The river-flow is greatly reduced by withdrawal of water for irrigation and domestic use. Since 1960, two barrages at Wazirabad and Indraprastha in Delhi hold water for purposes of domestic supply and a thermal power-station. Another barrage viz. Okhla barrage is located 22 km downstream of Wazirabad barrage diverts Yamuna water into Agra Canal for irrigation. (Table 2.5) (Naithani and Pande, 2015). Near Mathura a major part of water is diverted for drinking water supply through Gokul barrage. Beyond this, some other tributaries and city drains discharge water into Yamuna especially near Agra, Bateshwar and Etawah.

In the plains, the Chambal is the largest tributary of the Yamuna during non-monsoon period. River Chambal contributes about 5-10 times more water to the Yamuna than that by Yamuna itself. Large reservoirs viz., Gandhi Sagar and Rana Pratap Sagar have been constructed on the Chambal in terrain of deep gorges, for generating 386 MW of power. Another barrage at Kota diverts water to two canals for irrigating about 5.65 lakh ha area. The flow of other major tributaries has also been regulated and diverted through a series of medium sized or small reservoirs and barrages.

Flow Regime

The Yamuna exhibits conditions of dryness as well as flood during the year. The river remains mostly dry during January-June at many places of its stretch. Floods are experienced frequently during July-September due to inflow of water beyond its conveyance capacity. The water flows into the Yamuna from groundwater accrual, tributaries and streams; domestic and industrial discharges come through drains from urban areas. The mean monthly flows recorded at a few representative locations are depicted in Table 2.5.

Environmental Flow

Developmental activities, dams and barrages in the catchment often intercept natural flows in rivers and streams and impair ecosystem functions. To sustain ecological functions, a minimum continuous supply of water, known as environmental flow, must be maintained. Environmental flows, in general, should at least include the water required for four important components, i.e., ecological, seepage, evaporation, and dilution of pollutants. Ecological flow is important from standpoint of ecosystem functioning, and

can be maintained only if other three components are also satisfied (Rai *et al.*, 2011). Continuous availability of water for evaporation, groundwater conservation, aquatic-habitat conservation, assimilation of pollutants and other wastes besides sustaining groundwater recharge, river health and economic activities are important for environmental flow (O'Keefe, 2000; Smakhtin *et al.*, 2006; Tharme, 2003). Environmental flows also reduce water footprint, i.e., the quantity of freshwater used by an individual or community to produce goods and services for its consumption.

Table 2.5. Mean monthly flow of Yamuna River at various locations

Month	Mean monthly flow (m^3/s)				
	Paonta Sahib (Sirmaur, H.P.)	**Kalanaur (Yamunanagar, Haryana)**	***Delhi Railway Bridge (Delhi NCT)**	***Agra (U.P.)**	**Pratappur (Prayagraj, U.P.)**
June	84.9	35.9	37.8	27.0	356.8
July	302.4	287.8	248.3	157.2	2,426.8
August	595.5	604.8	630.9	505.9	6,608.4
September	399.3	389.6	453.3	504.6	6,230.7
October	104.5	89.6	93.3	157.2	1,166.7
November	53.2	52.1	57.8	81.0	569.0
December	40.7	11.9	35.8	43.6	466.7
January	40.7	11.9	34.3	29.8	366.2
February	56.2	10.3	33.5	28.9	392.6
March	71.7	43.7	28.0	20.9	345.3
April	30.8	17.7	42.4	27.0	356.8
May	40.3	17.2	24.3	17.4	242.6

*Though the flow is available, but water quality is very poor. ***Source:*** Rai *et al.*, 2011.

Environmental flow is an important issue concerning Yamuna. The water availability in the Yamuna, except for the Etawah to Prayagraj stretch, is inadequate to meet environmental demands during December-June. Stretch from Etawah to Prayagraj receives good quantity and quality of water from Chambal, Sind, Betwa and Ken and does not have major industrial and domestic requirements. The Delhi stretch is of high concern as this stretch receives pollutants from 23 wastewater drains and there is no release of water from the Wazirabad barrage. Therefore, water demand for assimilating pollutants becomes very high for this stretch.

The Hon'ble Supreme Court vide Writ Petition (Civil) 537 of 1992 directed on 14 May 1999, that a minimum flow of 10 $m^3 s^{-1}$ (or 353 cusec) must be allowed to flow throughout Yamuna. National Green Tribunal (NGT) in its judgment dated 13 January 2015 recommended the maintenance of requisite environmental flow in Yamuna downstream of barrage at Hathnikund, Haryana and at Okhla, Delhi (NCT) to retain enough fresh water flow till Agra for meeting the river's ecological functions. It was estimated that the minimum environmental flow in the Yamuna downstream of Hathnikund barrage should be 70 $m^3 s^{-1}$ i.e., around 70 per cent of the mean minimum virgin flow of 100 $m^3 s^{-1}$ at Hathnikund barrage during the leanest month of January). The corresponding minimum flow downstream of Okhla barrage was determined as 42.48 $m^3 s^{-1}$.

A hydraulic method was used by Rai *et al.* (2011) to estimate environmental flow requirements in different stretches of Yamuna. The estimated minimum environmental flow required, accounting for

seepage, evaporation losses and ecological requirement, from Hathnikund barrage was 73.8 m^3/s (Table 2.6), which amounts to about 50 per cent of mean minimum flow available at Hathnikund. Upadhyay and Rai (2013) used MIKE 11 model to simulate the baseline environmental flow of Yamuna without considering requirement for water resources development, and estimated minimum release of 70 $m^3 s^{-1}$ from Hathnikund barrage for maintaining the ecological flow of the river up to confluence with Chambal in Etawah (Fig. 2.10). Water flow downstream of this point is not an important issue for Yamuna at present. Maintaining this level of environmental flow is a big challenge due to requirements for other priority uses *viz.* drinking and irrigation.

Table 2.6. Environmental flow requirement of various reaches of Yamuna River

Month	Release from Hathni-kund (H'kund to Palla) (m^3s^{-1})	Release from Wazira-bad (W'bad to Okhla) (m^3s^{-1})	Release from Okhla (Okhla to Agra) (m^3s^{-1})	*Net release from H'kund for maintaining the e-flow up to Agra (m^3s^{-1})	From Agra (Agra to Etawah) (m^3s^{-1})	From Etawah (Etawah to Prayagraj) (m^3s^{-1})
January	36.8	14.5	42.4	82.2	63.8	91.6
February	40.4	14.7	45.5	89.9	67.8	98.8
March	47.2	12.3	36.7	78.4	54.9	86.3
April	37.0	17.6	48.4	88.0	69.7	89.2
May	39.2	11.0	33.8	73.8	51.1	60.7
June	46.4	15.99	45.5	89.5	66.6	89.2
July	121.8	83.3	117.3	188.5	198.6	606.7
August	227.2	189.0	221.1	318.0	435.4	1,707.3
September	155.6	162.4	209.5	323.6	409.0	1,507.5
October	63.0	36.4	115.3	167.6	182.4	301.4
November	48.5	22.4	69.4	113.8	107.4	137.7
December	36.8	15.0	47.0	87.0	72.9	116.7

*The net release amounts to the ecological flow of previous reach 72.9 m^3s^{-1} which will carry forward to the next reach. ***Source:*** Upadhyay and Rai, 2013.

In response to order by National Green Tribunal (NGT) Yamuna Monitoring Committee on 29th June 2020 recommended releases of water from Hathnikund barrage that would meet the minimum water depth of 0.60 m for indicator fish species, *viz.*, Indian carp (*Raiamas bola*) and Indian trout (*Bangana dero*) at 13 identified locations (Chandra and Sajwan, 2020).

2.3.5. Climate

The Yamuna basin experiences distinct winter, spring, summer, monsoon and autumn seasons. Broadly, climate of the basin can be classified as: (a) humid in the upstream Himalayan catchment; (b) semi-arid in north-west to western catchments; (c) sub-humid in south-west catchments and catchments located on the left bank of the river.

The temperature and precipitation vary considerably across the basin. The Himalayan part of the basin experience very low winter temperature and high rainfall (1,200 to 1,700 mm mean annual precipitation). Snowfall occurs above 1,500 m altitude during winter, however, snowfall is not much

frequent up to 2,000 m altitude. Areas above 2,000 m receive snowfall many times during the year; above 3,000 m precipitation during winter is mainly in the form of snow. Snowfall and severity of winter have decreased over the last three decades due to climate change. In the plains, peak temperatures rise above 45^{o}C during summer (late May-June) but drop to 2^{o} to 9^{o}C during winter (December-January). Temperature rarely falls to sub-zero temperature in the plains.

Based on average rainfall pattern during 1951 to 2002, the annual rainfall recorded is 893.3 mm (372.2-1,653.5 mm), monsoon rainfall 806.8 mm (327.0 - 1,568.9 mm), non-monsoon rainfall 86.5 mm (19.5 - 479.0 mm), annual rainy days 88 (46.0 - 160.0) and aridity index 38.0 (14.9 - 74.6) (Rai *et al.*, 2010).

About 90 % of the annual precipitation is received from south-west monsoon (June to September). Winter rainfall is scanty. The annual rainfall deceases towards the south and south-west; it is around 400 mm in the western part of the basin, 700 and 1,000 mm in the central part while it exceeds 1,200 mm in the south-east part of the basin. In Doon valley, rainfall is about 2200 mm which decreases northwards to about 1,700 in Uttarkashi and 1000 mm at higher altitudes.

Rai *et al.* (2010) observed an overall declining trend in the annual rainfall, monsoon rainfall, annual rainy days, monsoon rainy days, and aridity index. The decrease in monsoon rainfall and number of monsoon rainy days and frequent delays in the onset of effective monsoon are causes of great concern.

2.3.6. Topography and Geology

The Himalayan region comprising Uttarakhand and Himachal Pradesh has high mountains with steep slopes while the terrain of Chambal region, located in parts of Uttar Pradesh, Madhya Pradesh and Rajasthan, is irregular with low hills and steep slopes. Vindhya is a mountainous region in Madhya Pradesh and Uttar Pradesh with flat topped hills and stepped slopes. Aravalli ranges extend from eastern Rajasthan to Delhi and represent rocky hills that have been severely eroded by forces of weathering. The major part of Madhya Pradesh has undulating topography. The remaining area of Yamuna basin is mostly flat.

Elevation ranges from 6,320 m near Yamunotri glacier to about 100 m near its confluence with Ganga at Prayagraj. About 3.19% area lies in mountainous region (>600 m altitude), 43.96% in foothills and plateau region (300- 600 m altitude) and 47.15% in plains and valleys (100-300 m altitude). Five major geological formations, *viz.*, Proterozoic, Paleozoic, Mesozoic, Cenozoic and Deccan Volcanic/ Sediments are found in the Yamuna basin. The Himalayan and Shiwalik region of the basin has Proterozoic formation. The eastern and northern part of the Yamuna mostly has cenozoic formation which is the most recent of the geological formations. Deccan Volcanic/Sediments formation occurs in the south central part of basin mostly lying in Madhya Pradesh. Western and southern part of basin in Rajasthan pre-dominantly consists of Proterozoic Archean formation. Geological formations found in different sub-basins are depicted in Table 2.7.

2.3.7. Soil

The soils of the Yamuna basin exhibit wide variation as they have formed under different lithological, climatic, and pedogenetic conditions (Raychaudhury *et al.*, 1963). Riverbed of the upper Yamuna is sandy in texture (70.52-74.76% sand, 17.74-18.56% silt and 7.35-11.55% clay).

There are eight types of soils present in the Yamuna basin (Table 2.8; Rai *et al.*, 2011). Alluvial soil is the predominant soil type covering about 42 per cent of the basin area, followed by medium black soil spread over 25.5% of the basin area located in parts of Madhya Pradesh and Chambal basin in

Rajasthan. Due to large variation in climate and soils, the natural vegetation is also highly variable in the Yamuna River basin.

Table 2.7. Distribution of geological formations in different sub-basins of River Yamuna

Sub-basin	Predominant formation type	Geological formation	Extent (km^2)	Remarks
Chambal/ Betwa/ Ken/ Kali/ Sind (plateau region)	Hard rock	Crystalline: granite/ gneiss/ phyllite/ schist Deccan trap – basalt Sedimentary – limestone/ sand stone	1,96,232	Alluvium deposits are found in patches near and along major rivers
Yamuna/ Hindon/ Khari/ Sahibi, i.e., Yamuna-Ganga and Yamuna-Ghaghar Doab (Indo-Gangetic plain)		Older to recent alluvium sand, silt, gravel, clay, boulder	1,58,629	

(***Source:*** Rai *et al.*, 2012)

Table 2.8. Soil types in the Yamuna basin

Soil type	Per cent of total basin area	Location
Red sandy	2.5	Along Uttar Pradesh-Madhya Pradesh border in districts of Jhansi, Hamirpur, Chhatarpur, etc.
Red and yellow	5.0	Parts of Jaipur, Alwar, Sawai Madhopur districts and along western boundary of basin in Rajasthan; Banda and Panna districts in Uttar Pradesh
Calcareous sierozemic	0.5	Parts of Mahendragarh and Bhiwani districts in Haryana
Deep black	5.5	On the southern boundary of the basin in Sehore, Bhopal, Raisen, Vidisha, Sagar and Damoh districts in Madhya Pradesh
Medium black	25.5	Most of the basin in Madhya Pradesh and strips north of river Chambal in Rajasthan
Mixed red and black	15.0	Chittorgarh, Bhilwara districts in Rajasthan; Banda, Lalitpur, Tikamgarh in Uttar Pradesh; Mandsaur, Shivpuri, Panna and Chhatarpur in Madhya Pradesh
Brown hill	4.0	Hills and foothills in the Himalayan region
Alluvial	42.0	Plains and valleys in remaining regions

(***Source:*** Rai *et al.*, 2012)

2.4. WATER REQUIREMENT VIS-À-VIS AVAILABILITY

2.4.1. Surface Water

Yamuna water is used for irrigation, drinking and industries as well as for bathing, laundry, and cultural/religious activities such as disposal of idols and cremation ash. The construction of diversion structures at regular intervals (Hathnikund, Wazirabad, Okhla, Gokul, etc.) has modified the flow regime of the river. Since independence, the population in the Yamuna basin has increased by 2.5 times, and to ensure the food security, various irrigation schemes have been subsequently developed. Currently, the irrigated area in the basin has become twice of that in year 1950. Moreover, during sixty years since 1950, the contribution of groundwater resources for irrigation has trebled. The inflow of wastewater, as treated or partially treated water, increases the water volume but aggravates the water quality problem of the river. Excessive abstraction of groundwater during green revolution has led to depletion of groundwater.

The current water use and the analysis of ten years (2000-2009) of hydrological data (both surface water and groundwater) reveal that the entire basin is water deficit (approximately 34.54 BCM deficit). However, the Ken River (3.27 BCM surplus) and the Upper Himalayan (4.6 BCM surplus) catchments have surplus water resources (Upadhyay and Rai, 2013).

The major portion of the basin is in semi-arid climatic region. Rainfall and glaciers are the source of water. Most of the annual rainfall is limited to monsoon months. Yamuna, with Himalayan area of 11,700 km^2 is both rain- and snow-fed and is perennial in nature. During the non-monsoon season, flow from Himalayan region is mostly due to melting of snow. Water resources of the basin can be divided into surface and ground water resources. Availability of surface water in Yamuna basin is 61.22 BCM, of which Chambal (43.67%), Betwa (19.28%), Ken (13.21%) and Sind (3.08%) are the major contributors. It was suggested that the environmental flow of Himalayan rivers should be >2.5% of 75% dependable annual flow (WQAA, 2007). Accordingly, seventy-five per cent dependable notional virgin flow at Hathnihund in river Yamuna has been assessed as 11.7 BCM, while the mean availability of water up to Okhla is 13 BCM and 70-75 % of this is received in monsoon season (Rai *et al.,* 2011). Out of total 11.98 BCM utilizable flow of water of the river, share of Haryana, Uttar Pradesh, Rajasthan, Himachal Pradesh and Delhi are 5.73, 4.03, 1.12, 0.38 and 0.72 BCM, respectively. Uttar Pradesh and Haryana are the main users of Yamuna water, which is diverted at Hathnikund in Eastern Yamuna Canal and Western Yamuna Canal (Kumar *et al.,* 2018). Large part of total yearly flow goes down to the sea, without any use in the absence of any upstream storage mechanism.

2.4.2. Ground Water Resource

Ground water development (GWD) or extraction is increasing in Yamuna basin and is a source of concern. South and south-west part of the basin is overexploited. From Yamunanagar to Etawah, areas on the western and south-western sides of Yamuna are more exploited (semi-critical to over-exploited category) than those on the opposite side (CGWB, 2010). The major (90%) use of groundwater is for irrigation (Expert Committee, 2014).

The annual replenishable ground water resources in India have been estimated at 432 BCM while annual ground water draft is 249 BCM (CGWB, 2019). Net ground water availability in Yamuna basin is 45.43 BCM with 82.3 % ground water development (GWD). The southwest and central portion of basin has GWD more than 85 % (Rai *et. al.*, 2011) (Fig. 2.8). The annual consumption of ground water in Delhi, Haryana and Rajasthan is more than recharge (indicated by GWD value of >100). GWD in Uttar Pradesh is 70 while its value in Uttarakhand, Himachal Pradesh and Madhya Pradesh is <70 (Table 2.9) (CGWB, 2017).

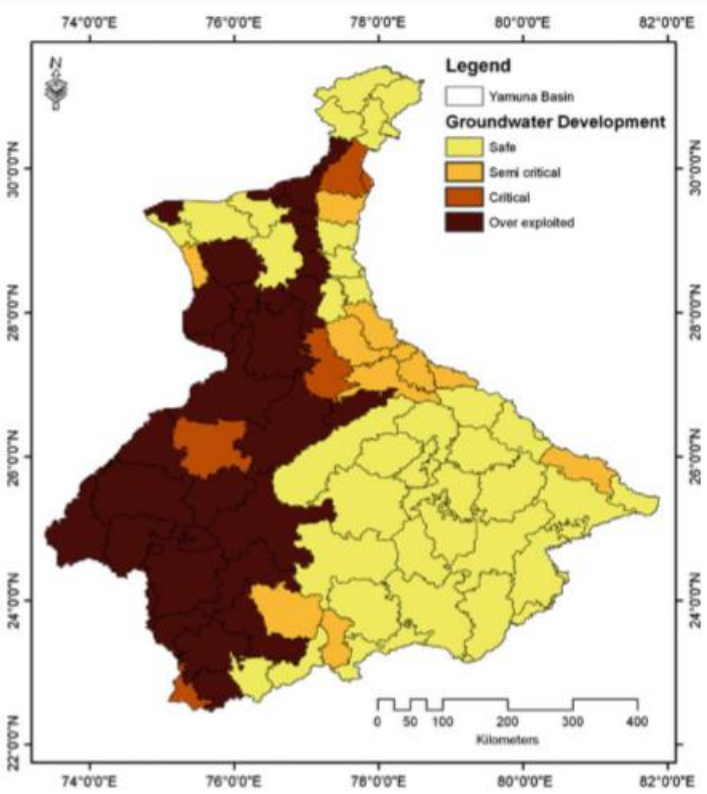


Fig. 2.8. Stages of ground water development in the basin
(***Source:*** Rai *et. al.*, 2011)

Table 2.9. State-wise ground water resources availability, utilization and stage of ground water development in the Yamuna River Basin (BCM, as on 31st March 2013)

S.no.	State	Net annual ground water availability	Total annual ground water draft	Projected demand for domestic and industrial uses up to 2025	GW availability for future irrigation use	Stage of GW Development (%)
1	Uttarakhand	1.97	0.99	0.30	0.82	50
2	Himachal Pradesh	0.53	0.27	0.07	0.30	51
3	Haryana	10.30	13.92	0.56	-3.58	135
4	Delhi	0.31	0.39	0.25	0.02	127
5	Uttar Pradesh	71.58	52.76	6.44	19.01	74
6	Rajasthan	11.26	15.71	2.32	0.90	140
7	Madhya Pradesh	34.16	19.36	2.35	13.86	57

(*Source:* Extracted from part of Annexure-I of CGWB, 2017)

Significant change has not been recorded in the overall stage of ground water development from 2011 to 2013. The over-exploited areas are mostly concentrated in three parts of the country: (i) north-western, including parts of Punjab, Haryana, Delhi and Western Uttar Pradesh where though replenishable resources is abundant, there have been indiscriminate withdrawals of ground water leading to over-exploitation; (ii) western, particularly in parts of Rajasthan and Gujarat, ground water recharge itself is limited leading to stress on the resource and (iii) southern part of peninsular India, where due to poor aquifer properties, ground water availability is low (Table 2.10).

Table 2.10. Categorisation of blocks, tehsils or districts in the states located in the Yamuna River Basin for ground water extraction (as on 31st March 2013)

S.no.	State	No. of unit assessed	Safe		Semi-critical		Critical		Over-exploited		Saline	
			No.	%	No.	%	No.	%	No.	%	No.	%
1	Uttarakhand[1]	18	16	89	1	6	1	6	0	0	0	0
2	Himachal Pradesh[3]	8	6	75	0	0	1	13	1	13	0	0
3	Haryana[1]	119	30	25	11	9	14	12	64	54	0	0
4	Delhi[2]	27	5	19	7	26	0	0	15	56	0	0
5	Uttar Pradesh[1]	820	603	74	45	5	59	7	113	14	0	0
6	Rajasthan[1]	248	44	18	28	11	9	4	164	66	3	1
7	Madhya Pradesh[1]	313	228	73	58	19	2	1	25	8	0	0

Units: [1] blocks, [2] tehsils, and [3] districts. ***Source:*** Part of Annexure-III of CGWB, 2017.

2.4.3. Surface Water - Ground Water Linkage

Surface water and ground water resources are inter-connected. Excessive abstraction and poor replenishment of water in the basin have adversely affected the linkage between surface and ground water, leading to change in surface water dynamics during the lean season of the river (Upadhyay and Rai, 2013). The net share of surface and groundwater for irrigation has now become 37 and 57 per cent instead of 60 and 20 per cent, respectively in 1950s. The rest of the irrigation water is met by other sources like ponds, tanks, anicuts, etc.

2.4.4. Soil Moisture Storage

The annual soil moisture storage in the Yamuna basin varies between 100 and 250 mm (http://www.iwmi.cgiar.org). Considering individual estimates of water resources (i.e., surface water, ground water and soil moisture storage), the total water resources of the catchments are presented in Table 2.11 (Rai *et al.*, 2011).

2.4.5. Treatment of Catchment

The catchment of Yamuna receives enough rainfall, however, most of it goes as runoff and causes soil erosion. Erosion of topsoil from the catchment reduces fertility and the vegetation growth. The off-site effects of soil erosion create problems like reservoir sedimentation and floods in downstream areas. The sedimentation at reservoirs depends on the soil erosion rate of the river catchment, thus, the useful life of any hydroelectric or irrigation project depends on soil erosion rate of catchment area. Controlling the factors of erosion could check the process of soil erosion and promote *in-situ* water harvesting. Thus, it

is imperative to treat the catchment area to lessen the incidence of flash flood, reduce silt load and recharge aquifers.

Table 2.11. Sub-basin-wise estimates of demand and groundwater resources

S. no.	Sub-basin	Area (km^2)	Soil moisture storage (MCM)	Net GW availability (MCM)	Surface water resources (MCM)	Total water resources (MCM)
1	Upper Yamuna	11,058.4	1,935.0	457.0	3,605.2 (5,162.2)	5,997.0 (7,554.0)
2	Chambal	134,967.6	23,619.0	9,382.9	26,736.6	59,739.0
3	Sind	27,940.0	4,890.0	3,441.7	1,888.5	10,220.0
4	Betwa	43,835.9	7,671.0	5,701.0	11,802.9	25,175.0
5	Ken	28,806.5	5,041.0	3,113.0	8,089.4	16,244.0
6	Yamuna	365,870.7	640,27.0	45,428.8	61,219.2 (62,776)	170,675.0 (172,231.0)

Note: Values within parentheses are the estimates after functioning of three dams in the upper Himalayan segment. (***Source:*** Rai *et al.,* 2011**)**

Various centrally sponsored schemes of soil conservation in the catchments of river valley projects were launched during the 3rd Five-Year Plan for prevention of catchment deterioration. The catchment area treatment (CAT) plan, aims to prepare a management blueprint for treatment of erosion-prone areas through mechanical and vegetative measures. Different watershed projects, which have been taken up in the country, aim at integrated watershed management with the people's participation. However, these works have been for carried out for a small part of the catchment.

2.4.6. Recharging of Aquifers

Yamuna basin experiences excess water during monsoon and water deficit during summer season in many areas. These situations can be checked to some extent if the aquifers are recharged in catchment area. An aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials. The area where water fills the aquifer is called the saturated zone. The depth from the surface at which ground water is found is called the water table. In regions where groundwater use is greater than natural recharge rates, aquifers will be depleted over time and permanently damaged hence, deserves interventions.

Rejuvenation of aquifers can play an important role in rejuvenation of river. It can absorb the water and slowly release water to the river. Aquifers are of two types: (a) unconfined aquifers, the upper boundary of this aquifer is the water table and (b) confined aquifers that are overlain by a confining layer, often made up of clay. The confining layer offers some protection from surface contamination. Confined aquifer is directly recharged by precipitation in the area where the aquifer crops out, and by infiltration in the cropping out area from the runoff from hill slopes.

Artificial recharge is the process by which the ground water reservoir is augmented at a rate exceeding that of natural condition of replenishment. The artificial recharge efforts consist in augmentation of natural movement of surface water into ground water reservoir through suitable civil structures. The artificial recharge techniques interrelate and integrate the source water to ground water reservoir and are dependent on the hydrogeology situation of the area. State-wise details of artificial recharging of aquifers have been provided in volume II of the DPR.

Kumar *et al.* (2019) stated that around 159,000 km^2 area of the basin in the Yamuna-Ganga and Yamuna-Ghaggar Doab is of alluvium formation for which ponds, wells, infiltration tubes and channels should be made, and regularly maintained, to facilitate infiltration and increase recharge. It was also emphasized to increase the water holding capacity of the basin by creating water bodies. It was also suggested that parks and playgrounds, covering around 10% of the urban area should be utilized to provide poundage of 0.30-0.45 m water. Harvesting pits should also be provided to increase infiltration. Low-height check dams need to be provided in minor and medium drains. In major drains, series of regulators can be applied to create storages.

2.4.7. Water Conservation

In India, around 83% of available fresh water is used for agriculture. Rainfall being the primary source of fresh water, the concept behind conserving water is to harvest it when it falls and wherever it falls.Water conservation in India is not a new concept. One of the earliest sites of the Indus Valley civilisation, Dholavira in Gujarat has well documented storage reservoirs in the form of lakes to collect surface runoff during the rainy season, besides intricate channels and check dams for various purposes (Puskar, 2018) (Table 2.12). Such structures have also been found in other sites such as Harappa and Mohenjodaro.

Table 2.12. Traditional water conservation and storage structures in the Yamuna River Basin states

Name of the state	Traditional water conservation/storage structure
Uttarakhand	***Naula*** is made traditionally from stones and is basically a small hut like structure that houses a spring. The floor should be left pervious.
Himachal Pradesh	***Khatri*** is basically a rainwater harvesting tank built out of stone to grant it some permanency. The structure should be impervious, so the water doesn't percolate.
Uttar Pradesh	***Kund*** is basically a reservoir usually shaped like a saucer and into a well that is used to store rainwater. The lining is done with lime to prevent contamination of water.
Delhi	***Baoli*** are stepwells and many survive till today in Delhi.
Rajasthan	***Johad*** is a simple yet ingenious, low cost method of collecting rainwater. A pit is dug and the connecting Johad are connected to it. ***Bawari*** are stepwells. Rainwater is collected inside the stepwell which also provides some protection against evaporation. ***Taanka*** is an underground tank into which water is collected by means of rainwater harvesting.
Madhya Pradesh	***Kata/Munda/Bandha*** block water in a large area to help meet the community needs for irrigation. The shape would generally resemble a triangle or rectangle and would be used for large fields.

In the plateau region of Chambal, Betwa, Ken, Kali, having 1,96,000 km^2 area, reservoirs should be made to hold around 50 % monsoon flow leaving the balance to flow downstream as environmental flow (Kumar *et al.*, 2019). It will reduce the peak flow and so the downstream flooding. The GWD of this area has been already very high, particularly Chambal sub-basin with GWD of more than 100 %. This measure will reduce the load on ground water resources and it will improve the recharge scenario.

2.5. WATER QUALITY

2.5.1. Water Quality Parameters

Most of the rivers in India have been subjected to heavy pollution load caused by the discharge of untreated or partially treated wastewater and industrial effluents (Sharma *et al.*, 2017a, b). The rivers have also been impacted by surface runoff from farmlands carrying high concentrations of pesticides, fertilizers and chemicals (Bhardwaj *et al.*, 2017). The river water becomes inappropriate for human consumption (Sharma *et al.*, 2017a, b).

Central Pollution Control Board (CPCB) studies the water-related environmental issues, identifies pollution sources and plans for improving the wholesomeness of water in streams. The water bodies of the country have been classified based on quality and pollution status and plans have been made to designate the best utilization of each class. As per IS 2296: 1982 classes *viz.* A, B, C, D, and E have been made to designate best uses of surface water resources, *viz.*, Class A: drinking without conventional treatment but after disinfection, Class B: outdoor bathing, Class C: Drinking with conventional treatment followed by disinfection, Class D: fish culture and wildlife propagation and Class E: irrigation, industrial cooling and controlled waste disposal.

CPCB has identified water quality requirements for the above classes in terms of important chemical characteristics, known as primary water quality criteria; these standards have been further notified by Bureau of Indian Standards as IS 2296:1992 (Table 2.13). Important water quality parameters are temperature, pH, dissolved oxygen (DO), 5-day biochemical oxygen demand (BOD-5), total dissolved solids (TDS), electrical conductivity (EC), total alkalinity (TA), total hardness (TH), calcium hardness (Ca-H), magnesium-hardness (Mg-H), ammonium ($NH4^{+}$), nitrite (NO_2^{-}), nitrate ($NO-^{3}$), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), chloride (Cl^{-}), fluoride (F^{-}), iron (Fe), and boron (B).

Characteristics for drinking water (requirement and permissible limits) are defined in term of 9 essential and 26 desirable parameters in IS 10500:1991 (Amended).

As there are several parameters, an index, viz., water quality index (WQI), that combined several parameters, was used by Jaiswal and co-workers (2019) to estimate quality of water for twelve sampling stations along the Yamuna. The index followed the protocol of the Canadian Council of Ministers of the Environment (CCME) (CCME, 2001) and assessed water quality at each class according to the Indian Standards (IS 1982: 1991. The WQI classes were as follows: excellent (95-100), good (80-94), fair (65-79), marginal (45-64) and poor (0-44).

The physico-chemical parameters are able to determine the changes in a limited number of characteristics of water bodies. In accordance with the objective of the Water Act, 1974, CPCB in 1999 bio-mapped Yamuna by employing biological system as biological water quality criterion to examine the wholesomeness of its water in terms of ecological sustainability. Taxa/families of Benthic macro-invertebrates collected from water bodies were used as indicators (CPCB, 2013).

2.5.2. Water Quality Parameters Water Quality Estimates

Several studies have been carried out on water quality in the Yamuna. Different parameters have been examined in various studies. A summary of parameters and related representative references have been compiled in Table 2.13.

Table 2.13. Quality parameters of water defined by Bureau of Indian Standards (IS 2296:1992)

Water quality parameter	Quality class				
	A	B	C	D	E
Dissolved Oxygen (DO) mg/l	≥ 6	≥5	≥4	≥ 4	-
Biochemical Oxygen demand (BOD) mg/l	≤2	≤3	≤3	-	-
Total coliform organisms MPN/100ml	≤50	≤500	≤5,000	-	-
pH value	≤6.5-8.5	≤6.5-8.5	≤6.0-9.0	6.5-8.5	6.0-8.5
Colour, Hazen units	≤10	≤300	≤300	-	-
Odour	Un-objectionable		-	-	-
Taste	Tasteless	-	-	-	-
Total dissolved solids, mg l^{-1}	≤500	-	≤1,500	-	≤2,100
Total hardness (as $CaCO_3$), mg l^{-1}	≤200	-	-	-	-
Calcium hardness (as $CaCO_3$), mg l^{-1}	≤200	-	-	-	-
Magnesium hardness (as $CaCO_3$), mg l^{-1}	≤200	-	-	-	-
Copper (as Cu), mg l^{-1}	≤1.5	-	≤1.5	-	-
Iron (as Fe), mg l^{-1}	≤0.3	-	≤0.5	-	-
Manganese (as Mn), mg l^{-1}	≤0.5	-	-	-	-
Chlorides (as Cu), mg l^{-1}	≤250	-	≤600	-	≤600
Sulphates (as SO_4), mg l^{-1}	≤400	-	≤400	-	≤1,000
Nitrates (as NO_3), mg l^{-1}	≤20	-	≤50	-	-
Fluorides (as F), mg l^{-1}	≤1.5	≤1.5	≤1.5	-	-
Phenolic compounds (as C_2H_5OH), mg l^{-1}	≤0.002	≤0.005	≤0.005	-	-
Mercury (as Hg), mg l^{-1}	≤0.001	-	-	-	-
Cadmium (as Cd), mg l^{-1}	≤0.01	-	≤0.01	-	-
Salenium (as Se), mg l^{-1}	≤0.01	-	≤0.05	-	-
Arsenic (as As), mg l^{-1}	≤0.05	≤0.2	≤0.2	-	-
Cyanide (as Pb), mg l^{-1}	≤0.05	≤0.05	≤0.05	-	-
Lead (as Pb), mg l^{-1}	≤0.1	-	≤0.1	-	-
Zinc (as Zn), mg l^{-1}	≤15	-	≤15	-	-
Chromium (as Cr^{6+}), mg l^{-1}	≤0.05	-	≤0.05	-	-
Anionic detergents (as MBAS), mg l^{-1}	≤0.2	≤1	≤1	-	-
Barium (as Ba), mg/l	≤1	-	-	-	-
Free Ammonia (as N), mg/l	-	-	-	≤1.2	-
Electrical conductivity, micromhos cm^{-1}	-	-	-	-	≤2,250
Sodium absorption ratio	-	-	-	-	≤ 26
Boron, mg l^{-1}	-	-	-	-	≤2

***Source**:*
https://www.indiawaterportal.org/sites/indiawaterportal.org/files/tolerance_and_classification_water_use_central_water_commission_2010.pdf.

Water-quality along the whole course of the Yamuna has been analyzed by the Central Water Commission and the Central Pollution Control Board. The studies show that six sections of the river, marked by their flow characteristics, sources of pollution and water quality, can be readily recognized. These are: the Himalayan stretch up to Hathnikund, the upper stretch from Hathnikund to

Wazirabad, the Delhi sector (between Wazirabad and Okhla), the Delhi-Agra sector, the lower stretch between Agra and the confluence with River Chambal, and the tail reach to Prayagraj (Gopal and Sah, 1993). Physico-chemical characteristics of River Yamuna documented by various experts are summarised in Table 2.14.

Table 2.14. Physico-chemical characteristics of River Yamuna over time

Parameter	**Reference**
Turbidity/ Total dissolved solids (TDS)	Chakrabarty *et al.*, 1959; Bhargava, 1985; Gopal and Sah, 1993; Prashant *et al.*, 2016
Biological Oxygen Demand (BOD)	CPCB,1983; Parmar and Keshari, 2012; Naithani and Pande, 2015
Dissolved oxygen (DO)	Rai, 1974; Maheshwari *et al.*, 2011; Sharma and Kansal, 2011
pH	Bhargava, 1983; Bhargava, 1985; de Zwart, 1991; Debey *et al.*, 2013
Total nitrogen concentration	CPCB, 1982 and 1983
Orthophosphate-P concentration/ Heavy metals (Cu, Cd, Cr, etc.)	CPCB, 1982; Ajmal *et al*., 1985; Jhingaran and Joshi, 1987, Wasay and Jain, 1988; Farago *et al.*, 1989; Malik *et al.*, 2014; Kashyap *et al.*, 2015; Bhardwaj *et al*., 2017; Gupta and Misra, 2018
Pesticide pollution (DDT)	Pillai and Agrawal, 1979; Sen, 1987; Thakkar and Sarin, 1987; de Zwart, 1991

An analysis of the secondary data collected from CPCB and primary sampling at various locations in the Yamuna River reveals that water quality is gradually deteriorating and will tend to deteriorate, if not managed properly. This can be seen through the comparison of DO profile of the Yamuna River for the year 2003 and 2008 (Fig. 2.9), which indicates that polluted stretch of Yamuna is gradually increasing.

Jaiswal and co-workers (2019) estimated the longitudinal profile of Yamuna based on WQI. The upper zones of the Yamuna River from Paonta Sahib to Palla had excellent to good WQI, whereas the middle locations from Delhi to Etawah had poor-to-marginal WQI. The decrease in WQI at the midstream of Yamuna could be due to the growing density of the human population on the riverbanks along with poor sanitation practices by inhabitants (Sharma *et al*., 2017a, b). Further, the WQI values in the lower zone from Auraiya to Pratappur were in good to-excellent WQI range. This result could be due to the dilution effect from the Chambal, Betwa, and Ken Rivers (CPCB 1999-2000). The WQI observations at Pratappur for all classes were similar to those at Paonta indicating that the water characteristics at the downstream region were recovered.

Water quality at Paonta Sahib was good for drinking purposes after disinfection and excellent for other applications (IS: 1982). The Yamuna River at Kalanaur and Mawi had good capabilities for drinking purposes after treatment and chlorination. The range of WQI for the Yamuna River at Palla dropped below C. The water quality at Delhi, Mohana (50 km downstream of Delhi), Mathura, and Agra were poor for most applications except for industrial cooling, and controlled waste disposal. Water quality at Auraiya and Hamirpur were excellent for the propagation of wildlife and fisheries (IS: 1982).

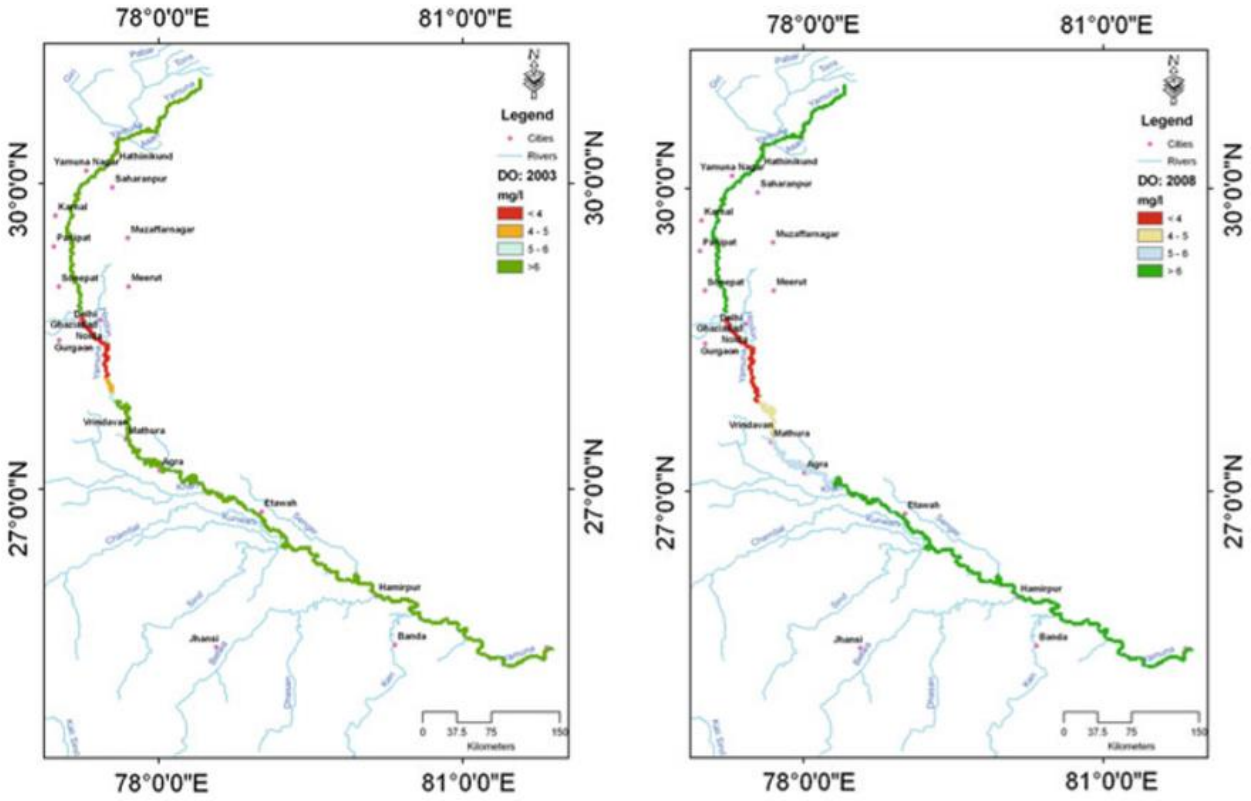


Fig. 2.9. Comparison of Yamuna water quality profile for the year 2003 and 2008.
(***Source:*** Rai *et al.*, 2011)

The physico-chemical as well as biological aspects of water quality of Yamuna and its tributaries have been extensively investigated and documented over the past six decades. It is well known that despite several efforts to mitigate the problem of pollution through regulatory measures and providing sewerage and sewage treatment systems, the water quality in the river continues to degrade. The monitoring report on Yamuna River water quality (CPCB, 2006) during the period 1999-2005 noted a gradual increase in organic pollution from Yamunotri to Delhi. Total coliforms were generally found above the prescribed water quality standards. About 580 km long stretch of Yamuna from Wazirabad barrage to Chambal river confluence was classed as critically polluted as it possessed high concentration of organic matter and nutrients, significant depletion in dissolved oxygen, severe odour, etc. The 22 km long Delhi stretch is severely polluted.

The physico-chemical characteristics of the water of Yamuna near major urban conglomerations have also been studied during the past many years (Chakrabarty *et al.*, 1959; Rai, 1974; Bhargava, 1984; Menon, 1990). The pollution status of Yamuna water (physical, chemical and bacteriological) were evaluated at three sites (Wazirabad, ITO and Okhla) near Delhi by Kathal *et al.* (2016). Tap water was used as control. The results indicated that ITO water sample was the most polluted as the total dissolved solids metals, turbidity and total hardness were highest in those samples (Table 2.15). Among heavy metal, Arsenic (As) content was ten times higher beyond BIS permissible limit in Okhla sample. Chromium (Cr) content was the highest in Wazirabad, followed by ITO. Plant growth was higher in polluted water than control indicating high tolerance of the plants to the pollution.

Table 2.15. Report on analysis of water samples from different sites of Yamuna River in Delhi

S.no.	Parameter	BIS permissible limit	Tap water	Wazirabad	ITO	Okhla
1	Colour, Hazen units	5	4	25	43	92
2	Odour	Agreeable	Agreeable	Foul Smell	Foul Smell	Foul Smell
3	Taste	Agreeable	Agreeable	Not agreeable	Not agreeable	Not agreeable
4	Turbidity, NTU	1.00	2.21	14.80	22.00	4.72
5	Fluoride (F) mgl^{-1}, Max	1.00	0.42	0.54	0.71	0.70
6	Magnesium (Mg), mg l^{-1}	30.00	20.64	21.60	43.68	27.36
7	Sulphate (SO_4) mg l^{-1}	200.00	56.76	55.57	126.56	71.73
8	Arsenic (As), mg l^{-1}	0.01	Nil	Nil	Nil	10.00
9	Chromium (Cr) mg l^{-1}	0.050	0.019	0.241	0.083	0.037
10	Manganese (Mn) mg l^{-1}	0.100	0.180	0.092	0.342	0.181
11	BOD	--	Nil	6.0	16.6	10.6
12	COD	--	Nil	24.0	26.0	22.0
13	Total coliform	0.00	0.00	$11x10^4$	$11x10^4$	$46x10^4$

The parameters which are not within the tolerance limits, indicate the influence by the inflow of sewage, domestic and industrial waste in the water body. Anthropogenic activities such as encroachments, construction activities, waste dumping, etc. also enhanced the total hardness of water to a larger extent. Hence, there is an urgent need to spread the awareness among people, so that, the pollution can be managed by adopting effective and eco-friendly approach.

Water quality has been judged (bio-mapped, Table 2.16) using various taxonomic groups of organisms as ecological indicators for prediction and detection of ecological effects with a view to protect rare and endangered biotic species surviving in surface water from pollution problem (CPCB,1999).

The integration of ecological aspects relating to vegetation through hydrological regimes would ensure sustainability of restoration activities on long-term basis in a cost-effective manner (Tabasum *et. al.*, 2009). Aquatic ecosystem harbours a variety of communities, which constitute the characteristics and functioning of the ecosystem in terms of maintaining production and food chain. Water quality also strongly influences distribution and extent of biodiversity in Yamuna River. Planktonic and benthic communities determine processes, functions and attributes of aquatic ecosystem. These organisms were critically linked to changes in ambient environment and species present were either tolerant to the rigorous chemical milieu or had wide ecological amplitude (Tare, 2012). The average standing crop of total plankton in upper Yamuna was 308 µ /l showing a gradual increase down the gradient: 273 µ/l at Hathnikund, 289 µ/l at Kalanaur, 329 µ/l at Badoli and 380 µ/l at Sanoli (Moza and Mishra, 2003).

Table 2.16. Water quality in stretches of rivers and tributaries of Yamuna Basin based on bio-mapping

River/ Tributary	Location of river stretch
Clean water stretches (Class 'A') of rivers and tributaries of Yamuna Basin	
Yamuna	Yamunotri to Kalsi (Uttarakhand)
Tons	Haripur to Kothi Minas (U.P.)
Banas* (tributary of Chambal)	Rameshwarghat (Rajasthan) before confluence of Chambal river
Ken	Panna (M.P.)
Slightly polluted stretches (Class 'B') of rivers and tributaries of Yamuna Basin	
Assani* (tributary of Giri)	Assani Khad, Solan (H.P.)
Giri	Giripul (H.P.) to Dakpatthar (Uttarakhand)
Yamuna	Dakpatthar (Uttarakhand) to Hathnikund (Haryana)
Betwa	Hamirpur (M.P.)
Kutni* (tributary of Ken)	Dumsa before confluence to Ken (M.P.)
Kail* (tributary of Ken)	Kishanpur before confluence to Ken (M.P.)
Ken	Banda before confluence to Yamuna (U.P.)
Mandakini	Karwi downstream of Chitrakoot (U.P.)
Chambal	Rameshwarghat (Rajasthan) before and after confluence of Banas
Parbati* (tributary of Chambal)	Upstream of Shivpuri - Baran Road (M.P.)
Chambal	Kota-Palighat (Rajasthan) before confluence of Parbati
Moderately polluted stretches (Class 'C') of rivers and tributaries of Yamuna Basin	
Chambal	72 stretches of rivers and tributaries in Yamuna Basin in Haryana, Delhi, Uttar Pradesh, Rajasthan and Madhya Pradesh States
Gambhiri* (tributary of Banas)	
Hindon	
Dhason* (tributary of Betwa)	
Mandakini* (Chitrakoot)	
Sind	
Betwa	
Kali Sindh* (Chambal)	
Bearch* (Banas*/Chambal)	
Kshipra* (Chambal)	
Alni* (Chambal)	
Yamuna	
Heavily polluted stretches (Class 'D') of rivers and tributaries of Yamuna Basin	
Khan* (Kshipra*/ Chambal)	Indore before confluence Kshipra (M.P.)
Hindon	Saharanpur to Barnawa (U.P.)
Kali* (Hindon)	Muzaffarnagar (U.P.)
Krishni* (Hindon)	Shamli-Muzaffarnagar Road (U.P.)
Betwa	Mandideep, Bhopal (M.P.)
Kalisindh* (Chambal)	Kalisindh (M.P.)
Chillar* (Chambal)	Shajapur (M.P.)
Parbati* (Chambal)	Ashtha (M.P.)
Severely polluted stretches (Class 'E') of rivers and tributaries of Yamuna Basin	
Hindon	Surana upstream of Ghaziabad (U.P.)
Krishni* (Hindon)	Shamli-Muzaffarnagar Road (U.P.)
Yamuna	Wazirabad-Okhla (Delhi)
Chambal	Downstream of Nagda (M.P.)

* Sub-tributaries of Yamuna. ***Source:*** CPCB, 1999

A report of IIT Kanpur (IIT, 2012) highlights characteristics features of community structure and diversity of phytoplankton, zooplankton, benthic communities and vertebrates of river Yamuna. The major findings of the study were as under:

1. The pollution load in Himalayan stretch, from origin to Hathnikund barrage is less as compared to downstream to Chambal confluence. DO values improved at Auraiya. Biotic community is less explored from origin to Hathnikund barrage. From Hathnikund barrage to Wazirabad barrage, reduction of Bacillariophyceae and presence of rotifers, crustacean, molluscs, annelids and other Arthopoda indicates the presence of organic pollution. In Delhi stretch Chlorophyceae and Myxophyceae are higher due to the combined sewage and industrial effluents.
2. In the river stretch affected by Mathura oil refinery waste, the Bacillariophyceae population was found to be thriving well (Prakash and Panwar, 2005). From the confluence of Chambal River to confluence to the Ganga confluence, the Yamuna is comparatively clean as reflected by dominance of Bacillariophyceae over other algal classes.
3. Changes in fishery composition were observed that suggest eco-degradation of Yamuna.

2.5.3. Factors Impairing Water Quality

Water quality in the Yamuna is degraded by two broad reasons:

a) Excessive discharge from of contaminants, and b) Less dilution of contaminants

a) Excessive Discharge of Contaminants

Contaminants enter the water resources from two types of sources:

Point Sources: A point source is a single, well defined source which generates a significant amount of pollution or sediment load in river water. Point sources include domestic pollution, industrial pollution and mining. Domestic and industrial pollutions are responsible for about 85 per cent of pollution in Yamuna (Malik *et al*,, 2014). Sewerage, detergents, oil, grease, organic material, etc. constitute domestic pollution. Untreated industrial waste from a variety of industries in the basin contaminates water. Sewage treatment plants (STPs) and effluent treatment plants (ETPs) are constructed to treat these wastes. Discharge of hot water into streams or rivers is also considered as a thermal pollutant. However, mining leads to discharge of silt or minerals in the water and cannot be checked by STPs or ETPs.

Non-point Sources: These are diffused sources of water degradation which are unspecified, numerous in numbers and contribution of individual source is quite small. The contaminants of diffused sources include soil, organic material, litter, plant residues, inorganic and organic chemicals, toxic material, microbes, etc. Important non-point sources of water degrading factors are (a) agricultural chemicals e.g. insecticides, fungicides, weedicides, fertilisers, (b) garbage, ash and dead bodies, (iii) immersion of idols, flowers, organic material (iv) ash from burning of forest and crop residues, (v) pollution due to in-stream uses of water e.g., bathing, washing of cattle, open defecation and (vi) runoff of soil from agricultural, forest or other lands/ river beds with water or air into stream or river water.

The problems of Yamuna are chiefly those related to the impacts of water extraction and flow-regulation, pollution from domestic and industrial effluents, as well as agricultural runoff, and rapid siltation due to erosion in the drainage basin. The catchment degradation, especially the loss of vegetation cover coupled with terrace cultivation and road construction, contributes to the alteration of the hydrological regimes as well as the degradation of habitats and water quality.

As per the studies carried out by the Central Pollution Control Board (CPCB, 1982-1983, 1994), the domestic wastewater is the predominant source of pollution of the Yamuna River. From a modest base of 25.8 M persons in 1901, the number of urban dwellers has risen to 285 M in 2001, signalling a

phenomenal eleven-fold increase in urban population over a period of 100 years (Rai *et al.*, 2011). Wastewater inflow in Yamuna is major source of pollution which is governed by population, water supply, sewerage network and collection, efficiency of the relevant infrastructure, etc. They further observed:

1. Out of 8,444 MLD of wastewater generated in the basin, about 4,458 MLD is discharged directly into the Yamuna River. About 1,200 MLD is discharged into tributaries of Yamuna River. Approximately 2,786 MLD is either disposed of on land or used for irrigation. Due to population growth, this wastewater generation will be further aggravated.
2. Delhi generates about 3,743 MLD of wastewater, which is 44% of the entire sewage generated in the basin and 84% of the sewage being discharged into the Yamuna along its entire course (Table 2.17).
3. Uttar Pradesh, Madhya Pradesh and Rajasthan share almost equal amounts of sewage generation in this basin (Fig. 2.10).
4. Delhi has the highest sewage treatment capacity of 2,330 MLD which is about 68% of the total sewage treatment capacity in the basin. However, there is still a large gap of 1,413 MLD between generation and treatment capacity.
5. Though several STPs have been installed along the river course with a designed capacity of the order of 2,332.25 MLD for Delhi, 327 MLD for Haryana, and 403.25 MLD for Uttar Pradesh, but the river water quality is still the worst.
6. The main causes of the inefficient functioning of STPs are (i) their capacity is inadequate as compared to the generated sewage (ii) STPs are, in general, practically not meeting their compliance, (iii) under running of most of the STPs due to the lack of sewer connection, (iv) improper drainage system and (v) excess BOD concentration coming to the plant due to inadequate water supply, etc.

Considering the current status of generation and treatment capacity of Delhi alone, even if treated effluent quality is achieved at 10 mg l^{-1} BOD for the entire existing treatment capacity, still BOD load would be 179 t d^{-1} which may result in BOD concentration of 46 mg l^{-1} in the final effluent and not complying with the prescribed standards. Even if the entire sewage of Delhi is treated to a level of 5 mg l^{-1} of BOD, still the BOD load in the final effluent would be 19.4 t d^{-1} which may continue to impair the water quality of the river.

Water quality in Yamuna is also affected by industrial effluents in the river basin. Chromium (Cr) present in Yamuna is attributed to electroplating industries situated near the banks of the river. Pumping out of metal-rich water from deep layers in the earth can also increase concentration of those metals. Ingestion of large amounts of Cr also has severe detrimental health effects like gastrointestinal, hepatic and renal damage (Bagchi *et al*, 2002).

Arsenic is usually applied in agriculture, livestock feed, metallurgy, electronics and chemical warfare agents. It comes into water from weathering and leaching of rocks, arsenical pesticides, fertilizers, disposal of industrial and animal wastes, and found in the form of arsenate and arsenite. Drinking water is the major source of ingestion of arsenic in the human system. For drinking water IS 10,500:2012 stipulates the acceptable limit of arsenic in drinking water as 0.01 ppm, while the maximum permissible limit of arsenic in the absence of other alternate source is 0.05 ppm (Specification, I.S.D.W., 2012). Saha (2009) found ground water in many areas in Yamuna Basin, affected by arsenic contamination.

Table 2.17. Wastewater generation and treatment capacity of Yamuna Action Plan (YAP) towns

City/Town	Volume of waste water (MLD)	Treatment capacity (MLD)
Yamunanagar	45	35
Saharanpur	45	38
Muzaffarnagar	40	32.5
Karnal	60	48
Panipat	60	45
Sonepat	45	30
Delhi	3,800	2,330
Gurgaon	45	30
Faridabad	140	115
Ghaziabad	150	126
Noida	90	70
Vrindavan	5	4.5
Mathura	35	28
Agra	190	90
Etawah	13	10
Prayagraj	223	89
Total	**4,986**	**3,121**

(***Source:*** Rai *et al.*, 2011)

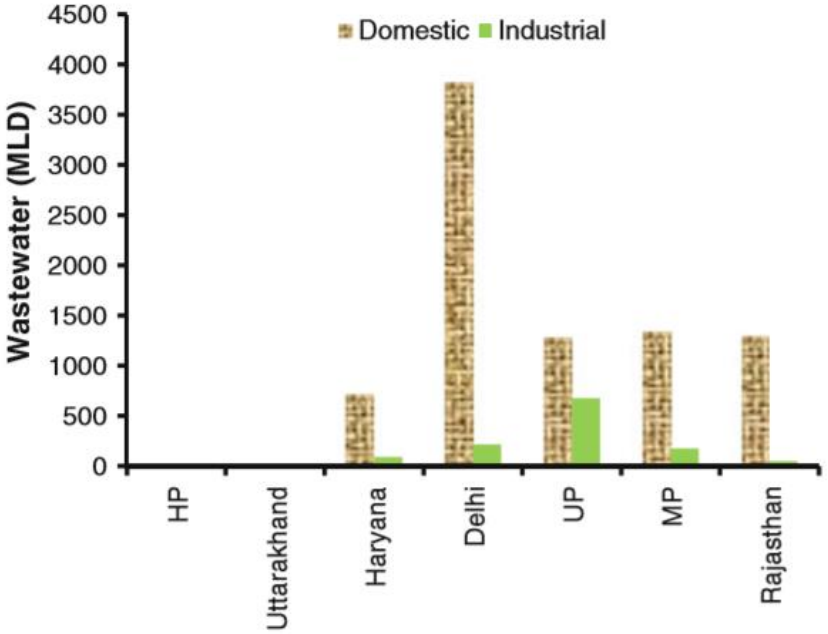


Fig. 2.10. State-wise domestic and industrial wastewater
(***Source:*** Rai *et al.*, 2011)

Districts in Yamuna Basin affected by high arsenic (>0.05 mg/l) concentration in ground water are as under (CGWB, 2015):

Haryana: Ambala, Faridabad, Panipat, Sonepat and Yamunanagar

Uttar Pradesh: Meerut

b) Less Dilution of Contaminants

There has been a continuous reduction in the quantity of water in water bodies over the last many decades. This is due to many reasons such decline in forest area, decline in quality of forest, encroachment of ponds, lakes and other water storage bodies, change in rainfall quantity and intensity, shift in land use towards concrete surface, change in cropping pattern, diversion of water from rivers to canals for agricultural, domestic and industrial usage, excessive abstraction of groundwater, etc. This has drastically reduced the availability of water in the streams and rivers, leading to less dilution of contaminants in water bodies. The result is that the concentration of contaminants in rivers has increased than in the past. The magnitude of decrease in quantity water has been discussed earlier in this chapter.

2.5.4. Change in Water Flow

Construction of dams and barrages also affects flow of river water and dilution of contaminants. The Yamuna basin has at least 12 operating hydropower projects with installed capacity of 495 MW, at least 5 under construction projects and 31 proposed projects with installed capacity of 2,361 MW. Rai *et al.* (2012) have listed about 470 dams on Yamuna and its tributaries. Building and planning of more hydroelectric and dam projects will have influences on river eco-system. The key tributaries are also under similar changes. Demand for construction of Renuka Dam on Giri River is still there even though the work on the dam has not been started. Kishau Dam on Tons River has been granted state clearance recently. Giri and Tons are major tributaries meeting the Yamuna from Himachal Pradesh side. Then, there are proposals to build 20 MW Damta-Naingaon and 42 MW Barkot-Kuwa hydro project upstream Lakhwar dam. Gangani, Hanuman Ganga and Badiyar Small hydro projects have been carried out on tributaries and perennial Yamuna in its upper segment. Even with so many existing, under construction and planned projects in upper Yamuna basin, there has been no cumulative impact assessment or carrying capacity study which is absolutely necessary before taking up any new project.

The total amount of annual water used in Yamuna basin from all the sources is approximately 44 B m^3 out of which as much as 42.2 B m^3 i.e., 96% is used for irrigation alone, leaving very little water in the river apart for its own beneficial uses for pollution dilution and assimilation (Mishra and Moza, 1997).

2.5.5. Change in Infiltration Rate through Land Use Land Cover Change

Kumar *et al.* (2019) analysed the pattern of urbanization and its impact on the quality and quantity of flow in the Yamuna river basin. During the last two decades, the basin has undergone urbanization at an unprecedented rate. The urbanization rate is more than one hundred per cent in Haryana and Rajasthan states of the Yamuna Basin (Fig. 2.11). Urbanization has resulted in adverse impacts on the surface water drainage system that often gets clogged up due to siltation. Although the flow during the monsoon season has increased in the River Yamuna, the water availability during the dry season is still not adequate to meet various competing demands. Due to urbanization, the flooding events in the basin, both in terms of magnitude and frequency, have exhibited an increasing pattern. Consequently, the vulnerability of thickly populated areas along the river has increased. Several implementable measures for sustainable development and flood risk management of the river Yamuna basin have been suggested.

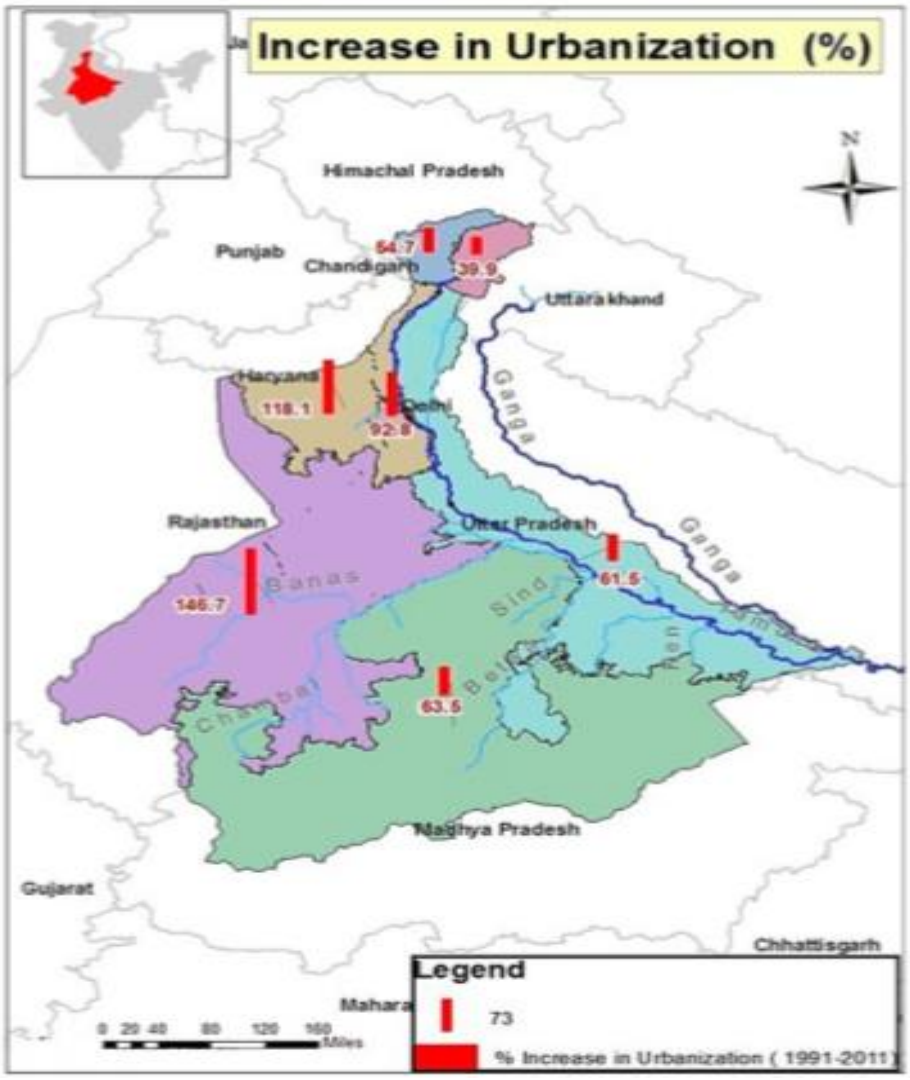


Fig. 2.11. Yamuna basin area with state-wise urbanisation
(***Source:*** Chandramouli and General 2011)

The major LULC changes observed during 1985-2005 at decadal intervals indicate increase in cropland and built-up and decrease in forest and water bodies (Table 2.18). The dominant processes of the LULC changes include transitions from forest, grassland, shrub land, water bodies and wasteland to cropland; transitions from cropland, shrub land, wasteland, grassland and forest to built-up; and conversion of forest to cropland, shrub land, plantation and built-up (Bansal *et al.*, 2016). The decrease in forest cover is mainly attributed to fragmentation, urbanisation, cropland expansion and construction of reservoirs and dams.

The human impacts on the Yamuna river basin have been discussed in several publications (Gopal and Sah, 1993; CPCB, 1982, 1983, 2006). Much emphasis has been laid on the rapid growth of human population accompanied by urban and industrial development (Fig. 2.12), and the discharge of untreated or partly treated domestic and industrial wastewaters as the major causes of degradation of the river and its water quality (Gopal and Chauhan, 2007).

Table 2.18. Change in land use and land cover pattern in Yamuna basin states

S. no.	LULC description	Area (km^2)			Percentage change in two decades
		1985	1995	2005	
1	Barren land	7,487	7,396	6,463	(−) 13.68
2	Built-up land	1,754	2,481	3,729	(+) 112.60
3	Crop land	131,899	133,795	135,119	(+) 2.44
4	Grassland	846	663	522	(−) 38.3
5	Forest land	33,951	32,090	30,570	(−) 9.96
6	Plant land	683	678	692	(+) 1.32
7	Wetland	117	101	98	(−) 16.24
8	Shrub land	12,215	12,385	12,414	(+) 1.63
9	Waterbodies	4,623	4,020	3,738	(−) 19.14
10	Wasteland	4,565	4,531	4,795	(+) 5.04

Source: Bansal *et al.*, 2016.



Fig. 2.12. Course of *Chhoti* Yamuna blocked by road construction (*Source:* Project Team)

Due to increased paved areas, the peak flow occurs in a relatively short time, resulting in congestion of drainage networks and flooding in rivers. The increasing trend of higher peak floods may be attributed to the decrease in basin water retention capacity. A very large quantity of water from the river Yamuna is diverted during the dry season, leaving no virgin flow in several stretches of the river. Quality of surface and groundwater in the basin has deteriorated to an alarming level (Kumar *et al.*, 2019). Several structural as well as non-structural measures have been suggested to overcome the damaging impact of urbanization and create sustainability in development.

2.6. PROBLEMS IDENTIFIED IN YAMUNA WATER

2.6.1. Himalayan Segment (Yamunotri, Uttarakhand to Hathnikund Barrage, Haryana)

Receding glaciers and shrinking forest areas for past few decades have turned many streams run dry, thus, reducing the overall water volume flowing in the river. The sediment load has increased due to devoid of vegetation in river's catchment. The studies have showed that the annual suspended was higher in degraded forest than in dense forest. The flow of rivers should be continued for survival of river ecosystems (flora and fauna). Moreover, muck dumping from developmental projects and debris from road construction has increased the riverbed level. Old human habitations and market areas are fast expanding on riverbanks and, in turn, are dumping all solid and liquid wastes in River Yamuna and its tributaries.

2.6.2. Upper Segment (Hathnikund Barrage, Haryana to Wazirabad Barrage, Delhi)

River Yamuna struggles to survive in absence of adequate flow downstream Hathnikund Barrage. Moreover, over the next 200 km, no key tributary meets the river. Illegal sand mining has hampered the process of ground water recharge and cultivation of water demanding crops such as poplar, paddy and sugarcane is fast over-drafting the shallow aquifers which deprive the river with lean season flow. The flow of water is also diverted in places where mining beyond permissible limits for collection of building materials is carried out. Vegetation is, sometimes, completely removed from the landscapes on the riverbanks and riparian areas of the rivers due to mining activities. The chemical farming in the catchment area is also negatively impacting the river. Meanwhile, industrial pollution from Yamunanagar, Karnal, Panipat and Sonipat districts are disposed of in the river by drain number 8 and 6. Releasing sufficient quantity of water from Hathnikund downstream for maintaining the ecological flow (estimated at 70 to 73.8 m^3 s^{-1} is a great challenge because of other priority uses of water such as drinking and irrigation.

2.6.3. Middle Segment (Wazirabad Barrage, Delhi to Etawah, Uttar Pradesh)

After Delhi, downstream cities of Noida, Faridabad, Mathura and Agra dump all sorts of industrial and domestic wastewater in Yamuna. Likewise, districts Saharanpur, Shamli, Baghpat, Ghaziabad, Meerut, etc., located in catchment area of Hindon and Karwan rivers dispose of wastewater into these rivers. As a result, level of pollution in Yamuna River exceeds the permissible level for Dissolved Oxygen, Biological Oxygen Demand, etc. and has been declared as the most polluted river of India. Discharge of wastewater, industrial effluents, pesticides and fertilisers is a major concern in relation to water quality.

2.6.4. Lower Segment (Etawah to Prayagraj, Uttar Pradesh)

In this stretch, a number of large tributaries such as Chambal, Sind, Ken, Betwa fall in the Yamuna. As a result, dolphins, ghariyals, turtles and many fish species are found inhabiting the stretch. However, use of poison and blasting in fishing, sand mining, levelling of ravine areas has started impacting the revived river. Moreover, ongoing work of 3,300 MW Bara and 1,980 MW Karchhana thermal power plants in Prayagraj district are posing threats to Yamuna.

2.7. STATUS OF FORESTS

2.7.1. Forest Cover and Recorded Forest Area

Forest Cover and Recorded Forest Area (RFA) are the two most used terms to describe extent of forest. Forest cover gives information about the forest canopy area covered on the ground irrespective of the

legal status of land, whereas RFA gives extent of forest in terms of legal status irrespective of actual forest canopy cover on the ground.

The term 'Forest cover' includes all tree patches which have canopy density more than 10% and area of 1 ha or more in size. The RFAs of the Yamuna River Basin states represent extremes, i.e., four states (Haryana, Uttar Pradesh, Delhi and Rajasthan) have 4 to 10% while for rest of three states (Madhya Pradesh, Uttarakhand and Himachal Pradesh) have 31 to72% of forest (Table 2.19) (FSI, 2019).

National Forest Policy of India, 1988 envisages a goal of achieving 33% of geographical area of the country under forest and tree cover. The forest cover of the country has been mapped into three canopy density classes, *viz.*, Very Dense Forest (VDF), Moderately Dense Forest (MDF) and Open Forest (OF). Scrub areas though not part of the forest cover, have also been mapped. The forest cover in the Yamuna River basin states, according to 2019 assessment and change therein as compared to the previous assessment of 2017, has been presented in the Table 2.20. Barring two hill states, namely, Uttarakhand and Himachal Pradesh where highest cover falls in medium density forest, rest of the five states have maximum of open forest, underlining the poor state of forest cover (Fig. 2.13).

Table 2.19. Recorded forest areas (RFAs, km^2) in Yamuna River Basin states

S. no.	State	Geographical area (GA)	RFA (in different categories)			Total RFA (2019)	Per cent of GA
			Reserved forest	Protected forest	Unclassed forest		
1	Uttarakhand	53,483	26,547	9,885	1,568	38,000	71.05
2	Himachal Pradesh	55,673	1,898	33,130	2,005	37,033	66.52
3	Haryana	44,212	249	1,158	152	1,559	3.53
4	Uttar Pradesh	240,928	12,071	1,157	3,354	16,582	6.88
5	Delhi	1,483	78	24	0	102	6.88
6	Rajasthan	342,239	12,475	18,217	2,045	32,737	9.57
7	Madhya Pradesh	308,252	61,886	31,098	1,705	94,689	30.72
	Total	**10,46,270**	**11,52,04**	**94,669**	**1,08,259**	**1,85,702**	**17.75**

Source: FSI, 2019.

Table 2.20. Forest cover (km^2) in the Yamuna River Basin states

S. no.	State	Geog. area (GA)	2019 assessment				Per cent of GA	Change % w.r.t FSI 2017	Scrub
			VDF	MDF	OF	Total forest cover			
1	Uttarakhand	53,483	5,047	12,805	6,451	24,303	45.44	0.03	383
2	Himachal Pradesh	55,673	3,113	7,126	5,195	15,434	27.72	2.21	315
3	Haryana	44,212	28	451	1,123	1,602	3.62	0.88	154
4	Uttar Pradesh	2,40,928	2,617	4,080	8,109	14,806	6.15	0.87	587
5	Delhi	1,483	6.72	56.42	132.30	195.44	13.18	1.57	3.30
6	Rajasthan	3,42,239	78	4,342	12,210	16,630	4.86	0.35	4,760
7	Madhya Pradesh	3,08,252	6,676	34,341	36,465	77,482	15.14	0..09	6,002
Total		10,46,270	17565.72	63201.42	69685.3	150452.44	14.38	6.00	12,204.3

(***Source:*** FSI, 2019)



Fig. 2.13. Forest around Tons, Uttarakhand
(*Source:* Project Team**)**

2.7.2. Tree Cover and Trees Outside Forest (TOF)

Tree cover is defined as all tree patches of size less than 1 ha occurring outside the recorded forest area. Tree cover includes trees in all formations including scattered trees. TOF refers to all trees growing outside RFA and tree cover is a subset of TOF. In India, requirement of wood and wood-based products to a large extent is met from Trees Outside Forests. They are also important for their ecological, socio-economic and cultural significance.

Table 2.21. State wise extent of TOF (km^2)

S.no	State	Geo. area	Tree cover 2019	Forest cover outside RFA	Extent of TOF**	Per cent of forest & tree cover of the state	Per cent of Geo. area of the state
1.	Uttarakhand	53,483	841	7,513	8,354	13.05	15.62
2	Himachal Pradesh	55,673	829	4,796	5,625	34.58	10.10
3	Haryana	44,212	1,565	1,229	2,794	88.22	6.32
4	Uttar Pradesh	2,40,928	7,342	5,611	12,953	27.03	5.38
5	Delhi	1,483	129	136.37	265	81.68	17.92
6	Rajasthan	3,42,239	8,112	4,348	12,460	53.21	3.64
7	Madhya Pradesh	3,08,252	8,339	12,730	21,069	24.55	6.83
	Total	10,46,270	27,157		63,520		

(***Source:*** FSI, 2019)

The extent of TOF has been assessed at 29.8 M ha which is 36.40% of the total forest and tree cover in the country. Table 2.22 shows TOF in the states of Yamuna River Basin (FSI, 2019). The tree cover is 27,157 km^2 which is 2.60% of geographical area of the seven states.

2.7.3. Forest Cover on Different Slope Classes

Forests play an important role in the stability of mountain ecosystems. Forest cover on hill slopes is a good indicator of soil stability and state of soil and water conservation in general in an ecosystem (FSI, 2019). There seems to be an inverse relationship between increasing slope class and per cent of forest cover (Table 2.22). Same is true for the scrub also.

Table 2.22. Forest cover in different slope classes (km^2) at the national level

Slope	Geo. area	VDF	MDF	OF	Forest cover (FC)	Scrub	Per cent of total FC	Per cent of GA
0^o-5^o	24,81,537	30,806	1,11,667	1,48,359	2,90,832	25,883	40.83	11.72
5^o-10^o	2,33,672	14,197	54,176	45,895	1,14,268	7,113	16.04	48.90
10^o-15^o	1,42,564	12,478	40,344	32,608	85,430	4,580	11.99	59.92
15^o-20^o	1,19,813	11,394	32,309	26,077	69,780	3,462	9.80	58.24
20^o-25^o	1,00,940	9,916	25,381	20,149	55,446	2,489	7.79	54.93
25^o-30^o	79,661	8,092	18,671	14,137	40,900	1,530	5.74	51.34
> 30^o	1,29,282	12,395	25,924	17,274	55,593	1,240	7.81	43.00
Total	**32,87,469**	**99,278**	**3,08,472**	**3,04,499**	**7,12,249**	**46,297**	**100.00**	**21.67**

(***Source:*** FSI, 2019)

2.7.4. Natural Vegetation

In the lower Himalayan region, the vegetation is predominantly semi-deciduous tropical forest, while at higher altitude species of *Pinus, Cedrus deodara, Picea smithiana, Abies pindrow, Quercus, Cupressus, Rhododendron* thrive depending upon altitude, aspect and other site factors (Champion and Seth, 1968). Lower down in the upper basin, and towards the east, sal (*Shorea robusta*) is the primary species, while the Malwa plateau supports forest vegetation dominated by teak (*Tectona grandis*) and sal. The large western part of the basin has typical dry deciduous thorn scrub vegetation composed chiefly of species of *Acacia* and *Prosopis*. The southern Kota region has dry deciduous forests.

A list of important forest tree species growing in the Yamuna basin states was prepared from IFSR 2019 to know their number and distribution. Overall, 39 species were recorded and few of them (*Acacia catechu, Anogeissus latifolia, Lannea coromandelica, Shorea robusta,* etc.) have wide distribution over other tree species (Table 2.23).

2.7.5. Weeds

Invasive plants are source of concern in Yamuna basin and its management. Terrestrial weeds such as *Lantana camara* and *Prosopis juliflora* are noxious weeds and have invaded large areas in the forest in plains, ravines and low altitudes in hills in Yamuna basin. *Eupatorium, Barleria prionitis, Alternanthera philoxeroides, Cassia uniflora, Chromolaena odorata* are also menace. *Parthenium hysterophorus* is a harmful weeds in urban areas. Attempts to control *Lantana camara* and *Prosopis juliflora* have not been successful so far. Although weeds are harmful, the presence of such plants on difficult fragile slopes helps in checking soil erosion. Efforts need to be made to replace them with more economically and ecologically useful plants. *Eichhornia crassipe* and *Ipomoea batatas* are common aquatic weeds in Yamuna basin. They impair water bodies, are not of much use and need to be managed.

Table 2.23. State-wise inventory of important tree species in Yamuna River Basin

Tree species	UK	HP	HY	UP	DL	RJ	MP	Tree species	UK	HP	HY	UP	DL	RJ	MP
Abies densa	-	y	-	-	-	-	-	*Holoptelea integrifolia*	-	-	-		y	-	-
Abies pindrow	-	y	-	-	-	-	-	*Lagerstroemia parviflora*	-	-	-	-	-	-	y
Abies smithiana	y	y	-	-	-	-	-	*Lannea coromandelica*	-	-	y	y	-	Y	y
Acacia nilotica	-	-	y	-	y	-	-	*Leucaena leucocephala*	-	-	-	-	y	-	-
Acacia catechu	-	-	y	y	y	y	-	*Lyonia ovalifolia*	y	-	-	-	-	-	-
Acacia lenticularis	-	-	-	-	y	y	-	*Madhuca latifolia*	-	-	-	-	-	Y	y
Acacia tortilis	-	-	y	-	-	-	-	*Mallotus philippensis*	y	-	-	y	-	-	-
Anogeissus latifolia	-	-	y	y	-	y	y	*Phoenix sylvestris*	-	-	y	-	-	-	-
Anogeissus pendula	-	-	-	-	-	y	-	*Pinus roxburghii*	y	y	-	-	-	-	-
Azadirachta indica	-	-	-	-	y	-	-	*Pinus wallichiana*	-	y	-	-	-	-	-
Boswellia serrata	-	-	-	-	-	y	y	*Prosopis juliflora*	-	-	y		y		
Butea monosperma	-	-	-	y	-	y	y	*Quercus floribunda*	y	-	-	-	-	-	-
Cassia fistula	-	-	-	-	y	-	-	*Quercus leucotrichophora*	y	y	-	-	-	-	-
Cedrus deodara	-	y	-	-	-	-	-	*Quercus semecarpifolia*	y	y	-	-	-	-	-
Dalbergia sisso	-	-	y	-	-	-	-	*Rhododendron arboreum*	y	y	-	-	-	-	-
Diospyros melanoxylon	-	-	-	-	-	y	y	*Shorea robusta*	y	y		y	-	-	y
Ethretia laevis	-	-	-	-	y	-	-	*Syzygium cumini*	-	-	y	y	-	-	-
Eucalyptus spp.	-	-	y	-	-	-	-	*Tectona grandis*	-	-	-	y	-	y	y
Ficus racemosa	-	-	-	y	-	-	-	*Terminalia tomentosa*	y	-	-	y	-	-	y
Ficus virens	-	-	-	-	y	-	-	*Dendrocalamus strictus* (a grass)	-	-	-	-	y	-	y

States are UK: Uttarakhand, HP: Himachal Pradesh, HP: Haryana, UP: Uttar Pradesh, DL: Delhi, RJ: Rajasthan, MP: Madhya Pradesh. (***Source:*** FSI, 2019)

2.7.6. Forest Diversity

The number of species of trees, shrubs and herb in Yamuna River Basin states has a direct relation with the forest cover (Table 2.24). For example, states like Uttarakhand (279), Himachal Pradesh (324) and Madhya Pradesh (297) which have more forests also have a greater number of plant species, but an exception is Uttar Pradesh (241). It is also significant to note that tree species are more in both the hill

states, *viz.*, Uttarakhand (112) and Himachal Pradesh (116) and in plains in Madhya Pradesh (146); notably, forest cover is also more in these states. While, in Haryana (50), Uttar Pradesh (86) and Delhi (36) herbs are most prevalent. This differential in species number among states can be useful in designing forestry models for varied management options for the Yamuna basin.

Table 2.24. Number of species of trees, shrubs and herb in Yamuna River Basin states

S. no.	State	Number of plant species			
		Tree	**Shrub**	**Herb**	**Total number**
1	Uttarakhand	112	73	94	279
2	Himachal Pradesh	116	99	109	324
3	Haryana	45	43	50	138
4	Uttar Pradesh	84	71	86	241
5	Delhi	16	11	36	63
6	Rajasthan	65	30	8	103
7	Madhya Pradesh	146	79	72	297
	Total	**554**	**406**	**455**	**1,415**

(***Source:*** FSI, 2019)

2.7.7. Aquatic Diversity

Eichhornia crassipes, Ipomoea batatas, Phragmites karka, Saccharum munja, Typha angustata, Scirpus maritimus, Veronica anagallis aquatic etc. are common species found in and around the floodplains. They are important as they hold the loose soil besides cleaning water.

Vegetation in the Delhi stretch of the floodplain of the river Yamuna was examined in relation to hydrological characteristics (Tabasum *et. al.*, 2009). The floodplain was delineated into four zones: Zone I, Jhangola to upstream Wazirabad barrage; Zone II, downstream Wazirabad barrage to upstream Yamuna barrage; Zone III, Yamuna barrage downstream to upstream Okhla; and Zone IV, downstream Okhla to Jaitpur (Table 2.25). Seventy-four plant species including forty-two aquatic/semi-aquatic were identified. The decrease in water discharge from Jhangola to downstream Okhla, led to reduction in species richness. Vegetation in the four identified zones was governed essentially by hydrological factors. Zones I and III exhibited near-perfect correspondence signifying that variation in vegetational composition in these zones could be explained, to a great extent, on the basis of variations in the hydrological conditions. Zone II and IV, with relatively weaker correspondence, indicated that there were factors other than hydrological conditions, which caused variations in vegetational characteristics. The study highlighted the importance of allocation of water for periodic inundation to maintain floodplain characteristics including aquatic/semi-aquatic vegetation cover.

2.7.8. Carbon Stock in Forests

Climate change poses a serious threat to the ecosystems and the quality of human life all over the world. It is for this reason that the parties to the United Nations Framework Convention on Climate Change (UNFCCC) have undertaken wide ranging policy measures, actions and programmes to address the issues of climate change adaptation and mitigation. India as a Party to the Convention is required to periodically communicate greenhouse gas inventory for the country from all the sectors including Land Use, Land-Use Change and Forestry (LULUCF) as National Communication (NATCOM). In forest ecosystems, enormous carbon is stored which is divided in five pools by Good Practices Guidance for Land Use, Land-Use Change and Forestry, GPG (2003).

Table 2.25. Plant species at various sites along Yamuna in the Delhi stretch

Plant species	Zone				Plant species	Zone			
	I	II	III	IV		I	II	III	IV
Aquatic and semi-aquatic					**Aquatic and semi-aquatic (contd.)**				
Achyranthes aspera	+	+	+	+	*Scirpus maritimus*	-	-	-	+
Alternanthera sessilis	+	-	+	-	*Typha angustata*	+	-	+	-
Amaranthus caudatus	+	+	-	-	*Vallisneria natans*	+	-	-	-
Annagalis arvensis	+	-	-	-	*Veronica anagallis aquatica*	+	-	-	-
Arundo donax	+	-	-	-	**Terrestrial**				
Azolla pinnata	+	+	-	-	*Abutilon indicum*	-	-	-	+
Bidens pervea	-	-	+	-	*Acacia nilotica*	+	-	-	-
Carex fedia	-	-	+	-	*Alternanthera paronychoides*	+	+	-	-
Chara sp.	+	-	-	-	*Argemone mexicana*	-	+	+	+
Chenopodium ambrosioides	-	+	+	+	*Calotropis procera*	+	+	-	+
Cynodon dactylon	+	+	+	+	*Cannabis sativa*	-	+	+	-
Cyperus pygmaeus	+	-	-	-	*Cenchrus setigerus*	+	-	+	-
Cyperus rotundus	+	-	-	-	*Chenopodium album*	+	+	+	+
Eichhornia crassipes	+	+	+	+	*Cleome viscosa*	-	-	+	-
Eragrostis pilosa	+	-	+	+	*Dalbergia sissoo*	+	+	-	-
Eragrostis poaeoides	+	-	+	+	*Datura innoxia*	+	-	+	-
Fimbristylis dichotoma	+	-	-	-	*Eclipta prostrata*	+	+	+	-
Gnaphalium indicum	-	-	+	-	*Erigeron bonariensis*	+	-	-	+
Gnaphalium luteo-album	+	-	+	-	*Eucalyptus globulus*	+	+	+	+
Hydrilla verticillata	+	-	-	-	*Euphorbia clarkeana*	-	-	+	-
Ipomoea batatas	-	-	+	-	*Heliotropium eichwaldi*	-	-	+	-
Jussiaea repens	+	-	+	-	*Kochia indica*	-	-	+	-
Lippia nodiflora	-	+	+	+	*Lantana camara*	+	-	-	-
Marsilea quadrifoliata	-	-	-	+	*Launaea nudicaulis*	+	-	+	+
Mazus japonicus	+	-	-	-	*Parthenium hysterophus*	+	+	+	+
Melilotus alba	+	+	-	-	*Phyllanthus niruri*	-	+	-	-
Nymphea stellata	-	-	-	+	*Portulaca oleracea*	+	-	-	-
Panicum adscendens	-	-	+	-	*Prosopis cineraria*	+	-	-	-
Phragmites karka	+	-	+	+	*Ricinus communis*	+	+	+	+
Polygonum glabrum	+	+	+	+	*Solanum nigrum*	+	-	-	-
Polygonum plebeium	+	-	+	-	*Soliva anthemifolia*	-	-	+	-
Polypogon monspeliensis	+	-	+	-	*Tabernaemontana divaricata*	-	-	+	-
Potamogeton indicus	+	-	-	-	*Tamarix dioica*	-	-	-	+
Potamogeton pectinatus	+	-	-	-	*Thysanolaena maxima*	+	-	+	-
Ranunculus scleratus	+	-	+	-	*Tridax procumbens*	+	-	+	-
Physalis minima	+	-	-	-	*Xanthium strumarium*	+	-	-	-
Rumex dentatus	-	-	+	-	*Zizyphus mumularia*	+	-	-	-
Saccharum munja	+	+	+	-	**Total number of species**	**52**	**21**	**41**	**22**

(***Source:*** Tabasum *et al.*, 2009)

The living portion of biomass carbon is categorised in two pools: the 'above ground biomass(AGB)' and 'below ground biomass (BGB)' and are stores of significant amount of carbon. The 'Dead Organic Matter' (DOM) is also categorised in two pools: 'dead wood' and 'litter'. The fifth pool is 'Soil Organic Matter' (SOM) which accounts for nearly 50% of the total carbon locked in forests.

The carbon stock in India's forests for 2019 has been estimated 7,124.6 million tonnes (Mt) There is an increase of 42.6 Mt of forest carbon stock in the country as compared to the estimates of previous assessment (Table 2.26). The annual increase of carbon stock is estimated 21.3 Mt which is 78.1 Mt 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 (FSI, 2019).

Table 2.26. Change in forest carbon stock (Mt) of India between 2017 and 2019

Component	**Carbon stock in forest in 2017**	**Carbon stock in forest in 2019**	**Net change in carbon stock**	**Annual change in carbon stock**
Above ground biomass	2,237.5	2,256.5	19.0	9.5
Below ground biomass	689.7	700.8	2.1	1.0
Dead wood	30.1	35.8	5.7	2.9
Litter	136.2	127.9	-8.3	-4.1
Soil	3,979.5	4,003.6	24.1	12.1
Total	**7,082.0**	**7,124.6**	**42.6**	**21.3**

(***Source:*** FSI, 2019)

There seems to be a positive correlation between forest area and total carbon stock of a state. However, the trend had a small deviation in case of Himachal Pradesh vis-a-vis Uttarakhand, when lower forest area of the latter had a substantive more carbon pool than the former (Table 2.27). The total carbon stock of the seven states adds up to 2,933.37 Mt.

2.7.9. Forests and Water

Forests play a vital role in water conservation as trees and other vegetation reduce the run-off and increase percolation of water into soil, thereby, improving the water regime in the area. Therefore, retaining and enhancing forest cover in critical watershed areas improves sustained river flows besides flood regulation. State forest departments, besides plantation, protection and various conservation measures, also undertake steps to improve water conservation through different interventions such as building check dams, vegetation barriers, percolation ponds, contour trenches etc. Programmes and schemes of the Government of India such as Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), Integrated Wasteland Development Project (IWDP) and various state government schemes have also contributed significantly towards water conservation (FSI, 2017) (Fig. 2.14). An assessment of coverage of water bodies within forest areas pertaining to the year 2005 and 2015 was made, in order to indicate decadal change in water bodies within forest. For the purpose, water bodies lying inside or up to an aerial distance of 1km from the forest and covering an area of more than 1 ha have been considered and the changes in their extent over a decade have been computed.

Table 2.27. Forest carbon stock in different carbon pools in Yamuna River Basin states (x1000 tonne)

S.no.	State	Forest area ($km^{2)}$	Unit	AGB	BGB	Dead wood	Litter	SOC	Total
1	Uttarakhand	24,303	t	1,52,540	40,975	2948	4,904	1,69,545	3,70,912
			$t\ ha^{-1}$	62.77	16.86	1.21	2.02	69.76	152.62
2	Himachal Pradesh	15,434	t	1,10,045	30,745	2,559	2,711	1,06,300	2,52,360
			$t\ ha^{-1}$	71.30	19.92	1.66	1.76	68.87	163.51
3	Haryana	1,602	t	2,455	929	18	137	6,927	10,466
			$t\ ha^{-1}$	15.32	5.80	0.11	0.86	43.23	65.31
4	Uttar Pradesh	14,806	t	32,498	10,374	372	1,893	70,553	1,15,690
			$t\ ha^{-1}$	21.95	7.01	0.25	1.28	47.65	78.14
5	Delhi	195	t	277	98	2	21	838	1,236
			$t\ ha^{-1}$	14.19	5.03	0.11	1.06	42.86	63.26
6	Rajasthan	16,630	t	26,155	10,865	191	928	70,224	1,08,363
			$t\ ha^{-1}$	15.73	6.53	0.12	0.56	42.23	65.17
7	Madhya Pradesh	77,482	t	16,50,687	64,630	1,535	8,156	3,49,339	20,74,347
			$t\ ha^{-1}$	21.30	8.34	0.20	1.05	45.09	75.98
	Total			**19,74,657**	**1,58,616**	**7,625**	**18,750**	**7,73,726**	**29,33,374**

(***Source:*** FSI, 2019)



Fig. 2.14. Forest and water
(*Source:* Project Team**)**

There in an increase of 2,647 km^2 in the extent of water bodies over the decade (2005-2015). In general, all the states registered an increase in water bodies except Haryana (-5.0) and Uttar Pradesh (-202.0) (Table 2.28). The state of Madhya Pradesh showed an increase of about 400 km^2 over the decade.

2.7.10. Wildlife

A fairly large number of birds utilize the shallow stretches of the River during summer and much larger population uses the riparian zones during winter. The creation of reservoirs, particularly at Okhla in Delhi, has provided a habitat suitable for many migratory birds as well - about 70 species of ducks, coots, cranes, herons, egrets, grebes, waders and other birds, have been recorded along the river's course. Large numbers of gulls and terns roost on islands in the river, and many swallows and martins in the reed-beds on riverbanks (Wolstencroft *et. al.,* 1989). The famous Keoladeo Ghana National Park at Bharatpur (Rajasthan) which lies in the floodplain of two small tributaries of Yamuna, attracts more than 350 species of resident and migratory birds.

Table 2.28. State-wise extent of water bodies (km^2) in the Yamuna River Basin

S. no.	State	Extent of water bodies 2005	Extent of water bodies 2015	Change
1	Uttarakhand	330	355	45
2	Himachal Pradesh	420	455	53
3	Haryana	21	16	-5
4	Uttar Pradesh	1,220	1,018	-202
5	Delhi	3.77	4.32	0.55
6	Rajasthan	414	454	40
7	Madhya Pradesh	1,930	2,319	389
	Total	**4,338.77**	**4,621.32**	**32,055**

(***Source:*** FSI, 2019)

Among other animals in Yamuna, the most important are turtles (*Kachuga* species). Crocodiles (*Crocodilus indicus*) which are common in Chambal, are also occasionally found in the Yamuna. A number of reptiles, amphibians and herbivorous mammals, are common in the floodplains. In case of gharial, Chambal River holds the largest population with an upper estimate of 306 adults (Converse, 2009). The other small population of gharial is in Ken River. The decline of the gharial (Indian crocodile) population in the river has also been reported (Lang *et al.,* 2019). Tiwari (2003) reported six species of turtles in the Yamuna at Etawah. Three species belong to one genus and one family of hard-shell turtle and other 3 species belonging to 3 other genera and one family of soft-shell turtle. Out of all reported turtles, *K. tentoria* is the most common turtle found in Yamuna.

Chambal also has a small population of Gangetic dolphins (*Platanista gangetica*), for which conservation efforts have recently been made (Rao *et al.,* 1989). In Yamuna River from confluence of Chambal to Hamirpur (350 km), 60 dolphins have been reported by Sinha *et al.* (2010). Fish from the family Cyprinidae dominate the variety of fish species found in the river. This includes Indian carp and also invasive species from the family. In a study, 93 species of fish were found in the river including catfish (Sharma, 2007; Sharma *et al.,* 2014). Species of non-native *Tilapia* fish have become established in the river.

Uttarakhand is rich in terms of fish diversity due to two major important perennial rivers Ganga and Yamuna supported by many other tributaries. Doon valley acts as a connective link between the plains and hill stream fishes. Geographically, the Dehradun district can be divided into eastern and

western Doon valley (Bhatt-Joshi *et al.*, 2016). A total of 9 genera, 3 families and 2 orders reported from the Yamuna. *Tor putitora* was the most abundant fish with 20.13% composition; it constitutes 0.169 abundance and 20.21% relative abundance. *T. putitora* was followed by *Barilius bendelisis* with per cent composition of 18.83, its abundance was 0.158 and with relative abundance of 18.89. Of all the fishes, *Tor tor* was least abundant. The fish species diversity during the study period was 0.889 which indicates good diversity of Yamuna. Certain parameters such as turbidity, result in increased fish motility due to choking of gills. Besides, the major problem is illegal fishing which results in declining fish population of Yamuna. Species diversity in different sampling sites indicated that altered habitat supports less fish species while shallow and deep pools are the primary habitats contributing to maximum diversity. Order Cypriniformes emerged as the most dominant group therefore, protection of these particular habitats is recommended for conservation and management of the fish diversity.

Study of wildlife is intimately linked with the forests and water. Any intervention that is approached from ecosystem point of view will also have direct or indirect connections with wildlife. State-wise description of wildlife is given in volume II of the DPR. All the seven states in the Yamuna basin have sanctuaries/ protected areas/ national parks (Table 2.29).

Table 2.29. Wildlife sanctuaries/ protected areas/ national parks in Yamuna basin

State	Wildlife sanctuary/ Protected area/ National park	District
Uttarakhand	Govind National Park	Uttarkashi
	Rajaji National Park	Dehradun
Himachal Pradesh	Churdhar Wildlife Sanctuary	Sirmaur
Haryana	Kalesar National Park	Yamuna Nagar
Uttar Pradesh	Sur Sarovar Bird Wildlife Sanctuary	Agra
	Etawah Lion Safari	Etawah
Delhi	Yamuna Biodiversity Park	Delhi
Rajasthan	Sariska National Park/Tiger Reserve	Alwar
	Ranthambore National Park	Sawai Madhopur
	Keoladeo Ghana National Park	Bharatpur
	National Chambal Ghariyal Sanctuary	Bharatpur, others
Madhya Pradesh	Kuno *National Park*	Sheopur
	Panna National Park	Chhatarpur
	National Chambal Ghariyal Sanctuary	Morena
	Ken Ghariyal Wildlife Sanctuary	Panna/ Chhatarpur

(***Source:*** SANDRP, 2015)

2.7.11. Land Use Pattern

The land use pattern in the Yamuna basin is presented in Table 2.30. More than 60% area of the area is the cultivable land, however, the actual cultivated land contributes about 52%. Forest cover extent is 12.5 %, in Uttarakhand, Himachal Pradesh and Madhya Pradesh (CPCB, 2006) (Fig. 2.15).

2.7.12. Agro-Climatic Zones

The Yamuna River basin comprises mainly five agro-climatic zones (Fig. 2.16): (i) Western Himalayan Region: Himachal Pradesh, Uttar Pradesh and Uttarakhand; (ii) Upper Gangetic Plains Region: Uttar ,Pradesh; (iii) Trans-Gangetic Plains Region: Haryana, Delhi and Rajasthan; (iv) Central Plateau and Hills Region: Madhya Pradesh, Rajasthan, and Uttar Pradesh; and (v) Western Plateau and Hills Region:

Madhya Pradesh and Rajasthan. However, a major part of the basin area falls under zone 8 (i.e. Central Plateau and Hills Region: MP, Rajasthan, UP). Considering agricultural planning in India, Chowdhury *et al.* (1993) demarcated another type of 15 agro-climatic classes. Based on this, the Yamuna River basin comprises three categories: The Satluj-Yamuna Alluvial Plains, the Central Semi-Arid Zone, and Lower Ganga basin.

Table 2.30. State-wise land use pattern in Yamuna River catchment

State	**Area (% of total catchment)**	**Land use pattern**			**Land actually cultivated (%)**	**Land under habitational use (%)**
		Non-arable land (%)	**Forest land (%)**	**Cultivable land (%)**		
Uttarakhand	1.1	5.0	22.0	23.0	14.3	1.6
Himachal Pradesh	1.6	25.0	59.4	15.6	14.2	1.5
Haryana	6.1	18.1	2.4	79.5	59.9	3.6
Uttar Pradesh	20.4	14.5	3.9	81.1	68.0	5.1
Delhi NCT	0.4	51	1.0	48.0	46.5	43.7
Rajasthan	29.8	40.8	8.8	50.4	43.9	2.2
Madhya Pradesh	40.6	26.0	18.0	56.0	50.7	1.8
Tot al	**100.0**	**27.5**	**12.5**	**60.0**	**51.9**	**2.9**

(***Source:*** CPCB, 2006)



Fig. 2.15. Farming in Yamuna Basin
(*Source:* Project Team**)**

2.7.13. Agroforestry

Agroforestry has traditionally been practiced in India as a way of life and livelihood since ancient times. Agroforestry meets almost half of the demand of fuelwood, 65% (small timber), 70-80% (wood for plywood), 60% (raw material for paper pulp) and 9-11% (green fodder requirement of livestock), in addition to its environmental benefits. Agroforestry systems store carbon in the soils and woody biomass, and these also reduce greenhouse gas emissions from soils. India targets a 33-35% reduction of emission intensity of its Gross Domestic Product (GDP) by 2030 from 2005 levels. India has announced the landmark National Agroforestry Policy 2014, which will help to bringing agroforestry in forefront in the country. National Agroforestry Policy (NAP) also recommends the sound database for Agroforestry in India and setup the institutional mechanism for promoting agroforestry research at national level (Dev *et al.*, 2018).

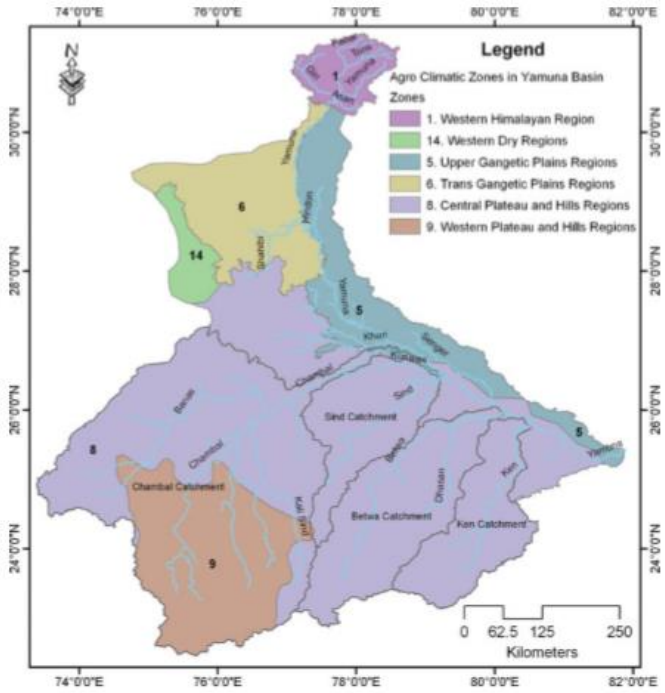


Fig. 2.16. Agro-climatic zones of Yamuna basin
(***Source:*** Rai *et al.*, 2011)

When tree green cover was worked out in relation to per cent of geographical area of the basin state, maximum area was recoded for Himachal Pradesh (4.14%) and minimum for Delhi (1.57%). Rest of the five states registered intermediate values of around 3.0 % (Table 2.31). The reason of referring to agroforestry in the basin area are, one, most of the farmers in India are having land holding around an ha which is by no means economic for perusing pure farming and, another, change in land use for various environmental issue like poor soil productivity coupled with pollution due to faulty cultivation practices. Therefore, only agroforestry remains a viable option for increasing farmer's income and mitigating environmental problems. That is how, agroforestry may be considered an alternative to pure agriculture in the forestry models for agriculture landscape.

Table 2.31. States-wise tree green cover under agroforestry in the Yamuna River Basin

State	Geographical area (km^2)	Tree green cover (km^2)	Tree green cover % to GA
Uttarakhand	53,483	1,966	3.68
Himachal Pradesh	55,673	2,303	4.14
Haryana	44,212	1,333	3.01
Uttar Pradesh	2,40,928	7,082	2.94
Delhi	1,483	23	1.57
Rajasthan	3,42,239	8,373	2.45
Madhya Pradesh	3,08,245	6,745	2.19

(***Source:*** FSI, 2019)

2.8. BIOLOGICAL PRODUCTION

Biological production is the amount of plants and animals produced, and diversity is the number of species present. Biological production and diversity provide value to society through fishing, bird-watching and waterfowl hunting. Aquatic plants take up excess nutrients - such as nitrate and phosphorus-from agricultural and urban runoff, and some of those plants are the food base for waterfowl and fish (USGS, 2003).

According to Davies *et al.* (2008), net primary production is a fundamental ecological process that reflects the amount of carbon synthesized within an ecosystem, which is ultimately available to consumers (Fig. 2.21) It reveals that aquatic algae are a significant contributor to food webs in tropical rivers and streams. Flood plains are important for fodder and for nursery habitat for fish, which re-invade main channels when floods recede. Streams and rivers are considered to be open systems, in the sense that energy and essential nutrients constantly 'leak' downstream and are effectively lost to primary producers or consumers at any particular stream or river reach, with little opportunity for return or recycling.

Secondary production represents the formation of living mass of a heterotrophic population or group of populations over some period of time (Benke and Huryn, 2006). Secondary production may involve animals eating plants, animals eating other animals, or microorganisms decomposing dead organisms to obtain the resources (material, energy, nutrients) needed to produce biomass. In a river system, biomass may be lost by export (e.g. downstream transport) or gained by import from other systems (such as leaves falling into a stream.

2.8.1. Primary Production

Study of primary production in the Yamuna shows that the net production ranges from less than 1 g $m^{-2}d^{-1}$ in the Himalayan stretch and the tail reach to 4.4 g $m^{-2}d^{-1}$ (range 1.5 to 9.3) in the Delhi-Agra sector (de Zwart, 1991; Kruijf *et al.*, 1992). The chlorophyll content increases from about 5 (lgl^{-1} in the Himalayan stretch and tail reach to 170 µg l^{-1} (range 140 to 1,027 µg/l) in the Delhi-Agra sector. As expected, the P/R ratio is at maximum (1.30-2.44) in the Delhi-Agra and lower stretches and lowest (0.06-0.28) in the Delhi sector.

2.8.2. Secondary Production

The production by zooplankton, benthos and fishes, has not been investigated for any section of the River except for some estimates of fish yields between Agra and Prayagraj during 1958 to 1966. It is

reported that the total annual fish-catch declined from 307 to 60 t at Agra and from 316 to 212 t at Prayagraj, during that period (Jhingran, 1982). *Cirrhinus mrigala* and *Wallago attu* were the major fish species.

2.8.3. Grassland Status

The grassland vegetation in warmer temperate grasslands, sub-alpine and cool temperate grassy slopes and alpine meadows of the Greater Himalayas are well recognised. Hay fields (*ghasni*) are intensively managed for grass production by local people. Cool temperate grassy slopes (>45^{o}) with thin soil in the cool temperate and sub-alpine zone (2,600-3,300 m) generally support herbaceous or grassland vegetation. Common grass species are *Chrysopogon, Dactylis, Koeleria, Andropogon, Danthonia* and *Themeda* species. Migratory pastorals create forest blanks within the cool temperate and sub-alpine forests. These grass openings within forests, maintained over a long period of time by grazing and burning, are dominated by herbaceous plants, *viz., Origanum, Taraxacum, Ranunculus, Rumex, Anemone, Senecio* and *Anaphalis* spp. Many of them are unpalatable and weedy. Only a few species of grass (e.g., *Poa, Phleum* and *Stipa* spp.) are found in such areas. The alpine meadow vegetation (above 3,500 m) comprises of a large number of herbaceous plants with varying proportions of tussock forming grasses, sedges and matted shrubs. The fifth category of grasslands i.e., steppe formation is relevant to the Trans-Himalaya region.

Yamuna plains can be divided into two sub-regions, *viz*., the *Khadar* and *Bhangar*. *Khadar* represents a unique biome in the sense that low lying areas remain inundated with water during most parts of the year. Such low-lying areas adjacent to the river course have tall wet grasslands (lowland grasslands). These are followed by slightly raised ground, largely dry sandy beds, where short grasses grow along with some herbs and shrubs and termed as dry grasslands (upland grasslands). These sand beds merge into gently sloping and undulating terrain locally known as *khola* which ultimately gives way to levelled plains (*Bhangar*). *Khola* are characterized by sandy to loamy soil and used to support growth of trees, shrubs, herbs and grasses. Today, there are a few places along the floodplains of Ganga where discrimination between *Khola* and *Bhangar* is possible. Most of the *Kholas* have now been levelled off and converted into crop fields (Khan *et al*., 2008).

2.8.4. Wetlands

The flood plains of Yamuna basin and seasonal wetlands perform valuable ecological functions such as ground water recharge, nutrient and sediment retention, habitats for water birds and spawning ground for fish. These wetlands are mostly utilized for irrigation, agricultural activities, and other consumptive purposes. However, most of those wetlands are treated as sewage discharge or waste dumping sites (Bassi *et al*., 2014). The unsustainable development and urbanization, untreated sewage discharge (Rai *et al*., 2011; Manral and Khudsar, 2013; Bassi *et al*., 2014), agricultural run-off (Jain *et al*., 2007), siltation, encroachment of floodplains (Sharma *et al*., 2014) are the biggest threats to the wetlands of the Yamuna Basin.

Wetlands in Uttarakhand

The extent of wetlands in Uttarakhand is 1,038.8 km^2, which comprise 1.92% of the total geographical area of the state (SAC, 2011). Rivers and streams dominate the wetland constituent with 77.14% covering 810.3 km^2 (Fig. 2.17). The reservoirs and barrages comprise 19.56% of the wetlands, covering an area of 203.2 km^2. Other wetland categories in the state are high altitude wetlands (1.4 km^2), lakes (20.8 km^2), tanks/ponds (1.0 km^2) and water logged areas (2.2 km^2). The important wetland close to Yamuna River in the state is Asan Reservoir in Dehradun which is a man-made wetland of about 3.2

km^2. Asan is also India's first Conservation Reserve, established in 2005 and is important for wetland migratory birds.

Wetlands in Haryana

According to NWIA (2011), there are 1441 wetlands in the state of Haryana covering 424.8 km^2 contributing 0.96% of the total area of the state. River/ stream are the dominant wetland types which cover 170.2 km^2. The other wetland types in the state are tank/pond (75.7 km^2), waterlogged (47.5 km^2), and reservoir/barrage (17.7 km^2). The Kalesar National Park & Wildlife Sanctuary, Sultanpur National Park and Bhindawas Bird Sanctuary are reservoirs protected under the Wild Life (Protection) Act, 1972. The Basai wetlands are waterlogged areas and important wetlands in the Yamuna floodplain.

Wetlands in Delhi

NWIA (2011) study identified 98 wetlands covering an area of 27.71 km^2 in Delhi (NCT) that is 0.93% of the geographic area. Rivers/streams dominate wetland types in Delhi, covering an area of 10.7 km^2. The other wetland types are reservoirs/barrages (4.7 km^2) and waterlogged (6.0 km^2).

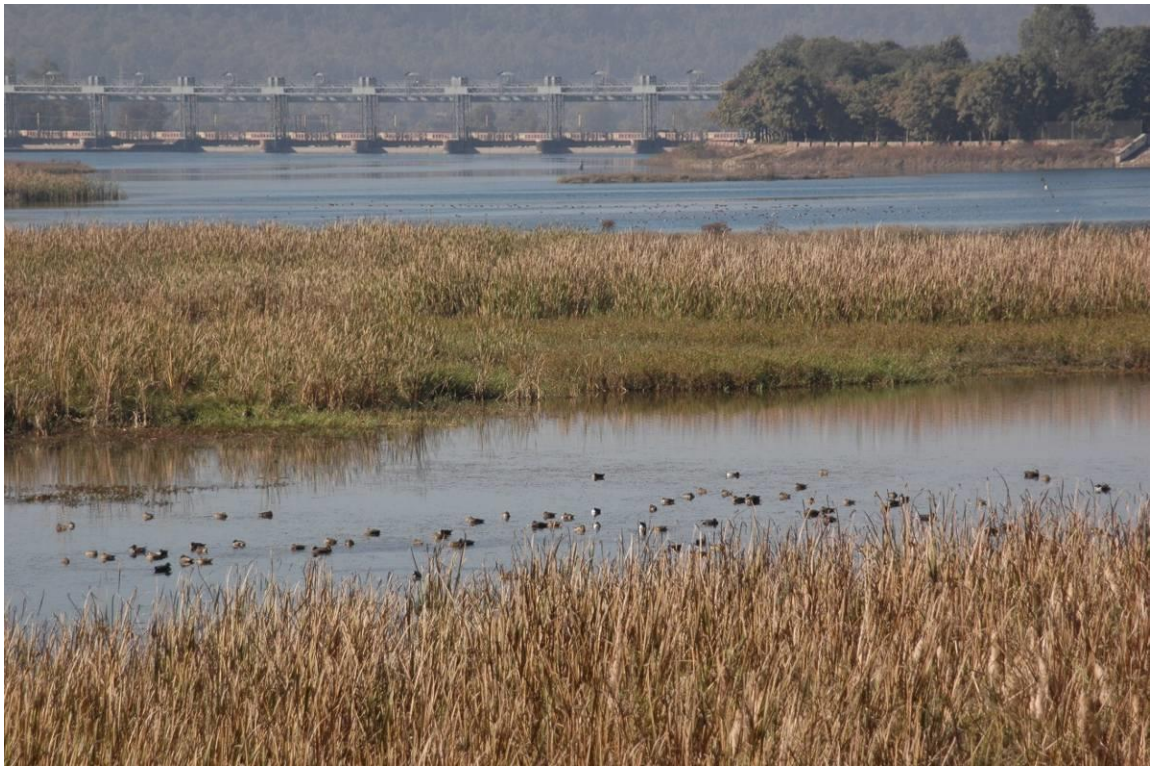


Fig. 2.17. Wetland: Asan Barrage, Uttarakhand
(*Source:* Project Team**)**

Wetlands in Uttar Pradesh

Uttar Pradesh has approximately 12,424.3 km^2 (SAC, 2011) wetland area which is 5.1% of its total geographical area (Jha, 2013). Rivers/streams are the dominant wetland types covering 6,073.1 km^2 area in the state (Table 2.32), and comprise 48.9% of the total wetland area. The Okhla Barrage is an important bird area. It has been declared as Okhla Bird Sanctuary and is protected under the Wild Life

(Protection) Act, 1972. The other wetland categories in the state are waterlogged (1,639.5 km^2), lakes/ponds (1,225.3 km^2), reservoirs/barrages (1,056.4 km^2), riverine wetland (611.0 km^2), ox-bow/cut-off meander (513.7 km^2) and tanks/ponds (332.6 km^2). There are 97,352 smaller wetlands having area less than 2.25 ha (SAC, 2011) which comprises 7.83% of its wetland area in the state.

Table 2.32. Area of different types of wetlands in the states along Yamuna

States	Lakes/ Ponds (km^2)	Oxbow/ Cutoff meander (km^2)	High altitude wetlands (km^2)	Riverine wetlands (km^2)	Water logged (km^2)	Rivers/ Streams (km^2)	Reservoirs /Barrages	Tanks /Ponds (km^2)	Wetlands (<2.25 ha)	Total (km^2)
Uttarakhand	20.8	0.6	1.4	-	2.2	801.3	203.1	1.0	8.1	1,038.8
Haryana	8.0	0.2	-	-	47.5	170.2	17.7	75.7	105.2	424.7
Delhi	0.4	-	-	-	6.0	10.7	4.7	2.6	3.0	27.7
Uttar Pradesh	1,225.3	513.7	-	611.0	1,639.5	6,073.1	1,056.4	332.6	973.5	12,424.3

(*Source:* Project Team**)**

2.8.5. Water and Water-Associated Birds

Water birds, being generally near or at the top of the most wetland food chains, are highly susceptible to habitat disturbances, and are, therefore, good indicators of the general conditions of aquatic habitats. Wolstencroft *et al*. (1989) recorded the presence of large numbers of gulls and terns roost on the riverine islands, and swallows and martins in the reed-beds of the river banks. Nair (2009) reported 118 species, including 16 migratory species. Taigor *et al.* (2010) reported 250 species of birds from Chambal River. Consolidated information on the birds of the mainstem Yamuna River and its tributaries is sparse. The species abundance of water birds in the wetlands along the Yamuna River is presented in Table 2.33.

Table 2.33. Water birds of the wetlands in the Yamuna Basin

Wetland	Status	No. of species	Reference
Asan Conservation Reserve	Conservation Reserve	60	Kaushik and Gupta, 2013
Kalesar National Park and Wildlife Sanctuary	National Park and Wildlife Sanctuary, IBA*	161	Kalsi, 1998
Hathnikund Barrage		31	Tak *et al.*, 2010
Bhindawas Bird Sanctuary	IBA	66	Kumar and Dhankar, 2015
Basai Wetland	IBA	128	Rai *et al.*, 2017
Sultanpur National Park	National Park	161	Kaushik and Gupta, 2016
Yamuna Biodiversity Park	-	196	Koul, 2017
Sur Sarovar Bird Sanctuary	IBA	63	Shukla and Lone, 2010
Okhla Bird Sanctuary	Wildlife Sanctuary	126	Mazumdar, 2017
Surajpur Wetland	IBA	186	Ansari and Nawab, 2015
Vijay Sagar Bird Sanctuary	Wildlife Sanctuary	53	Verma *et al.*, 2015
Saman Bird Sanctuary	IBA	63	Rahmani *et al.*, 2010
National Chambal Sanctuary	National Park and IBA	308	Nair *et al.*, 2013

*IBA: Important Bird Area

2.9. FORESTRY PRACTICES

The contemporary forestry practices are broadly grouped into two categories:

2.9.1. Silvicultural activities

Silvicultural activities include planting in open forest areas, stabilization of fragile slopes with vegetation, rehabilitation of forest areas infested with various intensities of weeds, assisted natural regeneration, treatment of gullies and steep slopes through vegetative measures with soil conservation, grassland development, biodiversity conservation, etc. in different patterns and quantities according to the site conditions, organized as different models. Such works are well established in forestry sector.

2.9.2. Non-Silvicultural activities

Apart from silvicultural activities that are widely undertaken by the state forest departments in the catchment area of Yamuna, soil and moisture conservation, wetland management, riverfront development, eco-park development, etc. are also undertaken. Bioremediation has not been done on a significant scale but can be carried out.

a) Soil and Moisture Conservation

Soil and moisture conservation is an important practice in forestry sector.

i) Measures for Arable Lands in Riparian Areas

Bench terraces

Bench terracing consists of construction of step like fields along contours by half cutting the slope and half filling. Then, the original slope in converted to level fields. It is a well adopted practice in the hill region with rainfall greater than 1,100 mm and slopes 10-33%. However steep slopes in the Himalaya up to 75% are effectively being cultivated with this practice. Reduction in runoff and soil loss due to terracing may be as high as 92% and 96%, respectively.

Puerto Rican Type Bench Terrace

Puerto Rican or natural type bench terrace comprises of laying an earthen bund (30 to 45 cm height) or a vegetative barrier of 1.0 m width along the contour at 1.0 m vertical intervals. The space between barriers is cultivated, which results in the formation of terraces through induced deposition of soil along the barriers in about 4-5 years. This is a fairly low cost practice compared to bench terracing on slopes up to 7-12%. The vegetative barriers should be established by staggered planting of 2 to 3 lines across the slope at appropriate vertical intervals. The recommended grass barriers are guinea grass, napier, bhabar, khus-khus, munj, etc.

Conservation Bench Terraces (CBT)

This system consists of a terrace ridge to impound runoff water on a level bench (recipient area) and donor area which is left in its natural slope and produces runoff which spreads on the level bench. The CBT system harvests runoff from upper area for the benefit of crops grown in the lower levelled portion of the field. It is suitable for 2-6% slopes, rainfall zone of 700-1,500 mm and heavy to deep soils. The ratio of donor to recipient area may be kept as 2:1 to 3:1. At the end of the receiving area a shoulder bund is provided to impound runoff. CBT system (Fig. 2.18 and 2.19) has been successfully demonstrated in the semi-arid region at Bellary, Kota and sub-humid region at Dehradun. In Dehradun, CBT system reduced runoff and soil loss by over 80% and 90%, respectively, over the conventional sloping land system at 2% slope.

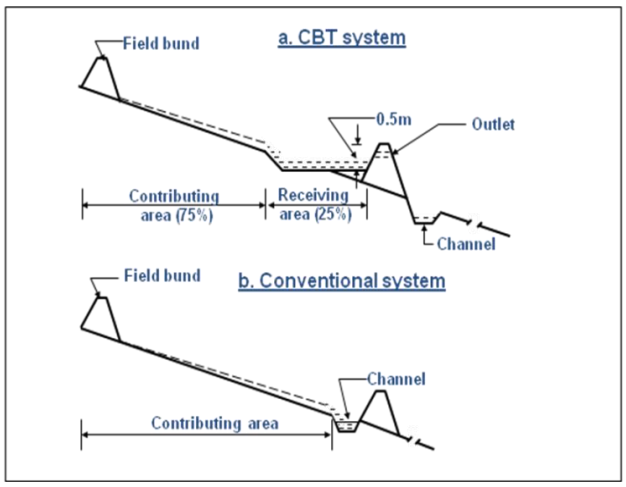


Fig. 2.18. Sectional view of CBT and conventional systems



Fig. 2.19. Performance of the crops at the farmers' field under CBT system

(**Source:** IISWC, Dehradun)

Vegetative Barriers

As an alternative to bunding, vegetative barriers comprising permanent strip of closely spaced grass grown on contours across the slope have been found to be equally effective. The grass strip is usually 1.0 m wide with 2-3 lines of grass clumps so as to provide a dense and sturdy barrier against runoff flow. Vegetative barriers are relatively cheaper and farmers friendly. They slow runoff and cause deposition of silt behind the barriers. For the barriers, economically important grasses that give dense and perennial cover should be selected. Locally adapted grasses like khus, bhabhar and munja in Shiwaliks, panicum (Guinea grass), napier and sambuta in lower Himalayas, khus have been found to be suitable for this practice. The vegetative barriers can reduce runoff and soil loss by 18-31% and 23-68% on slopes varying from 2-8%.

ii) Slope Stabilization Measures

Diversion Drains

Diversion drain is provided above the head of the slide or mined area, 3 to 5 m uphill side, to drain off the water safely away from the unstable area. A suitable grade is provided to the diversion drain, preferably around 0.5%.

Contour Vegetative Wattling

Wattling is a method of breaking the length of slope into shorter portions by providing contour wattles at 3 to 5 m interval upto 33 % slope. These are preferred on fragile slopes where soil working for trenching is difficult. Trenches 0.3 m wide and 1 m deep are dug up on contour and filled with brushwood bundles (5-6 cm diameter) lying horizontally. On the downhill side of the trenches, posts of species which sprout on planting are placed at 100-125 cm spacing. Examples of such self-sprouting species are *Ficus infectoria, Lannea coromandelica, Erythrina suberosa, Vitex negundo, Salix tetrasperma* (willow), *Hamiltonia suaveolens,* etc. If posts of these species are not really available, posts of any other hard wood species can be used. The trench is then filled back with the dug up earth till about 10 cm from the ground level. The posts are woven around with locally available shrubs upto about 20 cm above the ground level.

Trenching

Continuous/staggered contour trenches may be provided to break the velocity of flow, conserve moisture and retain soil to supplement better vegetation establishment on slopes. Generally, trenches may be dug with a cross section of 3.0 m x 0.30 m x 0.30 m at 1 to 2 m vertical interval. For proper drainage of excessive runoff, they may be connected with longitudinal drains and drop pits.

Mulching and Planting

The slide face in the inter wattle area or the inter trench area is further protected by spreading a thick layer of locally available grasses over the area. Wooden peg and binding wire can be tied to prevent displacing of mulch out of position. Recently, geotextiles (natural/synthetic) have also been used for such purposes to support mulches and help initial establishment of plantation. Some of the grasses may include *Chrysopogon fulvus, Tripsacum laxum* (Gautemala), *Cymbopogon* spp., *Pennisetum clandestinum, Cynodon dactylon*, *Saccharum* spp., etc. In between the trenches, sowing/planting with the local species of grasses and shrubs and easy to establish with quick growth may be planted to provide reinforced protective cover over the slide face. The common species may include *Acacia* spp., *Eucalyptus* spp., *Acacia dealbata, A. melanoxylon, Bombax ceiba, Lannea grandis, Erythrina* spp., *Terminalia* spp., *Cassia fistula,* etc.

Geojute

Also called as 'soil saver' is a natural geotextile used as mulch. This is essentially jute matting with an open mesh of 2 to 5 mm thick jute yarn having 10 mm apertures and is biodegradable. It has been successfully tried for stabilization of landslides, mine spoils and steep slopes. Success has been noticed in mine spoil rehabilitation at Sahastradhara, Dehradun by afforestation on affected area (Fig. 3). It has been found successful for initial establishment of vegetation on degraded slopes (upto 60-70%). Its application holds promise in badly degraded landslides and minespoil areas.

Crib Structures

Log wood crib structures filled with stone/brush wood can be used in stabilizing steep slopes (> 40%). Poles of 2 to 3 m length and 8 to 12 cm diameter are driven to depth of 50 to 75 cm and erected in two lines, 1 m apart line to line and pole to pole and these are nailed together by providing horizontal braces of poles (Fig. 2.20). The height of structure may be kept 1.5 m to 2.0 m above the ground. The inter-space may be vegetated with suitable quick growing vegetation.

iii) Stream Bank Protection Measures

Spurs

Spurs are commonly used for stream bank erosion control. Spurs are structures constructed at an angle to the stream flow, extending from the bank into the stream. Their main functions are to guide the stream flow along a desired alignment and to prevent bank erosion. A well-designed series of spurs built along an eroding bank will, firstly, check the erosion and secondly induce siltation in between the spurs. The silted banks may be put under perennial plantations subsequently. According to the function served, spurs are classified as (i) Repelling type (pointing upstream), (ii) Attracting type (pointing downstream), (iii) deflecting type (at right angle to flow). The projected length of a spur should not exceed 30 % of the stream width. A series of spurs are used to give a continuous effect. The spurs may be spaced 4-5 times its projected length in a straight reach, whereas on a curved reach the spacing may reduce to about 2 times the spur length.

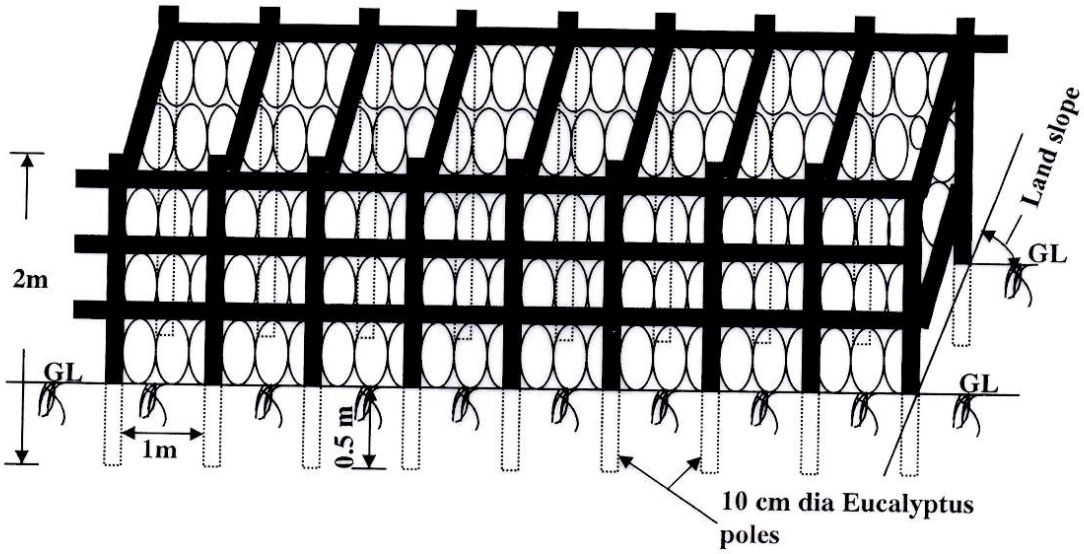


Fig. 2.20. Isometric view of log wood (Crib) check dam
(**Source:** IISWC, Dehradun)

Retaining Walls

A retaining wall works as revetment on steep slopes near the toe i.e. lower bank in protecting bank from erosion or deep cut on road side. It acts as a toe wall. As a rule of thumb, for gabion structures the bottom width is kept two-thirds of the height for walls up to 6 m in height with 1 m top width and for stone wall it may be kept a minimum one-third of the height. When there is surcharge, a 2 m top width may be adapted.

Retards

The retards serve the purpose of dampening stream velocity sufficiently near the bank to prevent erosive velocity sufficiently near the bank to prevent erosion of the banks or scour its toe by inducing deposition. There are three types of retards.

Live Hedges

Live hedges are commonly employed in small streams and torrent successfully. Shoots of *Ipomoea carnea, Arundo donax, Ziziphus,* etc. may be planted in trenches (60 cm wide) to serve as live hedges. *Arundo donax* has very strong root and shoot systems to resist the flood flows.

Jacks

Jacks are wooden posts of 8 cm diameter and 2 to 3 m in length, which are placed in series along the eroding bank, and are tied together.

Jetted Posts

These are green posts of 2 to 2.5 m in length and 6 to 12 cm diameter which are erected along the actively eroding banks in two rows, 1.0 m apart.

iv) Bamboo based interventions for reclaiming degraded gully beds in ravines

Bamboo Plantation with Staggered Contour Trenches:

Staggered contour trenches of 0.5 m (width) x 0.5 m (depth) x 2 m (length) are dug out at 4 m x 4 m spacing in ravine beds. Trenches should be excavated, across the slope. Seedlings are planted at the

centre of trench after filling the excavated soil up to 30 cm depth and equal volume of soil along with 1 to 3 kg of FYM is refilled after planting (Fig. 2.21).



Fig. 2.21. Bamboo plantation with supportive staggered trenches
(**Source:** IISWC, Dehradun)

Bamboo-based Bioengineering

In degraded gullies, series of earthen check dams (*bori* bunds) with polythene bags is constructed. The earth filled polythene bags of 3 rows at bottom, 2 rows at middle and one row at top are kept to maintain the stable slope (Fig. 2.22). After keeping these bags, soil is filled on top and sides and grass sodding/sowing is also be done. One end of the bund, the top *boris* are removed and kept at upstream and downstream to serve as outlet. For each *bori* bund, two rows, one each at upstream and downstream edge bamboo saplings are planted with plant to plant spacing of 2 m. In between the check dams, bamboo plantation is done with 4 m x 4 m spacing in staggered manner.

b) Bioremediation

Bio-remediation or bio-filtration is an option that enhances the efficacy of the natural bio-degradation process of the water bodies, and can be tested for application on a large scale. It uses decomposers and green plants, or their enzymes, to improve the condition of contaminated environment (Atlas and Hazen, 2011). The major advantage of the bioremediation methods is that it allows for contamination to be treated, neutralized or removed and, then, produces a waste product itself that is more easily disposed of. In some cases, there is no need for disposal at all. In case of phyto-remediation and rhizo-filtration, the plant is able to do something called bio-accumulation. This means it holds onto the contaminant. As the plant is still growing, there is no need to remove and destroy it.

Bio-filters

Bio-filters are a very popular technique in developed countries to prevent pollution of small flows emanating from small towns and urban and peri-urban areas and directly discharging into the river.



Fig. 2.22. Bamboo plantation with small earthen check dams made of sand bags
(**Source:** IISWC, Dehradun)

Riparian Vegetation Buffers as Biological Filters

Riparian vegetation buffers play an important role in connecting link between the terrestrial and aquatic ecosystems. It serves as an ecological corridor both between habitats and across elevation zones, and also affords protection against extreme temperatures. Riparian forests provide food and organic matter for terrestrial and aquatic organisms, moderate stream temperature, filter out sediments, nutrients and pollutants, stabilize river banks and function as a corridor for movement of animals. Riparian buffer shows many benefits like it protects the quality of water, intercept non-point source pollutants carried by surface water run-off and help in the removal of excess nitrogen, phosphorus and many other pollutants which are responsible for water body pollution. In addition, it stabilizes stream banks and minimizes erosion and also prevents sedimentation of waterways, provides food and habitat for wildlife of the land water and air and allows for wildlife movement within natural corridors and replenishes groundwater and protects associated wetlands. It modifies the condition of stream environments and the transporting mechanisms of materials, sediments, nutrients and pollutants loaded from the watersheds.

The current conventional approaches for removal of contaminants include sedimentation, membrane filtration, coagulation-flocculation, adsorption, chemical precipitation and ion-exchange. These processes depend on existing infrastructure and can be impractical to implement in developing countries and remote areas. As a result, there is an increasing need to detect and treat a contaminated water *in situ* using sustainable approach that is inexpensive and environmentally-friendly. Researchers are currently investigating the use of native biota for the detection and degradation or reduction of contaminants as a cheaper and sustainable alternative. Hence, the use of cleaner and cost-effective technologies such as the use of *biochar*, immobilized microbial beads, bioremediation techniques using effective microorganisms (agriculture, livestock, gardening and landscaping, composting, bioremediation, cleaning septic tanks, algal control and household uses) should be explored and applied.

Phyto-remediation

In aquatic ecosystems, several physico-chemical processes are regulated by biological factors or are to some extent subject to their effects. For example, sorption of pollutants by settling suspended particles depends on the number of phytoplankton cells; photochemical decomposition of substances requires

transparency of water which is provided, in turn, by filtering activity of aquatic organisms. Thus, biotic processes and factors are at the centre of the entire self-cleaning mechanism of water. Microorganisms, phytoplankton, higher plants, invertebrates and fishes are involved in self-purification of aquatic ecosystems and the formation of water quality. These functional filters will involves the direct water filtering by aquatic organisms that are filter-feeders, the filter (represented mainly by communities of aquatic plants/periphyton) which prevents input of pollutants and biogenic elements (N, P) from land into water bodies, the filter (represented by benthic organisms) which prevents re-entry of pollutants and biogenic elements from the bottom sediments into the water and the filter (represented by microorganisms attached to particles which are suspended in the water) that provides microbiological treatment of water column.

The self-purification of natural water system is a complex process that often involves physical, chemical and biological processes working simultaneously. Among various stages involved in self-purification, phyto-remediation is one in which the aquatic plant and vegetation on the river banks absorb nitrates, phosphates and other nutrients and remove pesticides and heavy metals. Phytoremediation has great potential as an efficient cleanup technology for contaminated soils, groundwater and wastewater. It is a cheap and efficient technique for metal removal and improving quality of river water. Filtering water by aquatic plant communities (duckweed, water hyacinth, *Azolla pinnata*, etc.) also prevents the entry of pollution and biogenic elements. The average heavy metal concentration at different location of Yamuna river water and its catchment area in Delhi varies in the order of Fe > Cr > Mn> Zn > Cr > Pb> Cu > Ni > Hg > As > Cd and the average heavy metal concentration at different location in soil varies in the order of Fe > Mn > Zn > Cr > Pb > Ni > Hg > Cu > As > Cd (Sehgal *et al.*, 2012). Phyto-remediation involves growing plants in a contaminated matrix to remove environmental contaminants by facilitating sequestration and/or degradation (detoxification) of the pollutants. It may be achieved in following ways:

a. Phyto-extraction: Plants remove metals from the soil and concentrate them in the harvestable parts of plants.

b. Phyto-degradation: Plants and associated microbes degrade organic pollutants.

c. Rhizo-filtration: Plant roots absorb metals from waste streams.

d. Phyto-stabilisation: Plants reduce the mobility and bioavailability of pollutants in the environment either by immobilisation or by prevention of migration.

e. Phyto-volatilisation: Volatilisation of pollutants into the atmosphere via plants.

Table 2.34. Details of plants and trees native to Yamuna Riverscape and their role in bioremediation

S. no.	Name of plant	Family	Storage organ	Pollution/Contaminant	Mechanism/ Process
	Aquatic plants				
1	*Spirodela polyrhiza* (Giant Duckweed) Floating aquatic plant	Araceae	Thallus	Reduce Cu-95%, Zn-79%, Cr-73, Hg-45%, Co-26%, Mn-20%, NO_3-100% and Ni-7%; BOD-37%, COD-49%, PO4-36%, SO4-16%, TDS-53%	Phyto-degradation
2	*Eichhornia crassipes* (Hyacinth) Floating aquatic plant	Pontedericeae	Root	Removal of heavy metal Cd-82%, Cu-78%, As-74%, Al-73%, Zn-65%, Cr-62.8, Fe-61% and Hg; Also removes cyanides, reduces chloride, iron, copper, manganese, lead (in root) fluoride, sulphate, nitrate and phosphorous.	Rhizo-filtration
3	*Pteris vittata*	Pteridaceae	Fronds	Fe, Cu, Zn, Ni, Al, Cr, Pb, Si and As	Phyto-extraction
4	*Anolia pinnata* (feathered mosquito fern/water velvet) Submerged plant	Salviniaceae	Roots and aerial parts	Domestic waste water, removes 70-90% of Cd and Hg	Phyto-extraction
5	*Arabidopsis thaliana*	Brassicaceaea	Shoots	Remove Hg, Cd and other heavy metals	
6	*Lemna minor* (duckweed)	Lamiaceae	Aerial parts and roots	Ni, Cu, Cd, Pb, Co and Cr	Phyto-degradation
7	*Typha orientalis*	Typhaceae	More in aerial part	Removes Pb	Phyto-accumulation
8	*Hydrilla verticillata*	Hydrocharitacea e	In aerial parts and roots	Removes As (92.5%), Zn (93.7%), TSS (60%), BOD (37.5%), NO_3 (33.41%) and P (46.01%)	
	Terrestrial herbs				
9	*Brassica juncea* (Indian mustard)	Brassicaceae	Root and shoot	Pb, Hg, Cd, Cr, Ni, Zn and Cu	Rhizo-filtration
10	*Helianthus annuus* (Sun flower)	Asteraceae	Root and shoot	Pb, Hg, Cd, Cr, Ni, Zn, Cu and radio nuclei Sr and Cs	Rhizo-filtration
	Trees				

11	*Dalbergia sissoo*	Fabaceae	Woody part	Removes Pb and Co	Bio-accumulation
12	Queens flower (*Terminalia arjuna*)	Combretaceac		Remove Se and the organic pollution in petroleum contaminated soil	
13	*Pongamia pinnata* (Pongam, Karanj)	Leguminosae	Roots, shoots and stems and transport further to upper part of the tree	Cr, Cu and Cd	Phyto-extraction
14	*Tectona grandis* (Teak tree)	Laminaceae	Bark and leaves	Fe, Cr, Cd, Cu, As, Mn, Zn, Pb and Hg	
15	*Salix viminalis* (Willow)	Salicaceae	Leaves, stem and roots	Remove inorganic nutrients and chlorinated solvents along with heavy metals such as Cd (83%) and Zn (71%)	Phyto-extraction
16	Poplars (*Populus* spp.) (Cotton Wood)	Salicaceae	More in roots than in shoots	Removes Cd, As, Ni and Pd tolerance	Phytoextraction
17	*Acer saccharum* Sugar maple tree	Sapindaceae		Removes Cd, Cr, Ni and Pb	
18	*Butea monosperma* (Flame of forest)	Fabaceae	Barks	Cr (VI), Fe, Cr, Mn, Cu, Zn, Cd, Pb and Hg	Phytoextraction
19	*Phyllanthus emblica* (Aonla)	Euphorbiaceae	Barks and leave	Remove Zn and Pb	
20	*Zea mays*	Poaceae		As and Cd accumulation	
21	*Ficus religiosa*	Moraceae	Leaves	As, Fe, Cr, Mn, Cu Zn, Cd, Pb and Hg	Bio-accumulation
22	*Prosopis cineraria*	Fabaceae	Roots	Floride	Bio-accumulation
23	*Azadirachta indica*	Meliaceae	Roots	Floride	Bio-accumulation

(Source: Pandey and Mishra, 2019**)**

Fast growing plants with high biomass and good metal uptake ability are more effective. Emphasis is given on the plantation of locally available native terrestrial plants and trees rather than aquatic plants due to their larger root system (Pandey and Mishra, 2018). *Tagetes patula, Bassica scoparia* and *Portulaca grandiflora* exhibited good bio-accumulation capacity for heavy metals in various parts. Such non-edible plants can be used for treatment of waste water and contaminated soils through *in-situ* techniques (Ghosh and Manchanda, 2019). Table 2.35 describes the role of some plant species in phytoremediation in Yamuna basin.

The technology has been successfully demonstrated in pilot projects by the Central Pollution Control Board the National Mission for Clean Ganga is now in the process of using bioremediation for cleaning up some parts of the river.

2.10. SOCIO-ECONOMY AND HUMAN LINKAGE

The World Summit on Sustainable Development (WSSD, 2002) recommended that integrated water resources management and water efficiency planning should be an essential element in all national or regional development strategies. The success of Integrated Water Resources Management (IWRM) and planning depends on institutional and human resources capacity, awareness and leadership. IWRM planning requires a variety of socio-economic data of the basin such as demography, population density, population growth rate, rate of urbanization, migrants, sex ratio, literacy, main and marginal workers, cultivator and agricultural labourer, health, population below poverty line, human development index, livelihood and employment, livestock, population and water supply (Rai *et al.*, 2011).

2.10.1. Socio-economy

Yamuna basin has a dominant rural economy. About 62.7% of the population, as per 2001 census, in the basin lived in villages (Rai *et al*., 2012); basin-specific data after that are not available. Agriculture is the dominant occupation in villages. People in villages live in joint family structure, and grow traditional crops with family labour and farm machinery. Landless people are also employed in farming by farmers with large landholding. Growing of commercial crops such as sugarcane, paddy and vegetables is common in Yamuna basin districts belonging to Western Uttar Pradesh and Haryana, and is gaining popularity. Growing of horticultural crops like apple, peach, plum, apricot and off-season vegetables is popular in Himachal Pradesh. People in villages rear domestic animals like cow and buffalo. Rearing of sheep, goat and poultry is also practised, especially in Uttarakhand, Himachal Pradesh and Rajasthan. Camel is reared in Rajasthan. Milk and meat of farm animals provide nourishment and generate income. Some families indulge in growing of vegetable crops on floodplain in an unauthorised manner. Fishing is practised on a small scale in unorganised way.

Skilled and unskilled workers in the unorganized sector constitute a large population in rural areas (for farming activities) and urban areas (for construction, business and industrial works). Urbanisation is growing at a rapid rate. Agricultural land is being been diverted for construction and commercial activities on a significant scale. Trade and service sectors also provide employment to a large population and support economy in the basin. Micro-, small- and medium-scale industries are the norm in urban industrial horizon.

2.10.2. Forests and People

In India, the rural population is about 68% of the country's total population and a significant part of it is dependent on the forests for meeting the needs of fuelwood, fodder, small timber, bamboo and NTFPs. The livestock population in the country is one of the largest in the world. As per the Census 2011, there are about 6,50,000 villages in the country, out of which nearly 1,70,000 villages are in the proximity of forest areas, they are often termed Forest Fringe Villages (FFVs). Forests play an important role in the socio-economic and cultural lives of the people inhabiting these villages. They

have been dependent on the forests for fuel wood, fodder, timber and bamboo since ages but with the manifold increase in their population in the last 60 to 70 years, pressure on forests has also increased**.**

A study was conducted to assess the dependence of communities inhabiting the forest fringe villages (FSI, 2019). In terms of average removal of fuelwood per capita in a year, the highest dependence is observed in Himachal Pradesh followed by Uttarakhand (Table 2.35). Similarly, for fodder, the highest dependence is observed in Madhya Pradesh closely followed by Uttarakhand and Himachal Pradesh. The average removal of small timber per capita in a year is observed highest in Madhya Pradesh followed by Himachal Pradesh. In terms of average removal of bamboo per capita in a year, the highest dependence is observed in Madhya Pradesh closely followed by Uttarakhand. There is no data available for Delhi. When same parameters were judged on all India basis, two states, namely, Himachal Pradesh (fuelwood: 2nd) and Madhya Pradesh (fodder: 10th, small timber: 4th and bamboo: 5th) find a place.

This relationship of people with forests may also influence the water resources. It is still an unexplored aspect and may find a place in forestry models (in selection of plant type and species). If these plants are part of forestry models, then, besides meeting their regular needs, these plants may also serve as an extra source of income.

Table 2.35. State wise quantities of fuelwood, fodder, small timber and bamboo removed from forests by the people living in forest fringe villages (FFVs) in Yamuna River Basin

State	Population in FFVs	Average removal (per capita/annum)			
		Fuelwood (t)	Fodder (t)	Small timber (m^3)	Bamboo (t)
Uttarakhand	61,89,670	0.659	5.922	0.006	0.015
Himachal Pradesh	7,81,340	0.759	5.831	0.014	0.006
Haryana	24,25,740	0.206	5.095	0.007	0.004
Uttar Pradesh	2,27,20,296	0.226	5.156	0.007	0.008
Rajasthan	2,47,10,255	0.346	4.316	0.003	0.005
Madhya Pradesh	3,87,66,588	0.198	6.098	0.038	0.016

(***Source:*** FSI, 2019)

2.10.3. Human Attitude and Enterprise

Yamuna and tributaries have religious and cultural significance in their basins (elaborated in chapter 1). Despite this, the condition of Yamuna has deteriorated to an alarming state. Increasing population However, Bhatia and Kumar (2016) observed that people living on river bank in Delhi revere Yamuna but are indifferent to Yamuna and, on account of diversion of sewer drains into it, do not prefer to use its water for irrigation and other purposes.

On the other hand, Mulloth and Rao (2018) noted encouraging examples of enterprise among few entrepreneurs in Yamuna basin. One entrepreneur worked on freeing up water resources for on-site usage, and restoring them by natural processes. The firm has been engaged by Delhi government since 2017 for cleaning of 8 km stretch of a drain that polluted Yamuna. Another firm manufactured an innovative boat fitted with GPS, sensors and image analyser that could detect and collect all kinds of trash, including plastic, chemicals, heavy metals and chemical effluents, and floating debris from the surface of water.

Countless individuals, groups and organisations are voluntarily working in the domain of environmental protection, moisture conservation and plantation activities in Yamuna basin. River Ruparel, a sub-tributary of Yamuna, was rejuvenated by volunteers of Tarun Bharat Sangh (an NGO led by Rajendra Singh, Stockholm Water Prize-2015) by constructing water storage structures (Down to Earth, 2015).

The success of a programme on river rejuvenation would thus require mobilisation of the common man by awareness means.

2.11. YAMUNA RIVER ECOSYSTEM: MAJOR ISSUES

Yamuna is one of the important and sacred rivers of India and is the largest tributary of the River Ganga. The area of Yamuna basin is 3,66,223 km^2 which is spread over seven states, *viz.*, Uttarakhand, Himachal Pradesh, Uttar Pradesh, Haryana, Delhi, Rajasthan and Madhya Pradesh. The major problems identified in relation to Yamuna, including tributaries, are as under:

2.11.1. Poor Ecological Flow

The ecological flow of water in Yamuna and its tributaries is greatly impaired: there is excessive water flow during monsoon while it is reduced to alarmingly low level during remaining part of the year. The major causes for this are as under:

Rapid Water Runoff

The catchment areas of Yamuna and its tributaries receive enough rainfall, however, most of it goes as runoff due to degraded forest and poor infiltration in agricultural and urban/peri-urban areas. During the monsoon season, the rivers overflow, flooding large areas on both sides. The water availability in the Yamuna is not enough to meet agricultural, human and environmental requirements during the months of December to June except for the Etawah to Prayagraj stretch. This stretch receives large quantity of water from four major tributaries, such as the Chambal, Sind, Betwa and Ken. There is hardly any flow of water into the Yamuna during the lean season in a long stretch of the river – that is about 900 km or two-thirds of the length of Yamuna – from Hathnikund in Haryana to confluence of the Yamuna and Chambal near Etawah in Uttar Pradesh. However, several seasonal small rivulets and streams discharge water into Yamuna during the monsoon season. The only major tributary of the Yamuna in this 900 km stretch is the Hindon, the condition of which is even worse than the Yamuna! This indicates impaired state of catchment and poor contribution of rainwater to ecological flow in this region.

Diversion of Water through Dams and Barrages for Agriculture and Urban Areas

Since independence, largescale construction of dams, such as Rana Pratap Sagar Dam, Gandhi Sagar Dam, Hathnikund Barrage, Wazirabad Barrage, etc., has taken place on Yamuna and its tributaries to meet requirements of expanding agricultural and industrial activities and meet domestic requirement of growing population in cities and towns. About 96% of the consumption of water in Yamuna basin is for irrigation alone (Mishra and Moza, 1997). Flow of water has also been regulated and diverted through a series of medium or small reservoirs and barrages for water consumption and flood control. Rai *et al.* (2012) have listed around 470 dams and barrages on Yamuna and its tributaries. The diversion of water also hampers the continuous flow of the river.

Excessive Groundwater Abstraction

Yamuna is a source of water for irrigation and drinking for very large area of north India. The flow of Yamuna and, to some extent, its tributaries, has been reduced by withdrawal of water for irrigation, domestic and industrial uses. Yamuna basin is about 34.54 BCM water-deficit (Upadhyay and Rai, 2013). Lack of regulation in the groundwater abstraction has led to ground water table depletion causing damage in causal linkage between surface and ground water, leading to change in surface water dynamics during the lean season of the river.

2.11.2. Poor Water Quality

There are serious concerns about quality of water in Yamuna as outlined below:

High Soil Erosion and Siltation Rates

Rapid water runoff in the catchment area is associated with soil erosion and damage to river banks. Erosion of topsoil from the catchment reduces fertility and vegetation growth. Unregulated mining in riverbed and river basin also lead to soil erosion. The off-site effects of soil erosion create problems like reservoir sedimentation and floods at the downstream. The sedimentation at dams and reservoirs depends on the soil erosion rate of the river catchment, thus, the useful life of any hydroelectric or irrigation project is adversely affected by soil erosion rate in the catchment area.

Discharge of pollutants and Waste

Discharge of domestic sewage, agricultural pesticides, fertilisers, industrial effluents and other waste material such as plastic, ash of dead bodies, religious idols, etc. have been persistently causing pollution of water. This has reduced suitability of water for drinking by human beings and animals and threatened the survival of aquatic life.

The problems related to quantity of water and quality of water together have serious implications on ecosystem services of water. On the basis of water quality index (WQI), the upper zones of the Yamuna River from Paonta Sahib, Himachal Pradesh to Palla, North-West Delhi have been reported to possess excellent (WQI 95-100) to good (WQI 80-94) whereas the middle locations from Delhi to Etawah (Uttar Pradesh) were described by poor (WQI 0-44) to marginal (WQI 45-64) (CCME, 2001). The decrease in WQI at the midstream of the Yamuna could be due to the growing density of the human population on the riverbanks along with poor sanitation practices by inhabitants. Further, the WQI values in the lower zone in Uttar Pradesh from Auraiya to Pratappur were enhanced and, thus, recorded as good to excellent. This is apparently due to the dilution effect from the Chambal, Betwa, and Ken Rivers. The WQI observations at Pratappur for all classes were similar to those at Paonta Sahib, Himachal Pradesh indicating that the water characteristics at the downstream region were recovered.

The dilution component is an essential component for maintaining water quality for human use as well as for the survival of aquatic habitat. Ecological flow of water has impact on quality of water too and deserves attention in the DPR.

2.12. SWOT ANALYSIS OF YAMUNA 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 Beas River and its environment, its past trends, and implications, the SWOT Analysis was performed. The findings of the SWOT Analysis are summarized in Table 2.38.

On the basis of review of the river basin, its environment, past trends, present situation and future potentials, the strengths, weaknesses, opportunities and threats (SWOT) analysis of Yamuna river ecosystem and its environment is summarized below:

(1) Strengths

i. The Yamuna River is one of the important and sacred rivers of India and is the largest tributary of the River Ganga. It originates from Yamunotri glacier in the Mussoorie range of the lower Himalayas and after traversing 1,376 km joins the river Ganga at Prayagraj. The drainage basin of Yamuna measures 3,66,223 km^2 which comprises part of seven states, *viz.*, Uttarakhand, Himachal Pradesh, Uttar Pradesh, Haryana, Delhi, Rajasthan and Madhya Pradesh. Some of these states are part of Indo-Gangetic plain- an area of high natural productivity and, consequently, of high population density. The Yamuna River and tributaries continues to be a major source of various economic values (e.g., irrigation, drinking water, hydropower, fish, sand and boulders, recreation, etc.).

ii. The Yamuna River has four main tributaries in the Himalayan region: Rishi Ganga, Hanuman Ganga, Tons, and Giri. In the plains, the main tributaries are the Hindon, Chambal, Sind,

Betwa and Ken. The water availability in the Yamuna River is not enough to meet water demands during the months of December to June except for the Etawah to Allahabad stretch, which receives good quality water from four major tributaries, such as Chambal, Sind, Betwa and Ken. These are important for keeping the river flowing throughout the year.

iii. Forests and trees are important modulators of water flows, with water flows being among the most prominent determinants of human health and wellbeing. They predominantly affect the volume and timing of water flow as well as rates of soil formation or erosion. Forests absorb rainfall and snow melt, slow runoff, reduce soil erosion, improve water infiltration rates and recharge aquifers. Thus, they have 'sponge effect'. Stream-side forests filter pollutants. Forest cover is one of the many factors which affect climate at the global as well as regional and local levels. Indeed, forests not only provide multiple services, but they are perceived to have multiple values those are being recognized by different sectors and stakeholders. It is one of the important reasons for taking up forestry interventions for rejuvenation of River Yamuna.

iv. Yamuna riverscape continues to harbour representative diversity of forests in Himalayan zone, Shiwalik region and even in plains despite heavy biotic pressures and deterioration. Representative terrestrial, aquatic and coastal wildlife values persist and are conspicuously distributed in select stretches and much can be restored and rejuvenated.

v. Taking cognizance of *Namame Gange programme*, Ganga rejuvenation by MoJ, the MOEF&CC, Govt. India is now taking the task related to the river conservation on priority basis and taking necessary steps for the management, rejuvenation and conservation of rivers in the country.

vi. Being the holy and sacred river in the country, the people of the country look forward to rejuvenation and conservation of Yamuna with their support in multiple ways.

vii. Owing to the geographical and environmental diversity of the Yamuna river system and its socio-economic, cultural and religious significance for the country, a large number of national/state government and non-government organizations have been involved in various aspects of river management. This network and baseline information is important strengths for execution of the Yamuna DPR.

(2) Weaknesses

i. Despite its diverse conservation values and significance to society and the nation, the Yamuna is over exploited by human need and greed, use, abuse and even neglect. Biological and water resources have already been deteriorated and ecological integrity is being challenged.

ii. Forests, grasslands, floodplains, wetlands, river banks around Yamuna and tributaries continue to experience unsustainable use. Enhanced landslides and erosion, high rate of sedimentation, fragmentation of the river, reduced e-flows and ever increasing pollution from agriculture landscapes, towns and cities, and industrial and pilgrimage centres are some of the main concerns.

iii. The construction of diversion structures at regular intervals (Hathnikund, Wazirabad, Okhla, Gokul, etc.) for irrigation, domestic and industrial water supply, has largely modified the flow regime of the River Yamuna. The inflow of wastewater either treated or partially treated in the river further aggravates the water quality problem of the river.

iv. Though the green revolution was important for food security, but lack of regulation in the groundwater abstraction has led to ground water table depletion causes damage in causal linkage between surface and ground water, resulting change in surface water dynamics during the lean season of the river. This is the main reason of dry river segments observed between Hathnikund and Palla (Delhi).

v. The country has created several policies, legislations and authorities to enforce law for use and regulation of river resources. However, there are gaps and challenges in rigid enforcement. Encroachment and illegal constructions on lands in close vicinity of the Yamuna and its tributaries, besides illegal mining in river beds for sand and boulders remains a contentious issue.

(3) Opportunities

i. River Yamuna, associated natural ecosystems and an array of biodiversity have enormous potential to flourish and recover. Much of the gene pool/biodiversity values in terrestrial and aquatic systems are still intact in many of the fragments/stretches of the river.

ii. The Yamuna remains a source of inspiration for peoples of India and provides an opportunity for the masses to contribute for its rejuvenation and conservation in many ways. Civil society organizations could mobilize public trust and support for the noble cause of ecological restoration which ultimately helps in their well-being.

iii. Being a multifaceted, complex and dynamic river ecosystem; the Yamuna and tributaries and adjacent natural, agricultural and urban built-up environments continue to provide innumerable opportunities for research and monitoring by various agencies and organizations. Successful experiences and expertise relevant to river management and restoration by way of appropriate retrofitting/engineering measures, bioremediation, etc. available around the country/globe could be optimally tapped for restoration of important river like Yamuna in the country.

iv. Experiences and expertise relevant to river management and restoration available around the country/globe could be optimally tapped for rejuvenation of river like Yamuna.

v. The current favourable environment wherein the present governments at the centre/states, various law enforcement agencies (Apex Courts, NGT, NGRBA, etc.), scientific organizations, technocrats, corporate, religious leaders and the masses have come together in a big way with a priority focused agenda provides a great opportunity for the rejuvenation of Yamuna and its conservation.

(4) Threats

i. The Yamuna and some of its tributaries originating from glaciers and snow-capped Himalayas in India being in the high seismic zone and experiencing increasing seismic activities in recent times, face multifarious threats, *viz.*, tectonic upheaval, enhanced landslides, cloudbursts, excessive rainfall and floods and the situation is expected to aggravate due to likely climate change and its impact. Natural ecosystems in the state of Uttarakhand and Himachal Pradesh Himalayas and the Yamuna plains are expected to be influenced in several ways.

ii. Increasing demands of hydropower projects in the hilly part of Uttarakhand and Himachal Pradesh and other developmental projects all along the Yamuna and its tributaries are expected to further fragment the river, causing loss of longitudinal, horizontal and lateral connectivity.

iii. Land degradation and high rates of sedimentation owing to various factors remain major challenges for the maintenance of e-flows and ecosystem integrity of the river and various tributaries.

iv. The geographic location of the river and its tributaries is across multiple states within the country. Issues related to inter-state/Centre-State coordination and any change in policies and priorities could severely impact planned activities of rejuvenation of Yamuna and its tributaries.

Chapter 3
THE APPROACH AND METHODOLOGIES

3.1. RIVER RESTORATION – EMERGING CONCEPTS

Various concepts have evolved over a period for planning, management and conservation of river ecosystems. The landscape level at which the planning is done is basin, sub-basin, catchment, watershed or riverscape. The river basin implies an area drained by a river and its tributaries. A river basin can have smaller sub-basins that combine to form a larger water basin. A catchment area is the part of land surface that drains into a particular stream or river and flows ultimately through a single outlet. River basins are usually separated by ridges, mountains and hills. A divide or landform from which water flows in different directions is called a watershed. Watershed is, sometimes, also used to imply the drainage basin of a smaller tributary. The water that flows down the entire catchment, basin or watershed is the lifeline of the river. The quantity and quality of water in a river is, thus, dependent on natural as well as artificial processes that take place in the catchment.

The National Committee of United Kingdom under International Union for Conservation of Nature (IUCN) defined river restoration as the re-establishment of natural physical processes (e.g., variation of flow and sediment movement), features (e.g., sediment sizes and river shape) and physical habitats of a river system (including submerged, bank and floodplain areas) (Addy *et al.*, 2016). River restoration involves reintroducing natural processes that may help the river to provide the diversity of habitat required for a healthy river ecosystem and ensure long-term recovery by addressing the root cause of the issue. Rivers like Yamuna have been extensively modified to accommodate societal needs for food production, electricity generation and economic activity; so, it may not always be possible to restore to a pristine condition. In such cases, improvement of river structure and habitats within the adjacent constraints can increase overall biodiversity and mitigate some issues. Chapter 1 lists 17 guiding principles for restoration of rivers, as identified by United States Environmental Protection Agency (US-EPA, 2000). From an initial focus on enhancing fish habitat or river appearance, primarily through structural modification of channel form, restoration has now expanded to incorporate a wide variety of management activities designed to enhance river processes and form. Restoration is conducted on headwater streams, large lowland rivers, and entire river networks in urban, agricultural, and less intensively human altered environments (Wohl *et al.*, 2015). River restoration is more than the greening of the catchment.

3.2. MULTIPLE ONGOING ACTIVITIES AND IMPLEMENTING AGENCIES

A number of programmes and activities are in progress in the catchment area of river Yamuna. Many more have the potential to take place. The impact of processes involved in these programmes and activities on the river may be positive or negative while some others may be neutral in their impact. Among the river-friendly developments, sewage treatment plants and effluent treatment plants are being set up in urban and peri-urban areas. Water-efficient irrigation facilities and systems are being promoted in a big way in agricultural landscape with a view to reduce pressure on natural water resources. Agroforestry is spreading and getting more and more popularity. An appeal from the Prime Minister Sh Narendra Modi on June 30, 2019 on radio programme *Mann Ki Baat* for water conservation movement has mobilised people all across the country to undertake a massive number of localised activities at individual as well as community level for *in situ* moisture conservation and recharge of ground water at all possible sites – rural as well as urban areas; digging of water recharge pits, desilting of existing ponds and lakes, removal of encroachments over land of ponds and village pastures; these acts are being expected to have favourable effect on ground water as well as surface water bodies. Under some schemes state forest departments (SFDs) have been carrying out soil and moisture conservation works in addition to the main task of afforestation in forest land (see examples in section 3.3.1).

While some of the above initiatives can be regarded as forestry interventions, many others are not related to forestry. It, therefore, becomes necessary at this stage to define the term 'forestry intervention' so that the DPR may proceed in a definite direction. On the negative side, excess withdrawal of river water or groundwater for industrial and drinking purposes is working towards depletion of water in the Yamuna. Expansion of irrigation network, increasing tendency towards cultivation of water-intensive cropping system, rising use of pesticides and fertilisers, etc. are having adverse impact on quantity and quality of water in the river. Mining and construction and developmental activities also have adverse impact on water. These issues too need to be addressed to realize the goal of restoration of Yamuna.

3.3. IDENTIFICATION OF GAPS IN ONGOING ACTIVITIES

3.3.1. Past schemes

In the past several schemes have been launched by Central and State governments through various departments in Yamuna basin. Some of such are expected to have influenced Yamuna and its tributaries. Information about important schemes has been collected from government agencies and websites belonging to departments or agencies on forest, watershed development, water resources, rural development and river rejuvenation, besides Forest Sector Report – 2019 (ICFRE, 2019). The information is summarised below:

a) River-specific projects

Three major schemes were implemented by Ministry of Jalshakti (earlier known as Ministry of Water Resources, River Development and Ganga Rejuvenation):

1. Yamuna Action Plan (YAP) was launched in 1993. The YAP has so far completed two phases as YAP-I and YAP-II. Now YAP-III is in operation. Under the two phases, 286 schemes were completed in 21 towns of Delhi, Uttar Pradesh, and Haryana and sewage treatment capacity of 767.25 ML d^{-1} was created.
2. *Maily se Nirmal Yamuna Revitalization Plan*, 2017 was implemented in two phases in Delhi NCT Delhi in response to the decision by Supreme Court based on *suo moto* cognizance of a newspaper report. The issue pertained to pollution in Yamuna caused by encroachment, dumping of debris, waste, untreated sewage and effluents. STP works of Rs. 344.81 crore were carried out under the project in Phase I. Works worth Rs. 1,755 crore were sanctioned to Delhi Jal Board in the same phase. Phase-II of the project involved interception of six large drains with partial funding from AMRUT scheme of GoI.
3. National Mission for Clean Ganga (NMCG) sanctioned projects worth Rs. 1,388 crore for Yamuna during 2018 for various activities such as sewage infrastructure, rural sanitation, etc. Three trash skimmers deployed at Mathura-Vrindavan, Delhi and Prayagraj.

b) State-specific projects

Uttarakhand

1. Micro-watersheds were treated under Doon Valley Watershed Management Project in three districts at a cost of Rs. 102.12 crore from 1993 to 2001.
2. Uttarakhand Decentralized Watershed Development Project (GRAMYA-I) treated 76 Micro-watersheds in 468 panchayats covering 2,34,787 ha during 2004-2012.
3. Under Uttarakhand Decentralized Watershed Development Project (Gramya-II) during 2014 to 2019, a total of 4,22,668 trenches, 31,858 recharge pits, 493 village ponds, 176 km irrigation channels, 992 irrigation tanks, 4,327 ha forestry plantations, 4,045 ha orchards, 3,47,000 m Napier crop border plantation and 154 ha forage row plantations were created.
4. Under 20-point programme, plantation was carried out on 1,18,028 ha area

5. Under *Hamara Ped Hamara Dhan Yojana* 50,000 plants are planned to be planted every year from 2014-15 for five years.
6. Under CAMPA scheme 14,634 ha area is proposed for planting for 2010-2020. Rs. 298.15 crore is envisaged for soil and moisture conservation and catchment area treatment.
7. Under FDA scheme 7,350 ha is proposed for treatment during 2020 to 2021.
8. A dam is being constructed under Lakhwar Vyasi project with a live storage capacity of 333.04 M m^3. It will help irrigate 40,000 ha land besides producing hydropower.

Himachal Pradesh

1. Under Integrated Wasteland Development Programme (IWDP) an area of 1,17,172.59 ha in nine districts in Himachal Pradesh was treated during 1997-98 to 2007-08 at a cost of Rs. 7,082.69 lakh.
2. Under Drought Prone Area Programme (DPAP) 6,205 ha area was treated in Solan district at a cost of Rs. 236.02 lakh.
3. Under Mid-Himalayan Watershed Development Project 272 Micro-Watersheds are being treated in 10 districts. Till 2012, 6,151 water harvesting tanks, 1,093 ponds/tanks, 287 dams, 263 lift/gravity irrigation schemes, 43 small underground tanks and 203 km of irrigation channels were constructed. The project has converted about 9,000 ha of rainfed area into irrigated.
4. Under 20-Point Programme, 1,05,926 ha area has been planted during 2012-13 to 2017-18.
5. Renukaji Dam Project, a storage project on Giri River, has been approved. It envisages construction of 148 m high rock-fill dam on Giri tributary to provide 498 M m^3 (49,800 ha m) of live water storage.

Haryana

1. Under Water Resources Consolidation Project (1994-2001) a total of 1,280 Water User Associations formed, 557 km water course was rehabilitated and 5,341 km water courses were modernised
2. Under Haryana Natural Resource Management and Poverty Reduction Project, plantations were raised on 48,800 hectares in 17 districts of Haryana, excluding Gurgaon and Faridabad during 2004-2014 at a cost of JPY 6,280 million.
3. During 2001-02 to 2010-11, 1,86,218 ha area was planted by SFD and 2,659.87 lakh seedlings were distributed to farmers. During 2012-13 to 2017-18, 2,34,138 ha was planted under 20-Point Programme.
4. 43 herbal parks have been developed in each district of Haryana from 2005-06 to 2010-11.
5. 690 ha area was restored under Rehabilitation of Degraded Forests scheme during 2002-03 to 2004-05

Delhi

1. 108.15 lakh seedlings were planted by SFD and other agencies during 2001-09 and 37.63 lakh seedlings during 2012-18. Additionally, 17.83 seedlings were distributed free.
2. Eco-Task Force raised 1,521 ha plantation during 2001-2010, and 2,079 ha during 2010-2014 in Bhatti Wildlife Sanctuary and also protected forest land from encroachment and illegal mining.
3. Fourteen city forests were densified and 18 city forests were created during 2007-09.
4. Compensatory plantation was raised over 26.90 ha area.
5. 17,500 seedlings planted near 175 water bodies.
6. Aravalli Biodiversity Park (287 ha) and Yamuna Biodiversity Park (9,770 ha) were created during 2005-2019.

Uttar Pradesh

1. 27,22,379 ha area was planted by different agencies during 1994-95 to 2015-16, 1,43,641 ha during 2016-17 to 2017-18, and 22 crore seedlings during 2019.
2. 58,007 km plantations have been created along roadside, 26,816 km along canal banks and 5,970 km along railway lines.
3. Twelve thousand one hundred seventy two micro-watersheds covering 111.76 lakh ha were treated till 2008. Four thousand three hundred fifty five micro-watersheds covering 33.82 lakh ha were treated by March 2014.
4. Villages on the bank of river Yamuna have been made open defecation-free (ODF) by constructing individual household toilets
5. One hundred seventeen real time water quality monitoring station are being installed at locations along Yamuna, Ganga, Ramganga and Kali river.

Rajasthan

1. An area of 18,34,296 ha in watershed was treated during 2011-12 to 2017-18 at a cost of Rs. 2,695.88 crore.
2. Under Forestry and Biodiversity Project – Phase I (JICA) afforestation was undertaken on 123,967 ha land during 2003-04 to 2008-09 at a cost of JPY 9,054 M.
3. Under Forestry and Biodiversity Project - Phase II (JICA) from 2011 onwards at JPY 15,749 M, planting was done on 83,675 ha land, besides creating 2,00,000 m^3 check dam, 5,00,967 m contour bund and 1,000 anicuts. About 5,000 ha area was closed for grazing.
4. From 1991-92 to 2002, 67,330 ha area was afforested and 86.78 lakh plants were distributed under Afforestation and Pasture Development in Indira Gandhi National Park scheme at a cost of Rs. 113.01 crore.
5. Volunteers of Tarun Bharat Sangh dug 350 ponds and built check-dams in Ruparel Basin to revive the river.
6. Under Mukhyamantri Jal Swavalamban Abhiyan from 2015 onwards, 3.90 lakh rain water harvesting structures were prepared and 148 lakh saplings were planted across the state covering 12,042 villages.
7. Under Forest Development Agency scheme, 28,190 ha area was treated during 2000-2006.
8. Under 20-Point Programme, 3,76,839 ha was planted during 2012-13 to 2017-18.

Madhya Pradesh

1. Five thousand one hundred thirty one minor, 104 medium and 25 major water conservation projects have been completed in the entire upto year 2017-18 located in various river basins (including Yamuna basin)
2. Eight dams above 100 Mm^3 have been completed in Yamuna Basin
3. Rural development department constructed 265 small tanks of total capacity 80 Mm^3 in the state during year 2018-19 in small villages for irrigation, drinking, etc.
4. Sustainable Livelihoods and Adaptation to Climate Change project is being implemented in Sheopur.
5. Under 20-Point Programme, 3,69,469 ha was planted during 2012-13 to 2017-18.

3.3.2. Gaps identified

1. EIA notification 1994 and 2006 prescribed Catchment and Command Area Treatments Plans for all river valley projects in India. Significant work has been done in this direction, but a lot more is yet to be done. For instance, 130 lakh ha of watershed in Rajasthan state is yet to be

treated (Department of Land Resources, 2019). The maintenance of treated watersheds also requires to be done on a regular basis; for this continuity in effort is required.

2. The focus of SFD's plantation programmes has mostly been on trees. Planting of shrubs and grasses has not been done adequately. Plantations are adversely affected by grazing animals, drought and other biotic/abiotic agencies, resulting in low survival and growth in some sites. The problem of grazing is more common in riverine areas.
3. Due to efforts of SFDs in conservation and afforestation, forest cover in the seven states has increased during 2003-2019 from 1,46,878 to 1,50,452 km^2 (an increase of 4.48%) (Table 3.1). After adjusting for change in density of forest cover, the forest cover in terms of very dense forest equivalent area increased from 75,216 to 78,956 km^2 (an increase of 4.97%) with respect to assessment year 2003. However, there is no evidence of improvement in e-flow and sediment load of Yamuna and its tributaries.

   Hence, while augmenting efforts of the forestry sector, the role of other sectors is also important to achieve the goal of rejuvenation of Yamuna.

Table 3.1. Change in forest cover in the seven states of Yamuna basin from assessment year 2003 to 2019 on basis of absolute area and density adjusted area

State	VDF	MDF	OF	Total FA	VDF_{VDFe}	MDF_{VDFe}	OF_{VDFe}	Total FA_{VDFe}
Assessment year 2003								
Uttarakhand	4,002	14,420	6,043	24,465	4,002	9,331	1,777	15,110
Himachal Pradesh	1,093	7,883	5,377	14,353	1,093	5,101	1,581	7,775
Haryana	2	518	997	1,517	2	335	293	630
Delhi	0	52	118	170	0	34	35	68
Uttar Pradesh	1,297	4,699	8,122	1,4118	1,297	3,041	2,389	6,726
Rajasthan	14	4,482	11,330	15,826	14	2,900	3,332	6,246
Madhya Pradesh	4,000	37,843	34,586	76,429	4,000	24,487	10,172	38,659
Total				**1,46,878**				**75,216**
Assessment year 2019								
Uttarakhand	5,047	12,805	6,451	24,303	5,047	8,286	1,897	15,230
Himachal Pradesh	3,113	7,126	5,195	15,434	3,113	4,611	1,528	9,252
Haryana	28	451	1,123	1,602	28	292	330	650
Delhi	7	56	132	195	7	37	39	82
Uttar Pradesh	2,617	4,080	8,109	14,806	2,617	2,640	2,385	7,642
Rajasthan	78	4,342	12,210	16,630	78	2,810	3,591	6,479
Madhya Pradesh	6,676	34,341	36,465	77,482	6,676	22,221	10,725	39,622
Total				**1,50,452**				**78,956**

Note: VDF, MDF and OF possess average density of 85, 55 and 25%, respectively. VDF_{VDFe}, MDF_{VDFe}, OF_{VDFe} and Total FA_{VDFe} indicate VDF, MDF, OF and Total FA values converted into equivalent VDF area. ***Source:*** FSI, 2003 and 2019

4. Though programmes have been undertaken in other sectors to reduce industrial pollution and sewage discharge in Yamuna and tributaries, these programmes require to be augmented to effectively treat all areas.
5. Adequate programmes have not been undertaken to reduce water extraction. In fact, new irrigation and drinking water schemes would increase the removal of water by different sectors. Irrigated area in Uttar Pradesh increased from 36.12 (1966-67) to 76.03% (2001-02) (Rai *et al.*, 2012). Rai *et al.* (2012) compiled a list of 474 dams and barrages in Yamuna basin. These increases in water extraction are justified due to increasing population. The population in the seven river basin states increased from 26.27 crore in 1991 to 40.03 crore in

2011, calculated on basis of Census of India. The cropping pattern has changes towards more water consuming crops like sugarcane, paddy, etc. (Times of India, 19 August 2019).

6. Problem of soil erosion from areas outside forest has not been adequately pursued in the past schemes.
7. Interdepartmental coordination on river rejuvenation is weak. Awareness programmes for stakeholders have been inadequate.
8. Literature survey indicates extensive research has been carried out for Yamuna main stem as compared to tributaries.

3.3.3. Way Ahead

1. While the forestry sector is augmenting afforestation and conservation programmes, at the same time there is a need for activities in non-forest areas that would reduce water runoff, increase ground water recharge and decrease soil erosion. Other sectors such as agriculture and rural development, highways, roads and railways, urban development and public works, industries, water resources, mining and quarrying, etc. also need to take undertake river rejuvenation initiatives. The programme should appeal to the local population to harness their cooperation and participation.
2. The activities and programmes stated above have been implemented at innumerable sites across the Yamuna Basin. Such activities will continue to occur and many new river-friendly projects and programmes will continue to be implemented at newer sites even in the absence of this DPR. It is virtually impossible to find out from any single agency the location of all sites that were treated in the past. Finding out sites/gaps for possible treatment under this proposed DPR presents a much bigger challenge. An individual located at a given place possesses information about his/her location only. It was, therefore, essential to take support of a network of reliable and responsible individuals/department with knowledge at grass roots level.

3.4. WHY FORESTRY INTERVENTIONS?

There can be more than one approach to rejuvenate rivers. Engineering structures, if constructed all along river banks, may reduce soil erosion but they would be exorbitantly expensive to make. Forestry interventions are the cheapest options towards river rejuvenation. They are eco-friendly, they redeem the riverscape and have low maintenance cost. Engineering structures have high environmental costs. Engineering structures lose their effectiveness over a period of time while forestry interventions are self-sustaining and gain in effectiveness. Forestry interventions provide countless economic, ecological and environmental goods and services. They support livelihood of local people at micro-level and, in turn, develop into value-chain and markets at macro-level. It was therefore imperative to undertake forestry interventions for river rejuvenation. This DPR, therefore, focuses only on forestry interventions.

However, there might be justifiable need to undertake other-than-forestry interventions in many situations, especially in areas outside the forest areas. Those interventions may well be undertaken by respective sectors.

3.5. DEFINING FORESTRY INTERVENTION

Before developing forestry interventions, it is necessary to define the scope of forestry interventions as this DPR essentially has to prescribe treatments within the domain of forestry interventions. Any activity that is carried out in the forest landscape with a view to improve forest ecosystem, or any activity that is carried out in agricultural, urban or peri-urban landscape involving planting or rearing of tree or woody vegetation will be categorised as a forestry intervention. The list of activities identified to be taken up in different landscapes under the DPR is as follows:

3.5.1. Activities in Natural Landscape:

Natural landscape in this DPR implies a collection of forest areas. Activities which are commonly carried out by forest department in forest areas are considered under the purview of forestry interventions e.g. planting of tree, shrub, grass, medicinal plants, underplanting/enrichment plantation, management of bamboo or coppice shoots, assisted natural regeneration (ANR), management of invasive weeds, low-cost soil and moisture conservation, riparian wildlife management, wetland management, etc. in forest areas.

3.5.2. Activities in Agricultural Landscape:

Private and community land in villages are categorised under agricultural landscape. Agroforestry activities in which tree or bamboo is an essential component such as planting of forest trees, fruit and bamboo by farmers in private land and raising plantation in common land in rural areas are included under forestry interventions.

3.5.3. Activities in Urban/Peri-urban Landscape:

Areas outside forest and agricultural landscape are treated as urban/peri-urban landscape. These activities would essentially include planting of trees or natural grasses in a sizeable part of the treatment site. Activities included are avenue, institutional and strip plantations, bioremediation/bio-filtration; riverfront and eco-park development, riverbank protection, etc.

3.5.4. Supporting Activities:

Other activities such as awareness generation, capacity building, monitoring, research, nursery development, development of value chain, installation of watch tower, protection against fire, etc. are essential to facilitate the above activities. These activities have also been treated as forestry interventions.

The DPR is focussed on synergizing the above activities from the point of view of improving water flow and quality of water in the Yamuna and its tributaries.

3.6. IDENTIFYING A COORDINATING AGENCY FOR PARTNERSHIP

SFDs have a large network of dedicated staff manning the entire forest landscape and in charge of every act that occurs there, thus, SFDs can be reliable sources of the information for the forest landscape. Their personnel have the power and resources to interact with local stakeholder departments and individuals and collect relevant information for agricultural, urban and peri-urban landscapes in their localities along the river and tributaries. Moreover, SFD would be the primary department that would be expected to implement the provisions of forestry interventions in any state. It was, therefore, necessary to rope in SFDs in preparation of the DPR. It was, thus, decided that proposals for DPR would be prepared by SFDs within their norms with technical guidance from FRI and the same would be suitably harmonized at a wider level for preparation of the DPR. The SFDs agreed to collaborate with FRI in this mechanism of DPR preparation and also agreed to implement it after its approval by the Ministry of Environment, Forest and Climate Change, Govt. of India.

3.7. APPROACH

A multi-stakeholder approach was followed for preparing the DPR. The preparatory phase for DPR included collection and review of information from primary and secondary sources and expert consultations. Information was obtained from various stakeholders, *viz.*, policy and decision makers, central and state governments, SFDs of the seven states, other relevant authorities; scientific and academic institutions dealing with environment, forestry and wildlife, civil society, non-governmental organizations and interest groups. The approach has been illustrated in Fig. 3.1.

The Logical Framework Analysis (LFA) tool was used for the preparation of present DPR viewing that humans interact with water in a wide variety of ways which impact the water environment, and that effective river management seeks to address the spatial dimension of water by taking catchment or drainage basin as the natural unit of management which itself experiences complex processes. Logical Framework Planning matrix for the project is given in Annexure 1.

3.7.1. Inception Workshop

An inception workshop was held at Dehradun on April 24-25, 2019. Guidelines were communicated by ICFRE to the project implementation teams for various rivers to ensure uniformity in methodology and outcome. The project team of FRI provided details of the methodology followed by it for preparation of a similar DPR on Ganga and clarified their queries.

3.7.2. Extensive Consultative Process

Consultations were held at state level as summarized in the Table 3.2. A wide range of stakeholders from central/state government ministries, departments, agencies, besides civil society and NGOs was consulted through their representatives that attended the meetings (Table 3.3).

3.7.3. Recommendations from Consultative Meetings with SFDs and Other Stakeholders

The SFDs of all the seven states, *viz.*, Uttarakhand, Himachal Pradesh, Haryana, Delhi, Uttar Pradesh, Rajasthan and Madhya Pradesh, that constitute the catchment area of Yamuna, willingly agreed to provide all support to FRI in preparation of the DPR and consented to the approach that site-specific proposals for DPR would be prepared and supplied by SFDs to FRI for harmonization and development of suitable models for the project.

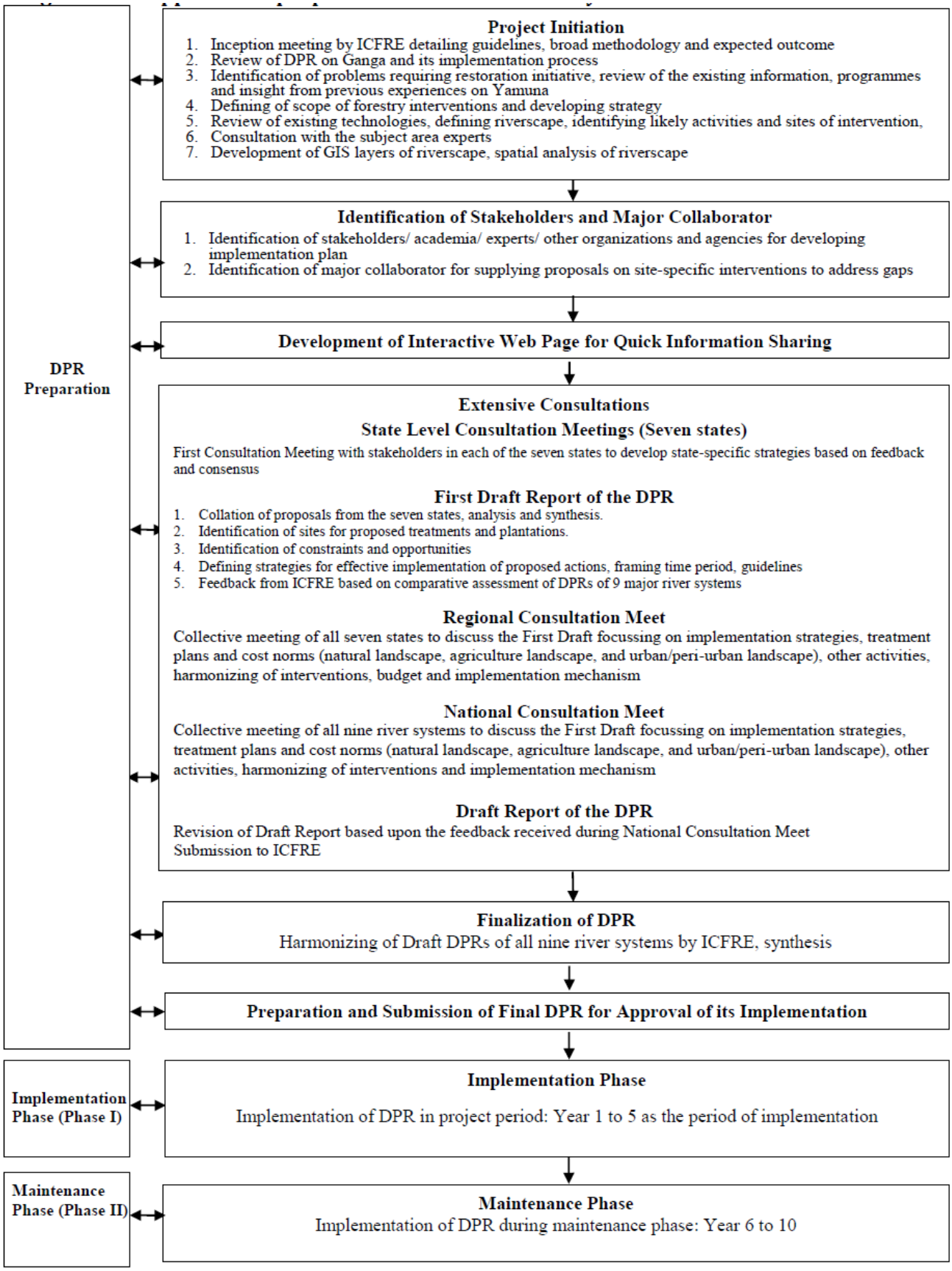


Fig. 3.1. The approach of preparation of DPR for forestry interventions on Yamuna

Table 3.2. Consultative meetings at the state level for the preparation of DPR

S. no.	Event	Venue	Date	No. of participants
1.	First Consultation Meeting for Uttarakhand	Forest Research Institute, Dehradun	July 5, 2019	60
2.	First Consultation Meeting for Himachal Pradesh	Himachal Pradesh Forest Department, Shimla (combined meeting for Satluj, Beas, Ravi, Chenab, Jhelum and Yamuna)	June 28, 2019	178
3.	First Consultation Meeting for Haryana	Haryana Forest Department, Panchkula	August 6, 2019	53
4.	First Consultation Meeting for Delhi	Delhi Forest Department, New Delhi	July 24, 2019	24
5.	First Consultation Meeting for Uttar Pradesh	Uttar Pradesh Forest Department, Lucknow	May 31, 2019	59
6.	First Consultation Meeting for Rajasthan	Arid Forest Research Institute, Jodhpur (Luni and Yamuna combined meeting)	May 27, 2019	80
		Rajasthan SFD Headquarters, Jaipur (separate meeting for Yamuna)	November 11, 2019	46
7.	First Consultation Meeting for Madhya Pradesh	Madhya Pradesh Forest Department, Bhopal (combined meeting for Narmada, Yamuna, Mahanadi)	June 19, 2019	80

The following recommendations emerged from consultative meetings organized at state level as well as discussions with SFDs during the preparation of the DPR.

Uttarakhand

1. The focus of all activities (plantation and others) would be on water and soil conservation, and the project may be considered different from afforestation projects. Water percolation tank (*chal-khal*) can be more effective than plantation. Construction of check dams, brush wood, loose dry dams, contouring and terracing should be focused rather than plantation activities.
2. Entire catchment of the Yamuna should be treated rather than restricting the activities to 5 or 2 km strip along the river in Uttarakhand state.
3. Plantation should be done in those areas where the canopy density is less than 0.4 and soil erosion rate is high.
4. Multi-tier plantation of local species of trees, shrubs and grasses may be done. Model nurseries should be established for shrubs and grasses.
5. Few species like walnut, acer, deodar, spruce, fir, thuner, oaks, etc. require longer time to reach plantable size in nursery, hence protection period may be extended to 5 instead of 2-3 years.

Table 3.3. Prominent stakeholders involved in the consultation process

A. Central Government Ministries/ Departments/Agencies/Organizations
Ministry of Environment, Forest and Climate Change (MoEF&CC), New Delhi
Indian Council of Forestry Research and Education (ICFRE), Dehradun
Forest Research Institute (FRI), Dehradun
Forestry Research Centre for Eco-Rehabilitation (FRCER), Prayagraj
Tropical Forest Research Institute (TFRI), Jabalpur
Himalayan Forest Research Institute (HFRI), Shimla
Institute of Forest Productivity (IFR), Ranchi
Wildlife Institute of India (WII), Dehradun
Indian Institute of Remote Sensing *(*IIRS), Dehradun
National Institute of Hydrology (NIH), Roorkee
Indian Institute of Soil and Water Conservation (IIS&WC), Dehradun
Central Ground Water Board(regional office), Dehradun
B. State Government ministries/ departments/ agencies/ organizations in states of Uttarakhand, Himachal Pradesh, Haryana, Delhi, Uttar Pradesh, Rajasthan and Madhya Pradesh
State governments (Hon'ble Chief Minister, Hon'ble Forest Minister)
State forest department(s) (PCCF, Addl. PCCF, CCFs, CFs, DFOs, ACFs, RFOs, foresters)
State forest development corporations
Delhi Development Authority
State Biodiversity Board
State Forest Research Institute, Kanpur
Pollution Control Board
Agriculture Department
Horticulture Department
Irrigation Department
Fisheries Department
Drinking Water Department
Remote Sensing Application Centre
State Programme Management Group (SPMG)
Universities
C. **Civil Society**
NGOs
Representatives of farmers
Nehru Yuvak Kendra

6. On flood-prone areas especially close to riverbanks, choice of species should be such that they can bear waterlogging and flash flood. Species like jamun, arjun, baheda, kan grasses, trewia, kanju, etc. will be suitable.
7. Wetlands can be constructed in riverscapes. Wetlands are likely to improve aquifers and biodiversity of the area.
8. In less fertile and barren lands, leguminous species like *Robinia, Dalbergia sissoo, Acacia catechu, Acacia nilotica, Albizia, Casuarina,* etc. can be planted.
9. Bioremediation should also be incorporated and representative from municipalities can be invited in meetings.
10. Planting of ornamental, fruit and medicinal plant species may also be given importance in agricultural and urban landscape. In the hills, walnuts (*kagzi akhrot*) may be tried. For this,

quality plants should be procured from Jammu and Kashmir UT or Himachal Pradesh. Organic farming may be promoted along with agroforestry plantations.

11. Market mechanism for selling of medicinal plants and other NTFPs can be developed for farmers in hills. Representatives from the farmers can be invited in meetings at later stages.
12. Suitable personnel should be used for the construction of contour bunds during project implementation. Napier grasses can be planted on bunds. The main objective should be to improve water yield and water quality.
13. Measures should be prescribed up to stream source for addressing the issue of water quantity, quality and run off in entirety. Springs should be rejuvenated, and their protection and maintenance should be continued.
14. Identification of fire prone area may be done, and measures prescribed for forest fire management and mitigation.
15. Modelling approach can be used to conduct a pilot study in plantation area to analyse the hydrological changes like water yield.
16. Encroachment should not be allowed on river basins. Support of all groups is necessary.
17. Provision should be made for cleanliness of rivers and future sustainability of eco-parks and *vatika*.
18. Involvement of local communities should be ensured.
19. Wastelands map developed by NRSC, Hyderabad can be used for identifying sites for forestry interventions.
20. Eco-task force may be involved for plantations which would work in coordination with forest department.
21. Traditional knowledge-based water conservation measures should also be an integral part of DPR.

Himachal Pradesh

1. Pabbar River may be included in the DPR as it is an important tributary of Tons River.
2. Interventions for Renukaji Lake was recommended as it is a very important Ramsar Wetland site in Sirmaur district.
3. Participation and inclusion of Municipal Corporation should be done for the solid waste management and treatment of *nallah*, etc.

Haryana

1. Ecological flow of the Yamuna has been affected due to excessive diversion/use of water for irrigation, drinking and industrial purposes. Polluted water enters the river from industrial effluents, agricultural fields, sewage, etc. Silt load in river water is also high. The DPR should be aimed to address these primary concerns (Fig. 3.2).
2. The problems of the Yamuna are diverse. The role of forestry sector must be defined and restricted to forestry interventions. Proposals for forestry interventions will be provided by SFD Haryana.
3. Block forest forms only about 1.5% of the geographical area in Haryana, hence there is very little scope of taking up activities on forest land. Agricultural land is the main land use on both sides of the river. Agroforestry can be the major activity in Haryana.
4. Apart from plantation of trees, activities like grass/shrub planting, assisted natural regeneration, removal of invasive weeds, soil and moisture conservation, etc. may be included in forest areas. Agroforestry may be taken up on private land. Avenue plantation, institutional estate plantation, bioremediation/bio-filtration, riverfront and eco-park development, etc. may be adopted in urban/peri-urban areas. Soil and water conservation, riparian wildlife and wetland management should also be proposed as conservation interventions, wherever needed, in forest areas.



Fig. 3.2. Consultation meeting with stakeholders at Panchkula, Haryana, August 6, 2019

5. This project is not a routine project of forestry sector; hence, the primary object is not to increase the forest cover. Focus of the project would be on improving ecological flow of water and reducing sediment load in the water. Areas with poor forest cover (less than 10%) and high incidence of soil erosion should be given highest priority. Soil moisture conservation measures and grasses are important for ground water recharge and promotion of favourable conditions for forest succession process. Such measures should also be adopted in the DPR.
6. Saline water aquifers exist in south-western part of the state including Yamuna basin districts of Palwal and Sonepat while freshwater aquifers occur in most of other parts of the state. Suitable treatment models may be proposed considering this situation.
7. Reports on ground water resources of different districts are available on website of Central Ground Water Board; the same may be downloaded for use during DPR preparation. Report on water quality has been published by TERI (http://fore.yale.edu/files/Current_Condition_of_Yamuna_River.pdf) which can be used during the DPR preparation. Soil erosion map and soil loss limit map have been prepared by ICAR-IISWCR, Chandigarh which might be of use in the DPR preparation process.
8. ICAR-IISWCR, Chandigarh would provide technical guidance in deciding when, where and how much water may be conserved. Software is also available at ICAR-IISWCR which helps in calculating the cost of soil moisture conservation works.
9. Farmers showed interest in planting fruit trees (e.g., mango, guava, etc.), and a few forest trees such as jamun, dhoura, poplar, eucalyptus, etc.
10. Faulty agricultural practices (e.g., excess irrigation and fertilizer application, burning of crop residue, etc.) and inappropriate choice of crop are contributing to problems associated with water quantity and water quality. Suitable measures must be taken. Paddy cultivation consumes large quantity of irrigation water, it may be replaced with maize cultivation through appropriate incentives. Contour bunding may help in reducing soil erosion from agricultural fields.
11. Soil moisture conservation needs integrated measures with participation of various departments. Haryana Pond and Wastewater Management Authority has been set up in this direction. Check dams, contour trenches, vegetation barriers, spurs, etc. are required for moisture conservation according to site conditions; plantation activities will not suffice

considering the mandate of the project. Teak, eucalypts, etc. should not be planted in the Shiwalik region.

12. Lantana may not be removed *en masse* as it helps in soil conservation in very harsh sites where other species are unable to grow. Lantana has a disadvantage that it does not allow natural or artificial regeneration. Measures may be adopted to address the problem.
13. Forest fire is a serious problem in Shiwalik region. Forest fire burns the leaf litter. Leaf litter creates favourable conditions for ground water recharge. Problem of forest fire may be addressed.
14. There is a problem of waterlogging in some sites. A proposal has been submitted by Haryana SFD to NABARD for treating such areas.
15. *Neelgai* (Blue Bull) causes damage to agricultural crops; measures may be adopted to tackle this menace.
16. Problem of mining and encroachment are common along the river and its tributaries; mining changes the course of the river, this problem must be highlighted and tackled in this DPR. Planting may be done in areas freed from encroachments.
17. Wetland conservation, aquatic wildlife conservation may also be taken up under the DPR. Creation of eco-parks should be planned in the DPR on lines of park in Panipat. Measures should be proposed in DPR for control of *Eichhornia* weed in water bodies.
18. Plantation should be done using native species and fruit trees and good quality material should be provided to farmers to fulfil the economic need of the local population.
19. Problem of invasion of African catfish in Yamuna should be tackled with the consultation of WII.
20. Flow of pollutants from industries should be checked through interventions to be proposed in DPR on Yamuna.
21. Public awareness and participation are crucial to the success of the project; suitable mechanism should be adapted to foster public goodwill and participation.

Delhi

1. There is not much land available in Delhi region for carrying out activities in natural landscape by SFD Delhi. The department will extend full support in preparation and implementation of the DPR on Yamuna rejuvenation through forestry interventions (Fig. 3.3).
2. The existing works and activities being undertaken on the Yamuna in Delhi NCR by other departments like DDA may also be taken into consideration.
3. Buffer area of 5 km on both sides of the Yamuna is good enough for carrying out forestry interventions in the region. However, more focus should be given to treat the entire catchment area of river in upper reaches, including the places of origin.
4. Planting of forest and fruit trees should be done in a manner to address the livelihood and to fulfil the economic needs of the local population in the region.
5. Quality and texture of soil differs from place to place so, proper measures should be taken according to the soil conditions of the concerned area while prescribing treatments under various landscapes.
6. Bioremediation models, creation of biodiversity and eco-parks should also be taken into consideration while preparing the DPR.
7. The geospatial maps, including ownership details, are available with Geospatial Delhi Ltd. (GSDL) which can be used in preparation of the DPR.
8. Planting of under-storey species may be undertaken in existing plantations, especially grasses and fruit-yielding shrubs.
9. For eastern coast of Yamuna falling in Uttar Pradesh, matter may be taken up with Uttar Pradesh SFD.
10. The work of restoration and conservation of wetlands may also be undertaken.

11. A manual on development of biodiversity parks is being prepared by Yamuna Biodiversity Park; the same can be utilized for proposing this intervention during the preparation of the DPR.



Fig. 3.3. Consultation meeting with stakeholders at New Delhi, July 24, 2019

Uttar Pradesh

1. Several schemes on rivers are in progress in the state. This project should complement and integrate with those schemes through forestry interventions. Lessons learnt from implementation of DPR on forestry interventions for the Ganga must be duly considered during preparation of DPR on the Yamuna. The physiographic conditions of the Yamuna are different from Ganga, hence, appropriate measures should be proposed in this DPR.
2. The treatment area should include the whole problematic area at strategic points instead of restricting it to 5 km strip on either side of highest flood zone along the main river and 2 km strips along tributary as adopted in the Ganga DPR. For Chambal, it can extend to the entire ravine tract (Fig. 3.4).
3. Appropriate models should be suggested for treating sodic soils, ravines, areas having shallow ground water table, wetlands, fire-prone areas, etc. Condition of terrain and problems of soil erosion in Yamuna ravines are harsher than in Chambal ravines, and hence need different measures. Creation/development of artificial wetlands should also be proposed in the DPR.
4. The menace of pollution by domestic sewage is bigger than industrial sewage. Bioremediation may be employed for treating sewage water and industrial effluents. Few models of this kind have been developed by research institutions like IITR. NBRI has phyto-remediation model in Haridwar for treatment of sewage water. Eco-friendly filters employing stone, *murram,* etc. may be also used based on experience of UPSFD. Biodiversity and eco-parks should also be proposed along the river/tributaries. Sites along Chambal River offer great potential for ecotourism.



Fig. 3.4. A site in ravinous terrain in catchment area of tributary Chambal requiring soil and moisture conservation
(*Source:* Project Team**)**

5. Various stakeholder departments that participated in the meeting offered their support to carry out the task. Lot of research and developmental activities have been/are being done by them in the area which can be utilized to aid in development of suitable models during DPR preparation. FRI Kanpur referred to their publications for use in afforestation in refractory areas. Indian Institute of Toxicology Research (IITR) may be roped in suitably as this institute is already working on rivers Hindon, Chambal and Ganga under *Namami Gange* programme in the state of UP and has bioremediation sites in Agra and Mathura districts.
6. Soil moisture conservation measures and grasses are important for soil conservation, ground water recharge and promotion of favourable conditions for forest succession process. Such measures should also be adopted in the DPR (Fig. 3.5).
7. Bathymetric contouring can help in deciding suitable sites for moisture conservation. However, bathymetric survey is in preliminary stage in the catchment area of Yamuna in UP.
8. Land for various models should be identified at time of sending proposals for DPR. Adequate time should be given to UPSFD for this purpose. It was decided to be carried out after the monsoon season of 2019.
9. Large areas of agricultural land exist along the riverbanks. Specific agroforestry models should be proposed for agricultural landscape in consultation with farmers and agriculture/horticulture department in the state of UP. Use of synthetic chemicals/ pesticides may be discouraged.



Fig. 3.5. Dry stream and soil erosion during monsoon season near Hindon River, Saharanpur Forest Division, Uttar Pradesh
(*Source:* Project Team**)**

10. Introduction of specific species of fish may also be proposed in Yamuna DPR to control water pollution in consultation with state fisheries /wildlife department. Invasive species such as African catfish must be avoided. Tilapia fish was suggested as a good species of fish worth considering. Turtle, gharial, etc. may also be introduced based on need.
11. Concept of riparian zone development should be introduced wherever possible along the riverbanks for filtering sediments and agricultural pollutants.
12. Species such as *Vetiveria, Typha*, *Canna indica*, bamboo, *Cymbopogon* (Jammu monard), etc. were recommended for planting in suitable sites in the riparian zone. *Vetiveria* is more profitable than sugarcane and can be planted in submerged areas, as suggested by expert from Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow. Small distillation units would need to be set up for *Vetiveria*. Palmarosa was recommended for planting in Bundelkhand as it provides good economic returns and can be planted for restoration of lands having pH as high as 10.5. Citronella was suggested as a mosquito repellent plant. Lemon grass may also be recommended. However, indigenous species only should be recommended.
13. Plant species preferred for nesting and as habitat by avifauna /vultures, etc. should be included in plantation models at strategic locations all along Yamuna and its tributaries.
14. Local communities, *panchayat samiti*, NGOs, schools, colleges, etc. may be suitably involved as a part of extension activity.
15. A core group may be created for closer coordination to address all aspects of DPR preparation.
16. River riparian zone development should be made compulsory and mandatory.
17. Wetlands situated near the riverbanks should be conserved and developed on priority basis.
18. Management plans for selected and designated aquatic biodiversity parks in wetlands situated near the riverbanks should be formulated and prepared along with public participation, so that continuity of improvement, development and management is maintained in a sustainable way.
19. Monitoring protocol and evaluation methodology should be clearly stated for wetlands and aquatic biodiversity parks.
20. Studies should be undertaken on impacts of riparian zone development, wetland management and creation, establishment and development of aquatic biodiversity parks on flood prevention, control and management.



Fig. 3.6. Interaction with frontline staff for forestry interventions in natural landscape, Berehta Forest Block, Chirgaon Range, Jhansi Forest Division, Uttar Pradesh in catchment area of Betwa river
(*Source:* Project Team**)**

21. DPR for rejuvenation of Yamuna River through forestry interventions should include the tributaries *viz.*, Chambal, Betwa, Ken, Dhasan, Birma, Hindon and Chandrawal (Fig. 3.6), so that, the DPR for the whole Integrated Yamuna River Basin Treatment Plan gets formulated and prepared.
22. Adoption of appropriate climate resilient technology (CRT) practices in forestry, agroforestry and agriculture, horticulture and pisciculture should be promoted more and more, for meeting the challenges of climate change and global warming by adaptation and mitigation strategies in the related sectors.
23. Promotion of cultivation of medicinal and aromatic plants in the Yamuna River basin for crop diversification should be adopted.
24. Organic farming should be promoted in the Yamuna River basin by including requisite provisioning scheme(s) for motivating farmers in the region.
25. Identification, planning and development of natural, geo-physiographic, terrestrial and aquatic wildlife and archaeological and historical sites with major aesthetic, environmental, cultural and educational values and importance may be undertaken for advancing and promoting ecotourism in the Yamuna river basin.

Rajasthan

1. Banas, Parvati, Kali Sind and Mej are important tributaries of Chambal and these should be included in the DPR.
2. Wildlife conservation activities should be undertaken and grass and fruit/food resources may also be developed for wildlife.
3. Aquatic system of the Chambal River and its tributaries should be maintained and developed further.
4. Organic farming should be promoted in the catchment areas to improve the water quality.
5. Bioremediation should be carried out at suitable places.

Madhya Pradesh

1. Forest area (i.e., natural landscape) in the entire catchment should be treated instead of restricting the interventions to only 2 km on both sides of the river. However, for agricultural areas and other areas (urban, peri-urban areas), only 2 km wide area along both sides of the river would be treated. Efforts should start from ridge to valley. Small streams and rivulets should be treated on priority; this would, in turn, benefit the main river too (Fig. 3.7).



Fig. 3.7. Consultation meeting at Gwalior, Madhya Pradesh, September 9, 2019 (*Source:* Project Team)

2. Apart from plantation of trees, activities like grass/shrub planting, removal of invasive weeds, management of coppice shoots and bamboos, assisted natural regeneration, soil and moisture conservation, etc. may be included in forest areas. Agroforestry may be taken up in private land. Avenue plantation, bioremediation/bio-filteration, riverfront development, eco-park development, institutional estate plantation, etc. may be adopted in urban /peri-urban areas. Soil and water conservation, riparian wildlife and wetland management should also be proposed as conservation interventions, wherever needed, in forest areas.
3. Focus of the project would be on improving ecological flow of water and reducing sediment load in the water. Soil moisture conservation measures and grasses are important for ground water recharge and promotion of favourable conditions for forest succession process. Such measures should also be adopted in the DPR.
4. Sand mining is one of the biggest challenges affecting the rivers in the catchment area of the Yamuna in Madhya Pradesh. Suitable measures should be proposed to address the problem in ecologically sensitive areas. Mining of sand in Ken riverbed causes movement of soil into the river water. Mining should be banned in such areas.
5. Areas with poor forest cover (less than 10%) and high incidence of soil erosion should be given highest priority, followed by areas with forest cover of 10-40%.
6. The pace of water flow should be slowed down through appropriate forestry interventions e.g., check dams, grass, percolation trenches, etc. Grass and under-storey vegetation are effective in halting soil erosion and should be included in the treatment plan.

7. Forestry measures would not treat the problem of pollution of river water by chemicals, sewer, etc.; suitable steps be taken up by the district administration to address this issue.
8. Planting of *Prosopis* sp. in trenches has served as a physical barrier and stopped sand miners in many areas. The same should be practised in sand-mining prone areas.
9. Ecological quality index of water in Chambal River is moderate to high. Such parameters may be used to monitor water quality.
10. There are genuine problems of biotic pressure for fuel and fodder. The menace of damage to forest and plantations by cattle is very high. Damage by domestic animals is much more than by wildlife. Measures are required to check cattle population. There is shortage of fuel wood in the villages, despite *Ujjwala* Scheme. Plantations are needed to increase availability of wood and fodder towards goal of forest protection.
11. Some areas of Bhopal district and Kuno Wildlife Sanctuary fall in the catchment of Yamuna were not mentioned in the list provided by FRI. Such areas will also be included in the DPR.
12. Problem of encroachment of forest land exists at many places in the river basin. Revenue department should be associated with implementation of DPR. Synergy should be developed with other line departments too. *Patta* should not be given in ecologically sensitive sites. It was however, clarified by FRI representatives that targets that are difficult to be achieved should not be proposed in the DPR.
13. Public awareness and participation are crucial to the success of the project; suitable mechanism should be adapted to foster public goodwill and participation. Efforts should be made to provide tangible benefits to the people. Ecosystem services should be quantified in monetary terms to generate and sustain the interest of the people. It is of utmost importance to highlight the benefits of the project to the public. Services of NGOs, JFM committees, *panchayat*, students, retired field staff of forest department, etc. should also be utilized for implementation of DPR.
14. Mahaseer fish population is declining in Chambal, Betwa and other tributaries of Yamuna at the expense of catfish population. Appropriate measures may be proposed in the DPR.
15. Conservation of gharial, mahaseer, turtle, dolphin, etc. should be promoted by suitable interventions in the DPR.
16. Madhya Pradesh Watershed Atlas has already been prepared. It contains information about every *nullah*. The Atlas can be utilized.
17. In some areas, trees other than *Prosopis juliflora*, are not able to establish while *P. julflora* comes up easily even by direct seeding. Removal of *P. juliflora* would trigger problem of soil erosion on slopes with fragile soil. *P. juliflora* may not be removed *in toto* from such sites. Aerial seeding can be adopted in suitable places in difficult terrain.
18. It was clarified by CCF, Gwalior and Nodal Officer of Madhya Pradesh for Yamuna DPR to the stakeholders of the state that proposals for the DPR are to be given by SFD for inclusion in the DPR. The field staff was, therefore, directed to give proposal considering practical feasibility.
19. Areas scheduled to be taken up under working plans/other schemes should not be included in the proposals for DPR.
20. Deadlines were worked out for sending of proposals from Forest Divisions to the State Nodal Officer, followed by their scrutiny and supply to FRI.
21. The proposals for treatment would be for a period of 5 years.
22. Maintenance of plantations is done for seven years in the state of Madhya Pradesh. It was decided that budget for seven years should be provided in the proposals in a suitable manner.
23. Abstract information about ongoing projects/ schemes would also be prepared by the Divisions in the entire catchment and submitted along with proposals.

It was, however, made clear to the SFDs and other stakeholders that above suggestions from the stakeholders would be addressed in the DPR provided suitable proposals are extented by the concerned SFDs to FRI.

3.7.4. Development of Project Team

Project team was developed at FRI to carry out the entire task of preparing DPR. Officers and staff of FRI were identified and assigned specific responsibilities. Staff was appointed for field works, data entry, analysis and coordinating field activities with SFD frontline staff. Two consultants were appointed to aid in collection and analysis of information and drafting of DPR. Nodal Officers were appointed by states to coordinate with FRI, oversee the entire process of information collection, compilation, supply to FRI and help in preparation of suitable models.

3.7.5. Discussion with Other Expert Agencies

Special meetings were also held with expert agencies related to the subject of hydrology, soil and moisture conservation, ground water, water quality and urban development. Visits to some of their sites were also conducted. The list of such agencies and schedule of meetings is given in Table 3.4. It was agreed between FRI and the expert organizations that FRI would take the opinion of those organizations at appropriate stages and would also seek their help in writing chapters on relevant topics in the report. The inputs of those organizations have been suitably used during preparation of the DPR.

Table 3.4. Consultation meetings with expert agencies

Agency	Date of meeting
Indian Institute of Toxicological Research, Lucknow	June 1, 2019
Delhi Development Authority, New Delhi	June 11, 2019
ICAR-Indian Institute of Soil and Water Conservation, Dehradun	June 26, 2019
National Institute of Hydrology, Roorkee	July 17, 2019
Central Ground Water Board, Dehradun	July 24, 2019
Experts of Kumaon and H.N.B. Garhwal (Central) University	January 24, 2020

3.7.6. Determination of Treatment Zone

The treatment zone was identified outside the active flood zone (or highest flood level) of the last twenty years. The active flood zone was delineated through GIS tools (described under ‘Digitization of Major Tributaries and Creation of Riverscape Boundary’) in this Chapter. The width of treatment zone was taken as 5 km on both sides of Yamuna and 2 km on both sides of tributaries in Haryana, Uttar Pradesh and Madhya Pradesh. The entire catchment area of Yamuna was included in the riverscape in Uttarakhand and Himachal Pradesh, and entire watershed area identified by Rajasthan SFD was included in Rajasthan’s riverscape. In Delhi NCT, the riverscape included area from Yamuna bank upto eastern side of Aravalli ridge. This riverscape approach was based on the methodology adopted by FRI for preparation of DPR on Ganga (FRI, 2016) and was in harmony with the methodology adopted under the project across all ICFRE Institutes. Forest areas extending beyond this width were also included wherever treatment was required, as assessed by the state forest departments and proposed for treatment in the prescribed data formats. Consensus on this approach was evolved during the First Consultation Meetings for different states.

3.7.7. Preparation of Format for Collection of Proposals

Formats were designed in which proposals were prepared by frontline staff of SFD. Five different sets of formats were prepared (See vol. II, Annexures 1-5): Plantation interventions in (i) natural landscape, (ii) agricultural landscape and (iii) urban/peri-urban landscape; (iv) other forestry interventions and (v) other activities. The formats provided cells in which information would be filled up about site location and descriptors, activities suggested, year- and activity-wise budget, GPS coordinates, sketches and images of site. GPS coordinates of polygon would be provided for treatment site in natural, urban and semi-urban landscapes while only one GPS coordinate (small planting area and variable site preferences) would suffice for agricultural landscape.

3.7.8. Training of Staff, Filling and Supply of Data Format with Proposals

State- and circle-level meetings were organised with SFDs to have focussed discussion with frontline staff on forestry interventions for Yamuna River, explain to them about the project and train them in the procedure for filling up of formats. Table 3.5 lists state-level meeting**.** In addition to the above state-level meetings, several circle-level meetings were held such as for Saharanpur, Meerut, Agra, Kanpur, Prayagraj, Chitrakoot, Jhansi, Gwalior, Shivpuri, Nahan, Solan, Shimla, etc. to resolve issues faced by the frontline staff and train them in preparation of proposals. Blank as well as filled-up sample formats were supplied to them and queries about the entire process were answered. The formats were later filled by the frontline staff in the field and submitted to FRI through the respective Nodal Officer of SFDs (Fig. 3.8 and 3.9). At several sites, FRI project team assisted the frontline staff of SFDs on-site.

3.7.9. Uploading and Analysis of Information through Data Portal and Development of Interactive Website

A web-portal, with master files, was created on the lines of data collection format and the information supplied by SFDs. Then, information was uploaded. The web-portal generated reports for different models as well as different hierarchical levels of site locations. The locations of sites were verified through ground truthing with purposive sampling implying that sites that appeared to be uncertain and random sites were visited and checked for the geo-reference. A website was created to provide information to the public on project activities.

3.7.10. Development of Treatment Models, Budget and Implementation Mechanism

Although every site is unique, however, differences in locality factors of some sites are so subtle that they can be subjected to similar treatment for a given objective. Several sites requiring the same set of prescriptions were grouped together and assigned to the same treatment package or treatment model. The proposals received from SFDs were critically reviewed and treatment models were worked out by the project team at FRI in consultation with nodal officer. Cost norms were framed for different models ensuring that they would be applicable over several localities spreading over many forest ranges, divisions and circles. For the calculation of cost estimates, the schedule of a representative place was adopted for an entire state. During implementation stage of the DPR, various activities will be performed by SFDs based on site-specific schedule of rates and actual quantum of work. At that stage, the cost estimates will get corrected to the locality of work. The implementation mechanism was worked out based on experience of implementation of DPR on Ganga as well as discussion that took place with stakeholders during current DPR preparation.

Table 3.5. State-level workshops with SFDs for training of field staff and focused discussion on forestry interventions for DPR on Yamuna

S.no.	Workshop	Venue	Date	No. of participants
1.	Consultation meeting between UKSFD and FRI for DPR preparation on Yamuna	Forest Research Institute, Dehradun	September 2, 2019	33
			November 5, 2019	24
2.	Consultation meeting between HPSFD and FRI for DPR preparation on Yamuna (Nahan Circle)	Himachal Pradesh Forest Department, Nahan	September 12, 2019	42
3.	Consultation meeting between HPSFD and FRI for DPR preparation on Yamuna (Shimla and Solan Circles)	HFRI Shimla	October 19, 2019	80
4.	Consultation meeting between Haryana SFD and FRI for DPR preparation on Yamuna	Haryana SFD, Karnal	October 4, 2019	40
5.	Consultation meeting between Delhi SFD and FRI for DPR preparation on Yamuna	Delhi Forest Department, New Delhi	November 22, 2019	15
6.	Consultation meeting between Rajasthan SFD and FRI for DPR preparation on Yamuna	Rajasthan Forest Department, Jaipur	November 11, 2019	46
7.	Consultation meeting between MP SFD and FRI for DPR preparation on Yamuna	Madhya Pradesh Forest Department, Gwalior	September 9, 2019	107

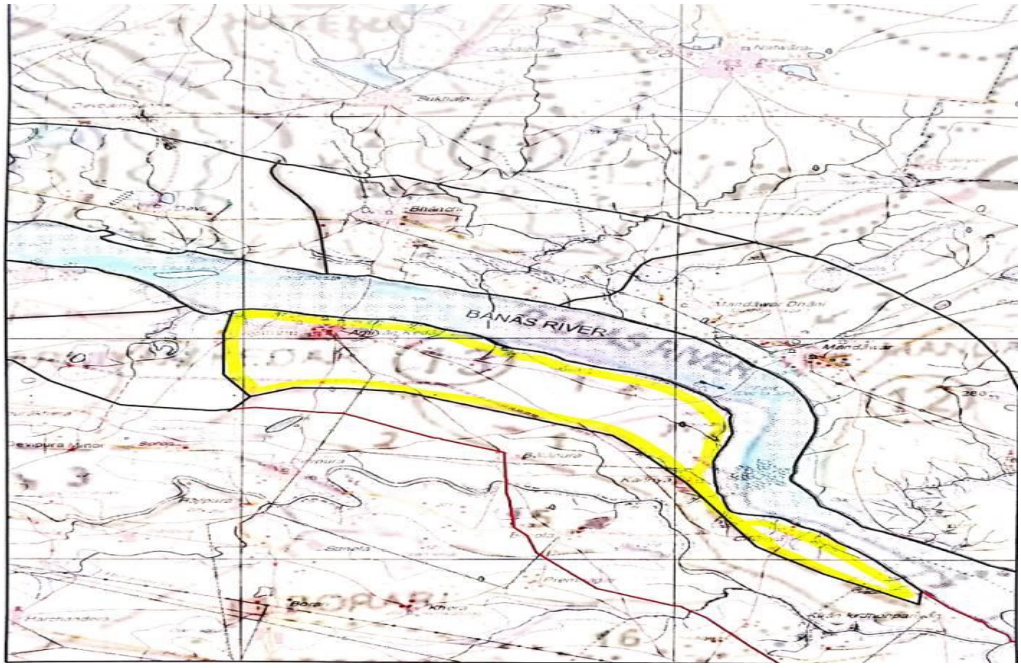


Fig. 3.8. Location map of a site proposed for treatment
(*Source:* Rajasthan State Forest Department)

3.7.11. Consultation Meetings with SFDs on Treatment Models, Budget and Implementation Mechanism

Second Consultation Meetings were held with SFDs to seek their consent on proposal prepared by us in the form of DPR. The list of meetings is given in the Table 3.6.

Table 3.6. List of second consultation meetings with SFDs

S. no.	Meeting	Venue	Date	No. of participants
1	Second Consultation Meeting between Uttarakhand SFD and FRI for DPR preparation on Yamuna	Forest Research Institute, Dehradun	February 24, 2020	35
2	Second Consultation Meeting between Haryana SFD and FRI for DPR preparation on Yamuna	Haryana Forest Department, Panchkula	February 24, 2020	22
3	Second Consultation Meeting between Uttar Pradesh SFD and FRI for DPR preparation on Yamuna	Saharanpur Forest Circle, Uttar Pradesh	February 25, 2020	30
4	Second Consultation Meeting between Uttar Pradesh SFD and FRI for DPR preparation on Yamuna	Meerut Forest Circle, Uttar Pradesh	February 26, 2020	24
5	Second Consultation Meeting between HPSFD and FRI for DPR preparation on Yamuna (SFD officials from Nahan Circle)	Himachal Pradesh Forest Separtment, Nahan	March 05, 2020	14
6	Second Consultation Meeting between HPSFD and FRI for DPR preparation on Yamuna (SFD officials from Shimla, Solan and Nahan)	Video conferencing, FRI and SFD	May 26, 2020	14
7	Second Consultation Meeting between Uttar Pradesh SFD and FRI for DPR preparation on Yamuna (SFD officials from all circles)	Video conferencing, FRI and SFD	June 10, 2020	30
8	Second Consultation Meeting between Madhya Pradesh SFD and FRI for DPR preparation on Yamuna (SFD officials from all circles)	Video conferencing, FRI and SFD	June 11, 2020	22
9	Second Consultation Meeting between Rajasthan SFD and FRI for DPR preparation on Yamuna (SFD officials from headquarters and few circles)	Video conferencing, FRI and SFD	June 22 ~~23~~, 2020	10

3.7.12. Recommendations of Second Consultation Meetings

Uttarakhand

There was consensus that that complete removal of *Lantana* would not be prescribed as it has good soil binding and water holding capacity and it also serves as habitat for fauna. Quantification of shrubs per hectare should also be done (200/ha). Bamboo and ringal should be planted in gaps created in weed management model. Cost estimate of weed management model should be increased. About 120-150 (approx.) contour trenches should be constructed in one hectare, seed sowing of suitable shrub species to be done on contour trenches and suggestive species to be planted on both sides of trenches. Contour trenches should be dug subject to slope of the site. These should be proposed for sites with less than 45^{o} slope. Maintenance for plantations should be provided for seven years. Stone-wall fences should be proposed for the plantations. Planting sites that are difficult but accessible, may be allotted to suitable groups/agencies. if required. *Chal-khal* to be constructed within the planting sites because it will collect water for benefit of plants during summer season also. In Eco park/Riverfront development models, creation of *Nakshatra vatika, Rashi vatika, Navgrah, Panchvati and Dhanvantri vatika* should be clearly mentioned. For agriculture landscape cost of Rs. 300 per plant may be proposed.

Himachal Pradesh

A model having combination of different SMC structures may be proposed. Proposals will be supplied for such model by SFD. Long term stabilization of landslide-prone or -affected such as through road widening, muck disposal, etc. may also be undertaken in the DPR. Proposals may also be provided by SFD for eco-park, riverfront development and avenue plantation along riverbank in suitable sites. Site specific details for plantation on community land under agri-landscape activity to be given by the SFD. Agroforestry models may be refined on the lines of other rivers in Himachal Pradesh.

Haryana

Grafted plants of horticultural species may be used in agricultural landscape. Procurement and planting in agricultural land will be done by SFD. In model on ANR invasive weeds may will also be removed. Pasture grasses may be suggested in plantation models wherever applicable. Visit may be conducted to villages in three different regions of Haryana to identify other activities that may be proposed for those regions. Bioremediation sites may be available in some of the villages. Entry point activities may be included. Departments concerned with mining and pollution control may be given directions to check unauthorised activities in their domains that have adverse effects on the river. Funds may also be provided for entry point activities in villages where sizeable amount of work is proposed. Rates of different operations may change over time, hence reasonable flexibility should be there in the rates to allow changes during execution.

Uttar Pradesh

Models proposed in DPR Yamuna River were appreciated for their holistic approach for the area. Suitable ravinous forest land may not be available in Prayagraj Circle for raising of plantations. However, feasibility of finding suitable land may be examined by team of/FRC-ER and local DFO before finalization of DPR. Silvi-pasture models may be suitable in some ravinous areas. As pits are not successful in ravinous areas provision for watering facility and fencing should be provided. Eco park may be developed in the proposal. Plantation density may be increased to 1600 - 2000 /hectare in the DPR from the recommended 1000 plants. Cost norms for different planting densities may be prescribed. Amount proposed for Conservation Interventions models CI 03, 04 and 05 was considered to be less and was suggested to be increased. Aromatic & medicinal plants may be incorporated in the models suitably. Proposal on eco-tourism may be supplied by every Forest Division for inclusion in the DPR. Flexibility may be provided for making necessary changes in

APO to adapt the model to the specific site condition. Dovetailing may be permitted with other schemes such as National Livelihood Mission. Making of *agarbatti*, *dona*, bamboo products, etc. may be undertaken.

Rajasthan

Watershed-wise treatment should be proposed for moisture conservation as well as in wildlife areas. Towards this, sites that have not been treated in the last ten years would be proposed by SFD. Removal of *Prosopis* species from wildlife areas should be prescribed under weed management model. Biodiversity conservation should be emphasized in models. A model on grassland development should be proposed. Kota territorial division would also send proposals for treatment of areas as it had not supplied the proposal earlier. Stone wall up to 4½ feet height should be proposed, greater height was not recommended. Silvipasture model followed by the department, may be included in the DPR. A treatment model may be proposed to address the ravines of Chambal for which proposals would be supplied by SFD.

Madhya Pradesh

Number of plants in NL-01 should be increased from the proposed 200 to 600-900 as per the site requirement. In Ujjain, flood plains should be stabilized with grasses. Fodder development model was suggested for Gandhi Sagar Sanctuary. Raising of plantations of hardy species was recommended for Chhattarpur belt. Soil and Moisture Conservation work should be adopted in the entire belt of Ratlam as the soil condition is not good and the top soil is too hard and dry for raising plantations. Similarly, seed sowing and soil and moisture conservation technique were suggested for Neemuch forest division as the plantation are not successful in the area. Pit planting was suggested in place of trench planting due to better success with the former in most of the areas. Horticulture plantations should be raised as per the norms of the existing Horticulture schemes in MP. Stone wall fencing should only be adopted when there is availability of the stones. The fencing technique to be adopted should be flexible as per the availability of the material at the site. Bioremediation or River remediation models should be adopted for removing heavy metals. Proposals may be submitted in this regard for the stretch of Chambal River.



Fig. 3.9. A site proposed for treatment

Source: Rajasthan State Forest Department

3.7.13. Addressing Recommendations of Second Consultation Meetings

The proposals received from different SFDs were included. To allow site-specific adaptations during implementation of the project, provision for adaptability was included and other necessary amendments were made in the models and strategies.

3.8. YAMUNA RIVERSCAPE –PROCESS FOR REMOTE SENSING AND GIS FOR SPATIAL ANALYSIS

The landscape elements such as forest, agriculture, urban-peri-urban areas 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 task on the preparation of DPR for forestry interventions on Yamuna required a better insight and understanding not only of Yamuna and its tributaries but also of the surrounding lands and expanding human footprints.

3.8.1. Remote Sensing

Planning for management of Yamuna River, particularly the proposed forestry interventions for its restoration, need information on the farthest bank lines during the maximum flood period for the main river and its tributaries so as 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 (Hughton, 1994).

Remote sensing serves as a technical tool to analyse land use and monitor land-use changes in the surroundings of the river at the regional and local scales. It also facilitates understanding the channel dynamics, particularly channel morphology, changes in the river course, and trends in sedimentation over a long period of time (Parsad *et al.,* 2015).

3.8.2. Geographic Information System (GIS)

Geographic Information System (GIS) is an information system working with geographically referenced spatial and non-spatial data for planning, monitoring and effective implementation of the management plans. GIS has two distinct utilization capabilities, the first pertaining to querying and obtaining information and the second pertaining to integrated analytical modelling (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 non-spatial databases.

3.8.3. Geospatial Modelling

Spatial modelling is an analytical process conducted in conjunction with GIS in order to describe basic processes and properties for a given set of spatial features. One of the most important utilities of geospatial data is its capability of being integrated for decision making through synthesis of spatial and non-spatial information within the framework of an application.

3.8.4. Remote Sensing and GIS Methodology

Image processing and GIS tools used in the present assessment were ERDAS Imagine, Geomedia Professional, Arc GIS along with other software packages. The GIS softwares provide the tool needed to store, analyse and display geographic information.

a) Satellite Data Used

Landsat-8 satellite data for the month of February to April 2019 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 states of and covering the riverscape is given in (Table 3.7).

Table 3.7. List of data downloaded and used in the study

State	Path	Row	Date of pass	Satellite
Uttarakhand	146	038	27-03-2019	Landsat-8
Uttarakhand	146	039	23-02-2019	Landsat-8
Uttarakhand	147	038	18-03-2019	Landsat-8
Himachal Pradesh	146	038	27-03-2019	Landsat-8
Himachal Pradesh	146	039	23-02-2019	Landsat-8
Himachal Pradesh	147	038	18-03-2019	Landsat-8
Himachal Pradesh	147	039	18-03-2019	Landsat-8
Haryana	146	039	23-02-2019	Landsat-8
Haryana	146	040	23-02-2019	Landsat-8
Haryana	146	041	28-04-2019	Landsat-8
Haryana	147	039	18-03-2019	Landsat-8
Delhi NCR	146	040	23-02-2019	Landsat-8
Rajasthan	145	041	05-04-2019	Landsat-8
Rajasthan	145	042	05-04-2019	Landsat-8
Rajasthan	146	041	28-04-2019	Landsat-8
Rajasthan	146	042	12-04-2019	Landsat-8
Rajasthan	146	043	27-03-2019	Landsat-8
Rajasthan	146	044	27-03-2019	Landsat-8
Rajasthan	147	042	18-03-2019	Landsat-8
Rajasthan	147	043	18-03-2019	Landsat-8
Rajasthan	148	043	09-03-2019	Landsat-8
Madhya Pradesh	143	043	22-03-2019	Landsat-8
Madhya Pradesh	144	042	13-03-2019	Landsat-8
Madhya Pradesh	144	043	29-03-2019	Landsat-8
Madhya Pradesh	145	041	05-04-2019	Landsat-8
Madhya Pradesh	145	042	05-04-2019	Landsat-8
Madhya Pradesh	145	043	05-04-2019	Landsat-8
Madhya Pradesh	145	044	05-04-2019	Landsat-8
Madhya Pradesh	146	041	28-04-2019	Landsat-8
Madhya Pradesh	146	042	12-04-2019	Landsat-8
Madhya Pradesh	146	043	27-03-2019	Landsat-8
Madhya Pradesh	146	044	27-03-2019	Landsat-8
Madhya Pradesh	147	043	18-03-2019	Landsat-8
Madhya Pradesh	147	044	18-03-2019	Landsat-8
Uttar Pradesh	143	042	06-03-2019	Landsat-8
Uttar Pradesh	143	043	22-03-2019	Landsat-8
Uttar Pradesh	144	042	13-03-2019	Landsat-8
Uttar Pradesh	144	043	29-03-2019	Landsat-8
Uttar Pradesh	145	041	05-04-2019	Landsat-8
Uttar Pradesh	145	042	05-04-2019	Landsat-8
Uttar Pradesh	145	043	05-04-2019	Landsat-8
Uttar Pradesh	146	039	23-02-2019	Landsat-8
Uttar Pradesh	146	040	23-02-2019	Landsat-8
Uttar Pradesh	146	041	28-04-2019	Landsat-8
Uttar Pradesh	147	039	18-03-2019	Landsat-8

b) Ancillary Data

Almost all of the ancillary information has been taken from various sources under Government

of India. Information about the state and district boundaries for the riverscape was obtained from the Survey of India. Basin, catchment, sub-catchment, watershed 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 Uttarakhand, Himachal Pradesh, Haryana, Delhi, Rajasthan, Madhya Pradesh and Uttar Pradesh' by 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 and Land Use Planning, Nagpur. Soil erosion data which is the backbone of multi-criteria analysis was obtained in GIS format from the Indian Institute of Soil and 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.

c) 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 flow chart of process of data downloading upto riverscape analysis is given in Fig. 3.10.

d) 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 modelling the land cover parameters. The projection parameters used in the current assessment are defined below:

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

e) Spatial Data Creation and Analysis

Spatial database creation is one of the most important steps in geospatial modelling. Spatial integration of basic layers is of utmost importance from the perspective of study/ assessment.

Pan Sharpening of Landsat Imagery

In this operation the 30-m multispectral image was sharpened using the 15-m 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 high pass filter resolution merge algorithm in ERDAS software.

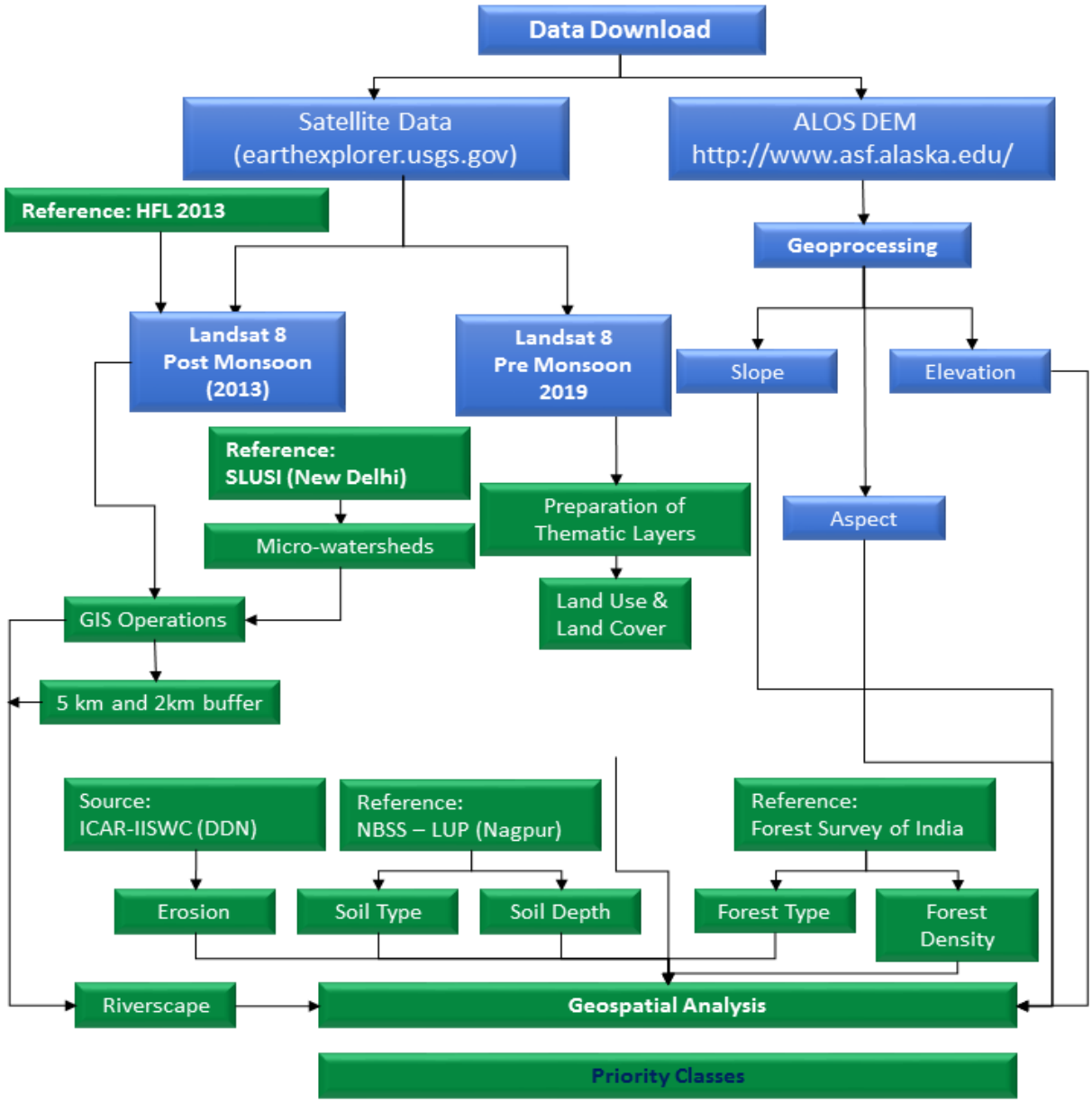


Fig. 3.10. Flow diagram of process of riverscape analysis

Digitization of Major Tributaries and Creation of Riverscape Boundary

For the identification of the riverscape, the year 2013 was identified as the highest flood level year based on literature review and stakeholder's consultation on various levels. A post-monsoon satellite image of the year 2013 was used to create the bank-line of the main stem and selected tributaries of the Yamuna River (Table 3.8). Further, a 5 km buffer on both sides of the bank line for the main stem of Yamuna and 2 km on both sides for the selected tributaries was created for the delineation of the current riverscape. The Micro-Watershed Atlas of India from Soil and Land Use Survey of India was referred for riverscape delineation besides the above mentioned buffer categories. Thus, 44,070.77 km^2 riverscape area which was carved out of the catchment area of the Yamuna has been demarcated by considering the selected micro-

watershed boundaries and merging areas close to the origin of the river. The SOI topographical sheets of 1:50,000 scale were used as a reference for the identification of the streams.

3.8.5. Geospatial Analysis and Modelling of the Yamuna Riverscape - Sites for Forestry Interventions

The sites for adoption of various treatment models of propose forestry interventions have been selected considering the geospatial analysis, modelling and resultant prioritization of treatment areas. The following section, thus, presents the geospatial analysis and findings of modelling and prioritization of sites for proposed interventions.

Watershed Boundary down to Micro-watershed

The watershed boundary was delineated down to micro-watershed level based on 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. For instance, the micro-watershed code 2C2A3a1 represented water resource region 2, basin 2C, catchment 2C2, sub-catchment 2C2A, watershed 2C2A3, and sub-watershed 2C2A3a (Source: Micro-watershed Atlas of India).

Land Use / Land Cover (LULC) Analysis

The pre-processed geometrically, radio-metrically corrected, and resolution merged Landsat-8 satellite datasets were used for visual interpretation of various land use classes. Standard image interpretation keys, were used to generate image interpretation scheme. Onscreen visual interpretation technique was used for delineating major land use and land cover types i.e., agriculture, dense forest, moderately dense forest, open forest, river perennial, river (dry)/river sand, scrub, settlement, water body, etc.

Table 3.8. List of data downloaded and used in the study

State	Path	Row	Date	Satellite
Uttarakhand	146	38	21_11_2013	Landsat-8
Uttarakhand	146	39	18_09_2013	Landsat-8
Himachal Pradesh	146	38	18_09_2013	Landsat-8
Himachal Pradesh	146	39	21_11_2013	Landsat-8
Himachal Pradesh	147	38	28_11_2013	Landsat-8
Himachal Pradesh	147	39	12_11_2013	Landsat-8
Haryana	146	39	21_11_2013	Landsat-8
Haryana	146	40	20_10_2013	Landsat-8
Haryana	146	41	20_10_2013	Landsat-8
Haryana	147	39	12_11_2013	Landsat-8
Delhi NCR	146	40	20_10_2013	Landsat-8
Rajasthan	145	41	29_10_2013	Landsat-8
Rajasthan	145	42	29_10_2013	Landsat-8
Rajasthan	146	41	20_10_2013	Landsat-8
Rajasthan	146	42	21_11_2013	Landsat-8
Rajasthan	146	43	05_12_2013	Landsat-8
Rajasthan	146	44	05_12_2013	Landsat-8
Rajasthan	147	42	27_10_2013	Landsat-8
Rajasthan	147	43	28_10_2013	Landsat-8
Rajasthan	148	43	03_11_2013	Landsat-8
Madhya Pradesh	143	43	31_10_2013	Landsat-8
Madhya Pradesh	144	42	22_10_2013	Landsat-8
Madhya Pradesh	144	43	22_10_2013	Landsat-8
Madhya Pradesh	145	41	29_10_2013	Landsat-8
Madhya Pradesh	145	42	29_10_2013	Landsat-8

Madhya Pradesh	145	43	29_10_2013	Landsat-8
Madhya Pradesh	145	44	29_10_2013	Landsat-8
Madhya Pradesh	146	41	20_10_2013	Landsat-8
Madhya Pradesh	146	42	21_11_2013	Landsat-8
Madhya Pradesh	146	43	05_11_2013	Landsat-8
Madhya Pradesh	146	44	05_11_2013	Landsat-8
Madhya Pradesh	147	43	28_11_2013	Landsat-8
Madhya Pradesh	147	44	28_11_2013	Landsat-8
Uttar Pradesh	143	42	31_10_2013	Landsat-8
Uttar Pradesh	143	43	31_10_2013	Landsat-8
Uttar Pradesh	144	42	22_10_2013	Landsat-8
Uttar Pradesh	144	43	22_10_2013	Landsat-8
Uttar Pradesh	145	41	29_10_2013	Landsat-8
Uttar Pradesh	145	42	29_10_2013	Landsat-8
Uttar Pradesh	145	43	29_10_2013	Landsat-8
Uttar Pradesh	146	39	21_11_2013	Landsat-8
Uttar Pradesh	146	40	20_10_2013	Landsat-8
Uttar Pradesh	146	41	20_10_2013	Landsat-8
Uttar Pradesh	147	39	12_11_2013	Landsat-8

3.8.6. 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 Yamuna riverscape, GIS-assisted decision-making process by way of geospatial analysis and modelling was used. 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 an area within the riverscape about vegetation, land use, erosion and degree of slope. The values were then categorized into low medium and high based on statistical quartile. For example, an agriculture area was classified as 'high priority' if it had a slope of >30º and erosion of 10 to >40 t $ha^{-1}yr^{-1}$. Likewise, the same area having slope 0º to 30ºand erosion rate <5 t $ha^{-1}yr^{-1}$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 information for Yamuna riverscape is given in (Tables 3.9 and 3.10).

Table 3.9. Weightage to different LULC, slope and erosion categories for MCA

S.no.	LULC	Weightage	Slope	Weightage	Erosion (t $ha^{-1}yr^{-1}$)	Weightage
1	Dense forest	5	0º to 15º	1	<5	1.5
2	Open forest	6	15º to 30º	2	5-10	3
3	Alpine Pasture/ Scrub	6	30º to 40º	3	10-20	4.5
4	Agriculture	4	Greater than 40º	4	3	6
5	Barren	3			Greater than 40	7.5
6	Others	1				
7	Settlement	2				

Table 3.10. Priority zones for forestry intervention in the Yamuna Riverscape

Landuse	Slope (degree) (^{0})	Erosion (t ha-1 yr-1)	Weight-age (Slope)	Weight-age (Erosion)	Weight-age (LULC)	Total	Priority
Agriculture	0 -15	<5	1	1.5	4	6.5	Low
Agriculture	0 -15	>40	1	7.5	4	12.5	High
Agriculture	0 -15	10-20	1	4.5	4	9.5	Medium
Agriculture	0 -15	20-40	1	6	4	11	High
Agriculture	0 -15	5-10	1	3	4	8	Medium
Agriculture	15 -30	<5	2	1.5	4	7.5	Medium
Agriculture	15 -30	>40	2	7.5	4	13.5	High
Agriculture	15 -30	10-20	2	4.5	4	10.5	Medium
Agriculture	15 -30	20-40	2	6	4	12	High
Agriculture	15 -30	5-10	2	3	4	9	Medium
Agriculture	30-40	<5	3	1.5	4	8.5	Medium
Agriculture	30-40	>40	3	7.5	4	14.5	High
Agriculture	30-40	10-20	3	4.5	4	11.5	High
Agriculture	30-40	20-40	3	6	4	13	High
Agriculture	30-40	5-10	3	3	4	10	Medium
Agriculture	>40	<5	4	1.5	4	9.5	Medium
Agriculture	>40	>40	4	7.5	4	15.5	High
Agriculture	>40	10-20	4	4.5	4	12.5	High
Agriculture	>40	20-40	4	6	4	14	High
Agriculture	>40	5-10	4	3	4	11	High
Alpine Pasture/Scrub	0 -15	<5	1	1.5	6	8.5	Medium
Alpine Pasture/Scrub	0 -15	>40	1	7.5	6	14.5	High
Alpine Pasture/Scrub	0 -15	10-20	1	4.5	6	11.5	High
Alpine Pasture/Scrub	0 -15	20-40	1	6	6	13	High
Alpine Pasture/Scrub	0 -15	5-10	1	3	6	10	Medium
Alpine Pasture/Scrub	15 -30	<5	2	1.5	6	9.5	Medium
Alpine Pasture/Scrub	15 -30	>40	2	7.5	6	15.5	High
Alpine Pasture/Scrub	15 -30	10-20	2	4.5	6	12.5	High
Alpine Pasture/Scrub	15 -30	20-40	2	6	6	14	High
Alpine Pasture/Scrub	15 -30	5-10	2	3	6	11	High
Alpine Pasture/Scrub	30-40	<5	3	1.5	6	10.5	Medium
Alpine Pasture/Scrub	30-40	>40	3	7.5	6	16.5	High
Alpine Pasture/Scrub	30-40	10-20	3	4.5	6	13.5	High
Alpine Pasture/Scrub	30-40	20-40	3	6	6	15	High
Alpine Pasture/Scrub	30-40	5-10	3	3	6	12	High
Alpine Pasture/Scrub	>40	<5	4	1.5	6	11.5	High
Alpine Pasture/Scrub	>40	>40	4	7.5	6	17.5	High
Alpine Pasture/Scrub	>40	10-20	4	4.5	6	14.5	High
Alpine Pasture/Scrub	>40	20-40	4	6	6	16	High
Alpine Pasture/Scrub	>40	5-10	4	3	6	13	High
Barren	0 -15	<5	1	1.5	3	5.5	Low

Barren	0 -15	>40	1	7.5	3	11.5	High
Barren	0 -15	10-20	1	4.5	3	8.5	Medium
Barren	0 -15	20-40	1	6	3	10	Medium
Barren	0 -15	5-10	1	3	3	7	Low
Barren	15 -30	<5	2	1.5	3	6.5	Low
Barren	15 -30	>40	2	7.5	3	12.5	High
Barren	15 -30	10-20	2	4.5	3	9.5	Medium
Barren	15 -30	20-40	2	6	3	11	High
Barren	15 -30	5-10	2	3	3	8	Medium
Barren	30-40	<5	3	1.5	3	7.5	Medium
Barren	30-40	>40	3	7.5	3	13.5	High
Barren	30-40	10-20	3	4.5	3	10.5	Medium
Barren	30-40	20-40	3	6	3	12	High
Barren	30-40	5-10	3	3	3	9	Medium
Barren	>40	<5	4	1.5	3	8.5	Medium
Barren	>40	>40	4	7.5	3	14.5	High
Barren	>40	10-20	4	4.5	3	11.5	High
Barren	>40	20-40	4	6	3	13	High
Barren	>40	5-10	4	3	3	10	Medium
Dense Forest	0 -15	<5	1	1.5	6	8.5	Medium
Dense Forest	0 -15	>40	1	7.5	6	14.5	High
Dense Forest	0 -15	10-20	1	4.5	6	11.5	High
Dense Forest	0 -15	20-40	1	6	6	13	High
Dense Forest	0 -15	5-10	1	3	6	10	Medium
Dense Forest	15 -30	<5	2	1.5	6	9.5	Medium
Dense Forest	15 -30	>40	2	7.5	6	15.5	High
Dense Forest	15 -30	10-20	2	4.5	6	12.5	High
Dense Forest	15 -30	20-40	2	6	6	14	High
Dense Forest	15 -30	5-10	2	3	6	11	High
Dense Forest	30-40	<5	3	1.5	6	10.5	Medium
Dense Forest	30-40	>40	3	7.5	6	16.5	High
Dense Forest	30-40	10-20	3	4.5	6	13.5	High
Dense Forest	30-40	20-40	3	6	6	15	High
Dense Forest	30-40	5-10	3	3	6	12	High
Dense Forest	>40	<5	4	1.5	6	11.5	High
Dense Forest	>40	>40	4	7.5	6	17.5	High
Dense Forest	>40	10-20	4	4.5	6	14.5	High
Dense Forest	>40	20-40	4	6	6	16	High
Dense Forest	>40	5-10	4	3	6	13	High
Gullied/Ravinous Land	0 -15	<5	1	1.5	7	9.5	Medium
Gullied/Ravinous Land	0 -15	>40	1	7.5	7	15.5	High
Gullied/Ravinous Land	0 -15	10-20	1	4.5	7	12.5	High
Gullied/Ravinous Land	0 -15	20-40	1	6	7	14	High
Gullied/Ravinous Land	0 -15	5-10	1	3	7	11	High

Gullied/Ravinous Land	15 -30	<5	2	1.5	7	10.5	Medium
Gullied/Ravinous Land	15 -30	>40	2	7.5	7	16.5	High
Gullied/Ravinous Land	15 -30	10-20	2	4.5	7	13.5	High
Gullied/Ravinous Land	15 -30	20-40	2	6	7	15	High
Gullied/Ravinous Land	15 -30	5-10	2	3	7	12	High
Gullied/Ravinous Land	30-40	<5	3	1.5	7	11.5	High
Gullied/Ravinous Land	30-40	10-20	3	4.5	7	14.5	High
Gullied/Ravinous Land	>40	<5	4	1.5	7	12.5	High
Open Forest	0 -15	<5	1	1.5	5	7.5	Medium
Open Forest	0 -15	>40	1	7.5	5	13.5	High
Open Forest	0 -15	10-20	1	4.5	5	10.5	Medium
Open Forest	0 -15	20-40	1	6	5	12	High
Open Forest	0 -15	5-10	1	3	5	9	Medium
Open Forest	15 -30	<5	2	1.5	5	8.5	Medium
Open Forest	15 -30	>40	2	7.5	5	14.5	High
Open Forest	15 -30	10-20	2	4.5	5	11.5	High
Open Forest	15 -30	20-40	2	6	5	13	High
Open Forest	15 -30	5-10	2	3	5	10	Medium
Open Forest	30-40	<5	3	1.5	5	9.5	Medium
Open Forest	30-40	>40	3	7.5	5	15.5	High
Open Forest	30-40	10-20	3	4.5	5	12.5	High
Open Forest	30-40	20-40	3	6	5	14	High
Open Forest	30-40	5-10	3	3	5	11	High
Open Forest	>40	<5	4	1.5	5	10.5	Medium
Open Forest	>40	>40	4	7.5	5	16.5	High
Open Forest	>40	10-20	4	4.5	5	13.5	High
Open Forest	>40	20-40	4	6	5	15	High
Open Forest	>40	5-10	4	3	5	12	High
Others	0 -15	<5	1	1.5	1	3.5	Low
Others	0 -15	>40	1	7.5	1	9.5	Medium
Others	0 -15	10-20	1	4.5	1	6.5	Low
Others	0 -15	20-40	1	6	1	8	Medium
Others	0 -15	5-10	1	3	1	5	Low
Others	15 -30	<5	2	1.5	1	4.5	Low
Others	15 -30	>40	2	7.5	1	10.5	Medium
Others	15 -30	10-20	2	4.5	1	7.5	Medium
Others	15 -30	20-40	2	6	1	9	Medium
Others	15 -30	5-10	2	3	1	6	Low
Others	30-40	<5	3	1.5	1	5.5	Low
Others	30-40	>40	3	7.5	1	11.5	High
Others	30-40	10-20	3	4.5	1	8.5	Medium
Others	30-40	20-40	3	6	1	10	Medium
Others	30-40	5-10	3	3	1	7	Low
Others	>40	<5	4	1.5	1	6.5	Low

Others	>40	>40	4	7.5	1	12.5	High
Others	>40	10-20	4	4.5	1	9.5	Medium
Others	>40	20-40	4	6	1	11	High
Others	>40	5-10	4	3	1	8	Medium
Settlement	0 -15	<5	1	1.5	2	4.5	Low
Settlement	0 -15	>40	1	7.5	2	10.5	Medium
Settlement	0 -15	10-20	1	4.5	2	7.5	Medium
Settlement	0 -15	20-40	1	6	2	9	Medium
Settlement	0 -15	5-10	1	3	2	6	Low
Settlement	15 -30	<5	2	1.5	2	5.5	Low
Settlement	15 -30	>40	2	7.5	2	11.5	High
Settlement	15 -30	10-20	2	4.5	2	8.5	Medium
Settlement	15 -30	20-40	2	6	2	10	Medium
Settlement	15 -30	5-10	2	3	2	7	Low
Settlement	30-40	<5	3	1.5	2	6.5	Low
Settlement	30-40	>40	3	7.5	2	12.5	High
Settlement	30-40	10-20	3	4.5	2	9.5	Medium
Settlement	30-40	20-40	3	6	2	11	High
Settlement	30-40	5-10	3	3	2	8	Medium
Settlement	>40	<5	4	1.5	2	7.5	Medium
Settlement	>40	>40	4	7.5	2	13.5	High
Settlement	>40	20-40	4	6	2	12	High

3.9. OUTPUT FROM REMOTE SENSING AND GIS ANALYSIS

The information was generated from Remote Sensing and GIS analysis is described in this section. In the current DPR, 16 tributaries of Yamuna along with the main stem of the river have been taken into consideration, some tributaries extend to more than one states (Table 3.11). Sub-catchments and watersheds are shown in Fig. 3.11 and 3.12. A brief description of the tributaries is given in chapter 2.

Table 3.11. Length of River Yamuna main stem and its major tributaries

S. no.	River name	State	River length (in km)
Yamuna main stem			
1	Yamuna	Uttarakhand	147.22
2	Yamuna	Himachal Pradesh	18.13
3	Yamuna	Delhi	48.53
4	Yamuna	Haryana	313.12
5	Yamuna	Rajasthan	22.98
6	Yamuna	Uttar Pradesh	1,253.04
Total length			**1,803.02**
Major tributaries			
1	Giri	Himachal Pradesh	148.66
2	Jalai	Himachal Pradesh	35.96
3	Pabar	Himachal Pradesh	53.05
4	Tons	Himachal Pradesh	62.94
5	Betwa	Madhya Pradesh	387.81
6	Chambal	Madhya Pradesh	685.61
7	Ghambir	Madhya Pradesh	189.13
8	Kalisindh	Madhya Pradesh	234.71
9	Ken	Madhya Pradesh	303.49
10	Parvati	Madhya Pradesh	355.43
11	Sindh	Madhya Pradesh	469.94
12	Banas	Rajasthan	555.24
13	Chambal	Rajasthan	497.08
14	Ghambir	Rajasthan	22.28
15	Kalisindh	Rajasthan	173.45
16	Mej	Rajasthan	189.66
17	Parvati	Rajasthan	195.81
18	Betwa	Uttar Pradesh	381.75
19	Chambal	Uttar Pradesh	153.8
20	Hindon	Uttar Pradesh	286.69
21	Ken	Uttar Pradesh	141.74
22	Sindh	Uttar Pradesh	14.2
23	Hanuman	Uttarakhand	8.03
24	Pabar	Uttarakhand	14.27
25	Rishi Ganga	Uttarakhand	5.64
26	Tons	Uttarakhand	142.72

3.9.1. Altitude and Digital Elevation Model (DEM)

The riverscape depicts large altitudinal variation from less than 70 m to more than 6,302 m asl. 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 (ALOS-DEM) data was downloaded from http://www.asf.alaska.edu/ and used to derive the digital elevation model (Fig. 3.13). The different elevation classes were regrouped and a total of 12 elevation classes have been derived (Fig. 3.14). The distribution of areas under different elevation classes within the riverscape is given in Fig. 3.15 and Table 3.12 revealed that the maximum extent of 20,386.81 km^2 (46.26%) area of the riverscape, lies in the lowest category of the elevation class, i.e., less than 250 m.

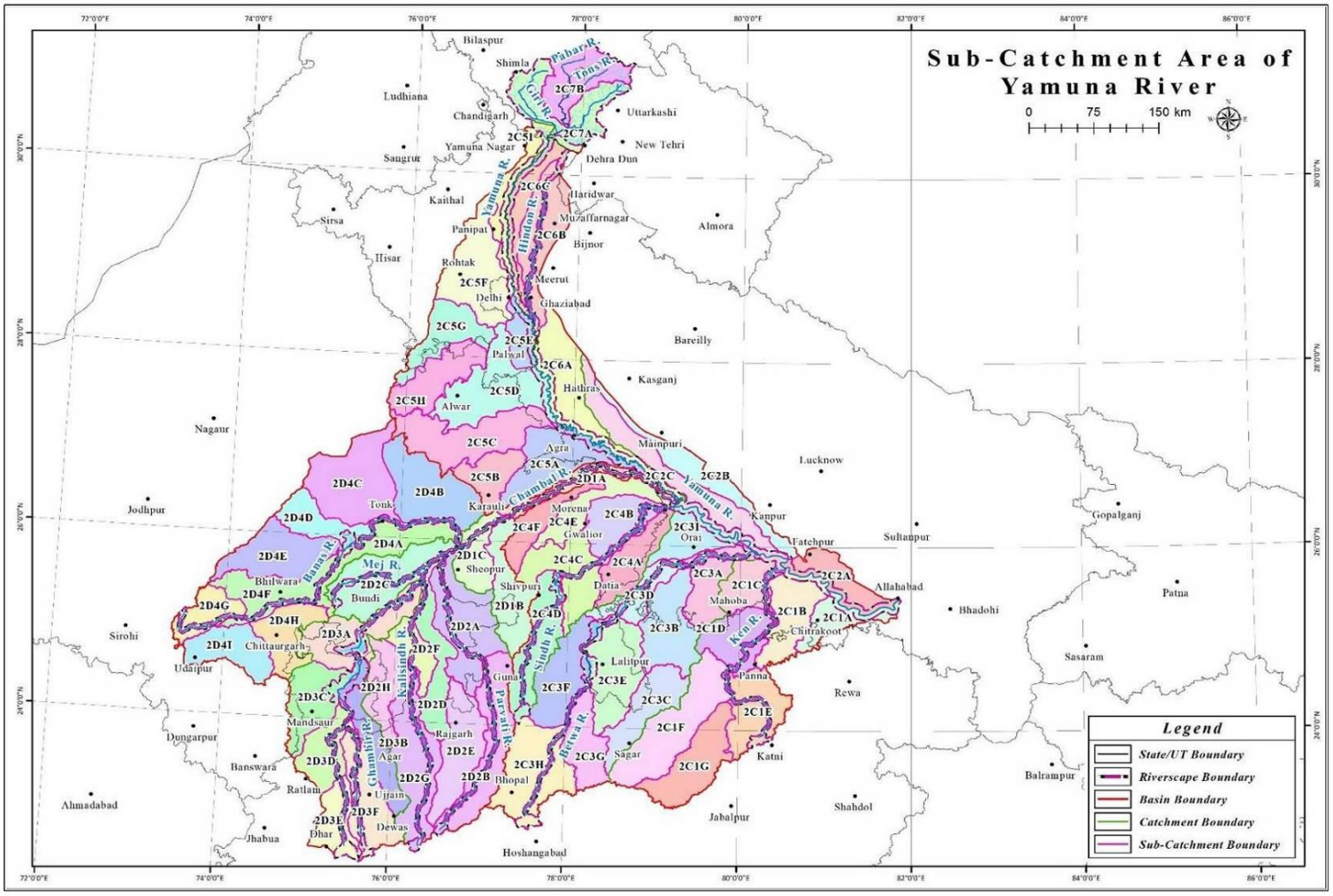


Fig. 3.11.Yamuna Riverscape with tributaries and sub-catchment
(Based on information from SLUSI, New Delhi)

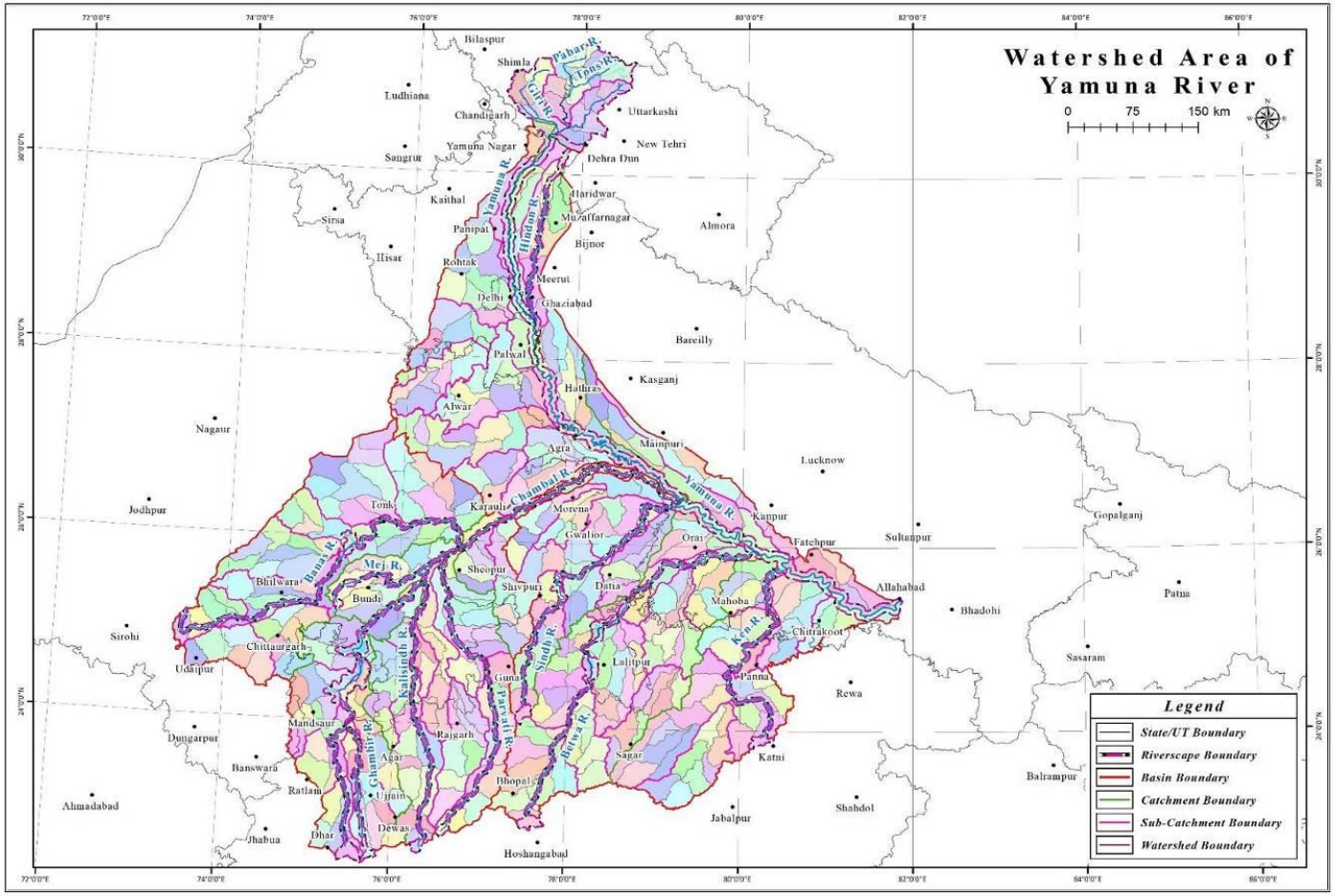


Fig. 3.12.Yamuna Riverscape with tributaries and watershed
(Based on information from SLUSI, New Delhi)

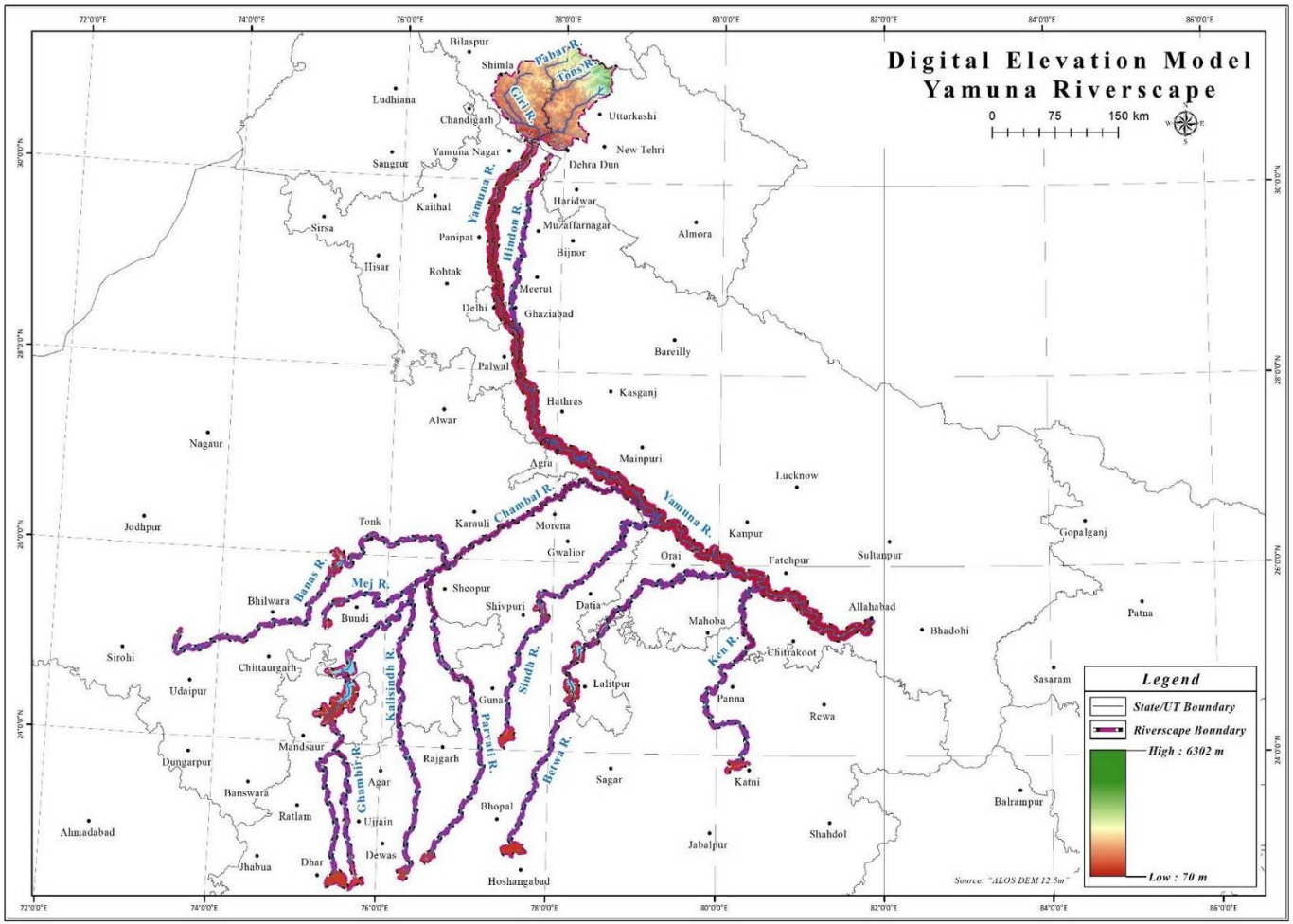


Fig. 3.13. Distribution of digital elevation in Yamuna Riverscape
(Based on information from NBSSLUP, Nagpur)

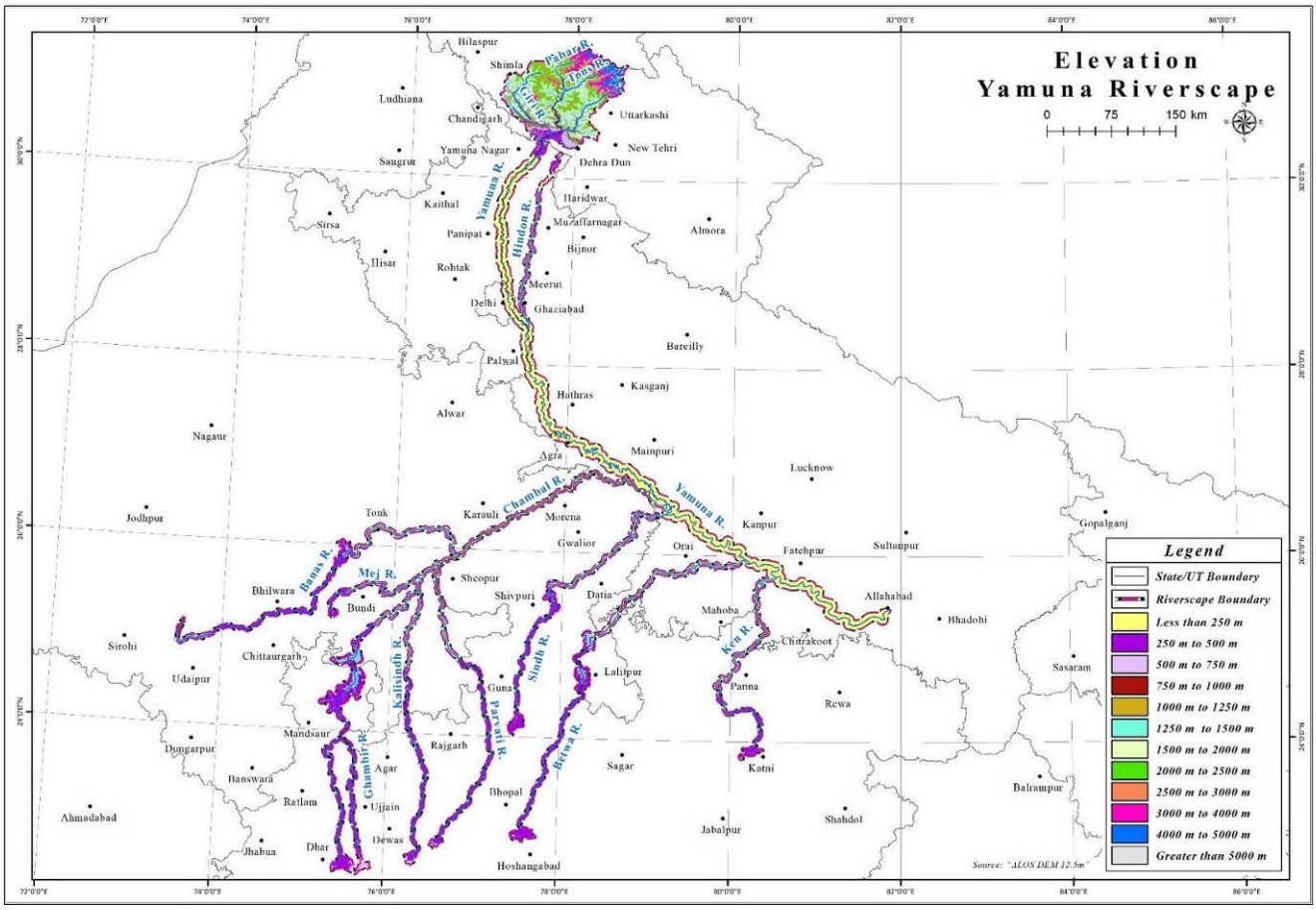


Fig. 3.14. Elevation variation in Yamuna Riverscape
(Based on information from NBSSLUP, Nagpur)

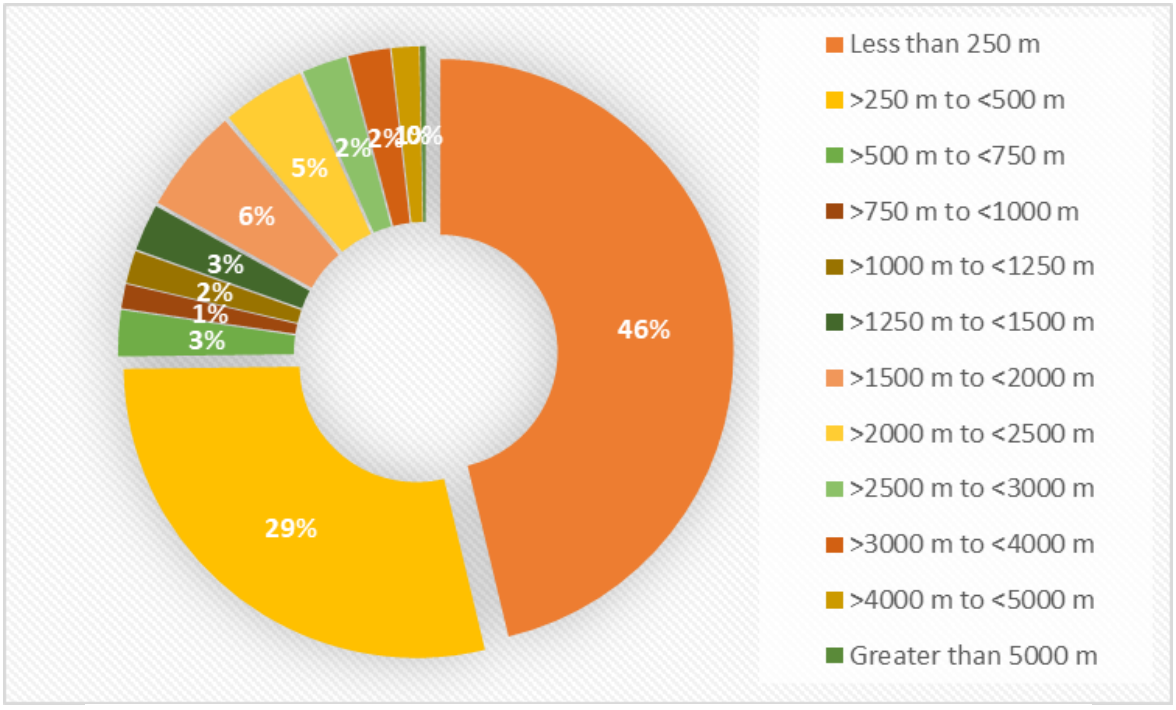


Fig. 3.15. Distribution of percent area under different elevation categories
(Based on information from NBSSLUP, Nagpur)

Table 3.12. Distribution of area under different elevation categories

S. no.	Elevation class (m)	Area (km^2)	Representation of the class (%)
1	Less than 250	20,386.81	46.26
2	>250 to <500	12,568.09	28.52
3	>500 to <750	1,118.94	2.54
4	>750 to <1000	587.38	1.33
5	>1000 to <1250	790.57	1.79
6	>1250 to <1500	1,136.72	2.58
7	>1500 to <2000	2,557.12	5.8
8	>2000 to <2500	2,016.38	4.58
9	>2500 to <3000	1,098.90	2.49
10	>3000 to <4000	1,011.08	2.29
11	>4000 to <5000	662.20	1.5
12	Greater than 5000	136.58	0.31
	Total	**44,070.77**	**100**

3.9.2. Soil Types

Soil is considered as one of the most important parameters for modelling suitability of forest plantation zones. Since choice of species mainly depend upon the soil type and soil depth these parameters have been derived from Soil map prepared by NBSS-LUP for further use in modelling in the present study. A total of soil type classes have been recorded in the riverscape (Figs. 3.16 and 3.17). Various soil types and their proportionate area estimates are given in Table 3.13.

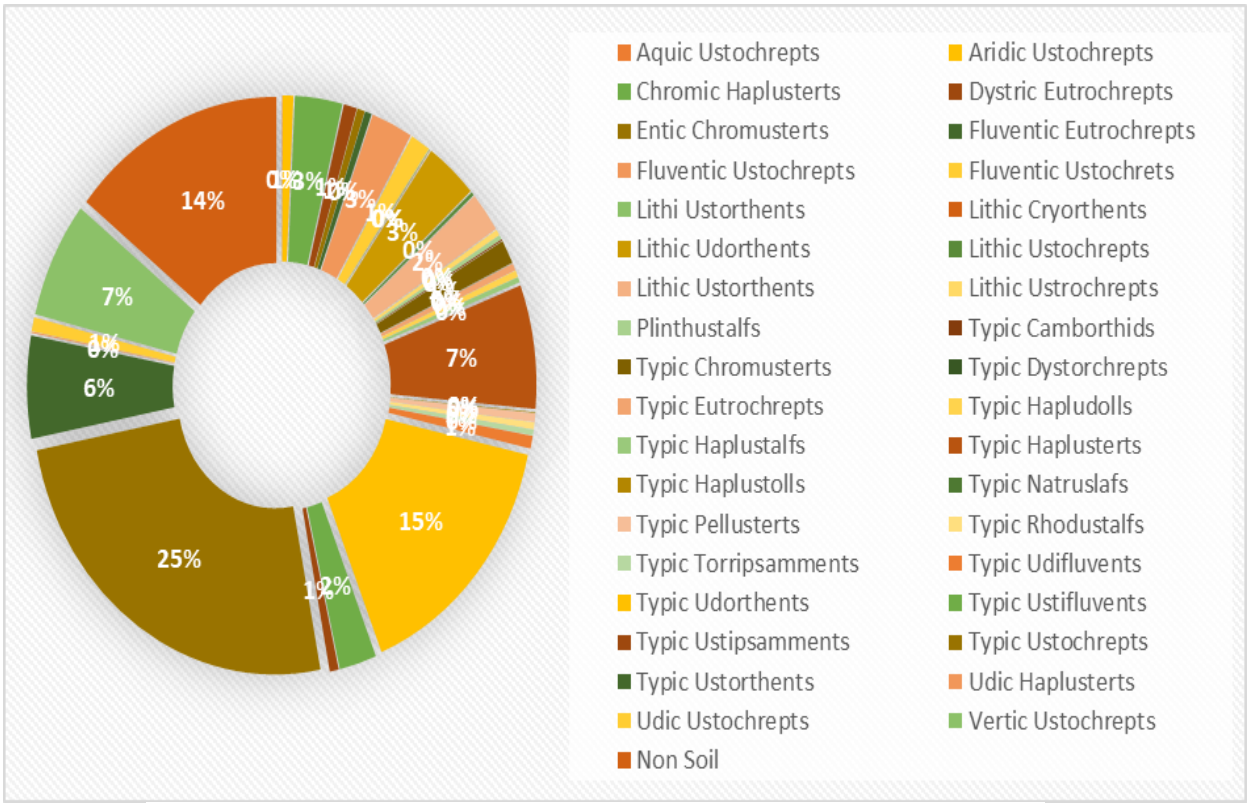


Fig. 3.16. Distribution of area under different soil types categories

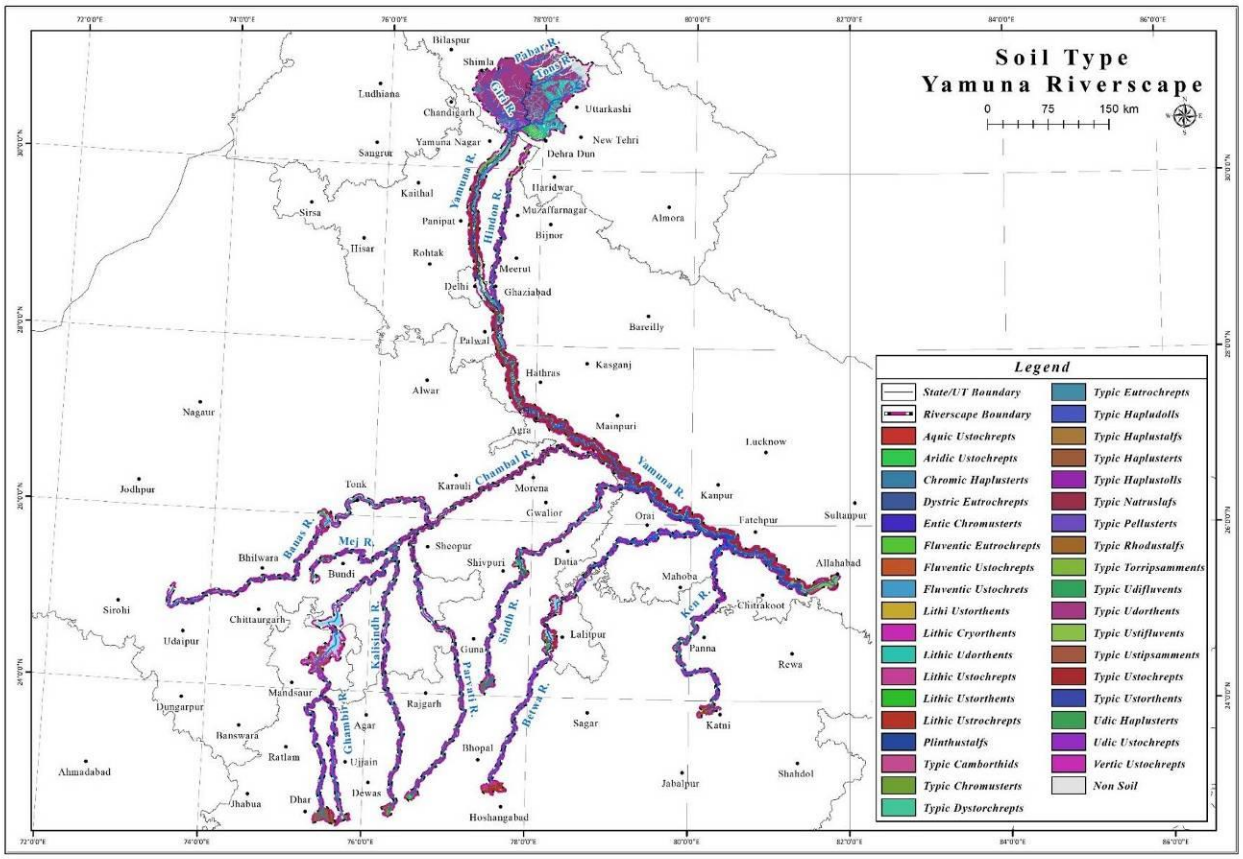


Fig. 3.17. Soil type map of the Yamuna Riverscape
(Based on information from NBSSLUP, Nagpur)

Table 3.13. Distribution of area under different soil types and other land attributes

S. no.	Soil type	Area (km^2)	Percentage of total area
1	Aquic Ustochrepts	15.60	0.04
2	Aridic Ustochrepts	314.95	0.71
3	Chromic Haplusterts	1,391.88	3.16
4	Dystric Eutrochrepts	389.33	0.88
5	Entic Chromusterts	224.38	0.51
6	Fluventic Eutrochrepts	196.25	0.45
7	Fluventic Ustochrepts	1,218.01	2.76
8	Fluventic Ustochrets	580.88	1.32
9	Lithic Ustorthents	21.71	0.05
10	Lithic Cryorthents	10.41	0.02
11	Lithic Udorthents	1,532.02	3.48
12	Lithic Ustochrepts	91.22	0.21
13	Lithic Ustorthents	1,045.41	2.37
14	Lithic Ustrochrepts	153.39	0.35
15	Plinthustalfs	112.64	0.26
16	Typic Camborthids	36.04	0.08
17	Typic Chromusterts	618.14	1.4
18	Typic Dystorchrepts	10.34	0.02
19	Typic Eutrochrepts	183.20	0.42
20	Typic Hapludolls	173.51	0.39

21	Typic Haplustalfs	134.98	0.31
22	Typic Haplusterts	3,189.29	7.24
23	Typic Haplustolls	21.68	0.05
24	Typic Natruslafs	5.52	0.01
25	Typic Pellusterts	218.29	0.5
26	Typic Rhodustalfs	174.63	0.4
27	Typic Torripsamments	147.68	0.34
28	Typic Udifluvents	327.16	0.74
29	Typic Udorthents	6,806.81	15.45
30	Typic Ustifluvents	1,093.95	2.48
31	Typic Ustipsamments	265.81	0.6
32	Typic Ustochrepts	11,000.41	24.96
33	Typic Ustorthents	2,636.34	5.98
34	Udic Haplusterts	37.22	0.08
35	Udic Ustochrepts	357.97	0.81
36	Vertic Ustochrepts	3,008.28	6.83
37	Non Soil	6,325.44	14.35
	Total	**44,070.77**	**100**

3.9.3. Soil Depth

Soil depth is another important variable for suggesting suitability of tree species for a plantation. The depth is important for the penetration of the roots of plant or tree species. Eight depth classes, *viz.*, Slightly Deep, Deep, Moderately Deep, Very Deep, Extremely Shallow, Very Shallow, Moderately Shallow, and Shallow have been mapped (Fig. 3.18). 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 3.14.

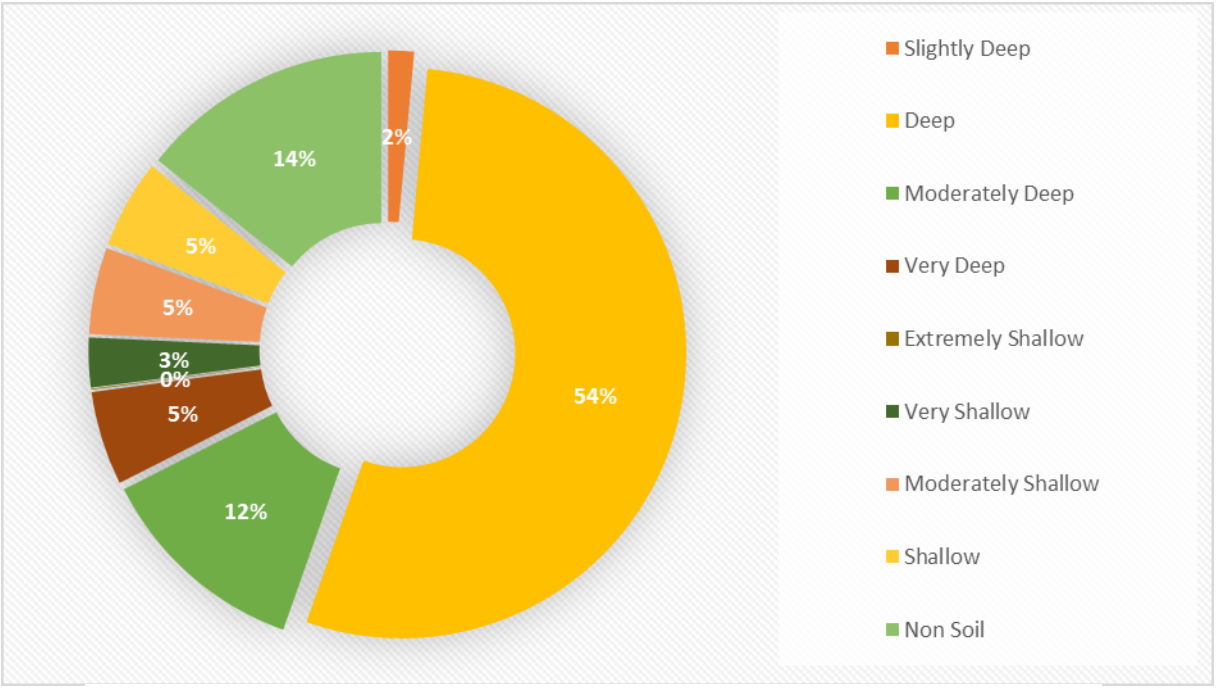


Fig. 3.18. Distribution of percent area under different soil depth categories

Table 3.14. Distribution of area under different soil depth categories

S.no.	Soil depth	Area (km^2)	Percentage of total area
1	Slightly Deep	641.79	1.46
2	Deep	23,777.95	53.95
3	Moderately Deep	5,354.50	12.15
4	Very Deep	2,344.91	5.32
5	Extremely Shallow	23.61	0.05
6	Very Shallow	1,236.30	2.81
7	Moderately Shallow	2,161.99	4.91
8	Shallow	2,204.28	5
9	Non Soil	6,325.44	14.35
	Total	**44,070.77**	**100.00**

3.9.4. Soil Erosion

Based on information obtained from the Indian Institute of Soil and Water Conservation (IISWC), Dehradun, six erosion classes have been mapped in the riverscape (Fig. 3.19 and Fig. 3.20). An area of 5837.99 km^2 falls under non-soil category (Table 3.15). These areas may not be suitable for forest plantations. About 40% area has more than 20 t ha^{-1} yr^{-1} soil erosion.

Table 3.15. Distribution of area under different soil erosion categories

S. no.	Soil Erosion (t ha^{-1} yr^{-1})	Area (km^2)	Percentage of total area
1	<5	4715.10	10.70
2	5-10	4213.17	9.56
3	10-20	11737.50	26.63
4	20-40	6197.70	14.06
5	>40	11369.31	25.80
6	Non Soil	5837.99	13.25
	Total	**44,070.77**	**100.00**

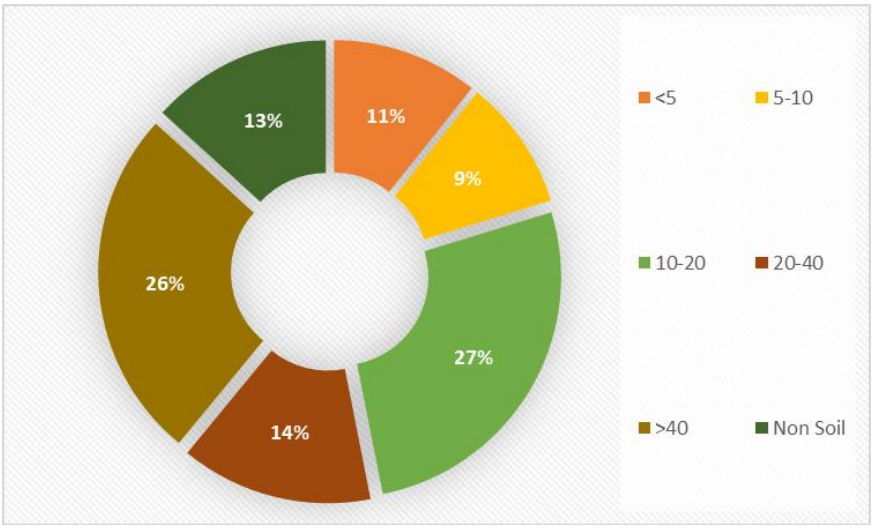


Fig. 3.19. Distribution of percent area under different soil erosion categories

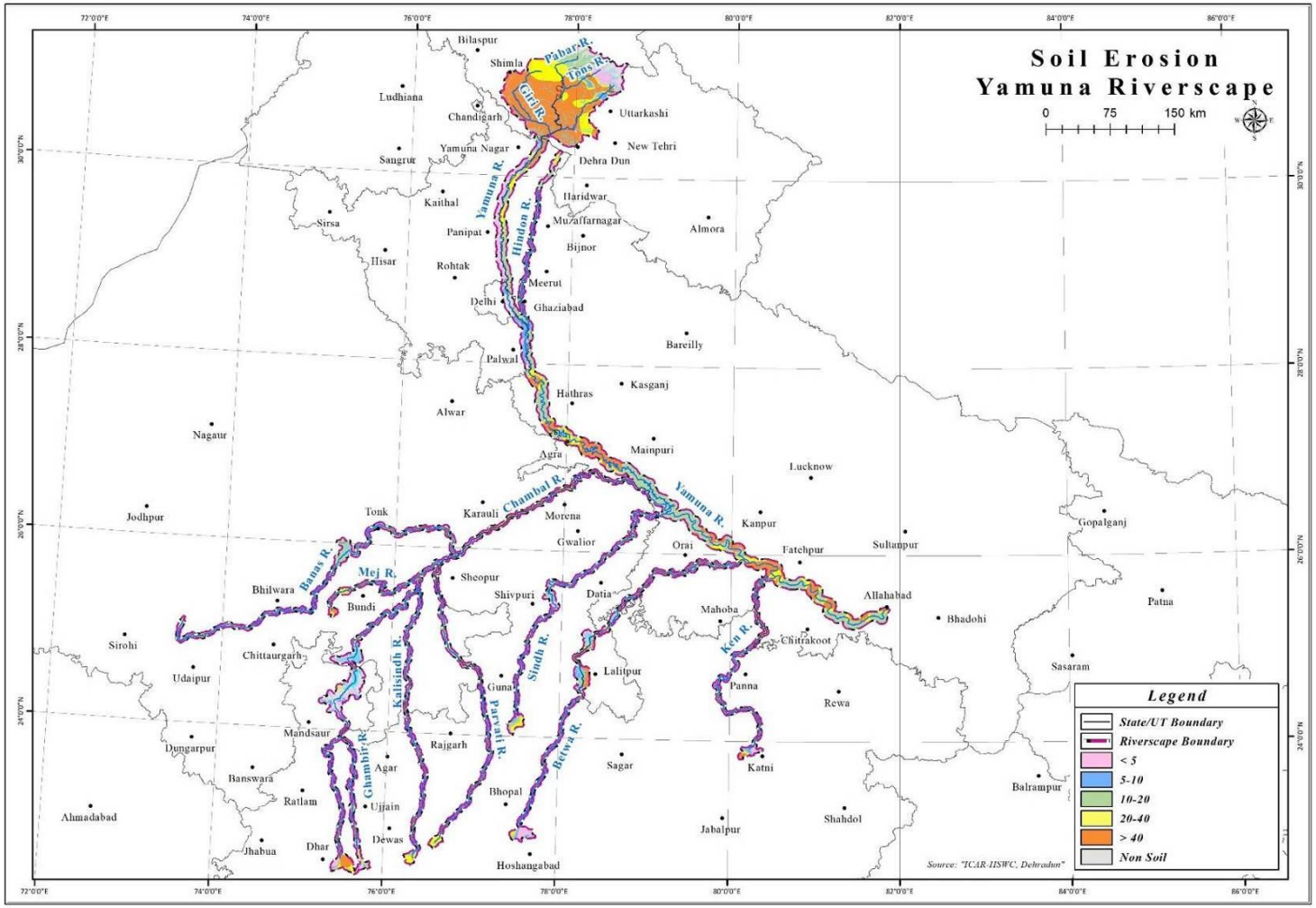


Fig. 3.20. Soil erosion map of the Yamuna Riverscape
(Based on information from ICAR-IISWC, Dehradun)

3.9.5. Forest type

As much as 73.52% area in the riverscape is non-forest while 9.22% area is under scrub vegetation. Tropical Dry Deciduous Forests occupy the largest 4,064.81 km^2 area followed by Himalayan Moist Temperate Forests 2,531.61 km^2. Moist Alpine scrub vegetation occupies the smallest area of 3.06 km^2 (Table 3.16., Figs. 3.21 and 3.22).

3.9.6. Forest cover

In the riverscape 32,400.59 km^2 area does not have forest cover while 4,064.81 km^2 area is under scrub. Dense forest cover includes canopy cover/density of more than 70%. Moderately dense cover include forest areas include the canopy cover/ density of 40-70%. Open forest areas include the canopy cover/density of 10-40%. Dense forest, moderately dense forest and open forest occupy 2,348.97, 2,332.69 and 2,923.71 km^2 area in the riverscape (Table 3.16, Figs. 3.23 and 3.24). This suggests that the extent of dense forest and moderately dense forest in the riverscape is broadly equal, but less than open forest cover (Table 3.17).

Table 3.16. Distribution of area under different forest types categories

S. no.	Forest type	Area (km^2)	Percentage of total area
1	Dry Alpine Forests	8.6	0.02
2	Himalayan Dry Temperate Forests	69.2	0.16
3	Himalayan Moist Temperate Forests	2,126.64	4.83
4	Moist Alpine Forests	3.06	0.01
5	Sal Mixed Moist Deciduous	74.25	0.17
6	Sub-Alpine Forests	55.17	0.13
7	Subtropical Pine Forests	1,647.3	3.74
8	Temperate Coniferous Forests	482.68	1.1
9	Tropical Dry Deciduous Forests	2,531.61	5.74
10	Tropical Moist Deciduous Forests	264.68	0.6
11	Tropical Thorn Forests	342.18	0.78
12	Scrub	4,064.81	9.22
13	Non Forest	32,400.59	73.52
	Total	**44,070.77**	**100.00**

Table 3.17. Distribution of area under different forest cover categories

S. no.	Forest cover	Area (km^2)	Percentage of total area
1	Dense Forest	2,348.97	5.33
2	Mod. Dense Forest	2,332.69	5.29
3	Open Forest	2,923.71	6.63
4	Scrub	4,064.81	9.22
5	Non Forest	32,400.59	73.52
	Total	**44,070.77**	**100.00**

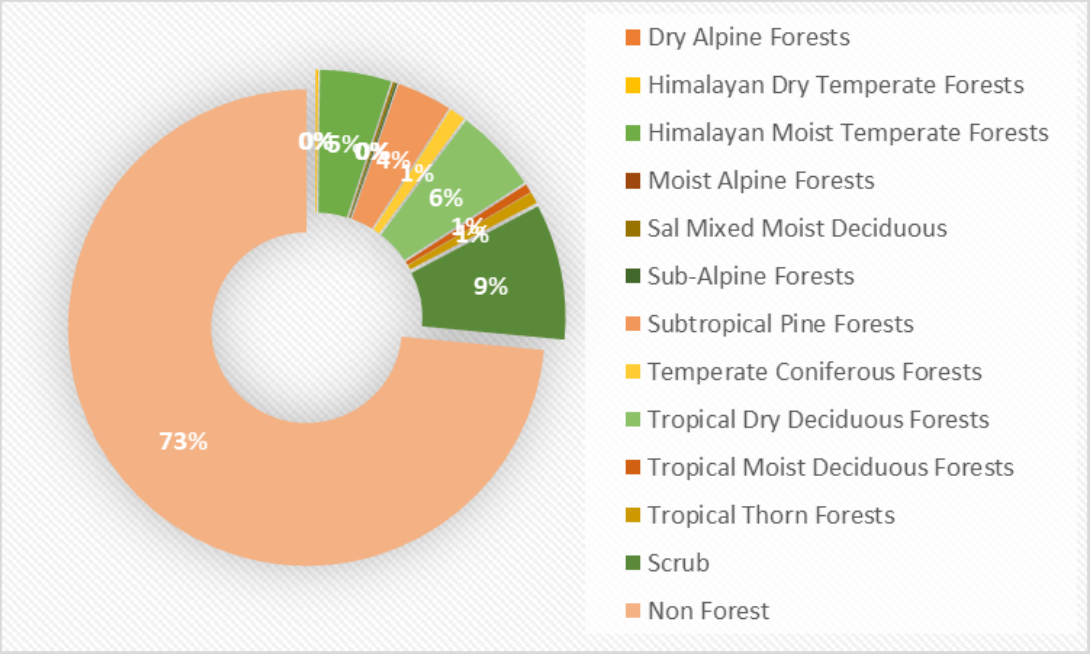


Fig. 3.21. Distribution of area under different forest types categories

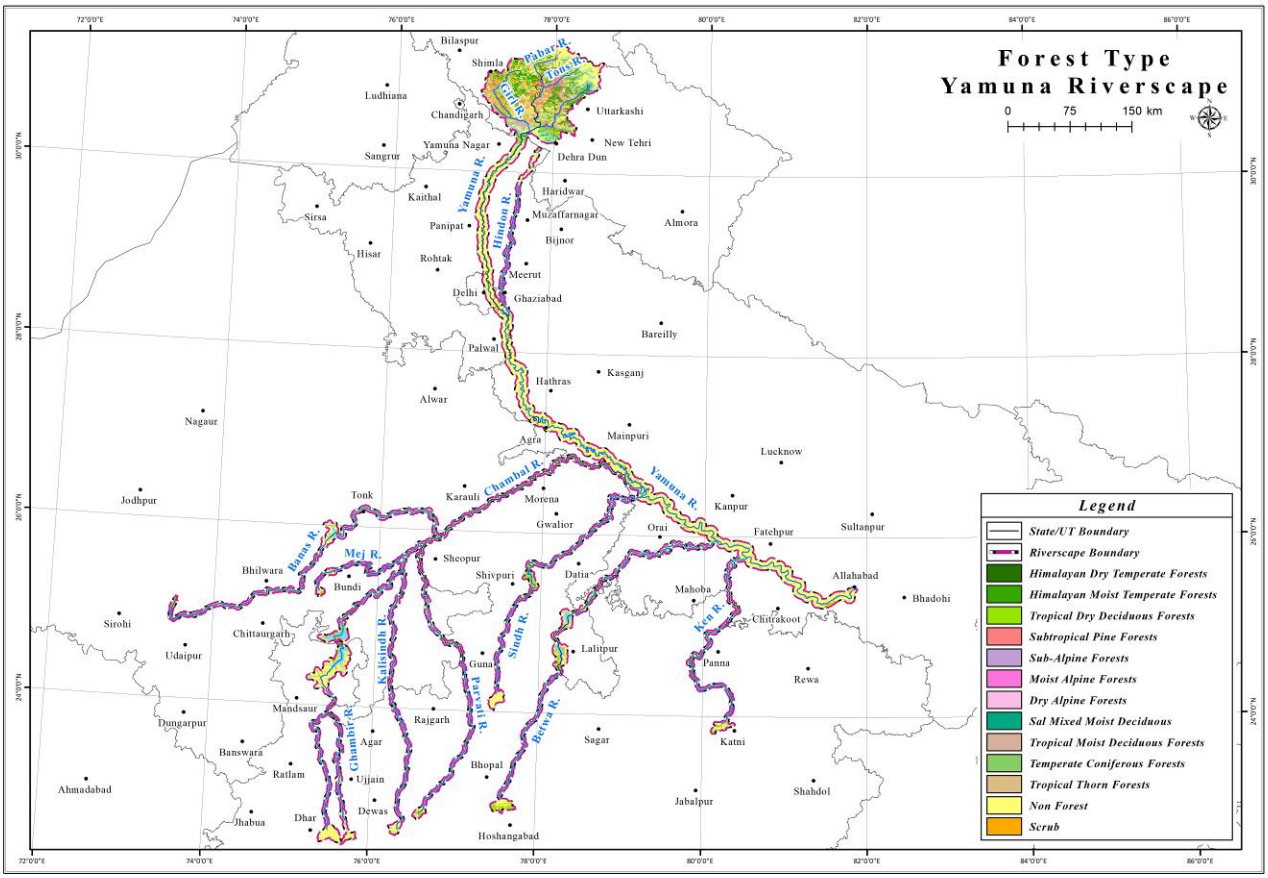


Fig. 3.22. Forest type distribution in Yamuna Riverscape
(Based on information from FSI, Dehradun)

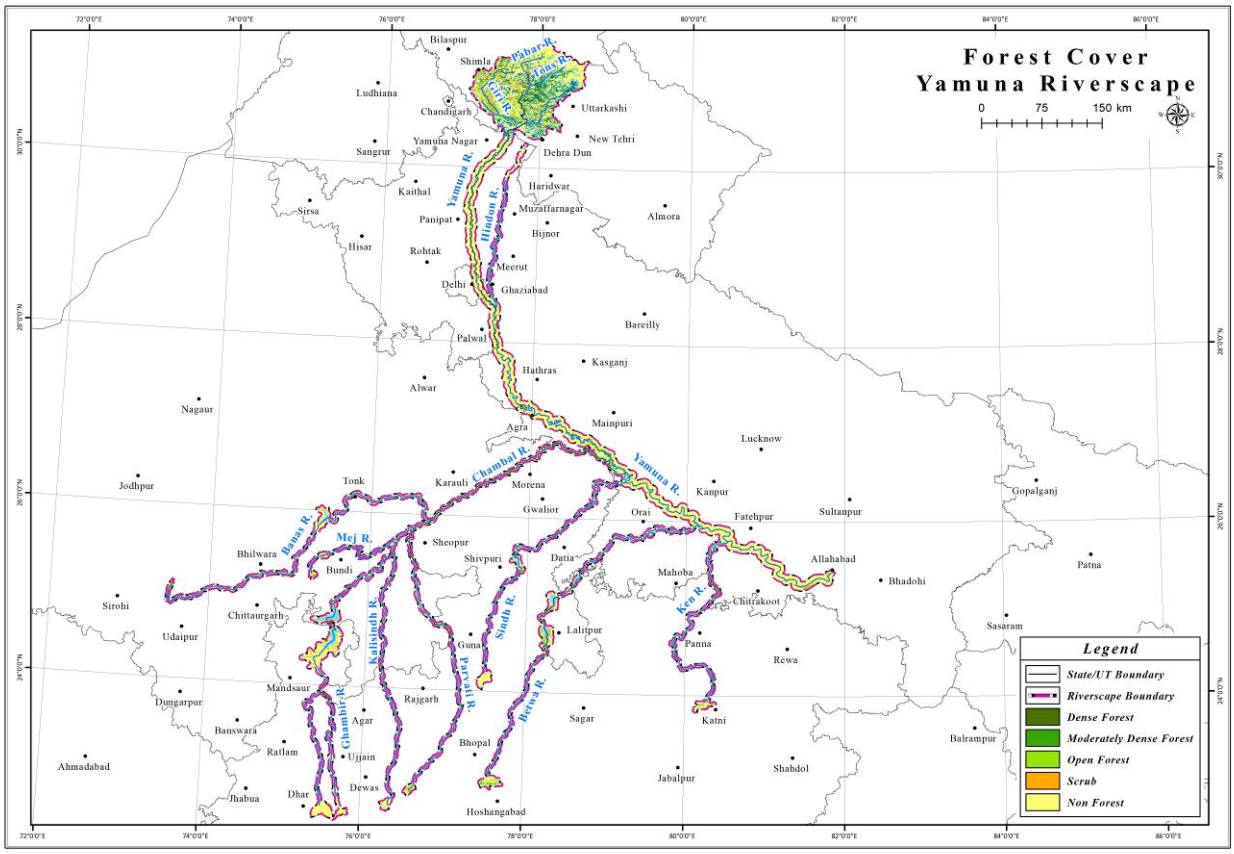


Fig. 3.23. Forest cover distribution in Yamuna Riverscape
(Based on information from FSI, Dehradun)

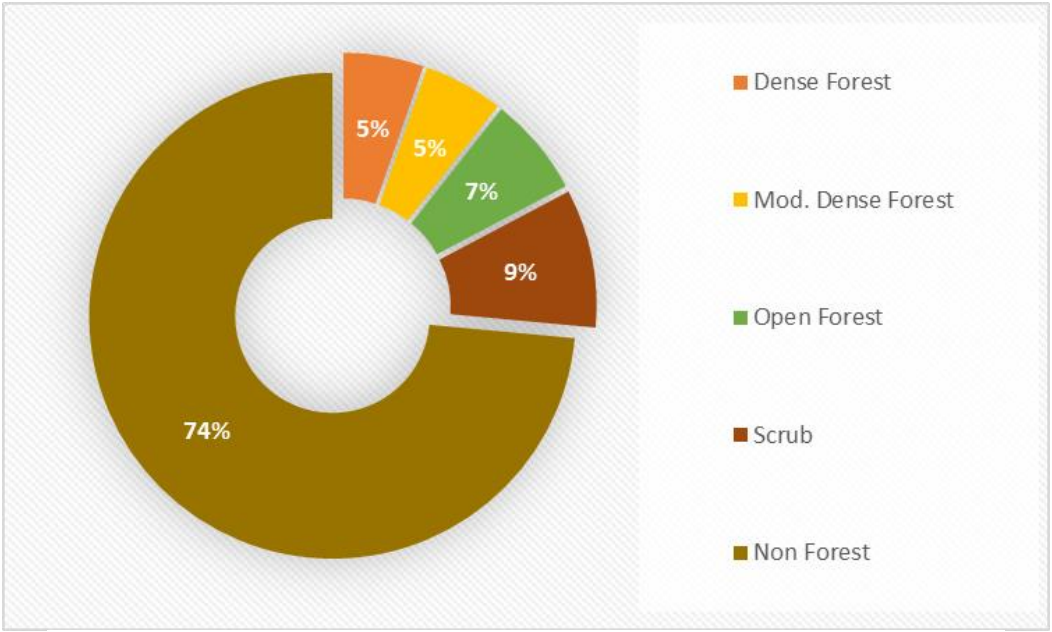


Fig. 3.24. Distribution of area under different forest density categories

3.9.7. Land Use and Land Cover

Prominent land use and land cover classes observed (Figs. 3.25 and 3.26) are described below:

Forest
These are the areas bearing an association predominantly of trees and other vegetation types (within the notified forest boundaries).

Agricultural Land
These are the lands primarily used for farming and for production of food, fibre, horticulture, etc. They are mainly the lands with standing crops (cropland; bright red to red colour on satellite image), fallow land (uncropped for one or more seasons; yellow to greenish blue tone), agriculture plantation (tea, coffee, etc.), plantation (herbs, nurseries, orchards, etc; dark red to red and regular sharp edged shapes).

Built-up/Settlements
These are areas of human habitation developed due to non-agricultural use and that have 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 centred, clustered, or in scattered form.

Industrial Area
These are the areas where human activity was 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.

Mining/Mining Dumps
Mining dumps are the areas where the debris is accumulated after extraction of minerals. These areas are often associated with the mining fields.

Barren
This can clearly be delineated from the image having bright white to light blue to yellow to brown colour tone depending upon the rock type. These are located on isolated hill slopes, plateau, etc.

Scrub
This land is prone to deterioration due to erosion. Scrublands 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.

Natural/Semi-natural Grasslands
These are the areas having grass (monocots) vegetation, and appear in light red to light brown of varying sizes and irregular shapes.

Alpine/Sub-alpine
These are the places between the coniferous forest and permanent snow covered areas. An alpine zone commencing point is variable and lies between 3,000-5,600 m asl.

Gullied/Ravinous Land
Gullied land is the first stage of excessive land dissection followed by their networking which leads to the development of ravinous land. The word ravine is usually associated with an intricate network of gullies formed generally in deep alluvium and entering a nearby river, flowing much lower than the surrounding table lands.

Water bodies

This category comprises areas with surface water (ponds, lakes, rivers, canals, etc.). These can clearly be seen on a satellite image in blue to dark blue or cyan colour 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, the sea, another river, lake, marsh, etc. They appear in light to dark blue, irregular shape (non linear). There are two major categories of rivers: perennial (flow continuously throughout the year) and, dry (flow only during monsoon period).

Agriculture is the dominant land use covering 22,994.99 km^2 area followed by Scrub 4,064.81 km^2 (Table 3.18 and Figs. 3.27 and 3.28). The extent of area by forest cover has been stated above. As much as 2,171.75 km^2 area is gullied/ravinous land while 1,574.89 km^2 area barren. Area under settlements is 1,506.24. River (perennial) and river (dry)/river sand cover 977.04 and 45.55 km^2 respectively.

Table 3.18. Distribution of area under different land use and cover categories

S.no.	Land use and cover	Area (km^2)	Percentage of total area
1	Agriculture	22,994.99	52.18
2	Alpine Pasture	42.44	0.1
3	Barren	1,574.89	3.57
4	Canal	29.92	0.07
5	Dense Forest	2,348.97	5.33
6	Gullied/Ravinous Land	2,171.75	4.93
7	Industrial Area	41.19	0.09
8	Mining/Mining Dump	32.72	0.07
9	Mod. Dense Forest	2,332.69	5.29
10	Open Forest	2,923.71	6.63
11	Plantation	66.96	0.15
12	River (Dry)/River Sand	977.04	2.22
13	River (Perennial)	1,506.24	3.42
14	Scrub	4,064.81	9.22
15	Settlement	1,605.65	3.64
16	Snow/Glaciers	1,142.92	2.59
17	Waterbody	45.55	0.1
18	Cloud	135.89	0.31
19	Cloud Shadow	32.44	0.07
	Total	**44,070.77**	**100.00**

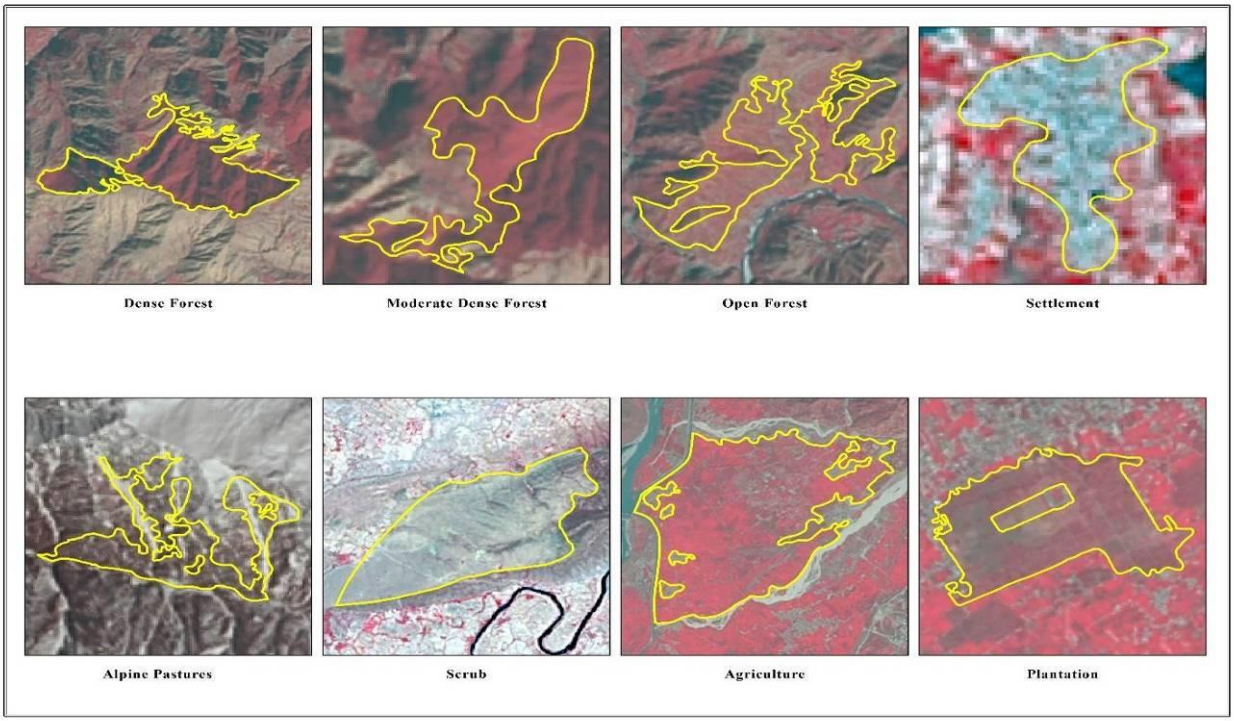


Fig. 3.25. Land use and cover classification key
(***Source:*** NRSA, 2006)



Fig. 3.26. Land use and cover classification key
(***Source:*** NRSA, 2006)

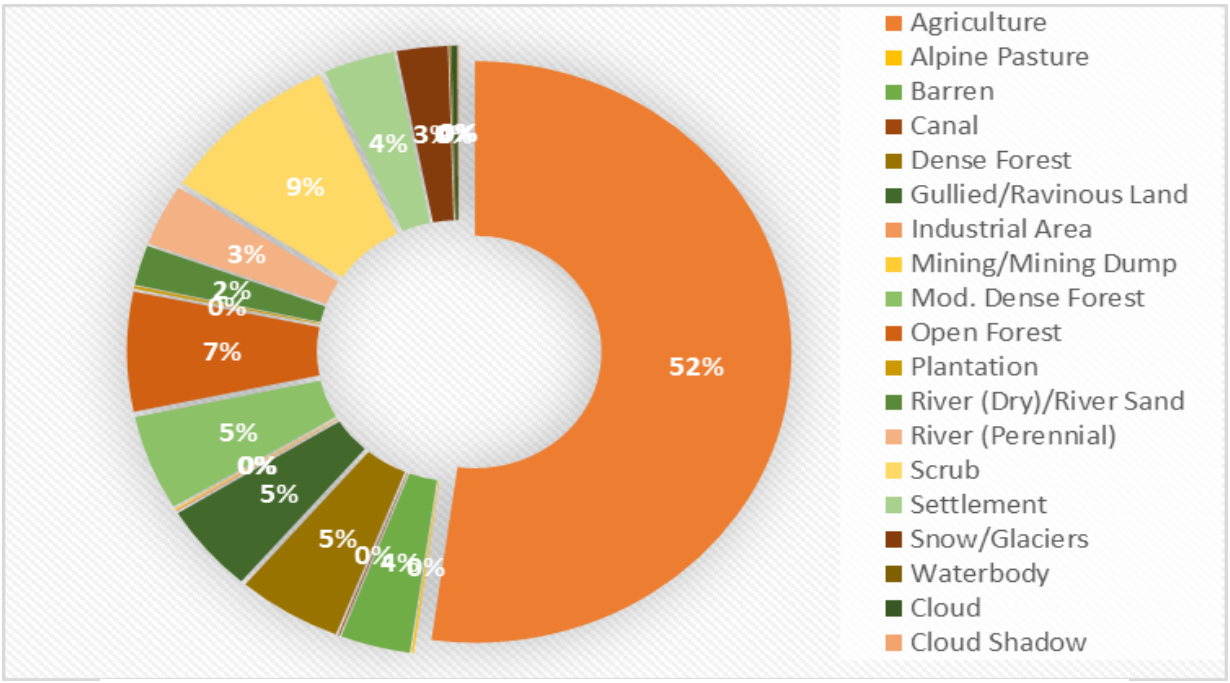


Fig. 3.27. Distribution of area under different land use and cover categories

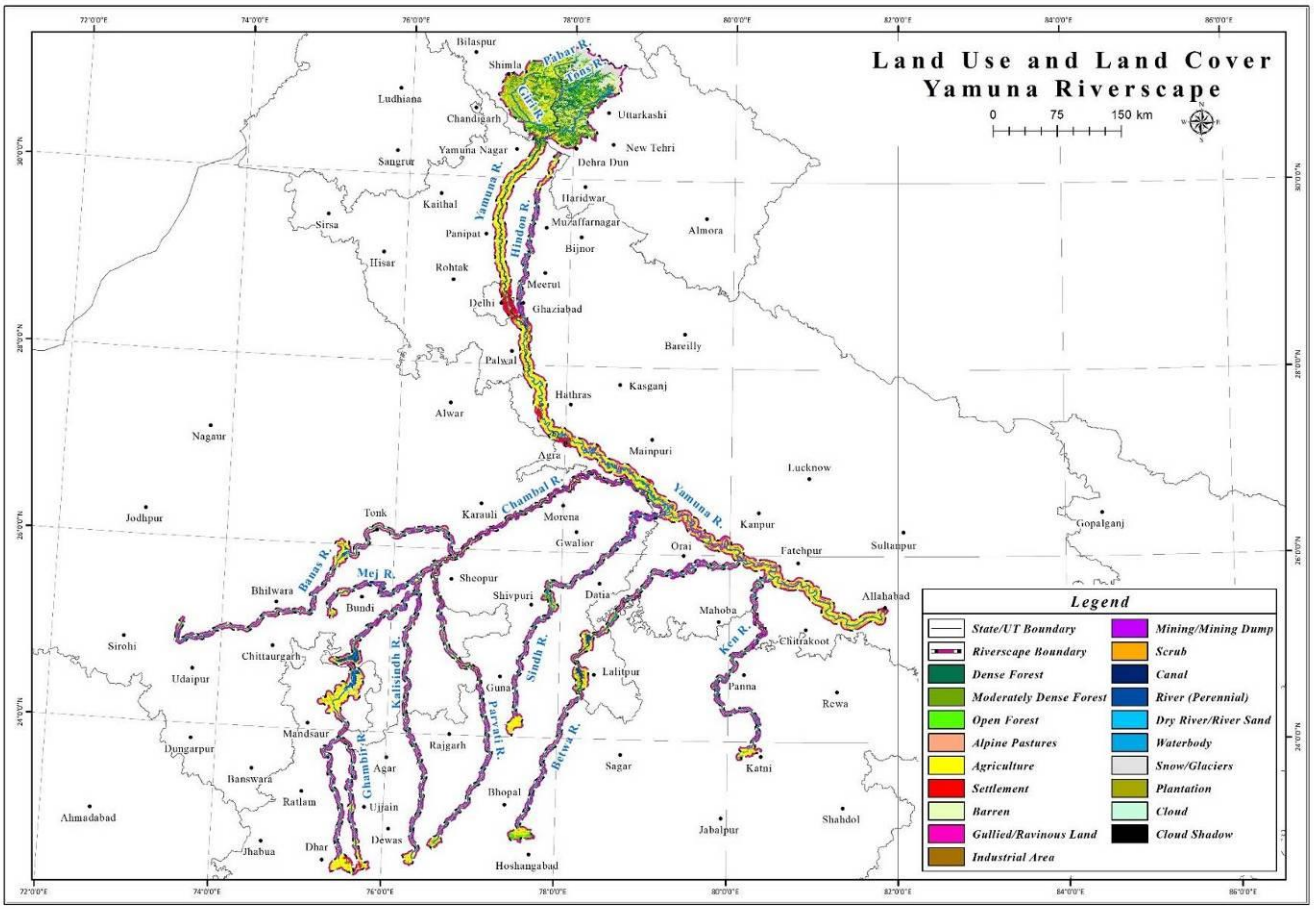


Fig. 3.28. Land use and cover categories in Yamuna Riverscape
(Based on information from SLUSI, New Delhi)

3.9.8. Number of Patches in Major Landuse Categories

Number of patches have also been found for five landuse classes. Firstly, these classes such as Alpine Pasture, 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 number of patches in scrub class is 8,578 and minimum in dense forest class is 2,046. Table 3.19 shows number of patches in select categories of natural and man-made land use and cover (Fig. 3.29 to 3.34).

Table 3.19. Distribution of patches in various natural and manmade LULC categories

S. no.	Area (km^2)	Number of patches	Percent representation
Dense Forest			
1	0.00 - 0.05	540	24.19
2	0.05 - 0.16	484	25.97
3	0.16 - 0.64	510	24.85
4	Greater than 0.64	512	24.98
	Total	**2,046**	**100**
Moderate Dense Forest			
1	0.00 - 0.06	833	13.83
2	0.06 - 0.18	902	11.86
3	0.18 - 0.54	880	11.93
4	Greater than 0.54	879	62.38
	Total	**3,494**	**100**
Open Forest			
1	0.00 - 0.02	1,725	14.84
2	0.02 - 0.07	2,542	11.16
3	0.07 - 0.21	1,953	10.5
4	Greater than 0.21	2,105	63.5
	Total	**8,325**	**100**
Scrub			
1	0.00 - 0.05	2,064	21.47
2	0.05 - 0.13	2,222	33.5
3	0.13 - 0.35	2,128	22.56
4	Greater than 0.35	2,164	22.47
	Total	**8,578**	**100**
Agriculture			
1	0.00 - 0.04	1,900	16.22
2	0.04 - 0.13	1,761	13.43
3	0.13 - 0.58	1,783	15.06
4	Greater than 0.58	1,819	55.28
	Total	**7,263**	**100**
Barren			
1	0.00 - 0.03	1,118	26.55
2	0.03 - 0.07	864	22.5
3	0.07 - 0.21	1,107	25.83
4	Greater than 0.21	1,019	25.11
	Total	**4,108**	**100**

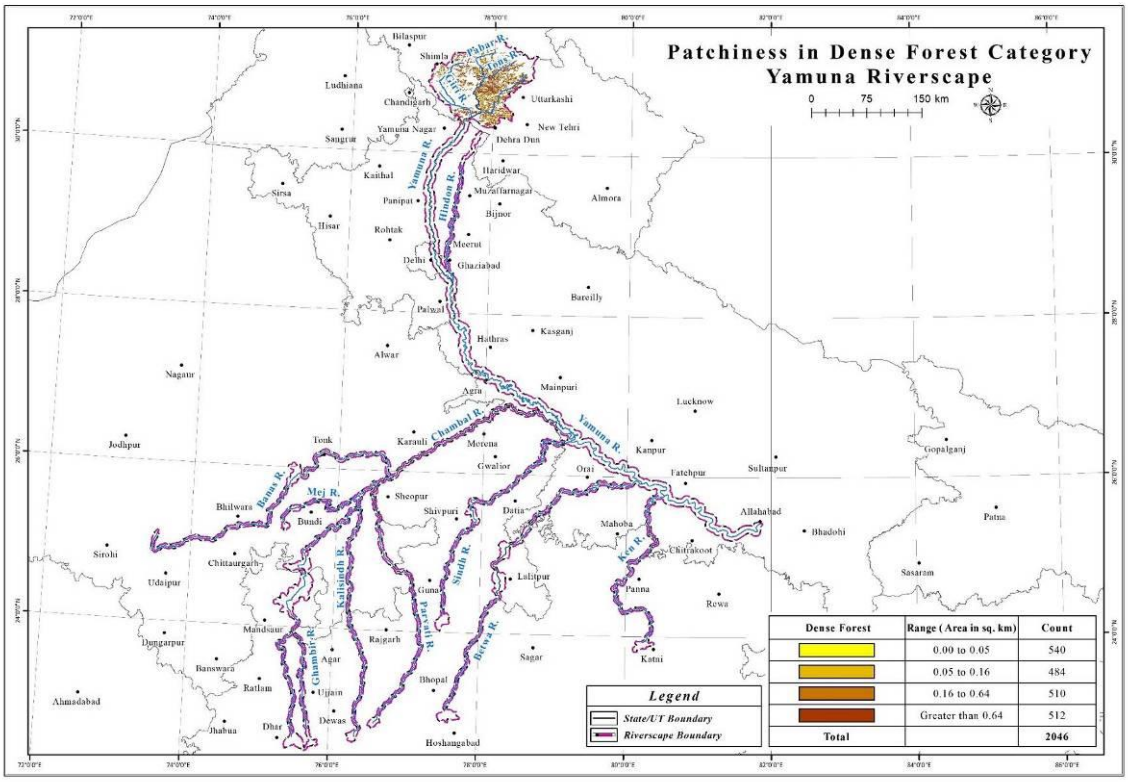


Fig. 3.29. Patchiness in dense forest in Yamuna Riverscape
(Based on information from FSI, Dehradun)

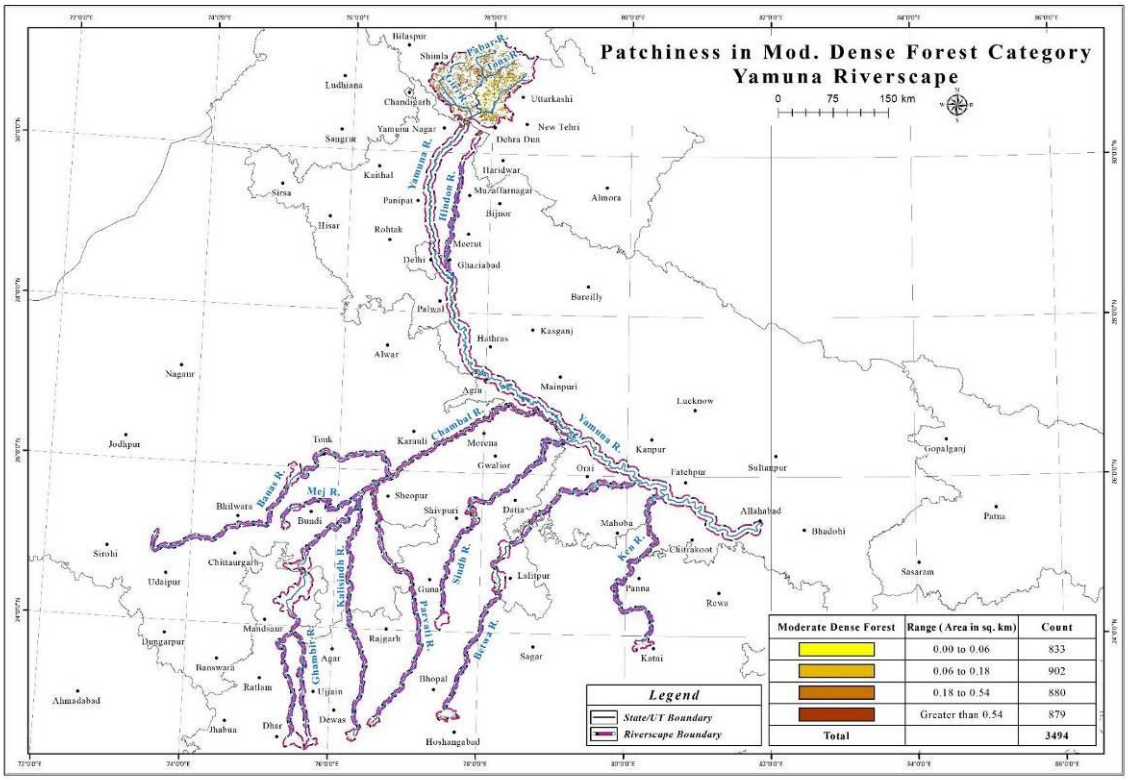


Fig. 3.30. Patchiness in moderately dense forest in Yamuna Riverscape
(Based on information from FSI, Dehradun)

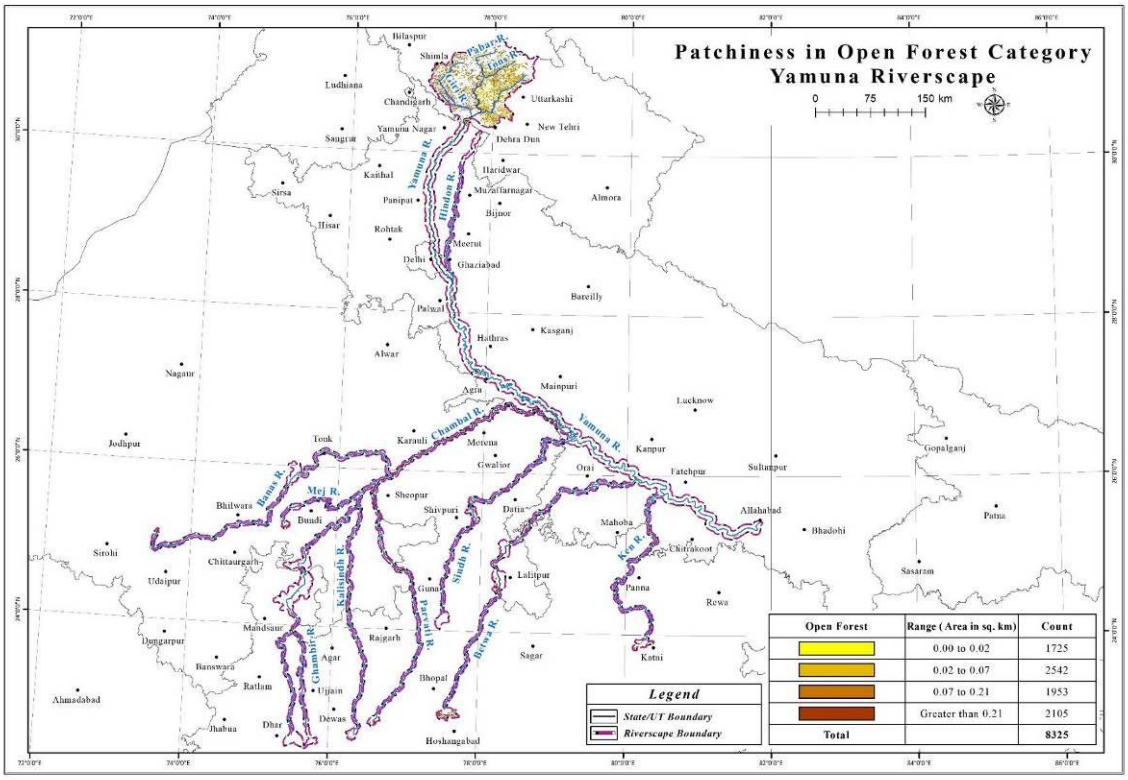


Fig. 3.31. Patchiness in open forest in Yamuna Riverscape
(Based on information from FSI, Dehradun)

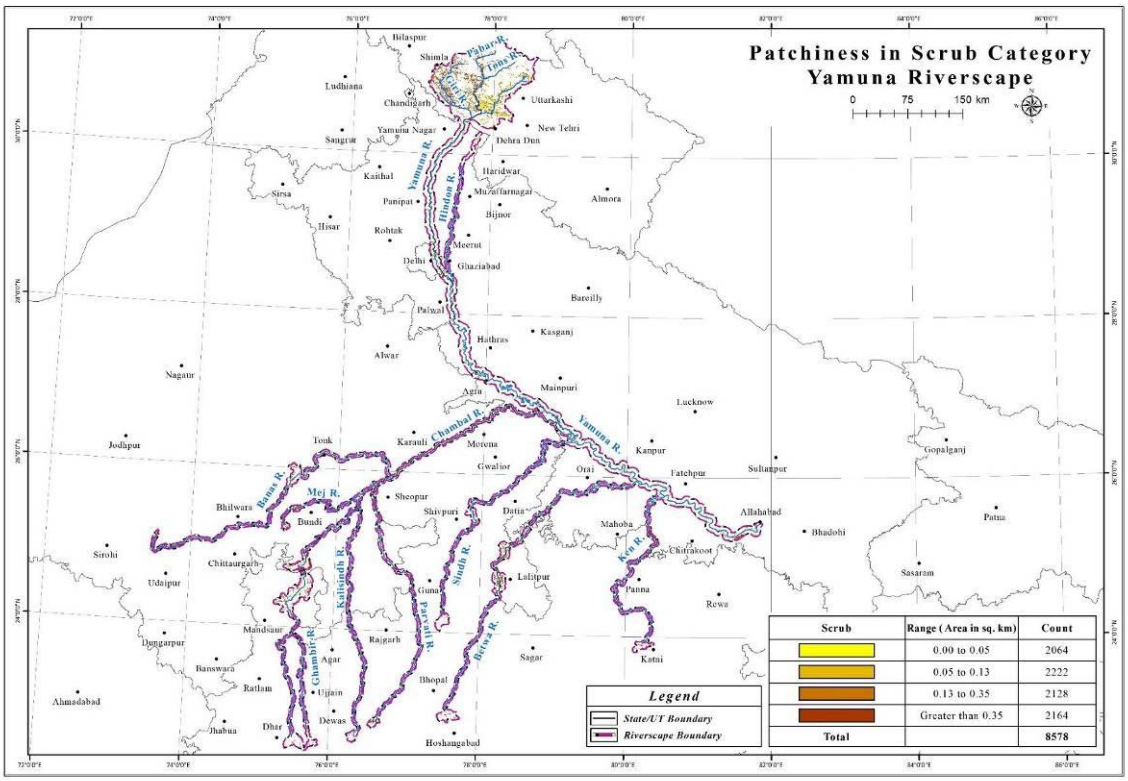


Fig. 3.32. Patchiness in scrub in Yamuna Riverscape
(Based on information from FSI, Dehradun)

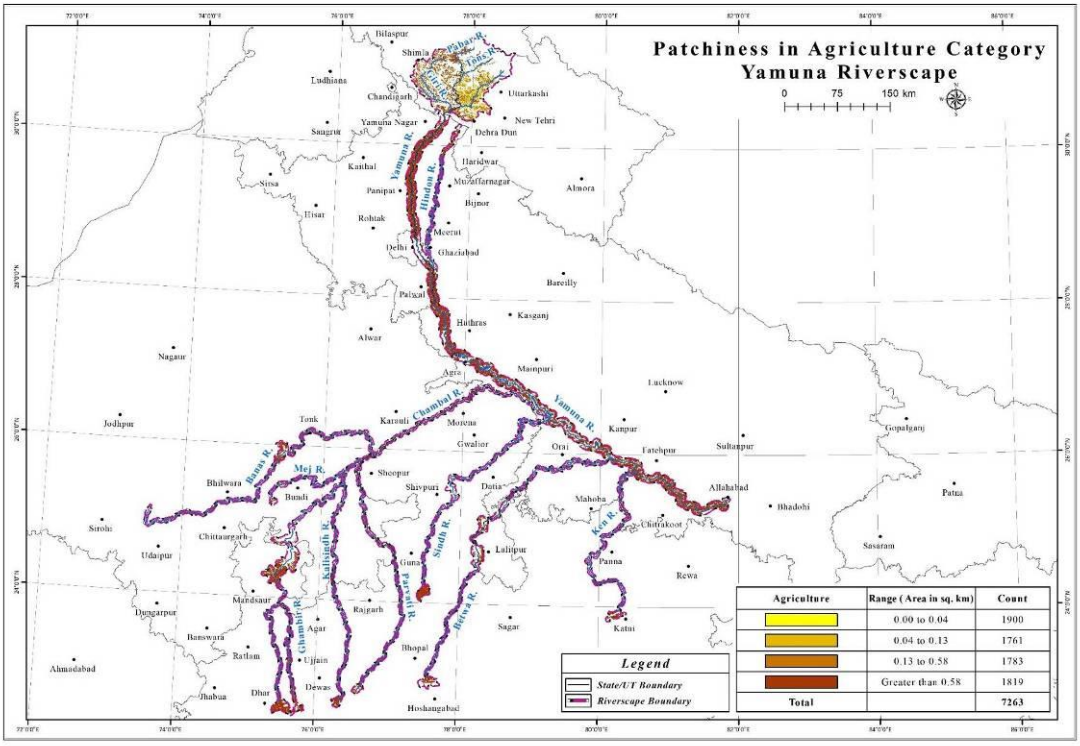


Fig. 3.33. Patchiness in agricultural area in Yamuna Riverscape
(Based on information from FSI, Dehradun)

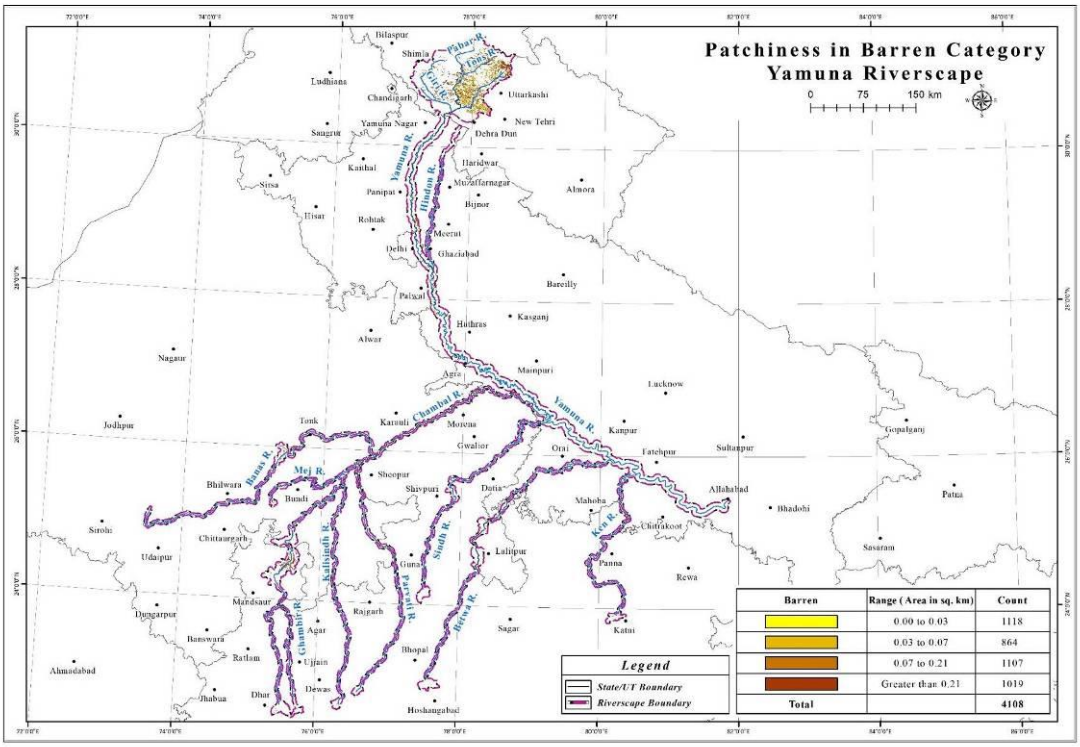


Fig. 3.34. Patchiness in barren area in in Yamuna Riverscape
(Based on information from FSI, Dehradun)

Chapter 4
LEGISLATIVE, POLICY AND INSTITUTIONAL CONTEXT

4.1. THE TASK

Forest Research Institute (FRI), Dehradun carried out the task of preparing a 'Detailed Project Report (DPR) for Rejuvenation of Yamuna through Forestry Interventions' under the ambit of the work being done by Indian Council of Forestry Research and Education (ICFRE) on preparation of similar reports for the purpose of rejuvenating major Indian rivers through forestry interventions. One of the key aspects in such rejuvenation through forestry is to understand the interventions within the broader law and policy framework of rivers in general and policy interventions on rejuvenation in particular, and secondly, to understand the forestry law framework and whether it enables river rejuvenation or not. It would also be instructive to examine whether the judiciary both at the Apex level as well as the National Green Tribunal supports such rejuvenation through forestry interventions. The above legal and policy framework is essential to understand so that such initiatives do not meet legal hurdles in its implementation. But before we understand the details of the legal framework, it is worthwhile to have a physical sense of the area in question, i.e., River Yamuna and the threats that it currently has which necessitates rejuvenation.

4.2. THE STRETCH AND THE THREATS TO YAMUNA

As is well known, River Yamuna, stretching across 1,376 km with a total basin area of 3,66,223 km^2 spans across states of Uttarakhand, Uttar Pradesh, Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh and Delhi NCT. This also means that in a federal polity, both central and state legislations would be crucial to understand the context in a multi-state ecological expanse of a river. The river Yamuna, like most of the major Indian rivers, is inter- state and highly venerated (Agarwal *et al.*, 1999). Like most rivers in India, it now faces increasing deterioration of water quality due to various factors such as urbanization, industrialization, untreated industrial effluents, run-offs, idol immersion and, in addition, degenerates due to certain agricultural, religious and social practices, resulting in huge discharge of untreated domestic sewage. Sixty per cent of Indian rivers are polluted and they flow past 650 towns that release 62,000 MLD sewage into the rivers every day (Sengupta and Pandey, 2017). Yamuna is no exception. As per the CPCB Report titled 'River stretches for restoration of water quality' (CPCB, 2018), the level of biochemical oxygen demand (BOD) in River Yamuna is high in various stretches in several states such as 9-80 mg/l in the stretch from Wazirabad to Asgarpur in Delhi, 4-55 mg/l in the stretch from Panipat to Sonepat in Haryana and 12-55 mg/l in the stretch from Asgarpur to Etawah Shahpur to Prayagraj (Balua Ghat), amidst several other polluted stretches in other states where Yamuna flows. Based on a study of water quality data of 17 years (2000-17) collected at 878 hydrological observation (HO) stations in all the major river basins of India by the Central Water Commission, Bureau of Indian Standards (BIS) has recommended 3.0 mg/l concentration of BOD for outdoor bathing (PIB, 2012). It is clear from the above that the water quality of the Yamuna is alarmingly poor and, therefore, its rejuvenation is an urgent need.

4.3. NATIONAL AND STATE WATER POLICIES AND RIVER REJUVENATION

What is quite stark over the years in National Water Policies enunciated in 1987, 2002 and 2012 is that there is no specific mandate on river rejuvenation, although, an important aspect discussed is water quality. The National Water Policies of 1987 and 2002 elaborated on existing strategies and state that new techniques, resting on a strong science and technology base, will be needed to eliminate the pollution of surface and ground water resources, improve water quality and step up the

recycling and re-use of water. Science, technology and training have important roles to play in water resources development in general. The water policies highlighted the need for enhancing water quality and improvement in existing strategies through new technologies. More importantly, the National Water Policy, 2012, noted the fact that characteristics of catchment areas of streams, rivers, and recharge zones of aquifers are changing as a consequence of land use and land cover changes, affecting water resource availability and quality. The Policy reiterated that growing pollution of water sources, especially through industrial effluents affecting the availability of safe water besides causing environmental and health hazards. In many parts of the country, large stretches of rivers are both heavily polluted and devoid of flows to support aquatic ecology, cultural needs and aesthetics. It is for this reason the Policy envisaged a holistic and inter-disciplinary approach to tackle water problems. Water quality and quantity are inter-linked, and they need to be managed in an integrated manner, consistent with broader environmental management approaches inter alia including the use of economic incentives and penalties to reduce pollution and wastage. It was emphasised to develop appropriate institutional arrangements for each river basin for monitoring water quality in both surface and ground waters (MoWR, 2012).

4.4. NATIONAL FOREST POLICY OF 1894, 1952 AND 1988

Significantly, much before the policy environment on water evolved, the Forest Policy enunciated in 1894 till the National Forest Policy 1988, emphasizes the role of forests whose preservation is essential from the climatic or physical grounds. The Forest Policy of 1952 again emphasized as one of the six vital needs – the need for checking denudation in mountainous regions on which depends the perennial water supply of the river system and whose basins constitute the fertile core of the country. It also emphasized the need for checking erosion along the banks of rivers leading to ravine formation among others. In fact, a special category of forest namely 'Protection Forest' was envisaged which would ensure prevention of erosion, conservation of moisture and control of rushing torrents and floods. It specifically states that the role of such forests in saving the soil from being washed away, and when maintained in catchment areas in the prevention of floods and maintenance of stream flow, cannot be over emphasized. Another specific mandate was the 'Reconditioning of hills and dales'. The Policy stated that progressive denudation of hill sides with serious repercussions on the fertility of the land, and the growing erosion on the banks of the rivers of which, Yamuna, Chambal, Mahi, Narmada, Kosi and Damodar rivers are notorious examples, and constitute a major considerations demanding immediate attention.

National Forest Policy, 1988 which is currently applicable, has within its basic objectives, the maintenance of environmental stability through preservation and restoration of ecological balance caused by serious depletion of forests; and checking soil erosion and denudation in the catchment areas of rivers, lakes, and reservoirs in the interest of soil and water conservation for mitigation of floods and droughts and for retardation of siltation of reservoirs. In fact, one of the essentials of forest management includes the increase in forest cover in the catchment areas of rivers. The NFP 1988 considers one of its important strategies as afforestation, especially along the sides of rivers and streams. Another important strategy is to restrict those schemes and projects which interfere with forests that cover the catchment of rivers and lakes among others. Further, one of the mandates of forestry research is also to revegetate the watershed areas and effectively conserve and manage existing forest resources (MoEF, 1988). It is clear from the above that there is no impediment to river rejuvenation either from the National Water Policies or the National Forestry Policies over the years. In fact, there is a clear policy enabling environment for river rejuvenation through forestry interventions, over the years.

4.5. LEGAL FRAMEWORK ON ENSURING WATER QUALITY IN RIVERS

As noted earlier, one of the important aspects emphasized by the National Water Policies is water quality. While there is a policy mandate to enhance water quality, the legal measure to ensure that

water quality does not deteriorate is through the Water (Prevention and Control of Pollution) Act, 1974 (hereinafter the 'Water Act'). The Water Act, 1974 read with Water (Prevention and Control of Pollution) Rules, 1975, follows the broad scheme of command and control, by constituting central and state pollution control boards to check and monitor the point pollution sources, setting standards specifying permissible levels of pollution and standards through penal provisions.

In addition to the Water Act, the Environment (Protection) Act, 1986 (hereinafter 'EPA') and the Environment (Protection) Rules, 1986 (hereinafter 'EP Rules') too provide an overall framework for protection and improvement of environment which include rivers by empowering the Central Government to issue directions regarding, closure, prohibition or regulation of any industry, operation or process; stoppage/regulation of the supply of electricity or water (or any other service) and formulating necessary Rules. The scientific parameters to identify pollution in water bodies (CPHEEO, 1999) have been laid down in the EP Rules (GoI, 1986), such as Biochemical Oxygen Demand (BOD), Faecal coliform, Chemical Oxygen Demand (COD), Suspended Solids (SS), pH, temperature, Dissolved Oxygen (DO), Ammonia (NH_3), heavy metals, pesticides, among others.

4.5.1. Water Quality of Yamuna

Specifically, with respect to River Yamuna, several studies have been conducted over the years, to collate information on physiography, hydrography, geology, mineral resources, soils, ground water resources, demography, land use, wastewater disposal, pattern of water use and the extent of water pollution load generated in the river basin. The study titled 'Quality and trend of River Yamuna' (CPCB, 1983), conducted by the Central Pollution Control Board from 1977-1982 brought out the possible relationships between different aspects of economic activities within the basin and the impact on water quality in the river. Further, it laid down the current minimum levels of water quality in different segments of the river and accordingly classified best use of the stream water. Later, in its report titled, 'Water quality status of Yamuna River (1999-2005)', the CPCB undertook monitoring studies, indicating several polluted stretches (CPCB, 2006). It identified as the prime reason of pollution, various urban centres like Delhi, Mathura, Agra, etc. located on the banks of the Yamuna, drawing fresh river water for various activities and discharging untreated wastewater back into the river. This is seen in the 580 km long critically polluted river stretch between Wazirabad barrage and Chambal river, characterized by high organic content, high nutrients, significant depletion, or increase in dissolved oxygen, severe odour, etc. As per the report, about 85% of the total pollution in the river is contributed by domestic sources. The condition of the river deteriorates further due to abstraction of significant amount of river water, leaving almost no fresh water in the river which is essential to maintain the assimilation capacity of the river. Based on water quality, the Yamuna was segregated into five distinct stretches, i.e., Himalayan stretch, Upper stretch, Delhi stretch, Mixed stretch and Diluted stretch. It was noted that the Najafgarh drain of NCT Delhi is the biggest polluter of River Yamuna, which contributes about 26 to 33% of total BOD load and 48 to 52% of total discharge that joins Yamuna River and canal at Delhi by various drains.

4.5.2. Other Related Problems

Several interlinked problems contributing towards nearly irreversible pollution in Yamuna have been identified by the government as well as the judiciary. These include: absence of proper sewerage network due to haphazard urban planning and unchecked expansion of unauthorized colonies; discharge of sewage into storm water drains with no consequences for environmental damage; poor maintenance of the sewage treatment plants (STPs); failure of authorities such as the Delhi Development Authority in fulfilling their duties including non-implementation of action plans; lack of clarity in Action Plans and no timelines for their execution; multiplicity of agencies and departments with overlapping responsibilities; and no mechanism to monitor the efficacy of the

Online Monitoring Devices (OMD), among others. Despite several long judicial proceedings and repeated directions by courts there have been large scale failures, zero compliance and no accountability.

4.5.3 Judicial Interventions on Yamuna

In relation to the Yamuna, the Supreme Court for the first time in the famous case titled, *Rural Litigation and Entitlement Kendra vs. State of Uttar Pradesh, 1986* (Doon Mining Case), dealt with unauthorised and illegal mining operations adversely affecting the ecology of the area including that of the Yamuna. The blockage due to screen and stones causing reduced flow of water in the tributaries led to drying up of Yamuna and consequent water scarcity in Dehradun. Here, the Hon'ble Supreme Court held that a balance must be struck between preservation and utilisation which in turn must be examined by an expert body, and the Government should take a policy decision in this regard and implement it. It further held that air and water are the most indispensable gifts of nature for life to thrive, and rivers and water sources must be preserved.

The issue of industrial pollution in Yamuna causing irreversible deterioration of river water, a source of drinking water for thousands, in complete violation of provisions of environmental laws was also recognized by the High Court of Delhi, in *Maneka Gandhi vs. Union Territory of Delhi & Ors., 1984,* with respect to highly polluting slaughter houses discharging blood and dung heaps in the Yamuna. Here, the Delhi High Court issued directions to be meticulously followed for improving the prevailing conditions in the larger public interest, and placed a restriction on the number of animals slaughtered to 2,500 per day, i.e., 2,000 sheep/goats and 500 buffaloes and ordered maintenance of minimum standard of hygiene and sanitation. On similar grounds of pollution of the Yamuna, the Allahabad (Prayagraj) High Court in *Megh Shyam Sharma and Ors. vs. State of U.P. and Anr., 1985,* dealt with discharge of noxious effluents from the paper mills causing irreversible pollution of the Yamuna, wherein it was held that public health could not be allowed to suffer for the consideration of any industry or company and its interest and that urgent restraint was necessary for preserving the vital source of drinking water for all. In *Baldev Singh and Ors. vs. State of H.P. and Ors., 2006,* a similar case of toxic discharge into Yamuna River was seen due to the fermentation plant of M/s. Ranbaxy Laboratories Ltd., manufacturing bulk drugs in Himachal Pradesh. The High Court pointedly stated that on the one hand was the public need for medicines of the highest quality and on the other hand was the imperative need to maintain and preserve the environment. It was held that no industry could be set up without a proper Environmental Impact Assessment (hereinafter 'EIA'). It was for the Impact Assessment Authority, and not for the proponent of the industry, to decide whether a comprehensive EIA should be prepared, or the rapid EIA is sufficient to meet the needs of the industry.

Courts have also pointedly dealt with the dismal state of the Yamuna in many cases, and suggested methods to rejuvenate the quality of the river water. In *Jai Narain and Ors. vs. Union of India and Ors., 1996,* the Apex Court found that the water quality of the Yamuna, in the Delhi stretch, was neither fit for drinking nor for bathing. The Biochemical Oxygen Demand (BOD) level in the river was so high that no flora or fauna could survive. The Court held that it was of utmost importance and urgency to complete the construction of the sewage treatment plants (hereinafter 'STP') in Delhi to protect the environment, control pollution and in the process maintain and develop the agricultural green. Further, in this context, the Delhi High Court in *Baldev Singh Dhillon & Ors. vv. Union of India & Ors., 1996,* dealt with the questions of how the Yamuna could be made pollution free and how the river could be channelized. The Court held that for making the Yamuna pollution free, treatment plants need to be erected to eliminate the pollutants from the drain water being discharged into it and this measure was to be supplemented by increasing the discharge of pure water into the river. It was held that channelization of River Yamuna might mean deepening of the natural river channel in the river bed or its floodplains, by making, plans, maps, alignments, depth of flow charts of its course through the Delhi, and working drawings, etc., all

drawn to scale. Notably, in *Comdr. Sureshwar D. Sinha vs. Union of India, 1992,* a leading case of continuing mandamus in the Supreme Court on River Yamuna, the question of significantly reduced flow in Yamuna was raised and orders were sought to permit fair levels of water flow which had been severely curtailed, depriving millions of people in downstream areas of the benefits of the river. The Supreme Court directed the High Powered Committee constituted, to take a decision with respect to the share of riparian states and to monitor the implementation of its decision to maintain a minimum flow of 10 cumecs throughout River Yamuna and of the short- and long-term measures recommended by it for maintaining the ecology of the river.

A few years hence in 1994, the Apex Court took *suo moto* cognizance of news item published in *The Hindustan Times* titled *'And Quiet Flows The Maily Yamuna',* considered the rapidly deteriorating water quality in Yamuna especially in Delhi, and deemed it expedient that all the concerned authorities must sit together, apply their minds on various factors including the source of generation of waste and industrial effluents and draw up a plan which may help in achieving results at the ground level (Prakash, 2012). A High Level Committee appointed by the Secretary, Ministry of Urban Development was required to prepare and submit to the Supreme Court an action plan within a period of six weeks suggesting the mode and manner in which the quality of water could be improved and the steps to be taken by various authorities. Vide Supreme Court order dated 24th April, 2017 the above case was shifted to National Green Tribunal and is being monitored at the moment along with another important case *Manoj Mishra vs. Union of India, 2012* which is described later. While it would be instructive to examine how the National Green Tribunal has specifically focused on the River Yamuna, it would be useful to assess in brief the executive action that has been taken pursuant to Supreme Court and High Court nudges, apart from the Government's own programmes.

4.6. YAMUNA AND EXECUTIVE ACTION

While a lot has been attempted for rejuvenation of River Yamuna through means of judicial activism as indicated above, several programmes and executive actions to clean Yamuna have also been undertaken by the government over the years. The formal inception of the *Yamuna Action Plan (YAP)* took place in 1993. It was one of the largest river restoration projects in the country and Ministry of Jal Shakti (earlier Ministry of Water Resources, River Development and Ganga Rejuvenation) has been supplementing the efforts of States for pollution abatement in Yamuna, a tributary of Ganga, by providing financial assistance. The Yamuna Action Plan (YAP) was to be implemented in a phased manner. It started in 1993 with a sanctioned cost of Rs. 705.51 crore against which an expenditure of Rs. 682 crore was incurred. Cleaning of Yamuna was also part of the *Namami Gange* Mission, and the Government of India had been supplementing the efforts of the states to check the rising pollution in the Yamuna by providing financial assistance to States of Haryana, Delhi, and Uttar Pradesh in a phased manner since 1993 under the Yamuna Action Plan (YAP) (PIB, 2011). YAP-I was taken up for Delhi during 1993-2003 and YAP-II was extended in 2003 to cover Uttar Pradesh and Haryana along with Delhi. A total sewage treatment capacity of 767.25 MLD had been created under both the phases. Building on the success and lessons learnt from YAP-I and II, Government of India launched YAP-III in Delhi with assistance from Japan International Cooperation Agency-JICA (bilateral project between India and Japan with funding from Government of Japan), at an estimated cost of Rs 1,656 crore for 7 years, which got integrated as a component of *Namami Gange* Mission. Delhi Jal Board was the executing agency for these projects. A wide range of works on sanitation, especially sewage treatment, and electrical/improved crematoria were initiated. No separate scheme for rejuvenation of river Yamuna has been made, because the *Namami Gange* programme includes all the tributaries of the Ganga, and the Yamuna being one of the tributaries is included under the *Namami Gange* programme (PIB, 2015).

In view of the current sewage generation in Delhi of about 3270 MLD (3270 MLd^{-1} or 327 crore litres per day) as against the existing treatment capacity of 2760 MLD, several projects have

been undertaken by the State Govt. of Delhi as well as National Mission for Clean Ganga (hereinafter 'NMCG') for tackling pollution of the Yamuna by erecting sewage infrastructure. Projects by the state government include (i) construction of 318 MLD STP with 10 years operation and maintenance (O and M) on at Coronation Pillar, (ii) construction of 15 MGD or 68.1 MLD waste water treatment plant at Delhi Gate drain, (iii) construction of 7 decentralised waste water treatment plant in Najafgarh Zone, (iv) laying of sewer lines in unauthorised colonies and (v) rehabilitation of 3 peripheral sewer lines (PIB, 2018). The projects under YAP-III, include creation of 564 MLD STP capacity at Okhla, rehabilitation and upgradation of 386 MLD STP capacity, rehabilitation of trunk sewer and rising main of 35 km length in Kondli and Rithala zones. Delhi has 28 approved industrial areas (Planned Industrial Areas) and 22 redevelopment areas (Redevelopment of Clusters of Industrial Concentration in Non- Conforming Areas). For the treatment of the wastewater generated from industrial areas in Delhi, 13 Common Effluent Treatment Plants (CETPs) (Department of Law, Justice and Legislative Affairs, GoNCTD, 2000) have been provided with a capacity of 211.8 MLD capacity. For proper operation and maintenance of these CETPs, operators of CETP have been asked to install Online Monitoring System. Besides CETPs, there are about 2,000 Effluent Treatment Plants (ETPs) installed by the individual units operating in Delhi including industries, hotels, restaurants, etc. Delhi Pollution Control Committee (DPCC) monitors the sewage treatment plants of Delhi Jal Board and 13 Common Effluent Treatment Plants (CETPs) and takes action to ensure compliance as per the provision of different legislation. Similar projects of 'STP and sewerage works' have been undertaken in Sonepat, Panipat and Mathura.

While at the face of it, several activities seem to be undertaken, the judicial scrutiny brought into light several deficiencies and one of the most prominent cases before the Hon'ble NGT, was *Manoj Mishra vs. Union of India,* wherein the rejuvenation of Yamuna took a landmark turn with the initiation of the '*Maily se Nirmal Yamuna Revitalization Plan, 2017'*. The matter primarily concerned the significant pollution caused due to encroachment, dumping of debris and waste, and discharge of untreated sewage and trade effluents in Yamuna in the National Capital Territory (NCT) of Delhi, spanning 54 km from Village Palla in the north to Village Jaitpur in the south, forming an inter-state border between Delhi and U.P.

Phase I of the *Maily se Nirmal Yamuna Revitalization Plan, 2017* related to Najafgarh, Delhi, and other supplementary drains, since these causes 63% of pollution in Yamuna. Phase-I also tackled the Delhi Gate drains. The said project was to be completed within 2016. The total cost of the project included costs of new STP, interceptors, and sewerage lines. The NCT Delhi was permitted to recover amount by way of environmental compensation. As part of various steps to clean river Yamuna under Phase-I, the then Ministry of Water Resources (MoWR) sanctioned the STP works in command area of Najafgarh Drain (Dhansa to Keshopur) in Delhi for an estimated amount of Rs. 344.81 crore. Further, Delhi Jal Board (hereinafter 'DJB') submitted projects amounting to Rs. 1,969 crore to be taken up under Phase I of the *Maily Se Nirmal Yamuna Revitalization Plan, 2017*. Projects under Phase I included, (i) rehabilitation of existing waste treatment plant of 182 MLD at Rithala, (ii) rehabilitation of peripheral sewer line of Ashok Vihar and Jahangirpuri, (iii) rehabilitation of 1,100 mm diameter and twin rising mains from Bharat Nagar Sewage Pumping Station to Pitampura Chamber, (iv) construction of 40 MGD (182 MLD) STP and rehabilitation of existing STPs at Coronation Pillar, (v) construction of 9 STPs and related works and (vi) construction of 5 STPs and related works.

Phase-II of '*Maily Se Nirmal Yamuna Revitalization Plan, 2017*, tackled the Shahdara, Barapullah, and other drains. The work under Phase-II entailed trapping/intercepting 10 drains and totally sealing the drains to ensure that there was no leakage from the point of interception/tapping to river Yamuna. It was executed by Delhi Jal Board (DJB) under the supervision of NMCG. DJB was to ensure installation, round-the-clock functioning and continuous power supply, of pumps for lifting sewage/effluents from said drains, so that they functioned to their optimum capacity. The pumps

were also to be operated and maintained without default. The STPs on Delhi Gate drain were to operate in a deficiency-free manner. A net filter was to be fixed at the end of the moat drain (dry drain) to ensure that even during the rainy season, waste did not enter the river through the drain. Drains were to be dredged clean every three months. Phase-II of the project involved interception of the following 6 drains – Shahdara Outfall Drain, Quadsia Bagh and Mori Gate Drain, Barapullah Drain, Maharani Bagh Drain, Kalkaji Drain and Tekhand Drain. Regarding establishment of STP and laying drains, it was to be ensured that no untreated sewage/effluents entered the river Yamuna through these drains. The funding of the six drains was also covered under Government of India's AMRUT (Atal Mission for Rejuvenation and Urban Transformation) scheme. Since, a major part of the work in Phase-II was covered under Japan International Cooperation Agency (JICA) projects, being financed by a foreign agency ensured timely performance of the project with efficiency and stringent norms.

4.7. MEASURES TO REJUVENATE YAMUNA: THE JUDICIAL DIRECTIONS AND IMPLICATIONS

The National Green Tribunal *inter alia* on the basis of various scientific, inspection, monitoring, action-taken and status reports, issued significant directions to achieve the outcome of a clean Yamuna *via,* legal mechanisms; operational, organizational and logistical reformations and scientific technologies and systems, to rejuvenate Yamuna. This has been done on the basis of several reports such as Monitoring Committee Reports dated 16.01.2019, 27.05.2019; Supplementary Reports dated 28.06.2019 and 02.07.2019; and further Reports commenting upon compliance status by authorities in Delhi dated 13.08.2019 and States of Haryana and U.P. dated 20.08.2019.

4.7.1. Biodiversity Parks

The Tribunal directed creation of more Biodiversity Parks in Delhi (*Manoj Mishra vs. UoI* Order dated 23.08.2019*)*. Biodiversity Parks are assemblages of species in the form of biotic communities that belong to an ecological range and help promote urban biodiversity conservation as they serve as nature reserves within urban areas (Khurana and Tiwari, 2016). The Yamuna Biodiversity Park, presently spread across the flat alluvial plains of Yamuna (https://dda.org.in/greens/biodiv/yamuna-biodiversitypark.html), seeks to conserve and preserve the ecosystems of river Yamuna through focusing on keystone species, threatened plant and animal species, and biodiversity likely to be converted into urban infrastructure; establishing field gene banks serving as gene pool for threatened land races and wild genetic resources; acting as repositories of indigenous native communities of Yamuna River Basin particularly of the Delhi region; developing mosaic of wetlands that sustain the rich aquatic flora and fauna of the Yamuna and monitoring the short- and long-term changes in the ecology of the Delhi region. These Biodiversity Parks reduce environmental pollution by acting as sinks for capturing CO_2 and other pollutants. They provide ideal alternative habitats for migratory and resident bird species (Harjani, 2013), enhance groundwater recharge, augment freshwater availability, ameliorate local weather conditions and buffer ambient temperatures represent unique ecological models possessing wildlife and natural values and promote eco-tourism and social connectivity across the urban community.

4.7.2. Preserving Floodplains

The Hon'ble Tribunal directed preservation and restoration of floodplains to enable performance of their critical ecological functions like facilitating the self-cleansing ability of the rivers, recharge of aquifers, and providing habitat to large number of riparian plants and animals (NGT, 2017). 'Floodplain' means such area of River Ganga or its tributaries such as River Yamuna which comes under water on either side of it due to floods corresponding to its greatest flow or with a flood of frequency once in hundred years (MoWR, RD and GR, 2016). The lack of protection of river floodplains from encroachment and diversion for 'developmental projects' is damaging. The river

suffers as it is unable to occupy and transport flood waters downstream during high rainfall. It is unable to recharge aquifers, wet the lands along its banks, or provide life-sustaining conditions to plant and animal habitats along the river margins and banks. It cannot also cut and deposit soil on its banks in a natural fashion or maintain its oxbow and floodplain wetlands (Bhaduri, 2018). The Delhi Development Authority and similar authorities need to undertake the task of physical demarcation of the entire Yamuna floodplain and must ban any construction activity; edible crop cultivation; dumping of any kind of construction debris, *malba* and material; throwing of *pooja* material or any kind of material except at designated sites, in the demarcated floodplain and areas in and around River Yamuna. Floodplains under illegal and unauthorized possession are to be repossessed. It is also important that the plan for floodplain delineates the area through proper mapping on the ground and that the area is secured (Down to Earth, 2018). Restricted activities pertaining to floriculture and silviculture should only be allowed. To keep a vigil on any violations, CCTVs should be installed in order to keep the area secure from further encroachments and fine must be imposed on violators as a deterrent measure.

4.7.3. Formation of Wetlands

The Hon'ble Tribunal has also directed the formation of wetlands which can facilitate biological cleaning of wastewater before it can enter and pollute the river (NGT, 2017). As per the Wetlands (Conservation and Management) Rules, 2017, 'Wetland' means an area of marsh, fen, peatland or water; whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres, but does not include river channels, paddy fields, human-made water bodies/tanks specifically constructed for drinking water purposes and structures specifically constructed for aquaculture, salt production, recreation and irrigation purposes (MoEF&CC, 2017). For the purposes of Yamuna rejuvenation and pollution abatement, definition of wetland will include those constructed on floodplains. More number of wetlands need to be constructed and developed, and ameliorative measures such as deepening and enlargement are to be undertaken for already existing wetlands. Notably, the CSIR-NEERI's Phytorid wastewater treatment technology involves a constructed wetland exclusively designed for the treatment of municipal, urban, agricultural and industrial wastewater. In this technique plants like elephant grass (*Pennisetum purpurem*), cat tails (*Typha* sp.), reeds (*Phragmites* sp.), *Canna* sp. and yellow flag iris (*Iris pseudocorus*), which normally occur in natural wetlands and have filtration and treatment capability, are planted. Some ornamental as well as flowering plant species such as bamboo, nerium, colocasia, etc. can also be used (Akhade, 2019).

4.7.4. Prevention of Dumping of Debris

The Hon'ble Tribunal also directed dumping of debris to be stopped and monitored by installing an electronic surveillance system (NGT, 2017). Aerial mapping can be used to track debris. Also, check-posts should be set up to track the transportation of debris. Dredging and desilting of the Yamuna which involves removal of sediments and debris should be done in a controlled fashion. Other remedial measures that can be undertaken include, prevention of any waste dumping, rectification of operation deficiencies, sealing borewells by authorities, forward planning with keeping future population growth in mind, better town planning, system for project monitoring, professional management inputs and setting up more water quality monitoring stations.

4.7.5. Setting up of Sewage Treatment Plants

The Hon'ble Tribunal recognized the need for setting up of new STPs to bridge the gap between the amount of sewage that is generated and the amount that is treated (NGT, 2017), in line with the Sewer Master Plan 2031, albeit decentralized (DJB, 2014). Many existing STPs are not meeting norms and are functioning on outdated parameters. Such STPs must be improved and upgraded based

on their influent characteristics, in order to function on up- to-date parameters. An end must be put to delay in installation of STPs. But it must be specifically ensured that new STPs should be installed only at areas without non-sewerage facility, while in areas with sewerage facilities, the existing STPs should be upgraded. A mechanism must be devised for addressing issue of treatment of sewage unauthorized colonies pending installation of sewer network. A Standard Operating Procedure for STPs must be formulated for their efficient operation. The efficacy of all STPs should be checked periodically by reputed independent agencies, so that, design and operational deficiencies are rectified. Lastly, Delhi Jal Board and park-owning societies must mandatorily use treated water from STPs for all parks within a 5-km radius of STPs.

4.7.6. Regular Cleaning of Drains

The Hon'ble Tribunal directed (NGT, 2017) that drains should be regularly cleaned, maintained, tapped and repaired. The capacity of outfall drain should be enhanced, and a separate outlet should be provided for the outfall drain. Interception of sewage by using interceptors and diversion of drains is imperative to ensure that no pollutant is discharged into the river or drains. An effective mechanism remains to be evolved for stopping solid waste from going into the Yamuna or its drains. Arrangements should be in place to ensure that Storm Water Drains do not carry any discharge during dry weather after diversion of sewage, and that no sewage should find their way from sewered areas into the storm water drain. There needs to be a stop to discharging effluents into storm water drains. All discharge going into these drains must be plugged.

4.7.7. Setting up Sewage Networks for Unauthorized Colonies

The NGT has also directed for setting up sewerage network for unauthorized colonies. The need for sewer lines and drains must be forecast and attended to in advance to lay down the required sewer lines and drains (Ministry of Law, 1957). There are other related laws too such as Delhi Municipal Corporation Act, 1957; Haryana Municipal Act, 1973; Haryana Municipal Corporation Act, 1994; Himachal Pradesh Municipal Corporation Act, 1994; Himachal Pradesh Municipal Act, 1994; Rajasthan Municipalities Act, 1959, Rajasthan Water Supply and Sewerage Corporation Act, 1979; Uttar Pradesh Municipalities Act, 1916, Uttar Pradesh Municipal Corporation Act, 1959 and Uttar Pradesh Water Supply and Sewerage Act, 1975.

The sewer network must be expanded. Authorities must take policy measures and forceful steps to compel households in sewered areas to take household connections. User charges must be levied, and charge must be levied upfront for sewage collection and treatment. It is imperative to envisage a policy to give free or extremely cheap sewer connections. Trunk sewer must be functioning, and sewer connection must be provided in colonies wherever required. Quantum of sewage generation must be assessed and taken stock of. The completion of all sewage projects must be completed within strict timelines, to avoid unnecessary delay. Sources of sewage must be identified and plugged immediately. Interceptor sewer, also known as an interceptor, is a component of a sewer network that helps to control its flow. It receives the flow from trunk sewer lines and, sometimes, from storm water runoff and directs it to the wastewater treatment plant. It is among the larger lines of a sewer system. Interceptor sewers to be used for tapping is seen by the government as a solution to the problem of untreated water reaching the Yamuna (Suresh Babu, 2015). The intercepted sewage must be treated. Several unauthorized colonies are a major source of sewage. Therefore, it is necessary that there be tapping or laying of sewer lines in unauthorized colonies. The ground reality is that many sewers are punctured and are sending sewage to storm drains, as has been identified by the Delhi Jal Board (Gosain, 2014). Such punctured sewers must be repaired. Sewage should be diverted by the Line Department from both, approved and unapproved areas, to the CETPs. The diverted sewage is to subsequently be treated. The sewage and wastewater generated should be disposed of only after treatment.

4.7.8. Setting up of Effluent Treatment Plants

A critical assessment of treatment facilities needs to be undertaken so that untreated effluent is not discharged into Yamuna. A check must be kept on the criminal offence of pollution of river or water bodies by setting up properly functioning effluent treatment plants (ETPs), common effluent treatment plants (CETPs), and sewage treatment plants (STPs) which effectuate 100% treatment of sewage generated. Further, the NGT directed improvement of CETPs, and for a separate sewer for carrying industrial effluents to CETPs. The primary objective of the conveyance system through sewers/pipelines is to protect the sewer/pipeline from corrosion, silting/choking and explosion, besides ensuring the compliance of pre-treatment standard for discharge of effluents (CPCB, 2001). If pipelines laying is pending, then treated water should be transported through tankers. Along with setting up CETPs, they must be regularly monitored by using online monitoring devices (OMDs), especially in industries. There must be periodic calibration of these devices to validate sensor results with lab results, for accuracy purposes. Utilization of treated wastewater from CETPs should be maximized in order to achieve zero liquid discharge and reduce dependence of green belts/parks around the CETPs on groundwater.

4.7.9. Interceptor Sewage Project

The Interceptor Sewerage Project (ISP) covers hundreds of smaller drains left out of the original plan, so that the smaller drains can be tapped in packages and the sewage from said drains can be carried to treatment plants. With increase in new settlements and damage to original sewer lines, the number of left-out drains has increased and without this project, Yamuna would have remained dirty. The idea behind the project is that rather than laying a massive network of new expanded. Authorities must take policy measures and forceful steps to compel households in sewered areas to take household connections. User charges must be levied, and charge must be levied upfront lines, a trunk sewer line running along the large drains will be able to intercept the smaller sewers from unauthorized settlements, block them from meeting the main drains, and keep the filth out of Yamuna (ToI, 2018). It is to be noted that the plains are linked to ISP and sewage treatment plant is linked to commissioning of ISP and connected STPs. The interceptor project is projected by the Delhi Jal Board (DJB) as a panacea to the pollution problems of River Yamuna. Laying of interceptor sewers is just one part of the whole project. There are other components including augmentation of existing capacity of STPs, rehabilitation of major trunk sewers to intercept drains out falling into Yamuna, and most importantly construction of sewage treatment plants after achieving full utilization of existing ones. These are parallel and mandatory efforts required making interceptors work (CSE, 2009).

4.7.10. Undertaking New Sewage and Wastewater Treatment Technologies

The National River Conservation Directorate has laid down several sewage and wastewater treatment technologies, which are, Activated Sludge Process; Trickling Filter or Biofilter; Rotating Biological Contactors (RBCs); Up flow Anaerobic Sludge Blanket (UASB) Process; Waste Water Stabilization Pond Technology; Aerated Lagoons Wastewater Treatment; Oxidation Ponds; Karnal Technology; Controlling Duckweeds; Aerobic Fluidized Bed Reactors (FBRs); Sequential Batch Reactor process; Tertiary or Advanced Wastewater Treatment and Chrome Recovery System (Tare and Bose, 2009).

4.7.11. Implementation of Septage Management Regulations

The Septage Management Regulations (GoNCT Delhi, 2018) must be implemented, for the purpose of regulating the collection, transportation, and disposal of waste of septic tanks (septage). Under the Regulations, ‘septage’ means faecal sludge produced in septic tanks. ‘septic tanks’ are defined as an underground tank that treats wastewater by a combination of solids settling and anaerobic digestion, and the effluents may be discharged into soak pits or small bore-sewers and the solids have to be

pumped periodically. ‘Sewers’ mean conduits provided for the purposes of carrying the liquid wastes of the community, otherwise known as sewage or sludge. ‘Sludge’ means the settled solid matter in semi-solid conditions which is usually a mixture of solids and waster deposited at the bottom of the septic tank, ponds, etc. The term sewage-sludge is generally used to describe residuals from centralized wastewater treatment while the term septage is used to describe residual from the septic tank.

The National Policy on Fecal Sludge and Septage Management (FSSM) (MUD, 2017), provides state-level guidelines, framework, objective, timelines and implementation plan to address septage management and sets a sanitation benchmark framework which must be adhered to. The National FSSM Policy is required to be modified and tweaked based on established guidelines to suit local conditions. Since in some drains, the catchment area includes both sewered as well as un-sewered areas, a two-pronged strategy is more suited, wherein one is for the sewered areas where leakages in the sewer network need to be fixed and the other is for unsewered areas where sewer network combined with septage management tools need to be planned. An institutional mechanism should be established for monitoring the collection, transportation and disposal of septic tank waste.

4.7.12. Bioremediation

In-situ bioremediation is the application of a biological treatment to clean up hazardous compounds present in the environment. The optimization and control of microbial transformations of organic contaminants require the integration of many scientific and engineering disciplines (Das and Dash, 2014). Phytoremediation is defined by UNEP as the use of living green plants for *in-situ* removal, degradation and containment of contaminants in soils, surface waters and groundwater (UNEP, 2002).

4.7.13. Maintaining E-Flow

‘Environmental flows (E-flows)’ are the acceptable flow regimes that are required to maintain a river in the desired environmental state or predetermined state. This would go a long way in ensuring the river’s *aviralata* or continuous flow. This means that the river will have at least the minimum environmental flow of water even after the river flow gets diverted by projects and structures for purposes like irrigation, hydropower, domestic, industrial use, etc. (MoWR, RD and GR, 2018). The current regime of Environmental flows needs to be augmented especially in lean seasons by way of coordination amongst member states stakeholders. Off-shallow reservoirs are to be created along the floodplains of River Yamuna.

4.7.14. Accountability in Authorities

Accountability and responsibility on the part of concerned authorities and agencies is vital for implementing the mandate of creation of artificial ponds on the occasion of religious festivals for immersion of idols. As per the ‘Public Trust Doctrine’, it is not only a legal but also a constitutional obligation of the state government and agencies to protect the water bodies from getting polluted (*M.C. Mehta vs. Kamal Nath & Ors., 1996* –SCC (1) 388). Furthermore, accountability can be bolstered through monthly review reports, stock-taking, logging individual failures and successes, carrying out proper studies, constant reporting on water quality of river, conducting survey and monitoring of industries in conforming and non-conforming areas and keeping an inventory and recording the pollution load at entry and exit point of each concerned state. Nodal officers are to be identified for different projects who are to be assigned specific responsibilities.

4.7.15. Closure of Polluting Industries

Closure action against water polluting industries under Section 33A of the Water Act must be taken which lays down the power to give directions with regard to the closure, prohibition, or regulation of

any industry, operation or process, or the stoppage or regulation of supply of electricity, water or any other service. The 'Polluter Pays Principle' requires that a polluter bear the remedial or clean-up costs as well as the amounts payable to compensate the victims of pollution (*Indian Council for Enviro-Legal Action vs. Union of India, 1996* - AIR 1446, 1996 SCC (3) 212). Environmental compensation for restoration and rejuvenation should be recovered from every household generating sewage, based upon the 'Polluter Pays Principle'. More stringent timelines for action with flexibility and due accountability for failure by way of departmental action and monetary compensation are to be ascertained.

4.8. FORESTRY INTERVENTIONS FOR REJUVENATING YAMUNA

It is observed that the present strategy for rejuvenating River Yamuna has not succeeded in its entirety and is largely limited only to tackling pollution load from domestic wastewater and regulation of industrial pollution. This can be remedied by adopting a rounded and all-inclusive forestry intervention approach, wherein water management and environment management are taken together to restore the lost ecology of the polluted stretches of the rivers (Aggarwal, 2018). Forests on a scientific basis are a *sine qua non* for river states.

Forestry/terrestrial ecosystems which include forests, grasslands, swamps, mangroves, etc. have a symbiotic relationship with the riverine/riparian ecosystem (Mertes *et al.,* 1995) and can be used for the wholesome rejuvenation of Yamuna through forestry interventions. Key components of forestry intervention are afforestation (flora and fauna) (OA 405/2019 of MoWR, RD & GR, 2017) activities in the catchment area which add to the water-retaining and water-infiltration capacity in the catchment area of Yamuna, afforestation in natural, agricultural, and urban landscapes by way of diverse plantations in the states of Yamuna riverscape, soil and water conservation, developing eco-parks along Yamuna banks to ensure unhindered and clear flow of water, riparian, wildlife and wetland management, nursery preparations, industrial plantation, avenue plantation, riverfront development, landscape activities and mass public awareness and outreach activities such as tree-planting campaigns. Forests and large-scale vegetation are to be planted in headwater areas and along the course of Yamuna to help enrich the aqua life of the river (PIB, 2016), prevent soil erosion, recharge water and increase groundwater level. There must be bio-diversity conservation of aquatic life and wetlands.

There is a paradigm shift in river rejuvenation by bringing in a multi-dimensional and multi-stakeholder approach, which entails a multi-sectoral and multi-afforestation drive on each side of the course of River Yamuna (PIB, 2018). This drive comprises maintaining vegetative cover on both the sides of River Yamuna and its tributaries (2030 Water Resources Group and Government of Uttar Pradesh, 2016) through plantation. It is widely accepted that the availability and quality of river are influenced by the efficacy of governmental departments – especially state forest departments and state water departments – and the location and condition of forests volunteer organizations and civil society organizations, both in the up- and down-stream areas of the river. The massive impact of forestry interventions can be through increased recharge of aquifers, reduced erosion and river basin management, as part of holistic improvement in the health of the river ecosystem.

Some examples of actions at the ground level are worth citing here. The village of Ufrenkhal in Pauri Garhwal (Uttarakhand) has grown its own forest and rebirthed a river – Gad Ganga. The plan involved planting trees around percolation pits. The pits and the trees developed a mutually beneficial relationship which rejuvenated an entire system. In Tamil Nadu, the increased tree cover has cut down rainwater run-off drastically as the soil absorbs more water now. And seasonal streams flow more slowly and steadily, lasting longer after the monsoon has ended, making it easier for more trees to survive. Experts have recommended maintaining a buffer zone of trees to ensure the Ganga's waterflow. Agricultural fields on both sides of the river add to the silt in the river. But the tree line on the banks helps in further release of water into the river. The precipitation process of trees triggers this release. Trees soak moisture which gets accumulated over a period. Forests can

give rise to a river, as happened in case of Godavari which emanates from a forest area and not from a glacier' [https://isha.sadhguru.org/rally-for-rivers/case-studies-initiatives/]. For instance, the Katha River Eco-Restoration Programme (2016-21) undertaken to revive Katha River, a tributary of Yamuna which originates in Saharanpur district and merges with Yamuna near Ramra village, Shamli district, Uttar Pradesh involves rainwater harvesting, thereby, recharging both surface and ground water, biodiversity restoration, lotus lake ecosystem development along with village tourism', interventions by way of afforestation, habitat management. Savita and Singh (2018) suggested that catchment treatment, soil and moisture conservation, restoration of riparian forest buffers and improved livelihood of forest dwellers and forest dependent communities, along with providing alternate income-generating activities such as eco-tourism should be part of a holistic approach.

The specific approach to carry out river rejuvenation through forestry interventions involves (1) identification and prioritization of critical areas/villages (land availability), (2) identification of possibilities for regeneration/improvement of forest catchment areas and its treatment through appropriate native local species for augmenting water flow, (3) involving stakeholders like local communities, fishing community, industries, NGOs, scientists, research institute for participation, (4) planning treatment activities through bio-filtering, bio- remediation and development of artificial wetlands for treatment of waste water, (5) plantation of medicinal plants and other appropriate species in upper reaches of Yamuna and (6) examining the possibility of eco-tourism and other income generation alternatives for the selected areas (Savita, 2018).

The primary indicators of having successfully achieved the objective of 'forest for water' would be when one begins to see cleaner rivers (Subramani, 2018). This can be done by increasing catchments in the forest to ensure flow of water to the rivers is increased. Water received by forests results in (1) recharge of ground water, (2) flow below the surface which emerges as a spring and (3) flow above the ground which goes to the streams and rivers (Gupta, 2019).

4.9. ROAD AHEAD

The problem of severe pollution and degradation in Yamuna has assumed considerable importance and urgency in recent years. Despite significant executive and judicial interventions, including point-wise measures to be undertaken by designated authorities, it is seen from the foregoing analysis that the efforts thus far have been restricted to only tackling pollution load largely from domestic wastewater and regulation of industrial pollution. It is seen that the immediate remedial steps require expansion and the inclusion of forestry and other interventions in order to tackle the issue of rejuvenation of Yamuna in a wholesome manner. An intervention in the National Green Tribunal through the case of *Gopal Chandra Sinha vs. Union of India, 2019*, initiated by a retired Forest Officer becomes significant in this regard wherein river restoration especially in forest areas as a measure of forestry intervention through desilting and maintaining the environmental flow of rivers passing the forest areas is under some legal confusion whether such activities would be qualified as forestry intervention or not. It is the plea of the applicant that eco-restoration in forest areas, even if it involves de-silting and deepening of rivers, would qualify as a forestry activity and is not violative of the Forest Conservation Act, 1980. The legal position will be clear once the above case is decided but it has a huge implication on eco-restoration of rivers through forestry interventions.

4.10. INSTITUTIONAL FRAMEWORK

4.10.1. Institutions and Implementing Agencies - Central and State Governments

Chapter 1 and 2 of this DPR have given detailed insight on the government and non-government agencies at the central and state levels besides civil society and other stakeholders that are associated with the disciplines of water resources, river development, forestry, wildlife environment and river Yamuna and its rejuvenation. Predominantly, at national level, the

Ministry of Jal Shakti and the Ministry of Environment, Forest and Climate Change are directly concerned with river Yamuna, its environment and rejuvenation. Details of the Jal Shakti Ministry, its mandate, programmes and activities (CWC, YAP, NMCG) have been touched upon in earlier chapters of this DPR. More details of the MoEF&CC, NAEB, ICFRE, FRI and state forest departments from the perspective of proposed forestry interventions as implementing agencies are detailed here while also elaborating the likely role of civil society in the implementation of present DPR. However, before discussion on the agencies within MoEF&CC, an account is given here about institutional arrangement of agencies that are dedicated to water resources *per se*.

4.10.2. Ministry of Jal Shakti

At the national level, the Ministry of Jal Shakti, Department of Water Resources, River Development and Ganga Rejuvenation is recognized as the nodal agency for water resources, Under which are several technical agencies, such as the Central Water Commission to manage surface water, the Central Groundwater Board (CGWB) on ground water resource and the National Water Development Agency (NWDA) in assessing inter-basin transfer options. Other agencies linked are the Indian National Committee for Irrigation and Drainage, the Indian Water Resources Society, Water and Land Management Institute, Central Water and Power Research Station (CWPRS), National Institute of Hydrology, Indian Council for Agricultural Research (ICAR) and others. In addition, there are agencies that are involved in various aspects of river basin management, through wasteland development, promoting drinking water and sanitation, agricultural development, pollution control and others. NITI Aayog (earlier known as Planning Commission) at the national level provides project clearance and approves financial allocation to various water (irrigation/ hydropower/ multipurpose) projects in different states (Raju and Taron, 2019). However, given that 'water resources' is a state subject under the constitution, the actual legislative and managerial responsibilities are with the public works, irrigation or water resources departments at the state level. There are also important organizational arrangements to achieve inter-state and centre-state coordination (Chapter 1, para 1.12.3). These include various river boards created under the River Boards Act of 1956 and the National Water Resources Council (NWRC) set up in 1983 and the National Water Board (NWB) established in 1990.

River Basin Organizations

River Basin Organizations (RBOs) are designed to help bring about Integrated Water Resources Management (IWRM) and improve water governance in trans-boundary water basins. These organizations are becoming increasingly significant in all regions of the world. Historically, shared rivers were governed through treaties at the international level, or interagency compacts at local or state levels. Today, river basin organizations constitute a fast-growing alternative. The International Network of Basin Organizations (INBO) currently has 133 member organizations in 50 countries, excluding RBOs at the local and state levels.

River Basin Organizations in India are either headed by the Ministry of Jal Shakti or Power or a Chairman appointed by the GoI (who may be a chief engineer of that particular basin or in certain cases may be the Chairman of the Central Water Commission). The Upper Yamuna River Board was established in the year 1994, details abouts purpose, structure and functios are given in Table 4.1. Few water users or water-using sector are generally represented on these boards. The majority of the Boards are single-tier consisting of the board members headed by a Chairman (Raju and Taron, 2019).

Central Water Commission

Central Water Commission (CWC) is a premier technical organization of the country in the field of water resources and it functions 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 responsible for initiating, coordinating and furthering consultation on 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. It also undertakes the investigations, construction and execution of such schemes. CWC is headed by a Chairman, with the status of Ex-Officio Secretary to the Government of India. The work of the Commission is divided among 3 wings namely, Designs and Research (D&R) Wing, River Management (RM) Wing and Water Planning and Projects (WP&P) Wing.

Table 4.1. Details of Upper Yamuna River Board

Purpose of origin		**Organizational structure**		**Function**		
Legal	**Policy**	**Tier**	**Board**	**Comprehensive plan for Basin management**	**Data generation and dissemination**	**Other**
MoU signed by the Chief Ministers of the riparian states (HP, Haryana, UP, Rajasthan and Delhi)	Allocation of utilizable surface water flow	Single	Board constituting of eleven members headed by Chairman of CWC and comprising of engineers (10) and one hydrogeologist	Planning for catchment area and watershed management, rehabilitation and conservation of environment	Submission of annual reports to the Central and the riparian states	Maintenance of ecological considerations and monitoring groundwater exploitation

(***Source:*** Upper Yamuna River Board)

Central Ground Water Board

Central Ground Water Board (CGWB), a subordinate office of the Ministry of Jal Shakti, Department of Water Resources, Government of India, is the National Apex Agency entrusted with the responsibilities of providing scientific inputs for management, exploration, monitoring, assessment, augmentation and regulation of ground water resources of the country. Major activities being taken up by Central Ground Water Board include macro/micro-level ground water management studies, exploratory drilling programme, monitoring of ground water levels and water quality through a network of ground water observation wells comprising both large diameter open wells and purpose-built bore/tube wells (piezometers), implementation of demonstrative schemes for artificial recharge and rainwater harvesting for recharge augmentation. Periodic assessment of replenishable ground water resources of the country is carried out by the Board jointly with the concerned State Government agencies. Geophysical studies, remote sensing/ GIS studies and ground water modelling are undertaken to supplement these activities. The Board also takes up special studies on various aspects of ground water sector such as ground water depletion, sea water ingress, ground water contamination, conjunctive use of surface, ground water, water balance, etc.

4.10.3. Ministry of Environment, Forest and Climate Change

The Ministry of Environment, Forest and Climate Change (MoEF&CC) is the apex nodal agency in the administrative structure of the Central Government for the planning, promotion, co-ordination and overseeing the implementation of country's environmental and forestry policies and programmes.

The primary tasks of the Ministry are implementation of policies and programmes relating to conservation of the country's natural resources including its water-bodies (lakes and rivers), its rich biodiversity, forests and wildlife, ensuring the welfare of animals, and the prevention and abatement of all kinds of pollution. The Ministry is guided by the principle of sustainable development and

enhancement of human well-being, while implementing these policies and programmes. The subjects of forests, wildlife and environment are in the Concurrent List as per the Constitution of India.

Afforestation and Eco-Development Board

The National Afforestation and Eco-Development Board (NAEB), set up in August 1992, is responsible for promoting afforestation, tree planting, ecological restoration and eco-development activities in the country, with special emphasis on 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 Ghats, Western Himalayas, Aravallis, etc. The detailed role and functions of the NAEB are:

1. Evolve mechanisms for ecological restoration of degraded forest areas and adjoining lands.
2. Restoration of the forest covers in the country through natural regeneration or appropriate forestry intervention, for ecological security and to meet the fuel wood, fodder and other needs of the rural communities.
3. Sponsor research and extension of research findings to disseminate new and advanced technologies for the regeneration and development of degraded forest areas and adjoining lands.
4. Create general awareness and help foster people's movement for promoting afforestation and eco-development with the assistance of voluntary agencies, non-government organisations, *Panchayati Raj* institutions and promote participatory and sustainable management of degraded forest areas and adjoining areas.
5. Coordination and monitoring of the action plans for tree planting, afforestation, ecological restoration and eco-development.

National River Conservation Directorate

Under Ministry of Environment, Forest and Climate Change, National River Conservation Directorate (NRCD) is implementing the centrally sponsored schemes of National River Conservation Plan (NRCP) and National Plan for Conservation of Aquatic Eco-systems' (NPCA) for conservation of rivers, lakes and wetlands in the country. NRCD is only providing financial assistance under the National River Conservation Plan to the state governments/ local bodies to set up infrastructure for pollution abatement of rivers in identified polluted river stretches based on proposals received from the state governments/ local bodies. NRCP has also been identified as one of the four core centrally sponsored schemes (CSS) of the ministry approved by the Cabinet (www.india.gov.in/information-national-river). The objective of NRCP is to improve the water quality of the rivers, which are the major water sources in the country, through the implementation of pollution abatement works (nrcd.nic.in).

The task of preparing the DPRs on Rejuvenation of major Indian rivers through forestry interventions has been assigned to ICFRE by NAEB and it will have a crucial role during the implementation phase of these DPRs.

Indian Council of Forestry Research and Education

In 1986 the Indian Council of Forestry Research and Education (ICFRE) was formed as an umbrella organisation for catering to the forestry research, education and extension needs of the country. On 1st June 1991, the ICFRE was declared an autonomous Council under MoEF&CC.

ICFRE with its Headquarters at Dehradun is an apex body in the national forestry research system that promotes and undertakes need based forestry research and extension. It is dedicated to its mission of generating, advancing and dissemination of scientific knowledge and technologies for

ecological security, improved productivity, livelihoods enhancement and sustainable use of forest resources through forestry research and education

The Council's vision is to achieve long-term ecological stability, sustainable development and economic security through conservation and scientific management of forest ecosystems. This will be achieved through its pan India presence of 9 Regional Research Institutes and 5 Centres in different bio-geographical regions of the country. Each Institute has a history of its own and under the umbrella of ICFRE are directing and managing research, extension and education in forestry sector in the states under their respective jurisdiction.

Forest Research Institute

Forest Research Institute (FRI), Dehradun has its roots in the erstwhile Imperial Forest Research Institute established in 1906 to organize and lead forestry research in the country. Its history is synonymous with the evolution and development of scientific forestry not only in India but in the entire Indian subcontinent. The institute also administered training to forest officers and forest rangers in the country and after independence, it was aptly named as Forest Research Institute and Colleges. In 1988, FRI and its research centres were brought under the administrative umbrella of Indian Council of Forestry Research and Education (ICFRE) under the Ministry of Environment, Forest and Climate Change, Government of India.

FRI is engaged in carrying out research and educational programmes on different aspects of forestry in the jurisdiction states of Uttarakhand, Uttar Pradesh, Punjab, Haryana, Chandigarh and Delhi. FRI has a very strong team of forestry scientists, professionals and skilled technical cadre, supported with modern research infrastructure and library and information centre. The institute has strong linkages with several state forest departments and research institutions and has undertaken collaborative research programmes including forestry interventions. The Institute is also pursuing identified priority areas of research in various research initiatives put forth by MoEF&CC.

State Forest Departments

The state forest department (SFD) in each state is the custodian of forests and wildlife of that state, besides being responsible for management, conservation and protection of the environment (land, water and air). The state forest departments are also responsible for implementation of various policies, strategies and enforcement of law framed/enacted from time to time by the MoEF&CC (FRI, 2016).

From exploitation to conservation, policing and mere silviculture operations to modern technologies like GIS and remote sensing for monitoring – the forest departments have evolved into versatile institutions, geared up to meet the multiple challenges facing environment, rural development, biodiversity conservation, integrated watershed development and management and climate change aimed through community participation. The broad mandate of SFD is:

1. Enhancing the green cover of the country through afforestation/reforestation activities.
2. Restocking the degraded areas through reforestation and regeneration techniques.
3. Forest protection and enforcement of forest laws.
4. Conservation of forests and allied natural resources.
5. Integrated watershed management through effective soil and water conservation measures.
6. Biodiversity and wildlife conservation activities.
7. Sustainable livelihood management in the forest fringe and rural areas.
8. Promotion of eco-tourism activities and urban forestry interventions.
9. Joint Forest Management by actively involving local communities in forest protection and management activities.

Therefore, it is evident that in the present times, the mandate of the forest department has enlarged in scope from just traditional multiple uses to multiple values. These diverse roles cut across various sectors of forest ecology, socio-economy, hydrology, law. Guided by scientific principles and

administrative excellence, these diverse roles can be fulfilled by adopting integrated landscape approach to conservation, effective community participation and ensuring sustainable livelihoods for the forest dwelling communities. In recent times, the focus of SFDs has shifted from small forest stands/coupes to large landscapes including protected areas, managed forests, community/private lands and other lands. Increasingly, SFDs are required to have inter-sectoral convergence so as to meet their goals and multiple objectives (FRI, 2016).

Projects and Schemes Operated by the SFDs

The SFDs have been successfully implementing various afforestation, water conservation, livelihood support projects and schemes aimed at fulfilling their mandates. These schemes can be broadly categorized as Central government, state government funded schemes and Externally Aided Projects (EAPs). The EAPs are usually funded by international agencies like the World Bank, EU, UNDP, GEF, ICIMOD, JBIC, ADB, USAID, etc. The forest departments carry out mega afforestation/reforestation projects under GIM, NFPs, CAMPA, IWDP, Social Forestry, etc. Thus, the SFDs are capable and apt for implementing the activities as envisaged in the present DPR. Activities similar in nature are proposed to be carried out for forestry interventions for the Yamuna at behest of the funding agencies. Since the SFDs also have a well-defined set of cost norms and plantation models, soil and moisture conservation activities specific to the region, the same can be easily adapted for the proposed forestry interventions.

4.10.4. Other Organisations and Groups

Ecological Task Force

The Territorial Army's Ecological Task Force (ETF) was set up in 1982 and is the world's first ecological battalion. They have successfully saved deforested hills from desertification and transformed abandoned mines into lush green forests. ETF was set up to undertake ecological restoration work in terrains rendered difficult due to remote location, severe degradation or risky law-and-order situations. These battalions are raised by the Ministry of Defence and operational expenditure is borne by MoEF&CC. They work in collaboration with SFDs for logistics and technical guidance.

The first battalion of the ETF, commissioned in 1982, carried out afforestation of 2,500 hectares deforested mining area near Mussoorie, Uttarakhand. Since then many battalions of ETF have been raised which have done spectacular work on ecorestotation in Uttarakhand, Rajasthan, Assam, Delhi, Himachal Pradesh, Jammu and Kashmir, Maharashtra, Uttar Pradesh, etc. The 128th Infantry Battalion (TA) Rajputana Rifles developed a lake at Amarapura, near Udaipur which attracts numerous migratory birds; the area has been declared a bird sanctuary. Extensively degraded quartzite quarries – the Bhatti mines in Delhi (NCT) were transformed into verdant forests by the 132nd Infantry Battalion (TA) (Rajput) (Fig. 4.1).

A composite ETF, the Ganga Task Force, has been raised to ensure the protection and cleanliness of the holy river along its entire course. The unit is based in Prayagraj, Uttar Pradesh. The funds have been allocated to the battalion under National Mission for Clean Ganga. The battalion will raise trees, raise awareness among people for cleanliness, patrol sensitive river areas for the protection of biodiversity, check pollution levels and assist in implementing pollution control measures (Pal, 2017).



Fig. 4.1. Bhatti mines, Delhi after reforestation
(*Source:* Project Team**)**

Civil Society/NGOs

Civil society refers to the space for collective action around shared interests, purposes and values, generally distinct from government and commercial for-profit actors. It is also referred to as the 'third sector' of society, distinct from the government and corporate. Civil society includes charities, development NGOs, community groups, SHGs, faith-based organizations, professional associations, social movements, coalitions and advocacy groups. Despite its complexity and heterogeneity, the inclusion of civil society voices is essential to give expression to the marginalised. Civil society actors (Joint Forest Management Committees, *Van Panchayat, Panchayat, Anganwadi* workers, *Nehru Yuva Kendras*, Self-Help Groups, etc.) can enhance the participation of communities in the provision of services and in policy decision-making. Since times immemorial, civil society in India has been playing a significant role by way of development of social institutions at various levels for different purposes such as promotion of cultural and religious values, campaigns against social evils, protection, conservation and worship of nature (forests, trees, animals, rivers and wildlife), sacred groves around religious places and social welfare measures particularly relief operations during natural disasters and other disturbances.

The Yamuna is the largest tributary of the scared Ganga River and similarly holds great religious and sacred significance in the lives of the Indian people. Millions depend on this sacred river for physical and spiritual sustenance and have immense faith in its powers of healing. The river is also connected to the religious beliefs about lord Krishna. Throughout its course of 1,376 km people depend on it for social, ecological and economic benefits. Once the river boasted of its clear blue water but now it has turned into one of the most polluted rivers in India, especially around the capital – New Delhi. Many NGOs, voluntary organizations like *Yamuna Jiye Abhiyan*, We Care, etc. have been implementing the people's advocacy programme '*Clean Yamuna Manch*' on behalf of the civic bodies. Other than public awareness programmes, civic bodies, in collaboration with NGOs, have launched a school health and hygiene project to develop children as change agents in prevention of pollution and cleaning the Yamuna. Apart from Yamuna cleaning projects of the government, several NGOs have also given their sincere contribution to clean it, from time to time. They have worked on the matter of keeping Yamuna safe from the ravages of pollution. There is definitely a role for these organizations in the implementation of the provisions of the DPR,

especially sensitizing the community on abatement of pollution and carrying out institutional plantation drives involving the community.

Nehru Yuva Kendra Sangathan

Nehru Yuva Kendra Sangathan (NYKS, earlier known as *Nehru Yuva Kendra*) was 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. NYKS is an autonomous organization under the Government of India, Ministry of Youth Affairs and Sports, 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, self-help and community participation.

Over the years, NYKS 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 network of youth clubs of NYKS with deep penetration in rural areas can be important partners in implementing the forestry interventions proposed in the DPR and create awareness among the masses about river rejuvenation.

National Service Scheme

National Service Scheme (NSS) is a Scheme of Government of India, Ministry of Youth Affairs and Sports that provides opportunity to the school, college and university students to participate in various community service activities and programmes. This is done by methods such as adoption of villages for intensive development work, carrying out medico-social surveys, setting up of medical centres, programmes of mass immunization, cleaning, afforestation activities, etc. Motivated youth of NSS can be actively engaged in afforestation activities under forestry interventions and also for creation of awareness in the community.

National Cadet Corps

The National Cadet Corps (NCC) is the youth wing of armed forces. It is open to school and college students on voluntary basis. National Cadet Corps is a tri-services organisation, comprising the Army, Naval and Air Wing engaged in grooming the youth of the country into disciplined and patriotic citizens. NCC is a voluntary organisation which recruits cadets from high schools, higher secondary, colleges and Universities all over the country. The cadets are given basic military training and they also participate in environmental programmes. This highly motivated and disciplined cadre of cadets can also be roped in for the various forestry interventions especially institutional ones under the forestry interventions proposed in the DPR.

The foregoing analysis provides an insight concerning legislations, policies and institutions relevant in the context of management and river rejuvenation and proposed forestry interventions aimed at rejuvenation of the Yamuna River. Details on various central and state government organizations including the MoEF&CC, ICFRE, FRI, SFDs, Ecological battalions and civil society have elaborated that most of these organizations are well-mandated to play an active and vital role in the implementation of present DPR.

4.11 YAMUNA RIVER: KEY POLICY AND INSTITUTIONAL ISSUES

4.11.1. Issues

The key issues pertaining to Yamuna Basin have been stated in Chapter 2 (para 2.11 **'**Yamuna River Ecosystem: Major Issues'). The gaps in ongoing activities have been described in Chapter 3 (para 3.3 'Identification of Gaps in Ongoing Activities'. The existing legislative, policy and institutional aspects related to water and forest have been elaborated in the present chapter. The key policy and institutional issues pertaining to other sectors are as follows:

1. Poor infiltration of water into ground in agricultural and urban/peri-urban areas causing water scarcity during non-monsoon periods.
2. Rapid water runoff due to impervious surfaces leading to floods, damage to landscape, soil erosion and siltation in water bodies.
3. Soil erosion caused by disturbance to ground/soil by way of construction, ploughing, mining and other activities.
4. Unsustainable exploitation of surface water in farming and urban areas.
5. Excessive groundwater abstraction resulting in decline in groundwater status.
6. Discharge of industrial chemicals, agricultural pesticides, fertilisers, sewage and other wastes.

4.11.2. Policy Interventions Proposed

The extent of Yamuna basin is 3,66,223 km^2 of which more than 60% area is the cultivable land. About 12.5 % of the land is under forest cover which is mainly distributed in Uttarakhand, Himachal Pradesh and Madhya Pradesh (CPCB, 2006). Forest area has a small contribution to the entire catchment. The condition of river is the resultant of activities taking place over the entire catchment. Forestry sector thus has limited role in the degradation of the river and a limited potential to rejuvenate the river. Agriculture accounts for the largest land use in the catchment. Although some of the cultivable land is not cultivated regularly, about 52 % land is actual cultivated land which is frequently tilled. The soil loosened by ploughing and other cropping operations is prone to soil erosion.

Agriculture sector is greatest user of Yamuna water. Chemical fertilisers and pesticides used in agriculture are largest source of non-point pollution of river water. Agriculture sector thus has a huge share in degradation of Yamuna river and thus has to play a great role in improving quality of water in the river.

About 27.5 per cent area of the Yamuna Basin is non-arable land (CPCB, 2006) under a varied land uses like river and river bed, barren land, community land, roads, railways, public places, mines, industries, water bodies, etc. while 2.9 per cent area is under use for habitation of human population. These areas are also under intensive use and lead to degradation of the river. It seems very difficult to address the problems of the river without active involvement of the other related sectors.

It is, therefore, recommended that other sectors should also undertake time-bound steps towards the goal of Yamuna rejuvenation in coordination with forestry sector. A plausible way to achieve active involvement of other related sectors towards this goal would be to request them to prepare and implement their sectoral plans in tandem with DPR relying on forestry interventions.
An indicative list of activities that can be undertaken by sectors other than the forestry sector, is given hereunder:

Agriculture and Rural Development

1. Promotion of more efficient utilisation of irrigation water, contour bunding of crop field, adopting water-efficient cropping patterns and cultural practices, agroforestry, organic farming, in-situ moisture conservation, digging of ponds.
2. Reduction in use of cropping systems with high requirement of water, fertilisers, pesticides, etc.

Highways, Roads and Railways

1. Promotion of safe disposal of excavated earth during road /railway line construction, stabilization of slopes exposed during construction, proper channelization of water along roads and railways hilly areas to minimize soil erosion.
2. Reduction in construction activities of roads and railways, especially in hilly and forest landscapes and places with loose soil.

Urban Development and Public Works

1. Encouraging rainwater harvesting, planting of grass, shrubs and trees in private and public places, stabilization of soil in erosion-prone areas, removal of encroachment, collection of flowing water in ponds and other structures.
2. Minimising the discharge of sewage in water bodies, abstraction of ground water, overuse and wastage of water, disposal of plastic, domestic waste, religious offerings in water, use of cement concrete for laying paths, pavements and flooring of parks and lawns.

Industries

1. Promoting green technologies, recycling of water.
2. Checking discharge of effluents and hot water into water bodies, excessive abstraction of ground water, etc.

Rivers, Water Bodies and Ground Water

1. Promoting riverbank/canal-side protection/stabilization, removal of encroachment, planting on flood plain, decelerating water flowing in streams, storage of water in natural and artificial reservoirs, releasing water in rivers to maintain environmental flow, cleaning of weeds, waste and dissolved chemicals from water.
2. Discouraging excessive fishing, structures or schedules that disturb continuous flow of water.

Mining and Quarrying

1. Promoting scientific mining practices and ecorestoration of mined areas.
2. Checking mining and quarrying in river beds and erosion prone areas and contamination of water from mined material.

Other sectors

There might be few other sectors too that may have role in addressing issues related to climate change, encroachment of land near rivers, etc. which have direct and indirect effects on Yamuna and its tributaries.

It is to be emphasized here that the activities mentioned above are indicative steps that may be taken by other related sectors. To some extent, steps have been taken by some sectors, but these will have to be augmented till the goal of river rejuvenated is achieved. A comprehensive list of activities may be worked out by the concerned sectors through discussion with experts and stakeholders. New policies would have to mainstream the water and river conservation objectives and would need to be supported by suitable institutional adaptation.

Chapter 5

FORESTRY INTERVENTIONS - THE OBJECTIVES AND STRATEGIES

5.1. THE YAMUNA RIVER ECOSYSTEM: KEY ISSUES FOR FORESTRY SECTOR

The key issues pertaining to Yamuna basin have been stated in Chapter 2 (para 2.11. Yamuna River Ecosystem: Major Issues). The gaps in ongoing activities have been described in Chapter 3 (para 3.3 Identification of Gaps in Ongoing Activities). The policy interventions have been proposed in Chapter 4 (para 4.11.1. Policy Interventions Proposed). The policy interventions relate to participation of other related sectors for carrying out non-forestry interventions. Forestry sector has to play a significant role in promoting ecological flow and reducing sedment load in the rover water. The present chapter contains the state-wise forestry interventions proposed in this DPR for rejuvenation of Yamuna River.

The major river water-related concerns from point of view of the forestry sector are:

a) Declining environmental flow and
b) high sedimentation load in river water.

These are, in turn, related to the following issues:

i) Forest degradation and landuse change.
j) Open and barren catchments/river banks.
k) Soil erosion in forest areas and sediment load in river water.
l) Presence of invasive weeds and their expansion into adjacent areas.
m) Biodiversity concerns.
n) Trees outside forest.
o) Livelihood issues and generation of industry-level surplus.
p) Awareness generation.

Accordingly, strategies have been worked out.

5.2. KEY THRUST AREAS

The catchment degradation, especially the loss of vegetation cover coupled with terrace cultivation and road construction, contributes to the alteration of the hydrological regimes as well as the degradation of habitats. Catchment degradation is also responsible for excessive soil erosion and high sediment load in river water. A major thrust of the DPR is on improving forest cover. Selection of plant species and their planting design (model) are based on the site conditions. It is expected that besides improving the vegetation cover in the basin, it will also check the soil erosion, reduce siltation and water run-off in the upstream and improve percolation and ground water regime and enhance water quality down-stream.

The large expanse of forest land in Yamuna basin has huge potential for improving ground water regime. This can be achieved by tapping rainwater through *in-situ* moisture conservation measures. *In-situ* moisture conservation would enhance moisture availability in the treated site and downstream areas and rejuvenate the entire ecosystem, thereby, encouraging regeneration of native vegetation, enhancing productivity of the forest, sustaining wildlife and augmenting water-related contribution from the forest indirectly as well. The *in-situ* moisture conservation measures are cheap and they have immediate and definite beneficial effect on water. Soil and moisture conservation measures have received adequate attention in the DPR.

The areas proposed for treatment under the DPR include forest lands (natural landscape), agricultural lands (agricultural landscape) and other lands (urban and peri-urban landscape) present in the riverscape, as was done in DPR on Ganga (FRI, 2016). The riverscape is 5 km strip of land on both sides of Yamuna and 2 km strip of land on both sides of important tributaries (outside the flood zone) in Haryana, Uttar Pradesh, Rajasthan and Madhya Pradesh. Areas extending beyond this width

have also been included in the riverscape where locality condition suggested need for forestry interventions, as judged by field functionaries of the SFDs. Forest areas outside the flood zone of Yamuna extending to the eastern side of Aravalli ridge constituted the riverscape in Delhi NCT. In Uttarakhand and Himachal Pradesh the entire catchment of Yamuna has been treated as riverscape. Tree plantation activities have been proposed in all the three landscapes. Conservation interventions such as *in-situ* soil and moisture conservation, wetland management and riparian wildlife management have been proposed in the natural landscape.

Provision has also been made for supporting activities such as awareness generation, capacity building, nursery improvement, fire protection, development of value-chain of forest produce, monitoring and evaluation, research activities, etc. Stakeholders have been involved in the consultation process. Treatment models have been prescribed for sites whose availability has been assured by the SFDs. A soil and moisture conservation model with modest quantum of work has been prescribed (as a default model) under conservation interventions for rehabilitation and strengthening of existing soil and moisture structures for sites not proposed by SFDs in Haryana, Delhi NCT, Uttar Pradesh and Madhya Pradesh.

The riverscape measures 44,070.77 km^2 which is proposed to be taken up under Phase 1 of the DPR. The extent of forest cover in the riverscape is 7,605.37 km^2 while scrub is 4,064.81 km^2. The forest and scrub area of the riverscape, taken together, account for 26.48 per cent of riverscape.

5.3. THE VISION, MISSION, GOALS AND OBJECTIVES OF THE PROPOSED DPR

5.3.1. Vision

To restore degraded forests of Yamuna basin alongwith tributaries to improve ecological flow and quality of river water

5.3.2. Mission

To establish /develop multi-tier forest of native vegetation and improve ground water recharge in the riverscape of Yamuna and its tributaries

5.3.3. Goals

1. To propose appropriate treatment models (technical prescriptions) for prioritised sites in the riverscape in consultation with SFDs, other stakeholders and experts.
2. To enhance capacity of SFDs to undertake the prescribed project activities in natural, agricultural and urban/peri-urban landscapes.
3. To propose implementation mechanism to MoEF&CC.

5.3.4. Objectives

The objectives of the formulated DPR are as under:

1. To identify key problems in reference to the Yamuna, including its tributaries.
2. To identify a suitable coordinating department that would provide site-specific proposals for treatment of sites in natural, agricultural and urban/peri-urban landscapes in liaison with local stakeholders and would undertake to implement technical treatment models prescribed in the DPR.
3. To develop site-specific treatment models for problem areas in consultation with the above-said coordinating department.
4. To propose funds for implementation of the treatment models and supporting activities.
5. To propose an effective implementation mechanism with potential sources of funding, institutional arrangement and monitoring and evaluation mechanism.

6. To suggest potential benefits in relation to key criteria of ecological flow and quality of water, and associated aspects such as livelihood, green cover, productivity enhancement, biodiversity, etc.

5.4. PROBLEMS IN ACHIEVING OBJECTIVES

Various problems in management of River Yamuna and its tributaries have been described in Chapter 2. SWOT analysis is given in para 2.12. Problems in achieving different project objectives are enumerated below:

1. Extreme or erratic climatic conditions, natural calamities and their impacts.
2. Anthropogenic effects of local or migratory communities and visitors and their direct and indirect adverse impacts, including such as landslides, soil / river bank erosion, high rate of sedimentation, etc.
3. Biotic interference from domestic and wild animals, pests, diseases and epidemics.
4. Faulty land use practices and inadequacy on the part of some agencies to check/ address problems arising from their respective sectors.
5. Encroachment of forest lands and other natural ecosystems.
6. Habitat loss, fragmentation of terrestrial and aquatic ecosystems including rivers and streams, and their degradation.
7. Proliferation of exotic and invasive species, decline in productivity of natural ecosystems, and lack of regeneration of native species.
8. Remoteness of villages, lack of alternate income generation opportunities and marketing mechanism.
9. Decline in social and village level institutions (e.g., *Van Panchayat*), and neglect of natural ecosystems.
10. Lack of awareness and receptivity of stakeholders.
11. Unsustainable human activities and their impact on natural ecosystems.
12. Multiplicity of policies and laws, occasional conflicting/ counter-productive, and lackadaisical policy and law enforcement.
13. Inadequate researches, monitoring, databases, baseline information, lack of technological support and innovations, and lack of capacity.
14. Isolationist approaches of different sectors/ agencies, and inadequate funds.
15. Incomplete implementation of strategies suggested in the DPR.

5.5. STRATEGIES

Various models and activities have been worked out for forest, agriculture and urban/peri-urban landscapes in the riverscape of Yamuna and its tributaries. Details of the same are given in the subsesequent sections.

Supporting activities, *viz.*, capacity building, nursery establishment/improvement, fire protection, development of value chain, monitoring and evaluation, research, etc. are also to be undertaken. Some other activities that are not part of any model but need to be carried out include removal of encroachment on forest land, stopping mining in no-mining zones, regulating mining to permissible limits in other areas, protection and conservation of the forest, etc., these may also be carried out under supporting activities.

5.6. FORESTRY INTERVENTIONS

This section gives detailed prescriptions of the DPR for implementation by forestry sector. The riverscape is a mosaic of different land uses i.e., natural ecosystems, rural and agricultural ecosystems, and urban/peri-urban environment and each of these broad land use categories harbour varied conditions, ownerships, use patterns and management needs. All these three land use categories hereafter being referred to as landscapes (natural, agriculture and urban/peri-urban)

directly or indirectly influence the complexity and dynamic nature of river Yamuna ecosystem. Thus, forestry interventions addressing these three broad land use types/ landscape categories are being planned as part of the execution of the implementation plan during the five-year implementation phase (year 1 to year 5); the spill-over maintenance activities of some treatment models would be completed in maintenance phase (year 6 onwards). Accordingly, for the purpose of Implementation Plan, three lower zones/ landscapes of the riverscape are being targeted for forestry interventions.

5.6.1. Zoning and Zone Plans

Following three zones/ landscape plans in the riverscape are delineated for the purpose of proposed forestry interventions:

Natural landscapes

Proposed forestry interventions for natural ecosystems (forests, grasslands, and wetlands) such as afforestation/reforestation, enhancement of density, improvement of biodiversity, habitat management by way of weed control, plantations, eco-restoration, etc. have been planned. Soil and moisture conservation works have been applied as adjunct to the above activities where absolutely essential to support these models. ~~Conservation interventions have been proposed for development of riparian wildlife and wetland in the natural landscape.~~ Independent soil and moisture conservation measures have also been proposed in natural landscape in sites where such measures were required without use of silvicultural measures. Considering the type of natural ecosystems, native vegetation, soil conditions, and agro-climatic zones, potential models of various types of plantations were identified, designed, and developed by the FRI using its multi-disciplinary expert knowledge. The purpose of various models planned in the natural landscapes is primarily protection, eco-restoration and conservation aiming at improvement of ecological flow and reducing silt load in flowing water. This landscape is the site of not only silvicultural measures but also conservation interventions.

Agriculture landscape

The agriculture landscape, largely in the rural environment, constituted the second zone in the matrix of the riverscape. The activities in this zone mainly seek enhanced agroforestry production and fodder availability. Various agricultural and horticultural crops are undertaken by villagers/ farmers on their private lands with agricultural crops. The purpose of this zone (agriculture landscapes) is to sustain productivity of agricultural lands with planting of economic and fruit trees so as to enhance the overall conservation values and other expected ecological functions and ecosystem services.

Urban/peri-urban landscape

Proposed forestry interventions in the urban landscape specifically seek to develop eco-park, riverfront, institutional and industrial estate plantations, and avenue plantations in urban/peri-urban landscapes to improve environment in these areas and create awareness among masses towards conservation of trees and water. Conservation interventions have been proposed for development of riparian wildlife and wetland in the natural landscape.

5.6.2. Model-wise Treatment Plans

A model is a treatment prescription consisting of several activities suggested for a number of sites with similar site condition and management objective. A total of 143 models/sub-models comprising 49 in natural landscape, 14 in agriculture landscape, 22 in urban/peri-urban landscape and 58 as conservation interventions have been formulated for the riverscape. Species recommended in the Working Plan have been prescribed in the models, thereby not recommending use of exotics in the natural landscape. Flexibility is permissible in application of the models to allow adaptation to unique site conditions and improvements based on local experiences while retaining the essence of the model. Use of species that are believed to draw excessive amounts of water or have other adverse effects on water and general environment must, however, be avoided. Some models suggested for different states within agriculture landscape and urban/peri-urban landscape are similar but have

been given unique model number for ease of application and uniformity across all DPRs on major rivers of India.

The number of models/sub-models for different states is as under: 17 in Uttarakhand, 16 in Himachal Pradesh, 20 in Haryana, 1 in Delhi, 35 in Uttar Pradesh, 26 in Rajasthan and 28 in Madhya Pradesh. The models are described in the next section (Tables 5.1 to 5.4).

Table 5.1. List of forestry interventions proposed in the natural landscape

State	S. no.	Model name	Model no.
Uttarakhand	1	Temperate mixed plantation	YM/UK/NL/01
	2	Sub-tropical mixed plantation	YM/UK/NL/02
	3	Southern dry slope mixed plantation	YM/UK/NL/03
	4	Rehabilitation of invasive species infested areas	YM/UK/NL/04
	5	Assisted natural regeneration	YM/UK/NL/05
	6	Shivalik mixed plantation	YM/UK/NL/06
Himachal Pradesh	7	Temperate mixed plantation	YM/HP/NL/01
	8	Sub-tropical mixed plantation	YM/HP/NL/02
	9	Riverine mixed plantation	YM/HP/NL/03
	10	Rehabilitation of invasive species infested areas	YM/HP/NL/04
	11	Assisted natural regeneration	YM/HP/NL/05
	12	Ecorestoration by Eco Task Force	YM/HP/NL/06
Haryana	13	Enrichment plantation in weed infested areas	YM/HY/NL/01
	14	Plantation in open forest	YM/HY/NL/02
	15	Sowing on contour trenches	YM/HY/NL/03
	16	Vegetative barrier	YM/HY/NL/04
Uttar Pradesh	17	Afforestation of erosion-prone ravinous slopes	YM/UP/NL/01
	18	Afforestation of slopes with shallow soil	YM/UP/NL/02
	19	Plantation in open forest areas	YM/UP/NL/03
	20	Plantation in open forest ravinous areas	YM/UP/NL/04
	21	Rehabilitation of weed-infested forest areas	YM/UP/NL/05
	22	Treatment of gullies and steep slopes through vegetative measures with soil conservation	YM/UP/NL/06
	22(a)	Earthen check dam	YM/UP/NL/06/A
	22(b)	Contour bunding	YM/UP/NL/06/B
	22(c)	Gully plug	YM/UP/NL/06/C
	23	Ecorestoration by Eco Task Force	YM/UP/NL/07
	24	Plantation in heterogenous areas in uneven terrain	YM/UP/NL/08
	25	Plantation in *usar* flat terrain	YM/UP/NL/09
Rajasthan	26	Rehabilitation of degraded forest	YM/RJ/NL/01
	27	Assisted natural regeneration	YM/RJ/NL/02
	28	Biodiversity conservation	YM/RJ/NL/03
	29	Rehabilitation of *Lantana*-infested forest area	YM/RJ/NL/04
	30	Rehabilitation of *Prosopis*-infested forest area	YM/RJ/NL/05
	31	Contour trenching and seeding	YM/RJ/NL/06
	32	Deep contour trenching and seeding	YM/RJ/NL/07
	33	Contour bunding and seeding	YM/RJ/NL/08
	34	Ecorestoration by Eco Task Force	YM/RJ/NL/09
Madhya Pradesh	35	Afforestation in open forest areas	YM/MP/NL/01
	36	Assisted natural regeneration	YM/MP/NL/02
	37	Rehabilitation of forest infested with high-density invasive weeds	YM/MP/NL/03
	38	Rehabilitation of forest infested with moderate-density invasive weeds	YM/MP/NL/04
	39	Rehabilitation of forest infested with low-density	YM/MP/NL/05

		invasive weeds	
	40	Removal of high-density invasive weeds	YM/MP/NL/06
	41	Removal of moderate-density invasive weeds	YM/MP/NL/07
	42	Grassland development in wildlife areas	YM/MP/NL/08
	43	Grass with moisture conservation	YM/MP/NL/09
	44	Treatment of gullies and slopes through vegetative measures with soil and moisture conservation	YM/MP/NL/10
	44(a)	Earthen check dam	YM/MP/NL/10/A
	44 (b)	Contour trench	YM/MP/NL/10/B
	44 (c)	Contour bund	YM/MP/NL/10/C
	45	Ecorestoration by Eco Task Force	YM/MP/NL/11

Table 5.2. List of forestry interventions proposed in the agricultural landscape

State	S. no.	Model name	Model no.
Uttarakhand	1	Planting of saplings by farmers	YM/UK/AL/01
	2	Plantation on community lands	YM/UK/AL/02
Himachal Pradesh	3	Planting of saplings by farmers	YM/HP/AL/01
	4	Plantation on community lands	YM/HP/AL/02
Haryana	5	Planting of saplings by farmers	YM/HY/AL/01
	6	Silvipasture on community land	YM/HY/AL/02
Uttar Pradesh	7	Planting of saplings by farmers	YM/UP/AL/01
	8	Silvipasture on community land	YM/UP/AL/02
	9	Community land afforestation in erosion-prone slope areas	YM/UP/AL/03
Rajasthan	10	Planting of fruit plants by farmers	YM/RJ/AL/01
	11	Planting of forestry plants by farmers	YM/RJ/AL/02
	12	Silvipasture on community land	YM/RJ/AL/03
Madhya Pradesh	13	Planting of fruit plants by farmers	YM/MP/AL/01
	14	Planting of forestry plants by farmers	YM/MP/AL/02

Table 5.3. List of forestry interventions proposed in the urban/peri-urban landscape

State	S. no.	Model name	Model no.
Uttarakhand	1	Eco-park development	YM/UK/UL/01
	2	River front development	YM/UK/UL/02
	3	Avenue plantation	YM/UK/UL/03
Himachal Pradesh	4	Eco- Park development	YM/HP/UL/01
	5	River front development	YM/HP/UL/02
Haryana	6	Strip plantation along roads	YM/HY/UL/01
	7	Strip plantation along canals	YM/HY/UL/02
	8	Floodplain treatment	YM/HY/UL/03
	9	Institutional plantation	YM/HY/UL/04
	10	Plantation in unprotected institutional areas	YM/HY/UL/05
Uttar Pradesh	11	Roadside linear plantation	YM/UP/UL/01
	12	Roadside strip plantation	YM/UP/UL/02
	13	Institutional plantation	YM/UP/UL/03
	14	Block plantation in land bank and revenue land	YM/UP/UL/04
	15	Land bank treatment in erosion prone slope areas	YM/UP/UL/05
	16	Treatment of floodplain and land of irrigation department	YM/UP/UL/06
	17	Eco-Park development	YM/UP/UL/07
	18	Riverfront development	YM/UP/UL/08

	19	Bioremediation with strip plantation	YM/UP/UL/09
Rajasthan	20	Eco-park development	YM/RJ/UL/01
Madhya Pradesh	21	Eco-park development	YM/MP/UL/01
	22	Floodplain treatment	YM/MP/UL/02

Table 5.4. List of conservation interventions proposed

State	S. no.	Model name	Model no.
Uttarakhand	1	SMC - Contour trenching	YM/UK/CI/01
	2	SMC - *Chal khal*	YM/UK/CI/02
	3	SMC - Check dam	YM/UK/CI/03
	4	SMC - Spur/Retaining wall	YM/UK/CI/04
	5	Wetland management	YM/UK/CI/05
	6	Mixed SMC works	YM/UK/CI/06
Himachal Pradesh	7	Contour trenching	YM/HP/CI/01
	8	SMC - Percolation pond	YM/HP/CI/02
	9	SMC - Check dam	YM/HP/CI/03
	10	SMC - Spur/Retaining wall	YM/HP/CI/04
	11	Wetland management	YM/HP/CI/05
	12	Mixed SMC works	YM/HP/CI/06
Haryana	13	Water storage bodies	YM/HY/CI/01
	14	Managing water flow, soil moisture and sedimentation	YM/HY/CI/02
	14(a)	RCC structure	YM/HY/CI/02/A
	14(b)	CC stud	YM/HY/CI/02/B
	14 (c)	Dry stone structure	YM/HY/CI/02/C
	14 (d)	Stone cratewire structure	YM/HY/CI/02/D
	14 (e)	Crate wire mesh	YM/HY/CI/02/E
	14 (f)	Guide bandh	YM/HY/CI/02/F
	15	Rehabilitation of soil and moisture conservation structures	YM/HY/CI/03
	16	Riparian wildlife management	YM/HY/CI/04
Delhi	17	Rehabilitation of soil and moisture conservation structures	YM/DL/CI/01
Uttar Pradesh	18	Water storage bodies/structures	YM/UP/CI/01
	19	Managing water flow, soil moisture and sedimentation	YM/UP/CI/02
	19 (a)	SMC - Sidewall	YM/UP/CI/02/A
	19 (b)	SMC - Spur	YM/UP/CI/02/B
	19 (c)	SMC - *Pucca* check dam	YM/UP/CI/02/C
	19 (d)	Dry gully plug	YM/UP/CI/02/D
	19 (e)	Brushwood check dam	YM/UP/CI/02/E
	19 (f)	Spillway	YM/UP/CI/02/F
	19 (g)	Mixed soil and moisture conservation	YM/UP/CI/02/G
	20	Riparian wildlife management	YM/UP/CI/03
	21	Wetland management in uniform site conditions	YM/UP/CI/04
	22	Wetland management in heterogenous areas	YM/UP/CI/05
	23	Rehabilitation of soil and moisture conservation structures	YM/UP/CI/06
Rajasthan	24	Water storage bodies/structures	YM/RJ/CI/01
	24 (a)	SMC - Mini percolation tank/ Naadi/ Water harvesting structure	YM/RJ/CI/01/A
	24 (a)	SMC - Tanka	YM/RJ/CI/01/B

	25	Managing water flow, soil moisture and sedimentation	YM/RJ/CI/02
	25 (a)	SMC - Loose stone check dam	YM/RJ/CI/02/A
	25 (b)	SMC - *Pucca* check dam	YM/RJ/CI/02/B
	25 (c)	SMC - Anicut	YM/RJ/CI/02/C
	25 (d)	SMC - Gabion	YM/RJ/CI/02/D
	25 (e)	SMC - Stone wall	YM/RJ/CI/02/E
	25 (f)	SMC - *Pucca* wall	YM/RJ/CI/02/F
	25 (g)	SMC - Silt detention structure (SDS)	YM/RJ/CI/02/G
	25 (h)	SMC - Miscellaneous structures	YM/RJ/CI/02/H
	25 (i)	SMC - Mixed structures	YM/RJ/CI/02/I
	26	Riparian wildlife management	YM/RJ/CI/03
	27	Wetland management	YM/RJ/CI/04
	28	Rehabilitation of soil and moisture conservation structures	YM/RJ/CI/05
Madhya Pradesh	29	Water storage bodies/structures	YM/MP/CI/01
	29 (a)	SMC- *Kachcha* pond, *dabra dabri*	YM/MP/CI/01/A
	29 (b)	Pitched pond	YM/MP/CI/01/B
	29 (c)	Percolation tank	YM/MP/CI/01/C
	30	Managing water flow, soil moisture and sedimentation	YM/MP/CI/02
	30 (a)	SMC - Loose boulder check dam/structure	YM/MP/CI/02/A
	30 (b)	SMC - Anicut	YM/MP/CI/02/B
	30 (c)	SMC - Stopdam	YM/MP/CI/02/C
	30 (d)	SMC – *Kharanja* (brick/stone passage)	YM/MP/CI/02/D
	30 (e)	SMC – *Rapta* (causeway)	YM/MP/CI/02/E
	30 (f)	SMC - Protection wall along riverbank/treatment site	YM/MP/CI/02/F
	30 (g)	Mixed soil and moisture conservation	YM/MP/CI/02/G
	31	Rehabilitation of soil and moisture conservation structures	YM/MP/CI/03

5.6.3. Treatment Models

Treatment models prescribed for the three zones and conservation interventions are described in this section. Models are grouped zone and state-wise. The following general prescriptions are made for all models:

a) Native species of tree, shrub and herbs will be planted. Traditional horticultural crops which have long been in cultivation in the region are also included in agricultural and urban landscapes. Mixed crops that would promote biodiversity will be raised as far as possible in preference to pure plantation. Species that provide economically useful non-wood forest produce (NWFP) will be planted to the extent of 70% or more by number. Effort would be made to produce industrial surpluses of select raw material in consultation with local nutraceutical, food processing and other NWFP-based industries.

b) Digging of pits, contour trenches, protection trenches, fencing etc will be carried out sufficiently before planting operation according to the standard practice in the plantation area.

c) Site-specific modifications in the models are permitted provided they capture the essence of the respective models. The rates prevailing in SFD at the site and time of operation would be applicable. The DFOs at time of implementation of the project will have the power to make site-specific modifications in prescriptions to suit the site conditions within the total budget proposed in the DPR for the Division. The flexibility applies to choice of species, site, model, quantity of work and timing of activities.

d) Species will be selected in consultation with industries /market experts to plant species that would create industry-level surpluses.
e) Seed or other propagules of forest tree species will be sourced from natural forests and plantations, especially seed orchards, plus trees or seed production areas, wherever available in sufficient quantity, aiming at quality seed. Seed would not be purchased from market for plantation in natural landscape.
f) Survival of plants will be ensured by providing life-saving irrigation; the frequency of irrigation would vary with weather conditions. Casualty replacement will be done according to the existing norms of the state. If such norms are not existing, prescriptions in the respective models will be refrerred to.
g) During site preparation prior to plantation work, seedlings already growing in the site would be retained, nurtured (through soil working, manure, irrigation operations) and protected.
h) Complete removal of ground vegetation would not be done during rehabilitation of weed-infested areas, Partial removal of invasive weeds would be done followed by artificial regeneration to facilitate gradual replacement of the weeds with economically and ecologically useful species.
i) Biofertilizers such as arbuscular mycorrhiza (AM) organic manures will be applied in nurseries and plantations to boost plant growth. Eco-friendly plant protection measures (e.g. physical or mechanical methods, use of natural products, etc.) will be adopted to manage weed and pest without resorting to use of synthetic products. Tall seedlings may be planted to achieve greater survival in areas with high biotic disturbances.
j) Effective protection will be provided to the planted seedlings against biotic and abiotic stresses through watch and ward, public awareness besides fence, cattle-proof trenches, etc. according to the site.

(i) Treatment Models for Natural Landscape

A. Uttarakhand

YM/UK/NL/01: Temperate mixed plantation

This model has been prescribed in temperate forest areas above 1,800 m altitude, below the alpine zone. The landscape is characterised by dense forests of chiefly conifer species. The zone experiences snow and rain several times during winter and enjoys a cool climate. The major precipitation is in the form of rainfall during monsoon season. Soil is covered with a thick layer of humus. Despite dense forests in the zone, blank patches also exist at many places. Degraded landscape is also noticed along the riverbanks. Such areas will be taken up for treatment under the project.

Under the model, 525 plants of broadleaved and conifer species and 300 plants of shrubs, medicinal plants and bamboos will be will be planted per hectare. 100 contour trenches (40 m^3 volume) and 525 pits of 45 cm x 45 cm x 45 cm size will be dug. A *chal khal* (a local water percolation structure with stone work) of 20 m^3 volume is also proposed to be created to conserve water and make it available for irrigation of plants. Slips of grasses will be planted on soil along contour trenches. Tree seedlings grow slow in the nursery and will be nurtured in the nursery for at least two growing seasons before planting out in the pits. Protection against fire will be provided.

Important elements of the model (ha^{-1}) are:

Tree seedlings: 525 (grown in nursery for at least two growing seasons)
Shrubs, shrubs, medicinal plants and bamboo: 300
Pit size: 45 cm x 45 cm x 45 cm
Contour trenches: 100 (40 m^3 volume)
Grasses: On soil along contours

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree:*Abies pindrow, Picea smithiana, Cedrus deodara, Pinus wallichiana, Aesculus indica, Acer caesium, A. oblongum, Prunus cornuta, Betula utilis, Taxus baccata, Rhododendron lepidotum, R. campanulatum, Buxus wallichiana, Alnus nepalensis, Quercus semecarpifolia, Q. Floribunda,* etc.

Bamboo/ Ringal: *Thamnocalamus falconeri, Sinarundinaria anceps (Arundinaria jaunsarensis),* etc.

Shrub: *Prinsepia utilis, Rosa moschata, Berberis lycium, Woodfordia* sp., *Cotoneaster macrophyllus, Daphnae cannabina, Ziziphus oxyphylla, Hippophae* sp., *Cornus capitata,* etc.

Medicinal plant: *Podophyllum hexandrum, Dictamnus albus, Ferula jaeschkeana, Polygonatum verticillatum, Acorus* sp., *Nardostachys*sp., etc.

Grass/sedge:*Arundinella setosa, Pennisetum orientale, Chrysopogon gryllus, C. fulvus, Apluda mutica, Melica persica*, Calamagrostis emodensis*,* etc.

* Landslide area

YM/UK/NL/02: Sub-tropical mixed plantation

This model will be applied in mid-hill region of the state at an altitude of 900-1,800m. South-facing slopes having shallow soil and sites infested with invasive weeds will not be treated with this model. The zone experiences heavy rainfall during monsoon season and modest rainfall during winter season. Most of the rainwater flows down the streams washing away top soil especially in degraded sites. The forests are dominated by *Pinus roxburghii* (chir pine). High temperature and humidity conditions prevail during summer and the forest floor during winter and summer is covered with pine needles. Grasses flush out during monsoon season.

Under the model, 325 plants of broadleaved species and 300 plants of shrubs, medicinal plants and bamboos will be will be planted per ha. 100 contour trenches (40 m^3 volume) and 325 pits of 45 cm x 45 cm x 45 cm size will be dug. *Chal khal* of 20 m^3 volume is also proposed to be dug to conserve water and make it available for irrigation of plants. Slips of grasses will be planted on soil along contour trenches. Fire is a common occurrence during summer and protection measures will be adopted.

Important elements of the model (ha^{-1}) are:

Tree seedlings: 325 (grown in nursery for at least two growing seasons)
Shrubs, shrubs, medicinal plants and bamboo: 300
Pit size: 45 cm x 45 cm x 45 cm
Contour trenches: 100 (40 m^3 volume)
Grasses: On soil along contours

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree: *Cuppressus torulosa, Lyonia ovalifolia, Acer oblongum, Prunus cornuta, Alnus nitida, Olea glandulifera, Pterospermum* sp., *Quercus leucotrichophora,* etc.

Bamboo/ Ringal: *Dendrocalamus* sp., *Thamnocalamus falconeri, Sinarundinaria anceps,* etc.

Shrub: *Prinsepia utilis, Rosa moschata, Berberis lycium, Woodfordia* sp., *Ziziphus oxyphylla, Cornus capitata, Flemingia* sp., *Artemisia nilagirica, Rhus parviflora,* etc.

Medicinal plant: *Plumbago indica, Dictamnus albus, Ferula jaeschkeana, Polygonatum verticillatum, Acorus* sp., *Nardostachys* sp., etc.

Grass/sedge:*Pennisetum orientale, Arundinella setosa, A. nepalensis, Chrysopogon fulvus, Heteropogon contortus, Apluda mutica,* Vetiver grass(*Chrysopogon zizanioides), Themeda anathera,* etc.

YM/UK/NL/03: Southern dry slope mixed plantation

This model has been prescribed for southern aspects at 900-1,800 m altitude where stunted growth of vegetation is found due to hot conditions and moisture stress during summer season. The region experiences heavy rainfall during monsoon season and modest rainfall during winter season, causing soil erosion in degraded sites.

Under the model, it is proposed to grow 200 plants of tree species and 200 plants of shrubs, medicinal plants and bamboos per ha. 200 contour trenches (80 m^3 volume) and 200 pits of 45 cm x 45 cm x 45 cm size will be dug. Two *Chal khal* of 40 m^3 volume will also be dug to conserve water and make it available for irrigation of plants. Slips of grasses will be planted on soil along contour trenches. Forest fires commonly occur during the summer season and protection will be provided.

Important elements of the model (ha^{-1}) are:

Tree seedlings: 200.
Shrubs, shrubs, medicinal plants and bamboo: 200.
Pit size: 45 cm x 45 cm x 45 cm.
Contour trenches: 200 (80 m^3 volume).
Grasses: On soil along contour trenches.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree: *Anogeissus latifolia, Lagestroemia parviflora, Acacia catechu, Holoptelea integrifolia, Terminalia bellirica, Terminalia chebula, Bauhinia variegata, Wendlandia, Pinus roxburghii,* etc.

Bamboo/ Ringal: *Dendrocalamus* sp., *Bambusa* sp. *Thamnocalamus falconeri,* etc.

Shrub:*Trema politoria, Debregeasia longifolia, Rhus parviflora, Carissa opaca, Buddleia asiatica, Euphorbia* sp., *Rubus ellipticus, Pycantha* sp., *Prinsepia utilis, Berberis lycium, Woodfordia fruticosa, Ziziphus oxyphylla, Cornus capitata, Flemingia* sp. *Artemisia nilagirica, Rhus parviflora, Indigofera cassioides,* etc.

Medicinal plant: *Withania* sp., *Asparagus racemosus, Mucuna pruriens, Plumbago indica, Ferula jaeschkean, Nardostachys* sp., etc.

Grass/sedge:*Pennisetum orientale, Chrysopogon gryllus, C. fulvus, C. zizanioides, Heteropogon contortus, Apluda mutica, Calamagrostis emodensis*,Arundinella nepalensis, A. setosa, Thysanolaena maxima,* etc.

* Landslide area

YM/UK/NL/04: Rehabilitation of invasive species infested areas

This model is proposed for areas infested with dense growth of invasive species in sub-tropical areas and mid-hills in the state of Uttarakhand. It is proposed to cut and uproot invasive species in patches in the treatment areas and plant indigenous trees, shrubs, bamboos and other species of economic utility to replace the invasive species. The area will be maintained to prevent regrowth of invasive species.

It is proposed to raise 325 plants of tree species and 300 plants of shrubs, medicinal plants and bamboos per ha. 100 contour trenches (40 m^3 volume) and 325 pits of 45 cm x 45 cm x 45 cm size will be dug. One *chal khal* of 20 m^3 volume will also be dug to conserve water and provide this water for irrigation of plants. Slips of grasses will be planted on soil along contour trenches. Forest fires commonly occur during the summer season and protection will be provided.

Important elements of the model (ha^{-1}) are:
Tree seedlings: 325
Shrubs, shrubs, medicinal plants and bamboos: 300
Pit size: 45 cm x 45 cm x 45 cm
Contour trenches: 100 (40 m^3 volume)
Grasses: On soil along contour trenches

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:
Tree:*Anogeissus latifolia, Lagestroemia parviflora, Acacia catechu, Dalbergia sissoo, Toona ciliata, Holoptelea integrifolia, Terminalia bellirica, Terminalia chebula, Bauhinia variegata, Wendlandia* sp., etc.
Bamboo/ Ringal: *Dendrocalamus* sp.,*Bambusa* sp., *Thamnocalamus falconeri*, etc.
Shrub:*Trema politoria, Debregeasia longifolia, Rhus parviflora, Carissa opaca, Buddleia asiatica, Euphorbia* sp., *Rubus ellipticus, Pycantha* sp., *Prinsepia utilis, Berberis lycium, Woodfordia fruticosa, Ziziphus oxyphylla, Cornus capitata, Flemingia* sp., *Artemisia nilagirica, Rhus parviflora, Indigofera cassioides*, etc.
Medicinal plant: *Withania* sp., *Asparagus racemosus, Mucuna pruriens, Plumbago indica, Ferula jaeschkeana, Acorus* sp., *Nardostachys* sp., etc.
Grass/sedge:*Pennisetum orientale, Arundinella setosa, Pennisetum orientale, Chrysopogon fulvus, Heteropogon contortus, Apluda mutica, Vetiver grass,Arundinella nepalensis, A. setosa, Thysanolaena maxima, Arundo donax, Phragmites karka,* etc.

Table 5.5. Cost norms for models (YM/UK/NL/01, YM/UK/NL/02 and YM/UK/NL/03) in Uttarakhand

Activity	YM/UK/NL/01		YM/UK/NL/02		YM/UK/NL/03	
	Man-days	Cost (Rs.)	Man-days	Cost (Rs.)	Man-days	Cost (Rs.)
Year 1 (Advance work)						
Survey and alignment of planting lines	5	1,650	5	1,650	5	1,650
Cleaning of site and making of inspection path	10	3,300	10	3,300	15	4,950
Advance soil works (digging of pits)	40	13,200	30	9,900	20	6,600
Contour trenching (100 trenches = 40 m^3, rate Rs. 120 m^{-3})	100 trenches	4,800	100 trenches	4,800	200 trenches	9,600
Chal khal (one= 20 m^3, rate Rs. 500 m^{-3})	1 *chal khal*	10,000	1 *chal khal*	10,000	2 *chal khals*	20,000
Fencing		60,000		60,000		60,000
Nursery		68,000		32,500		22,500
Total		**1,60,950**		**1,22,150**		**1,25,300**
Year 2 (Planting and establishment)						
Planting in pits and trenches	30	9,900	20	6,600	15	4,900
Sowing in contour trenches	10	3,300	10	3,300	15	4,950
Seed/grass slips cost		1,000		1,000		1,500
Fire protection		2,000		2,000		2,000
Vermicompost/ FYM		1,500		1,500		1,500
Maintenance of plants (5 d mo^{-1}	40	13,200	40	13,200	40	13,200

for eight months)						
Contingency (irrigation, etc.)		2,000		2,000		2,000
Total		**32,900**		**29, 600**		**30,100**
Maintenance cost						
Year 3 (1st maintenance year)	30	9,900 2,000 1,500	30	9,900 2,000 1,500	30	9,900 2,000 1,500
Year 4 (2nd maintenance year)	30	9,900 2,000 1,500	30	9,900 2,000 1,500	30	9,900 2,000 1,500
Year 5 (3rd maintenance year)	30	9,900	30	9,900	30	9,900
Year 6 (4th maintenance year)	30	9,900	30	9,900	30	9,900
Year 7 (5th maintenance year)	30	9,900	30	9,900	30	9,900
Grand total		**2,50,350**		**2,08,250**		**2,11,900**

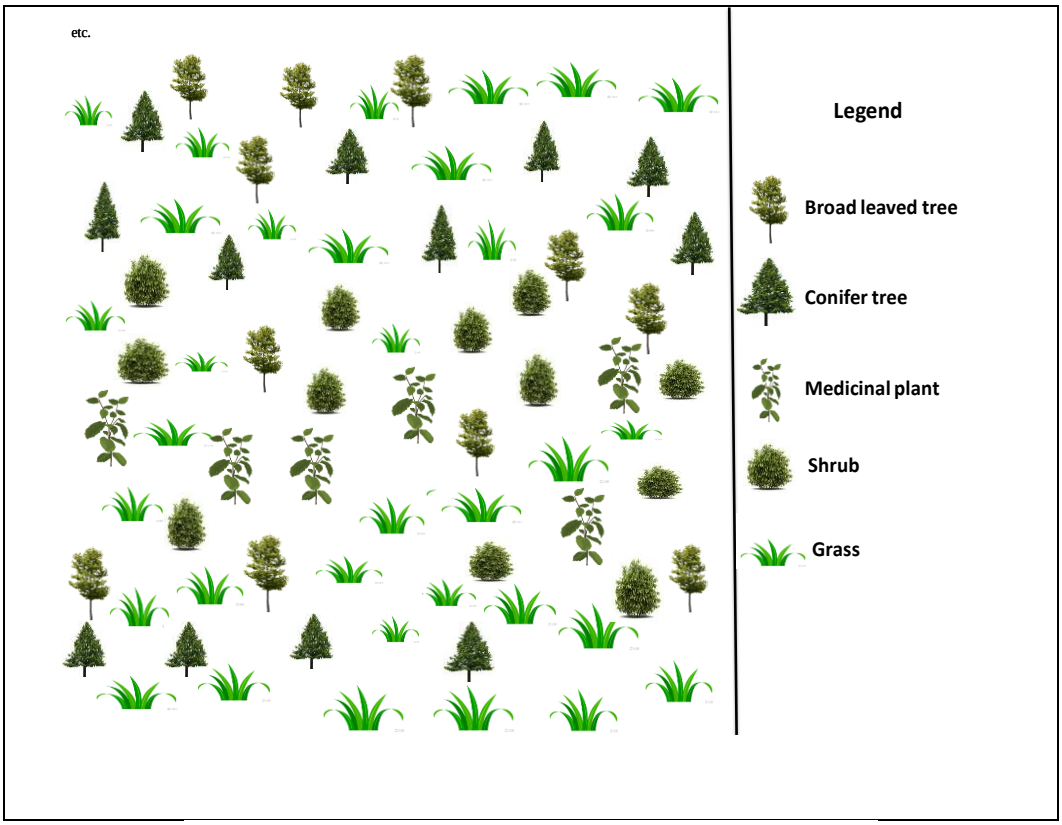


Fig. 5.1. Illustration of temperate mixed plantation

YM/UK/NL/05: Assisted Natural Regeneration

The model aims to aid and accelerate the natural process of succession and overcome impediments to natural regeneration such as from degradation of soil, invasive action of weeds, drought, grazing/browsing, fire, human disturbance, etc.). Assisted Natural Regeneration (ANR) costs less and is speedier in its effect than artificial regeneration, and is very effective in watershed protection and soil conservation.

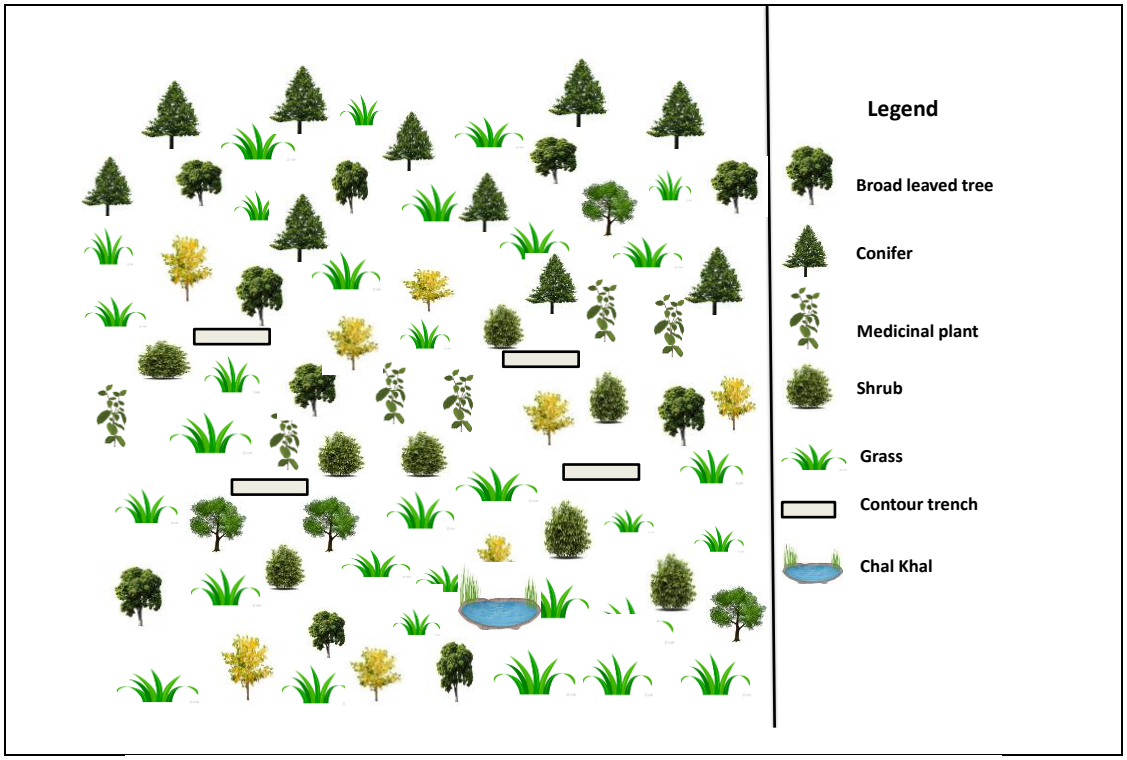


Fig. 5.2. Illustration of planting in sub-tropical mixed plantation



Fig. 5.3. Southern dry slope with scanty trees requiring mixed plantation
(*Source:* **Project Team**)

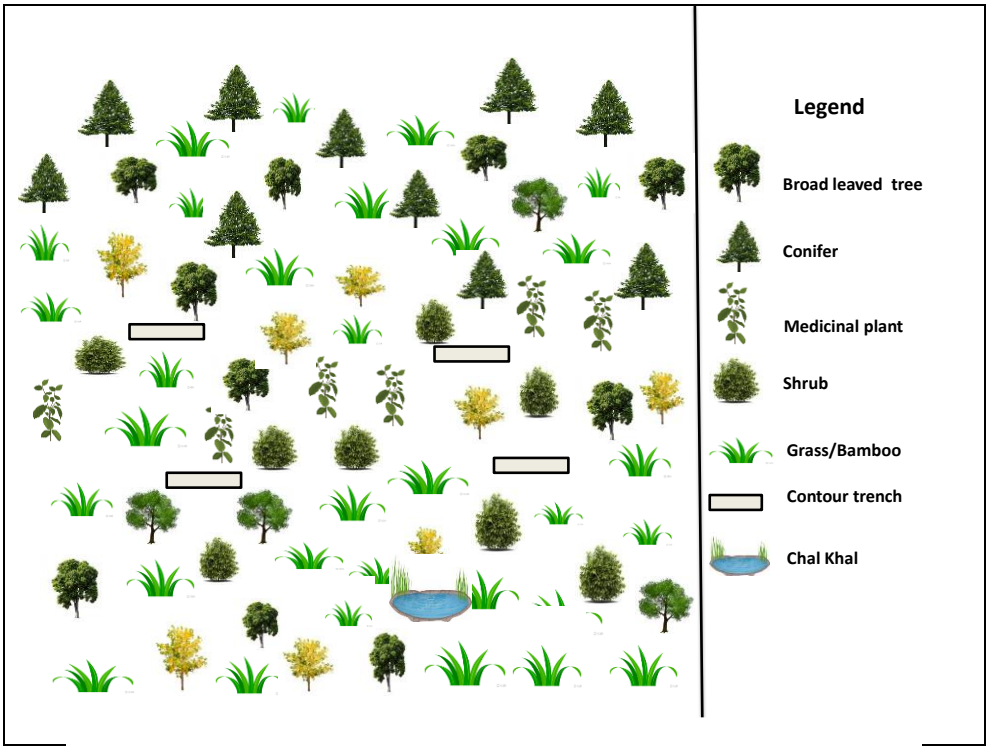


Fig. 5.4. Illustration of mixed plantation in southern dry slopes

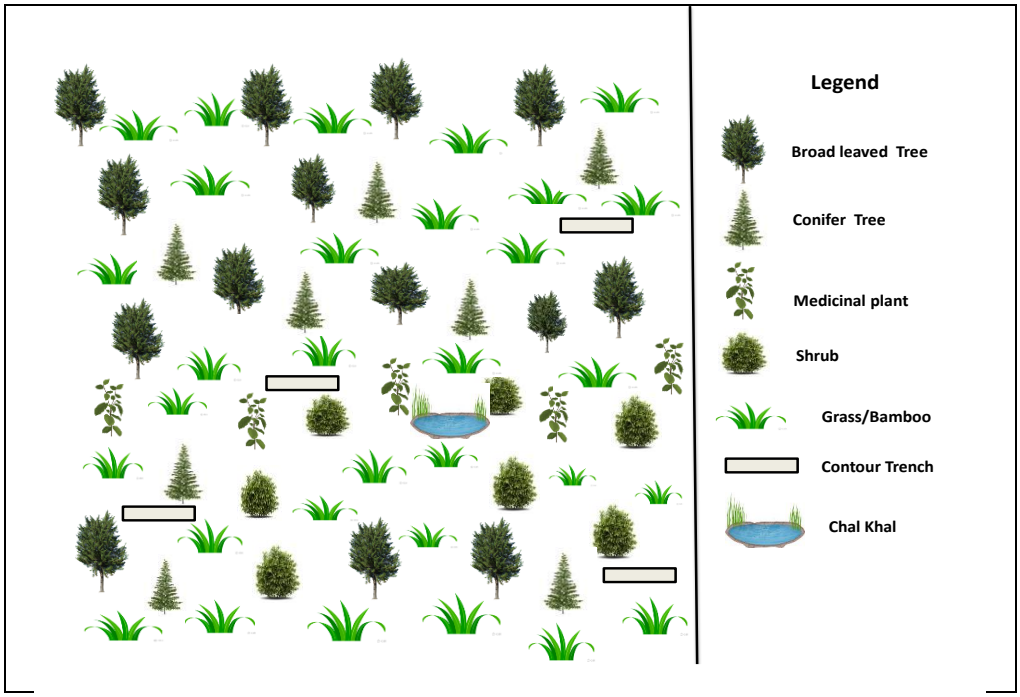


Fig. 5.5. Illustration of rehabilitation of invasive species infested areas

Under this model, protection will be provided to overcome the adverse anthropogenic factors. Removal of interfering vegetation will be done, besides digging of 200 contour trenches (80 m^3 volume) and creation of one *Chal khal* (20 m^3 volume) per ha to reduce biotic stress, promote moisture conservation. 200 seedlings of trees, bamboos and shrubs will be planted to supplement natural regeneration. Grasses will be planted along contours to aid soil and water conservation.

Silvicultural operations such as regeneration clearing, singling, pruning, etc. will be done to support regeneration of existing plants.

Important elements of the model (ha^{-1}) are:
Tree, shrub and bamboo seedlings: 200.
Pit size: 45 cm x 45 cm x 45 cm.
Contour trenches: 200 (80 m^3 volume).
Grasses: On soil along contour trenches.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree: *Toona ciliata, Lannea coromandelica, Albizia lebbeck, Acacia catechu, Dalbergia sissoo, Anogeissus latifolia, Lagestroemia parviflora, Holoptelea integrifolia, Terminalia bellirica, Bauhinia variegate,* etc.

Bamboo/ Ringal: *Dendrocalamus* sp.,*Bambusa* sp. *Thamnocalamus falconeri,* etc.

Shrub:*Trema politoria, Debregeasia longifolia, Rhus parviflora, Carissa opaca, Buddleia asiatica, Euphorbia* sp., *Rubus ellipticus, Pycantha* sp., *Prinsepia utilis, Berberis lycium, Woodfordia fruticosa, Ziziphus oxyphylla, Cornus capitata, Flemingia* sp. *Artemisia nilagirica***,** *Rhus parviflora, Indigofera cassioides,* etc.

Grass/sedge:*Pennisetum orientale, Chrysopogon fulvus, Heteropogon contortus, Apluda mutica, Thysanolaena maxima,* etc.

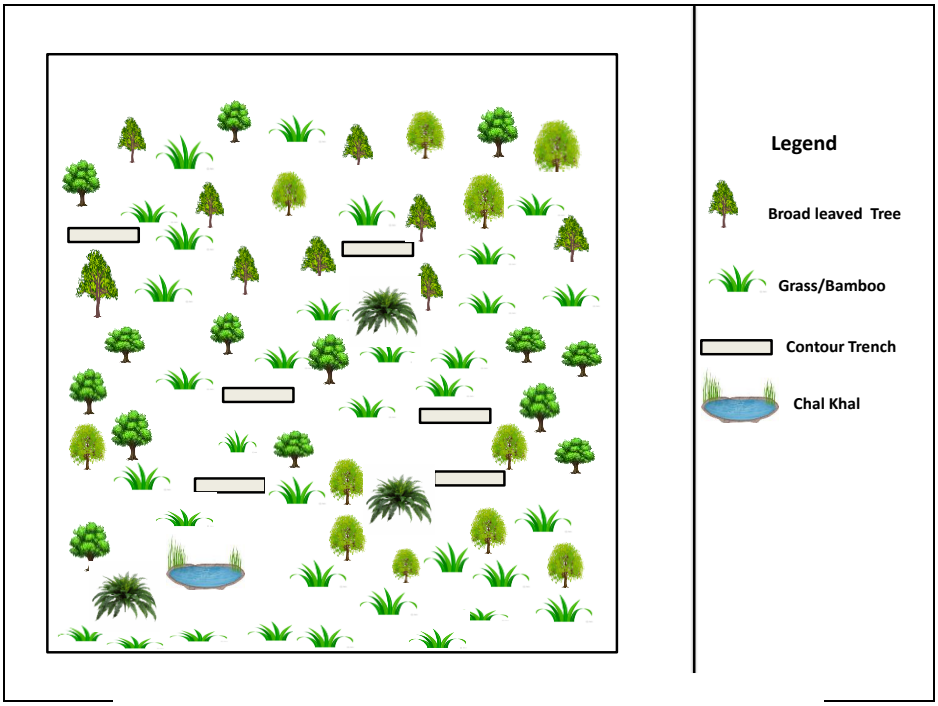


Fig. 5.6. Illustration of assisted natural regeneration

Table 5.6. Cost norms for models (YM/UK/NL/04 and YM/UK/NL/05) (ha^{-1})

Activity	UK/NL/04		UK/NL/05	
	Man-days	Cost (Rs.)	Man-days	Cost (Rs.)
Year 1 (Advance work)				
Survey and alignment of planting lines	5	1,650	5	1,650
Cleaning of site and making of inspection path	5	1,650	10	3,300
Lantana removal		30,000	NA	-
Advance soil works (digging of pits)	30	9,900	10	3,300
Contour trenching (100 trench = 40 m^3, rate Rs. 120 m^{-3})	100 trenches	4,800	200 trenches	9,600
Chal khal (1 *chal khal* =20 m^3), rate Rs. 500 m^{-3}	1 *chal khal*	10,000	1 *chal khal*	10,000
Fencing		60,000		60,000
Nursery		32,500		12,000
Total		**1,50,500**		**99,850**
Year 2 (Planting and establishment)				
Planting in pits and trenches	40	13,200	20	6,600
Sowing in contour trenches	10	3,300	15	4,950
Seeds/grass slips		1,000		1,500
Fire protection/Fire watcher, etc.		2,000		30,000
Vermicompost/ FYM		1,500		1,000
Maintenance of plants (5 d mo^{-1} for eight months)	40	13,200	40	13,200
Contingency (irrigation, etc.)		2,000		1,000
Silviculture operations (regeneration clearings, singling/pruning, SMC works, etc.)	NA			10,000
Total		**36,200**		**68,250**
Maintenance cost				
Year 3 (1st maintenance year)	30	9,900 2,000 1,500	30	9,900 1,000 1,000
Year 4 (2nd maintenance year)	30	9,900 2,000 1,500	30	9,900 1,000 1,000
Year 5 (3rd maintenance year)	30	9,900	30	9,900
Year 6 (4th maintenance year)	30	9,900	30	9,900
Year 7 (5th maintenance year)	30	9,900	30	9,900
Grand Total		**2,43,200**		**2,21,600**

YM/UK/NL/06: Shiwalik mixed plantation

The Shiwalik belt has an open landscape along the riverbanks. The soil is deep and fertile with good moisture content. Animals prefer graze in this zone due to proximity to water and cause damage to the vegetation. There is a high incidence of damage to trees by lopping. Soil from road construction and other development activities collects along river causing damage to the flora.

In this model, it is planned to raise 325 plants of broadleaved trees and 300 plants of shrubs, bamboos and medicinal plants per ha. Digging of 100 contour trenches (40 m^3 volume) and creation of one *Chal khal* (20 m^3 volume) will also be undertaken. Grass will be raised along contour trenches to help in soil and water conservation. Protection will be provided to check damage from adverse anthropogenic factors and fire in the area.

Important elements of the model (ha^{-1}) are:

Tree seedlings: 325.

Shrubs, medicinal plants and bamboo: 300.

Pit size: 45 cm x 45 cm x 45 cm.

Contour trenches: 100 (40 m^3 volume).
Grasses: On soil along contour trenches.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree: *Dalbergia sissoo, Anogeissus latifolia, Lagestroemia parviflora, Acacia catechu, Toona ciliata, Holoptelea integrifolia, Terminalia bellirica, Terminalia chebula, Bauhinia variegata, Alnus nepalensis, Shorea robusta,* etc.

Bamboo/ Ringal: *Dendrocalamus* sp.,*Bambusa* sp. *Thamnocalamus falconeri,* etc.

Shrub:*Trema politoria, Debregeasia longifolia, Rhus parviflora, Carissa opaca, Buddleia asiatica, Euphorbia* sp., *Rubus ellipticus, Pycantha* sp., *Prinsepia utilis, Berberis lycium, Woodfordia fruticosa, Ziziphus oxyphylla, Cornus capitata, Flemengia* sp. *Artemisia nilagirica, Rhus parviflora, Indigofera cassioides,* etc.

Medicinal plant: *Withamia* sp., *Asparagus racemosus, Mucuna pruriens, Plumbago indica, Ferula jaeschkeana, Acorus* sp., *Nardostachys* sp., etc.

Grass/sedge:*Pennisetum orientale, Arundinella setosa, Chrysopogon fulvus, Heteropogon contortus, Apluda mutica, Vetiver grass,Arundinella nepalensis, A. setosa, Thysanolaena maxima, Arundo donax, Phragmites karka, Saccharum bengalense, Narenga porphyrocoma,* etc.

* Landslide area

Table 5.7. Cost norms for models (YM/UK/NL/06) in Uttarakhand (ha^{-1})

Activity	YM/UK/NL/06	
	Man-days	**Cost (Rs.)**
Year 1 (Advance work).		
Surveyand alignment of planting lines	5	1,650
Cleaning of site and making of inspection path	10	3,300
Advance soil works (digging of pits)	20	6,600
Contour trenching (100 trench = 40 m^3, rate Rs. 120 m^{-3})	100 trenches	4,800
Chal khal (one =20 m^3 Rate Rs. 500 m^{-3})	1 *Chal khal*	10,000
Fencing		60,000
Nursery		32,500
Total		**1,18,850**
Year 2 (Planting and establishment)		
Planting in pits and trenches	20	6,600
Sowing in contour trenches	10	3,300
Seed/grass slips cost		1,000
Fire protection		2,000
Vermicompost/FYM		1,500
Maintenance of plants (5 d mo^{-1} for eight months)	40	13,200
Contingency (irrigation, etc.)		2,000
Total		**29,600**
Maintenance cost		
Year 3 (1st maintenance year)	30	9,900 2,000 1,500
Year 4 (2nd maintenance year)	30	9,900 2,000 1,500
Year 5 (3rd maintenance year)	30	9,900
Year 6 (4th maintenance year)	30	9,900
Year 7 (5th maintenance year)	30	9,900
Grand Total		**2,04,950**

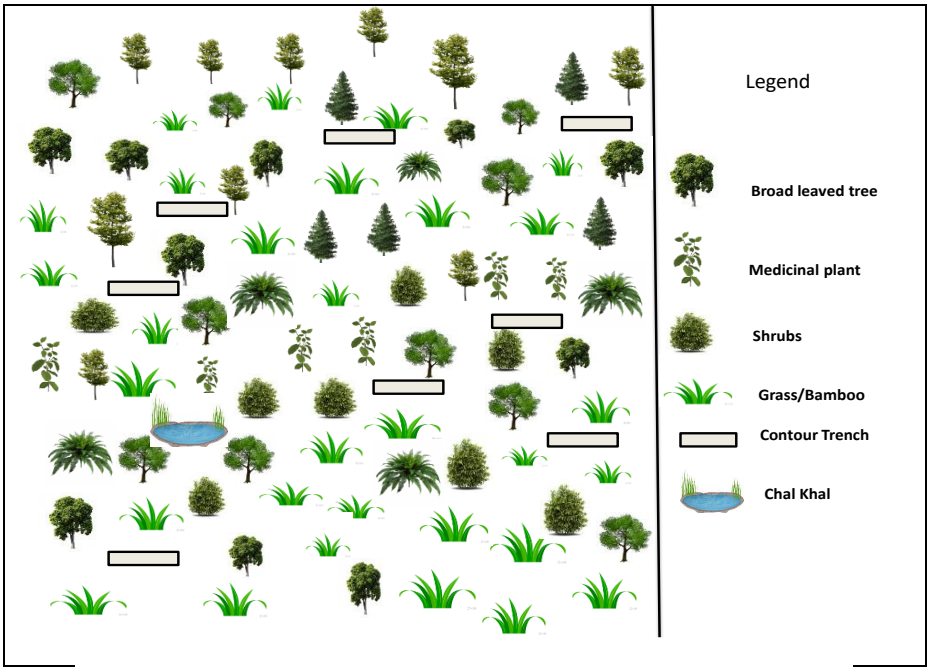


Fig. 5.7. Illustration of mixed plantation in Shiwalik area

B. Himachal Pradesh

YM/HP/NL/01: Temperate mixed plantation

The context and prescriptions of this model are similar to those for YM/UK/NL/01 'Temperate mixed plantation' except that contour trench and *chal khal* will not be dug in Himachal Pradesh. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.8.

YM/HP/NL/02: Sub-tropical mixed plantation

The context and prescriptions of this model are same as those for YM/UK/NL/02 'Sub-tropical mixed plantation' except that contour trench and *chal khal* will not be dug in Himachal Pradesh. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.8.

YM/HP/NL/03: Riverine Mixed plantation

This belt is characterised by an open landscape along the riverbanks running close to areas of fairly dense temperate forests. The soil is deep and fertile with good moisture content. Animals prefer to graze in this zone due to proximity to water and cause huge damage to the vegetation. Soil from road construction and other development activities collect in this zone causing damage to the flora. Damage to trees due to lopping is high. A lot of tourist activities cause harm to the plants and animals.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree: *Dalbergia sissoo, Acacia catechu, Toona ciliata, Holoptelea integrifolia, Terminalia bellerica, Terminalia chebula, Bauhinia variegata. Wendlandia, Alnus nepalensis, A. nitida,Shorea robusta. Anogeissus latifolia, Lagestroemia parviflora*, etc.

Bamboo/ Ringal: *Dendrocalamus* sp., *Bambusa* sp. and *Thamnocalamus falconeri*, etc.

Shrub:*Trema politoria, Debregeasia longifolia, Rhus parviflora, Carissa opaca, Buddleia asiatica, Euphorbia* sp., *Rubus ellipticus, Pycantha* sp., *Prinsepia utilis, Berberis lycium, Woodfordia fruticosa, Ziziphus oxyphylla, Cornus capitata, Flemengia* sp., *Artemisia nilagirica***,** *Rhus parviflora,Indigofera cassioides*, etc.

Medicinal plant: *Withania* sp., *Asparagus racemosus, Mucuna pruriens, Plumbago indica, Ferula jaeschkeana, Acorus* sp., *Nardostachys* sp, etc.

Grass/sedge:*Pennisetum orientale, Arundinella setose, Pennisetum orientale, Chrysopogon fulvus, Heteropogon contortus, Apluda mutica, Vetiver grass.Arundinella nepalensis, A. setosa, Thysanolaena maxima, Arundo donax, Phragmites karka, Saccharum bengalense* and *Narenga porphyrocoma,* etc.

Table 5.8. Cost norms for models (YM/HP/NL/01, YM/HP/NL/02 and YM/HP/NL/03)

Activity	YM/HP/NL/01		YM/HP/NL/02		YM/HP/NL/03	
	Man-days	Cost (Rs.)	Man-days	Cost (Rs.)	Man-days	Cost (Rs.)
Year 1 (Advance work)						
Survey and alignment of planting lines	5	1,250	4	1,250	5	1,250
Cleaning of site and making of inspection path	10	2,500	10	2,500	10	2,500
Advance soil works (digging of pits)	50	12,500	40	10,000	40	10,000
Fencing		50,000		50,000		50,000
Nursery		77,000		34,000		40,000
Total		**1,43,250**		**97,750**		**103,750**
Year 2 (Planting and establishment)						
Planting in pits	50	12,500	40	10,000	40	10,000
Fire protection		2,000		2,000		2,000
Vermicompost/FYM		1,500		1,500		1,500
Maintenance of plants (5 d mo^{-1} for 8 months)	40	10,000	40	10,000	40	10,000
Contingency		2,000		2,000		2,000
Total		**28,000**		**25,500**		**25,500**
Maintenance cost						
Year 3 (1st maintenance year)	30	7,500 2,000 1,500	30	7,500 2,000 1,500	30	7,500 2,000 1,500
Year 4 (2nd maintenance year)	30	7,500 2,000 1,500	30	7,500 2,000 1,500	30	7,500 2,000 1,500
Year 5 (3rd maintenance year)	30	7,500	30	7,500	30	7,500
Year 6 (4th maintenance year)	30	7,500	30	7,500	30	7,500
Year 7 (5th maintenance year)	30	7,500	30	7,500	30	7,500
Grand total		**2,15,750**		**1,67,750**		**1,73,750**

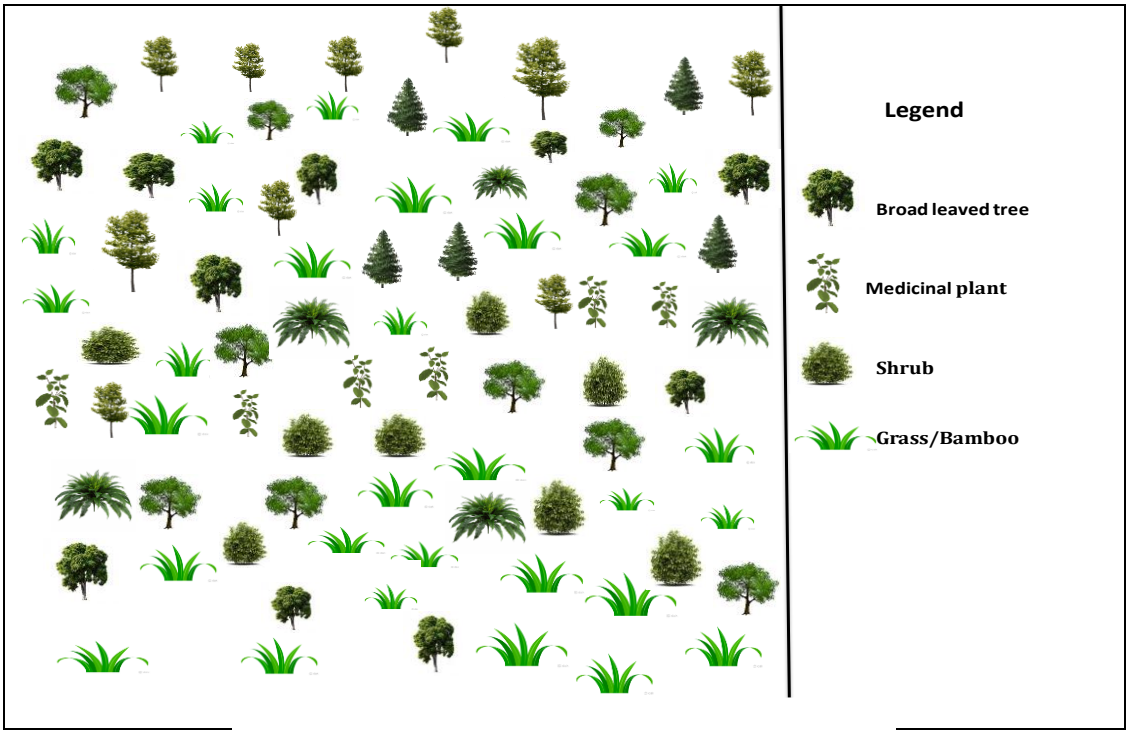


Fig. 5.8. Illustration of riverine mixed plantation

YM/HP/NL/04: Rehabilitation of invasive species infested areas

The context and prescriptions of this model are same as those for YM/UK/NL/04 'Rehabilitation of invasive species infested areas' except that contour trench and *chal khal* will not be dug in Himachal Pradesh. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.9.

YM/HP/NL/05 Assisted natural regeneration

The context and prescriptions of this model are same as those for YM/UK/NL/05 'Assisted natural regeneration' except that contour trench and *chal khal* will not be dug in Himachal Pradesh. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.9.

Table 5.9. Cost norms for models (YM/HP/NL/04 and YM/HP/NL/05)

Activity	**YM/HP/NL/04**		**YM/HP/NL/05**	
	Man-days	**Cost (Rs.)**	**Man-days**	**Cost (Rs.)**
Year 1 (Advance work)				
Survey and alignment of planting lines	5	1,250	5	1,250
Cleaning of site and making of inspection path	5	1,250	10	2,500
Lantana removal		35,000	NA	
Advance soil works (digging of pits)	40	10,000	15	3,750
Contour trenching (100 trenches = 40 m^3, rate Rs.120 m^{-3})	100 trenches	4,800	100 trenches	4,800
Fencing		50,000		50,000
Nursery		45,500		12,500
Total		**1,47,800**		**74,800**
Year 2 (Planting and establishment)				
Planting in pits and trenches	40	10,000	15	3,750
Sowing in contour trenches	10	2,500	10	2,500
Seeds/grass slips		1,000		1,000
Fire protection/fire watcher		2,000		30,000
Vermicompost/FYM		1,500		1,000

Maintenance of plants (5 d.mo^{-1} for 8 months)	40	10,000	40	10,000
Contingency (irrigation, etc.)		2,000		1,000
Silviculture operations (regeneration clearings, singling/pruning, SMC works, etc.)		NA		10,000
Total		**29,000**		**59,250**
Maintenance cost				
Year 3 (1st maintenance year)	30	7,500 2,000 1,500 2000	30	7,500 1,000 1,000
Year 4 (2nd maintenance year)	30	7,500 2,000 1,500 2,000	30	7,500 1,000 1,000
Year 5 (3rd maintenance year)	30	7,500 2,000	30	7,500
Year 6 (4th maintenance year)	30	7,500	30	7,500
Year 7 (5th maintenance year)	30	7,500	30	7,500
Grand total		**2,27,300**		**1,75,550**

YM/HP/NL/06: Ecorestoration by Eco Task Force

The context and prescriptions of this model are same as those for YM/UK/NL/07 'Ecorestoration by Eco Task Force'. An area of 600 ha is proposed to be treated in the state. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.10.

Cost norm for YM/HP/NL/06 (Rs. ha^{-1})

Table 5.10. Year-wise cost summary for YM/HP/NL/06 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
2,30,000	0	0	0	0	0	**2,30,000**

C. Haryana

YM/HY/NL/01: Enrichment plantation in weed infested areas

This model will be applied in moist forest areas in Shiwalik hills in northern part of Haryana. The area is an important wildlife habitat. The terrain has gentle slope with moderately fertile soil. Some sites are infested with moderate to dense growth of various shrub species, including *Lantana,* having low ecological and economic utility. The roots of the bushes hold soil, and *en masse* uprooting of bushes for planting of trees would be undesirable as it would promote soil erosion. In such areas, native forest species would be brought back in a phased manner by enrichment planting. Moisture conservation activities are also proposed to be carried out to create more favourable environment for artificial and natural regeneration of indigenous species.

In this model, small pockets, 200 in number per hectare, of about 20-25 m^2 area would be cleared of shrubs by uprooting them. Seedlings of indigenous tree species, wherever found growing while creating these gaps, will be retained, and soil working would be carried by making *thawla* around them. Passages connecting such gaps would also be cleared to allow movement of workers between the gaps. One trench of size 3 m length, 45 cm width and 45 cm depth will be dug in each gap. A pit of 45 cm x 45 cm x 45 cm would be dug about one metre downhill the trench at the middle of the length of the trench. Enrichment planting of tall trees of indigenous species will be done in the pits. Direct sowing of seeds of indigenous trees will be carried out at three points (one each at both ends, and one in the middle) on the soil heaped along the trench. Slips of grasses would be planted at six points along the trench. The tall trees will be fenced all around with six-stick fence made of local material. The treated patches will be kept free of weeds and of shoots projecting from adjacent

untreated area. Plants and fence will be maintained for seven years. The requirement for maintenance and watch ward will reduce gradually.

Species to be planted

Native species of the area will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree: *Bauhinia racemosa, Butea monosperma, Acacia catechu, Ougenia ougeinensis, Lagerstroemia parviflora, Anogeissus latifolia, Terminalia tomentosa, T. bellirica, Dalbergia sissoo. Bombax ceiba, Holoptelea integrifolia,* etc.

Bamboo: *Dendrocalamus strictus,* etc.

Important elements of the model (ha^{-1}) are:

i. Clearing of 50% area: 3,000 m^2 total area (200 patches of about 20-25 m^2 area each and inspection paths connecting the patches) will be cleared by uprooting shrubs.
ii. Two hundred contour trenches of size 3 m x 0.45 m x 0.45 m.
iii. Two hundred pits of 0.45 m x 0.45 m x 0.45 m.
iv. Planting of plants in pits.
v. Six-stick fencing around the tall plants.
vi. Sowing of tree seeds at 3 places per trench and planting of 6 slips of grasses per trench. More than one seed may be sown per spot to ensure seedling establishment at each spot.
vii. Application of manure/vermicompost to plants in the pits.
viii. Beating up of tall plants 10% in first year.
ix. Maintenance for 5 years after planting year including weeding and hoeing, removal of shoots of plants projecting from adjacent areas in the treated patches, maintenance of fence. Intensity of aftercare will decrease year by year.

Table 5.11. Cost norm for YM/HY/NL/01

Particular	**Quantity ha^{-1}**	**Rs. ha^{-1}**
Year 1 (Advance work)		
Survey and alignment		1,000
Protection trench (1.20 m wide at top, 0.90 m at base and 1.00 m deep) all around		2,6130
Uprooting of shrubs from patches totalling 30% area and placing on periphery of patches as brushwood fence	3,000 m^2	990
Digging of trenches 200 nos. (3 m x 0.45 m x 0.45)	200 trenches	19,500
Digging of pits 600 pits (0.45 m x 0.45 m x 0.45 m)	600 pits	2,650
Raising of nursery stock (including 10% extra for culling)	600 seedlings	26,400
Total		**74,670**
Year 2 (Planting activity)		
Planting in pits	600 plants	1,000
Sowing of seed on protection trench (incl. cost of seed)	Lumpsum	900
Direct sowing on contour trenches (incl. cost of quality seed)	400 tree seeds, 800 grass seeds/slips	2,900
Manure/ vermicompost application	Lumpsum	900
Maintenance of plants (for 9 months)		4,000
Watch and ward (for 9 months)		7,500
Contingency	Lumpsum	750
Total		**19,950**

Maintenance cost			
Year 3	10% beating up	20 plants	2,400
	Weeding and hoeing (4 times yr^{-1})	Lumpsum	3,000
	Irrigation (6 times)	Lumpsum	18,000
	Watch and ward	One year	9,990

	Contingency	Lumpsum	200
	Total		**33,590**
Year 4	Weeding, hoeing (3 times yr^{-1})	Lumpsum	2,250
	Irrigation (2 times)	Lumpsum	6,000
	Watch and ward	One year	9,990
	Total		**18,240**
Year 5	Weeding and hoeing (2 times yr^{-1})	Lumpsum	1,200
	Watch and ward	One year	9,990
	Total		**11,190**
Year 6			**9,990**
Year 7			**9,990**

Table 5.12. Year-wise cost summary for YM/HY/NL/01

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	74,670
Year 2 (Planting and establishment)	19,950
Year 3 (1st maintenance)	33,590
Year 4 (2nd maintenance)	18,240
Year 5 (3rd maintenance)	11,190
Year 6 (4th maintenance)	9,990
Year 7 (5th maintenance)	9,990
Total	**1,75,620**

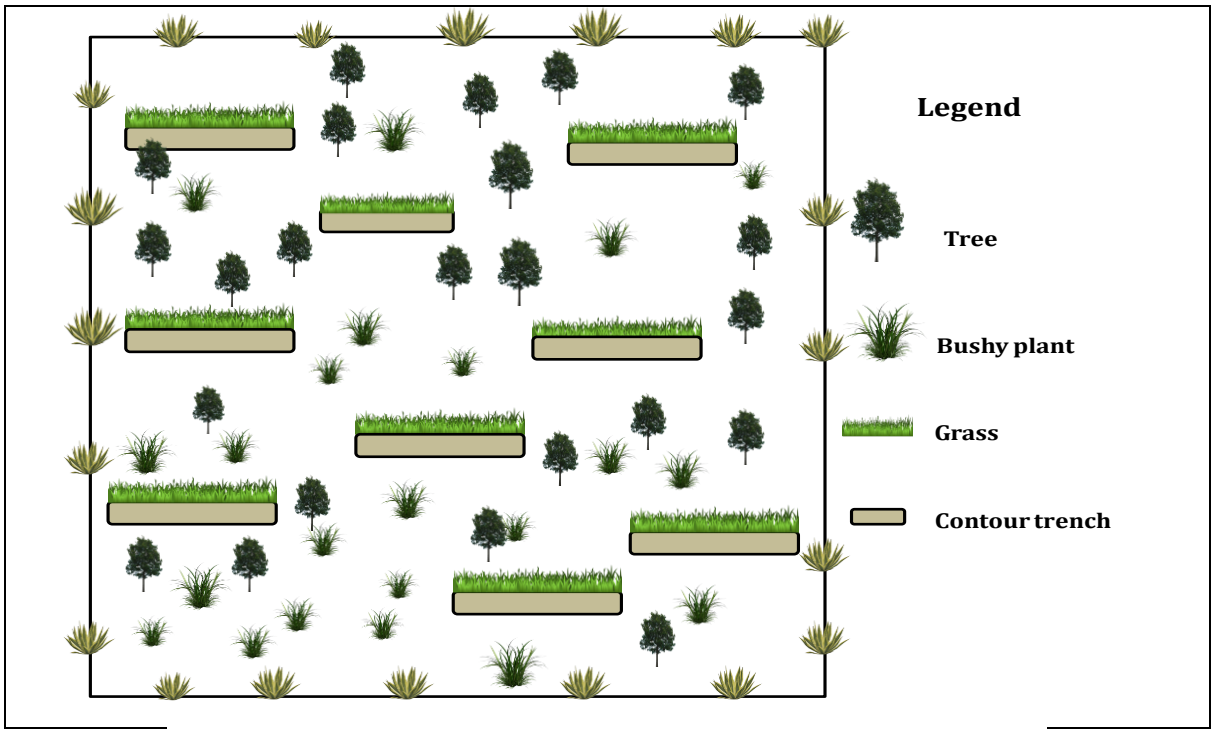


Fig. 5.9. Illustration of enrichment plantation weed infested area

YM/HR/NL/02: Plantation in open forest

This model will be applied in forest areas with have poor crown cover. The terrain of the proposed sites is mostly flat and the soil is poor in nutritional status. Some seedlings and trees already exist in such sites, but their density is quite low. Such saplings and trees will be retained and supported through soil working activities. Planting of tree saplings will be done in pits of 0.45 m x 0.45 m x 0.45 m size at density of 1,000 plants ha^{-1} and maintained for five years after the planting year. *Kachcha* water pond(s) of total 50,000 L storage capacity will be created as a part of this model

outside the plantation area for free access of grazing animals. This pond will be surrounded by a strip of grass covering 150 m^2 area, fenced with brushwood. *Kachcha* water pond(s), with base of stone or some impermeable or semi-permeable material, of total 25,000 L will be created inside the plantation to store water for a longer period of time for irrigation of plants; after two years the stone at the base will be removed to facilitate ground water recharge.

Species to be planted

Native species of the area will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree:*Dalbergia sissoo, Acacia catechu, Acacia nilotica, Albizia lebbeck, Azadirachta indica, Prosopis cineraria, Salvadora persica, Holoptelea integrifolia, Bauhinia racemosa, Butea monosperma, Ougeinia oojeinensis, Lagerstroemia parviflora, Anogeissus latifolia, Terminalia alata, T. bellirica,* etc.

Bamboo: *Dendrocalamus strictus,* etc.

Biofence: *Zizyphus nummularia, Carissa opaca,Acacia catechu, Acacia nilotica, Agave sisalana,* etc.

Grass: *Chrysopogon fulvus, Heteropogon contortus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris,* etc.

Important elements of the model (ha^{-1}) are:

i. Fencing and protection trench (1.20 m wide at top, 0.90 m at base and 1.00 m deep) all around (Cost of barbed wire fence and cost of protection trench may be given separately).
ii. Biofence of fast-growing thorny plants all around.
iii. One thousand pits of 0.45 m x 0.45 m x 0.45 m size.
iv. Planting of seedlings in pits.
v. Application of manure / vermicompost to plants in the pits.
vi. Beating up of plants 20% in first year, 15% in second year and 5% in third year.
vii. Maintenance for 5 years after planting including weeding and hoeing, maintenance of fence, watch and ward.
viii. *Kachcha water pond* 50,000 L outside the plantation area in nearby place.
ix. *Kachcha* water pond of 25,000 L having base of stone or some impermeable or semi-permeable material.

Table 5.13. Cost norm for YM/HY/NL/02

Particular	Quantity ha^{-1}	Rs. ha^{-1}
Year 1 (Advance work)		
Survey and alignment		1,000
Cleaning of site and making inspection path	1 ha	2,540
Fencing of site (barbed wire/stone wall)		5,8000
Protection trench (1.20 m wide at top, 0.90 m at base and 1.00 m deep) all around		26,130
Cost of nursery stock of trees (including 10% extra for culling)	1,000 +100 plants	33,000
Cost of grass seed for outer pond at 50 cm x 50 cm spacing	600 seeds	2,400
Digging of pits 0.45 m x 0.45 m x 0.45 m size	1,000 pits	8,820
Digging of *Kachcha* water pond inside plantation with stone pitching at base	25 m^3	5,000
Digging of *Kachcha* water pond outside plantation with *Kachcha* base	50 m^3	7,500
Total		**14,4390**
Year 2 (Planting activity)		
Transportation of tree seedlings and planting in pits	1,000 plants	8,000
Planting of grass in pits around outer pond	600 seeds/slips	600
Erecting brushwood fence around grass strip		800
Seed sowing on protection trench		900
Manure/ vermicompost	Lumpsum	2,000
Maintenance of plants (for 9 months)		4,000
Watch and ward (for 9 months)		7,500
Contingency	Lumpsum	1,000
Total		**24,800**

Maintenance cost			
Year 3	20% beating up (Plant + planting)	200 plants	7,000
	Weeding and hoeing (4 times yr^{-1})	Lumpsum	3,000
	Irrigation (6 times)	Lumpsum	9,000
	Watch and ward	One year	9,990
	Contingency	Lumpsum	500
	Total		**29,490**
Year 4	15% beating up (Plant + planting)	150 plants	5,250
	Irrigation (2 times)	Lumpsum	3,000
	Weeding and hoeing (3 times yr^{-1})	Lumpsum	2,250
	Watch and ward	One year	9,990
	Total		**20,490**
Year 5	5% beating up (Plant + planting)	50 plants	1,750
	Weeding and hoeing (2 times yr^{-1}), removal of stone base from pond	Lumpsum	2,000
	Watch and ward	One year	9,990
	Total		**13,740**
Year 6			**9,990**
Year 7			**9,990**

Table 5.14. Year-wise cost summary for YM/HY/NL/02

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	14,4390
Year 2 (Planting and establishment)	24,800
Year 3 (1st maintenance)	29,490
Year 4 (2nd maintenance)	20,490
Year 5 (3rd maintenance)	13,740
Year 6 (4th maintenance)	9,990
Year 7 (5th maintenance)	9,990
Total	**2,52,890**

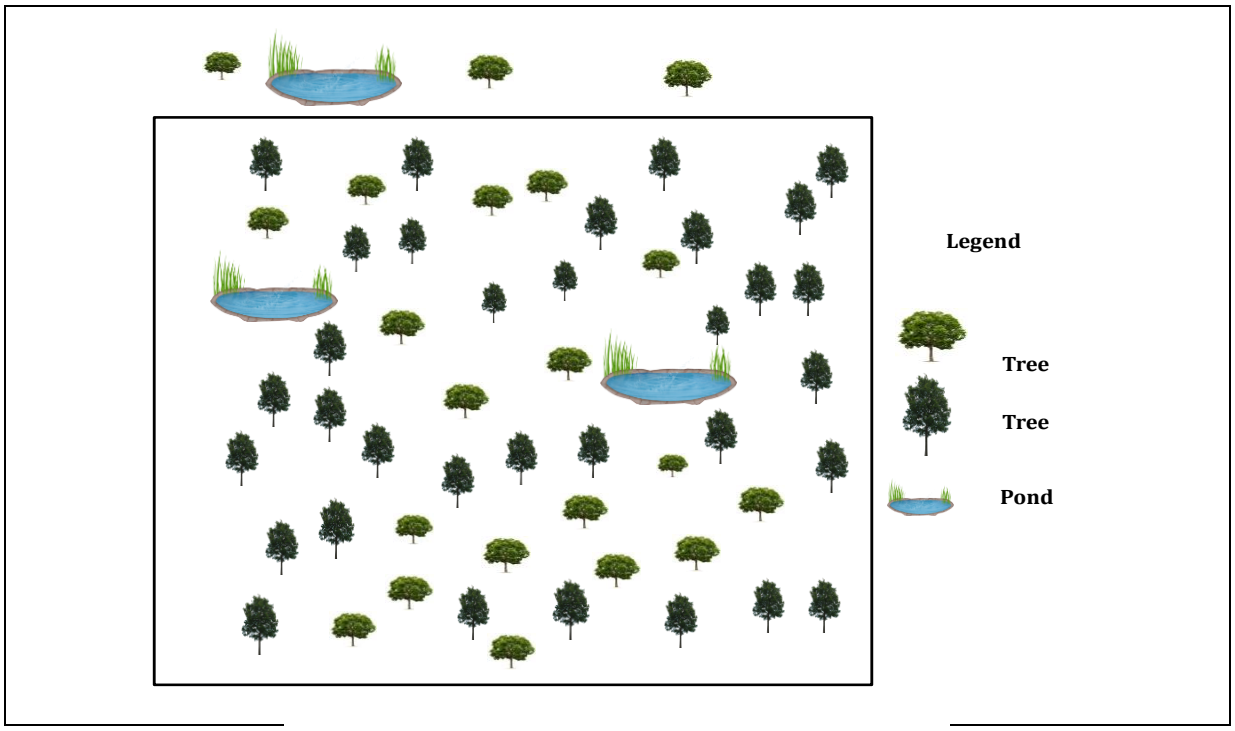


Fig. 5.10. Illustration of plantation in open forest

YM/HY/NL/03: Sowing on contour trenches

There are several areas along the river where general forest cover is good, yet contour trenches are required to be dug to conserve water and improve ground water recharge for promoting natural regeneration of the native vegetation. Seeds of thorny native tree/shrub species and grasses will be sown on the loose soil heaped along contour trenches to stabilize the contour trench, besides helping in artificial regeneration. Tree saplings *per se* will not be planted.

Species recommended

Native species of the area will be sown in the model. Few examples of species for the purpose of illustration are as follows:

Tree/shrub: *Acacia catechu, Acacia nilotica, Ziziphus nummularia, Carissa opaca,* etc.

Grass: *Chrysopogon fulvus, Heteropogon contortus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Poa annua, Arundo donax,* etc.

Important elements of the model (ha^{-1}) are:

Contour trenches: 200 contour trenches ha^{-1} of 3 m length, 45 cm width and 45 cm depth in staggered arrangement.

Dibbling: Seed of grasses and thorny species will be sown on the soil along contour trench.

Fencing: Not required.

Table 5.15. Cost norm for YM/HY/NL/03

Particular	Quantity ha^{-1}	Rs. ha^{-1} or 200 contour trenches ha^{-1}
Year 1 (Advance work)		
Survey and inspection paths, cleaning of spots of contour trenches,	1 ha	2,000
Survey and alignment of contour trenches (3 m x 0.60 m x 0.45 m)	200 contour trenches	600
Digging of contour trenches (3 m x 0.60 m x 0.60 m)	200 contour trenches	19,500
Advance soil work		**20,100**
Year 2 (Planting activity)		
Sowing of seed on contour trenches incl. cost of seed		1,200
Maintenance of contour trenches and seedlings (for 9 months.)		1,200
Total		**2,400**
Year 3		**2,070**
Year 4		**1,550**
Year 5		**1,550**
Year 6		**1,550**
Year 7		**1,550**

Table 5.16. Year-wise cost summary for YM/HY/NL/03

Year	Rs. ha^{-1}
Year 1 (Advance work)	20,100
Year 2 (Planting and establishment)	2,400
Year 3 (1st maintenance)	2,070
Year 4 (2nd maintenance)	1,550
Year 5 (3rd maintenance)	1,550
Year 6 (4th maintenance)	1,550
Year 7 (5th maintenance)	1,550
Total	**30,770**

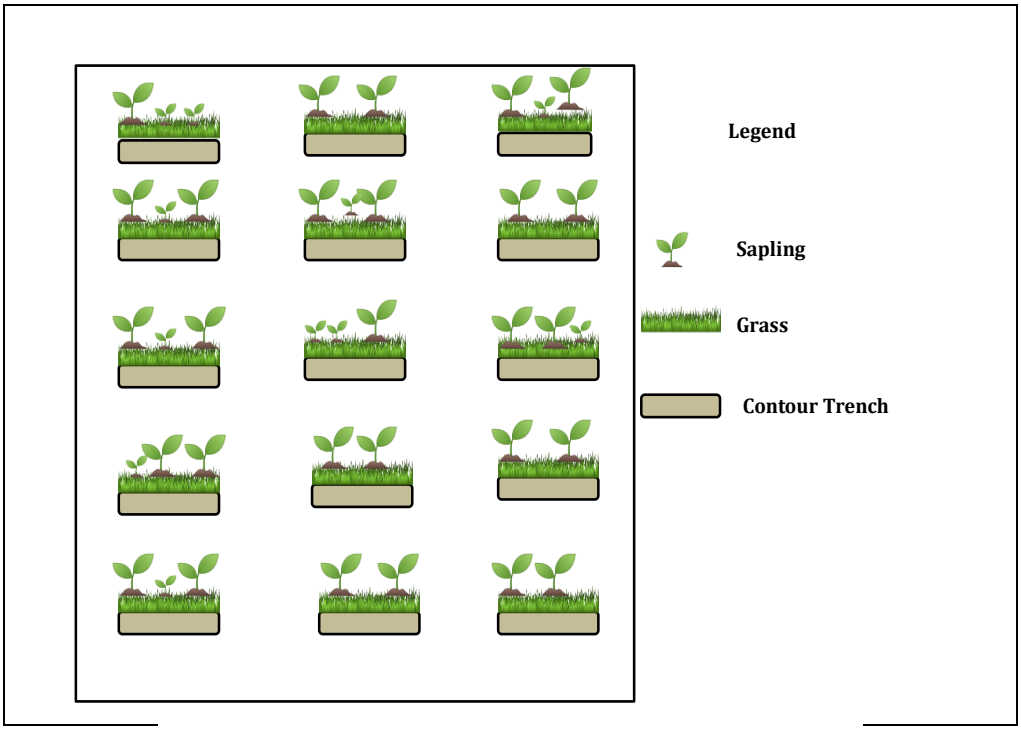


Fig. 5.11. Illustration of sowing on contour trenches

YM/HY/NL/04: Vegetative barrier

In hilly area such as in north Haryana, the width of river and tributaries is relatively less. The water level during rainy season rises high and the high momentum of flowing water that comes in contact with river bank tends to exerts erosive force on the soft loose soil present there. Presence of perennial vegetation with hydrophilic nature, deep rooted, ability for rapid establishment, low height, spreading tendency, helps in holding the soil and reducing the erosive action of water. A narrow strip of plants such as *Ipomeoa*, *Vitex negundo*, bhabhar grass, monopodial bamboo, cane, etc. would be planted.

Species recommended

Native species of the area will be sown in the model. Few examples of species for the purpose of illustration are as follows:

Shrub/bamboo/grass/others:*Phragmites karka, Arundo donax, Saccharum bengalense, Saccharum spontaneum, Ipomoea batatas, Vitex negundo, Scirpus affinis, Cyperus eleusinoides, Cyperus exaltatus, Themeda arundinacea, Vetiveria zizanioides, Melocanna*, etc.

Important elements of the model (ha^{-1}) are:

Fencing: Not required.

Advance soil work: Planting will be done by digging small sized pits, 30 cm x 30 cm x 30 cm sizes at the time of planting. Pits will not be dug in advance of the planting time.

No. of plants: 2,000 plants km^{-1} of stream length (1,000 plants km^{-1} on each side).

Maintenance: For one year after planting year.

Table 5.17. Cost norm for YM/HY/NL/04

Particular	Quantity 1,000 m	Rs./1,000
Year 1 (Advance work)		
Making inspection path, cleaning of spots for vegetative barrier	1,000 m	3,000
Cost of nursery stock (including 10% extra for culling)	1,000+100 nos.	33,000
Advance soil work		**36,000**
Year 2 (Planting activity)		
Digging of pits in soft, moist soil (0.30 m x 0.30 m x 0.30 m size)	1,000 pits	2,650
Planting in pits		6,000
Maintenance		1,200
Watch and ward (for 9 months)		2,500
Total		**12,350**
Year 3 (Maintenance 1st year) including 20% beating up		**8,000**
Year 4 (Maintenance 2nd year) including 5% beating up		**4,000**
Total for 1000 m length		**60,350**

Conversion of cost from km to ha basis

	km^{-1}	ha^{-1}
Year 1 (Advance work)	36,000	1,20,000
Year 2 (Planting activity)	12,350	41,167
Year 3 (Maintenance 1st year) including 20% beating up	8,000	26,667
Year 4 (Maintenance 2nd year) including 5% beating up	4,000	13,333
Total for 1000 m length or per ha (assuming 0.30 ha = 1000 m length)	60,350	2,01,167

Table 5.18. Year-wise cost summary for YM/HY/NL/04

Year	Rs. ha^{-1}
Year 1 (Advance work)	1,20,000
Year 2 (Planting and establishment)	41,167
Year 3 (1st maintenance)	26,667
Year 4 (2nd maintenance)	13,333
Total	**2,01,167**

D. Delhi

Sites in Delhi NCT for natural landscape in the riverscape were not proposed by SFD. However, a model on rehabilitation/strengthening of soil and moisture conservation measures has been proposed for forest areas in the catchment area of Yamuna river in Delhi NCT (elaborated under conservation interventions).

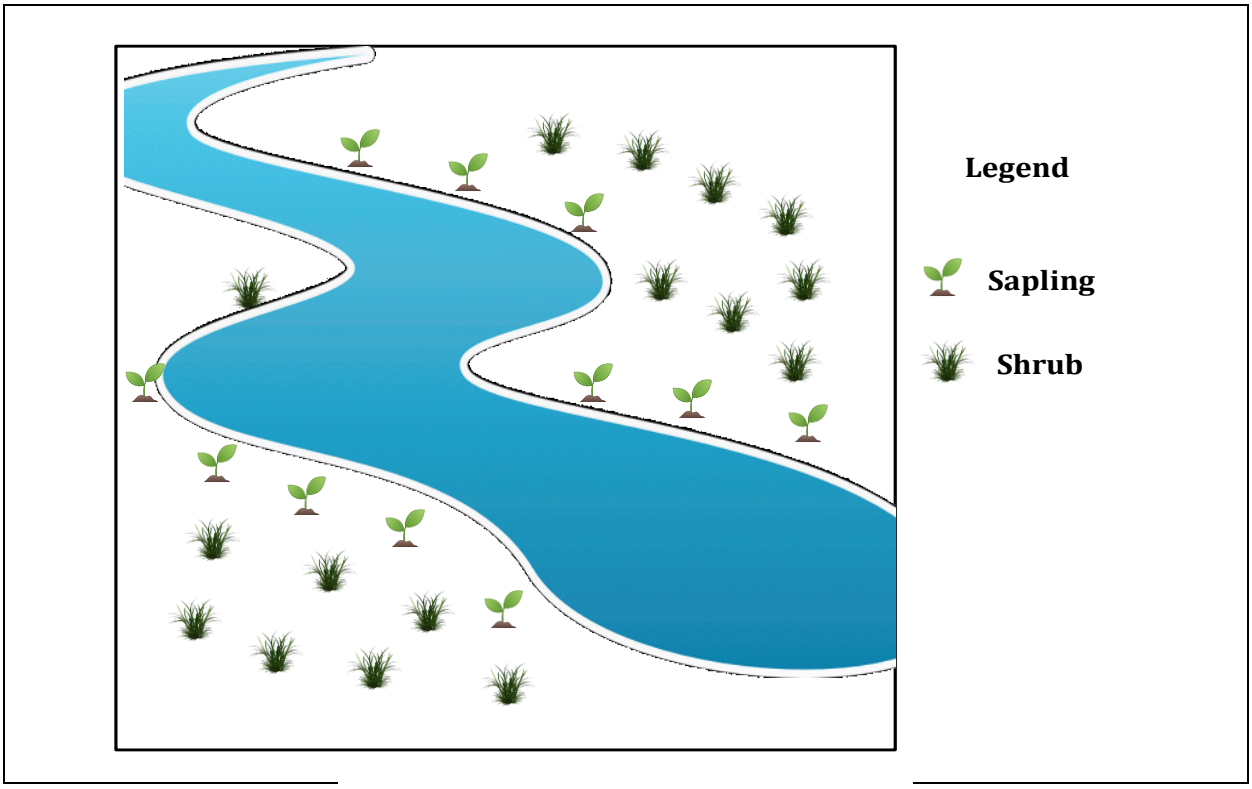


Fig. 5.12. Illustration of vegetative barrier

E. Uttar Pradesh

YM/UP/NL/01: Afforestation of erosion-prone ravinous slopes

This model will be applied in degraded forest areas in ravine formation having loose, sandy or kankar soil, rugged topography with steep slopes and high incidence of gully erosion. The area is full of *Prosopis juliflora* introduced through earlier afforestation programmes or invasion by this species. Native forest species need to be brought back in a phased manner by creating several gaps in the form of strips in *Prosopis* in places less prone to gully formation or soil erosion. The gaps will be created to the extent of 50 percent of the entire area by cutting off *P. juliflora* stems and their branches that project into the cleared strips. 200 contour trenches and 200 pits will be dug in the cleared strips uniformly distributed over an area of one hectare. 100 earthen check dams will be constructed per ha in areas prone to gully erosion. Plants of native tree, shrub and bamboo species will be planted in the pits. Sowing of native trees and grasses will be done on earthen check dams and contour trenches.

A protection trench will be dug all around the area and the soil will be heaped along the trench in the form of bund. Seeds of thorny and dense vegetation will be sown on this soil to create a biofence for protection of the area. Plants and fence will be maintained for five years. The treated patches will be kept free of invasive weeds or other interfering vegetation and shoots projecting from adjacent untreated area. The requirement of watch ward will reduce gradually.

Important elements of the model (ha^{-1}) are:

i. Clearing of 50% area: Strips of 5 m width will be cleared, alternating with 5 m wide uncleared strips, by cutting *Prosopis* at base and removal of shoots of *Prosopis* projecting from adjacent areas in the treated strips.
ii. Protection trench and biofence all around.
iii. Two hundred pits of 0.45 m x 0.45 m x 0.45 m and 200 contour trenches of size 3 m x 0.60 m x 0.45 m each.
iv. 100 earthen check dams of size 3 m x 0.90 m x 0.45 m each (121.5 m^3 volume will be equivalent to one ha).

v. Tree and bamboo saplings will be planted in pits.
vi. Sowing of grasses and native tree species (*Prosopis* not to be planted) on earthen check dams and contour trenches.
vii. Maintenance upto 5 years after plantation year with decreasing intensity including weeding and hoeing, removal of shoots of *Prosopis* projecting from adjacent areas in the treated strips, maintenance of fence.

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species on earthen check dams

Tree and shrub: As indicated above

Grass: *Saccharum bengalense,Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica, Vetiveria zizanioides,* etc.

Legume: *Alysicarpus rugosus, Rhynchosia minima, Indigofera glandulosa, Rhynchosia capitata, Alysicarpus longifolius, Stylosanthes hamata,* etc.

Species in pits

Tree and shrub:*Acacia nilotica, Azadirachta indica, Madhuca indica, Albizia lebbeck, Emblica officinalis, Bombax ceiba, Pithecellobium dulce, Ziziphus mauritiana, Cordia dichotoma, Dalbergia sissoo, Holoptelea integrifolia, Sesbania sesban, Capparis zeylanica, Capparis decidua,*etc.

Bamboo: *Dendrocalamus strictus,* etc.

Table 5.19. Cost norm for YM/UP/NL/01

Particular	Quantity ha^{-1}	Rate(Rs. 194 d^{-1})	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	45.59 ha^{-1}	45.59
Cutting of *Prosopis* from strips of 5 m width totalling 50% area	1 km	899.33 km^{-1}	899.33
Alignment			
a) Pits	200 no.	36.91/100	73.82
b) Contour trenches	200 no.	89.04/100	198.08
c) Earthen check dams	100 no.	89.04/100	89.04
Soil work			
a) Pits (45 cm x 45 cm x 45 cm)	200 no.	9.03 pit^{-1}	1,806
b) Contour trenches (3.00 m x 0.60 m x 0.45 m)	200 no.	79.93 $trench^{-1}$	15,986
c) Earthen check dams (3.00 m x 0.90 m x 0.45 m, 100 no. or other size/no. equivalent to 121.5 m^3	121.5 m^2	105 m^{-3}	12,757.50
Protective structures			
Protection trench			
a) Protection trench (1.20 m wide at top, 0.90 m at base and 1.00 m deep)	50 m	98.63 m^{-1}	4,931.50
b) Jhakarhbari work, including transportation (with protection trench)	50 m	8.68 m^{-1}	434
Stonewall fence			
a) Stone wall fence with 10 cm earthing up (1.20+0.80/2) x 1.20 m (stone available beyond 500 m)	50 m	423.75 m^{-1}	21,187.50
Making of inspection path 1 m wide inside plantation	50 m	2,085.33 km^{-1}	104.27
Cost of seed			
a) Quality seed for pits (200 plants + 20% for culling)	240 plants	Lump sum	2,400

b) Quality seed for contour trenches (at double of normal rate)	200 trenches	15.50 trench^{-1}	3,100
c) Seed for earthen check dams (other than *P. juliflora*) (at double of normal rate)	Equivalent to 100 earthen check dams	15.50 earthen check dam^{-1}	1,550
d) Seed for protection trenches (other than *P. juliflora*) (at double of normal rate)	50 m	2.40 m^{-1}	120
Cost of plant (incl. 20% culling for obtaining quality stock) for pits	240	7 plant^{-1}	1,680
Plantation sign board (per 25 ha)	1	3,500/25 ha	140
Miscellaneous			1,000
Total			68,482.63 **or 68,483**
Planting year			
Refilling/dressing pits, trenches and earthen check dams			
a) Refilling pits (45 cm x 45 cm x 45 cm)	200 no.	0.90 pit^{-1}	180
b) Refilling contour trenches (3.00 m x 0.60 m x 0.45 m)	200 no.	2.22 trench^{-1}	444
c) Dressing contour trenches	200 no.	1.74 trench^{-1}	348
d) Dressing earthen check dams	100 no.	1.74 earthen check dam^{-1}	194
e) Protection trenches	50 m	1.45 m^{-1}	72.50
Transportation of plants upto 25 km	200 no.	1.94 plant^{-1}	388
Local transport of plants	200 no.	1.52 plant^{-1}	304
Sowing of seed			
a) Sowing of seeds on contour trenches	200 trenches	1.45 trench^{-1}	290
b) Sowing of seeds on earthen check dams	100 earthen check dams	1.45 earthen check dam^{-1}	145
c) Sowing of seeds on protection trenches in two lines	50 m	1.11 m^{-1}	55.50
d) Re-sowing of seeds of a, b and c			490.50
Planting in pits	200 plants	3.47 plant^{-1}	694
Application of manure, AM, micronutrients	1,100 plants	5.80 plant^{-1}	6,380
Weeding and hoeing			
a) Around pits (three times)	200 pits x 3	89.90/100	539.00
b) On contour trenches (three times)	200 trenches x 3	298.89/100 trench	1,793.34
c) On earthen check dams (three times)	100 earthen check dams	298.89/100 earthen check dam^{-1}	298.89
d) On protection trenches (three times)	40 m x 3	1.11 m^{-1}	133.20
Irrigation of plants (6 times)	1,100 plants x 6	1.70 plant^{-1}	11,220
Removal of shoots of *Prosopis* projecting from adjacent areas in the treated strips and miscellaneous silvicultural works	0.5 ha	508.33	254.19
Watch and ward for 9 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		4,550/26 days of 8 hrs	9,450
Contingency	Lump sum		2,000
Total			35,654.10 **or 35,654**

Maintenance cost			
Year 3			
20% beating up of planted seedlings	40 plants	30 plant^{-1}	1,200
Weeding and hoeing			
a) Around pits (three times)	200 pits x 3	89.90/100	539.40
b) On contour trenches (three times)	200 trenches x 3	298.89/100 trench	1,793.34
c) On earthen check dams (three times)	100 earthen check dams x 3	298.89/100 earthen check dams	896.67
d) On protection trenches (three times)	50 m x 3	1.11 m^{-1}	188.50
Irrigation of plants (12 times)	1,100 plants x 12	1.70 plant^{-1}	22,440
Application of manure, AM, micronutrients	1,100 plants	5.80 plant^{-1}	6,380

Removal of shoots of *Prosopis* projecting from adjacent areas in the treated strips and miscellaneous silvicultural works	0.5 ha	508.33	254.19
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			43,642.08 **or43,643**
Year 4			
15% beating up of planted seedlings	30 plants	30 plant^{-1}	900
Weeding, and hoeing (1 time yr^{-1})			
a) Around pits	200 pits x 1	89.90/100	199.80
b) On contour trenches	200 trenches x 1	298.89/100 trench	597.78
c) On earthen check dams	100 earthen check dams x 1	298.89/100 earthen check dams	298.89
Irrigation of plants (6 times)	1,100 plants x 6	1.70 plant^{-1}	11,220
Application of manure, AM, micronutrients	1,100 plants	5.80 plant^{-1}	6,380
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			29,526.47 **or 29,527**
Year 5			
5% beating up of planted seedlings	10 plants	30 plant^{-1}	300
Weeding and hoeing (1 time yr^{-1})			
a) Around pits	200 pits x 1	89.90/100	199.80
b) On contour trenches	300 trenches x 1	298.89/100 trench	896.67
c) On earthen check dams	100 earthen check dams x 1	298.89/100 earthen check dams	298.89
Irrigation of plants (3 times)	1,100 plants x 3	1.70 plant^{-1}	5,610
Application of manure, AM, micronutrients	1,100 plants	5.80 plant^{-1}	6,380
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			23,615.36 **or 23,615**
Year 6			
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			**9,950**
Year 7			**9,950**

Table 5.20. Year-wise cost summary for YM/UP/NL/01

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	68,483
Year 2 (Planting and establishment)	35,654
Year 3 (1st maintenance)	43,643
Year 4 (2nd maintenance)	29,527
Year 5 (3rd maintenance)	23,615
Year 6 (4th maintenance)	9,950
Year 7 (5th maintenance)	9,950
Total	**2,20,822**

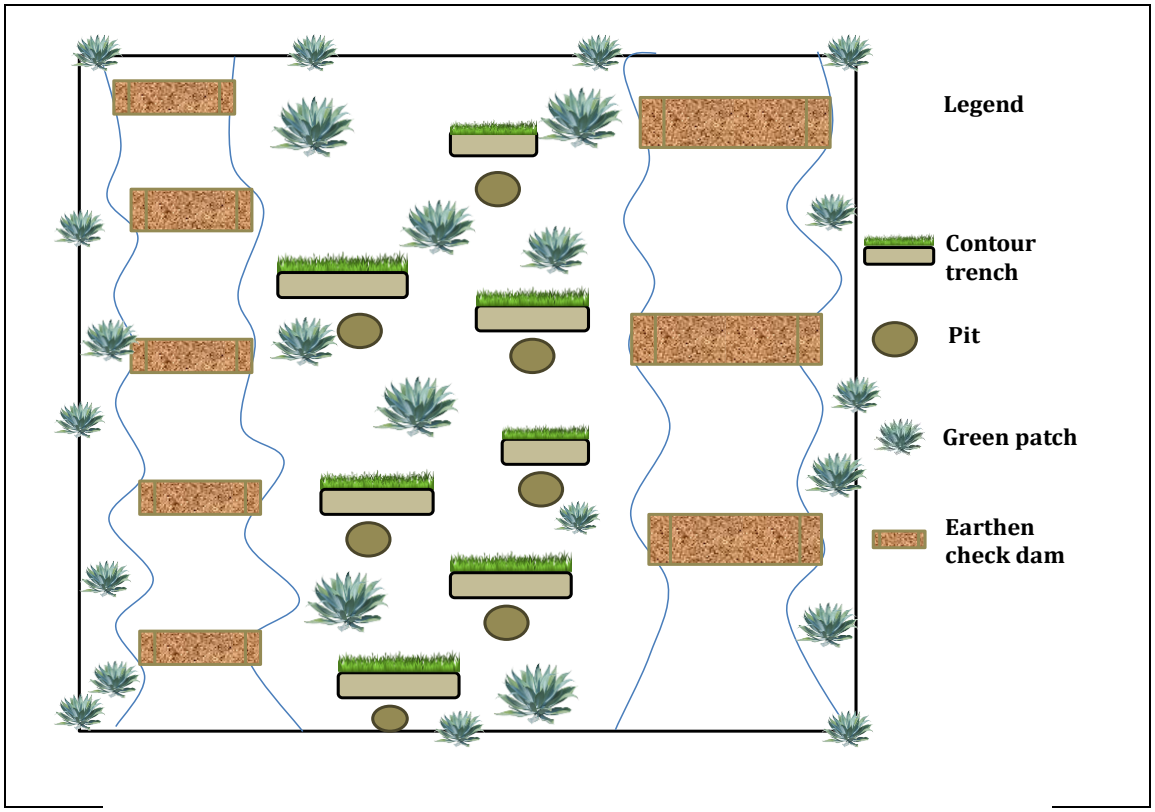


Fig. 5.13. Illustration of afforestation in erosion prone ravenous areas

YM/UP/NL/02: Afforestation of slopes with shallow soil

This model will be applied in areas where terrain is undulating with shallow soil. Slopes are gentle or moderate and have poor moisture retention ability. The soil is poor in nutritional content. Contour trenches are required to collect rainwater for supporting moisture and soil conservation. Contour trenches will be made and seeds of grasses, legumes and local vegetation will be sown on contour trenches. Some trees already exist in such sites, but their density is quite low. Such trees will be retained and supported through soil working and tending activities. In the model, it is envisaged to make 300 contour trenches ha^{-1}. Additionally, 200 pits will also be dug. Sowing of native grasses, legumes shrubs and trees will be done on trenches. Seedlings will be planted in pits.

The areas where this model is proposed to be implemented have high incidence of grazing. Barbed wire fence alone is not effective. Biofence takes longer time to establish. A combination of both will be used.

Important elements of the model (ha^{-1}) are:

i. Biofence of thorny fast-growing plants and barbed wire fence all around.
ii. Three hundred trenches of 3 m x 0.6 m x 0.45 m.
iii. Two hundred pits of 0.45 m x 0.45 m x 0.45 m.
iv. Seedlings in pits.
v. Sowing of grasses and native tree species (*Prosopis* not to be sown) along trenches.
vi. Maintenance upto 5 years after plantation year.

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species on contour trenches
Tree and shrub: As indicated above
Grass: *Saccharum bengalense,Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica*, *Vetiveria zizanioides*, etc.
Legume: *Alysicarpus rugosus, Rhynchosia minima, Indigofera glandulosa, Rhynchosia capitata, Alysicarpus longifolius,Stylosanthes hamata*, etc.
Species in pits
Tree and shrub: *Acacia nilotica, Azadirachta indica, Madhuca indica, Butea monosperma, Albizia lebbeck, Emblica officinalis, Bombax ceiba, Pithecellobium dulce, Ziziphus mauritiana, Cordia dichotoma, Dalbergia sissoo, Acacia nilotica, Holoptelea integrifolia, Sesbania sesban, Capparis zeylanica, Capparis decidua*,etc.
Bamboo in pits: *Dendrocalamus strictus*, etc.

Table 5.21. Cost norm for YM/UP/NL/02

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	45.59 ha^{-1}	45.59
Cleaning of area	1 ha	299.73 ha^{-1}	299.73
Alignment			
a) Pits	200 no.	36.91/100	73.82
b) Contour trenches	300	89.04/100	267.12
Soil work			
a) Pits (45 cm x 45 cm x 45 cm)	200 no.	9.03 pit^{-1}	1,806
b) Contour trenches (3.00 m x 0.60 m x 0.45 m)	300 no.	79.93 $trench^{-1}$	23,979
Protective structure			
Protection trench			
a) Protection trench (1.20 m wide at top, 0.90 m at base and 1.00 m deep)	40 m	98.63 m^{-1}	3,945.20
b) Jhakarhbari work, including transportation (with protection trench)	40 m	8.68 m^{-1}	347.20
Stonewall fence			
a) Stone wall fence with 10 cm earthing up (1.20+0.80/2) x 1.00 m (stone available within 500 m)	45 m	145.47 m^{-1}	6,546.15
b) Stone wall fence with 10 cm earthing up (1.20+0.80/2) x 1.00 m (stone available beyond 500 m)	15 m	265.95 m^{-1}	3,989.25
Miscellaneous advance silvicultural works	1 ha	508.33 ha^{-1}	508.33
Making of inspection path			
a) 3 m wide path inside plantation for jeep	25 m	8,984.30 km^{-1}	224.61
b) 1 m wide path inside plantation	50 m	2,085.33 km^{-1}	104.27
Cost of seed			
a) Quality seed for pits (200 plants + 20% for culling)	240 plants	Lump sum	2,400
b) Quality seed for contour trenches (at double of normal rate)	300 trenches	15.50 $trench^{-1}$	4,650
c) Seed for protection trenches (other than *P. juliflora*) (at double of normal rate)	40 m	2.40 m^{-1}	96
Cost of plant (incl. 20% culling for obtaining quality stock) for pits	240	7 $plant^{-1}$	1,680
Plantation sign board (per 25 ha)	1	3,500/25 ha	140
Miscellaneous			1,000
Total			52,102.27 **or 52,102**
Planting year			
Refilling/dressing pits and trenches			

a) Refilling pits (45 cm x 45 cm x 45 cm)	200 no.	0.90 pit^{-1}	180
b) Refilling contour trenches (3.00 m x 0.60 m x 0.45 m)	300 no.	2.22 $trench^{-1}$	666
c) Dressing contour trenches	300 no.	1.74 $trench^{-1}$	522
d) Protection trenches	40 m	1.45 m^{-1}	58
Transportation of plants upto 25 km	200 no.	1.94 $plant^{-1}$	388
Local transport of plants	200 no.	1.52 $plant^{-1}$	304
Planting in pits	200 plants	3.47 $plant^{-1}$	694
Sowing of seed			
a) Sowing of seeds on contour trenches	300 trenches	1.45 $trench^{-1}$	435
b) Sowing of seeds on protection trenches in two lines	40 m	1.11 m^{-1}	44.40
c) Re-sowing of seeds of a and b			479.40
Application of manure, AM, micronutrients	1,100 plants	5.80 $plant^{-1}$	6,380
Weeding and hoeing			
a) Around pits (three times)	200 pits x 3	89.90/100	539.00
b) On contour trenches (three times)	300 trenches x 3	298.89/100 trench	2,690.01
c) On protection trenches	40 m x 3	1.11 m^{-1}	133.20
Irrigation of plants (6 times)	1,100 plants x 6	1.70 $plant^{-1}$	11,220
Watch and ward for 9 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		4,550/26 d of 8 hrs	9,450
Contingency	Lump sum		2,000
Total			36,183.01 **or 36,183**

Maintenance cost			
Year 3			
20% beating up of planted seedlings	40 plants	30 $plant^{-1}$	1,200
Weeding and hoeing (3 times yr^{-1})			
a) Around pits (three times)	200 pits x 3	89.90/100	539.40
b) On contour trenches	300 trenches x 3	298.89/100 trench	2,690.01
c) On protection trenches	40 m x 3	1.11 m^{-1}	133.20
Irrigation of plants (12 times)	1,100 plants x 12	1.70 $plant^{-1}$	22,440
Application of manure, AM, micronutrients	1,100 plants	5.80 $plant^{-1}$	6,380
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			43,332.61 or **43,333**
Year 4			
15% beating up of planted seedlings	30 plants	30 $plant^{-1}$	900
Weeding and hoeing (1 time yr^{-1})			
a) Around pits	200 pits x 1	89.90/100	199.80
b) On contour trenches	300 trenches x 1	298.89/100 trench	896.67
Irrigation of plants (6 times)	1,100 plants x 6	1.70 $plant^{-1}$	11,220
Application of manure, AM, micronutrients	1,100 plants	5.80 $plant^{-1}$	6,380
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			29,526.47 or **29,527**
Year 5			
5% beating up of planted seedlings	10 plants	30 $plant^{-1}$	300
Weeding and hoeing (1 time yr^{-1})			
a) Around pits	200 pits x 1	89.90/100	199.80
b) On contour trenches	300 trenches x 1	298.89/100 trench	896.67
Irrigation of plants (3 times)	1,100 plants x 3	1.70 $plant^{-1}$	5,610
Application of manure, AM, micronutrients	1,100 plants	5.80 $plant^{-1}$	6,380

Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			23,316.47 or **23,316**
Year 6			
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			**9,950**
Year 7			**9,950**

Table 5.22. Year-wise cost summary for YM/UP/NL/02

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	52,102
Year 2 (Planting and establishment)	36,183
Year 3 (1st maintenance)	43,333
Year 4 (2nd maintenance)	29,527
Year 5 (3rd maintenance)	23,316
Year 6 (4th maintenance)	9,950
Year 7 (5th maintenance)	9,950
Total	**2,04,361**

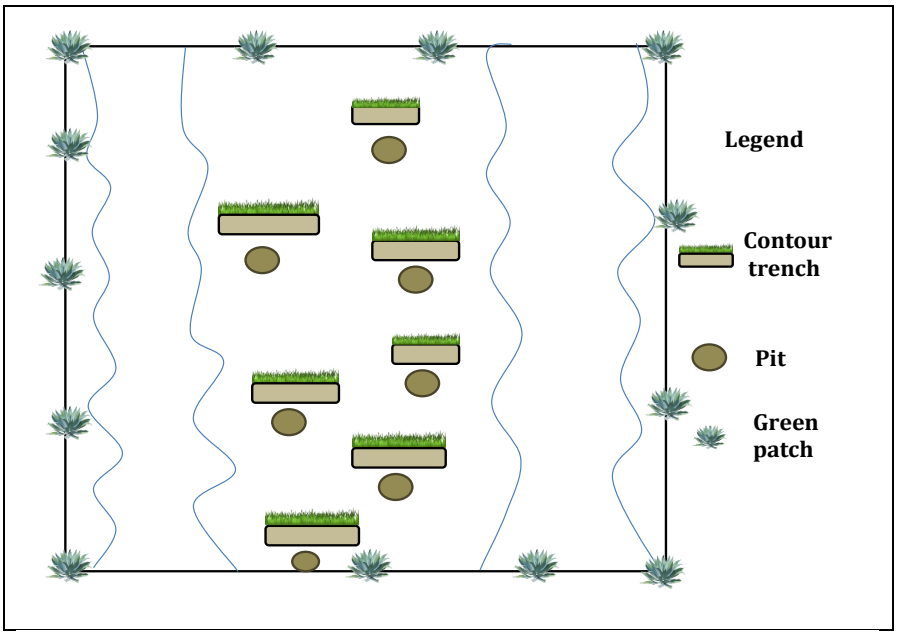


Fig. 5.14. Illustration of afforestation of slopes with shallow soil

YM/UP/NL/03: Plantation in open forest

This model will be applied in forest areas with have poor crown cover. The terrain of the proposed sites is mostly flat and the soil is poor in nutritional status. Some seedlings and trees already exist in such sites, but their density is quite low. Such saplings and trees will be retained and supported through soil working activities. Planting will be done in pits of 0.45 m x 0.45 m x 0.45 m size at density of 1000 plants ha^{-1} and maintained for five years after the planting year. *Kachcha* water pond(s) of total 50,000 L storage capacity will be created as a part of this model outside the plantation area for free access of grazing animals. 700 m^2 strip of grass will be planted around this pond which will be protected with brushwood fence during first year. *Kachcha* water pond(s), with base of stone or some impermeable or semi-permeable material, of total 25,000 L will be created

inside the plantation to store water for a longer period of time for irrigation of plants; after two years the stone at the base will be removed to facilitate ground water recharge.

The areas where this model is proposed to be implemented have high incidence of grazing. Barbed wire fence alone is not effective. Biofence takes longer time to establish. A combination of both will be used.

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species in pits

Tree and shrub: *Azadirachta indica, Madhuca indica, Albizia lebbeck, Emblica officinalis, Bombax ceiba, Pithecellobium dulce, Ziziphus mauritiana, Cordia dichotoma, Dalbergia sissoo, Acacia nilotica, Holoptelea integrifolia, Sesbania sesban, Capparis zeylanica, Capparis decidua,*etc.

Bamboo: *Dendrocalamus strictus,* etc.

Grass around pond: *Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica*, etc.

Important elements of the model (ha^{-1}) are:

i. Fencing and protection trench (1.20 m wide at top, 0.90 m at base and 1.00 m deep) all around (Cost of barbed wire fence and cost of protection trench may be given separately)
ii. Biofence of fast-growing thorny plants all around.
iii. One thousand fifty pits of 0.45 m x 0.45 m x 0.45 m size.
iv. Planting of seedlings in pits.
v. Application of manure / vermicompost to plants in the pits.
vi. Beating up of plants 20% in first year, 15% in second year and 5% in third year.
vii. Maintenance for 1+5 years (planting year plus five additional years) including weeding and hoeing, maintenance of fence, watch and ward.
viii. *Kachcha water pond* 50,000 L outside the plantation area in nearby place along with 700 m^2 strips of grass.
ix. *Kachcha* water pond of 25000 L having base of stone pitching or some impermeable or semi-permeable material.

Table 5.23. Cost norm for YM/UP/NL/03

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	45.59 ha^{-1}	45.59
Cleaning of plantation area	1 ha	299.73 ha^{-1}	299.73
Cleaning of area outside plantation area for planting of grass	250 m^2	299.73 ha^{-1}	7.49
Alignment of pits	1,050 no.	36.91/100	387.56
Digging of pits (45 cm x 45 cm x 45 cm)	1,050 no.	9.03 pit^{-1}	9,481.50
Protective structure			
Protection trench			
a) Protection trench (1.20 m wide at top, 0.90 m at base and 1.00 m deep)	50 m	98.63 m^{-1}	4,931.50
b) Jhakarhbari work, including transportation (along protection trench)	50 m	8.68 m^{-1}	434
Ploughing of area for pasture grass around pond, loosening and	250 m^2	Lumpsum	25

levelling of soil			
Stonewall fence			
a) Stone wall fence with 10 cm earthing up (1.20+0.80/2) x 1.20 m (stone available beyond 500 m)	50 m	423.75 m^{-1}	21,187.50
Kachcha pond inside plantation area with stone pitching at base			
a) Digging of *Kachcha* pond inside plantation in area of hard rock	25 m^3	128 m^{-3}	3,200
b) Providing stone pitching at base (incl. cost of material)	Lump sum		800
Digging of *Kachcha* water pond outside plantation with *Kachcha* base	50 m^3	128 m^{-3}	6,400
Making of inspection path			
a) 3 m wide path inside plantation for jeep	25 m	8,984.30 km^{-1}	224.61
b) 1 m wide path inside plantation	50 m	2,085.33 km^{-1}	104.27
Cost of seed			
a) Quality seed for pits (1,050 plants + 20% for culling)	1,260 plants	Lump sum	1,260
b) Seed for protection trenches (other than *P. juliflora*) (at double of normal rate)	50 m	2.40 m^{-1}	120
Cost of plants (incl. 20% culling for obtaining quality stock) for pits	1,260	7 $plant^{-1}$	8,820
Plantation sign board (per 25 ha)	1	3,500/25 ha	140
Miscellaneous			1,000
Total			58,868.57 **or 58,869**
Planting year			
Refilling/dressing pits and trenches			
a) Refilling pits (45 cm x 45 cm x 45 cm)	1,050 no.	0.90 pit^{-1}	945
b) Dressing protection trenches	50 m	1.45 m^{-1}	72.50
Transportation of plants upto 25 km	1,050 no.	1.94 $plant^{-1}$	2,037
Local transport of plants	1,050 no.	1.52 $plant^{-1}$	1,596
Planting of plants in pits	1,050 plants	3.47 $plant^{-1}$	3,643.50
Sowing of seed			
a) Sowing of seeds on protection trenches in two lines	50 m	1.11 m^{-1}	55.50
b) Sowing of pasture grass around outer pond (incl. cost of seed)	250 m^2	524.80 ha^{-1}	13.12
c) Re-sowing of seeds of a and b			68.62
Creation of brushwood fence around pasture grass area	120 m	8.68 m^{-1}	1,041.60
Application of manure, AM, micronutrients in pits	1,050 plants	5.80 $plant^{-1}$	6,090
Application of manure to pasture grass	250 m^2	Lump sum	50
Weeding and hoeing			
a) Around pits (three times)	1,050 pits x 3	89.90/100	2,831.85
b) On protection trenches (three times)	50 m x 3	1.11 m^{-1}	166.50
c) In pasture grass area (two times)	250 m^2 x 2	Lumpsum	150
Irrigation			
a) Plants in pits (6 times)	1,050 plants x 6	1.70 $plant^{-1}$	10,710
b) Pasture grass area (two times)	250 m^2 x 2	Lumpsum	100
Watch and ward for 9 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		4,550/26 days of 8 hrs	9,450
Contingency	Lump sum		2,000
Total			41,021.19 **or 41,021**

Maintenance cost			
Year 3			
20% beating up of planted seedlings	210 plants	30 $plant^{-1}$	6,300
Weeding and hoeing			
a) Around pits (three times)	1,050 pits x 3	89.90/100	2,831.85

b) On protection trenches (three times)	50 m x 3	1.11 m^{-1}	166.50
Irrigation			
a) Plants in pits (12 times)	1,050 plants x 12	1.70 $plant^{-1}$	21,420
b) Pasture grass area (two times)	250 m^2 x 2	Lumpsum	200
Application of manure, AM, micronutrients in pits	1,050 plants	5.80 $plant^{-1}$	6,090
Application of manure to pasture grass	250 m^2	Lump sum	50
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			47,008.35 or **47,008**
Year 4			
15% beating up of planted seedlings	158 plants	30 $plant^{-1}$	4,740
Weeding and hoeing			
a) Around pits (1 time yr^{-1})	1,050 pits x 1	89.90/100	943.95
Irrigation			
a) Plants in pits (6 times)	1,050 plants x 6	1.70 $plant^{-1}$	10,710
Application of manure, AM, micronutrients in pits	1,050 plants	5.80 $plant^{-1}$	6,090
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			32,433.95 **or 32,434**
Year 5			
5% beating up of planted seedlings	53 plants	30 $plant^{-1}$	1,590
Weeding and hoeing (1 time yr^{-1})			
a) Around pits	1,050 pits x 1	89.90/100	943.95
Irrigation of plants (3 times)	1,050 plants x 3	1.70 $plant^{-1}$	1,785
Application of manure,AM, micronutrients	1,050 plants	5.80 $plant^{-1}$	6,090
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			20,358.95 or **20,359**
Year 6			
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			**9,950**
Year 7			**9,950**

Table 5.24. Year-wise cost summary for YM/UP/NL/03

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	58,869
Year 2 (Planting and establishment)	41,021
Year 3 (1^{st} maintenance)	47,008
Year 4 (2^{nd} maintenance)	32,434
Year 5 (3^{rd} maintenance)	20,359
Year 6 (4^{th} maintenance)	9,950
Year 7 (5^{th} maintenance)	9,950
Total	**2,19,591**

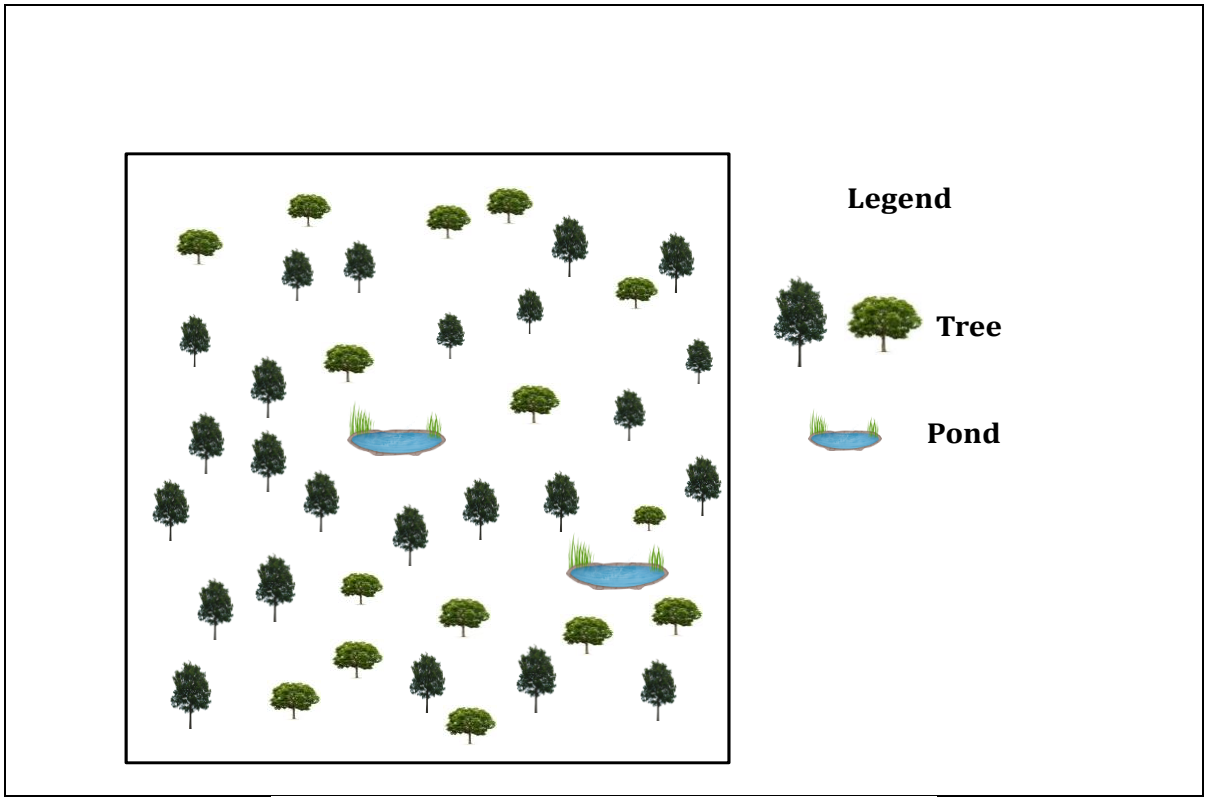


Fig. 5.15. Illustration of plantation in open forest

YM/UP/NL/04: Plantation in open forest ravinous areas

This model will be applied in ravine areas with less steep slopes (less than 15^0) having open forest cover. The afforestation model developed by State Forest Research Institute, Kanpur will be used that prescribes planting in V-ditches (contour ridges) spaced at 4 m intervals in a multi-storey arrangement. Contour furrows of 0.15 m x 0.15 m will be made between V-ditches. Trees, fodder grasses and legumes will be raised.

Cost norm for YM/UP/NL/04 (Rs. ha^{-1})

Cost per ha is **Rs. 2,50,000**

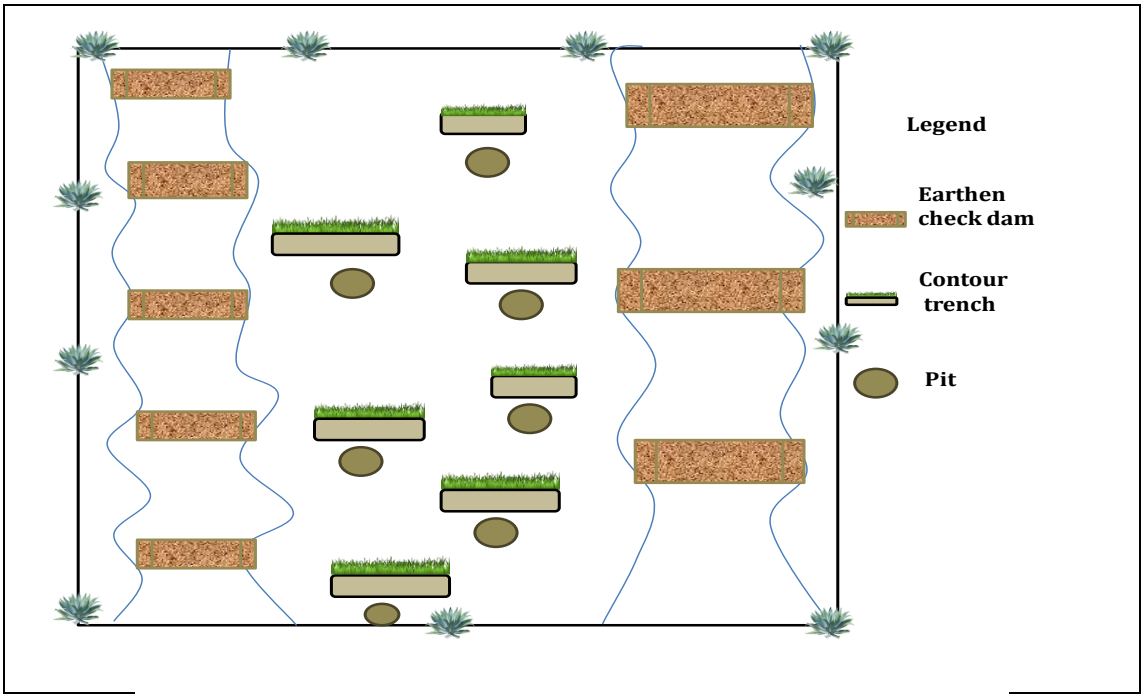


Fig. 5.16. Illustration of plantation in open forest ravinous areas

YM/UP/NL/05: Rehabilitation of weed-infested forest areas

This model will be applied in moist forest areas in Shiwalik hills in northern part of Uttar Pradesh and other areas where natural regeneration is not able to establish due to presence of weeds and damage by grazing animals. The sites are infested with moderate to dense growth of various shrub species, including *Lantana*, having invasive nature and low ecological and economic utility. The roots of the bushes hold soil, and *en masse* uprooting of bushes for planting of economic trees would be undesirable as it would promote soil erosion. In such areas, native forest species would be regenerated in a phased manner by enrichment planting. Moisture conservation activities are also proposed to be carried out to create more favourable environment for artificial and natural regeneration of indigenous species.

In this model, the area will be fenced and small pockets, 150 in number per hectare, of about 20 m^2 area would be cleared of invasive shrub species by uprooting them. Seedlings of species having ecological or economic utility, wherever present, will be retained while creating these gaps, and soil will be worked to make *thala* around them. Passages connecting such gaps will also be cleared to allow movement of workers between the gaps. One trench of size 3 m length, 45 cm width and 45 cm depth will be dug in each gap. A pit of 45 cm x 45 cm x 45 cm would be dug about one metre downhill the trench at the middle of the length of the trench. Enrichment planting of seedlings of indigenous species will be done in the pits. Direct sowing of seeds of indigenous trees will be carried out at three points (one each at both ends and in the middle) on the soil heaped along the trench. Grass slips will be planted at six points along the trench. The treated patches will be kept free of weeds and of shoots projecting from adjacent untreated area. Plants and fence will be maintained for five years.

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species in pits

Tree and shrub:*Terminalia alata, Terminalia bellirica, Anogeissus latifolia, Lagerstroemia parviflora, Haldina cordifolia, Albizia lebbeck, Syzygium cumini, Bombax ceiba, Pithecellobium dulce, Cordia dichotoma, Dalbergia sissoo, Acacia nilotica, Holoptelea integrifolia, Ficus religiosa, Ficus benghalensis, Madhuca indica,* etc.

Important elements (ha^{-1}):

i. Fencing of site with stone wall or barbed wire with biofence.
ii. Clearing of 30% area: 3000 sq m total area (150 patches of about 20 m^2 area each, inspection paths connecting the patches) will be cleared by uprooting shrubs.
iii. One hundred fifty contour trenches of size 3 m x 0.45 m x 0.45 m.
iv. One hundred fifty pits of 0.45 m x 0.45 m x 0.45 m.
v. Planting of seedlings in pits.
vi. Sowing of tree seeds at 3 places per trench and planting of 6 grass slips per trench. More than one seed may be sown per spot to ensure seedling establishment at each spot.
vii. Application of manure / vermicompost to plants in the pits.
viii. Maintenance for 5 years after planting year including weeding and hoeing, removal of shoots of plants projecting from adjacent areas in the treated patches.

Table 5.25. Cost norm for YM/UP/NL/05

Particulars	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	45.59 ha^{-1}	45.59
Cleaning of area by uprooting shrubs including *Lantana*	0.30 ha	2997.66 ha^{-1}	899.30
Alignment			
a) Pits	150 no.	36.91/100	55.37
b) Contour trenches	150 no.	89.04/100	133.56
Soil work			
a) Pits (45 cm x 45 cm x 45 cm)	150 no.	9.03 pit^{-1}	1,354.50
b) Contour trenches (3.00 m x 0.60 m x 0.45 m)	150 no.	79.93 $trench^{-1}$	11,989.50
Protective structure			
Protection trench			
a) Protection trench (1.20 m wide at top, 0.90 m at base and 1.00 m deep)	40 m	98.63 m^{-1}	3,945.20
b) Jhakarhbari work, including transportation (with protection trench)	40 m	8.68 m^{-1}	347.20
Stonewall fence			
a) Stone wall fence with 10 cm earthing up (1.20+0.80/2) x 1.00 m (stone available within 500 m)	45 m	145.47 m^{-1}	6,546.15
b) Stone wall fence with 10 cm earthing up (1.20+0.80/2) x 1.00 m (stone available beyond 500 m)	15 m	265.95 m^{-1}	3,989.25
Making of thawla around pre-existing seedlings, saplings	500 no.	1.94 $plant^{-1}$	970
Miscellaneous advance silvicultural works	1 ha	508.33 ha^{-1}	508.33
Making of inspection path			
a) 3 m wide path inside treatment area for jeep	25 m	8,984.30 km^{-1}	224.61
b) 1 m wide path inside treatment area	50 m	2,085.33 km^{-1}	104.27

Cost of seed			
a) Quality seed for pits (150 plants + 20% for culling)	180 plants	Lump sum	1,800
b) Quality seed for contour trenches (at double of normal rate)	150 trenches	15.50 trench^{-1}	2,325
c) Seed for protection trenches (other than *P. juliflora*) (at double of normal rate)	40 m	2.40 m^{-1}	96
Cost of plant (incl. 20% culling for obtaining quality stock) for pits	180	7 plant^{-1}	1,260
Plantation sign board (per 25 ha)	1	3,500/25 ha	140
Miscellaneous			1,000
Total			37,733.83 **or 37,734**
Planting year			
Refilling/dressing pits and trenches			
a) Refilling pits (45 cm x 45 cm x 45 cm)	150 no.	0.90 pit^{-1}	135
b) Refilling contour trenches (3.00 m x 0.60 m x 0.45 m)	150 no.	2.22 trench^{-1}	333
c) Dressing contour trenches	150 no.	1.74 trench^{-1}	261
d) Protection trenches	40 m	1.45 m^{-1}	58
Transportation of plants upto 25 km	150 no.	1.94 plant^{-1}	291
Local transport of plants	150 no.	1.52 plant^{-1}	228
Planting in pits	150 plants	3.47 plant^{-1}	520.50
a) Sowing of seeds on contour trenches	150 trenches	1.45 trench^{-1}	219.50
b) Sowing of seeds on protection trenches in two lines	40 m	1.11 m^{-1}	44.40
c) Re-sowing of seeds of a and b			261.90
Application of manure, AM, micronutrients	600 plants	5.80 plant^{-1}	3,480
Weeding and hoeing			
a) Around pits (three times)	150 pits x 3	89.90/100	404.55
b) On contour trenches (three times)	150 trenches x 3	298.89/100 trench	1,345.01
c) On protection trenches	40 m x 3	1.11 m^{-1}	133.20
Irrigation of plants (6 times)	600 plants x 6	1.70 plant^{-1}	6,120
Watch and ward for 9 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		4550/26 days of 8 hrs	9,450
Contingency	Lump sum		2,000
Total			25,282.90 **or 25,283**

Maintenance cost			
Year 3			
20% beating up of planted seedlings	30 plants	30 plant^{-1}	900
Weeding, and hoeing (3 times yr^{-1})			
a) Around pits (three times)	150 pits x 3	89.90/100	404.55
b) On contour trenches	150 trenches x 3	298.89/100 trench	1,345.01
c) On protection trenches	40 m x 3	1.11 m^{-1}	133.20
Irrigation of plants (12 times)	600 plants x 12	1.70 plant^{-1}	12,240
Application of manure, AM, micronutrients	600 plants	5.80 plant^{-1}	3,480
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			28,452.76 **or 28,453**
Year 4			
15% beating up of planted seedlings	23 plants	30 plant^{-1}	690
Weeding, hoeing (1 time yr^{-1})			
a) Around pits	150 pits x 1	89.90/100	134.85
b) On contour trenches	150 trenches	298.89/100 trench	448.34

	x 1		
Irrigation of plants (6 times)	600 plants x 6	1.70 plant^{-1}	6,120
Application of manure, AM, micronutrients	600 plants	5.80 plant^{-1}	3,480
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			20,823.19 or **20,823**
Year 5			
5% beating up of planted seedlings	8 plants	30 plant^{-1}	240
Weeding and hoeing (1 time yr^{-1})			
a) Around pits	150 pits x 1	89.90/100	134.85
b) On contour trenches	150 trenches x 1	298.89/100 trench	400.51
Irrigation of plants (3 times)	600 plants x 3	1.70 plant^{-1}	3,060
Application of manure, AM, micronutrients	600 plants	5.80 plant^{-1}	3,480
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			19,265.36 **or 19,265**
Year 6			
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			**9,950**
Year 7			**9,950**

Table 5.26. Year-wise cost summary for YM/UP/NL/05

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	37,734
Year 2 (Planting and establishment)	25,283
Year 3 (1st maintenance)	28,453
Year 4 (2nd maintenance)	20,823
Year 5 (3rd maintenance)	19,265
Year 6 (4th maintenance)	9,950
Year 7 (5th maintenance)	9,950
Total	**1,49,458**

YM/UP/NL/06: Treatment of gullies and steep slopes through vegetative measures with soil conservation

There are many forest areas which are already well vegetated, but are suffering from problem of gully erosion in some spots. Gully plugs and earthen check dams will be prepared in places of problem. Steep slopes are also cause of erosion in some spots; slopes will be broken through contour bund or contour trench. The quantity of these need-based works will vary with site. Sowing of seeds of trees and shrubs and planting of slips of grasses will be done on the treated gullies, earthen check dam, contour bunds and trenches.

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Grass: *Saccharum bengalense,Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Chrysopogon fulvus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica, Vetiveria zizanioides,* etc.

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Table 5.27. Cost norms for YM/UP/NL/06/A to YM/UP/NL/06/C

Sub-model	Cost of soil work (Rs.)	Cost of seed and sowing	Estt. cost (Rs.)	Maint. cost (yr^{-1})	Total cost (Rs. m^{-3} or ha)
YM/UP/NL/06/A Earthen check dam 3m x 0.60 m x 0.45 m size; quantity as per requirement of particular site (200 no. or 162 m^3 earthen check dams will be equivalent to 1 ha)	Rs. 105 m^{-3} (or Rs. 21,000 ha^{-1})	Rs. 15 m^{-3} (or Rs. 3,000 ha^{-1})	Rs. 120 m^{-3} (or Rs. 24,000 ha^{-1})	Rs. 12 m^{-3} (or Rs. 2,400 ha^{-1}) x 5 years = 60 m^{-3} or 12,000 ha^{-1}	Rs. 180 m^{-3} (or Rs. 36,000 ha^{-1})
YM/UP/NL/06/B Contour bunding (40 cm +20 cm)/2 x 25 cm x 1m; quantity as per requirement of particular site (1000 m or 75 m^3 bunds will be equivalent to 1 ha)	Rs. 11.19 m^{-1} (or Rs. 11,190 ha^{-1})	Rs. 3.47 m^{-1} (or Rs. 3,470 ha^{-1})	Rs. 14.66 m^{-1} (or Rs. 14,660 ha^{-1})	Rs. 1.466 m^{-1} (or Rs. 146.60 ha^{-1}) x 5 years = 7.33 m^{-1} or 7,330 ha^{-1}	Rs. 21.99 m^{-1} (or Rs. 21,990 ha^{-1})
YM/UP/NL/06/C Gully plug; quantity as per requirement of particular site (150 m^3 will be equivalent to 1 ha)	Rs. 100 m^{-3} (or Rs. 15,000 ha^{-1})	Rs. 25 m^{-3} (or Rs. 3,750 ha^{-1})	Rs. 125 m^{-3} (or Rs. 18,750 ha^{-1})	Rs. 12.50 m^{-3} (or Rs. 1875 ha^{-1}) x 5 years = 62.50 m^{-3} or 9,375 ha^{-1}	Rs. 187.50 m^{-3} (or Rs. 28,125 ha^{-1})

Table 5.28. Year-wise cost summary for YM/UP/NL/06/A to YM/UP/NL/06/C (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
YM/UP/NL/06/A Earthen check dam						
24,000	2,400	2,400	2,400	2,400	2,400	**36,000**
YM/UP/NL/06/B Contour bunding						
14,660	146.60	146.60	146.60	146.60	146.60	**21,990**
YM/UP/NL/06/C Gully plug						
18,750	1,875	1,875	1,875	1,875	1,875	**28,125**

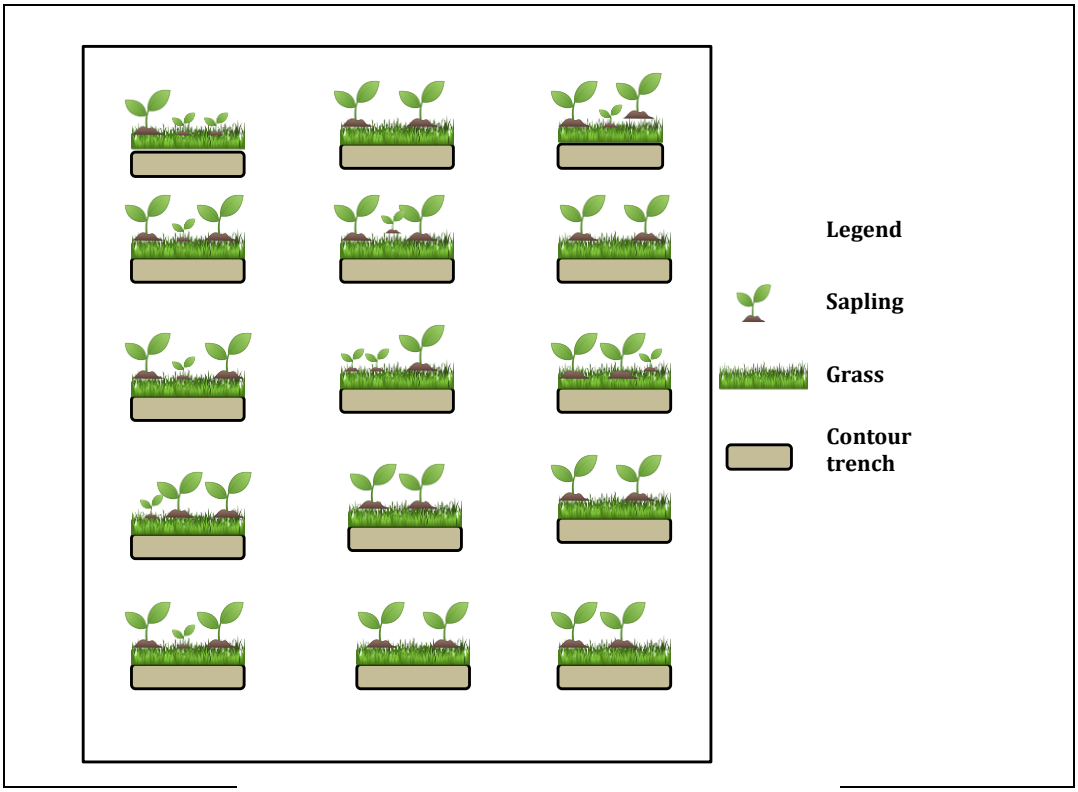


Fig. 5.17. Illustration of vegetative measures

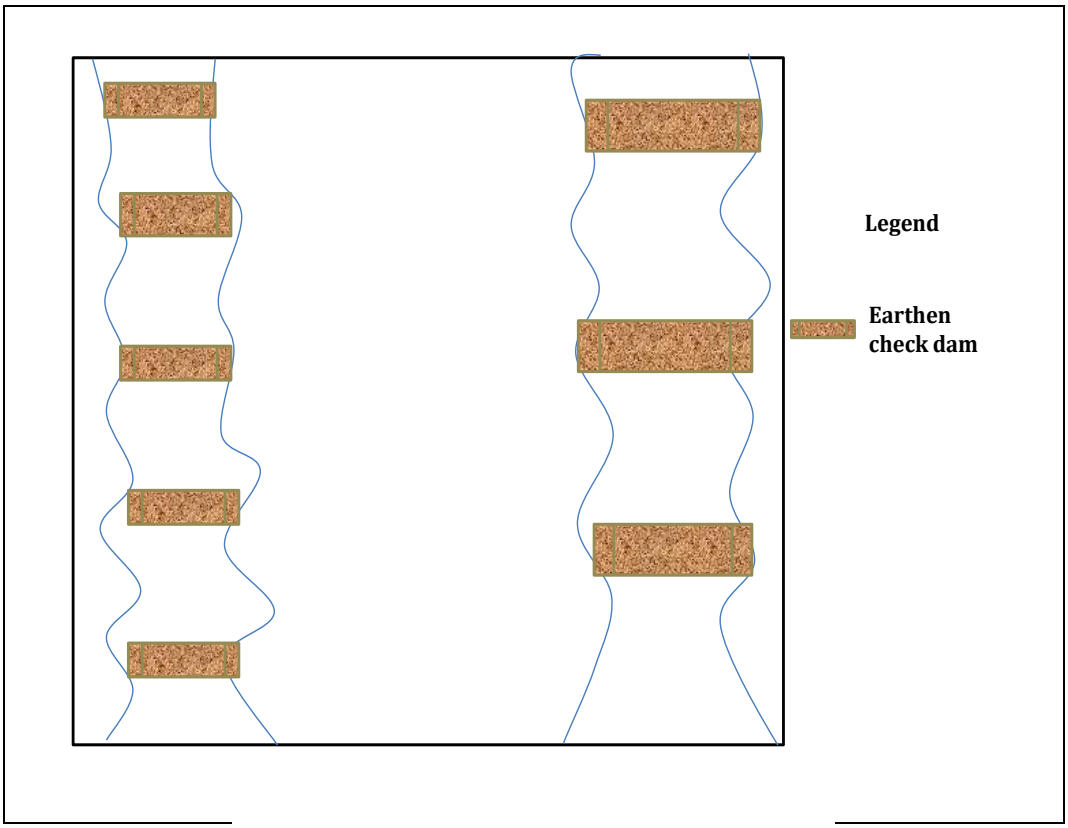


Fig. 5.18. Illustration of earthen check dams



Fig. 5.19. Illustration of contour bunds

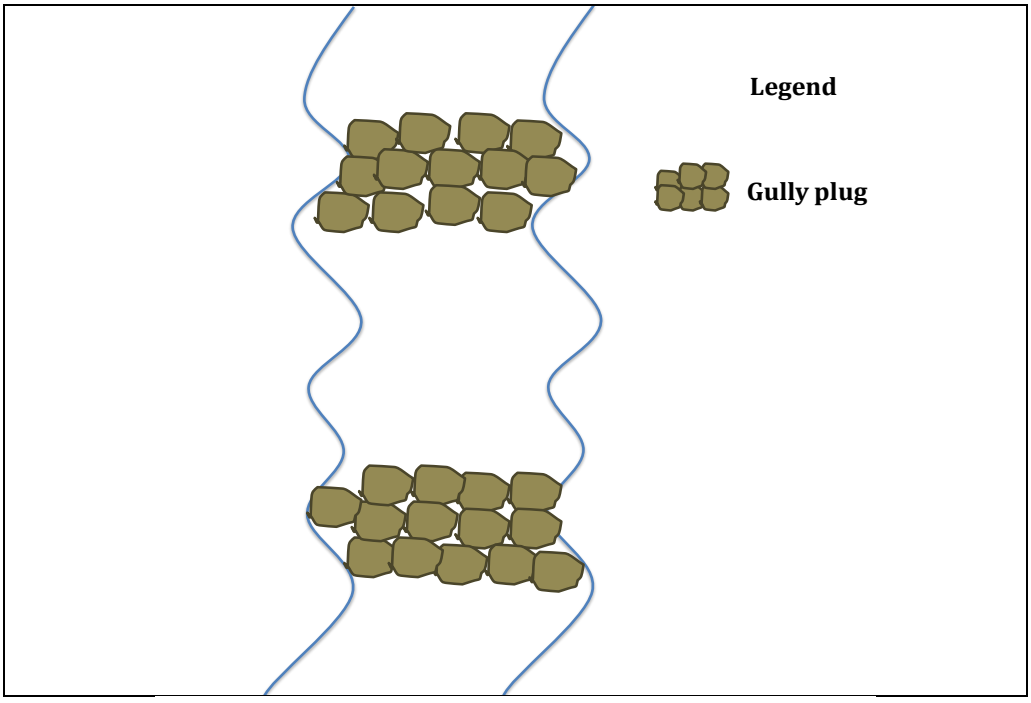


Fig. 5.20. Illustration of representation of gully plugs

YM/UP/NL/07: Ecorestoration by Eco Task Force

The context and prescriptions of this model are broadly similar to those of YM/UK/NL/07 'Ecorestoration by Eco Task. It is proposed that inhospitable sites in difficult terrain measuring 600 ha will be assigned by SFD to Eco-Tack Force for carrying out afforestation activities.

Cost: Cost norms are given in Table 5.29.

Table 5.29. Year-wise cost summary for YM/UP/NL/07 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
2,30,000	0	0	0	0	0	**2,30,000**

YM/UP/NL/08: Plantation in heterogenous areas in uneven terrain

This model is proposed to be applied in sites in Etawah district of Uttar Pradesh which is the confluence of the Yamuna and the Chambal. The region falling all along Yamuna River has uneven topography characterised by ravines. Southern and southwestern parts of the district have ravinous land with small narrow deep depression usually carved by the running water. The forest terrain proposed for forestry interventions under the project is highly variable which defies uniform treatment over the proposed area. Site-specific activities will be carried out at different places in harmony with the site conditions. Planting of native species will be undertaken.



Fig. 5.21. Heterogenous area near Chambal for afforestation
(*Source:* **Project Team**)

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree and shrub: *Acacia catechu, Acacia nilotica, Vitex negundo,Dalbergia sissoo, Syzygium cumini, Terminalia arjuna, Terminalia alata, Terminalia bellirica, Lagerstroemia parviflora, Acacia nilotica, Albizia lebbeck, Azadirachta indica, Haldina cordifolia, Pongamia pinnata, Holoptelea integrifolia, Ougeinia oojeinensis*, etc.

Grass:*Saccharum bengalense, Saccharum spontaneum, Scirpus affinis, Cyperus eleusinoides, Cyperus exaltatus, Arundo donax, Phragmites karka, Themeda arundinacea, Vetiveria zizanioides, Cymbopogon flexuosus, Desmostachya bipinnata, Dichanthium annulatum, Pseudosorghum fasciculare, Cymbopogon jwarancusa, Hygroryza aristata, Panicum paludosum*, etc.

Table 5.30. Year-wise cost summary for YM/UP/NL/08

Sub-model	Establishment cost	Maintenance cost	Total cost
YM/UP/NL/08	Site-specific requirement	Site-specific requirement	Site-specific cost

YM/UP/NL/09: Plantation in *usar* flat terrain

This model is proposed to be applied in *usar* land of Uttar Pradesh characterized by high pH and presence of hard *kankar* pan in the tree root zone with othersie normal looking area. The soil may be saline or alkaline. The low amount of sulphate and phosphate in *usar* soil can't support normal growth of plant species. These soils also have very low total nitrogen content. Hard *kankar* pan will be broken by digging deep pits with the help of an augur. The pH needs to neutralized by addition of acidic soil amendments such as gypsum. Planting of tolerant species will be undertaken.

Kachcha water pond(s) of total 50,000 L storage capacity will be created as a part of this model outside the plantation area for free access of grazing animals. 700 m^2 strip of grass will be planted around this pond which will be protected with brushwood fence during first year. *Kachcha* water pond(s), with base of stone or some impermeable or semi-permeable material, of total 25,000 L will be created inside the plantation to store water for a longer period of time for irrigation of plants; after two years the stone at the base will be removed to facilitate ground water recharge.

The areas where this model is proposed to be implemented have high incidence of grazing. Barbed wire fence alone is not effective. Biofence takes longer time to establish. A combination of both will be used.

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species in pits

Tree and shrub: *Azadirachta indica, Pongamia pinnata, Terminalia arjuna, Albizia lebbeck, Emblica officinalis, Acacia nilotica,* etc.

Grass around pond: *Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica*, etc.

Important elements of the model (ha^{-1}) are:

i. Fencing and protection trench (1.20 m wide at top, 0.90 m at base and 1.00 m deep) all around (Cost of barbed wire fence and cost of protection trench may be given separately)
ii. Biofence of fast-growing thorny plants all around.
iii. One thousand fifty pits of one metre depth and diameter around 20 cm with augur.
iv. Planting of seedlings in pits.
v. Application of manure / vermicompost to plants in the pits.
vi. Beating up of plants 20% in first year, 15% in second year and 5% in third year.
vii. Maintenance for 1+5 years (planting year plus five additional years) including weeding and hoeing, maintenance of fence, watch and ward.
viii. *Kachcha* water pond 50,000 L outside the plantation area in nearby place along with 700 m^2 strips of grass.
ix. *Kachcha* water pond of 25,000 L having base of stone pitching or some impermeable or semi-permeable material.

Table 5.31. Cost norm for YM/UP/NL/09

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	45.59 ha^{-1}	45.59
Cleaning of plantation area	1 ha	299.73 ha^{-1}	299.73
Cleaning of area outside plantation area for planting of grass	250 m^2	299.73 ha^{-1}	7.49
Alignment of pits	1,050 no.	36.91/100	387.56
Digging of pits	1,050 no.	15 pit^{-1}	15,750.00
Protective structure			
Protection trench			
a) Protection trench (1.20 m wide at top, 0.90 m at base and 1.00 m deep)	50 m	98.63 m^{-1}	4,931.50
b) Jhakarhbari work, including transportation (along protection trench)	50 m	8.68 m^{-1}	434
Ploughing of area for pasture grass around pond, loosening and levelling of soil	250 m^2	Lumpsum	25
Stonewall fence			
a) Stone wall fence with 10 cm earthing up (1.20+0.80/2) x 1.20 m (stone available beyond 500 m)	50 m	423.75 m^{-1}	21,187.50
Kachcha pond inside plantation area with stone pitching at base			
a) Digging of *Kachcha* pond inside plantation in area of hard rock	25 m^3	128 m^{-3}	3,200
b) Providing stone pitching at base (incl. cost of material)	Lump sum		800
Digging of *Kachcha* water pond outside plantation with *Kachcha* base	50 m^3	128 m^{-3}	6,400
Making of inspection path			
a) 3 m wide path inside plantation for jeep	25 m	8,984.30 km^{-1}	224.61
b) 1 m wide path inside plantation	50 m	2,085.33 km^{-1}	104.27
Cost of seed			
a) Quality seed for pits (1,050 plants + 20% for culling)	1,260 plants	Lump sum	1,260
b) Seed for protection trenches (other than *P. juliflora*) (at double of normal rate)	50 m	2.40 m^{-1}	120
Cost of plants (incl. 20% culling for obtaining quality stock) for pits	1,260	7 $plant^{-1}$	8,820
Plantation sign board (per 25 ha)	1	3,500/25 ha	140
Miscellaneous			1,000
Total			65,137.50**or 65,138**
Planting year			
Refilling/dressing pits and trenches			
a) Refilling pits (45 cm x 45 cm x 45 cm)	1,050 no.	1.90 pit^{-1}	1,995.00
b) Dressing protection trenches	50 m	1.45 m^{-1}	72.50
Transportation of plants upto 25 km	1,050 no.	1.94 $plant^{-1}$	2,037
Local transport of plants	1,050 no.	1.52 $plant^{-1}$	1,596
Planting of plants in pits	1,050 plants	4.00 $plant^{-1}$	4,200.00
Sowing of seed			
a) Sowing of seeds on protection trenches in two lines	50 m	1.11 m^{-1}	55.50
b) Sowing of pasture grass around outer pond (incl. cost of seed)	250 m^2	524.80 ha^{-1}	13.12
c) Re-sowing of seeds of a and b			68.62
Creation of brushwood fence around pasture grass area	120 m	8.68 m^{-1}	1,041.60
Application of soil amendments, manure, cyanobacteria, micronutrients in pits	1,050 plants	10 $plant^{-1}$	10,500
Application of manure to pasture grass	250 m^2	Lump sum	50
Weeding and hoeing			
a) Around pits (three times)	1,050 pits x 3	89.90/100	2,831.85

b) On protection trenches (three times)	50 m x 3	1.11 m^{-1}	166.50
c) In pasture grass area (two times)	250 m^2 x 2	Lumpsum	150
Irrigation			
a) Plants in pits (6 times)	1,050 plants x 6	1.70 $plant^{-1}$	10,710
b) Pasture grass area (two times)	250 m^2 x 2	Lumpsum	100
Watch and ward for 9 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		4,550/26 days of 8 hrs	9,450
Contingency	Lump sum		2,000
Total			47,037.70**or 47,038**

Maintenance cost			
Year 3			
20% beating up of planted seedlings	210 plants	30 $plant^{-1}$	6,300
Weeding and hoeing			
a) Around pits (three times)	1,050 pits x 3	89.90/100	2,831.85
b) On protection trenches (three times)	50 m x 3	1.11 m^{-1}	166.50
Irrigation			
a) Plants in pits (12 times)	1,050 plants x 12	1.70 $plant^{-1}$	21,420
b) Pasture grass area (two times)	250 m^2 x 2	Lumpsum	200
Application of soil amendments, manure, cyanobacteria, micronutrients in pits	1,050 plants	10 $plant^{-1}$	10,500
Application of manure to pasture grass	250 m^2	Lump sum	50
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			51,418.35 or **51,418**
Year 4			
15% beating up of planted seedlings	158 plants	30 $plant^{-1}$	4,740
Weeding and hoeing			
a) Around pits (1 time yr^{-1})	1,050 pits x 1	89.90/100	943.95
Irrigation			
a) Plants in pits (6 times)	1,050 plants x 6	1.70 $plant^{-1}$	10,710
Application of soil amendments, manure, cyanobacteria, micronutrients in pits	1,050 plants	10 $plant^{-1}$	10,500
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			36,843.95**or 36,844**
Year 5			
5% beating up of planted seedlings	53 plants	30 $plant^{-1}$	1,590
Weeding and hoeing (1 time yr^{-1})			
a) Around pits	1,050 pits x 1	89.90/100	943.95
Irrigation of plants (3 times)	1,050 plants x 3	1.70 $plant^{-1}$	1,785
Application of soil amendments, manure, cyanobacteria, micronutrients in pits	1,050 plants	10 $plant^{-1}$	10,500
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			24,768.95 or **24,769**
Year 6			

Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			**9,950**
Year 7			**9,950**

Table 5.32. Year-wise cost summary for YM/UP/NL/03

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	65,138
Year 2 (Planting and establishment)	47,038
Year 3 (1st maintenance)	51,418
Year 4 (2nd maintenance)	36,844
Year 5 (3rd maintenance)	24,769
Year 6 (4th maintenance)	9,950
Year 7 (5th maintenance)	9,950
Total	**2,45,107**

F. Rajasthan

YM/RJ/NL/01: Rehabilitation of degraded forest

Many forest areas are degraded and suffer from problems of poor forest cover, soil erosion and grazing by domestic animals along with poor water holding capacity and low rainfall. In this model 400 plants ha^{-1} will be planted in in pits. Soil and moisture conservation activities will be carried out in advance work year as well as planting year. The existing plants will be supported by silvicultural practices like cutting back, pruning and making crescent-shaped ridges on the lower side of seedlings. This model is broadly similar to the traditional RDF-I model of SFD.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species inside plantation area

Tree: *Anogeissus pendula, Acacia nilotica, Acacia leucophloea, Azadirachta indica, Emblica officinalis, Pithecellobium dulce, Butea monosperma, Diospyros melanoxylon, Holoptelea integrifolia, Pongamia pinnata, Ailanthus excelsa,* etc.

Shrub: *Ziziphus nummularia, Carissa carandas, Adhatoda vasica, Commiphora wightii, Capparis zeylanica, Capparis decidua, Grewia villosa,* etc.

Grass: *Cenchrus ciliaris, C. setigerus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Themeda triandra, Apluda mutica, Eremopogon foveolatus, Lasiurus scindicus,* etc.

Important elements of the model (ha^{-1}) are:

i. Fencing of area by stone wall and/or trench.
ii. Restoration of natural regeneration by cutting back, pruning, crescent-shaped ridges.
iii. Contour trenches totalling 200 m.
iv. Additional in-situ soil and moisture conservation works during advance work year and planting year.
v. Four hundred seedlings ha^{-1} will be planted in pits.

Table 5.33. Cost norm for YM/RJ/NL/01

Particular	Quantity ha^{-1}	Rs. ha^{-1}
Advance work (Year 1)		
Microplanning and preparing management plan		550
Survey and alignment, removal of invasive woody weeds		1,450
Stone wall fence (2.10 m high)/ fence with RCC posts of 2.70 m height having six-line barbed wire fence of 1.50 m height	60 m	18,000
Digging trenches of different sizes as in the SFD standard ANR model	200 m	16,000
Digging of pits (0.60 x (0.70+0.50)/2)	400	16,000
In-situ soil and moisture conservation works (e.g. check dam, contour trench, earthen bud, percolation tank)		4,100
Restoration of natural regeneration by cutting back, pruning, crescent-shaped ridges on lower side of seedlings and saplings		1,070
Cost of nursery stock of trees including 20% extra for culling	400 + 80 plants	3,500
Cost of nursery stock of trees in 30 cm x 25 cm bags (including 20% extra for culling)	200 + 40 plants	1,050
Cost of tree seeds and grass seed/slips (quantity twice the SFD standard ANR model)	-	500
Manure, organic plant protection consumables		1,500
Digging of water storage pond/buying tank	Double of SFD norm	800
Watch and ward (for 4 months)		770
Contingency		2,000
Total		**67,290**
Planting and establishment year (Year 2)		
Maintenance of seedlings in nursery (incl. 20% for beating up)	400+80	900
Maintenance of seedlings in 15 cm x 10 cm bags (incl. 20% for beating up)	200+40	300
In-situ soil and moisture conservation works (e.g., check dam, contour trench, earthen bud, percolation tank)		4,100
Digging of 30 cm x 30 cm cross section trench along inner side of stone wall fence and seed sowing	60 m	1,080
Sowing/ dibbling of seed of tree, grass, shrub, medicinal plant species along ridges of trench, ditch fence	460 m	260
Sowing/ dibbling of grass seed, raking in interspace		500
Planting of tree seedlings in pits (incl. transportation cost)	400 plants	2,200
Transport and planting seedlings of 15 cm x 10 cm bags	200	670
Manure, organic plant protection measures		2,000
Making of crescent-shaped mounds below planted seedlings, dibbling 3 seeds of thorny species	400	1,400
Weeding and hoeing, repair of mounds (twice)	800	2,750
Irrigation of seedlings in pits with 30 litre water plant^{-1} brought from average 5 km x (4 times)	1,600	29,100
Weeding on contour trenches, bunds etc., singling		560
Restoration of natural regeneration by cutting back, pruning, crescent-shaped ridges on lower side of seedlings and saplings	120	450
Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
Raising of 20% plants for casualty replacement		350
Construction of approach road, inspection path		400
Contingency	Lumpsum	1,500
Total		**50,820**

Maintenance cost			
Year 3	20% beating up (Plant maintenance in nursery + planting)	80	2,600
	Weeding and hoeing 2 times, repair of fences	800	2,710
	Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 8 times	3,200	58,200

	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Contingency	Lumpsum	1,000
	Total		**66,810**
Year 4	15% beating up (Plant + planting)	60 plants	1,800
	Silvicultural operations and maintenance, protection from fence	Lumpsum	520
	Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 7 times	2,800	50,925
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Total		**55,545**
Year 5	5% beating up (Plant + planting)	20 plants	680
	Silvicultural operations and maintenance of fence, frost protection	Lumpsum	540
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Total		**3,520**
Year 6			**2,300**
Year 7			**2,300**

Table 5.34. Year-wise cost summary for YM/RJ/NL/01

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	67,290
Year 2 (Planting and establishment)	50,820
Year 3 (1st maintenance year)	66,510
Year 4 (2nd maintenance year)	55,245
Year 5 (3rd maintenance year)	3,220
Year 6 (4th maintenance year)	2,300
Year 7 (5th maintenance year)	2,300
Total	**2,48,585**

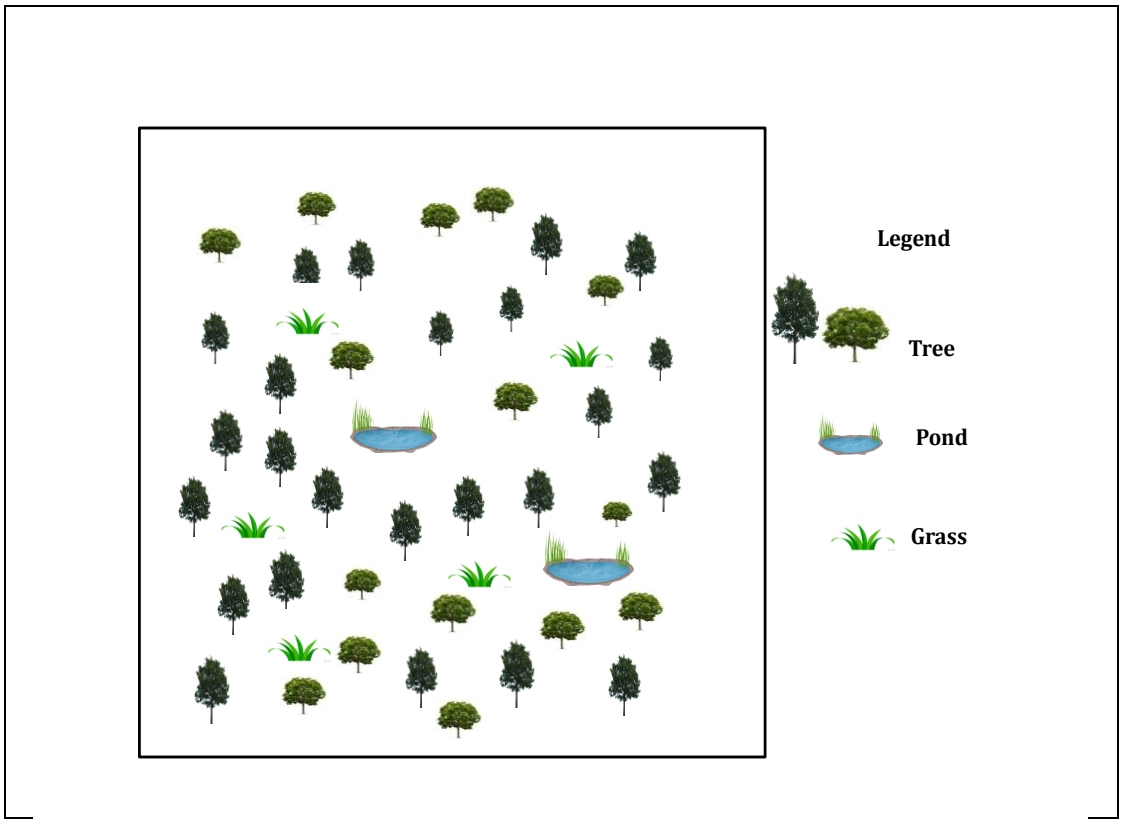


Fig. 5.22. Illustration of rehabilitation of degraded forest (YM/RJ/NL/01)

YM/RJ/NL/02: Assisted Natural Regeneration

This model is broadly similar to the traditional ANR model of SFD and will be applied in forest areas in which gaps, existing in the canopy, are smaller than those in the model YM/RJ/NL/02. Natural regeneration needs to be supported through protection from biotic agencies, and practices like cutting back, pruning and crescent-shaped ridges. Natural regeneration further needs to be supplemented by planting of 200 seedlings per hectare and sowing of tree and grass seedlings on contour trenches.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species inside plantation area

Tree: *Anogeissus pendula, Acacia nilotica, Acacia leucophloea, Azadirachta indica, Emblica officinalis, Pithecellobium dulce, Butea monosperma, Diospyros melanoxylon, Holoptelea integrifolia, Pongamia pinnata, Ailanthus excelsa,* etc.

Shrub: *Ziziphus nummularia, Carissa carandas, Adhatoda vasica, Commiphora wightii, Capparis zeylanica, Capparis decidua, Grewia villosa,* etc.

Grasse: *Cenchrus ciliaris, C. setigerus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Themeda triandra, Apluda mutica, Eremopogon foveolatus, Lasiurus scindicus,* etc.

Important elements of the model (ha^{-1}) are:

i. Fencing of area by stone wall and/or trench.
ii. Restoration of natural regeneration by cutting back, pruning, crescent-shaped ridges.
iii. Staggered contour contour trenches totalling 200 m.
iv. Additional in-situ soil and moisture conservation works.
v. Two hundred pits.
vi. Two hundred seedlings ha^{-1} will be planted in pits.

Table 5.35. Cost norm for YM/RJ/NL/02

Particular	Quantity ha^{-1}	Rs. ha^{-1}
Advance work (Year 1)		
Microplanning and preparing management plan		550
Survey and alignment, removal of invasive woody weeds		1,450
Stone wall fence (2.10 m high)/ fence with RCC posts of 2.70 m height having six-line barbed wire fence of 1.50 m height	60 m	18,000
Digging trenches of different sizes as in the SFD standard ANR model	200 m	16,000
Digging of pits (0.60 x (0.70+0.50)/2)	200	8,000
In-situ soil and moisture conservation works (e.g. check dam, contour trench, earthen bud, percolation tank)		4,100
Restoration of natural regeneration by cutting back, pruning, crescent-shaped ridges on lower side of seedlings and saplings		1,070
Cost of nursery stock of trees in 30 cm x 25 cm bags (including 20% extra for culling)	200 +40 plants	1,910
Cost of tree seeds and grass seed/slips	-	450
Manure, organic plant protection consumables		1,500
Digging of water storage pond/buying tank	Double of SFD norm	800
Watch and ward (for 4 months)		770
Contingency		1,800

Total			**56,400**
Planting and establishment (Year 2)			
Maintenance of seedlings in nursery (incl. 20% for beating up)		200+40	450
Digging of 30 cm x 30 cm cross section trench along inner side of stone wall fence and seed sowing		60 m	1,080
Sowing/ dibbling of seed of tree, grass, shrub, medicinal plant species along ridges of trench, ditch fence		460 m	260
Sowing of grass seed, raking in interspace			1,300
Planting of tree seedlings in pits (incl. transportation cost)		200 plants	1,360
Making of crescent-shaped mounds below planted seedlings, dibbling 3 seeds of thorny species		200	680
Weeding and hoeing, repair of mounds (twice)		400	1,360
Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 6 times		1,200	21,900
Weeding on contour trenches, bunds etc., singling			560
Restoration of natural regeneration by cutting back, pruning, crescent-shaped ridges on lower side of seedlings and saplings			1,070
Watch and ward 12 months (every day of month, sunrise to sunset)			2,300
Raising of 20% plants for casualty replacement			350
Construction of approach road, inspection path			400
Contingency		Lumpsum	1,500
Total			**34,570**
Maintenance cost			
Year 3	20% beating up (Plant maintenance in nursery + planting)	40	1,330
	Weeding and hoeing 2 times, repair of fences	400	1,360
	Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 8 times	1,600	29,100
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Contingency	Lumpsum	500
	Total		**34,590**
Year 4	15% beating up (Plant + planting)	30 plants	1,000
	Silvicultural operations and maintenance, protection from fence	Lumpsum	520
	Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 7 times	1,400	25,465
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Total		**29,285**
Year 5	5% beating up (Plant + planting)	10 plants	340
	Silvicultural operations and maintenance of fence, frost protection	Lumpsum	540
	Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 6 times	1,200	21,900
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Total		**25,080**
Year 6			**2,300**
Year 7			**2,300**

Table 5.36. Year-wise cost summary for YM/RJ/NL/02

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	56,400
Year 2 (Planting and establishment)	34,570
Year 3 (1st maintenance year)	34,590
Year 4 (2nd maintenance year)	29,285

Year 5 (3rd maintenance year)	25,080
Year 6 (4th maintenance year)	2,300
Year 7 (5th maintenance year)	2,300
Total	**1,84,525**

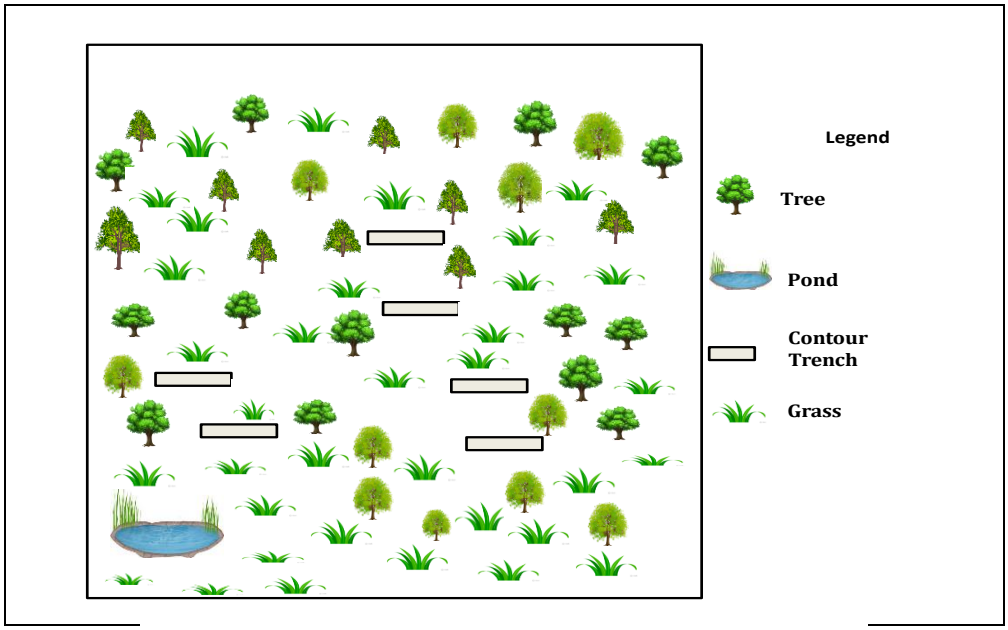


Fig. 5.23. Illustration of assisted natural regeneration

YM/RJ/NL/03: Biodiversity conservation

This model will be applied in wildlife-rich areas to conserve biodiversity. In this model, the forest area will be closed for protection against damage by animals, soil moisture conservation measures will be applied to promote regeneration and seed of shrubs and ground vegetation species, including medicinal plants, will be sown on contour trenches. Seedlings of tree species will not be planted; however, natural regeneration will be supported by cultural operations such as cutting back and making of crescent-shaped ridges on lower side of seedlings.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Shrub/Herb: *Commiphora wightii, Rauvolfia serpentina, Chlorophytumtuberosum, Urginea indica, Curcuma caesia, Andrographis paniculata, Plumbagozeylanica, Carissa carandas, Adhatoda vasica, Capparis zeylanica, Capparis decidua,* Dioscorea spp., *Withania somnifera,* etc.

Table 5.37. Cost norm for YM/RJ/NL/03

Particular	Quantity ha^{-1}	Rs. ha^{-1}
Advance work (Year 1)		
Microplanning and preparing management plan		550
Survey and alignment of pits, marking of segments/plots		450
Fencing by stone and/or by ditch		
a) Stone wall fence (1.20 m high), 0.80 m at base and 0.60 m at top	30 m	6,400
b) Ditch fencing 1.20 m deep, 1.50 m wide at top and 0.90 m at base	30 m	6,950
Digging 400 m staggered contour trenches 45 cm x 45 cm cross section on middle slopes and V-ditch as per site requirement	400 m	10,650
Cost of collection and purchase of seeds/cuttings of shrubs and medicinal plants	Lumpsum	225
In-situ soil and moisture conservation works (e.g. check dam, contour	Lumpsum	5,700

trench, earthen bud, percolation tank, etc)		
Restoration of natural regeneration by cut back, cultural operations and by making crescent shaped ridges on lower side of seedlings and saplings	Lump sum	2,135
Construction of approach road, inspection path and walking trail	Lumps um	1,590
Watch and ward (for 4 months)		770
Contingency		1,500
Total		**36,920**
Sowing and establishment (Year 2)		
In-situ soil and moisture conservation works (e.g. check dam, contour trench, earthen bud, percolation tank, etc)	Lumpsum	2,820
Digging of 30 cm x 30 cm cross section trench along inner side of stone wall fence and seed sowing	30 m	700
Sowing/ dibbling of seed of shrub, medicinal plant species along ridges of trench, ditch fence	430 m	240
Weeding and hoeing (2 times) on trenches, V-ditches	Lumpsum	1,180
Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
Contingency		1,500
Total		**8,740**
Year 3		
Repair of fence		220
Weeding and hoeing		600
Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
Contingency		300
Total		**3,420**
Year 4		
Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
Total		**2,300**

Table 5.38. Year-wise cost summary for YM/RJ/NL/03

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	36,920
Year 2 (Sowing and establishment)	8,740
Year 3 (1st maintenance year)	3,420
Year 4 (2nd maintenance year)	2,300
Total	**51,380**

YM/RJ/NL/04: Rehabilitation of *Lantana*-infested forest area

Areas infested with *Lantana camara* will be treated with this model for the purpose of replacing this invasive species with ecologically more useful trees species. *Lantana camara* is usually present in patches occupying about 50 per cent area of the forest; it will be uprooted from the patches and 200 seedlings of trees will be planted per hectare forest area in pits in vacated areas so that space is not available for invasion by *Lantana*. The plant density will thus be double of density in the model in assisted natural regeneration. Contour trenches will be also be dug in the gaps and sown with grass/tree seeds. Weeding will be done for three years to ensure that *Lantana* does not regrow.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species inside plantation area

Tree: *Anogeissus pendula, Acacia nilotica, Acacia leucophloea, Azadirachta indica, Emblica officinalis, Pithecellobium dulce, Butea monosperma, Diospyros melanoxylon, Holoptelea integrifolia, Pongamia pinnata, Ailanthus excels,*etc.

Shrub: *Ziziphus nummularia, Carissa carandas, Adhatoda vasica, Commiphora wightii, Capparis zeylanica, Capparis decidua, Grewia villosa,* etc.

Grass: *Cenchrus ciliaris, Cenchrus setigerus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Themeda triandra, Apluda mutica, Eremopogon foveolatus, Lasiurus scindicus,* etc.

Important elements of the model (ha^{-1}) are:

i. Fencing of area by stone wall and/or trench.
ii. Uprooting of *Lantana* in patches of infestation.
iii. Two hundred pits (assuming 50% area ha^{-1} is infested).
iv. Two hundred seedlings ha^{-1} will be planted in pits.
v. Staggered contour contour trenches totalling 200 m.
vi. Restoration of natural regeneration by cutting back, pruning, crescent-shaped ridges.
vii. Additional in-situ soil and moisture conservation works.

Table 5.39. Cost norm for YM/RJ/NL/04

Particular	Quantity ha^{-1}	Rs. ha^{-1}
Advance work (Year 1)		
Microplanning and preparing management plan		550
Survey and alignment		450
Uprooting of *Lantana camara*	5,000 m^2	4,600
Stone wall fence (2.10 m high)/ fence with RCC posts of 2.70 m height having six-line barbed wire fence of 1.50 m height	60 m	18,000
Digging trenches of different sizes as in the SFD standard ANR model	200 m	16,000
Digging of pits (0.60 x (0.70+0.50)/2)	200	8,000
In-situ soil and moisture conservation works (e.g., check dam, contour trench, earthen bud, percolation tank)		4,100
Restoration of natural regeneration by cutting back, pruning, crescent-shaped ridges on lower side of seedlings and saplings		1,070
Cost of nursery stock of trees in 30 cm x 25 cm bags (including 20% extra for culling)	200 +40 plants	1,910
Cost of tree seeds and grass seed/slips	-	450
Manure, organic plant protection consumables		1,500
Digging of water storage pond/buying tank	Double of SFD norm	800
Watch and ward (for 4 months)		770
Contingency		1,800
Total		**60,000**
Planting and establishment (Year 2)		
Maintenance of seedlings in nursery (incl. 20% for beating up)	200+40	450
Digging of 30 cm x 30 cm cross section trench along inner side of stone wall fence and seed sowing	60 m	1,080
Sowing/ dibbling of seed of tree, grass, shrub, medicinal plant species along ridges of trench, ditch fence	460 m	260

Sowing of grass seed, raking in interspace		1,300
Planting of tree seedlings in pits (incl. transportation cost)	200 plants	1,360
Making of crescent-shaped mounds below planted seedlings, dibbling 3 seeds of thorny species	200	680
Weeding and hoeing, repair of mounds (twice)	400	1,360
Irrigation of seedlings in pits with 30 litre water plant^{-1} brought from average 5 km x 6 times	1,200	21,900
Weeding on contour trenches, bunds etc., singling		560
Uprooting of *Lantana* sprouts/seedlings, restoration of natural regeneration of trees by cutting back, pruning, crescent-shaped ridges on lower side of seedlings and saplings		1,370
Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
Raising of 20% plants for casualty replacement		350
Construction of approach road and inspection path		400
Contingency	Lumpsum	1,500
Total		**34,870**

Maintenance cost			
Year 3	20% beating up (Plant maintenance in nursery + planting)	40	1,330
	Weeding and hoeing (2 times), repair of fences	400	1,360
	Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 8 times	1,600	29,100
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Contingency	Lumpsum	500
	Total		**34,590**
Year 4	15% beating up (Plant + planting)	30 plants	1,000
	Silvicultural operations and maintenance, protection from fence	Lumpsum	520
	Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 7 times	1,400	25,465
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Total		**29,285**
Year 5	5% beating up (Plant + planting)	10 plants	340
	Silvicultural operations and maintenance of fence, frost protection	Lumpsum	540
	Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 6 times	1,200	21,900
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Total		**25,080**
Year 6			**2,300**
Year 7			**2,300**

Table 5.40. Year-wise cost summary for YM/RJ/NL/04

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	60,000
Year 2 (Planting and establishment)	34,870
Year 3 (1st maintenance year)	34,590
Year 4 (2nd maintenance year)	29,285
Year 5 (3rd maintenance year)	25,080
Year 6 (4th maintenance year)	2,300
Year 7 (5th maintenance year)	2,300
Total	**1,88,425**

YM/RJ/NL/05: Rehabilitation of *Prosopis*-infested forest area

Areas infested with *P. juliflora* will be treated with this model with the purpose of replacing this invasive species with ecologically more useful trees species. *P. juliflora* is usually present in patches occupying about 50 per cent area of the forest. It is more deep-rooted and grows faster than *Lantana*.

P. juliflora will be uprooted with JCB from the patches and 200 seedlings of trees will be planted per hectare forest area in pits in vacated areas so that space is not available for invasion by this invasive species. The plant density will thus be double of density in the model in assisted natural regeneration. Contour trenches will be also be dug in the gaps and sown with grass/tree seeds. Weeding will be done for three years to ensure that *Lantana* does not regrow.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species inside plantation area

Tree: *Anogeissus pendula, Acacia nilotica, Acacia leucophloea, Azadirachta indica, Emblica officinalis, Pithecellobium dulce, Butea monosperma, Diospyros melanoxylon, Holoptelea integrifolia, Pongamia pinnata, Ailanthus excelsa,* etc.

Shrub: *Ziziphus nummularia, Carissa carandas, Adhatoda vasica, Commiphora wightii, Capparis zeylanica, Capparis decidua, Grewia villosa,* etc.

Grass: *Cenchrus ciliaris, C. setigerus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Themeda triandra, Apluda mutica, Eremopogon foveolatus, Lasiurus scindicus,* etc.

Important elements of the model (ha^{-1}) are:

i. Fencing of area by stone wall and/or trench.
ii. Uprooting of *P. juliflora* in patches of infestation.
iii. Two hundred pits (assuming 50% area ha^{-1} is infested).
iv. Two hundred seedlings ha^{-1} will be planted in pits.
v. Staggered contour contour trenches totalling 200 m.
vi. Restoration of natural regeneration by cutting back, pruning, crescent-shaped ridges.
vii. Additional in-situ soil and moisture conservation works.

Table 5.41. Cost norm for YM/RJ/NL/05

Particular	Quantity ha^{-1}	Rs. ha^{-1}
Advance work (Year 1)		
Microplanning and preparing management plan		550
Survey and alignment		450
Uprooting of *P. juliflora* with JCB	5,000 m^2	3,200
Stone wall fence (2.10 m high)/ fence with RCC posts of 2.70 m height having six-line barbed wire fence of 1.50 m height	60 m	18,000
Digging trenches of different sizes as in the SFD standard ANR model	200 m	16,000
Digging of pits (0.60 x (0.70+0.50)/2)	200	8,000
In-situ soil and moisture conservation works (e.g. check dam, contour trench, earthen bud, percolation tank)		4,100
Restoration of natural regeneration by cutting back, pruning, crescent-shaped ridges on lower side of seedlings and saplings		1,070
Cost of nursery stock of trees in 30 cm x 25 cm bags (including 20% extra for culling)	200 +40 plants	1,910
Cost of tree seeds and grass seed/slips	-	450
Manure, organic plant protection consumables		1,500
Digging of water storage pond/buying tank	Double of SFD norm	800
Watch and ward (for 4 months)		770
Contingency		1,800

Total		**58,600**
Planting and establishment (Year 2)		
Maintenance of seedlings in nursery (incl. 20% for beating up)	200+40	450
Digging of 30 cm x 30 cm cross section trench along inner side of stone wall fence and seed sowing	60 m	1,080
Sowing/ dibbling of seed of tree, grass, shrub, medicinal plant species along ridges of trench, ditch fence	460 m	260
Sowing of grass seed and raking in interspace		1,300
Planting of tree seedlings in pits (incl. transportation cost)	200 plants	1,360
Making of crescent-shaped mounds below planted seedlings, dibbling 3 seeds of thorny species	200	680
Weeding and hoeing, repair of mounds (twice)	400	1,360
Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 6 times	1,200	21,900
Weeding on contour trenches, bunds etc., singling		560
Uprooting of *Prosopis* sprouts/seedlings, restoration of natural regeneration of trees by cutting back, pruning, crescent-shaped ridges on lower side of seedlings and saplings		2,000
Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
Raising of 20% plants for casualty replacement		350
Construction of approach road, inspection path		400
Contingency	Lumpsum	1,500
Total		**35,500**

Maintenance cost			
Year 3	20% beating up (Plant maintenance in nursery + planting)	40	1,330
	Uprooting of *Prosopis* and other weeds, hoeing 4 times, repair of fence		3,000
	Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 8 times	1,600	29,100
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Contingency	Lumpsum	500
	Total		**36,230**
Year 4	15% beating up (Plant + planting)	30 plants	1,000
	Uprooting of *Prosopis*, Silvicultural operations and maintenance, protection from frost	Lumpsum	2,200
	Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 7 times	1,400	25,465
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Total		**30,965**
Year 5	5% beating up (Plant + planting)	10 plants	340
	Uprooting of *Prosopis*, Silvicultural operations and maintenance, protection from frost	Lumpsum	1,540
	Irrigation of seedlings in pits with 30 L water plant^{-1} brought from average 5 km x 6 times	1,200	21,900
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Total		**26,080**
Year 6			**2,300**
Year 7			**2,300**

Table 5.42. Year-wise cost summary for YM/RJ/NL/05

Year	Rs. ha^{-1}
Year 1 (Advance work)	58,600
Year 2 (Planting and establishment)	35,500
Year 3 (1st maintenance year)	36,230
Year 4 (2nd maintenance year)	30,965
Year 5 (3rd maintenance year)	26,080
Year 6 (4th maintenance year)	2,300
Year 7 (5th maintenance year)	2,300
Total	**1,91,975**

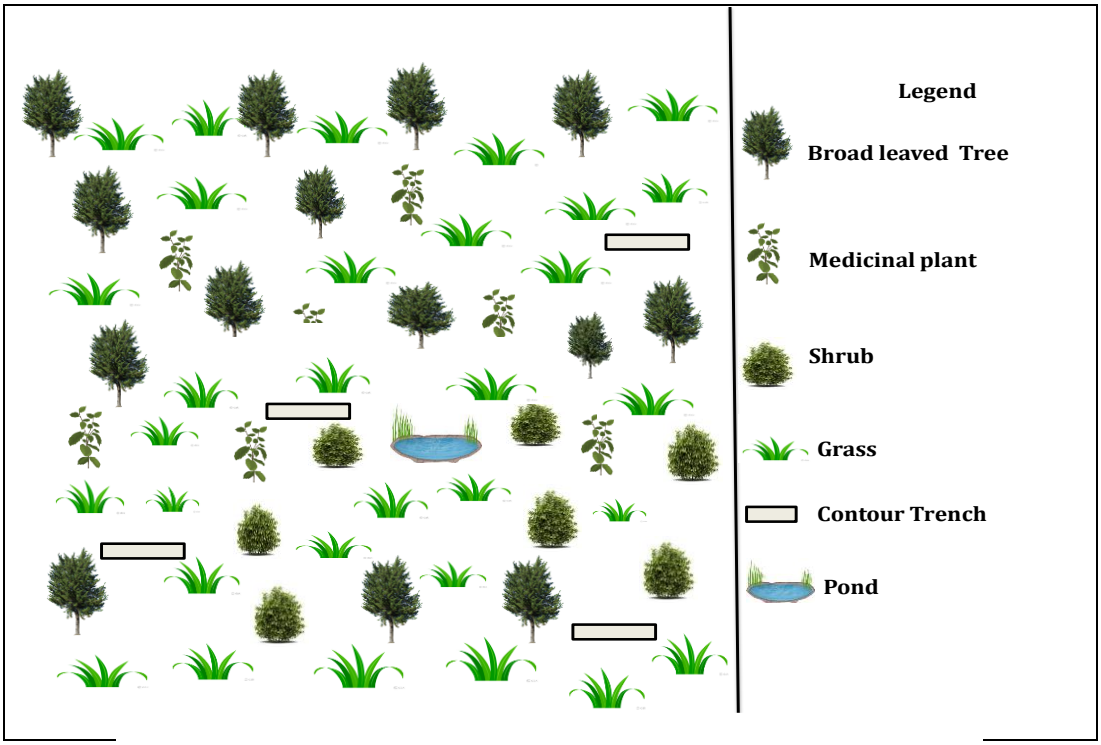


Fig. 5.24. Illustration of rehabilitation of *Lantana* infested areas

Treatment of gullies and steep slopes through vegetative measures with soil conservation

There are many forest areas which are already well vegetated, but are suffering from problem of soil erosion and scarcity of soil moisture; slopes will be broken through contour bund or contour trench. The quantity of these need-based works will vary with site. Sowing of seeds of trees, shrubs and grasses will be done on the contour bunds and trenches.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree: *Anogeissus pendula, Acacia nilotica, Acacia leucophloea, Azadirachta indica, Emblica officinalis, Pithecellobium dulce, Butea monosperma, Diospyros melanoxylon, Holoptelea integrifolia, Pongamia pinnata,* etc.

Shrub: *Ziziphus nummularia, Carissa carandas, Adhatoda vasica, Commiphora wightii, Capparis zeylanica, Capparis decidua, Grewia villosa,* etc.

Grass: *Cenchrus ciliaris, C. setigerus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Themeda triandra, Apluda mutica, Eremopogon foveolatus, Lasiurus scindicus,* etc.

YM/RJ/NL/06: Contour trenching and seeding

YM/RJ/NL/07: Deep contour trenching and seeding

YM/RJ/NL/08: Contour bunding and seeding

Table 5.43. Cost norms for YM/RJ/NL/06 to YM/RJ/NL/08

Activity	Cost of soil work (Rs.)	Cost of seed and sowing	Estt. cost	Maint. cost	Total cost (Rs. m^{-3} or ha)
YM/RJ/NL/06 Contour trenching and seeding 3 m x 0.45 m x .45 m size; quantity as per requirement of particular site (200 trenches or 121.5 m^3 will be equivalent to 1 ha)	Rs.197.53 m^{-3} (or Rs, 21,570 ha^{-1}	Rs.10 m^{-3} or Rs.1,215 ha^{-1}	Rs.187.53 m^{-3} or Rs.22,785 ha^{-1}	(Rs.18.75 m^{-3} or Rs.2,279 ha^{-1}) x 5 yrs = Rs.93.75m^{-3} or Rs.11,395 ha^{-1}	Rs.281.28m^{-3} or Rs.34,180 ha^{-1}
YM/RJ/NL/07 Deep contour trenching and seeding 3 m x 0.45 m x 0.60 m size; quantity as per requirement of particular site (200 trenches or 162 m^3 will be equivalent to 1 ha)	Rs.197.53 m^{-3} (or Rs, 28,760 ha^{-1})	Rs.10 m^{-3} or Rs.1,620 ha^{-1}	Rs.187.53 m^{-3} or Rs.30,380 ha^{-1}	(Rs.18.75m^{-3} or Rs.3,038 ha^{-1} x 5 yrs = Rs.93.75 m^{-3} or Rs.15,190 ha^{-1}	Rs.281.28 m^{-3} or Rs.45,570 ha^{-1}
YM/RJ/NL/08 Contour bunding and seeding 30 cm top to 60 cm base height x 30 cm x 1 m; quantity as per requirement of particular site (750 m or 101.25 m^3 will be equivalent to 1 ha)	Rs.14 m^{-1} (or Rs.10,500 ha^{-1})	Rs.2 m^{-1} (or Rs.1,500 ha^{-1})	Rs.16 m^{-1} (or Rs.12,000 ha^{-1})	Rs.1.60 m^{-1} (or Rs.1,200 ha^{-1}) x 5 yrs = Rs.8 m^{-1} (or Rs.6,000 ha^{-1})	Rs.24 m^{-1} (or Rs.18,000 ha^{-1})

Table 5.44. Year-wise cost summary for YM/RJ/NL/06 to YM/RJ/NL/08 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
YM/RJ/NL/06 Contour trenching and seeding						
22,785	2,279	2,279	2,279	2,279	2,279	**34,180**
YM/RJ/NL/07 Deep contour trenching and seeding						
22,785	2,279	2,279	2,279	2,279	2,279	**34,180**
YM/RJ/NL/08 Contour bunding and seeding						
12000	1,200	1,200	1,200	1,200	1,200	**18,000**

YM/RJ/NL/09 Ecorestoration by Eco Task Force

The context and prescriptions of this model are broadly similar to those of YM/UK/NL/07 'Ecorestoration by Eco Task Force'. It is proposed that inhospitable sites in difficult terrain

measuring 800 ha will be assigned by SFD to Eco-Tack Force for carrying out afforestation and other ecorestoration activities.

Cost norm for YM/RJ/NL/09 (Rs. ha^{-1}): The cost norms are given in Table 5.45.

Table 5.45. Year-wise cost summary for YM/RJ/NL/09 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
2,30,000	0	0	0	0	0	**2,30,000**

G. Madhya Pradesh

YM/MP/NL/01: Afforestation in open forest areas

This model will be applied in forest areas that have poor crown cover. The terrain of the proposed sites is sloped and the soil is poor in nutritional status. The sites are infested with *Lantana* of moderate density. Some seedlings and trees already exist in such sites, but their density is quite low. Such saplings and trees will be retained and supported through soil working activities. Contour trenches, 256 ha^{-1}, will be dug and direct sowing of seeds of indigenous trees will be carried out at three points (one each at both ends, and one in the middle) on the soil heaped along the trench. Grass seeds/slips will be planted at six points along the trench. More than one seed may be sown per spot to ensure seedling establishment at each spot.

Planting of seedlings will be done in pits of 0.45 m x 0.45 m x 0.45 m size at density of 256 pits ha^{-1} and maintained for five years after the planting year. *Kachcha* water pond(s) of total 50 m^3 storage capacity will be created as a part of this model outside the plantation area for free access of grazing animals. 500 m^2 strip of grass will be planted around this pond which will be protected with brushwood fence during first year. *Kachcha* water pond(s), with base of stone or some impermeable or semi-permeable material, of total 25 m^3 will be created inside the plantation to store water for a longer period of time for irrigation of plants; after two years the stone at the base will be removed to facilitate ground water recharge.

The areas where this model is proposed to be implemented have high incidence of grazing. Barbed wire fence alone is not effective. Biofence takes longer time to establish. A combination of both will be used.

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on contour trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Grass: *Saccharum bengalense, Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica, Vetiveria zizanioides,* etc.

Species in pits

Tree and shrub: *Azadirachta indica, Madhuca indica, Anogeissus latifolia, Acacia nilotica, Dalbergia sissoo, Albizia lebbeck, Emblica officinalis, Pithecellobium dulce, Terminalia alata, Terminalia chebula, Terminalia arjuna, Bridelia retusa, Holoptelea integrifolia, Bombax ceiba,* etc.

Bamboo: *Dendrocalamus strictus, Bambusa bambos,* etc.

Important elements of the model (ha^{-1}) are:

i. Fencing with chain link fence all around.
ii. 256 contour trenches of 3 m length.
iii. Sowing of tree and grass seeds/slips on contour trenches.
iv. 256 pits of 0.45 m x 0.45 m x 0.45 m size.

v. Planting of seedlings in pits.
vi. Application of manure/vermicompost to plants in the pits.
vii. Beating up of 20% plants in pits in the first year, 15% in second year and 5% in third year.
viii. Maintenance for 5 years including weeding and hoeing, maintenance of fence, watch and ward.
ix. *Kachcha water pond* 50 m^3 (1 m^3 = 1000 litre) outside the plantation area in nearby place alongwith 500 m^2 strip of grass.
x. *Kachcha* water pond of 25 m^3 having base of stone pitching or some impermeable or semi-permeable material.

Table 5.46. Budget norm for YM/MP/NL/01

Particular	**Quantity ha^{-1}**	**Rate**	**Rs. ha^{-1}**
Advance work			
Survey and demarcation of area	1 ha	0.45 mdays ha^{-1}	138.60
Cleaning of plantation area by cutting bushes (excluding *Lantana*)	1 ha	4 mdays ha^{-1}	1,232.00
Alignment			
a) Pits	200 no.	2.5 mdays /1,000	154.00
b) Contour trenches	300 no.	0.15 mdays/100	1,386.00
Soil work			
a) Pits (45 cm x 45 cm x 45 cm)	200 no.	5 mdays/100	3,080.00
b) Contour trenches (3.00 m x 0.60 m x 0.45 m)	300 no.	0.33 trench^{-1}	30,492.00
Chain link fence	100 m	450	45,000.00
Miscellaneous advance silvicultural works	1 ha	1.2 mdays ha^{-1}	369.60
Making of inspection path			
a) 3 m wide path upto plantation for jeep	25 m	30.65 mdays km^{-1}	236.01
b) 1 m wide path inside plantation	50 m	Lump sum	110.00
Cost of seed			
a) Quality seed for pits (200 plants + 20% for culling)	240 plants	Lump sum	240.00
b) Quality seed of trees for contour trenches (300 trenches)	14 kg	100 kg^{-1}	1,400,00
c) Grass seed	9 kg	120 kg^{-1}	1,080.00
Cost of plant (incl. 20% culling for obtaining quality stock) for pits	240	5.60 mdays /100 plant	4,139.52
Plantation sign board (per 25 ha)	1	Rs. 3,500/25 ha	140.00
Contingency			1,000.00
Total			88,797.73 **or 88,798**
Planting year			
Refilling/dressing pits and trenches			
a) Refilling pits (45 cm x 45 cm x 45 cm)	200 no.	1.5 mdays /100 pits	924.00
b) Refilling contour trenches (3.00 m x 0.60 m x 0.45 m)	300 no.	Rs. 2.25 trench^{-1}	675.00
c) Dressing contour trenches	300 no.	Rs. 2 trench^{-1}	600.00
Transportation of plants to roadhead	200 no.	0.912 mdays /100	561.80
Local transport of plants	200 no.	0.4 mdays/100	224.72
Planting in pits	200 plants	1.8 mdays /100	1,108.80
Sowing of tree seeds on contour trenches (100 trenches)at three points per trench	900 m	Lumpsum	600.00
Re-sowing of tree seeds on contour trenches to ensure targeted germination on trenches	600 m	Lumpsum	450.00
Sowing of grass seed along contour trench (six points trench^{-1})	1,800 seed	0.16 mdays/ 100 seed	887.04
Application of manure, AM, micronutrients	1,100 plants		

a) Plants in pits	200	Rs. 5.80 plant^{-1}	1,160.00
b) Seedlings on contour trenches	900	Rs. 2.50 plant^{-1}	2,250.00
Weeding and hoeing			
a) Around pits (three times)	200 pits x 3	1.5 mday/ 100	2,772.00
b) On contour trenches (three times)	300 trenches x 3	0.01 mdays/ 100	2,772.00
c) On cattle-proof trenches	40 m x 3	Rs.1.11 m^{-1}	133.20
Irrigation of plants 6 times			
a) Plants in pits	200 plants x 6	1.25 mdays/100	4,620.00
b) Seedlings on contour trenches at half of normal rate of plants in pits	900 x 6	0.62 mdays/ 100	10,311.84
Raising of plants for beating up casualties (20% failure)	40 no.	5.6 mdays/ 100	689.92
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Watch and ward for 9 months (Average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)	9 months	10.80 mdays yr^{-1}	2,494.80
Contingency	Lump sum		2,000.00
Total			35,373.72 **or 35,374**

Maintenance cost			
Year 3			
20% beating up of planted seedlings (labour)	40 plants	1.5 mdays/ 100	184.80
Weeding and hoeing (3 times yr^{-1})			
a) Around pits (three times)	200 pits x 3	1.5 mdays/100	2,772.00
b) On contour trenches	300 trenches x 3	0.01 mdays trench^{-1}	2,772.00
Irrigation of plants (12 times)			
a) Plants in pits	200 plants x 12	1.25 mdays/100	9,240.00
b) Seedlings on contour trenches at half of normal rate of plants in pits	900 x 12	0.62 mdays/ 100	20,623.68
Application of manure, AM, micronutrients			
a) Plants in pits	200 plants	Rs. 5.80 plant^{-1}	1,160.00
b) Seedlings on contour trenches	900	Rs. 2.50 plant^{-1}	2,250.00
Raising of plants for beating up casualties (15% casualty)	30 no.	5.6 mdays/ 100	519.44
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Watch and ward for 12 months (Average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	500.00
Total			43,484.92 **or 43,485**
Year 4			
15% beating up of planted seedlings (labour)	30 plants	1.5 mdays/ 100	138.60
Weeding and hoeing (1 time yr^{-1})			
a) Around pits	200 pits x 1	1.5 mdays/ 100	924.00
b) On contour trenches	300 trenches x 1	0.01mdays trench^{-1}	924.00
Irrigation of plants (6 times)			
a) Plants in pits	200 plants x 6	1.25 mdays/100	4,620.00
b) Seedlings on contour trenches at half of normal rate of plants in pits	900 x 6	0.62 mdays/ 100	10,311,84
Application of manure, AM, micronutrients			
a) Plants in pits	200 plants	Rs. 5.80 plant^{-1}	1,160.00
b) Seedlings on contour trenches	900	Rs. 2.50 plant^{-1}	2,250.00

Raising of plants for beating up casualties (5% casualty)	10 no.	5.6 mdays/ 100	192.48
Watch and ward for 12 months (Average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	500.00
Total			14,015.48 **or 14,015**
Year 5			
5% beating up of planted seedlings	10 plants	1.5 mdays/ 100	46.20
Weeding and hoeing (1 time yr^{-1})			
a) Around pits	200 pits x 1	1.5 mdays/ 100	924.00
b) On contour trenches	300 trenches x 1	0.01 mdays trench	924.00
Irrigation of plants (3 times)			
a) Plants in pits	200 plants x 3	1.25 mdays/100	2,310.00
b) Seedlings on trenches at half of normal rate of plants in pits	900 x 3	0.62 mdays/ 100	5,152.92
Application of manure, AM, micronutrients			
a) Plants in pits	200 plants	Rs. 5.80 $plant^{-1}$	1,160.00
b) Seedlings on contour trenches	900	Rs. 2.50 $plant^{-1}$	2,250.00
Watch and ward for 12 months (Average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	200.00
Total			16,293.52 or **16,294**
Year 6			
Watch and ward for 12 months (Average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	100
Total			3,426.40 or **3,426**
Year 7			**3,326**

Table 5.47. Cost summary for YM/MP/NL/01

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	88,798
Year 2 (Planting and establishment)	35,374
Year 3 (1^{st} maintenance)	43,485
Year 4 (2^{nd} maintenance)	14,015
Year 5 (3^{rd} maintenance)	16,294
Year 6 (4^{th} maintenance)	3,426
Year 7 (5^{th} maintenance)	3,326
Total	**2,04,718**

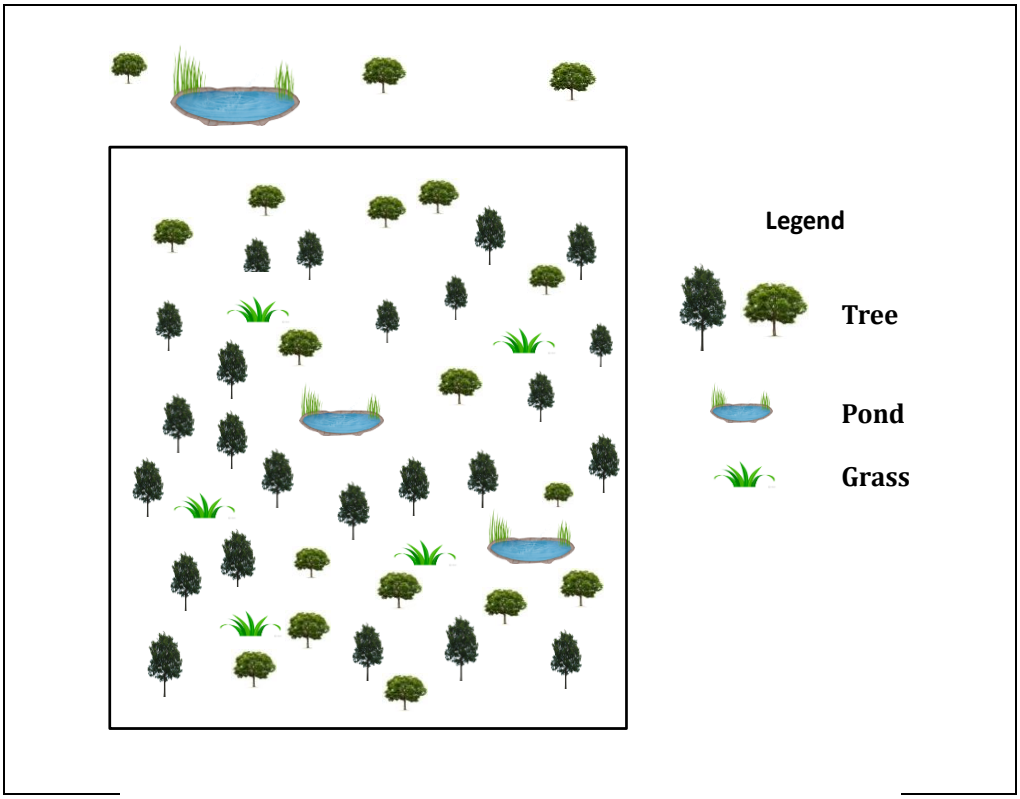


Fig. 5.25. Illustration of afforestation in open forest areas

YM/MP/NL/02: Assisted natural regeneration

This model will be applied in moist forest areas with good overwood where natural regeneration is not able to establish due to damage by grazing animals and competition from weeds. The regeneration needs to be protected from grazing animals, supported through soil and moisture conservation and supplemented through sowing in blanks.

In this model, the area will be fenced with cattle-proof trench and biofence. *Thawla* will be made around the seedlings and contour trenches will be dug in patches where regeneration is poor. Shoots of existing saplings and poles will be tended to give them improved form. The soil along the trenches will be seeded with indigenous tree and grass species. Sowing of seeds of indigenous trees will be carried out at three points (one each at both ends and in the middle) on the soil heaped along the trench. Grass will be sown at six points along the trench. More than one seed may be sown per spot to ensure seedling establishment at each spot.

Species recommended

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species on contour trenches

Tree and shrub: *Azadirachta indica, Madhuca indica, Anogeissus latifolia, Acacia nilotica, Dalbergia sissoo, Albizia lebbeck, Emblica officinalis, Pithecellobium dulce, Terminalia alata, Terminalia chebula, Terminalia arjuna, Bridelia retusa, Holoptelea integrifolia, Bombax ceiba,* etc.

Bamboo: *Dendrocalamus strictus, Bambusa bambos,* etc.

Grass: *Saccharum bengalense, Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica, Vetiveria zizanioides,* etc.

Important elements of the model (ha^{-1}) are:

i. Fencing with animal-proof trench and biofence.
ii. Making of *thawla* and tending of shoot of available saplings/poles.
iii. Hundred contour trenches of size 3 m x 0.45 m x 0.45 m.
iv. Sowing of tree and grass seeds/slips on contour trenches.
v. Maintenance for 5 years after planting year including weeding and hoeing.

Table 5.48. Budget norm for YM/MP/NL/02

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	0.45 mdays ha^{-1}	138.60
Cleaning of plantation area by cutting bushes (excluding *Lantana*)	1 ha	4 mdays ha^{-1}	1,232.00
Alignment of contour trenches	100 no.	0.15 mdays/ 100	46.20
Digging of contour trenches (3.00 m x 0.60 m x 0.45 m)	100 no.	0.33 trench^{-1}	10,164.00
Protective structure all around			
a) Cattle-proof trench (1.50 m x 0.90 m x 0,75 m)	60 m	0.6 mday m^{-1}	11,088.00
b) Stone wall (1.50 m x 0.90 m x 0,75 m)	40 m	0.7 mday m^{-1}	8,624.00
Tending of shoots of existing saplings and poles	1 ha	1.2 mdays ha^{-1}	369.60
Thawla making around 750 seedlings	750	Lumpsum	2,250.00
Making of inspection path			
a) 3 m wide path upto plantation for jeep	25 m	30.65 mdays km^{-1}	236.01
b) 1 m wide path inside plantation	50 m	Lump sum	110.00
Quality seed of trees for contour trenches (100 trenches)	4 kg	100 kg^{-1}	400,00
Grass seed	3 kg	120 kg^{-1}	360.00
Plantation sign board (per 25 ha)	1	Rs. 3,500/25 ha	140.00
Contingency			1,000.00
Total			35,758.41**or 35,758**
Planting year			
Refilling contour trenches (3.00 m x 0.60 m x 0.45 m)	100 no.	Rs. 2.25 trench^{-1}	225.00
Dressing contour trenches	100 no.	Rs. 2 trench^{-1}	200.00
Seed sowing			
a) Sowing of tree seeds on contour trenches (100 trenches) at three points per trench	300 m	Lumpsum	200.00
b) Re-sowing of tree seeds on contour trenches to ensure targeted germination on trenches	200 m	Lumpsum	150.00
c) Sowing of grass seed along contour trench (six points trench^{-1})	600 seed	0.16 mdays/ 100 seed	295.68
d) Sowing of seed on bund along cattle-proof trench (trees/shrubs other than *P. juliflora*) in three lines at double of normal rates	60 m	5 mdays km^{-1}	92.40
Application of manure, AM, micronutrients	300 plants	Rs. 2.50 plant^{-1}	750.00
Weeding and hoeing			
a) On contour trenches (three times)	100 trenches x 3	0.01 mdays trench^{-1}	924.00
b) On cattle-proof trenches	40 m x 3	Rs. 1.11 m^{-1}	133.20
Irrigation of plants 3 times at half of normal rate of plants in pits	300 plants x 3	0.62mdays/ 100	1,718.64
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40

b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Watch and ward for 9 months (Average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)	9 months	10.80 mdays yr^{-1}	2,494.80
Contingency	Lump sum		1,000.00
Total			8,322.32 **or 8,322**

Maintenance cost			
Year 3			
Weeding, hoeing on contour trenches 3 times yr^{-1}	100 trenches x 3	0.01mdays $trench^{-1}$	924.00
Irrigation of plants 6 times at half of normal rate of plants in pits	300 plants x 6	0.62 mdays/ 100	3,437.28
Application of manure, AM, micronutrients	300 plants	Rs. 2.50 $plant^{-1}$	750.00
Repair of animal-proof trench	60 m	0.07 mdays m^{-1}	1,619.00
Repair of protection wall	40 m	0.14 mdays m^{-1}	1,724.80
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Watch and ward for 12 months (Average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	500.00
Total			12,418.08 or **12,418**
Year 4			
Weeding, hoeing on contour trenches 1 time yr^{-1}	100 trenches x 1	0.01 mdays $trench^{-1}$	308.00
Irrigation of plants 2 times at half of normal rate of plants in pits	300 plants x 2	0.62 mdays/ 100	1,145.76
Application of manure, AM, micronutrients	300 plants	Rs. 2.50 $plant^{-1}$	750.00
Repair of animal-proof trench	60 m	0.07 mdays m^{-1}	1,619.00
Repair of protection wall	40 m	0.14 mdays m^{-1}	1,724.80
Watch and ward for 12 months (Average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	500.00
Total			9,371.96 **or 9,372**
Year 5			
Weeding, hoeing contour trenches 1 time yr^{-1}	100 trenches x 1	0.01 mdays $trench^{-1}$	308.00
Repair of animal-proof trench	60 m	0.2 mdays m^{-1}	3,696.00
Watch and ward for 12 months (Average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	200.00
Total			7,530.40 or **7,530**
Year 6			**3,326**
Year 7			**3,326**

Table 5.49. Cost summary for YM/MP/NL/02

Year	Rs. ha^{-1}
Year 1 (Advance work)	35,758
Year 2 (Planting and establishment)	8,322
Year 3 (1st maintenance)	12,418
Year 4 (2nd maintenance)	9,372
Year 5 (3rd maintenance)	7,530
Year 6 (4th maintenance)	3,326
Year 7 (5th maintenance)	3,326
Total	**80,052**

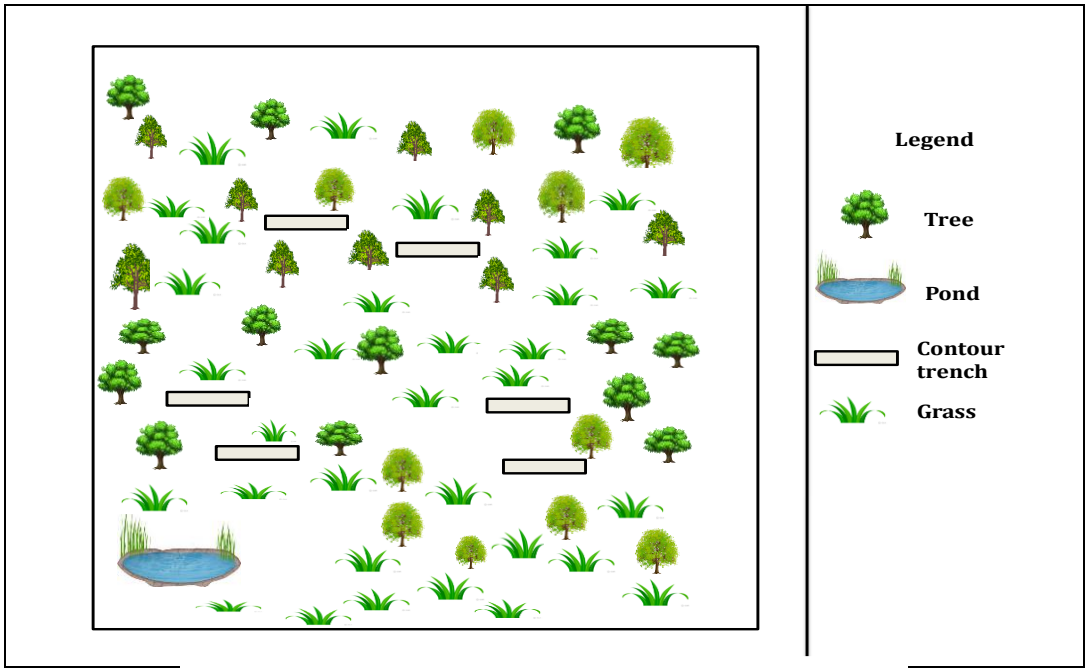


Fig. 5.26. Illustration of assisted natural regeneration

YM/MP/NL/03: Rehabilitation of forest infested with high-density invasive weeds

This model will be applied in areas having dense (more than 1,500 plants ha^{-1}) growth of invasive weed. *Lantana* has invaded the area due to its prolific reproduction and wide adaptability. *Lantana* will be removed. Cattle-proof trench will be dug all around the area and biofence will be raised. Removal of *Lantana* from entire area would be undesirable as it would result in deterioration of the site, hence a total of 5,000 m^2 area per ha will be cleared in alternating strips. Improved moisture conservation would create conditions favourable for regeneration of native species and would help in suppression of *Lantana*, therefore 128 contour trenches ha^{-1} will be dug in the cleared space. The soil along the contour trenches will be seeded with indigenous tree and grass species. Sowing of seeds of indigenous trees will be carried out at three points (one each at both ends, and one in the middle) on the soil heaped along the trench. Grass will be sown at six points along the trench. More than one seed may be sown per spot to ensure seedling establishment at each spot. The site will be maintained for five years.

As most of the sites for this model have rugged topography, steep to moderate slopes and loose soil, earthen check dams or similar structures (e.g. brushwood check dam, loose boulder check dam, etc.) have also been provided.

. Species recommended

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species on contour trenches

Tree and shrub: *Azadirachta indica, Madhuca indica, Anogeissus latifolia, Acacia nilotica, Dalbergia sissoo, Albizia lebbeck, Emblica officinalis, Pithecellobium dulce, Terminalia alata, Terminalia chebula, Terminalia arjuna, Bridelia retusa, Holoptelea integrifolia, Bombax ceiba,* etc.

Bamboo: *Dendrocalamus strictus, Bambusa bambos,* etc.

Grasse: *Saccharum bengalense, Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica, Vetiveria zizanioides,* etc.

Important elements of the model (ha^{-1}) are:

i. Fencing with Cattle-proof trench and biofence.
ii. One hundred twenty eight contour trenches of size 3 m x 0.45 m x 0.45 m.
iii. Earthen check dams (3.00 m x 0.90 m x 0.45 m), 100 no. or other size/no. equivalent to 121.5 m^{3}or brushwood check dam or other structures of equivalent value.
iv. Sowing of tree and grass seeds on contour trenches and earthen check dams.
v. Maintenance for 5 years after planting year including weeding and hoeing.

Table 5.50. Budget norm for YM/MP/NL/03

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	0.45 mdays ha^{-1}	138.60
Removal of high-density *Lantana* (>1500 bushes ha^{-1})	5,000 m^2	22 mdays ha^{-1}	3,388.00
Alignment of contour trenches	128 no.	0.15 mdays/ 100	59.14
Digging of contour trenches (3.00 m x 0.60 m x 0.45 m)	128 no.	0.33 trench^{-1}	13,009.92
Preparation of earthen check dams (3.00 m x 0.90 m x 0.45 m, 100 no. or other size/no. equivalent to 121.5 m^{3}or brushwood check dam or other structures of equivalent value	121.5 m^2	0.6 mdays m^{-3}	22,453.20
Protective structure all around			
a) Cattle-proof trench (1.50 m x 0.90 m x 0,75 m)	60 m	0.6 mday m^{-1}	11,088.00
b) Stone wall (1.50 m x 0.90 m x 0,75 m)	40 m	0.7 mday m^{-1}	8,624.00
Tending of shoots of existing saplings and poles	5,000 m^2	1.2 mdays ha^{-1}	184.80
Thawla making around 750 seedlings/poles	750	Lumpsum	2,250.00
Making of inspection path			
a) 3 m wide path upto plantation for jeep	25 m	30.65 mdays km^{-1}	236.01
b) 1 m wide path inside plantation	50 m	Lump sum	110.00
Quality seed of trees for contour trenches (128 trenches)	5.12 kg	100 kg^{-1}	512.00
Grass seed for contour trenches	3.84 kg	120 kg^{-1}	460.80
Seed for earthen check dams (other than *P. juliflora*) (at double of normal rate)	Equivalent to 100 earthen check dams	15.50 earthen check dam^{-1}	1,550.00
Plantation sign board (per 25 ha)	1	Rs. 3,500/25 ha	140.00
Contingency			1,200.00
Total			65,407.47 **or 65,407**

Planting year			
Removal of *Lantana* at half of normal rate for the area	5,000 m^2	11 mdays ha^{-1}	1,694.00
Refilling contour trenches (3.00 m x 0.60 m x 0.45 m)	128 no.	Rs. 2.25 $trench^{-1}$	288.00
Dressing contour trenches	128 no.	Rs. 2 $trench^{-1}$	256.00
Dressing earthen check dams	100 no.	Rs. 3.08 earthen check dam^{-1}	308.00
Seed sowing			
a) Sowing of tree seeds on contour trenches (128 trenches) at three points per trench	384 m	Lumpsum	256.00
b) Re-sowing of tree seeds on contour trenches to ensure targeted germination on trenches	256 m	Lumpsum	190.67
c) Sowing of grass seed along contour trench (six points $trench^{-1}$)	768 seed	0.16 mdays/ 100 seed	378.47
d) Sowing of tree and grass seed on earthen check dam	100 earthen check dams	Rs. 1.33 earthen check dam^{-1}	1,330.00
e) Re-sowing of tree and grass seed on earthen check dam	100 earthen check dams	Rs. 0.88 earthen check dam^{-1}	880.00
f) Sowing of seed on bund along cattle-proof trench (trees/shrubs other than *P. juliflora*) in three lines at double of normal rates	60 m	5 mdays km^{-1}	92.40
g) Dibbling of seed in vacant spaces 3 m below contour trenches	384 no.	0.2 mdays/ 100	236.55
Application of manure, AM, micronutrients	384 plants	Rs. 2.50 $plant^{-1}$	960.00
Weeding and hoeing			
a) On contour trenches (three times)	128 trenches x 3	0.01mdays $trench^{-1}$	1,182.72
b) On cattle-proof trenches	40 m x 3	Rs. 1.11 m^{-1}	133.20
Irrigation of plants 3 times at half of normal rate of plants in pits	384 plants x 3	0.62 mdays/ 100	2,219.50
Repair of animal-proof trench	60 m	0.07 mdays m^{-1}	1,293.60
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Watch and ward for 9 months (Average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)	9 months	10.80 mdays yr^{-1}	2,494.80
Contingency	Lump sum		1,200.00
Total			15,510.51 **or 15,511**

Maintenance cost			
Year 3			
Removal of *Lantana* at one-fourth of normal rate for the area	5,000 m^2	5.5 mdays ha^{-1}	847.00
Weeding, hoeing on contour trenches 3 times yr^{-1}	128 trenches x 3	0.01mdays $trench^{-1}$	1,182.72
Irrigation of plants 6 times at half of normal rate of plants in pits	384 plants x 6	0.62 mdays/ 100	4,399.72
Application of manure, AM, micronutrients	384 plants	Rs. 2.50 $plant^{-1}$	960.00
Repair of animal-proof trench	60 m	0.14mdays m^{-1}	2,587.20
Repair of protection wall	40 m	0.14 mdays m^{-1}	1,724.80
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Watch and ward for 12 months (Average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	500.00
Total			15,666.44 **or 15,666**

Year 4			
Removal of *Lantana* at one-tenth of normal rate for the area	5,000 m^2	2.2 mdays ha^{-1}	33.88
Weeding, hoeing on contour trenches 1 time yr^{-1}	128 trenches x 1	0.01 mdays trench^{-1}	394.24
Irrigation of plants 2 times at half of normal rate of plants in pits	384 plants x 2	0.62 mdays/ 100	1,466.58
Application of manure, AM, micronutrients	384 plants	Rs. 2.50 $plant^{-1}$	960.00
Repair of animal-proof trench	60 m	0.20mdays m^{-1}	3,696.00
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	500.00
Total			10,377.10 **or 10,377**
Year 5			
Weeding, hoeing contour trenches 1 time yr^{-1}	128 trenches x 1	0.01 mdays trench^{-1}	394.24
Repair of animal-proof trench	60 m	0.20mdays m^{-1}	3,696.00
Repair of protection wall	40 m	0.14 mdays m^{-1}	1,724.80
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	200.00
Total			9,341.44 **or 9,341**
Year 6			**3,326**
Year 7			**3,326**

Table 5.51. Cost summary for YM/MP/NL/03

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	65,407
Year 2 (Planting and establishment)	15,511
Year 3 (1st maintenance)	15,666
Year 4 (2nd maintenance)	10,377
Year 5 (3rd maintenance)	9,341
Year 6 (4th maintenance)	3,326
Year 7 (5th maintenance)	3,326
Total	**1,22,954**

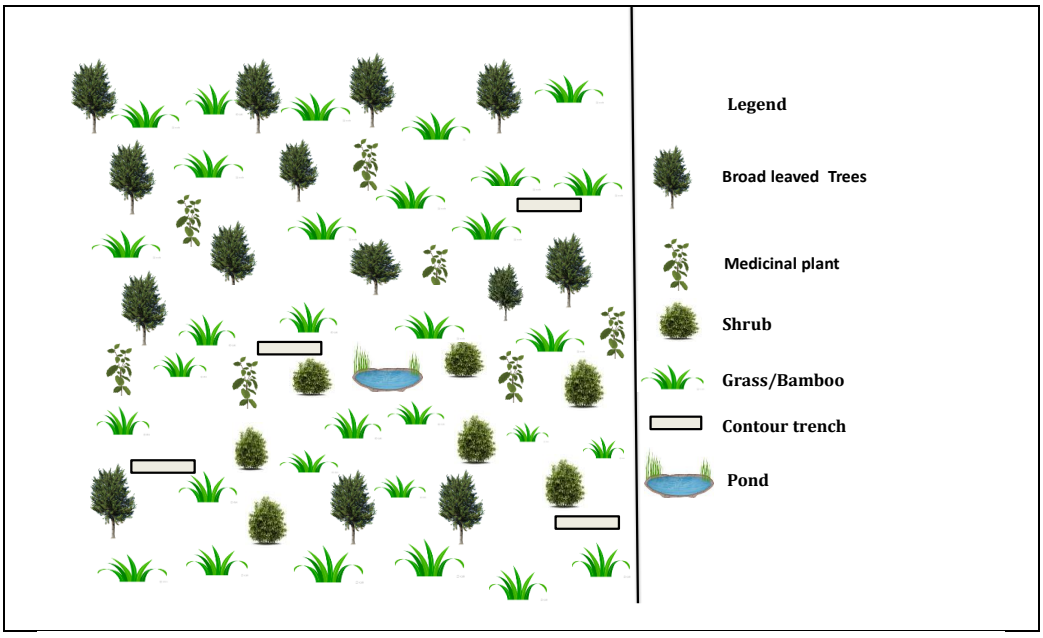


Fig. 5.27. Illustration of rehabilitation of invasive species infested areas

YM/MP/NL/04: Rehabilitation of forest infested with moderate-density invasive weeds

This model will be applied in conditions similar to the previous model except that the density of invasive weed is 500-1500 ha^{-1} which is less than the previous model. *Lantana* has invaded the area due to its prolific reproduction and wide adaptability. *Lantana* will be removed. Cattle-proof trench will be dug all around the area and biofence will be raised. Removal of *Lantana* from entire area would be undesirable as it would result in deterioration of the site, hence a total of 5,000 m^2 area per ha will be cleared in alternating strips. Improved moisture conservation would create conditions favourable for regeneration of native species and would help in suppression of *Lantana*, therefore 128 contour trenches ha^{-1} will be dug in the cleared space. The soil along the contour trenches will be seeded with indigenous tree and grass species. Sowing of seeds of indigenous trees will be carried out at three points (one each at both ends, and one in the middle) on the soil heaped along the trench. Grass will be sown at six points along the trench. More than one seed may be sown per spot to ensure seedling establishment at each spot. The site will be maintained for five years.

As most of the sites for this model have rugged topography, steep to moderate slopes and loose soil, earthen check dams or similar structures (e.g. brushwood check dam, loose boulder check dam, etc.) have also been provided.

Species recommended

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Species on protection trenches

Tree and shrub: *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.

Species on contour trenches

Tree and shrub: *Azadirachta indica, Madhuca indica, Anogeissus latifolia, Acacia nilotica, Dalbergia sissoo, Albizia lebbeck, Emblica officinalis, Pithecellobium dulce, Terminalia alata, Terminalia chebula, Terminalia arjuna, Bridelia retusa, Holoptelea integrifolia, Bombax ceiba,* etc.

Bamboo: *Dendrocalamus strictus, Bambusa bambos,* etc.

Grass: *Saccharum bengalense, Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica, Vetiveria zizanioides,* etc.

Important elements of the model (ha^{-1}) are:

i. Fencing with Cattle-proof trench and biofence.
ii. One hundred twenty eight contour trenches of size 3 m x 0.45 m x 0.45 m.
iii. Earthen check dams (3.00 m x 0.90 m x 0.45 m), 100 no. or other size/no. equivalent to 121.5 m^3or brushwood check dam or other structures of equivalent value.
iv. Sowing of tree and grass seeds on contour trenches and earthen check dams.
v. Maintenance for 5 years after planting year including weeding and hoeing.

Table 5.52. Budget norm for YM/MP/NL/04

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	0.45 mdays ha^{-1}	138.60
Removal of medium-density *Lantana* (500^{-1},500 bushes ha^{-1})	5,000 m^2	12.5 mdays ha^{-1}	1,925.00
Alignment of contour trenches	128 no.	0.15 mdays/ 100	59.14
Digging of contour trenches (3.00 m x 0.60 m x 0.45 m)	128 no.	0.33 $trench^{-1}$	13,009.92

Preparation of earthen check dams (3.00 m x 0.90 m x 0.45 m, 100 no. or other size/no. equivalent to 121.5 m^3or brushwood check dam or other structures of equivalent value	121.5 m^2	0.6 mdays m^{-3}	22,453.20
Protective structure all around			
a) Cattle-proof trench (1.50 m x 0.90 m x 0,75 m)	60 m	0.6 mday m^{-1}	11,088.00
b) Stone wall (1.50 m x 0.90 m x 0,75 m)	40 m	0.7 mday m^{-1}	8,624.00
Tending of shoots of existing saplings and poles	5,000 m^2	1.2 mdays ha^{-1}	184.80
Thawla making around 450 seedlings/poles	450	Lumpsum	1,350.00
Making of inspection path			
a) 3 m wide path upto plantation for jeep	25 m	30.65 mdays km^{-1}	236.01
b) 1 m wide path inside plantation	50 m	Lump sum	110.00
Quality seed of trees for contour trenches (256 trenches)	5.12 kg	100 kg^{-1}	512.00
Grass seed for contour trenches	3.84 kg	120 kg^{-1}	460.80
Seed for earthen check dams (other than *P. juliflora*) (at double of normal rate)	Equivalent to 100 earthen check dams	15.50 earthen check dam^{-1}	1,550.00
Plantation sign board (per 25 ha)	1	Rs. 3,500/25 ha	140.00
Contingency			1,000.00
Total			62,841.47 **or 62,841**
Planting year			
Removal of *Lantana* at half of normal rate for the area	5,000 m^2	6.25 mdays ha^{-1}	962.50
Refilling contour trenches (3.00 m x 0.60 m x 0.45 m)	128 no.	Rs. 2.25 $trench^{-1}$	288.00
Dressing contour trenches	128 no.	Rs. 2 $trench^{-1}$	256.00
Dressing earthen check dams	100 no.	Rs. 3.08 earthen check dam^{-1}	308.00
Seed sowing			
a) Sowing of tree seeds on contour trenches (128 trenches) at three points per trench	384 m	Lumpsum	256.00
b) Re-sowing of tree seeds on contour trenches to ensure targeted germination on trenches	256 m	Lumpsum	190.67
c) Sowing of grass seed along contour trench (six points $trench^{-1}$)	768 seed	0.16 mdays/ 100 seed	378.47
d) Sowing of tree and grass seed on earthen check dam	100 earthen check dams	Rs. 1.33 earthen check dam^{-1}	1,330.00
e) Re-sowing of tree and grass seed on earthen check dam	100 earthen check dams	Rs. 0.88 earthen check dam^{-1}	880.00
f) Sowing of seed on bund along cattle-proof trench (trees/shrubs other than *P. juliflora*) in three lines at double of normal rates	60 m	5 mdays km^{-1}	92.40
g) Dibbling of seed in vacant spaces 3 m below contour trenches	384 no.	0.2 mdays/ 100	236.55
Application of manure, AM, micronutrients	384 plants	Rs. 2.50 $plant^{-1}$	960.00
Weeding and hoeing			
a) On contour trenches (three times)	128 trenches x 3	0.01 mdays $trench^{-1}$	1,182.72
b) On cattle-proof trenches	40 m x 3	Rs. 1.11 m^{-1}	133.20
Irrigation of plants 3 times at half of normal rate of plants in pits	384 plants x 3	0.62 mdays/ 100	2,219.60
Repair of animal-proof trench	60 m	0.07 mdays m^{-1}	1,293.60
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Watch and ward for 9 months (Average 12 hrs	9 months	10.80 mdays yr^{-1}	2,494.80

sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)			
Contingency	Lump sum		800.00
Total			14,379.11 **or 14,379**

Maintenance cost			
Year 3			
Removal of *Lantana* at one-fourth of normal rate for the area	5,000 m^2	5.5 mdays ha^{-1}	847.00
Weeding, hoeing on contour trenches 3 times yr^{-1}	128 trenches x 3	0.01mdays $trench^{-1}$	1,182.72
Irrigation of plants 6 times at half of normal rate of plants in pits	384 plants x 6	0.62 mdays/ 100	4,399.72
Application of manure, AM, micronutrients	384 plants	Rs. 2.50 $plant^{-1}$	960.00
Repair of animal-proof trench	60 m	0.14 mdays m^{-1}	2,587.20
Repair of protection wall	40 m	0.14 mdays m^{-1}	1,724.80
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	500.00
Total			15,666.44 **or 15,666**
Year 4			
Removal of *Lantana* at one-tenth of normal rate for the area	5,000 m^2	2.2 mdays ha^{-1}	33.88
Weeding, hoeing on contour trenches 1 time yr^{-1}	128 trenches x 1	0.01 mdays $trench^{-1}$	394.24
Irrigation of plants 2 times at half of normal rate of plants in pits	384 plants x 2	0.62 mdays/ 100	1,466.58
Application of manure, AM, micronutrients	384 plants	Rs. 2.50 $plant^{-1}$	960.00
Repair of animal-proof trench	60 m	0.20 mdays m^{-1}	3,696.00
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	500.00
Total			10,377.10 **or 10,377**
Year 5			
Weeding, hoeing contour trenches (1 time yr^{-1})	128 trenches x 1	0.01 mdays $trench^{-1}$	394.24
Repair of animal-proof trench	60 m	0.20 mdays m^{-1}	3,696.00
Repair of protection wall	40 m	0.14 mdays m^{-1}	1,724.80
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	200.00
Total			9,341.44 **or 9,341**
Year 6			**3,326**
Year 7			**3,326**

Table 5.53. Cost summary for YM/MP/NL/04

Year	Rs. ha^{-1}
Year 1 (Advance work)	62,841
Year 2 (Planting and establishment)	14,379
Year 3 (1st maintenance)	15,666
Year 4 (2nd maintenance)	10,377
Year 5 (3rd maintenance)	9,341
Year 6 (4th maintenance)	3,326
Year 7 (5th maintenance)	3,326
Total	**1,19,256**

YM/MP/NL/05: Rehabilitation of forest infested with low-density invasive weeds

This model will be applied in conditions similar to the previous model except that the density of invasive weed is negligible (less than 500 plants ha^{-1}). The invasive weed will be removed. Cattle-proof trench will be dug all around the area and biofence will be raised. Removal of *Lantana* from entire area would be undesirable as it would result in deterioration of the site, hence a total of 5,000 m^2 area per ha will be cleared in alternating strips. Improved moisture conservation would create conditions favourable for regeneration of native species and would help in suppression of *Lantana*, therefore 128 contour trenches ha^{-1} will be dug in the cleared space. The soil along the contour trenches will be seeded with indigenous tree and grass species. Sowing of seeds of indigenous trees will be carried out at three points (one each at both ends, and one in the middle) on the soil heaped along the trench. Grass will be sown at six points along the trench. More than one seed may be sown per spot to ensure seedling establishment at each spot. The site will be maintained for five years.

As most of the sites for this model have rugged topography, steep to moderate slopes and loose soil, earthen check dams or similar structures (e.g. brushwood check dam, loose boulder check dam, etc.) have also been provided.

Plant species recommended: Same as the species recommended for YM/MP/NL/03.

Important elements of the model (ha^{-1}) are:

i. Fencing with Cattle-proof trench and biofence.
ii. One hundred twenty eight contour trenches of size 3 m x 0.45 m x 0.45 m.
iii. Earthen check dams (3.00 m x 0.90 m x 0.45 m), 100 no. or other size/no. equivalent to 121.5 m^3or brushwood check dam or other structures of equivalent value.
iv. Sowing of tree and grass seeds on contour trenches and earthen check dams.
v. Maintenance for 5 years after planting year including weeding and hoeing.

Table 5.54. Budget norm for YM/MP/NL/05

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	0.45 mdays ha^{-1}	138.60
Removal of low-density *Lantana* (500-1500 bushes ha^{-1})	5,000 m^2	8 mdays ha^{-1}	1,232.00
Alignment of contour trenches	128 no.	0.15 mdays/ 100	59.14
Digging of contour trenches (3.00 m x 0.60 m x 0.45 m)	128 no.	0.33 trench^{-1}	13,009.92
Preparation of earthen check dams (3.00 m x 0.90 m x 0.45 m, 100 no. or other size/no. equivalent to 121.5 m^{3}or brushwood check dam or other structures of equivalent value	121.5 m^2	0.6 mdays m^{-3}	22,453.20
Protective structure all around			
a) Cattle-proof trench (1.50 m x 0.90 m x 0,75 m)	60 m	0.6 mday m^{-1}	11,088.00
b) Stone wall (1.50 m x 0.90 m x 0,75 m)	40 m	0.7 mday m^{-1}	8,624.00
Tending of shoots of existing saplings and poles	5,000 m^2	1.2 mdays ha^{-1}	184.80
Thawla making around 200 seedlings/poles	200	Lumpsum	600.00
Making of inspection path			
a) 3 m wide path upto plantation for jeep	25 m	30.65 mdays km^{-1}	236.01
b) 1 m wide path inside plantation	50 m	Lump sum	110.00
Quality seed of trees for contour trenches (256 trenches)	5.12 kg	100 kg^{-1}	512.00
Grass seed for contour trenches	3.84 kg	120 kg^{-1}	460.80
Seed for earthen check dams (other than *P. juliflora*) (at double of normal rate)	Equivalent to 100 earthen check dams	15.50 earthen check dam^{-1}	1,550.00
Plantation sign board (per 25 ha)	1	Rs. 3,500/25 ha	140.00
Contingency			1,000.00
Total			61,398.47 **or 61,398**
Planting year			
Removal of *Lantana* at half of normal rate for the area	5,000 m^2	4 mdays ha^{-1}	616.00
Refilling contour trenches (3.00 m x 0.60 m x 0.45 m)	128 no.	Rs. 2.25 trench^{-1}	288.00
Dressing contour trenches	128 no.	Rs. 2 trench^{-1}	256.00
Dressing earthen check dams	100 no.	Rs. 3.08 earthen check dam^{-1}	308.00
Seed sowing			
a) Sowing of tree seeds on contour trenches (128 trenches) at three points per trench	384 m	Lumpsum	256.00
b) Re-sowing of tree seeds on contour trenches to ensure targeted germination on trenches	256 m	Lumpsum	190.67
c) Sowing of grass seed along contour trench (six points trench^{-1})	768 seed	0.16 mdays/ 100 seed	378.47
d) Sowing of tree and grass seed on earthen check dam	100 earthen check dams	Rs. 1.33 earthen check dam^{-1}	1,330.00
e) Re-sowing of tree and grass seed on earthen check dam	100 earthen check dams	Rs. 0.88 earthen check dam^{-1}	880.00
f) Sowing of seed on bund along cattle-proof trench (trees/shrubs other than *P. juliflora*) in three lines at double of normal rates	60 m	5 mdays km^{-1}	92.40
g) Dibbling of seed in vacant spaces 3 m below contour trenches	384 no.	0.2 mdays/ 100	236.55
Application of manure, AM, micronutrients	384 plants	Rs. 2.50 plant^{-1}	960.00
Weeding and hoeing			
a) On contour trenches (three times)	128 trenches x 3	0.01 mdays trench^{-1}	1,182.72
b) On cattle-proof trenches	40 m x 3	Rs. 1.11 m^{-1}	133.20
Irrigation of plants 3 times at half of normal rate of	384 plants x 3	0.62 mdays/ 100	2,219.60

plants in pits			
Repair of animal-proof trench	60 m	0.07 mdays m^{-1}	1,293.60
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Watch and ward for 9 months (average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)	9 months	10.80 mdays yr^{-1}	2,494.80
Contingency	Lump sum		800.00
Total			14,032.61 **or 14,033**

Maintenance cost			
Year 3			
Removal of *Lantana* at one-fourth of normal rate for the area	5,000 m^2	2 mdays ha^{-1}	308.00
Weeding, hoeing on contour trenches 3 times yr^{-1}	128 trenches x 3	0.01mdays $trench^{-1}$	1,182.72
Irrigation of plants 6 times at half of normal rate of plants in pits	384 plants x 6	0.62 mdays/ 100	4,399.72
Application of manure, AM, micronutrients	384 plants	Rs. 2.50 $plant^{-1}$	960.00
Repair of animal-proof trench	60 m	0.14 mdays m^{-1}	2,587.20
Repair of protection wall	40 m	0.14 mdays m^{-1}	1,724.80
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	500.00
Total			14,627.44 **or 14,627**
Year 4			
Removal of *Lantana* at one-tenth of normal rate for the area	5,000 m^2	0.8 mdays ha^{-1}	15.40
Weeding, hoeing on contour trenches 1 time yr^{-1}	128 trenches x 1	0.01 mdays $trench^{-1}$	394.24
Irrigation of plants 2 times at half of normal rate of plants in pits	384 plants x 2	0.62 mdays/ 100	1,466.58
Application of manure, AM, micronutrients	384 plants	Rs. 2.50 $plant^{-1}$	960.00
Repair of animal-proof trench	60 m	0.20 mdays m^{-1}	3,696.00
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	500.00
Total			10,358.62 **or 10,359**
Year 5			
Weeding, hoeing contour trenches (one time yr^{-1})	128 trenches x 1	0.01 mdays $trench^{-1}$	394.24
Repair of animal-proof trench	60 m	0.20 mdays m^{-1}	3,696.00
Repair of protection wall	40 m	0.14 mdays m^{-1}	1,724.80
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mdays yr^{-1}	3,326.40
Contingency		Lumpsum	200.00
Total			9,341.44 **or 9,341**
Year 6			**3,326**
Year 7			**3,326**

Table 5.55. Cost summary for YM/MP/NL/05

Year	Rs. ha^{-1}
Year 1 (Advance work)	61,398
Year 2 (Planting and establishment)	14,033
Year 3 (1st maintenance)	14,627
Year 4 (2nd maintenance)	10,359
Year 5 (3rd maintenance)	9,341
Year 6 (4th maintenance)	3,326
Year 7 (5th maintenance)	3,326
Total	**1,16,410**

YM/MP/NL/06: Removal of high-density invasive weeds

This model will be applied in Madhav National Park, Shivpuri in sites having high-density (more than 1,500 plants ha^{-1}) infestation by invasive weeds. Protection from cattle is not required in the area. *Lantana* will be removed from half of the area so as not to expose the soil that would otherwise risk site deterioration. Ground water recharge will be improved through contour trenches at a modest density of 64 contour trenches per ha. The soil along the trenches will be seeded with indigenous tree and grass species. Sowing of seeds of indigenous trees will be carried out at three points (one each at both ends, and one in the middle) on the soil heaped along the trench. Grass will be sown at six points along the trench. More than one seed may be sown per spot to ensure seedling establishment at each spot. These steps will encourage regeneration of native vegetation and reduce the probability of invasion of *Lantana* after the project activities are over. The site will be maintained for five years.

Important elements of the model (ha^{-1}) are:

i. Sixty four contour trenches of size 3 m x 0.45 m x 0.45 m.
ii. Sowing of tree and grass seeds on contour trenches.
iii. Maintenance for 5 years after planting year including weeding and hoeing.

Species recommended

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree and shrub: *Azadirachta indica, Madhuca indica, Anogeissus latifolia, Acacia nilotica, Dalbergia sissoo, Albizia lebbeck, Emblica officinalis, Pithecellobium dulce, Terminalia alata, Terminalia chebula, Terminalia arjuna, Bridelia retusa, Holoptelea integrifolia, Bombax ceiba,* etc.

Bamboo: *Dendrocalamus strictus, Bambusa bambos,* etc.

Grass: *Saccharum bengalense, Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica, Vetiveria zizanioides,* etc.

Table 5.56. Budget norm for YM/MP/NL/06

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	0.45 mdays ha^{-1}	138.60
Removal of high-density *Lantana* (>1,500 bushes ha^{-1})	5,000 m^2	22 mdays ha^{-1}	3,388.00
Alignment of contour trenches	64 no.	0.15 mdays/ 100	29.57
Digging of contour trenches (3.00 m x 0.60 m x 0.45 m)	64 no.	0.33 trench^{-1}	6,504.96
Seed of trees for contour trenches (64 trenches)	2.56 kg	100 kg^{-1}	256.00
Grass seed	1.92 kg	120 kg^{-1}	230.40
Contingency			400.00
Total			10,947.53 **or 10,948**

Planting year			
Refilling contour trenches (3.00 m x 0.60 m x 0.45 m)	64 no.	Rs. 2.25 trench^{-1}	144.00
Removal of *Lantana* at half of normal rate for the area	5,000 m^2	11 mdays ha^{-1}	1,694.00
Dressing contour trenches	64 no.	Rs. 2 trench^{-1}	128.00
Seed sowing			
a) Sowing of tree seeds on contour trenches (64 trenches) at three points per trench	192 m	Lumpsum	128.00
b) Re-sowing of tree seeds on contour trenches to ensure targeted germination on trenches	128 m	Lumpsum	55.33
c) Sowing of grass seed along contour trench (six points trench^{-1})	384 seed	0.16 mdays/ 100 seed	189.24
d) Dibbling of seed in vacant spaces 3 m below contour trenches	192 no.	0.2 mdays/ 100	118.27
Application of manure, AM, micronutrients	192 plants	Rs. 2.50 plant^{-1}	480.00
Weeding, hoeing on contour trenches (three times)	64 trenches x 3	0.01 mdays trench^{-1}	591.36
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Contingency	Lump sum		300.00
Total			3,966.80 **or 3,967**

Maintenance cost			
Year 3			
Removal of *Lantana* at one-fourth of normal rate for the area	5,000 m^2	5.5 mdays ha^{-1}	847.00
Weeding, hoeing on contour trenches 3 times yr^{-1}	64 trenches x 3	0.01mdays trench^{-1}	691.36
Irrigation of plants 6 times at half of normal rate of plants in pits	192 plants x 6	0.62 mdays/ 100	2,199.86
Application of manure, AM, micronutrients	192 plants	Rs. 2.50 plant^{-1}	480.00
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Contingency		Lumpsum	200.00
Total			4,556.82 **or 4,557**
Year 4			
Removal of *Lantana* at one-tenth of normal rate for the area	5,000 m^2	2.2 mdays ha^{-1}	338.80
Weeding, hoeing on contour trenches 1 time yr^{-1}	64 trenches x 1	0.01 mdays trench^{-1}	197.11
Irrigation of plants 2 times at half of normal rate of plants in pits	192 plants x 2	0.62 mdays/ 100	733.29
Application of manure, AM, micronutrients	192 plants	Rs. 2.50 plant^{-1}	480.00
Contingency		Lumpsum	100.00
Total			1,849.20 **or 1,849**
Year 5			
Weeding, hoeing contour trenches (one time yr^{-1})	64 trenches x 1	0.01 mdays trench^{-1}	197.12
Contingency		Lumpsum	100.00
Total			297.12 or **297**

Table 5.57. Cost summary for YM/MP/NL/06

Year	Rs. ha^{-1}
Year 1 (Advance work)	10,948
Year 2 (Planting and establishment)	3,967
Year 3 (1st maintenance)	4,557
Year 4 (2nd maintenance)	1,849
Year 5 (3rd maintenance)	297
Total	**21,618**

YM/MP/NL/07: Removal of moderate-density invasive weeds

Like the previous model, this model too will be applied in Madhav National Park, Shivpuri, but the density of invasive weed in this model is moderate (500-1500 plants ha^{-1}).

Plant species recommended: Same as the species recommended for YM/MP/NL/06.

Important elements of the model (ha^{-1}) are:

i. Sixty four contour trenches of size 3 m x 0.45 m x 0.45 m.
ii. Sowing of tree and grass seeds on contour trenches.
iii. Maintenance for 5 years after planting year including weeding and hoeing.

Table 5.58. Budget norm for YM/MP/NL/07

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	0.45 mdays ha^{-1}	138.60
Removal of medium-density *Lantana* (>1,500 bushes ha^{-1})	5,000 m^2	12.5 mdays ha^{-1}	1,925.00
Alignment of contour trenches	64 no.	0.15 mdays/ 100	29.57
Digging of contour trenches (3.00 m x 0.60 m x 0.45 m)	64 no.	0.33 $trench^{-1}$	6,504.96
Seed of trees for contour trenches (64 trenches)	2.56 kg	100 kg^{-1}	256.00
Grass seed	1.92 kg	120 kg^{-1}	230.40
Contingency			400.00
Total			9,484.53 **or 9,485**
Planting year			
Refilling contour trenches (3.00 m x 0.60 m x 0.45 m)	64 no.	Rs. 2.25 $trench^{-1}$	144.00
Removal of *Lantana* at half of normal rate for the area	5,000 m^2	6.25 mdays ha^{-1}	962.50
Dressing contour trenches	64 no.	Rs. 2 $trench^{-1}$	128.00
Seed sowing			
a) Sowing of tree seeds on contour trenches (64 trenches) at two points per trench	128 m	Lumpsum	85.33
b) Re-sowing of tree seeds on contour trenches to ensure targeted germination on trenches	84 m	Lumpsum	56.00
c) Sowing of grass seed along contour trench (six points $trench^{-1}$)	384 seed	0.16 mdays/ 100 seed	189.24
d) Dibbling of seed in vacant spaces 3 m below contour trenches	192 no.	0.2 mdays/ 100	118.72
Application of manure, AM, micronutrients	128 plants	Rs. 2.50 $plant^{-1}$	320.00
Weeding, hoeing on contour trenches (three times)	64 trenches x 3	0.01 mdays $trench^{-1}$	591.36
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Contingency	Lump sum		300.00
Total			**3,033.75 or 3,034**

Maintenance cost			
Year 3			
Removal of *Lantana* at one-fourth of normal rate for the area	5,000 m^2	5.5 mdays ha^{-1}	847.00
Weeding, hoeing on contour trenches 3 times yr^{-1}	64 trenches x 3	0.01mdays $trench^{-1}$	691.36
Irrigation of plants 6 times at half of normal rate of plants in pits	128 plants x 6	0.62 mdays/ 100	1,466.57
Application of manure, AM, micronutrients	128 plants	Rs. 2.50 $plant^{-1}$	320.00
Fire protection			
a) Creating 6 m wide fire line	0.200 km	1.5 mday km^{-1}	92.40
b) Controlled burning	0.200 km	0.75 mday km^{-1}	46.20
Contingency		Lumpsum	200.00
Total			3,663.53 **or 3,664**
Year 4			
Removal of *Lantana* at one-tenth of normal rate for the area	5,000 m^2	2.2 mdays ha^{-1}	338.80
Weeding, hoeing on contour trenches (one time yr^{-1})	64 trenches x 1	0.01 mdays $trench^{-1}$	197.11
Irrigation of plants 2 times at half of normal rate of plants in pits	128 plants x 2	0.62 mdays/ 100	488.86
Application of manure, AM, micronutrients	128 plants	Rs. 2.50 $plant^{-1}$	320.00
Contingency		Lumpsum	100.00
Total			1,444.77 **or 1,445**
Year 5			
Weeding, hoeing contour trenches (one time yr^{-1})	64 trenches x 1	0.01 mdays $trench^{-1}$	197.12
Contingency		Lumpsum	100.00
Total			297.12 or **297**

Table 5.59. Cost summary for YM/MP/NL/07

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	9,485
Year 2 (Planting and establishment)	3,034
Year 3 (1^{st} maintenance)	3,664
Year 4 (2^{nd} maintenance)	1,445
Year 5 (3^{rd} maintenance)	297
Total	**19,925**

YM/MP/NL/08: Grassland development in wildlife areas

This model will be implemented for developing rangeland with the objective of producing forage grasses and legumes for wildlife. The site will be fenced with cattle-proof trench and biofence, the land will be ploughed to pulverize the soil and seeds/ plants of pasture grass and legumes will be sown during the monsoon season. *Kachcha* water pond(s) /*dabra dabri* with stone pitching of total 50 m^3 storage capacity will be created within the plantation area to store water for drinking by animals. Weeding and hoeing will be done to help establishment of pasture. Suitable organic manures will be applied. After one and a half year the fence will be removed and site will be opened for grazing. Additional *Kachcha* water pond(s)/*dabra dabri* of total 50,000 L storage capacity will be created as a part of this model outside the plantation area for free access to grazing animals during the period of development of grassland and also afterwards.

Species recommended

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree and shrub:*Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana*, etc.

Grass:*Saccharum bengalense, Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica, Vetiveria zizanioides*, etc.

Legume:*Alysicarpus rugosus, Rhynchosia minima, Indigofera glandulosa, Rhynchosia capitata, Alysicarpus longifolius, Stylosanthes hamata*, etc.

Important elements of the model (ha^{-1}) are:

Fencing: Cattle-proof trench with biofence.

Sowing of pasture grass.

Chowkidar will protect the grassland for one year.

Table 5.60. Budget norm for YM/MP/NL/08

Particular	**Quantity ha^{-1}**	**Rate**	**Rs. ha^{-1}**
Advance work			
Survey and demarcation of area	1 ha	0.45 mdays ha^{-1}	138.60
Cleaning of area by cutting bushes	1 ha	4 mdays ha^{-1}	1,232.00
Digging out roots of bushes and removal of boulders that may interfere with ploughing by tractor	1 ha	Rs. 2,000	2,000.00
Cattle-proof trench (1.50 m x 0.90 m x 0,75 m) all around	100 m	0.6 mday m^{-1}	18,480.00
Kachcha pond inside plantation area with stone pitching at base			
a) Digging of *Kachcha* pond inside plantation in area of hard rock	25 m^3	128 m^{-3}	3,200.00
b) Providing stone pitching at base (incl. cost of material)	Lump sum		800.00
Digging of *Kachcha* pond outside plantation with *Kachcha* base	50 m^3	128 m^{-3}	6,400.00
Making of inspection path 3 m wide path upto plantation for jeep	25 m	30.65 mdays km^{-1}	236.01
Seed of pasture grasses and legumes	15 kg	120 kg^{-1}	1,800.00
Plantation sign board (per 25 ha)	1	Rs. 3,500/25 ha	140.00
Contingency			1,000.00
Total			35,426.61 **or 35,427**
Planting year			
Ploughing with tractor to pulverize soil	1 ha	Lump sum	2,000.00
Sowing of grass seed in the area	1 ha	Lump sum	1,500.00
Sowing of seed on bund along cattle-proof trench (trees/shrubs other than *P. juliflora*) in three lines at double of normal rates	100 m	5 mdays km^{-1}	154.00
Application of manure, AM, micronutrients		Lump sum	1,000.00
Irrigation of grass and plants on protection trench	1 ha	Lump sum	1,200.00

(one time)			
Weeding and hoeing			
a) Grassed area to dig out bushes and unpalatable plants (twice)		Lump sum	2,000.00
b) On cattle-proof trenches (twice)	100 m x 2	Rs. 1.11 m^{-1}	222.00
Watch and ward for 9 months (average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)	9 months	10.80 mdays yr^{-1}	2,494.80
Contingency		Lump sum	800.00
Total			11,370.80 **or 11,371**

Maintenance cost			
Year 3			
Irrigation of grass and plants on protection trench (one time)	1 ha	Lump sum	1,200.00
Weeding, hoeing of grassed area to dig out bushes and unpalatable plants (one time)	1 ha	Lump sum	1,000.00
Watch and ward for 6 months (average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 days mo^{-1} x 8 hrs)	6 months	10.80 mdays yr^{-1}	1,663.20
Uprooting of biofence and levelling off protection trench at the end of year	100 m	Lump sum	1,000.00
Contingency		Lumpsum	500.00
Total			5,363.20 **or 5,363**
Year 4	Maintenance		**1,000**

Table 5.61. Cost summary for YM/MP/NL/08

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	35,427
Year 2 (Planting and establishment)	11,371
Year 3 (1st maintenance)	5,363
Year 4 (2nd maintenance)	1,000
Total	**53,161**

YM/MP/NL/09: Grass with moisture conservation

This model will be implemented in areas that require measure to reduce soil erosion and conserve moisture for producing forage grasses and legumes. Conservation ditches will be dug to conserve rain water. The conservation ditches may have greater density in depressions. Conservation ditches of 1.5 m width will be constructed in areas having less than 10 per cent slope. On slopes exceeding 10 per cent, the width of conservation ditch will be reduced and number increased accordingly. Check dams may be provided in gullies, if needed in lieu of ditches, within the same cost. Pasture grasses and legumes will be sown in the entire area.

Weeding and hoeing will be done to help establishment of pasture. Suitable organic manures will be applied. After one and a half year the fence will be removed and site will be opened for grazing.

Grass: *Saccharum bengalense, Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Chrysopogon fulvus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica, Vetiveria zizanioides,* etc.
Legume: *Alysicarpus rugosus, Rhynchosia minima, Indigofera glandulosa, Rhynchosia capitata, Alysicarpus longifolius, Stylosanthes hamata,* etc.

Important elements of the model (ha^{-1}) are:
Fencing: Cattle-proof trench with biofence.
Conservation ditches 150 m length, 1.5 m width and 60 cm depth on slopes less than 10 percent. On greater slope, the width of ditches will be decreased to suit the slope and total length will be increased.
Grass and legume sowing in entire area.

Table 5.62. Budget norm for YM/MP/NL/09

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	0.45 mdays ha^{-1}	138.60
Cleaning of area by cutting bushes	1 ha	4 mdays ha^{-1}	1,232.00
Conservation ditches total 150 m length, 1.5 m width and 60 cm depth or equivalent volume (less width and more length on sites with >10 per cent slope)	135 m^3	Lumpsum	12,000.00
Making of inspection path 3 m wide path upto plantation for jeep	25 m	30.65 mdays km^{-1}	236.01
Contingency			400.00
Total			12,006.61 **or 12,007**
Planting year			
Seed of pasture grasses and legumes for sowing on and around conservation ditches	2 kg	120 kg^{-1}	240.00
Sowing of grass seed on and around conservation ditches	750 m^2	Lump sum	120.00
Application of manure, AM, micronutrients		Lump sum	70.00
Contingency		Lump sum	300.00
Total			**730.00 or 730**

Maintenance cost			
Year 3	Maintenance		**750**
Year 4	Maintenance		**750**
Year 5	Maintenance		**750**

Table 5.63. Cost summary for YM/MP/NL/09

Year	Rs. ha^{-1}
Year 1 (Advance work)	12,007
Year 2 (Planting and establishment)	730
Year 3 (1st maintenance)	730
Year 4 (2nd maintenance)	730
Year 5 (3rd maintenance)	730
Total	**14,927**

YM/MP/NL/10: Treatment of gullies and slopes through vegetative measures with soil and moisture conservation
The context and prescriptions of this model are broadly similar to those of YM/UK/UP/06 'Treatment of gullies and steep slopes through vegetative measures with soil and moisture conservation'. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.64.

Species recommended

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree and shrub: *Azadirachta indica, Madhuca indica, Anogeissus latifolia, Acacia nilotica, Dalbergia sissoo, Albizia lebbeck, Emblica officinalis, Pithecellobium dulce, Terminalia alata, Terminalia chebula, Terminalia arjuna, Bridelia retusa, Holoptelea integrifolia, Bombax ceiba, Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc.
Bamboo: *Dendrocalamus strictus, Bambusa bambos,* etc.
Grass: *Saccharum bengalense, Aristida adscensionis, Eremopogon foveolatus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Cynodon dactylon, Chrysopogon fulvus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Cenchrus ciliaris, Themeda triandra, Iseilema laxum, I. prostratum, Apluda mutica, Vetiveria zizanioides,* etc.

YM/MP/NL/10/A: Earthen check dam
YM/MP/NL/10/B: Contour trench
YM/MP/NL/10/C: Contour bund

Table 5.64. Budget norm for YM/MP/NL/10/A to YM/MP/NL/10/C

Sub-model	Cost of soil work (Rs.)	Cost of seed and sowing	Estt. cost	Maint. cost (yr^{-1})	Total cost (Rs. m^{-3} or ha)
YM/MP/NL/10/A Earthen check dam 3m x 0.60 m x 0.45 m size; quantity as per requirement of particular site (200 no. or 162 m^3 earthen check dams will be equivalent to 1 ha)	Rs. 185 m^{-3} (or Rs. 29,970 ha^{-1}) Rs. 105 m^{-3} (or Rs. 21,000ha^{-1})	Rs. 18 m^{-3} (or Rs. 2,916ha^{-1})	Rs. 203 m^{-3} (or Rs. 32,886 ha^{-1})	Rs. 20 m^{-3} (or Rs. 3,240 ha^{-1}) x 5 years = 100 m^{-3} or 16,200ha^{-1}	Rs. 303 m^{-3} (or Rs. 49,08 ha^{-1})
YM/MP/NL/10/B Contour trench 3 m x 0.45 m x 0.45 m size; quantity as per requirement of particular site (200 trenches or 121.5 m^3 will be equivalent to 1 ha)	Rs. 102 m^{-3} (or Rs. 12,393 ha^{-1})	Rs. 10 m^{-3} or Rs. 1,215 ha^{-1}	Rs. 112 m^{-3} or Rs. 13,608 ha^{-1}	Rs. 11.20 m^{-3} or Rs. 1,360.80 ha^{-1} x 5 years = Rs. 56.00 m^{-3} or Rs. 6,804 ha^{-1}	Rs. 168 m^{-3} or Rs. 20,412 ha^{-1}
YM/MP/NL/10/C Contour bund (40 cm +20 cm)/2 x 25 cm x 1m; quantity as per requirement of particular site (1000 m or 75 m^3 bunds will be equivalent to 1 ha)	Rs. 11.19 m^{-1} (or Rs. 11,190 ha^{-1})	Rs. 3.47 m^{-1} (or Rs. 3,470 ha^{-1})	Rs. 14.66m^{-1} (or Rs. 14,660 ha^{-1})	Rs. 1.466 m^{-1} (or Rs. 1,466 ha^{-1}) x 5 years = 7.33 m^{-1} or 7,330 ha^{-1}	Rs. 21.99 m^{-1} (or Rs. 21,990 ha^{-1})

Table 5.65. Cost summary for YM/MP/NL/10/A to YM/MP/NL/10/C (Rs. m^{-3})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
YM/MP/NL/10/A Earthen check dam						
32,886	3,240	3,240	3,240	3,240	3,240	49,086
YM/MP/NL/10/B Contour trench						
13,608	1,360.80	1,360.80	1,360.80	1,360.80	1,360.80	20,412
YM/MP/NL/10/CContour bund						
14,660	1,466	1,466	1,466	1,466	1,466	21,990



Fig. 5.28. Illustration of treatment of gullies and slopes through vegetative measures with soil and moisture conservation
(**Source:** IISWC, Dehradun)

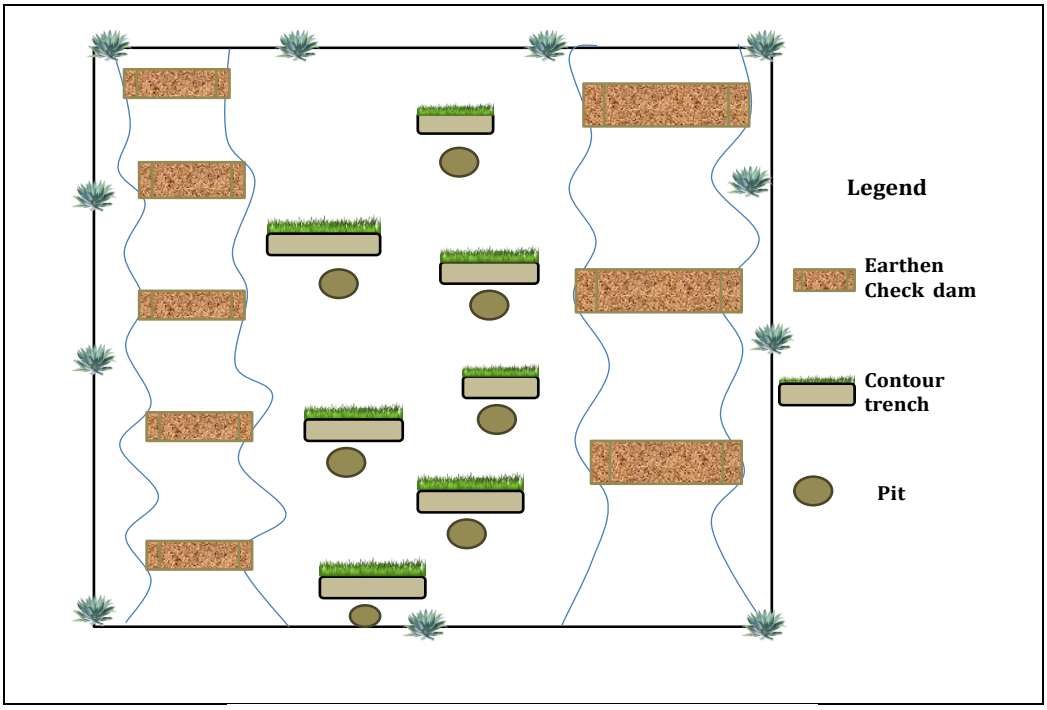


Fig. 5.29. Illustration of earthen check dam

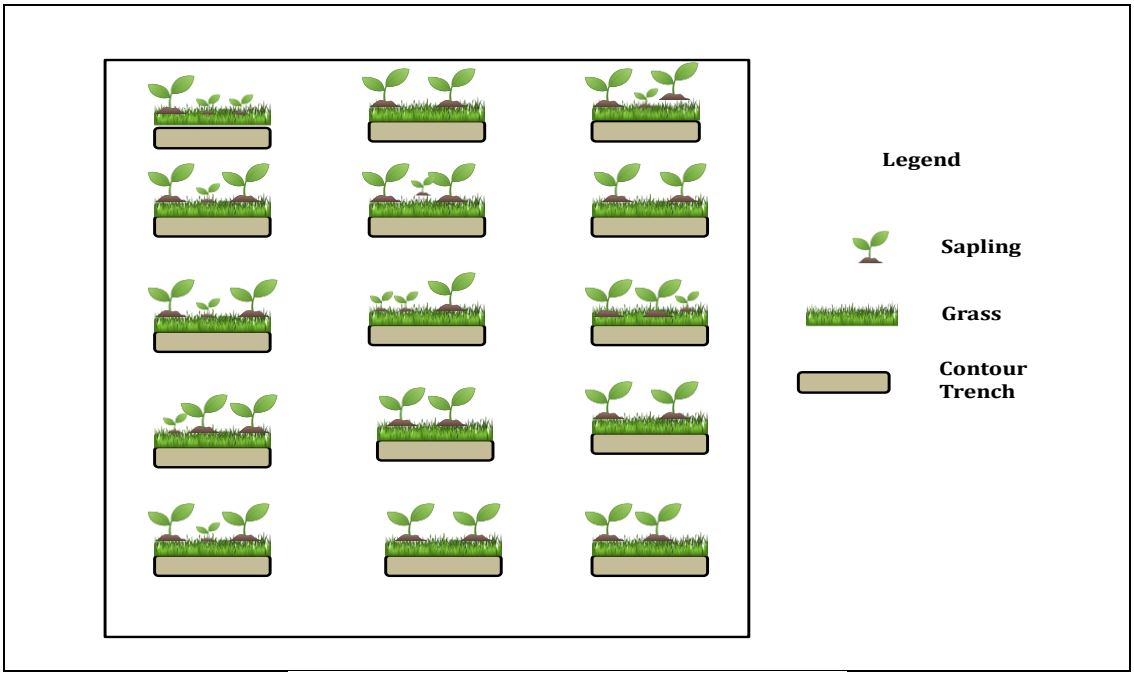


Fig. 5.30. Illustration of contour bunding

YM/MP/NL/11: Ecorestoration by Eco Task Force

The context and prescriptions of this model are broadly similar to those of YM/UK/NL/07 'Ecorestoration by Eco Task Force'. It is proposed that inhospitable sites in difficult terrain measuring 800 ha will be assigned by SFD to Eco-Tack Force for carrying out afforestation activities.

Cost: The cost norms are given in Table 5.66.

Table 5.66. Cost summary for YM/MP/NL/11

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
2,30,000	0	0	0	0	0	**2,30,000**

(ii) Treatment Models for Agricultural Landscape

A. Uttarakhand

YM/UK/AL/01: Planting of saplings by farmers

This model will be implemented in agricultural land in temperate, sub-temperate and sub-tropical zone in Uttarakhand. Forestry as well as horticultural species will be planted depending upon the requirement of the landowners. Planting stock and technical knowledge will be supplied to them through appropriate mechanism under this project. Planting and maintenance of the plants will be done by the landowners themselves. Financial incentive to the growers will be provided based on the survival of plants.

Plants will be planted along the bunds in two rows at a spacing of 3 m. Two hundred sixty four plants will be considered equivalent to one hectare.

The model may be implemented as per the provisions of *'Hamara Ped, Hamara Dhan'* scheme of Uttarakhand SFD.

Species recommended

Native species of the area will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree:*Grewia optiva, Bauhinia variegata, Bauhinia purpurea, Celtis australis, Dalbergia sissoo, Ficus roxburghii, F. palmata, Terminalia alata, T. bellirica, Cordia dichotoma, Quercus leutrichophora, Q. dilatata, Salix alba, Juglans regia, Morus alba,* etc.

Bamboo: *Dendrocalamus strictus, Thamnocalamus falconeri, Sinarundinaria anceps,* etc.

Fruit tree: Apple, pear, peach, plum, apricot, walnut,etc.

Cost norms for model YM//UK/AL//01:

Cost of plant including carriage (Year 1): Rs. 100 plant^{-1}, and
Planting and maintenance cost during planting year (Year 1): Rs. 100 plant^{-1}.
Maintenance cost in Year 2: Rs. 25 plant^{-1}.
Maintenance cost in Year 3: Rs. 25 plant^{-1}.
Maintenance cost in Year 4: Rs. 25 plant^{-1}.
Maintenance cost in Year 5: Rs. 25 plant^{-1}.
i.e. Rs. 300 plant^{-1} or Rs 79,200 ha^{-1}

YM/UK/AL/02: Plantation on Community Lands

Landholding size of farming families in the Yamuna basin is small and many families are landless. Community land serves as place for grazing by cattle and source of firewood and fodder. At many places these lands are degraded and are source of soil erosion and rapid runoff of water. Local communities have evinced interest to regenerate the sites. It is proposed to help the rural communities plant these sites with useful species of plants.

Planting will be done as per details given for model YM/UK/NL/03. Local community will be entrusted with the responsibility to plant, maintain and manage the plantation through appropriate local institution.

Cost norms: Same as the cost norms of model YM/UK/NL/03

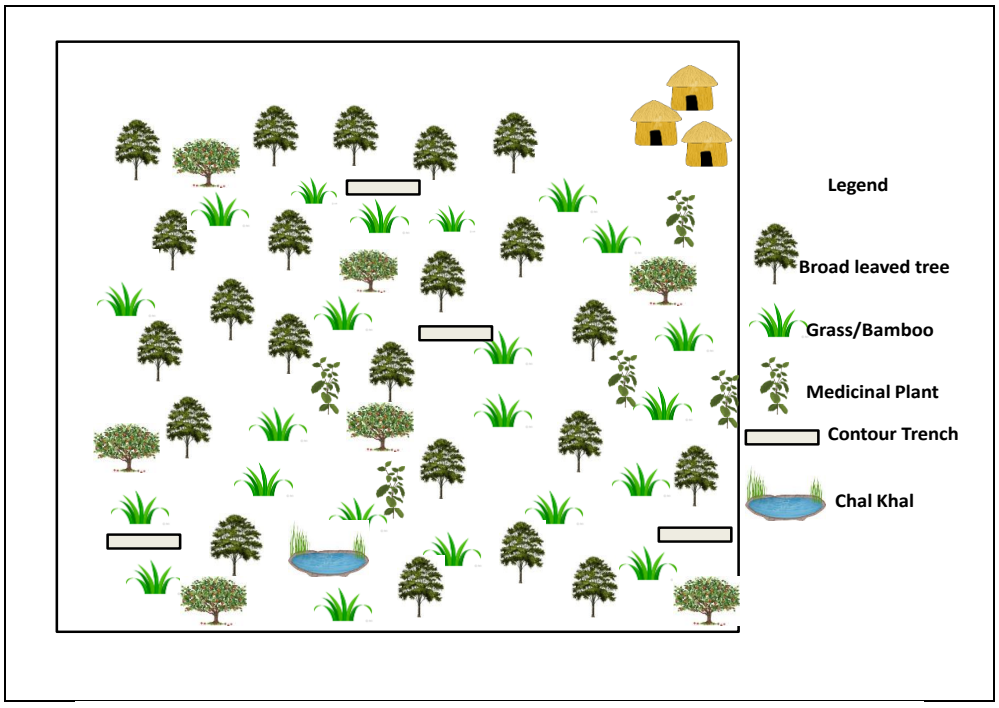


Fig. 5.31. Illustration of plantation model on community lands

B. Himachal Pradesh

YM/HP/AL/01: Planting of saplings by farmers

The context and prescriptions of this model are same as those for YM/UK/AL/01 'Planting of saplings by farmers'. The cost norms applicable to the model in Himachal Pradesh are given as follows:

Cost norms for model YM/ HP /AL//01:

Cost of plant including carriage (Year 1): Rs. 50 plant^{-1}, and
Planting and maintenance cost during planting year (Year 1): Rs. 50 plant^{-1}
Maintenance cost in Year 2: Rs. 25 plant^{-1}
Maintenance cost in Year 3: Rs. 25 plant^{-1}
Maintenance cost in Year 4: Rs. 25 plant^{-1}
Maintenance cost in Year 5: Rs. 25 plant^{-1}
Maintenance cost in Year 6: Rs. 25 plant^{-1}
i.e. Rs. 225 plant^{-1} or Rs 59,400 ha^{-1}

YM/HP/AL/02: Plantation on community lands

The context and prescriptions of this model are same as those for YM/UK/AL/02 'Plantation on community lands'.

Cost norms: Same as the cost norms of model YM/HP/NL/03

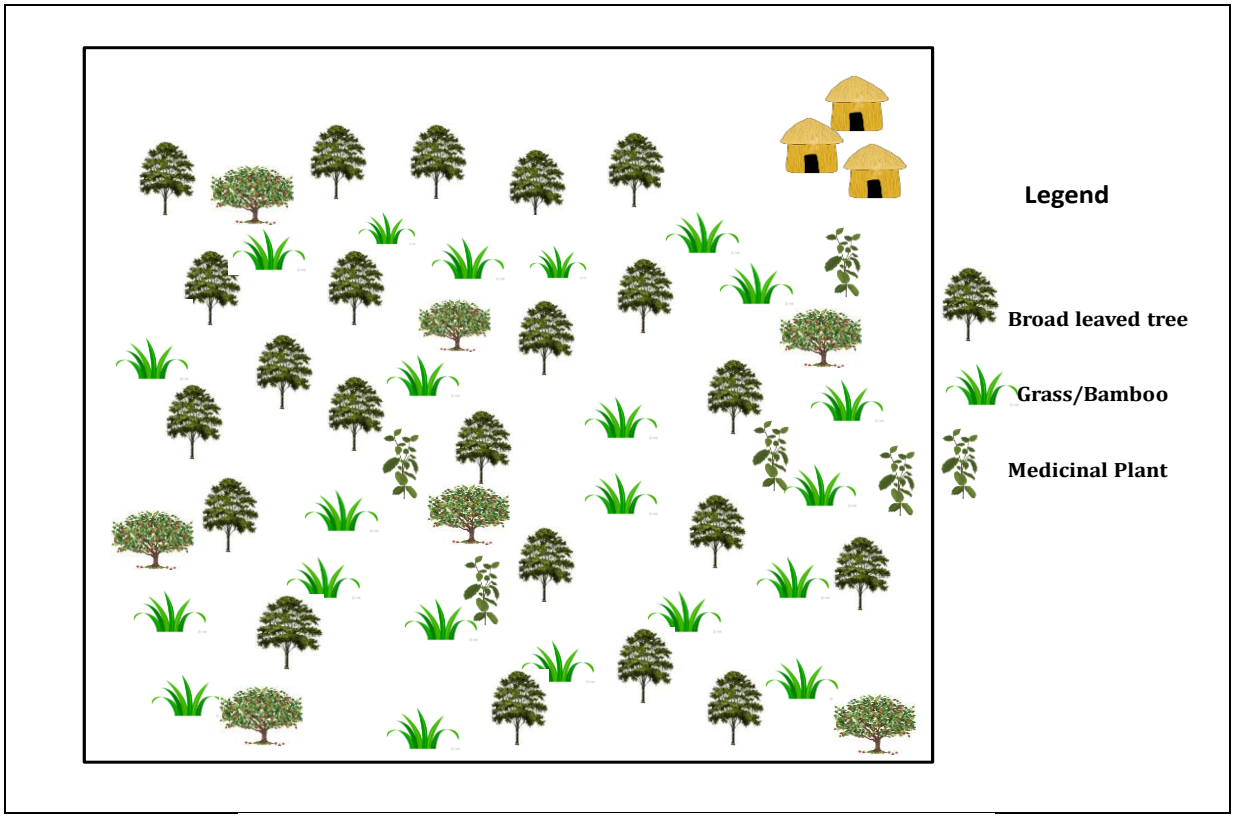


Fig. 5.32. Illustration of plantations on community land

C. Haryana

YM/HY/AL/01: Planting of saplings by farmers

Tree planting is expected to benefit the river and general environment of the area in many ways in the long run. Saplings of plants are proposed to be distributed to farmers for planting in their private agricultural land in the riverscape. Technlogy for plantation and maintenance will also be provided. Planting may be done on field bunds or as block plantation. All the plantation and aftercare operations will be done by the farmers. This will ensure active participation and capacity building of the farmers.

Species recommended

Native species of the area will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree:*Dalbergia sissoo, Albizia lebbeck, Prosopis cineraria, Azadirachta indica, Salvadora persica, Holoptelea integrifolia, Melia azedarach, Terminalia alata, T. bellirica, Cordia dichotoma,* etc.

Bamboo: *Dendrocalamus strictus,* etc.

Fruit tree: *Ziziphus mauritiana, Zizyphus jujuba, Emblica officinalis, Punica granatum, Citrus* spp., *Morus alba,* etc.

Cost norm for YM/HY/AL/01

Cost of tree sapling, including carriage to village: Rs. 50 plant^{-1}.
Planting and maintenance cost during planting year: Rs. 50 plant^{-1}.
Maintenance cost in 1st year: Rs. 25 plant^{-1}.
Maintenance cost in 2nd year: Rs. 25 plant^{-1}.
Maintenance cost in 3rd year: Rs. 20 plant^{-1}.
Maintenance cost in 4th year: Rs. 15 plant^{-1}.
Establishment cost: Rs. 100 plant^{-1} or Rs 50,000 ha^{-1} (notional density: 500 plants ha^{-1}).
Maintenance cost: Rs. 85 plant^{-1} or Rs 42,500 ha^{-1}.
Total cost: Rs. 185 plant^{-1} or Rs. 92,500 ha^{-1}.

Table 5.67.Year-wise cost summary for YM/HY/AL/01 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Total
50,000	12,500	12,500	10,000	7,500	**92,500**

YM/HY/AL/02: Silvipasture on community land

Tree planting on community land is very important for utilizing this land resource and providing economic and environmental benefits to the rural society. While planting trees, planting of grasses is of immense importance to arrest soil erosion. Grasses establish and grow fast, cover the ground rapidly and start providing environmental goods and services earlier than trees do. Grasses, in comparison with trees, need less aftercare and show greater survival on marginal lands. Silvi-pasture model for highly degraded land/ waste lands of ICAR-Indian Grassland and Fodder Research Institute, Jhansi (http://www.igfri.res.in/Proven%20Technologies6.aspx) will be adopted with necessary local modification. Tree saplings and grass slips will be planted on community land. Site will be prepared before monsoon season. 400 pits of 45 cm x 45 cm x 45 cm size will be dug per ha. Seedlings of trees will be planted during the monsoon season. Remaining area will be intercropped with high-yielding fodder grasses at 50 cm row-to-row. One weeding will be done to benefit establishment of pasture. Suitable organic manures will be applied. Harvesting of pasture grasses will be done 2-3 times (from September to December) depending on monsoon and growth of pasture up to initial 5 years following the cut and carry system. After attaining growth of tree, grazing may be allowed for small ruminant. After 3rd year 20-40 % lopping of trees may be done.

Kachcha water pond of 50,000 L storage capacity will be created as a part of this model outside the plantation area for free access of grazing animals. This pond will be surrounded by a strip of grass covering 150 m^2 area, fenced with brushwood. *Kachcha* water pond(s), with base of stone or some impermeable or semi-permeable material, of total 25000 L will be created inside the plantation to store water for a longer period of time for irrigation of plants; after two years the stone at the base will be removed to facilitate ground water recharge. Fodder and other produce will be used by the entire community.

Species to be planted

Native species of the area will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree: *Azadirachta indica, Prosopis cineraria, Dalbergia sissoo, Moringa oleifera, Morus alba, Salvadora persica, Pongamia pinnata, Melia azedarach, Holoptelea integrifolia, Bauhinia racemosa, Ougeinia oojeinensis*, etc.

Biofence: *Ziziphus nummularia, Carissa opaca,Acacia catechu, Acacia nilotica, Agave sisalana* etc.

Grass: *Pennisetum purpureum* (napier grass), *Pennisetum pedicellatum* (dinanath grass), *Chrysopogon fulvus* (dhawalu grass), *Cenchrus ciliaris* (anjan grass), *Dichanthium annulatum* (kel grass), *Bothriochloa pertusa* (phulwa grass), *Setaria sphacelata* (nandi grass), *Sehima nervosum* (sen grass), *Heteropogon contortus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya*, etc.

Important elements of the model (ha^{-1}):

Fencing: Barbed wire fence.
Pit size: 45 cm x 45 cm x 45 cm.
Four hundred trees ha^{-1}.
Interspaces will be intercropped with pasture grasses at 50 cm x 50 cm.
Watch and ward will be provided through a chowkidar.

Table 5.68. Cost norm for YM/HY/AL/02

Particular	Quantity ha^{-1}	Rs. ha^{-1}
Advance work		
Survey and alignment		500
Cleaning of site and making inspection path	1 ha	3,500
Fencing of site (barbed wire/stone wall)		58,000
Cost of quality nursery stock of trees (including 10% extra for culling)	400 +40 plants	13,200
Cost of seed/nursery stock of pasture grasses and legumes	Lumpsum	2,000
Digging of pits 0.45 m x 0.45 m x 0.45 m size	400 pits	3,530
Ploughing of site for planting grass		2,000
Digging of *Kachcha* water pond inside plantation with stone pitching at base	25 m^3	5,000
Digging of *Kachcha* water pond outside plantation with *Kachcha* base	50 m^3	7,500
Total		**95,230**
Planting activity		
Planting in pits	400 plants	1,250
Seed sowing on protection trench		1,000
Sowing / planting of grass in plantation area	Lumpsum	2,000
Planting of grass in pits around outer pond	600 slips	600
Erecting brushwood fence around grass strip		600
Manure/ vermicompost	Lumpsum	2,000
Maintenance of plants (for 9 months)		7,500
Contingency	Lumpsum	2,000
Total		**16,950**

Maintenance cost			
Year 3 (Maintenance	20% beating up of tree seedlings	80 tree seedlings	2,640

1st year)	Weeding and hoeing (4 times yr^{-1})	Lumpsum	5,000
	Irrigation (6 times)	Lumpsum	18,000
	Watch and ward	One year	9,990
	Contingency	Lumpsum	500
	Total		**36,130**
Year 4 (Maintenance 2nd year)	15% beating up	60 tree seedlings	1,980
	Weeding, hoeing, fence repair (3 times yr^{-1})	Lumpsum	3,750
	Irrigation (2 times)	Lumpsum	6,000
	Watch and ward	One year	9,990
	Total		**21,720**
Year 5	5% beating up	20 plants	660
	Weeding, hoeing, fence repair (2 times yr^{-1}), removal of stone base from pond	Lumpsum	3,000
	Watch and ward	One year	9,990
	Total		**13,650**
Year 6			**9,990**
Year 5			**9,990**

Table 5.69. Year-wise cost summary for YM/HY/AL/02

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	95,230
Year 2 (Planting and establishment)	16,950
Year 3 (1st maintenance)	3,630
Year 4 (2nd maintenance)	21,720
Year 5 (3rd maintenance)	13,650
Year 6 (4th maintenance)	9,990
Year 7 (5th maintenance)	9,990
Total	**2,03,660**

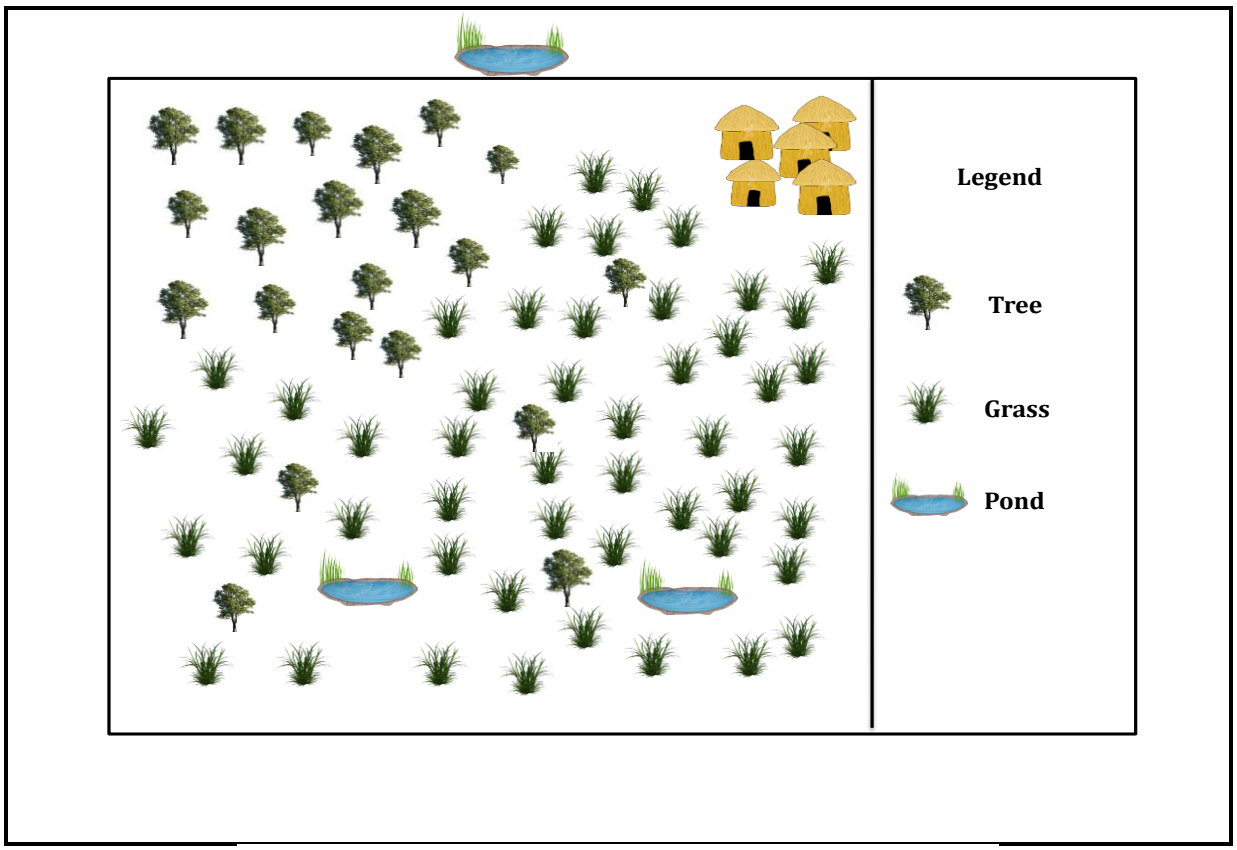


Fig. 5.33. Illustration of silvipasture on community land

D. Delhi

Sites in Delhi NCT for agriculture landscape in the riverscape were not proposed by SFD.

E. Uttar Pradesh

YM/UP/AL/01: Planting of saplings by farmers

The context and prescriptions of this model are broadly similar to those of YM/HY/AL/01 'Planting of saplings by farmers'.

Cost norm for YM/UP/AL/01 (Rs. ha^{-1})

Cost of tree sapling, including carriage to village: Rs. 50 plant^{-1}.
Planting and maintenance cost during planting year: Rs. 50 plant^{-1}.
Maintenance cost in 1st year: Rs. 25 plant^{-1}.
Maintenance cost in 2nd year: Rs. 25 plant^{-1}.
Maintenance cost in 3rd year: Rs. 25 plant^{-1}.
Maintenance cost in 4th year: Rs. 25 plant^{-1}.
Establishment cost ha^{-1}: Rs. 50,000 ha^{-1}.
Maintenance cost: Rs. 50,000 ha^{-1}.
Total cost: Rs. 1,00,000 ha^{-1}.

Table 5.70. Year-wise cost (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Total
50,000	12,500	12,500	12,500	12,500	**1,00,000**

YM/UP/AL/02: Silvipasture on community land

The context and prescriptions of this model are broadly similar to those of YM/HY/AL/02 'Planting of saplings by farmers'.

Important elements of the model (ha^{-1}) are:

Fencing: Barbed wire fence with biofence for plantation area, and brushwood fence around pasture area near outer pond.
Pit size: 45 cm x 45 cm x 45 cm.
Four hundred trees ha^{-1}.
Interspaces will be intercropped with pasture grasses.
Kachcha water pond 50,000 L outside the plantation area in nearby place alongwith 700 m^2 strip of grass.
Kachcha water pond of 25000 L having base of stone pitching or some impermeable or semi-permeable material.
Watch and ward will be provided through a chowkidar.

Cost norms: The cost norms applicable to the model in the state are given in Table 5.71.:

Table 5.71. Cost norm for YM/UP/AL/02

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	45.59 ha^{-1}	45.59
Cleaning of area by uprooting shrubs including *Lantana*	1 ha	2,997.66 ha^{-1}	2,997.66
Cleaning of area outside plantation area (near outer pond) for planting of grass	250 m^2	299.73 ha^{-1}	7.49
Alignment of pits	400 no.	36.91/100	147.64
Digging of pits (45 cm x 45 cm x 45 cm)	400 no.	9.03 pit^{-1}	3,612

Protective structure			
Protection trench			
a) Protection trench (1.20 m wide at top, 0.90 m at base and 1.00 m deep)	50 m	98.63 m^{-1}	4,931.50
b) Jhakarhbari work, including transportation (along protection trench)	50 m	8.68 m^{-1}	434
Ploughing of area for pasture grass around pond, loosening and levelling of soil	250 m^2	Lumpsum	70
Stonewall fence			
a) Stone wall fence with 10 cm earthing up (1.20+0.80/2) x 1.20 m (stone available beyond 500 m)	50 m	423.75 m^{-1}	21,187.50
Kachcha pond inside plantation area with stone pitching at base			
a) Digging of *Kachcha* pond inside plantation in area of hard rock	25 m^3	128 m^{-3}	3,200
b) Providing stone pitching at base (incl. cost of material)	Lump sum		800
Digging of *Kachcha* pond outside plantation with *Kachcha* base	50 m^3	128 m^{-3}	6,400
Making of inspection path			
a) 3 m wide path inside plantation for jeep	25 m	8,984.30 km^{-1}	224.61
b) 1 m wide path inside plantation	50 m	2,085.33 km^{-1}	104.27
Cost of seed			
a) Quality seed for pits (400 plants + 20% for culling)	480 plants	Lump sum	480
b) Seed for protection trenches (other than *P. juliflora*) (at double of normal rate)	50 m	2.40 m^{-1}	120
Cost of plants (incl. 20% culling for obtaining quality stock) for pits	480	7 $plant^{-1}$	3,360
Plantation sign board (per 25 ha)	1	3,500/25 ha	140
Miscellaneous			1,500
Total			49,762.26 **or 49,762**
Planting year			
Cleaning of plantation area (to facilitate ploughing by tractor)	1 ha	299.73 ha^{-1}	299.73
Refilling/dressing pits and trenches			
a) Refilling pits (45 cm x 45 cm x 45 cm)	400 no.	0.90 pit^{-1}	360
b) Dressing protection trenches	50 m	1.45 m^{-1}	72.50
c) Ploughing of area, loosening and levelling of soil for pasture grass in plantation area	9,500 m^2	Lumpsum	800
d) Ploughing of area, loosening and levelling of soil for pasture grass around outer pond	250 m^2	Lumpsum	25
e) Ploughing of area, loosening and levelling of soil for pasture grass around outer pond	250 m^2	Lumpsum	800
Transportation of plants upto 25 km	400 no.	1.94 $plant^{-1}$	776
Local transport of plants	400 no.	1.52 $plant^{-1}$	608
Sowing of seeds on protection trenches in two lines	50 m	1.11 m^{-1}	55.50
Planting of plants in pits	400 plants	3.47 $plant^{-1}$	1,388
Sowing of seed			
a) Sowing of seed inside plantation area	9,500 m^2	524.80 ha^{-1}	498.56
b) Sowing of pasture grass around outer pond (incl. cost of seed)	250 m^2	524.80 ha^{-1}	13.12
c) Re-sowing of seeds of a and b			511.68
Creation of brushwood fence around pasture grass area near outer pond	120 m	8.68 m^{-1}	1,041.60
Application of manure, AM, micronutrients in pits	400 plants	5.80 $plant^{-1}$	2,320
Application of manure, AM, micronutrients to grass in plantation area	9,500 m^2	Lump sum	1,900
Application of manure to pasture grass	250 m^2	Lump sum	50
Weeding and hoeing			
a) Around pits (three times)	400 pits x 3	89.90/100	359.60
b) On protection trenches (three times)	50 m x 3	1.11 m^{-1}	166.50

c) In pasture grass in plantation area (two times)	9,500 m^2 x 2	Lumpsum	570
d) In pasture grass area near outer pond (two times)	250 m^2 x 2	Lumpsum	15
Irrigation			
a) Plants in pits (6 times)	400 plants x 6	1.70 $plant^{-1}$	6,800
b) Pasture grass in plantation area near outer pond (two times)	9,500 m^2 x 2	Lumpsum	1,900
c) Pasture grass area (two times)	250 m^2 x 2	Lumpsum	50
Watch and ward for 9 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		4,550/26 days of 8 hrs	9,450
Contingency	Lump sum		2,000
Total			32,830.79 **or 32,831**

Maintenance cost			
Year 3			
20% beating up of planted seedlings	80 plants	30 $plant^{-1}$	2,400
Weeding, hoeing			
a) Around pits (three times)	400 pits x 3	89.90/100	1,078.80
b) On protection trenches (three times)	50 m x 3	1.11 m^{-1}	166.50
c) In pasture grass in plantation area (two times)	9,500 m^2 x 2	Lumpsum	570
d) In pasture grass area near outer pond (two times)	250 m^2 x 2	Lumpsum	15
Irrigation			
a) Plants in pits 12 times	400 plants x 12	1.70 $plant^{-1}$	8,160
b) Pasture grass in plantation area near outer pond (two times)	9,500 m^2 x 2	Lumpsum	1,900
c) Pasture grass area (two times)	250 m^2 x 2	Lumpsum	50
Application of manure, AM, micronutrients in pits	400 plants	5.80 $plant^{-1}$	2,320
Application of manure to pasture grass in plantation area	9,500 m^2	Lump sum	1,900
Application of manure to pasture grass	250 m^2	Lump sum	50
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			28,560.30 **or 28,560**
Year 4			
15% beating up of planted seedlings	60 plants	30 $plant^{-1}$	1,800
Weeding and hoeing			
a) Around pits (one time yr^{-1})	400 pits x 1	89.90/100	359.60
Irrigation			
a) Plants in pits 6 times	400 plants x	1.70 $plant^{-1}$	4,080
Application of manure, AM, micronutrients in pits	1,050 plants	5.80 $plant^{-1}$	2,320
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			18,509.60 **or 18,510**
Year 5			
5% beating up of planted seedlings	20 plants	30 $plant^{-1}$	600
Weeding and hoeing (one time yr^{-1})			
a) Around pits	400 pits x 1	89.90/100	359.60
Irrigation of plants (3 times)	400 plants x 3	1.70 $plant^{-1}$	680
Application of manure, AM, micronutrients, etc.	400 plants	5.80 $plant^{-1}$	2,320
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			13,909.60 **or 13,910**
Year 6			
Watch and ward for 12 months (average 12 hr. sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450

Contingency		Lumpsum	500
Total			**9,950**
Year 7			**9,950**

Table 5.72. Year-wise cost summary for YM/UP/AL/02

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	49,762
Year 2 (Planting and establishment)	32,831
Year 3 (1st maintenance)	28,560
Year 4 (2nd maintenance)	18,510
Year 5 (3rd maintenance)	13,910
Year 6 (4th maintenance)	9,950
Year 7 (5th maintenance)	9,950
Total	**1,63,473**

YM/UP/AL/03: Community land afforestation in erosion-prone slope areas

This model will be applied in agricultural landscape having site conditions similar to ravine land of natural landscape. The loose, fragile slopes of sand or kankar will be treated like model YM/UP/NL/01 'Afforestation of erosion-prone ravinous slopes'. The cost norms of the said model will be followed.

Species and cost norms: The species and cost norms are similar to those prescribed for YM/UP/NL/01 'Afforestation of erosion-prone ravinous slopes'.

F. Rajasthan

YM/RJ/AL/01: Planting of fruit plants by farmers

The context and prescriptions of this model are broadly similar to those of YM/HY/AL/01 'Planting of saplings by farmers'. However, under this model, only fruit plants will be planted. Fruit plants will be supplied with help of the state's agriculture department. Payment to farmers will be made by the SFD on the basis of survival achieved.

Plant species recommended

Fruit species of the area recommended by Agriculture Department /Horticulture Department will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree/shrub: Grafted plants of horticultural varieties of *Emblica officinalis, Ziziphus nummularia, Carissa carandas, Punica granatum, Citrus* spp., etc.

Cost norm for YM/RJ/AL/01 (Rs. ha^{-1}):

Cost of tree sapling, including carriage to village (Year 1): Rs. 75 plant^{-1} and
planting and maintenance cost during planting year (Year 1): Rs. 50 plant^{-1}.
Maintenance cost in Year 2: Rs. 25 plant^{-1}.
Maintenance cost in Year 3: Rs. 20 plant^{-1}.
Maintenance cost in Year 4: Rs. 15 plant^{-1}.
Maintenance cost in Year 5: Rs. 10 plant^{-1}.
i.e. Rs. 195 plant^{-1} or Rs 97,500 ha^{-1}.

Table 5.73. Year-wise cost summary for YM/RJ/AL/01 (Rs. ha^{-1})

Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
62,500	12,500	10,000	7,500	5,000	**97,500**

YM/RJ/AL/02: Planting of forestry plants by farmers

This model is similar to YM/RJ/AL/01 except that instead of horticultural species, forestry species will be planted by the farmers.

Plant species recommended
Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows: **Tree:** *Prosopis cineraria, Azadirachta indica, Tecomella undulata, Ailanthus excelsa, Moringa oleifera, Anogeissus pendula, Acacia nilotica, Acacia leucophloea, Emblica officinalis, Pithecellobium dulce, Holoptelea integrifolia, Pongamia pinnata,* etc.

Cost norm for YM/RJ/AL/02 (Rs. ha^{-1}):

Cost of tree sapling, including carriage to village (Year 1): Rs. 50 plant^{-1} and planting and maintenance cost during planting year (Year 1): Rs. 50 plant^{-1}.
Maintenance cost in Year 2: Rs. 25 plant^{-1}.
Maintenance cost in Year 3: Rs. 25 plant^{-1}.
Maintenance cost in Year 4: Rs. 25 plant^{-1}.
Maintenance cost in Year 5: Rs. 25 plant^{-1}.
i.e. Rs. 200 plant^{-1} or Rs 1,00,000 ha^{-1}.

Table 5.74. Year-wise cost summary for YM/RJ/AL/02 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Total
50,000	12,500	12,500	12,500	12,500	**1,00,000**

YM/RJ/AL/03 Silvipasture on community land

The context of this model is broadly similar to that for YM/UP/AL/02 'Silvipasture on community land'. This model is similar to the SFD model 'Silvi-pastoral plantation in non-IGNP areas'. The fodder produced will be shared by the entire local community.

Plant species recommended
Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows: **Species on protection trenches** **Tree and shrub:** *Acacia nilotica, Acacia catechu, Ziziphus nummularia, Pithecellobium dulce, Agave sisalana,* etc. **Species inside plantation area** **Tree:** *Anogeissus pendula, Acacia nilotica, Acacia leucophloea, Azadirachta indica, Ailanthus excelsa, Emblica officinalis, Pithecellobium dulce, Butea monosperma, Diospyros melanoxylon, Holoptelea integrifolia, Pongamia pinnata,* etc. **Shrub:** *Ziziphus nummularia, Carissa carandas, Adhatoda vasica, Commiphora wightii, Capparis zeylanica, Capparis decidua, Grewia villosa,* etc. **Grass:** *Lasiurus scindicus, Cenchrus ciliaris, C. setigerus, Sehima nervosum, Heteropogon contortus, Dichanthium annulatum, Chrysopogon fulvus, Andropogon pumilus, Brachiaria ramosa, Chloris dolichostachya, Themeda triandra, Apluda mutica, Eremopogon foveolatus,* etc.

The cost norms are prescribed in Table 5.75.

Table 5.75. Cost norm for YM/RJ/AL/03

Particular	Quantity ha^{-1}	Rs. ha^{-1}
Advance work (Year 1)		
Microplanning and preparing management plan		550
Survey and alignment, removal of invasive woody weeds		1,450
Stone wall fence (2.10 m high)/ fence with RCC posts of 2.70 m height having six-line barbed wire fence of 1.50 m height	60 m	18,000
Digging of pits (0.45 x 0.45 x 0.45 m)	200	2,600
In-situ soil and moisture conservation works (e.g. check dam, contour trench, earthen bud, percolation tank)		4,100
Quality seed of sewan grass, khejari, ber and other indigenous species (Rate double of Non-IGNP silvi-pastoral model)	6 kg	1,300
Cost of nursery stock of trees including 20% extra for culling	200 + 40 plants	1,900
Raising of sewan grass and plants in 10 cm x 15 cm bags		
a) Sewan grass (800+20% extra)	960 slips	1,950
b) Other indigenous species like khejari, ber, raunj, etc. (200 + 20%)	240 plants	500
Manure, organic plant protection consumables		200
Digging of water storage pond/buying tank		850
Watch and ward for 4 months (every day of the month, morning to evening average 12 hrs d^{-1})		770
Contingency (tools, sign board, cattle guard hut, labour amenities, etc.)		2,000
Total		**36,190**
Planting and establishment (Year 2)		
Maintenance of seedlings in nursery (incl. 20% for beating up)	200+40	450
Maintenance of sewan grass and indigenous species		
a) Sewan grass (800+20% extra)	960 slips	1,150
b) Other indigenous species like khejari, ber, raunj, etc. (200 + 20%)	240 plants	300
Digging of trench 20 cm deep x 30 cm at bottom and 50 cm at top for purpose of irrigation	600 m	1,060
Transport of 220 plants including loading, unloading (upto 5 km)	220	360
Transport of 800 grass slips and 220 plants in 10 cm x 15 cm bags plants including loading, unloading (upto 5 km)	1,000	740
Sowing of grass seeds	Lumpsum	200
Planting of 200 plants	200	1,100
Planting of 800 grass slips and 200 pre-germinated plants including local transport	1,000	2,500
Manure, organic plant protection measures for 200 plants	200	500
Weeding and hoeing 200 plants	200	600
Hoeing of 200 plants (3 times)	600 m	1,060
Irrigation of 200 seedlings in pits with 30 L water $plant^{-1}$ brought from average 5 km x 4 times	800	14,550
Raising of 40 plants for casualty replacement	40	320
Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
Construction of approach road, inspection path		400
Contingency (labour amenities, unforeseen expenses)	Lumpsum	1,000
Total		**28,590**

Maintenance cost			
Year 3	20% beating up (Plant maintenance in nursery + planting)	40	560
	Irrigation of plants before casualty replacement 160 plants two waterings	320	3,640
	Irrigation of plants after casualty replacement 200 plants two waterings	400	4,520
	Hoeing of 200 plants x 3 times	600 m	1,060
	Raising of 15% plants for casualty replacement	30	240
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Contingency (labour amenities, unforeseen expenses)	Lumpsum	500

	Total		**12,820**
Year 4	15% beating up (Plant maintenance in nursery + planting)	30	420
	Weeding and hoeing of 200 plants (2 times)	400	715
	Irrigation of plants before casualty replacement 190 plants one watering	190	1,933
	Irrigation of plants after casualty replacement (200 plants one watering)	200	2,260
	Raising of 5% plants for casualty replacement	10	80
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Contingency (labour amenities, unforeseen expenses)	Lumpsum	400
	Total		**8,108**
Year 5	5% beating up (Plant maintenance in nursery + planting)	10	140
	Irrigation of plants before casualty replacement 190 plants two waterings	190	2,150
	Irrigation of plants after casualty replacement (200 plants one watering)	200	2,260
	Weeding and hoeing of 200 plants (2 times)	400	715
	Watch and ward 12 months (every day of month, sunrise to sunset)		2,300
	Contingency (labour amenities, unforeseen expenses)	Lumpsum	400
	Total		**7,965**
Year 6	Watch and ward 12 months (every day of month, sunrise to sunset)		**2,300**
Year 7	Watch and ward 12 months (every day of month, sunrise to sunset)		**2,300**

Table 5.76. Year-wise cost summary for YM/RJ/AL/03

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	36,190
Year 2 (Planting and establishment)	28,590
Year 3 (1st maintenance year)	12,820
Year 4 (2nd maintenance year)	8,108
Year 5 (3rd maintenance year)	7,965
Year 6 (4th maintenance year)	2,300
Year 7 (5th maintenance year)	2,300
Total	**98,253**

G. Madhya Pradesh

YM/MP/AL/01: Planting of fruit plants by farmers

The context and prescriptions of this model are broadly similar to those of YM/RJ/AL/01 'Planting of fruit plants by farmers'.

Plant species recommended

Fruit species of the area recommended by Agriculture Department /Horticulture Department will be planted in the model. Few examples of species for the purpose of illustration are as follows:
Tree/shrub: Grafted plants of horticultural varieties of *Emblica officinalis, Ziziphus nummularia, Carissa carandas, Citrus* spp., *Mangifera indica*, etc.

Budget norm for YM/MP/AL/01 (Rs. ha^{-1})

Cost of tree sapling, including carriage to village (Year 1): Rs. 75 plant^{-1},
Planting and maintenance cost during planting year (Year 1): Rs. 50 plant^{-1}.
Maintenance cost in Year 2: Rs. 25 plant^{-1}.
Maintenance cost in Year 3: Rs. 20 plant^{-1}.

Maintenance cost in Year 4: Rs. 15 plant^{-1}.
Maintenance cost in Year 5: Rs. 10 plant^{-1}.
i.e. Rs. 195 plant^{-1} or Rs 97,500 ha^{-1}.

Table 5.77. Cost summary for YM/MP/AL/01 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Total
62,500	12,500	10,000	7,500	5,000	**97,500**

YM/MP/AL/02: Planting of forestry plants by farmers
This model is similar to YM/MP/AL/01 except that instead of horticultural species, the forestry species will be planted by farmers.

Plant species recommended
Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:
Tree: *Azadirachta indica, Moringa oleifera, Sesbania grandiflora, Schleichera oleosa, Pithecellobium dulce, Bridelia retusa, Holoptelea integrifolia, Pongamia pinnata, Dalbergia sissoo, Syzygium cumini, Madhuca latifolia, Tectona grandis, Feronia limonia, Tecomella undulata,* etc.

Budget norm for YM/MP/AL/02 (Planting of forestry plants by farmers) (Rs. ha^{-1})
Cost of tree sapling, including carriage to village (Year 1): Rs. 50 plant^{-1},
planting and maintenance cost during planting year (Year 1): Rs. 50 plant^{-1}.
Maintenance cost in Year 2: Rs. 25 plant^{-1}.
Maintenance cost in Year 3: Rs. 25 plant^{-1}.
Maintenance cost in Year 4: Rs. 25 plant^{-1}.
Maintenance cost in Year 5: Rs. 25 plant^{-1}.
i.e. Rs. 200 plant^{-1} or Rs 1,00,000 ha^{-1}.

Table 5.78. Cost summary for YM/MP/AL/02 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Total
50,000	12,500	12,500	12,500	12,500	**1,00,000**

(iii) Treatment Models for Urban/Peri-urban Landscape
A. Uttarakhand
YM/UK/UL/01: Eco-park development model
Eco-park is a mini ecological park or an amusement park established without hampering the natural environment of the area. Generally, a particular area of a forest is demarcated and brought under intensive management for this purpose and the beauty offered by nature is opened to the visitors. Sometimes forest areas having special natural features are selected for eco-park development. 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 manoeuvred in such a way that the aesthetic beauty will be enhanced without much investment. Landscaped area will be designed to afford good soil, moisture and biodiversity conservation. *Nakshatra vatika, Rashi vatika, Nav-grah vatika, Panchvati vatika, Dhanvantri vatika,* etc. will be established within the park for awareness generation, meditation and spiritual fulfilment. Site-specific activities will be carried out at different places in harmony with the site conditions. An eco-park will have better facilities than riverfront development to facilitate the visitors.

The proportion of ornamental plants will be relatively more in eco-park than in the riverfront development model. An eco-park may have vegetative and non-vegetative components:

Vegetative part*:* Miscellaneous ornamental species
Non-vegetative part*:* Fencing, stairs, pathways, walking trails, stone pitching, rain shelter, benches, public utilities, parking area, information centre, children playing area, pond beautification, landscaping, etc. as per site-specific requirement.

Plant species recommended
Indigenous species will be planted in the model. Few examples of plant types for the purpose of illustration are as follows: Lawn grasses, hedge plants, shrubs, creepers, vines, hanging plants, grove of ornamental trees, fruit trees, forest trees and ornamental bamboos, flowering herbs/shrubs, cacti, ferns, palms, aquatic plants, medicinal plants.

YM/UK/UL/02: Riverfront development

Riverbanks near urban areas provide opportunity to integrate habitat restoration, public awareness and recreation, and provide the people a grand sight of the river along with fresh air, mental peace and spiritual fulfilment that would connect them with the river. It serves to create green infrastructure and accommodate activities of the local communities as well as visitors.

Under the model, the natural elements of the area will be enhanced while developing the riverfront. Plantation of trees, shrubs and grasses will be done to stabilise the riverbank and control soil erosion. Hard river edges are a significant concern in riverfront because they disrupt the natural fluctuations of water (Reverlife, 2012) and its interaction with riparian plant and animal communities on the riverbank. Hence, the use of civil works would be limited to the most essential ones. The infrastructure in the riverfront would be simple and integrated with the landscape.

Riverfront development envisages providing spaces and amenities for activities such as running, strolling, boating, fishing, bathing, adventure, sitting, meditation, awareness generation, etc. besides providing a pleasing and relaxing environment to the visitors in harmony with provision of ecosystem services. Increased tree canopy and livelihood would be essential concerns of riverfront development.

Riverfront plantation will stabilize the riverbank by protecting it from soil erosion by intercepting the rain drops and sunlight at various heights of canopy through multiple layers of vegetation. A multi-tier arrangement of grasses at the ground, small to medium sized herbs and shrubs as second layer of vegetation and small to medium sized trees as third vegetation layer interspersed with the topmost layer of tall trees will effectively serve the intended functions. A basic support system may also be developed for the convenience of visitors.

The riverscape of Yamuna and tributaries has different stakeholders such as farmers, *panchayats*, municipal corporations, irrigation department, institutions, forests department, defence, etc. and substantial portion is under private ownership. Suitable steps would be taken to ensure smooth coordination of the activities among different agencies. One model for riverfront development has been proposed. Site-specific activities will be carried out at different places commensurate with the site conditions.

A typical landscaping area may have vegetative and non-vegetative components.

List of components to be created according to requirement:

Vegetative part: Grove consisting of shade trees, ornamental trees and bamboos, medicinal plant garden, climbers, hedges, grasses, lawn.

Non-vegetative part: Stairs, pathways, walking trails, stone pitching, rain shelter, benches, low-cost public utilities, parking area, information centre, etc. as per site-specific requirement.

The vegetative and non-vegetative components will be arranged to enhance the aesthetic appeal. Various species will be planted according to their recommended spacing and resource use ability. Water loving and soil-binder tree species are ideal choice species for riverbank planting. The species will be accommodated as per the use value. In urban areas, planting will be done keeping in

view aesthetic improvement while planting in rural areas will be done for providing multiple benefits for meeting local needs.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Large tree: *Bauhinia variegata, B. purpurea, Cupressus torulosa, Terminalia bellirica, T. chebula, T. arjuna, Syzygium cumini, Pongamia pinnata, Albizia lebbeck, Acer nepalensis, Quercus* spp., etc.

Dwarf tree/shrub/bamboo: *Cassia fistula, Thespesia populnea, Dendrocalamus strictus, Woodfordia fruticosa, Sesbania grandiflora, Rosa moschata, Adhatoda vasica,* etc.

Herb: *Ocimum sativum, Wedelia trilobata,* etc.

Grass: *Stylosanthes* sp., *Arundo donax, Axonopus compressus, Saccharum bengalense, S. spontaneum,* etc.

Miscellaneous ornamental plants: Lawn grasses, hedge plants, shrubs, ornamental trees, ornamental bamboos, flowering herbs/shrubs, palms, aquatic plants.

YM/UK/UL/03: Avenue plantation

Roads provide a readily available space for planting of trees. Roadside plantations provide shade to pedestrians and vehicles, beautify surroundings, reduce the impacts of air and noise pollution, serve as natural sink for carbon and air pollutants, arrest soil erosion at the embankment slopes, prevent glare from the headlight of incoming vehicles, moderate the effect of wind, give employment to local people and help in maintaining biodiversity. It is proposed to establish avenue plantations along roads in the treatment zone and adjoining area.

Plant species recommended

Native species of the area prescribed in the Working Plan will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Trees: *Cedrus deodara, Cupressus torulosa, Toona ciliata, Bauhinia variegata, B. purpurea, Terminalia bellirica, Terminalia chebula, Terminalia arjuna, Syzygium cumini, Albizia lebbeck, Alnus nepalensis,* etc.



Fig. 5.34. Illustration of eco-park development

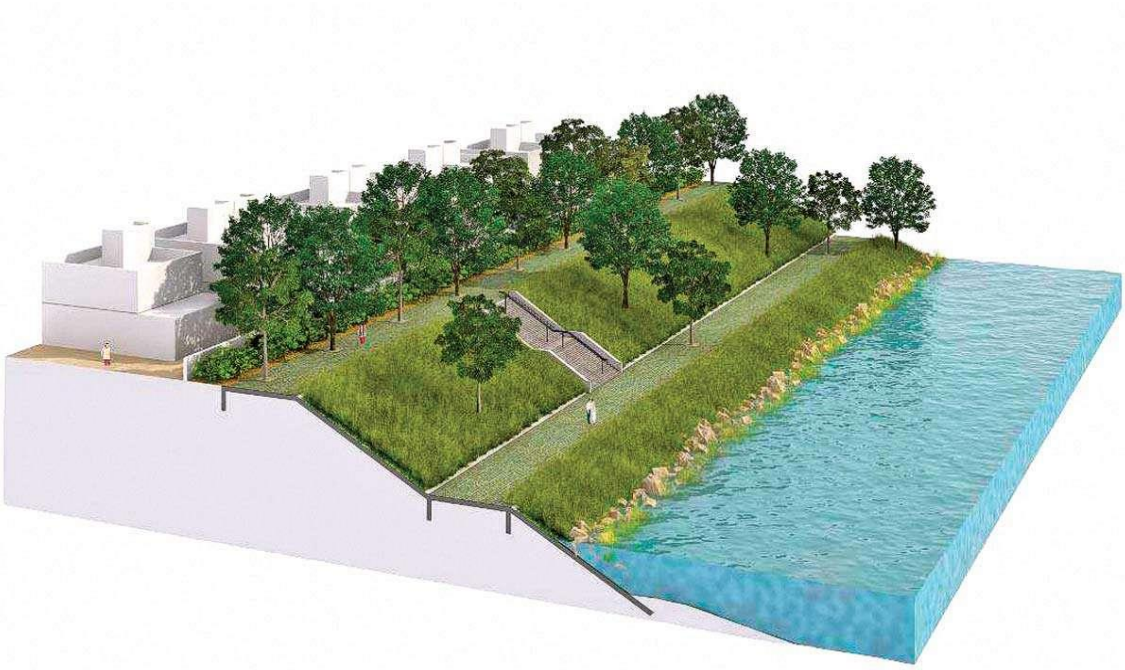


Fig. 5.35. Illustration of riverfront development
(***Source:*** https://www.dnaindia.com/ahmedabad/report-amc-vows-green-island-reservoir-at-riverfront-2624416)



Fig. 5.36. Illustration of avenue plantation
(***Source:***http://thewoodlandnursery.in/avenue-plantation.html)

The following cost norms are prescribed:

Table 5.79. Cost norms for models (YM/UK/UL/01, YM/UK/UL/02 and YM/UK/UL/03) in Uttarakhand

Model	Estt. cost (Rs. in lakh ha^{-1})	Maint. cost (Rs. in lakh ha^{-1})	Total cost (Rs. in lakh ha^{-1})
Eco-park Development (YM/UK/UL/01)	25.0	7.2 (12,000 mo^{-1} or 1.44 lakh yr^{-1} for 5 yrs.)	**32.2**
River Front Development (YM/UK/UL/02)	35.0	7.2 (12,000 mo^{-1} or 1.44 lakh yr^{-1} for 5yrs.)	**42.2**
Avenue Plantation (YM/UK/UL/03)	2.50	1.5 (2,500 mo^{-1} or 0.30 lakh yr^{-1} for 5yrs.)	**4.0**

B. Himachal Pradesh

YM/HP/UL/01: Eco-park development

The context and prescriptions of this model are same as those for YM/UK/UL/01 'Eco-park development'. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.80.

YM/HP/UL/02: Riverfront development with chainlink fence

This model is prescribed in areas adjacent to the river where chainlink fence is required to afford protection to the plantation, prevent falling of pedestrians into the river and act as barrier to throwing of waste by people into the river. Some activities on development of riverfront on the lines of YM/UK/UL/02 may also be carried.

Table 5.80. Cost norms for models (YM/ HP /UL/01 and YM/ HP /UL/02)

Model	Estt. cost (Rs. in lakh ha^{-1})	Maint. cost (Rs. in lakh ha^{-1})	Total cost (Rs. in lakh ha^{-1})
Eco-Park Development (YM/HP/UL/01)	25.00	7.20 (12,000 mo^{-1} or 1.44 lakh yr^{-1} for 5 yrs.)	**32.20**
Riverside plantation with chainlink fence (YM/HP/UL/02)	Site-specific requirement	Site-specific requirement	Site-specific cost

C. Haryana

YM/HY/UL/01: Strip plantation along roads

Under this model, plantations will be raised along road. In most of the sites multi-row strips will be created along the road. The area will be fenced and tall seedlings will be planted. In flat areas free from problem of water logging, a wide variety of local tree species is available for planting. Trees with tall and spreading crown will be avoided in row adjacent to the road. In depressions along roads where rainwater accumulates during rainy season for more than two weeks, mounds will be prepared and seedlings will be planted on mounds. Water-logging tolerant tree species will be planted in depressions. 500 plants will be planted per ha.

Species recommended

Native species of the area will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree:*Dalbergia sissoo, Syzygium cumini, Terminalia arjuna, Terminalia alata, Terminalia bellirica, Lagerstroemia parviflora, Acacia nilotica, Albizia lebbeck, Azadirachta indica, Prosopis cineraria, Salvadora persica, Bombax ceiba, Holoptelea integrifolia, Bauhinia purpurea, Ougeinia oojeinensis,* etc.

Important elements of the model (ha^{-1}):

Fencing: Barbed wire fence.

Plants ha^{-1}: 250 plants in pits x 2 sides of road (500 plants km^{-1} length of road).

Size of plants: Tall seedlings.

Watch and ward: Provided upto five years after planting year.

Table 5.81. Cost norm for YM/HY/UL/01

Particular	Quantity ha^{-1}	Rs. ha^{-1}
Year 1 (Advance work)		
Survey and alignment		500
Cleaning of site and making inspection path	1 ha	3,500
Tree guards	500	20,000
Cost of tall seedlings (including 10% extra for culling)	500 +50 plants	66,000
Digging of pits 0.45 m x 0.45 m x 0.45 m size	500 pits	8,000
Total		**98,000**
Year 2 (Planting activity)		
Planting	500 plants	2,500
Manure/ vermicompost	Lumpsum	2,000
Weeding, hoeing, maintenance of mounds 2 rounds		1,000
Irrigation (2 times)	Lumpsum	6,000
Watch and ward (for 9 months)		3,750
Contingency	Lumpsum	2,000
Total		**19,250**
Maintenance cost		
Year 3	20% beating up	100 plants	13,500
	Weeding, hoeing, maintenance of mounds (4 times yr^{-1})	Lumpsum	1,250
	Irrigation (6 times)	Lumpsum	18,000
	Watch and ward	One year	5,000
	Contingency	Lumpsum	500
	Total		**38,250**
Year 4	15% beating up	75 plants	10,125
	Weeding, hoeing, maintenance of mounds (3 times yr^{-1})	Lumpsum	940
	Irrigation (2 times)	Lumpsum	6,000
	Watch and ward	One year	5,000
	Contingency	Lumpsum	500
	Total		**22,565**
Year 5	5% beating up	25 plants	3,375
	Weeding, hoeing, maintenance of mounds (2 times yr^{-1})	Lumpsum	625
	Watch and ward	One year	5,000
	Contingency	Lumpsum	500
	Total		**9,500**
Year 6			**5,000**
Year 7			**5,000**

Table 5.82. Year-wise cost summary for YM/HY/UL/01 (Rs. ha^{-1})

Year	Rs. ha^{-1}
Year 1 (Advance work)	98,000
Year 2 (Planting and establishment)	19,250
Year 3 (1^{st} maintenance)	38,250
Year 4 (2^{nd} maintenance)	22,565
Year 5 (3^{rd} maintenance)	9,500
Year 6 (4^{th} maintenance)	5,000
Year 7 (5^{th} maintenance)	5,000
Total	**1,95,565**

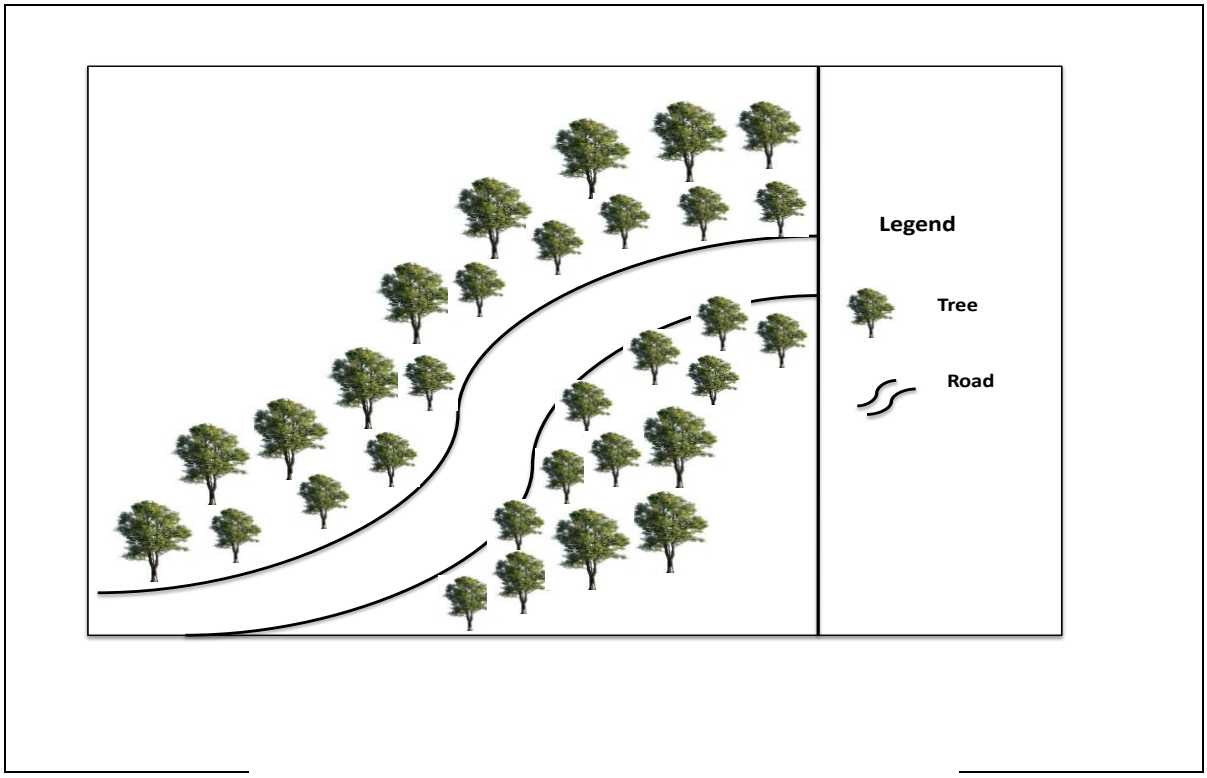


Fig. 5.37. Illustration of strip plantation along roads

YM/HY/UL/02: Strip plantation with mounds

Under this model, plantations will be raised along road and canal. In most of the sites multi-row strips will be created along the canal. The area will be fenced and tall seedlings of water-logging tolerant trees and slips of grass species will be planted. 500 tree seedlings will be planted per ha.

Species recommended

Native species of the area will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Trees:*Dalbergia sissoo, Acacia nilotica, Syzygium cumini, Terminalia arjuna, Terminalia alata, Terminalia bellirica, Bombax ceiba, Albizia lebbeck, Azadirachta indica, Prosopis cineraria, Salvadora persica, Holoptelea integrifolia, Bauhinia purpurea,* etc.

Important elements of the model (ha^{-1}):

Fencing: Barbed wire fence.

Plants ha^{-1}: 250 plants in mound x 2 sides of road (500 plants per kilometre length of road).

Size of plants: Tall seedlings.

Watch and ward: Provided upto four years after planting year.

Table 5.83. Cost norm for YM/HY/UL/02

Particular	Quantity ha^{-1}	Rs. ha^{-1}
Year 1 (Advance work)		
Survey and alignment		500
Cleaning of site and making inspection path	1 ha	3,500
Fencing of site (barbed wire)		58,000
Cost of tall seedlings (including 10% extra for culling)	500 +50 plants	66,000
Digging of mounds	500 pits	4,410

Total			**1,32,410**
Year 2 (Planting activity)			
Planting		500 plants	2,500
Manure/ vermicompost		Lumpsum	2,000
Weeding and hoeing			535
Irrigation (2 times)		Lumpsum	6,000
Watch and ward (for 9 months)			3,750
Contingency		Lumpsum	2,000
Total			**16,785**

Maintenance cost			
Year 3	20% beating up	100 plants	13,500
	Weeding and hoeing (4 times yr^{-1})	Lumpsum	1,100
	Irrigation (6 times)	Lumpsum	18,000
	Watch and ward	One year	5,000
	Contingency	Lumpsum	500
	Total		**38,100**
Year 4	15% beating up	75 plants	10,125
	Weeding and hoeing(3 times yr^{-1})	Lumpsum	825
	Irrigation (2 times)	Lumpsum	6,000
	Watch and ward	One year	5,000
	Contingency	Lumpsum	500
	Total		**22,450**
Year 5	5% beating up	25 plants	3,375
	Weeding and hoeing (2 times yr^{-1})	Lumpsum	525
	Watch and ward	One year	5,000
	Contingency	Lumpsum	500
	Total		**9,400**
Year 6			**5,000**
Year 7			**5,000**

Table 5.84. Year-wise cost summary for YM/HY/UL/02

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	1,32,410
Year 2 (Planting and establishment)	16,785
Year 3 (1^{st} maintenance)	38,100
Year 4 (2^{nd} maintenance)	22,450
Year 5 (3^{rd} maintenance)	9,400
Year 6 (4^{th} maintenance)	5,000
Year 7 (5^{th} maintenance)	5,000
Total	**2,29,145**



Fig. 5.38. Illustration of strip plantation with mounds
(***Source:*** https://www.wikiwand.com/en/Irrigation_in_India)

YM/HY/UL/03: Floodplain treatment

Floodplain sites are available near river where sandy soil, loose in texture, is found with gravel and boulders. The soil is very poor in fertility and is frequently inundated by water from the river. Grazing incidence is common. Raising of trees is quite difficult in such conditions. Under this model, water-tolerant or water-loving grasses such *Saccharum* and thorny or browsing-resistant shrubs/small trees such as *Acacia catechu,* will be established by planting slips of the grass species and dibbling of seeds on such sites. The area will not be fenced. The existing vegetation will not be removed. The seedlings already growing in the area will be protected from animals by surrounding them with pile of brushwood. 8,000 plants of grass will be planted per ha. Pits will be dug at time of planting (not in advance).

Species recommended
Native species of the area will be planted in the model. Few examples of species for the purpose of illustration are as follows: **Grass:***Scirpus affinis, Cyperus eleusinoides, Cyperus exaltatus, Arundo donax, Saccharum bengalense, Saccharum spontaneum,* etc. **Tree and shrub:** *Acacia catechu, Vitex negundo,* etc.

Important elements of the model (ha^{-1}):

Fencing: Not required.

Plants per ha: 8,000 plants of grass; dibbling of seeds of shrubs/small thorny trees at 4,000 points.

Table 5.85. Cost norm for YM/HY/UL/03

Particular	**Quantity ha^{-1}**	**Rs. ha^{-1}**
Year 1 (Advance work)		
Survey and alignment		500
Cleaning of site and making inspection path	1 ha	700
Cost of nursery stock of grass	8,000 plants	32,000
Total		**33,200**
Year 2 (Planting activity)		
Digging of pits 0.20 m x 0.20 m x 0.30 m size		

	8,000 pits	10,000
Planting of grass in pits	8,000 plants	8,000
Dibbling of seed (including cost of seed)	4,000 spots	2,500
Maintenance of plants for 9 months, including heaping of brushwood around existing seedlings, if available		3,600
Contingency	Lumpsum	500
Total		**24,600**

Maintenance cost			
Year 3	Weeding and hoeing trees and grass (4 times yr^{-1})	Lumpsum	4,000
	Watch and ward	One year	5,000
	Contingency	Lumpsum	500
	Total		**9,500**
Year 4	Weeding and hoeing (2 times yr^{-1})	Lumpsum	1,000
	Watch and ward	One year	5,000
	Contingency	Lumpsum	500
	Total		**6,500**
Year 5	Weeding and hoeing trees (one time yr^{-1})	Lumpsum	500
	Watch and ward	One year	5,000
	Contingency	Lumpsum	500
	Total		**6,000**
Year 6			**5,000**
Year 7			**5,000**

Table 5.86. Year-wise cost summary for YM/HY/UL/03

Year	**Rs. ha^{-1}**
Year 1 (Advance work)	33,200
Year 2 (Planting and establishment)	24,600
Year 3 (1st maintenance)	9,500
Year 4 (2nd maintenance)	6,500
Year 5 (3rd maintenance)	6,000
Year 6 (4th maintenance)	5,000
Year 7 (5th maintenance)	5,000
Total	**89,800**



Fig. 5.39. Illustration of flood plain treatment
(*Source:* **Project Team**)

YM/HY/UL/04: Institutional plantation

Several government, private, social and religious organisations are located in the treatment zone of the DPR. Space is available in some of these for planting trees. Trees in their estates or surrounding may improve aesthetic appearance of the area, improve environment and reduce soil erosion. Ornamental, shade and fruit plants will be planted in such areas. Plants will be supplied to the institutions for planting and maintenance by themselves.

Species recommended

Native species of the area will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree:*Dalbergia sissoo, Syzygium cumini, Holoptelea integrifolia, Bauhinia purpurea, Ougeinia oojeinensis, Terminalia arjuna, Terminalia alata, Terminalia bellirica, Lagerstroemia parviflora, Albizia lebbeck, Azadirachta indica, Ficus religiosa, Ailanthus excelsa, Bombax ceiba,* etc.

Cost norm for YM/HY/UL/04

Cost of tree sapling, including carriage to the institution: Rs. 50 plant^{-1}.
Planting and maintenance cost during planting year: Rs. 50 plant^{-1}.
Establishment cost: Rs. 100 plant^{-1} or Rs. 50,000 ha^{-1}.
Maintenance cost: Nil.
Total cost: Rs. 100 plant^{-1} or Rs. 50,000 ha^{-1}.

Table 5.87. Year-wise cost summary for YM/HY/UL/04 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Total
50,000	0	0	0	0	50,000



Fig. 5.40. Illustration of institutional plantations
(*Source:*MoEF&CC, New Delhi website)

YM/HY/UL/05: Plantation in unprotected institutional areas

Some institutional areas are outside the limit of institution's watch and ward. Plantation on such sites require to be provided some protection under the project for their establishment. Such areas will be planted and maintained with support of the project with active involvement of the concerned institution. One hectare will be equivalent to planting of 500 plants.

Cost norm for YM/HY/UL/05

Cost of tree sapling, including carriage to the institution: Rs. 50 plant^{-1}
Planting and maintenance cost during planting year: Rs. 100 plant^{-1}.
Establishment cost: Rs. 150 plant^{-1} or Rs. 75,000 ha^{-1}.
Maintenance cost: Rs. 60, Rs, 40, Rs. 40 and Rs. 40 plant^{-1} for Year 2, 3, 4 and 5 respectively
Maintenance cost will be paid based on the number of surviving plants.
Total cost: Rs. 330 plant^{-1} or Rs. 1,65,000 ha^{-1}

Table 5.88. Year-wise cost summary for YM/HY/UL/05 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Total
75,000	30,000	20,000	20,000	20,000	**1,65,000**

D. Delhi

Sites in Delhi NCT for urban landscape in the riverscape were not proposed by SFD.

E. Uttar Pradesh

YM/UP/UL/01: Roadside linear plantation

Under this model, plantations will be raised along roads. Linear rows of trees will be created along the road on both sides. The plants will be protected with tree guards made of bricks. In flat areas free from problem of water logging, a wide variety of local tree species is available for planting. Trees with tall and spreading crown will be avoided in row adjacent to the road. In depressions along roads where rainwater accumulates during rainy season for more than two weeks, mounds will be prepared and seedlings will be planted on mounds. Water-logging tolerant tree species will be planted in depressions. 200 plants will be planted per kilometre: 100 plants on each side and will notionally constitute a hectare.

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:
Tree:*Dalbergia sissoo, Syzygium cumini, Haldina cordifolia, Pongamia pinnata, Saraca asoca, Terminalia arjuna, Terminalia alata, Terminalia bellirica, Lagerstroemia parviflora, Albizia lebbeck, Azadirachta indica, Holoptelea integrifolia, Bauhinia purpurea, Ougeinia oojeinensis,* etc.

Important elements of the model (per km; 1 km = 1 ha):

Plants per km: 100 plants x 2 sides of road (200 plants per kilometre length of road).
Size of plants: Tall seedlings.
Watch and ward: Provided upto four years after planting year.

Table 5.89. Cost norm for YM/UP/UL/01

Particular	Quantity ha^{-1}	Rs. km^{-1}
Advance work		
60% of cost of making brickguard, pit digging, planting, weeding and hoeing 60% of Rs. 3,269 per brickguard	400 plants	3,92,280
Total		**3,92,280**

Planting activity		
40% of cost of making brickguard, pit digging, planting, weeding and hoeing 60% of Rs. 3,269 per brickguard	400 plants	1,56,912
Total		**2,61,520**
Total establishment cost		**6,53,800**

Maintenance cost			
Year 1	Beating up, weeding, hoeing, protection (Rs. 362/brickguard)	400 plants	72,400
	Total		**72,400**
Year 2	Beating up, weeding, hoeing, protection (Rs. 289/brickguard)	400 plants	57,800
	Total		**57,800**
Year 3			**9,950**
Year 4			**9,950**
Year 5			**9,950**

Table 5.90. Year-wise cost summary for YM/UP/UL/01

Year		**Rs. ha^{-1}**
Planting year	Advance soil work	3,92,280
	Planting and establishment	2,61,520
1st year		72,400
2nd year		57,800
3rd year		9,950
4th year		9,950
5th year		9,950
Total		**8,13,850**

YM/UP/UL/02: Roadside strip plantation

Under this model, plantations will be raised along road. In most of the sites multi-row strips will be created along the road. The area will be fenced and tall seedlings will be planted. In flat areas free from problem of water logging, a wide variety of local tree species is available for planting. Trees with tall and spreading crown will be avoided in row adjacent to the road. In depressions along roads where rainwater accumulates during rainy season for more than two weeks, mounds will be prepared and seedlings will be planted on mounds. Water-logging tolerant tree species will be planted in depressions. 500 plants will be planted per ha.

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Tree:*Dalbergia sissoo, Syzygium cumini, Terminalia arjuna, Terminalia alata, Terminalia bellirica, Lagerstroemia parviflora, Acacia nilotica, Albizia lebbeck, Azadirachta indica, Haldina cordifolia, Pongamia pinnata, Holoptelea integrifolia, Ougeinia oojeinensis*, etc.

Important elements of the model (ha^{-1}):

Fencing: Barbed wire fence.

Plants per ha: 200 plants in pits, 50 plants on mounds (total 250 plants) x 2 sides of road (500 plants km^{-1} length of road).

Size of plants: Tall seedlings.

Watch and ward: Provided up to four years after planting year.

Table 5.91. Cost norm for YM/UP/UL/02

Particular	Quantity ha^{-1}	Rs. ha^{-1}
Year 1 (Advance work)		
Survey and alignment		500
Cleaning of site and making inspection path	1 ha	740
Fencing of site (barbed wire)		58,000
Cost of tall seedlings (including 10% extra for culling)	500 +50 plants	66,000
Digging of pits 0.45 m x 0.45 m x 0.45 m size	400 pits	3,530
Making of mounds (2.10 m lower dia, 0.90 m upper dia, 0.70 m height)	100 mounds	3,600
Total		**1,32,370**
Year 2 (Planting activity)		
Planting	500 plants	2,500
Manure/ vermicompost	Lumpsum	2,000
Weeding, hoeing, maintenance of mounds (2 rounds)		320
Watch and ward (for 9 months)		2,500
Contingency	Lumpsum	1500
Total		**8,820**
Total establishment cost		**1,41,190**

Maintenance cost			
Year 1	20% beating up	100 plants	13,500
	Weeding, hoeing and maintenance of mounds (4 times yr^{-1})	Lumpsum	625
	Watch and ward	One year	13,200
	Contingency	Lumpsum	500
	Total		**27,825**
Year 2	15% beating up	75 plants	10,125
	Weeding, hoeing and maintenance of mounds (3 times yr^{-1})	Lumpsum	470
	Watch and ward	One year	13,200
	Contingency	Lumpsum	500
	Total		**24,295**
Year 3	5% beating up	25 plants	3,375
	Weeding, hoeing and maintenance of mounds (2 times yr^{-1})	Lumpsum	470
	Watch and ward	One year	13,200
	Contingency	Lumpsum	500
	Total		**19,545**
Year 4			**13,200**
Year 5			**13,200**

Table 5.92. Year-wise cost summary for YM/UP/UL/02

Year		Rs. ha^{-1}
Planting year	Advance soil work	1,32,370
	Planting and establishment	8,820
1st year		27,825
2nd year		24,295
3rd year		19,545
4th year		13,200
5th year		13,200
Total		**2,37,255**

YM/UP/UL/03: Institutional plantation

The context and prescriptions of this model are broadly similar to those of YM/HY/UL /04 'Institutional plantation'.

Species recommended for planting: Same as YM/HY/UL /04

Cost norm for YM/UP/UL/03 (Rs. ha^{-1}):

Cost of tree sapling, including carriage to the institution: Rs. 50 plant^{-1}

Planting and maintenance cost during planting year: Rs. 50 plant^{-1}

Establishment cost: Rs. 100 plant^{-1} or Rs. 50,000 ha^{-1}

Maintenance cost: Nil

Total cost: Rs. 100 plant^{-1} or Rs. 50,000 ha^{-1}

Table 5.93. Year-wise cost summary for YM/UP/UL/03 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Total
50,000	0	0	0	0	**50,000**

YM/UP/UL/04: Block plantation in landbank and revenue land

Some pieces of land are available near the river which were not under forestry activity in the recent years and are categorised as landbank. These are suitable for tree plantation activity. Land of revenue department and other departments are also available where soil is suitable for growing of trees. Plantation will be raised in such sites under this model. The practices prescribed for model YM/UP/NL/03 (Plantation in open forest areas) will be followed.

Species and cost norms: Same as the species and cost norms for YM/UP/NL/03 'Plantation in open forest areas'.

YM/UP/UL/05: Landbank treatment in erosion prone slope areas

Some pieces of land available near the river, categorised as landbank, are not suitable for planting of trees. These have fragile, loose soil with moderate slopes and are prone to soil erosion. These sites will be treated like YM/UP/NL/01 (Afforestation of erosion-prone ravinous slopes).

Species: Same as the species for YM/UP/NL/01 'Afforestation of erosion-prone ravinous slopes'.

Cost norms: Same as the cost norms for YM/UP/NL/01 for planting of entire area (Afforestation of erosion-prone ravinous slopes). However, for the development of check dam only with sowing of seeds of trees and grasses, 1,100 check dams ha^{-1} or 891 m^3 ha^{-1} will be considered to cost Rs. 2,20,822 ha^{-1}.

YM/UP/UL/06: Treatment of floodplain and land of irrigation department

Floodplain sites and lands of irrigation department near the river are available where loose, sandy soil is found with gravel and boulders. The soil is very poor in fertility and is frequently inundated by water from the river. Grazing incidence is high. Raising of trees is quite difficult in such conditions. Under this model, water-tolerant or water-loving grasses such *Saccharum* and thorny shrubs/small trees such as *Acacia catechu*, will be established by planting slips of the grass species and dibbling of seeds on such sites. The area will not be fenced. The existing vegetation will not be removed. The seedlings already growing in the area will be protected from animals by surrounding them with pile of brushwood. 8,000 plants of grass will be planted per ha. Pits will be dug at time of planting (not in advance).

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Grass:*Saccharum bengalense, Saccharum spontaneum, Scirpus affinis, Cyperus eleusinoides, Cyperus exaltatus, Arundo donax, Phragmites karka, Themeda arundinacea, Vetiveria zizanioides, Cymbopogon flexuosus, Desmostachya bipinnata, Dichanthium annulatum, Pseudosorghum fasciculare, Cymbopogon jwarancusa, Hygroryza aristata, Panicum paludosum,* etc.

Tree and shrub: *Acacia catechu, Acacia nilotica, Vitex negundo,* etc.

Important elements of the model (ha^{-1}):

Plants per ha: 8,000 plants of grass; dibbling of seeds of shrubs/small thorny trees at 4,000 points.

Table 5.94. Cost norm for YM/UP/UL/06

Particular	**Quantity ha^{-1}**	**Rate**	**Rs. ha^{-1}**
Advance work			
Survey and demarcation of area	1 ha	45.59 ha^{-1}	45.59
Cleaning of plantation area	1 ha	299.73 ha^{-1}	299.73
Making of inspection path			
a) 3 m wide path inside plantation for jeep	25 m	8,984.30 km^{-1}	224.61
b) 1 m wide path inside plantation	50 m	2,085.33 km^{-1}	104.27
Plantation sign board (per 25 ha)	1	3,500/25 ha	140
Miscellaneous			500
Total			1,314.20 **or 1,314**
Planting year			
Sowing of seed			
a) Sowing of seed of trees/shrubs	1,000 m	3.47 m^{-1}	3470
b) Sowing of seeds of grasses	9,500 m	524.80 ha^{-1}	498.56
c) Re-sowing of seeds of a and b			3,968.56
Making of thawla around existing plants	300 no.	1.94 $plant^{-1}$	582
Application of manure	1 ha	Lump sum	2,000
Weeding and hoeing in grass and seedlings area (two times)	1 ha x 2	Lumpsum	600
Watch and ward for 9 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)		4,550/26 days of 8 hrs	9,450
Contingency	Lump sum		500
Total			21,069.12 **or 21,069**

Maintenance cost			
Year 3			
Weeding, hoeing in grass and seedlings area (two times)	1 ha x 2	Lumpsum	600
Irrigation in grass and seedlings area (two times)	1 ha x 2	Lumpsum	2,000
Application of manure to pasture grass	250 m^2	Lump sum	50
Watch and ward for 12 months (Average 12 hrs sunrise to sunset, everyday, for 10 ha)		5,460/26 days of 8 hrs	9,450
Contingency		Lumpsum	500
Total			12,600 **or 12,600**
Year 4			**9,950**
Year 5			**9,950**

Table 5.95. Year-wise cost summary for YM/UP/UL/06

Year	Rs. ha^{-1}
Year 1 (Advance work)	1,314
Year 2 (Planting and establishment)	21,069
Year 3 (1st maintenance)	12,600
Year 4 (2nd maintenance)	9,950
Year 5 (3rd maintenance)	9,950
Total	**54,883**

YM/UP/UL/07: Eco-park development

The context and prescriptions of this model are broadly similar to those of YM/UK/UL/01 'Eco park development'.

Plant types for plantation: Same as YM/UK/UL/01 according to the climate of the area

Table 5.96. Cost norm for YM/UP/UL/07

Model	Estt. cost (Rs. in lakh ha^{-1})	Maint. cost (Rs. in lakh ha^{-1})	Total cost (Rs. in lakh ha^{-1})
Eco-park development	25.00	7.20 (12,000 mo^{-1} for next 5 yrs)	32.20

Table 5.97. Year-wise cost summary for YM/UP/UL/07 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
25,00,000	1,44,000	1,44,000	1,44,000	1,44,000	1,44,000	**32,20,000**



Fig. 5.41. Illustration of eco-park development
(***Source:*** https://www.biswabanglagatekolkata.in)

YM/UP/UL/08: Riverfront development

The context and prescriptions of this model are broadly similar to those of YM/UK/UL/02 'Riverfront development'.

List of illustrativespecies / plant types: Same as YM/UK/UL/02 according to the local climate

Table 5.98. Cost norm for YM/UP/UL/08

Model	Estt. cost (Rs. in lakh ha^{-1})	Maint. cost (Rs. in lakh ha^{-1})	Total cost (Rs. in lakh ha^{-1})
River front development	35.00	7.20 (12,000 mo^{-1} for next 5 yrs)	42.20

Table 5.99. Cost summary for YM/UP/UL/08 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
35,00,000	1,44,000	1,44,000	1,44,000	1,44,000	1,44,000	**42,20,000**

YM/UP/UL/09: Bioremediation with strip plantation

This model is proposed to be applied in sites in areas near the confluence of Yamuna and Chambal in Etawah district of Uttar Pradesh. Sites of strip plantations are often inundated or flooded by water and allow planting of species that would promote bioremediation, besides providing other ecosystem good and services. The terrain proposed for forestry interventions under the project is highly variable and require site-specific activities to be carried out at different places according to the site conditions.

Species recommended for planting

Native species of the area, as are prescribed in the Working Plan, will be planted in the model. Few examples of species for the purpose of illustration are as follows:

Grass: *Saccharum bengalense, Saccharum spontaneum, Arundo donax, Phragmites karka, Themeda arundinacea, Vetiveria zizanioides, Cymbopogon flexuosus, Desmostachya bipinnata, Dichanthium annulatum, Pseudosorghum fasciculare, Cymbopogon jwarancusa,* etc.

Tree and shrub: *Acacia catechu, Acacia nilotica, Terminalia arjuna, Terminalia alata, Terminalia bellirica, Vitex negundo,Dalbergia sissoo, Syzygium cumini, Lagerstroemia parviflora, Acacia nilotica, Albizia lebbeck, Azadirachta indica, Haldina cordifolia, Pongamia pinnata, Holoptelea integrifolia, Ougeinia oojeinensis,* etc.

Table 5.100. Cost norm for YM/UP/UL/09 (Rs. ha^{-1})

Sub-model	Establishment cost	Maintenance cost	Total cost
YM/UP/UL/09	Site-specific requirement	Site-specific requirement	Site-specific cost

F. Rajasthan

YM/RJ/UL/01: Ecopark development

The context and prescriptions of this model are broadly similar to those of YM/UK/UL/01 'Eco park development'.

Plant types for plantation: Same as YM/UK/UL/01 according to climate of the area.

Table 5.101. Cost norm for YM/RJ/UL/01

Model	Estt. cost (Rs. in lakh ha^{-1})	Maint. cost (Rs. in lakh ha^{-1})	Total cost (Rs. in lakh ha^{-1})
Eco-park development	25.00	7.20 (12,000 mo^{-1} for 5 yrs)	32.20

Table 5.102. Year-wise cost summary for YM/RJ/UL/01 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
25,00,000	1,44,000	1,44,000	1,44,000	1,44,000	1,44,000	**32,20,000**

G. Madhya Pradesh

YM/MP/UL/01: Eco-park

The context and prescriptions of this model are broadly similar to those of YM/UK/UL/01 'Eco-park development'.

Plant types for plantation: Same as YM/UK/UL/01 according to climate of the area

Table 5.103. Budget norm for YM/MP/UL/01

Model	Estt. cost (Rs. in lakh ha^{-1})	Maint. cost (Rs. in lakh ha^{-1})	Total cost (Rs. in lakh ha^{-1})
Eco-park development	25.00	7.20 (12,000 mo^{-1} for 5 yr)	**32.20**

Table 5.104. Cost summary for YM/MP/UL/01 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
25,00,000	1,44,000	1,44,000	1,44,000	1,44,000	1,44,000	**32,20,000**



Fig. 5.42. Illustration of eco-park
(***Source:*** https://kolkatatourism.travel/eco-tourism-park-kolkata)

YM/MP/UL/02: Floodplain treatment

The context and prescriptions of this model are broadly similar to those of YM/HY/UL/03 'Floodplain treatment'.

Plant types for plantation: Same as YM/HY/UL/03 according to climate of the area.

Species recommended for planting: Same as YM/HY/UL/03 according to climate of the site

Important elements of the model (ha^{-1}):

Eight thousand plants of grass; dibbling of seeds of shrubs/small thorny trees at 4,000 points.

Table 5.105. Budget norm for YM/MP/UL/02

Particular	Quantity ha^{-1}	Rate	Rs. ha^{-1}
Advance work			
Survey and demarcation of area	1 ha	0.45 mdays ha^{-1}	138.60
Cleaning of plantation area by cutting bushes (excluding *Lantana*)	1 ha	4 mdays ha^{-1}	1,232.00
Making of inspection path			
a) 3 m wide path upto plantation for jeep	25 m	30.65 mdays km^{-1}	236.01
b) 1 m wide path inside plantation	50 m	Lump sum	110.00
Plantation sign board (per 25 ha)	1	3,500/25 ha	140.00
Miscellaneous			500.00
Total			986.01 **or 986**
Planting year			
Sowing of seed			
a) Sowing of seed of trees/shrubs	4,000 no.	0.2 mdays/100	2,464.00
b) Sowing of seeds of grasses	8,000 no.	0.16 mdays/100	3,942.40
Re-sowing of seeds of a and b			3,968.56
a) Sowing of seed of trees/shrubs at half of above quantity	2,000 no.	0.2 mdays/100	1,232.00
b) Sowing of seeds of grasses at half of above quantity	4,000 no.	0.16 mdays/100	1,971.20
Making of thawla around existing plants	300 no.	Lump sum	900.00
Application of manure	1 ha	Lump sum	2,000.00
Weeding, hoeing in grass and seedlings area (two times)	1 ha x 2	Lumpsum	600.00
Watch and ward for 9 months (average 12hrs sunrise to sunset, everyday, for 50 ha instead of 26 d mo^{-1} x 8 hrs)	9 months	10.80 mdays yr^{-1}	2,494.80
Contingency	Lump sum		500.00
Total			20,072.96 **or 20,073**

Maintenance cost			
Year 3			
Weeding and hoeing in grass and seedlings area (two times)	1 ha x 2	Lumpsum	600.00
Irrigation in grass and seedlings area (two times)	1 ha x 2	Lumpsum	2,000.00
Application of manure to pasture grass	250 m^2	Lump sum	50.00
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 50 ha instead of 26 d mo^{-1} x 8 hrs)	12 months	10.80 mds yr^{-1}	3,326.40
Contingency		Lumpsum	500.00
Total			6,476.40 **or 6,476**
Year 4			
Contingency			500.00
Watch and ward for 12 months (average 12 hrs sunrise to sunset, everyday, for 10 ha)	12 months	10.80 mds yr^{-1}	3,326.40
Total			3,826.40 **or 3,826**
Year 5			**3,326**

Table 5.106. Cost summary for YM/MP/UL/02

Year	Rs. ha^{-1}
Year 1 (Advance work)	986
Year 2 (Planting and establishment)	20,073
Year 3 (1st maintenance)	6,476
Year 4 (2nd maintenance)	3,826
Year 5 (3rd maintenance)	3,326
Total	**34,687**

(iv) Treatment Models for Conservation Interventions

A. Uttarakhand

There are several sites which are affected by the problem of soil erosion or inadequate infiltration of rainwater despite having satisfactory tree cover. Soil and moisture conservation measures will be applied in such areas. Contour trench, *chal khal* and check dam will be created under different models in such areas depending upon their suitability. In some sites where the above structures are not likely to sustain the pressure of flowing water, spur and retaining wall will be erected. Planting of trees is not proposed on these structures. The surrounding forest area will not be treated under these models. The models are intended to check soil erosion, increase ground water recharge, reduce problem of soil erosion, increase availability of drinking water for animals and improve the site quality.

YM/UK/CI/01: Contour trenching

Contour trenching, either staggered or continuous, is a very effective conservation practice to check soil erosion and enhance groundwater recharge for improving base flow in hilly streams. Contour trenching is proposed on uniform hill slopes or landscapes with rolling/undulating topography in plain areas.

YM/UK/CI/02: *Chal khal*

A *chal khal* is a small water harvesting structure traditionally used in the state of Uttarakhand. It is an artificial pond, lined with stones, that is constructed across a natural stream or water course to harvest and impound the runoff. It provides water for irrigation and drinking and facilitates vertical and lateral percolation of impounded water into the soil substrata, thereby recharging groundwater in the area.

YM/UK/CI/03: Check dam

Check dams are versatile conservation structures to check soil erosion caused by flowing water, enable water harvesting and improve groundwater recharge. These structures are suitable for small order ephemeral streams both in hilly and plain topographic conditions. Where the purpose of the check dam is soil conservation in small streams and gullies, the drop of head wall should not be more than 1.5 m. Proper spillway and downstream protection measures need to be provided where drop of structure exceeds 1.5 m.

YM/UK/CI/04: Spur/Retaining

A spur is a stone or RCC (reinforced cement concrete) structure built on the bank of a river at some angle to the direction of flow of water with the objective of deflecting water away from the bank. This reduces the pressure of water striking the riverbank and helps reduce soil erosion. A retaining wall is a stone or RCC structure that holds back soil or rock from slipping down. Retaining walls are particularly useful where there is a change in level within a restricted area.

YM/UK/CI/05: Wetland Management

This model aims at restoration of identified wetlands in the hilly upstream catchment as well as in the floodplain. The causes of degradation of wetlands will be addressed and bio-engineering measures will be applied that combine vegetation and other naturally available materials, to produce a functioning system that would prevent soil erosion and improve habitat. Under the model, de-siltation will be carried out in wetlands and in their entry-exit channels. Terrestrial and aquatic weeds will be removed and regeneration of native species of trees, shrubs, grasses and other herbs will be augmented by natural regeneration or artificial regeneration considering site-specific requirement. Need-based measures will also be taken to improve habitat and augment the population of native aquatic fauna and control of invasive faunal species. Water ponds may be created or dug deeper for collecting water to prevent runoff or check inundation in surrounding areas. Water-logging tolerant plant species will be planted wherever possible.

YM/UK/CI/06: Mixed SMC Works

Some sites require a combination of activities for soil and moisture conservation and the quantity of individual activities per unit areavary greatly with site. Such activities will be carried out under this model.

Table 5.107. Cost norms for models (YM/UK/CI/01, YM/UK/CI/02, YM/UK/CI/03, YM/UK/CI/04, YM/UK/CI/05 and YM/UK/CI/06) in Uttarakhand

Model	Estt. cost (Rs. m^{-3})	Maint. cost (Rs. $m^{-3}yr^{-1}$)	Total cost (Rs. m^{-3})
YM/UK/CI/01: Contour trenching (3×0.3×0.45m = 0.40 m^3)	120	60 (10% of estt. cost or 12 yr^{-1} for 5 yrs.)	180
YM/UK/CI/02: Chal khal (5×4×1m = 20 m^3)	500	250 (10% of estt. cost or 50 yr^{-1} for 5yrs.)	750
YM/UK/CI/03: Check dam (5×1.5×2m = 15 m^3)	2,000	1,000 (10% of estt. cost or 200 yr^{-1} for 5yrs,)	3,000
YM/UK/CI/04- Spur/Retaining wall (5×1.5×2m = 15 m^3)	2,200	1,100 (10% of estt. cost or 220 yr^{-1} for 5yrs),	3,300
YM/UK/CI/05-Wetland management	6.5 lakh ha^{-1}	3.25 lakh (10% of estt. cost or 0.65 lakh yr^{-1} for 5yrs,)	9.75 lakh ha^{-1}
YM/UK/CI/06-Mixed SMC works	Site-specific requirement	Site-specific requirement	Site-specific cost

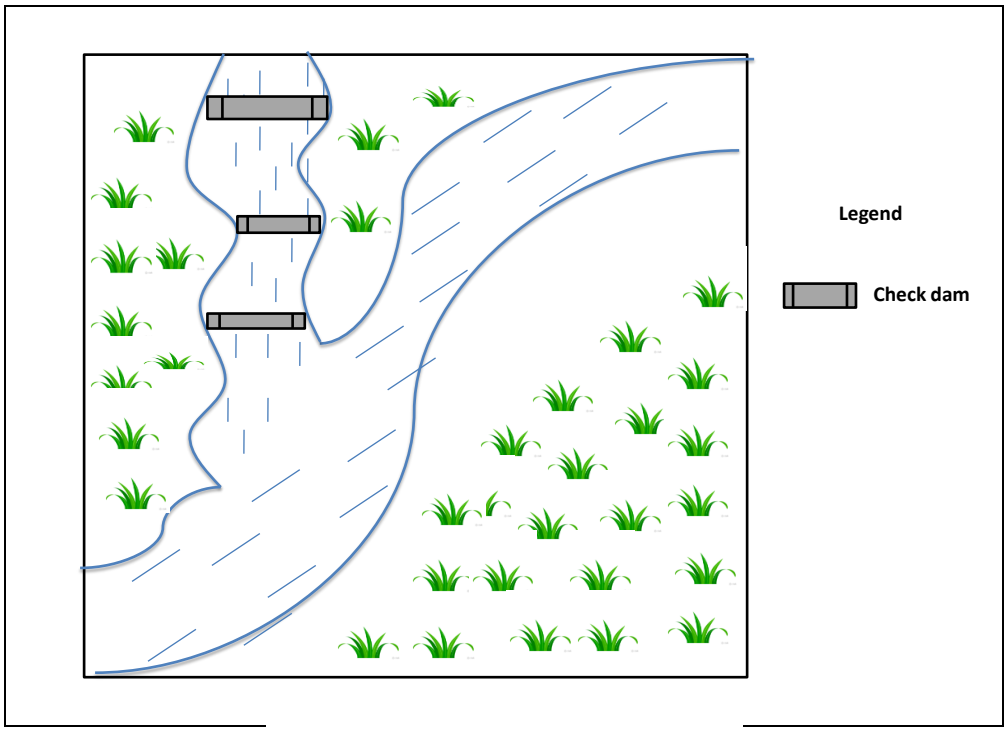


Fig. 5.43. Illustration of check dam

B. Himachal Pradesh

YM/HP/CI/01: SMC - Contour trenching

The context and prescriptions of this model are same as those for YM/UK/CI/01 'Contour trenching'. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.108.

YM/HP/CI/02: SMC - Percolation pond

The context and prescriptions of this model are same as those for YM/UK/CI/02 '*Chal khal*. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.108.

YM/HP/CI/03: SMC - Check dam

The context and prescriptions of this model are same as those for YM/UK/CI/03 '*Check dam'*. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.108.

YM/HP/CI/04: SMC - Spur/Retaining wall

The context and prescriptions of this model are same as those for YM/UK/CI/04 'Spur/Retaining wall'. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.108.

YM/HP/CI/05: SMC - Wetland management

The context and prescriptions of this model are same as those for YM/UK/CI/05 'Wetland management'. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.108.

YM/HP/CI/06: Mixed SMC Works

The context and prescriptions of this model are same as those for YM/UK/CI/06 'Mixed SMC works'. The cost norms applicable to the model in Himachal Pradesh are given in Table 5.108.

Table 5.108. Cost norms for models (YM/ HP /CI/01, YM/ HP /CI/02, YM/ HP /CI/03, YM/ HP /CI/04, YM/ HP CI/05 and YM/ HP CI/06)

Model	Estt. cost (Rs. m^{-3})	Maint. cost (Rs. $m^{-3}yr^{-1}$)	Total cost (Rs. m^{-3})
YM/HP/CI/01: Contour trenching (3×0.3×0.45m = 0.40 m^3)	120	60 (10% of estt. cost or 12 yr^{-1} for 5 yrs.)	180
YM/HP/CI/02: Percolation tank (5×4×1m = 20 m^3)	500	250 (10% of estt. cost or 50 yr^{-1} for 5yrs.)	750
YM/HP/CI/03: Check dam (5×1.5×2m = 15 m^3)	2,000	1,000 (10% of estt. cost or 200 yr^{-1} for 5yrs,)	3,000
YM/HP/CI/04: Spur/Retaining wall (5×1.5×2m = 15 m^3)	2,200	1,100 (10% of estt. cost or 220 yr^{-1} for 5yrs),	3,300
YM/UK/CI/05-Wetland management	6.5 lakh ha^{-1}	3.25 lakh (10% of estt. cost or 0.65 lakh yr^{-1} for 5yrs,)	9.75 lakh ha^{-1}
YM/HP/CI/06-Mixed SMC works	Site-specific requirement	Site-specific requirement	Site-specific cost

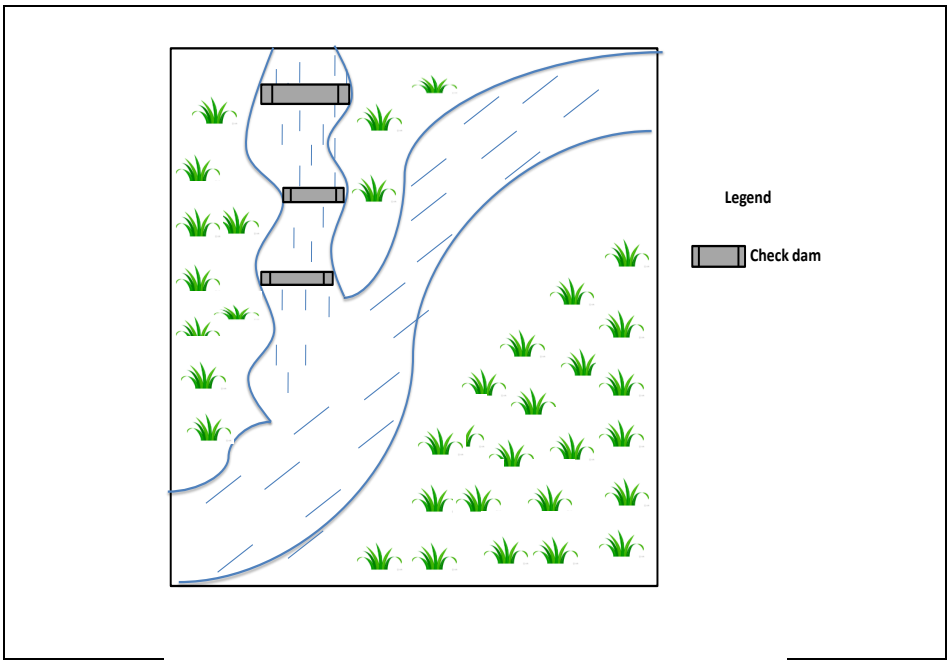


Fig. 5.44. Illustration of wetland management

C. Haryana

YM/HY/CI/01: Water storage structures

Ponds and water percolation tanks will be created in forest areas where sites have been proposed by the forest department. The stored water will increase ground water recharge, reduce problem of soil erosion, provide drinking water for animals and improve the site quality. Planting work will not be done.

Table 5.109. Cost norm for YM/HY/CI/01

Model code	Model name	Estt. cost (Rs. m^{-3})	Main. cost (Rs/ m^3 yr^{-1})	Total cost (Rs. m^{-3})
YM/HY/CI/01	*Kachcha* pond	Rs. 100 m^{-3} (manual digging) (1 m^3=1,000 L)	Rs. 25 m^{-3} (Rs. 5 m^3 yr^{-1} x 5 yrs)	**Rs. 125 m^{-3}**

Table 5.110. Year-wise cost summary for YM/HY/CI/01 (Rs. m^{-3})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
100	5	5	5	5	5	**125**

YM/HY/CI/02: Managing water flow, soil moisture and sedimentation

There are several sites where problem of soil erosion is present. The soil lose showing incidence of erosion of the upper soil layer and/or gully formation. Stone (boulder) checkdams and guidebunds will be created. In some sites where stone checkdam is not likely to sustain the pressure of flowing water, stone cratewire will be erected. At a few places, unstable checkdams or slopes are existing which require stabilisation with cratewire support. Cratewire will be provided in those areas. At many places the forceful impact of water flowing in the river, or falling down the slope, is quite severe which has resulted in, or likely to soon result in, erosion or localized collapse of the river bank. Such places require CC stud and RCC structure to prevent or check problem of severe landslide, stream bank collapse or soil erosion. Planting of trees will not be done on these structures. Grass will be planted on guide bandh.

Table 5.111. Cost norm for YM/HY/CI/02/A to YM/HY/CI/02/F

Structure	Estt. cost (Rs./ m^3)	Maint. cost (Rs./ m^3)	Total cost (Rs./ m^3)
YM/HY/CI/02/A RCC structure	3,500	875 (195 yr^{-1} for 5 yrs)	**4,375**
YM/HY/CI/02/B CC stud	3,000	750 (150 yr^{-1} for 5 yrs)	**3,750**
YM/HY/CI/02/C Dry stone structure	1,000	250 (50 yr^{-1} for 5 yrs)	**1,250**
YM/HY/CI/02/D Stone cratewire structure	2,000	500 (100 yr^{-1} for 5 yrs)	**2,500**
YM/HY/CI/02/E Crate wire mesh	200	50 (10 yr^{-1} for 5 yrs)	**250**
YM/HY/CI/02/F Guide bandh	200	50 (10 yr^{-1} for 5 yrs)	**250**

Table 5.112. Year-wise cost summary for YM/HY/CI/02/A to YM/HY/CI/02/F

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
YM/HY/CI/02/A RCC structure (Rs./ m^3)						
3,500	195	195	195	195	195	**4,375**
YM/HY/CI/02/B CC stud (Rs./ m^3)						
3,000	150	150	150	150	150	**3,750**
YM/HY/CI/02/C Dry stone structure (Rs./ m^3)						
1,000	50	50	50	50	50	**1,250**
YM/HY/CI/02/D Stone cratewire structure (Rs./ m^3)						
2,000	100	100	100	100	100	**2,500**
YM/HY/CI/02/E Crate wire mesh (Rs./ m^2)						
200	10	10	10	10	10	**250**
YM/HY/CI/02/F Guide bandh (Rs./ m^3)						
200	10	10	10	10	10	**250**



Fig. 5.45. Illustration of stone crate wire structure
(**Source:** IISWC, Dehradun)

YM/HY/CI/03: Rehabilitation of soil and moisture conservation structures

This model will be deployed in all such sites in forest areas in the riverscape area of Yamuna where no other model is proposed to be used. Soil and moisture conservation is crucial to river rejuvenation as it increases percolation of water in the soil and reduces surface runoff and soil erosion thereby prolonging retention of water in the catchment area, improvement of environmental flow and improvement of quality of water. This indirectly ameliorates site quality which in turn results in improvement of natural regeneration, plant survival and growth, and enhancement of forest productivity and biodiversity conservation. Soil and moisture conservation structures have direct, definite and immediate effect on water quality and quantity. The soil and moisture structures in several forest areas are quite old or inadequate and need repair /strengthening. This model aims to strengthen the soil and water conservation measures in different areas in the riverscape at a modest scale through need-based repair/ development of low-cost structures such as contour trenches, contour bunds, loose boulder check dams, earthen check dams, brushwood check dams, ponds, gully

plugs, etc. The forest area in the riverscape in the state, which is not proposed to be treated by any other treatment model, is about 15,000 ha. This extent of area will be treated under this model.

Table 5.113. Cost norm for YM/HY/CI/03

Model	Year 1 (Rs. ha^{-1})	Year 2 to 5 (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
YM/HY/CI/03 Rehabilitation of soil and water conservation structures	3,600 ha^{-1}	2,000 (400 yr^{-1} for 5 yrs)	**5,600 ha^{-1}**

Table 5.114. Year-wise cost summary for YM/HY/CI/03 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
3,600	400	400	400	400	400	**5,600**

YM/HY/CI/04: Riparian wildlife management

For providing a good habitat for wildlife, various activities have been proposed as part of aforesaid models. Under this model on riparian wildlife management, water ponds will be created in wildlife-rich area for providing drinking water for the wild animals. Fodder grasses and wild fruit tree species will be planted in the surrounding area to provide a wholesome environment for the animals. Amount will be provided according to the activities to be undertaken.

Table 5.115. Cost norm for YM/HY/CI/04

Model	Estt. cost (Rs. ha^{-1})	Maint. cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
YM/HY/CI/04 Riparian wildlife management	6.50 lakh ha^{-1}	3.25 lakh (10% of estt. cost or 0.65 yr^{-1} for 5 yrs)	9.75 lakh ha^{-1}

Table 5.116. Year-wise cost summary for YM/HY/CI/04 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
6,50,000	65,000	65,000	65,000	65,000	65,000	**9,75,000**

D. Delhi

YM/DL/CI/01: Rehabilitation of soil and moisture conservation structures

The context and prescriptions of this model are broadly similar to those of YM/HY/CI/03 'Rehabilitation of soil and moisture conservation structures'. This model aims to rehabilitate/ strengthen the soil and water conservation measures in different forest areas in the riverscape and catchment area of Yamuna at a modest scale through need-based repair/ development of low-cost structures such as conservation ditches, contour trenches, contour bunds, earthen check dams, brushwood check dams, loose boulder check dams, ponds, gully plugs, etc.

Unlike plantation models, this model would not change the land use or interfere with existing land use of the forest area.

Table 5.117. Cost norm for YM/DL/CI/01

Model	Year 1 (Rs. ha^{-1})	Year 2 to 6 (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
YM/DL/CI/01 Rehabilitation of soil and water conservation structures	8,000 ha^{-1}	10,000 (2,000 yr^{-1} for 5 yrs)	**18,000 ha^{-1}**

Table 5.118. Year-wise cost summary for YM/DL/CI/01 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
8,000	2,000	2,000	2,000	2,000	2,000	**18,000**

The amount mentioned for year 2 to 6 may be used for construction or maintenance of structure(s).
The typical sizes of various soil and moisture conservation structures are as under:
Conservation ditch: 3 m x 1.5 m x 0.60 m size per structure.
Contour trench: 3 m x 0.45 m x 0.45 m size per structure.
Contour bund: (40 cm base +20 cm top)/2 x 25 cm x 1 m size per structure.
Loose boulder check dam: 3m x 0.60 m x 0.45 m size per structure.
Brushwood check dam: Site-specific size.
Pond: Site-specific size, depth not more than 1.50 m.
Earthen check dam: Site-specific size.
Gully plug: Site-specific size.
The number of these structures per ha will be such that the total cost will be equal to the model cost stated above.
About 9,000 ha forest area in the riverscape/catchment area is proposed to be treated with this model.

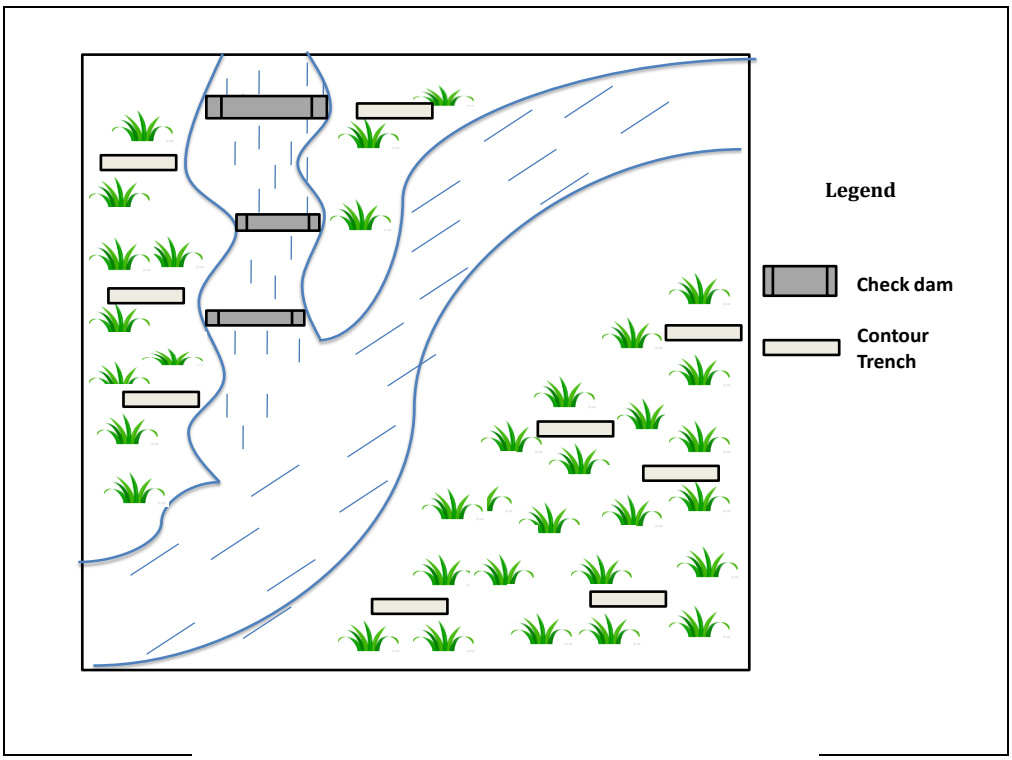


Fig. 5.46. Illustration of model on SMC works

E. Uttar Pradesh

YM/UP/CI/01: Water storage bodies/structures

Ponds and water percolation tanks will be created in forest areas where sites have been proposed by the forest department. The stored water will increase ground water recharge, reduce problem of soil erosion, provide drinking water for animals and improve the site quality. Planting work will not be done.

Table 5.119. Cost norm for YM/UP/CI/01

Sub-model*	Estt. cost (Rs. m^{-3})	Maint. cost (Rs. m^{-3})	Total cost (Rs. m^{-3})
YM/UP/CI/01/A Pond	100 (manual digging) (1 m^3=1,000 L)	25 (5 yr^{-1} x 5 yrs)	**Rs. 125 m^{-3}**

Table 5.120. Year-wise cost summary for YM/UP/CI/01 (Rs. m^{-3})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
100	5	5	5	5	5	**125**

YM/UP/CI/02: Managing water flow, soil moisture and sedimentation

There are several sites where problem of soil erosion is present. The loose soil shows incidence of erosion of the upper soil layer and/or gully formation. Dry check dam (boulder check dam), brushwood check dam and dry gully pugs will be created where they are expected to be effective. For brushwood check dam wooden or bamboo posts of suitable length, 8-12 cm diameter will be placed at 1 m interval with each pole driven around 50-75 cm inside soil for better strength. These posts will be held together with bamboo poles.

In some sites where the above structures are not likely to sustain the pressure of flowing water, spur, spillway and sidewall will be erected. Planting of trees will not be done on these structures. The remaining forest area will not be treated.

Table 5.121. Cost norm for YM/UP/CI/02/A to YM/UP/CI/02/G

Sub-model	Estt.cost (Rs. m^{-3})	Maint. cost (Rs. m^{-3})	Total cost (Rs. m^{-3})
YM/UP/CI/02/A Sidewall*	Site-specific requirement	Site-specific requirement	Site-specific cost
YM/UP/CI/02/B Spur*	Site-specific requirement	Site-specific requirement	Site-specific cost
YM/UP/CI/02/C Dry check dam*	200	100 (20 yr^{-1} for 5 yrs)	300
YM/UP/CI/02/D Dry gully plug*	190	95 (19 yr^{-1} for 5 yrs)	285
YM/UP/CI/02/E Brushwood check dam	8.68	8.68 (1.74 yr^{-1} for 5 yrs)	19.36
YM/UP/CI/02/F Spillway*	Site-specific requirement	Site-specific requirement	Site-specific cost
YM/UP/CI/02/G Mixed SMC*	Site-specific requirement	Site-specific requirement	Site-specific cost

* Requirement is given in monetary terms as rates vary widely with site and specifications.

Table 5.122. Year-wise cost summary for YM/UP/CI/02/A to YM/UP/CI/02/G (Rs. m^{-3})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
YM/UP/CI/02/A to YM/UP/CI/02/B						
80% of amount demanded	-	-	10% of amount demanded	-	10% of amount demanded	Site-specific cost
YM/UP/CI/02/C (Rs. m^{-3})						
200	20	20	20	20	20	**300**
YM/UP/CI/02/D (Rs. m^{-3})						
190	19	19	19	19	19	**285**
YM/UP/CI/02/E (Rs. m^{-3})						
8.68	1.74	1.74	1.74	1.74	1.74	**19.36**
YM/UP/CI/02/F to YM/UP/CI/02/G						
80% of amount demanded	-	-	10% of amount demanded	-	10% of amount demanded	Site-specific cost

YM/UP/CI/03: Riparian wildlife management

The context and prescriptions of this model are broadly similar to those of YM/HY/CI/04 'Riparian wildlife management'.

Table 5.123. Cost norm for YM/UP/CI/03

Model	Estt. cost (Rs. ha^{-1})	Maint. cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
YM/UP/CI/03 Riparian wildlife management	2.00 lakh ha^{-1}	2.00 lakh (20% of estt. cost / year for 5 yrs)	4.00 lakh ha^{-1}

Table 5.124. Year-wise cost summary for YM/UP/CI/03 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
2,00,000	40,000	40,000	40,000	40,000	40,000	**4,00,000**

YM/UP/CI/04: Wetland management in uniform site conditions

This model of wetland management will be undertaken in sites which have small area and are fairly uniform to allow similar treatment per hectare. Under this model, water ponds will be created or dug deeper for collecting water to prevent runoff or check inundation in surrounding areas. Removal of water hyacinth and other aquatic weeds will be carried out. Population of fishes of native species will be augmented. Water-logging tolerant plant species will be planted wherever possible.

Table 5.125. Cost norm for YM/UP/CI/04

Model	Estt. cost (Rs. ha^{-1})	Maint. cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
Wetland management (YM/UP/CI/04)	2.00 lakh ha^{-1}	1.00 lakh (10% of estt. cost yr^{-1} for 5 yrs)	3.00 lakh ha^{-1}

Table 5.126. Year-wise cost summary for YM/UP/CI/04 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
2,00,000	20,000	20,000	20,000	20,000	20,000	**3,00,000**

YM/UP/CI/05: Wetland management in heterogenous areas

The region near the confluence of Chambal and Yamuna in Etawah district is dotted with wetlands of diverse sizes. These serve as habitat of aquatic animals and in particular, these are renowned as breeding places of sarus crane (*Grus antigone*). Under the project it is proposed to carry out activities for conservation and scientific management of such wetlands.

Activities such as the following will be taken up depending upon site-specific requirement: Removal of encroachments, afforestation and aided regeneration, small scale engineering, measures (gully plugging, check dams, gabion structures, etc.), selective dredging and desilting to improve hydrological connectivity, interception, diversion and treatment of point sources of pollution, maintenance of breeding and spawning grounds for key species, management of invasive species, microenterprise development, sustainable fisheries development, etc.

Table 5.127. Cost norm for YM/UP/CI/05 (Rs. ha^{-1})

Model	Estt. Cost	Maint. cost	Total cost
YM/UP/CI/05	Site-specific requirement	Site-specific requirement	Site-specific cost

YM/UP/CI/06: Rehabilitation of soil and water conservation structures

The context and prescriptions of this model are broadly similar to those of YM/HY/CI/03 'Rehabilitation of soil and water conservation structures.

Table 5.128. Cost norm for YM/UP/CI/06 (Rs. ha^{-1})

Model	Year 1 (Rs ha^{-1})	Year 2 to 5 (Rs. ha^{-1})	Total cost (Rs ha^{-1})
YM/UP/CI/06 Rehabilitation of soil and water conservation structures	3,600 ha^{-1}	2,000 (400 yr^{-1} for 5 yrs)	5,600 ha^{-1}

Table 5.129. Year-wise cost summary for YM/UP/CI/06 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
3,600	400	400	400	400	400	**5,600**

F. Rajasthan

YM/RJ/CI/01: Water storage bodies/structures

The context and prescriptions of this model are broadly similar to those of YM/HY/CI/01 Water storage bodies/structures.

These prescriptions will be implemented as per rates existing at the site, some of which are too complex to be generalised as they depend on location and detailed specifications of the structure.

Table 5.130. Cost norms for YM/RJ/CI/01/A and YM/RJ/CI/01/B

Model	Estt. cost (Rs.)	Maint. cost (Rs.)	Total cost (Rs.)
YM/RJ/CI/01/A SMC - Mini percolation tank/ Naadi/ Water harvesting structure	Site-specific requirement	Site-specific requirement	Site-specific cost
YM/RJ/CI/01/B SMC – Tanka	Site-specific requirement	Site-specific requirement	Site-specific cost

Table 5.131. Year-wise cost summary for YM/RJ/CI/01/A and YM/RJ/CI/01/B

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
YM/RJ/CI/01/A to YM/RJ/CI/01/B						
80% of amount demanded	-	-	10% of amount demanded	-	10% of amount demanded	Site-specific cost



Fig. 5.47. Illustration of water storage bodies/structures
(**Source:** IISWC, Dehradun)



Fig. 5.48. Illustration of water storage bodies/structures
(***Source***:https://en.wikipedia.org/wiki/Johad)

YM/RJ/CI/02: Managing water flow, soil moisture and sedimentation

The context and prescriptions of this model are broadly similar to those of YM/HY/CI/02 'Managing water flow, soil moisture and sedimentation'.

These prescriptions will be implemented as per rates existing at the site, some of which are too complex to be generalised as they depend on location and detailed specifications of the structure.

Table 5.132. Cost norms for YM/RJ/CI/02/A and YM/RJ/CI/02/H)

Model	Estt. cost (Rs. m^{-3})	Maint. cost (Rs. m^{-3})	Total cost (Rs. m^{-3})
YM/RJ/CI/02/A (SMC - Loose stone check dam)	213	21.3 x 5 yrs =106.50 for 5 yrs	319.5
YM/RJ/CI/02/B* (SMC - Pucca check dam)	Site-specific requirement	Site-specific requirement	Site-specific cost
YM/RJ/CI/02/C* (SMC - Anicut)	Site-specific requirement	Site-specific requirement	Site-specific cost
YM/RJ/CI/02/D* (SMC - Gabion)	Site-specific requirement	Site-specific requirement	Site-specific cost
YM/RJ/CI/02/E* (SMC - Stone wall)	Site-specific requirement	Site-specific requirement	Site-specific cost
YM/RJ/CI/02/F* (SMC - Pucca wall)	Site-specific requirement	Site-specific requirement	Site-specific cost
YM/RJ/CI/02/G* (SMC – silt detention structure)	Site-specific requirement	Site-specific requirement	Site-specific cost
YM/RJ/CI/02/H* (SMC - Miscellaneous structures)	Site-specific requirement	Site-specific requirement	Site-specific cost
YM/RJ/CI/02/I* (SMC - Mixed structures)	Site-specific requirement	Site-specific requirement	Site-specific cost

* Requirement is given in monetary terms as rates vary widely with site. Miscellaneous structures include inspection path etc. not covered in above model. Mixed structures include a combination of above structures within a site.

Table 5.133. Year-wise cost summary for YM/RJ/CI/02/A and YM/RJ/CI/02/H (Rs. m^{-3})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
YM/RJ/CI/02/A						
213	21.30	21.30	21.30	21.30	21.30	**319.50**
YM/RJ/CI/02/B to YM/RJ/CI/02/I						
80% of amount demanded	-	-	10% of amount demanded	-	10% of amount demanded	**Site-specific cost**



Fig. 5.49. Illustration of managing water flow, soil moisture and sedimentation
(*Source:* **Project Team**)



Fig. 5.50. Illustration of Anicut
(*Source:* **Project Team**)



Fig. 5.51. Illustration of SMC stone wall
(*Source:* **Project Team**)

YM/RJ/CI/03: Riparian wildlife management
The context and prescriptions of this model are broadly similar to those of YM/HY/CI/04 'Riparian wildlife management'.

Table 5.134. Cost norm for YM/RJ/CI/03

Model	Estt. cost (Rs. ha^{-1})	Maint. cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
Riparian wildlife management* (YM/RJ/CI/03)	2.00 lakh ha^{-1}	1.00 lakh (10% of estt. cost yr^{-1} for 5 yrs)	3.00 lakh ha^{-1}

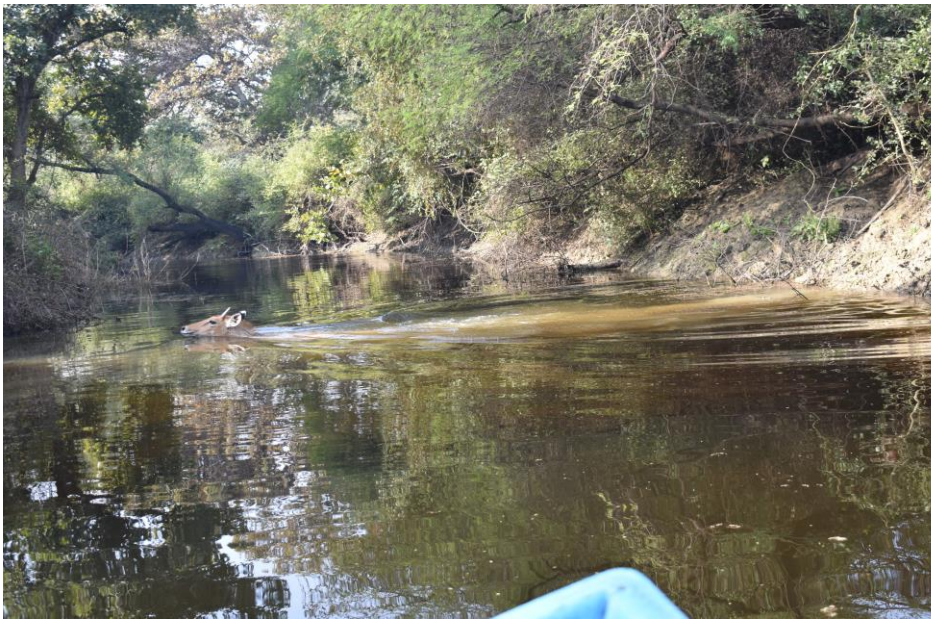


Fig. 5.52. Illustration of riparian wildlife management

Table 5.135. Year-wise cost summary for YM/RJ/CI/03 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
2,00,000	20,000	20,000	20,000	20,000	20,000	**3,00,000**

YM/RJ/CI/04: Wetland Management

The context and prescriptions of this model are broadly similar to those of YM/HY/CI/05 'Wetland management'. The cost norms applicable in the state are given in Table 5.136.

Table 5.136. Cost norm for YM/RJ/CI/04

Model	Estt. cost (Rs. ha^{-1})	Maint. cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
Wetland management (YM/RJ/CI/04)	Site-specific requirement	Site-specific requirement	Site-specific cost

Table 5.137. Year-wise cost summary for YM/RJ/CI/04

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
80% of amount demanded	-	-	10% of amount demanded	-	10% of amount demanded	**Site-specific cost**



Fig. 5.53. Illustration of wetland management

YM/RJ/CI/05: Rehabilitation of soil and moisture conservation structures

The context and prescriptions of this model are broadly similar to those of YM/HY/CI/03 'Rehabilitation of soil and moisture conservation structures'. The cost norms applicable in the state are given in Table 5.138.

Table 5.138. Cost norm for YM/RJ/CI/05

Model	Year 1 (Rs. ha^{-1})	Year 2 to 5 (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
YM/RJ/CI/05 Rehabilitation of soil and water conservation structures	3,600 ha^{-1}	2,000 (400 yr^{-1} for 5 yrs)	**5,600 ha^{-1}**

Table 5.139. Year-wise cost summary for YM/RJ/CI/05 (Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
3,600	400	400	400	400	400	**5,600**

G. Madhya Pradesh

YM/MP/CI/01: Water storage bodies/structures

The context and prescriptions of this model are broadly similar to those of YM/HY/CI/01 'Water storage bodies/structures'. *Kachcha* pond, *dabra dabri*, pitched pond, percolation tank and similar traditional water storage bodies or structures will be created in forest areas where sites have been proposed by the forest department. The cost norms applicable in the state are given in Table 5.140.

YM/MP/CI/01/A: *Kachha* pond, *Dabra Dabri*

YM/MP/CI/01/B: Pitched pond

YM/MP/CI/01/C: Percolation tank

Table 5.140. Cost norm for YM/MP/CI/01/A to YM/MP/CI/01/C(Rs. m^{-3})

Model code	Model name	Estt. cost (Rs. m^{-3})	Maint.cost (Rs. m^{-3})	Total cost (Rs. m^{-3})
YM/MP/CI/01/A	*Kachha* pond, *dabra dabri*	100(manual digging) (1 m^3=1,000 L)	25 (5 yr^{-1} x 5 yrs)	**Rs. 125 m^{-3}**
YM/MP/CI/01/B*	Pitched pond	Site-specific requirement	Site-specific requirement	**Site-specific cost**
YM/MP/CI/01/C	Percolation tank	100 (manual digging) (1 m^3=1,000 L)	25 (5 yr^{-1} x 5 yrs)	**Rs. 125 m^{-3}**

*Requirement was given by SFD in monetary terms as rates vary widely with site and specifications.

Table 5.141. Cost summary for YM/MP/CI/01/A to YM/MP/CI/01/C(Rs. m^{-3})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
YM/MP/CI/01/A						
100	5	5	5	5	5	**125**
YM/MP/CI/01/B						
80% of amount demanded	-	-	10% of amount demanded	-	10% of amount demanded	**Site-specific cost**
YM/MP/CI/01/C						
100	5	5	5	5	5	**125**



Fig. 5.54. Illustration of percolation tank
(*Source:* **Project Team**)

YM/MP/CI/02: Managing water flow, soil moisture and sedimentation

The context and prescriptions of this model are broadly similar to those of YM/HY/CI/02 'Managing water flow, soil moisture and sedimentation'. The cost norms applicable in the state are given in Table 5.142.

A *kharanja* is a path made of brick or stone joined by cement and supported on *murrum* (local name of laterite soil) at the base. A *rapta* is a path made of reinforced cement. Both these structure are constructed in the forest to facilitate movement of vehicles and personnel on soft wet soil.



Fig. 5.55. View of a *kharanja*
(***Source:*** Madhya Pradesh Forest Department)



Fig. 5.56. View of a *Rapta*
(***Source:*** Madhya Pradesh Forest Department)

Table 5.142. Budget norm for YM/MP/CI/02

Model	**Estt. cost (Rs. m^{-3})**	**Maint. cost (Rs. m^{-3})**	**Total cost (Rs. m^{-3})**
YM/MP/CI/02/A Loose boulder check dam/structure 3m x 0.60 m x 0.45 m size; quantity as per requirement of particular site (200 no. or 162 m^3 earthen check dams will be equivalent to 1 ha)	308	15.40 x 5 yrs= 77	**385**
YM/MP/CI/02/B* SMC - Anicut	Site-specific requirement	Site-specific requirement	**Site-specific cost**
YM/MP/CI/02/C* SMC - Stopdam	Site-specific requirement	Site-specific requirement	**Site-specific cost**
YM/MP/CI/02/D* SMC - *Kharanja* (brick/stone passage)	Site-specific requirement	Site-specific requirement	**Site-specific cost**
YM/MP/CI/02/E* SMC – *Rapta* (causeway)	Site-specific requirement	Site-specific requirement	**Site-specific cost**
YM/MP/CI/02/F* Protection wall	Site-specific requirement	Site-specific requirement	**Site-specific cost**
YM/MP/CI/02/G* Mixed soil and moisture conservation (Mrida Jal Sanrakshan)	Site-specific requirement	Site-specific requirement	**Site-specific cost**

*Requirement was given by SFD in monetary terms as rates vary widely with site and specifications

Table 5.143. Cost summary for YM/MP/CI/02 (Rs. m^{-3})

Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Total**
YM/MP/CI/02/A						
308	15.40	15.40	15.40	15.40	15.40	**385**
YM/MP/CI/02/B to YM/MP/CI/02/G						
80% of amount demanded	-	-	10% of amount demanded	-	10% of amount demanded	**Site-specific cost**

YM/MP/CI/03: Rehabilitation of soil and moisture conservation structures

The context and prescriptions of this model are broadly similar to those of YM/HY/CI/03 'Rehabilitation of soil and moisture conservation structures'. The cost norms applicable in the state are given in Table 5.144.

Table 5.144. Budget norm for YM/MP/CI/03

Model	Year 1 (Rs. ha^{-1})	Year 2 to 6 (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
YM/MP/CI/03 Rehabilitation of soil and water conservation structures	3,600	2,000 (400 yr^{-1} for 5 yrs)	**5,600**

Table 5.145. Cost summary for YM/MP/CI/03(Rs. ha^{-1})

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Total
3,600	400	400	400	400	400	**5,600**

5.7. POLICY INTERVENTIONS FOR FORESTRY SECTOR

The policy interventions have been elaborated in chapter 4 (para 4.11.1. Policy Interventions Proposed. Some specific forestry interventions that relate to forestry sector and are worth consideration include strengthening of existing laws and ensuring effective implementation. Encroachment, fragmentation of forest areas and muck disposal on forest land need to be checked.

5.8. SUPPORTING ACTIVITIES

Apart from treatment moels and policy interventions, a number of other activities are also required to be carried out in order to accomplish the goal of the DPR, These activities are as under:

Awareness generation

Public participation is very important for mobilizing public towards checking deterioration of water and forest and elicting support in project implementation. Awareness campaigns will be organized to educate the public about importance of river and good and bad practices that affect the river. People of all age groups and all walks of life will be made aware of. Special focus wil be on communities those are directly dependent on the riverine system and reside in the riverscape areas. Printing and distribution of pamphlets, brochures, booklets. signages, boards, hoardings, organsing of meetibgs, etc. may be done. Effective awareness generation would also translate into voluntary help from the communities in project activities.

Capacity building and value-chain development

Capactity building will be undertaken to impart technical knowhow to the staff of the Implementing Agency (IA), i.e., SFDs and other department swho would assist the IA in imementation of the prescriptions of the DPR. Special focus will be on soil and moisture conservation measures, grassland development, riparian wildlife management, wetland management, riverfront development, ecopark development and other aspects as may be considered necessary at time of project implementation. Self-help groups will be created to help the local communities carry out value-addition and supply to potential markets. Local industries would be consulted during the process.

Entry point activities

Entry point activities are needed to generate a favourable rapport with the local communities from the beginning of the project implementation and their confidence. Suitable activites will be identified and implemented in consultation with the communities.

Nursery improvement and fire protection

Improvement may be carried out in nursery infrastructure of the SFD to undertake the work of nursery stock production. Fire watchers, fire beaters, and other suitable staff may be deputed and equipment for control of forest fire may be purchased and used. Any other meaure required for

protection of plantations and forest area from forest fire and other biotic/abiotic agencies in and around the riverscape may be adopted.

Research

Research may be undertaken to identify the most effective forestry practices for river rejuvenation by analyzing the impacts of the past schemes and efforts. Benchmarking of the condition of water, forest and silt load in Yamuna and tributaries may also be carried out. Use of new technologies such as seed balls, Miyawaki technique, improved nursery techniques etc. may be explored as pilot project under the DPR.

Monitoring and evaluation

The activities of the project will be continuously monitored. Monitoring may be at different levels:

1. Internal monitoring.
2. Third party or the external evaluation.

Monitoring may be done by different means,*viz.*,

1. Online monitoring through reports.
2. On-ground monitoring.
3. GIS based monitoring.

Other field activities and miscellaneous works

In order to accomplish the targets under the project, SFD may have to hire additional staff, purchase vehicles, equipments, etc., and carry out various other supportive activities. Such need-based works are required and budgetary allocation has been made in the project for this purpose. The budget for supporting activities is given in Table 5.146.

Table 5.146. Budget proposed for seven supporting activities in different states (Rs. in lakh)

Particular	Uttarakhand	Himachal Pradesh	Haryana	Delhi	Uttar Pradesh	Rajasthan	Madhya Pradesh	Total
Awareness generation	81.00	72.00	46.00	14.00	320.00	1,750.00	410.00	**2,693.00**
Capacity building and value-chain development	87.00	74.00	47.00	11.00	375.00	2,050.00	470.00	**3,114.00**
Entry point activities	50.00	40.00	21.00	0.00	150.00	750.00	500.00	**1,511.00**
Nursery improvement and fire protection	108.30	73.00	22.00	0.00	540.00	2,400.00	540.00	**3,683.30**
Research	77.60	45.00	33.00	60.00	335.00	1,140.00	500.00	**2,190.60**
Monitoring and evaluation	55.00	54.00	18.00	5.00	280.00	710.00	580.00	**1,702.00**
Field activities, contingency and miscellaneous costs	187.00	145.00	55.72	42.82	500.00	2,200.00	725.00	**3,855.54**
Total	**645.90**	**503**	**242.72**	**132.82**	**2,500**	**11,000**	**3,725**	**18,749.44**

5.9. PROJECT MANAGEMENT

All the activities under the project will be managed by a Project Management Unit (PMU) at the state level for Yamuna basin who would liase with MoEF&CC at the state level and DFOs and other officials responsible for execution of the project. PMU will also coordinate with other sectoral departments in Yamuna basin at the state level. The budget for PMU is given in Table 5.147.

Table 5.147. Budget proposed for PMU in different states (Rs. in lakh)

Particular	Uttarakhand	Himachal Pradesh	Haryana	Delhi	Uttar Pradesh	Rajasthan	Madhya Pradesh	Total
Recurring	88.00	70.00	52.00	14.29	530.00	2,300.00	795.00	**3,849.29**
Non-recurring	31.00	30.00	18.00	8.32	62.00	124.00	62.00	**335.32**
Total	**119.00**	**100.00**	**70.00**	**22.61**	**592.00**	**2,424.00**	**857.00**	**4,184.61**

A sum of Rs. 4,184.61 lakh has been provided for creating and operating the State PMUs.

Chapter 6
IMPLEMENTATION: MECHANISM AND SUSTAINABILITY

6.1. INTRODUCTION

The Yamuna basin is spread over in seven states, *viz.*, Uttarakhand, Himachal Pradesh, Haryana, Delhi, Uttar Pradesh, Rajasthan and Madhya Pradesh and encompasses varied site conditions. A number of forestry plantations, soil and water conservation measures, wetland and riparian wildlife management, bio-remediation and filtration in natural, agriculture and urban landscapes including supporting activities *viz.*, monitoring, evaluation, research and awareness, etc. have been proposed to rejuvenate River Yamuna and its major tributaries, for implementation in the stakeholder states. The mechanism for implementation of the proposed DPR has been discussed in this chapter. There are four major components from perspective of implementation of the DPR:

6.1.1. Component 1: Forestry Interventions in Seven States of Yamuna Basin

The implementation of forestry interventions to be carried in the seven stakeholder states in delineated riverscape and catchments of River Yamuna and its tributaries is detailed in this DPR. The 5-year implementation plan (1-5 years from the date of approval/implementation) with further a 4-year maintenance phase envisages extensive plantations and conservation interventions in suggested landscapes by participating states in riverscape of Yamuna in the project. The state forest departments (SFDs) of the seven stakeholder states will be the primary Implementing Agencies (IAs) for various activities under the DPR on forestry interventions. The existing situation, organizational setup, mandate, activities, schemes and strengths of SFDs in implementation of forestry interventions as IAs have already been highlighted in Chapter 4 (Legislative, Policy and Institutional Context). The SFDs provide an institutional framework for implementation of the forestry interventions. Every level in the hierarchy has corresponding roles and responsibilities that transform into the desired synergy among various disciplines of science and knowledge required for these interventions. This activity includes:

(1) Forestry interventions in three major landscapes of the riverscape, *viz.*, (i) Natural Landscapes (NL), (ii) Agriculture Landscape (AL) and (iii) Urban Landscape (UL) by way of plantations and related activities through various scientifically designed models.

(2) Conservation Interventions (CI) such as (i) Soil and Water Conservation (SMC); (ii) riparian wildlife management and (iii) wetland management have also been planned for the delineated riverscape.

(3) Supporting activities that are essential and supportive to the major project on forestry interventions, such as (i) awareness generation, (ii) capacity building and value-chain development, (iii) concurrent research and development, (iv) monitoring and evaluation, (v) protection against forest fire and development of nurseries, (vi) supportive field activities/ miscellaneous works and (vii) efforts for amendments in policy and law. Support for the establishment and running of activities of the State-level Project Management Units (SPMUs) in stakeholder states is also provisioned in the DPR to implement, coordinate, and monitor the state wide programme and activities for forestry interventions in Yamuna riverscape.

6.1.2. Component 2: Strengthening Knowledge Management and National Capacity for Forestry Interventions in Riverscape

Understanding of forest-river linkages, their intricacies and successful river conservation needs research and development activities. Beneficial outcomes from any such effort of river conservation are unlikely unless science can be actively engaged in the development and assessment of

appropriate policies and management decision making. A Knowledge Management Centre will be designated by the Ministry of MoEF&CC for providing R&D inputs for sustainable management of rivers in India, improved knowledge and capacity building on learning and experience from the seven stakeholder states in this DPR, organizing of knowledge management and capacity building programmes,

6.1.3. Component 3: Scaling Up and Replication of Successful Models of Forestry Interventions in Additional Sites

The present implementation plan incorporated in the DPR focuses on prioritized sites in seven stakeholder states in Yamuna Basin and selected tributaries. Scaling up and replication of successful models in additional sites are proposed by selecting some of the other tributaries or more areas in Yamuna basin.

6.1.4. Component 4: National Coordination for Forestry Interventions in Riverscape

The management of water resources, river development and rejuvenation of rivers through forestry interventions are priority agendas of the country. A mechanism for national level coordination for forestry interventions and riverscape conservation is vital at the level of Central Nodal Ministry (MoEF&CC). For this, a National Project Management Unit (NPMU) at the nodal ministry will be formed with the following tasks:

(i) Establishment of Decision Support and Management Information System (DSMIS) on rivers conservation,
(ii) facilitating activities related to policy interventions, rivers basin level coordination and monitoring and
(iii) administering the implementation of this pilot project on forestry interventions and future replication at additional sites or other suitable modification.

The NPMU will be responsible for execution of the Implementation Plan (IP) and coordination with implementing agencies at the state level in the stakeholder states.

6.2. INSTITUTIONAL AND IMPLEMENTATION MECHANISM

6.2.1 Institutional framework

a) Multi-sectoral framework

The institutional arrangements for the execution of the DPR for implementation and monitoring will be at national, river, state, and district levels. The arrangement at all hierarchical levels will focus on implementation of planned activities; financial management; and monitoring, learning, and reporting in transparent and accountable manner.

Apart from the proposed forestry interventions, several other initiatives are already existing at all the above levels. Many more are likely to be initiated in future. The DPR should fit in the right place to create synergy with the existing framework. Fig. 6.1. outlines the broad institutional framework for implementation of this DPR together with other activities for rejuvenation of rivers at national, state and district levels.

National level

As water resources in the country are governed by the Ministry of Jalshakti, GoI, it is envisaged that the overall task of execution of various programmes on water might be carried out by Ministry of Jalshakti (or other suitable ministry that may be identified by the GoI). The Ministry of Jalshakti is assisted by various ministries for carrying out schemes related to their respective sectors. Accordingly, it is suggested that a National Project Management Group (NPMG) may be created by Ministry of Jalshakti with members drawn from various ministries for coordination across ministries. A directorate or cell on rivers may be created, wherever required, in relevant ministries to address

their sectoral issues in relation to rivers. The DPRs on forestry interventions will be implemented by the Ministry of Environment, Forest and Climate Change (MoEF&CC), GoI. Forestry sector will implement forestry interventions with appropriate vertical liaison within the sector and horizontal liaisons with other sectors.

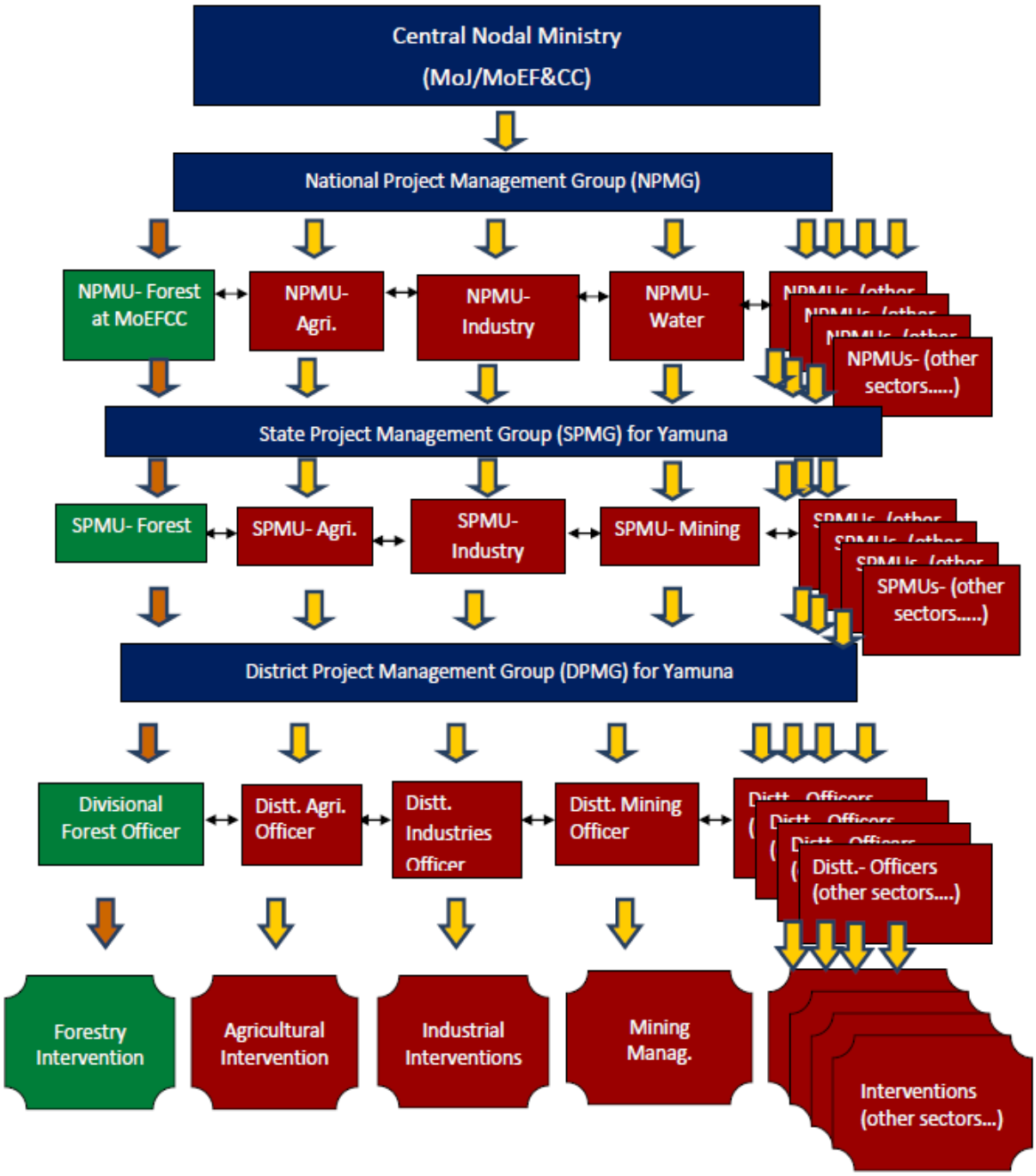


Fig. 6.1. Institutional framework for implementation of DPR on rejuvenation of Yamuna River at national, river, state and district levels with participation of various sectors

(Note: NPMG, SPMG and DPMG stand for National Project Management Group, State Project Management Group and District Project Management Group, respectively)

River level

Within national-level ministries of different sectors, river-wise cells may be created. All states in the Yamuna basin will be grouped in Yamuna Cells of respective ministries to enable coordinated action across states.

State level

A State Project Management Group (SPMG) will be created at the state level under the control of the State Government. The SPMG will be the nodal agency for implementation of all projects on river rejuvenation in the state. It will coordinate with heads of various departments and District Collectors or District Magistrates for effective implementation of the projects in the state. It will also liaise with experts of different subjects to seek their opinion on various technical aspects. Such institutions are already in operation in Uttarakhand, Uttar Pradesh, Bihar, West Bengal and Jharkhand and executing activities like treatment of urban sewage and industrial effluent and implementation of DPR on Forestry for Ganga under the *Namami Gange* programme of the Ministry of Jalshakti, In Uttarakhand, SPMG is a part of the Department of Drinking Water and Sanitation. The sphere of work of SPMG may be expanded to undertake implementation of DPR on rejuvenation of rivers other than Ganga. A cell on rivers may be created within the state by each relevant ministry, wherever required, to prepare and execute programmes in relation to rivers.

District level

At district level, all the schemes of river rejuvenation will be implemented under the control of the District Collector or District Magistrate. This will be done through a District Project Management Group (DPMG) created in coordination with SPMG. DPMG will have representatives from various departments and regions in the district. All groups/ministries/department may have their own steering committees and monitoring committees.

b) Framework within forestry sector:

Implementation of the present DPR on Yamuna would be the done by the MoEF&CC, GoI. DPRs on eight other major river systems viz. Indus, Luni, Mahanadi, Brahmaputra, Narmada, Godavari, Cauvery and Krishna being prepared by ICFRE, would also be executed by the Ministry. The institutional framework that may be followed within the Ministry for implementation of the DPRs is illustrated in Fig. 6.2. Detailed framework is shown for the DPR on Yamuna river; the framework for other rivers may be same as for Yamuna.

National level

The existing framework within the MoEF&CC, GoI will broadly be used for implementation of the DPR on Yamuna for its rejuvenation through forestry interventions. National River Conservation Directorate (NRDC) or National Afforestation and Eco-Development Board (NAEB) under MoEF&CC may serve as NPMU-Forest on river rejuvenation.

River level

Under NRDC/NAED, a cell may be created on Yamuna (parallel cells may be created for other rivers for implementation of their respective DPRs on forestry interventions. Yamuna Cell will be responsible for water-related issues in Yamuna from perspective of forestry.

State level

The SFD will be the agency responsible for implementation of forestry interventions. Besides, the SFD will coordinate with other departments such as agriculture, horticulture, revenue, urban development, etc. to obtain their assistance in implementation of the DPR on forestry interventions for cross-sectoral linkages.

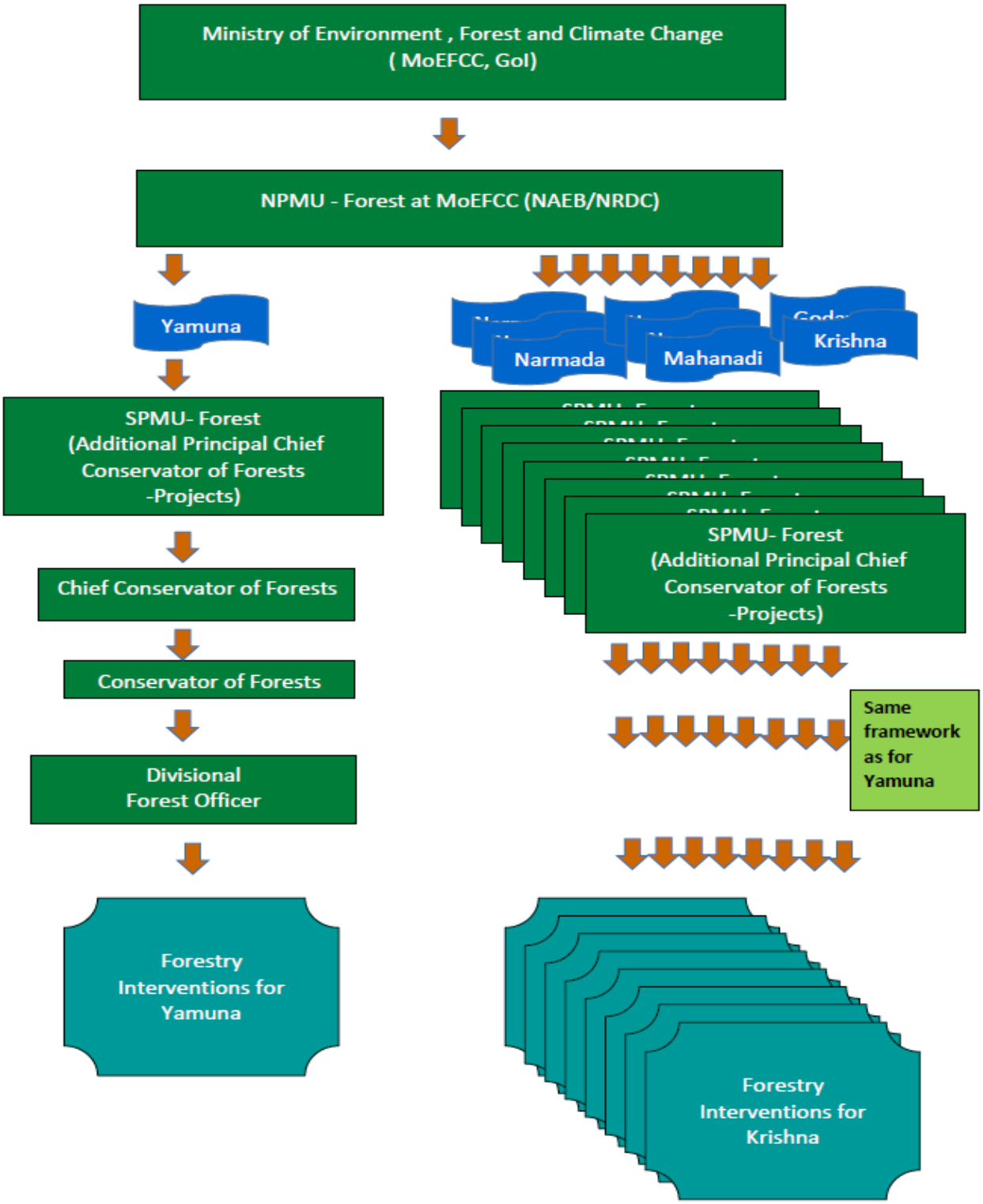


Fig. 6.2. Institutional framework for implementation of DPR on rejuvenation of rivers through forestry interventions within forestry sector at national, river, state and district levels

(Note: All states in the Yamuna basin will be grouped in Yamuna Cell at MoEF&CC. Forestry sector will implement forestry interventions with appropriate vertical liaison within MoEF&CC and horizontal liaisons with other sectors).

An SPMU-Forest will be set up at the headquarters of SFD in each of the seven states viz. Uttarakhand, Himachal Pradesh, Haryana, Delhi, Uttar Pradesh, Rajasthan and Madhya Pradesh. APCCF (Projects) may look after the SPMU-Forest. SPMU-Forest will implement the DPR through its hierarchical structure of CCF → CF → DFO.

Division level

Divisional Forest Officer(s) will be responsible for implementation of the DPR on forestry interventions within the district. The DFO(s) will coordinate and collaborate with other departments such as agriculture, horticulture, revenue, urban development, etc. to get their assistance in implementation of the DPR on forestry interventions. Plants of horticultural species may be raised/procured with consultation or help of horticulture departments. DFOs will also provide assistance to those departments in planning and executing programmes for river rejuvenation. Heads of various other departments representing other sectors within the district will prepare and implement programmes/ activities of their respective departments/sectors to ensure holistic approach for rejuvenation of the river. In case watersheds of more than one major river occur in a district, a nodal officer may be identified for river-wise record keeping and coordination.

6.2.2. Implementation Mechanism for DPR on Forestry Interventions

Within the broad institutional framework outlined above, the nodal ministry (MoEF&CC), will provide overall guidance, supervision and policy support for the DPR. The hierarchical implementation arrangement framework for forestry interventions within the Ministry is as follows: (i) NPMU-Forest at the Nodal Ministry i.e., MoEF&CC, New Delhi, (ii) SPMU-Forest as State level Implementing Agency (IA) i.e., SFDs Uttarakhand, Himachal Pradesh, Haryana, Delhi, Uttar Pradesh, Rajasthan and Madhya Pradesh, and (iii) DPMU-Forest as implementing agency at in district level. The implementation process of the DPR on forestry interventions is illustrated in Fig. 6.3.

a) Implementation Mechanism at National Level

A **National Project Management Unit - Forest (NPMU-Forest**) in the Ministry will oversee and coordinate the implementation of the DPRs on forestry interventions for river rejuvenation, including guiding, timely release of funds reporting, monitoring, learning, etc. for DPR on Yamuna. The Project Director, MoEF&CC will be supported by a project management team. Similar structure is already existing in the Ministry; the same may be strengthened, if necessary, by appointing additional staff on contractual basis for communication, supervision, financial management, monitoring and evaluation pertaining to the DPRs.

The NPMU-Forest will carry out the following tasks relevant to financial management: (a) Annual budgetary provision for the DPR and monitoring of project expenditure against budget; (b) approval of Annual Plan of Operations (APO)/Work Plan and budgets; (c) coordination and ensuring sufficient and timely funds flow to the seven state IAs and national partner organization for various activities; (d) Regular financial reporting at all levels of the project and compilation of quarterly financial reports and annual financial statement of the project; (e) ensuring annual external (e.g. by CAG) and internal audits for the project.

National level organization(s) under the Ministry may be assigned the tasks of capacity building, resolution of concurrent institutional and policy issues, conducting research, monitoring and evaluation.

Provisions have been provided for engagement of international/national consultants, capacity building, planning and conduct of national level seminars/workshops and coordination meetings, awareness, international exposure visits/exchange, project and impact evaluation, etc. to make the NPMU functional and effective in its mandate.

Flow of funds from NPMU to the lower level will be through SPMG.

b) Implementation Mechanism at River Level

River-specific Cells in the MoEF&CC will implement and monitor the works of respective rivers. The **Yamuna Cell** will be responsible for carrying out all activities of NRDC/NAEB in respect of Yamuna river.

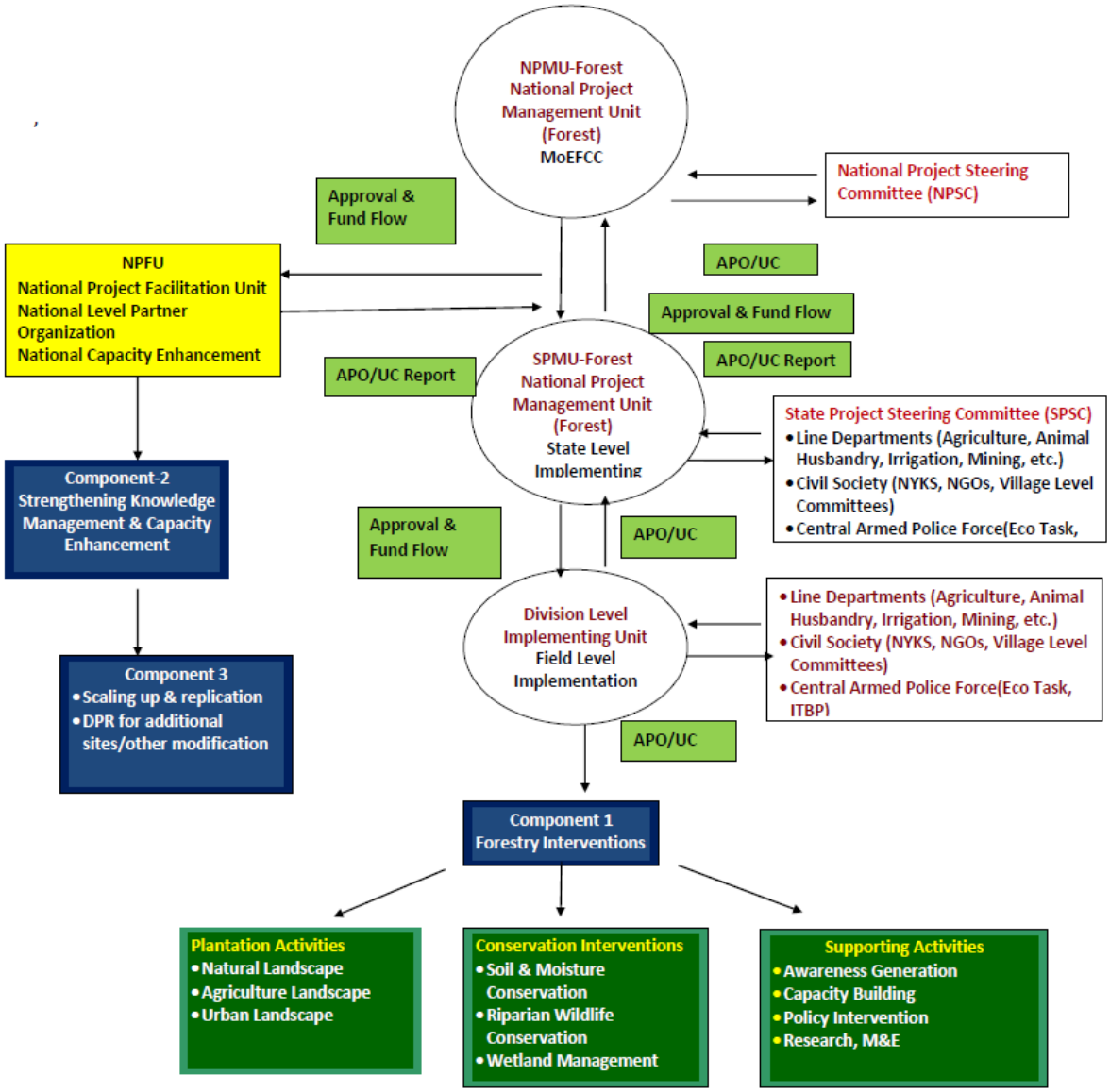


Fig. 6.3. Flow chart of implementation process of DPR on forestry interventions

c) Implementation Mechanism at State Level

The SFDs in seven states are primary Implementing Agencies (IAs) for forestry interventions. Within a state, the work will be carried out in several divisions. For this, each SFD as IA will require the support of a PMU at the state level. All the states already have well-established system for implementation of externally-aided projects. The same system will be involved in executing the DPR. Each of the seven states-level Implementing Agencies will designate its State Project Management Unit - Forest (SPMU-Forest) for planning and assisting in execution at the state level. SPMU will do the job of project facilitation, management and monitoring. Thus, the SPMU in each of the seven states will be headed by the existing officers of Addl. PCCF/CCF level officer who would be designated as the Project Coordinator of the project. A River Rejuvenation Cell may be

identified for managing the implementation of the DPRs on river rejuvenation. The SPMU of Yamuna will also have representatives of line departments, civil society, NGOs, Eco-Task Force, etc.

The states are expected to cover large extents of natural, agricultural and urban and carry out diverse activities ranging from raising plantations, soil and moisture conservation works, riverfront development, eco-parks, riparian wetland management and bio-remediation besides implementation of various allied/supporting activities viz., community mobilization, capacity building, awareness, research, monitoring, development of value chain, etc.. Additional experts or technical staff having expertise in Forest Hydrology/River Ecology and Conservation/Soil and Moisture Conservation/ Ecosystem-Services/Riverfront Development/Value Chain Development, etc. may be engaged, if required. Adequate provisions for capacity building, planning and conduct of state-level coordination meetings and seminars, exposure visits, etc. have been included.

Flow of fund from SPMU to the lower level will be through DPMG.

d) Implementation Mechanism at District Level

A District Project Management Unit - Forest (DPMU-Forest) in each stakeholder district will be responsible for overseeing and coordinating the implementation of the DPR on forestry interventions in respective districts. The DFOs will carry out the field work in accordance with existing mechanism in the Division. The mechanism of existing FDAs operating at District/Division level could be utilized for implementation in the field while executing at the local level. Agriculture, Horticulture, Revenue Department, etc. would provide necessary assistance to the DFO whenever specific requested is to them. Additional project staff can be engaged and co-terminus with the project for implementing project activities.

The District level Implementing Committee (DIC), to be specially constituted for the implementation of this DPR on forestry interventions for Yamuna, will have Conservator of Forests as Chairman, the concerned DFOs as Member Secretary and district level representatives of line departments as well as civil society as members. The DFO as Member Secretary, who are also the Chief Executive Officers of the FDA wherever functional, shall submit an Annual Plan of Operations (APO) under forestry interventions to the DPMU (Yamuna Cell) in consultation with the representatives of line departments, NGOs, Eco-Task Force, and other civil societies who shall be invited every time for the consultation process by the DFOs. The civil society functional at Division/District level will also be involved for implementing forestry interventions at the field level. The DPMU (Yamuna Cell) shall scrutinize the APOs and get the same approved by District Project Steering Committee (DPSC), with necessary amendments, if required, for further submission to the State Project Steering Committee (SPSC) which will scrutinise it and submit to National Project Steering Committee (NPSC) at MoEF&CC, GoI. Upon approval of the APO by the NPSC, the funds shall be transferred against the APO to an account maintained separately by the respective State Forest Development Agencies (SFDAs). Separate accounts shall be opened by DFOs exclusively to operate the forestry interventions at divisional level. The SPSC (Yamuna Cell) shall authorize SFDA to further transfer funds against approved APOs to account opened by divisions specifically for the purpose. Financial expenses, creation and management of assets, incurring overhead expenditures, etc. shall be as per provisions of General Financial Rules (GFRs and/or any rules/guidelines framed by the central government and state governments in this regard from time to time. The implementing department and/or line departments as well as civil society shall be responsible for achieving the objective targets and maintaining complete accountability and transparency. It has been proposed that Eco Task Force will undertake afforestation and ecorestoration works in Uttarakhand, Himachal Pradesh, Uttar Pradesh (600 ha per state), Rajasthan and Madhya Pradesh (800 ha per state). The SFDs of the concerned states will allot to Eco Task Force and ensure their active involvement for carrying out plantations in difficult sites besides involving them in soil & moisture conservation works and other activities. The SPMGs of concerned states will allocate funds to these agencies for actual implementation in areas under their command. Youth Clubs/Eco Clubs and *Mahila Mandals*

and other leading CSOs will also be actively involved in plantation works and awareness campaigns; the detailed mechanism will be worked by the individual states as per the prevailing conditions and duly brought on record. Appropriate budget on awareness has been provisioned in the IP for each of the state and will be utilized through these state-level and local-level formations.

e) Participation of Other Partners at Field Level

Once the work is allotted to a Forest Division as per the Annual Plan of Operations (APOs), the work shall be executed with active involvement of JFMC and/ or other civil society organisations of the area. In case the works are executed by the JFMC and/ or other civil society organizations, the cash book and the account so maintained by them, in turn, shall be submitted to the concerned DFO who will ensure that the work have been done in accordance with the physical and financial parameters prescribed. The total accounts including the bank transactions for the works carried out under the project shall be maintained separately. The Measurement Books (MBs) for such activities done through JFMCs or community-based organisations of the SFDs shall be maintained by the concerned official of the SFDs while the JFMCs shall submit Utilization Certificate (UC) duly verified by RFOs and Completion Certificates (CC) to the concerned Division (DFO) office. For the works to be executed by other line departments, Eco-Task Force, NGOs and other community-based organizations, the DFOs shall intimate the approved APO to concerned official of the respective departments and also release corresponding funds to them. The responsibility of execution shall completely rest with the line departments and other agencies and they shall maintain Measurement Books at their own levels and submit accounts 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. DFOs who are Member Secretary of District level Implementing Committee (DIC) specifically designed for implementation of this project shall issue cheques or make electronic fund transfer to the executing agencies to facilitate timely execution of works. SFDs will maintain records for individual sites 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 SFDs. The UCs and CCs compiled at state level at the SPMU-Yamuna Cell shall be submitted to NPMU in MoEF&CC for monitoring.

6.3. Implementation and Fund Flow Mechanism

The project envisages setting of four Programme Steering Committees (PSCs), (a) at the national level in the Nodal Ministry (MoEF&CC), i.e., National Programme Steering Committee (NPSC) that will work with NPMU, (b) River Programme Steering Committee that will work with Yamuna Cell, (c) at the state level in each of the seven states, i.e., State Programme Steering Committee (SPSC) that will work with respective SPMU and (d) at the district level, i.e., District Programme Steering Committee (DPSC) that will work with respective DPMU.

6.3.1. National Programme Steering Committee (NPSC)

The national level NPSC will be chaired by the Secretary, MoEF&CC and the Member Secretary would be the Project Director. The NPSC will have multiple members represented by senior officials of the MoEF&CC and other ministries. The NPSC shall meet at least once in a year at appropriate time for approving the Annual Plan of Operations (APOs) submitted by the SPMGs of the stakeholder states (Yamuna Basin) and National level organization(s) under the NPMU. The funds against the approved APOs of the states shall be transferred by the NPSC to the respective SPMGs.

6.3.2. State Programme Steering Committee (SPSC)

The state level SPSC will be chaired by the PCCF (HoFF) of the state and the Member Secretary would be the Project Coordinator of the state. The existing framework at state level like State Forest Development Agency (SFDA) or similar/equivalent agency will be responsible for transferring and parking of funds at state level to be released on the recommendation of the State Project Steering Committee (SPSC).

At the circle/district level a Circle Project Implementation Committee (CPIC) will be constituted under the chairpersonship of Conservator with concerned DFO as member secretary. With this arrangement, the works to be undertaken under forestry interventions in Yamuna could be implemented in close association and involvement of village/JFMC level set-up. SPMU (Yamuna Cell) shall be formed in each of the implementing states.

The SPMC of Yamuna Cell shall comprise of PCCF or an Addl. PCCF rank Officer nominated by PCCF (HoFF) as the Project Director with equivalent representatives of line departments, civil society, NGOs, Eco-Task Force, etc. The SPSC shall meet at least twice a year at appropriate times for approving the APOs and discussing other issues related to implementation of forestry interventions in River Yamuna.

The SPSC shall meet at least once in a year at appropriate time for approving the Annual Plan of Operations (APOs) submitted by the DPMGs of the stakeholder districts (Yamuna Basin). The funds against the approved APOs of the states shall be transferred by the SPSC to the respective DPMGs.

6.3.3. District Programme Steering Committee (DPSC)

The district level DPSC will be chaired by the District Collector/District Magistrate of the district and the Member Secretary would be the DFO of the state. The Conservator of Forest related with the district will be an expert member of the DPSC. In case there are more than one Forest Divisions within a district, one Member Secretary will be designated by the chairperson. The existing framework at district level like State Forest Development Agency (SFDA) or similar/equivalent agency will be responsible for transferring and parking of funds at state level to be released on the recommendation of the District Project Steering Committee (SPSC).

The DPSC shall meet at least twice a year at appropriate time for approving the Annual Plan of Operations (APOs) and discussing other issues related to implementation of forestry interventions in Yamuna. The funds against the approved APOs of the Forest Divisions shall be transferred by the DPSC to the respective Forest Divisions.

6.4. SUSTAINABILITY, REPLICABILITY AND COST EFFECTIVENESS

Sustainability

The DPR addresses two major thematic areas viz. water and forest. Water and forests are related symbiotically. Nevertheless, water is required for sustenance of the forest. Improved water availability and quality would revitalise the entire ecosystem and have positive impact on the forest. Water and forest have several ecological, socio-economic, ecological, environmental and biodiversity-related benefits. The project seeks to promote livelihood support, empower local communities besides fostering agricultural sustainability. All these benefits are expected to sustain the overall prosperity in the region.

Replicability

FRI had prepared and submitted a DPR on Ganga to Ministry of Water Resources, River Development and Ganga Rejuvenation (present-day Ministry of Jalshakti) during 2016. This DPR is a sequel to the DPR on Ganga. Other rivers are likely to be treated though DPRs on forestry interventions in the future. The DPR on Yamuna would serve as a treatment plan that may have the potential to be replicated for the goal of rejuvenation of other rivers of India.

Cost effectiveness

Forestry interventions are the most cost effective means of river rejuvenation. Forestry activities are relatively cheaper and eco-friendly than other approaches to river rejuvenation. These provide largescale employment to unskilled people, generate diverse goods and services for local communities. The various models have been proposed based on site-specific requirement and experience coupled with scientific methodology. Schedule of rates of the states have largely been followed for preparation of cost estimates. A modest 5% per annum compound rate of cost escalation

has been used for preparation of budget. The schedule of rates applicable at the time and place would be used by the SFDs during DPR implementation process. The DPR, thus, prescribes a cost-effective approach for rejuvenation of Yamuna.

6.5. ADAPTABILITY

Programme sustainability planning should allow reasonable flexibility in responding to changing stakeholder needs, national, regional or local priorities and learnings from concurrent efforts. For practical reasons, a treatment or implementation plan should not be too rigid to disallow such amendments. A good approach would be one that would permit flexibility to allow incorporating local knowledge and experience that have already accumulated or that may develop concurrently during implementation of the DPR. Hence, site-specific modifications in a model are permitted provided they capture the essence of the model. The estimates suggested for various treatment models are for guidance and are not intended to serve as factual cost of work for a treatment site because the cost at a site estimate depends on several variables. Further, the rates vary with administrative location and may be revised by the SFD over time. Hence, rates applicable at a particular time and place would be applicable and reflected in the APO. Further it is likely that some of the sites proposed in the DPR might be already taken up under some other scheme, or might be unavailable due to some other valid reasons. Such sites may not be taken up for treatment. APO would determine the location, quantum of work and budget. Species that support livelihood would be given priority in this connection NTFP species deserve special consideration, other things being equal. Cluster approach is suggested for production of NTFPs with a view to generating produce at a marketable scale. Exotics would not be used. Value-chain of the species should be developed by the SFD though suitable means. The existing mechanism of similar schemes or activities may be adopted as it would allow easier implementation at the ground level. Convergence with other schemes and existing system and mechanism would be welcome and encouraged. In plantation models on agricultural landscape, the choice of farmers would be given high priority. Farmers would be allowed to exercise choice in choosing agroforestry species and planting geometry of their choice.

6.6. FUNDING PARTNERS/SOURCES

The DPR will require huge budgetary provision as detailed in Chapter 7. Funding from various national, state and local funding agencies would be required to meet the requirement. Funds may also be explored from overseas agencies. Table 6.1 provides a list of such funding agencies pertaining to different activities in the target landscapes and thematic areas.

6.7. CONVERGENCE

Since the Yamuna DPR covers diverse activities over a very large area spread out in seven states of India, it is envisaged to dovetail it with similar ongoing activities being carried out, similar activities that may be proposed by in the future by various departments (Central/State/NGOs) (an brief overview of present and past schemes is provided in Chapter 3 (para 3.3.1. Past schemes). An appropriate MoU may be signed between the concerned departments for carrying out the various activities while avoiding duplication.

6.8. SUPPORTING ACTIVITIES

The following supporting activities have been proposed under the DPR:

1. Awareness generation
2. Capacity building and value-chain development
3. Entry point activities
4. Nursery improvement and fire protection

Table. 6.1. Probable funding agencies

Landscape	Thematic Area	Possible Funding Agencies
Natural	Plantations on forest land	Various schemes of stakeholder SFDs, Forest Corporations, CAMPA, NABARD, UNDP, World Bank, ADB, Corporate Social Responsibility (CSR)
	Plantations in riparian areas	CAMPA, NMCG/Ministry of Jal Shakti, Ministry of Agriculture, Ministry of Mines, CSR
	Medicinal plants	Ministry of AYUSH, NMPB, State Medicinal Plant Boards, industries, CSR
	Activities in Protected Areas	WWF, MoEF&CC, CAMPA, CSR
Agriculture	Plantations on farmers field	Ministry of Agriculture, CAMPA, state agriculture departments, NABARD, CSR
	Plantations on community lands	CAMPA, Ministry of Rural Development, MNERGA, CSR
Urban	Riverfront development/ Eco-park development	Ministry of Urban Affairs SPMG, municipal corporations, CSR
	Institutional/ Industrial plantations/ Bio-remediation	Ministry of Industry, industries, universities, CAMPA, CSR
	Avenue plantations	Ministry of Surface Transport, horticulture departments, irrigation departments, CAMPA, CSR
Conservation Interventions	Soil and water conservation	Ministry of Rural Development, MNERGA, state soil conservation departments, irrigation departments, watershed development projects, voluntary individuals, civil society organisations, fisheries departments, CAMPA, CSR
	Wetland management	MoEF&FCC, UNDP, CAMPA, CSR
	Riparian wildlife management	WWF, MoEF&CC, CSR
	Aquifer recharging	SFDs, CGWB, CSR
Supporting Activities	Awareness	Ministry of Youth Affairs, civil society organisations, NYKS, CSR
	Research activities	CAMPA, NMCG, MoEF&CC, WWF, ICAR, CSR
	Monitoring and Evaluation	CAMPA/MoEF&CC

5. Field activities, contingency and miscellaneous costs
6. Research
7. Monitoring and evaluation

Details of these activities have been given in Chapter 5 (section 5.8. Supporting activities). Monitoring and evaluation is elaborated in the following section.

Monitoring and Evaluation

Monitoring will have two dimensions: (i) monitoring of project activities and (ii) monitoring for ecological and socio-economic indicators.

List of treatment sites of the seven states in Yamuna basin is provided in Volume II of this DPR. Some of the sites in the said list might be treated by SFDs under other schemes before the initiation of this DPR. At the same time, some other sites that were not available earlier at time of data collection for this DPR, might become available at time of initiation of the DPR. Hence APO will serve as the standard document for GPS location and extent of treatment site for DPR Yamuna. To allow proper monitoring, each plantation site will have a sign board containing details of planting site. For agricultural landscape, one sign board per village will be used.

Monitoring may be IT-enabled or on-ground monitoring. The IT-enabled monitoring may be remote sensing & GIS-based or on-line web-portal or App-based monitoring. On-ground monitoring may comprise participatory monitoring at the forest division level or third-party monitoring by external agency.

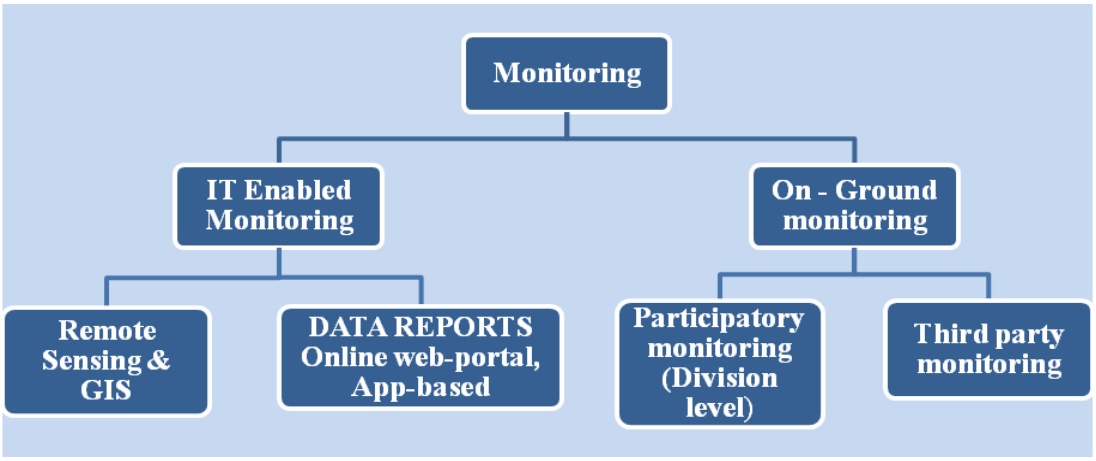


Fig. 6.4. Method of monitoring of DPR

The SFDs of the concerned states will carry out in-house monitoring of works. Annual monitoring will be done by SFD in the following way: 45-50 % monitoring of works by ACF, 25 % by DFO and 10-12 % by the concerned CF/CCF. For agricultural landscape, monitoring of 100 % villages and 50-80% plants is envisaged by Range Officer/ACF/Assistant Director of Agriculture/Assistant Director of Agriculture/representatives of NGOs and social society.

Third-party monitoring will be carried out by NPMU as per procedure laid down under CAMPA. Participatory monitoring by communities and Civil Society Organizations (CSOs) will be encouraged. Twenty five per cent (25%) or a suitable number to be defined by NPMU, of the actual works carried out will be compulsorily monitored by third party. National Project Management Unit will determine the detailed mechanism for third party monitoring in consultation with SPSCs of different states.

The logical framework provides information about vital aspects of project monitoring. The logical framework also provides verifiable indicators and means of verifications. Project outcomes (biological, socio-economic and institutional) will be measured to assess the impact of project interventions against the baseline developed during the Year-1 of the project implementation. The baseline will be generated by the concerned SFDs in respect of monitorable indicators.

The national-level partner organization in collaboration with SFDs would involve concerned experts and organizations to develop an integrated, long-term ecological and socio-economic monitoring programme during the first year and baseline information generated for evaluation of the project impact in future. The long-term ecological and socio-economic monitoring programme will

be appropriately executed periodically depending upon the intensity of monitoring decided for each of the variables/species. Additional studies and evaluations would be supported at each of the landscape category type, river and its tributaries to supplement the participatory impact monitoring programme. Local universities, expert scientific organizations and CSOs will also be involved in specialized monitoring planned for the project.

The mid-term review will specifically focus on assessing progress in achieving project outcomes/outputs and deliverables besides effectiveness of institutional arrangements, involvement of CSOs in project implementation, management and monitoring effectiveness and national capacity building. The set of measurable indicators, elucidated below, will be monitored on a time line to be decided by the concerned agencies:

Indicators for Monitoring and Evaluation

a) Ecological indicators

1. Area covered under forestry interventions.
2. Survival and growth parameters of plants such as height and collar diameter.
3. Biomass production.
4. Quantitative measure of water in river and other water bodies during non-monsoon period.
5. Silt load/soil erosion in treated river basin area.
6. Depth of water table.

b) Socio-economic indicators

1. Employment generation during plantation and maintenance works.
2. Number of awareness generation camps organized and participants.
3. No. of training camps and persons of local communities trained.
4. No. of training camps and personnel of SFDs and other stakeholder departments trained.
5. No. of self-help groups formed and members connected in value chain.
6. No. of clusters formed and buyer units/industries connected in value chain.
7. Change in availability of forest resources to local population.
8. Period of water availability for agriculture and other activities during non-monsoon season.
9. Per capita change in income of the stakeholder population.

6.9. RISK ASSESSMENT IN FORESTRY INTERVENTIONS

Forestry interventions are influenced by several biotic and abiotic factors. While some of these factors can be managed to an extent, others are beyond the scope of human interventions. Therefore, a certain degree of risk is involved in the implementation of forestry interventions in rejuvenating the Yamuna and its tributaries. These risks can be broadly classified into biotic and abiotic factors as listed in Table 6.2.

Table 6.2. Risk factors and measures for managing them

S. no.	Risk factor	Risk management measures
1.	**Biotic factor**	
1.1	Grazing of plantations by domestic livestock and wild herbivores	Proper fencing of plantation area, watch and ward and social fencing.
1.2	Pest and disease attack	Little scope of management as use of chemical pesticides is discouraged due to toxic effect on water sources. IAs to encourage use of plant-based bio-control methods.
2.	**Abiotic factor**	
2.1	Climatic factors – Rains	Timing of planting activities in harmony with rainfall is important for survival. Heavy rainfall after planting, especially in the floodplains can cause damage and death of seedlings. Success of plantation depends on timely and optimum rainfall.
2.2	Climatic factors – Temperature	High temperature may lead to drying up of seedlings and root stock. Irrigation can be done in very few select areas especially in the riverfront development component, eco-parks and agroforestry models. Low winter temperatures in the Yamuna Plains and in catchment areas of Uttarakhand are likely to cause mortality among plantations due to frost injury and desiccation. Little scope for reducing the risk factor.
2.3	Edaphic factors	Problem areas like floodplains, marshes and rocky upper reaches are likely to affect the survival of plants. Species selection and use of quality nursery material is important to reduce the risk factor.

Any one or a combination of risk factors may affect the survival and growth of plants. Therefore, the SFDs shall consider the following measures to minimize above risks:

- Planting site and species should be carefully chosen; adaptability of plantation species should be matched with site conditions especially in sites that have given poor survival and growth in repeated efforts in the past.
- Nursery should be raised timely. Delays and damages to plants during transit and handling must be avoided.
- Quality planting stock should be planted in plantations.
- Advance site preparation works and plantation activities should be planned and implemented well supplemented by use of bio-fertilizers, organic manures and compost, mulching, etc.
- Adequate fencing and protection from cattle and wild herbivores should be provided to check the risk of damage from grazing and browsing. Watch and ward must be provided on all days of the year from morning to late evening, depending upon local grazing practices. The local communities need to be sensitised and mobilised to reduce the biotic risks.

Efforts should be made to minimize the risks involved and the rest is left to the nature. Other broader risk factors associated with the project are enumerated in Chapter 5 (para 5.4 ‘Problems in achieving objectives’ and in SWOT analysis in Chapter 2 (para 2.12. SWOT Analysis of Yamuna River Ecosystem and its Environment).

Chapter 7
PROJECT BUDGET AND SCHEDULE

Budget estimate for implementation of forestry intervention for rejuvenation of Yamuna River (including tributaries) in the seven states is presented in this chapter.

The total projected outlay for the implementation phase of project on Forestry Interventions for Yamuna River is Rs. 3,868.89 crore. The project cost by component and/or activity is presented in Table 7.1.

The Component A on Implementation of Forestry Interventions in Riverscape Area of Seven States is Rs. 3,620.05 crore which accounts for 93.57% of the total project budget outlay. Component B on Strengthening Knowledge Management and National Capacity for Forestry Interventions and Conservation of Riverscapes has been allocated Rs. 197.74 crore which accounts for 5.11% of the overall project outlay. The project also envisages Preparation of Follow-up DPR for scaling up, monitoring and replication of successful models of forestry interventions and riverscape conservation in additional sites provided by the state forest departments, for which a sum of Rs. 2 crore (0.05% of the Project budget outlay) has been provisioned as Component C**.** In order to oversee, steer and manage this important project by the Central Nodal Ministry (MoEF&CC), an amount of Rs. 49.10 has been allocated as Component D which is 1.27% of the projected budget outlay. Thus, it is evident that about 94 % of the budget outlay is meant for field activities on Plantations, Treatment Models, Conservation Interventions and Supporting activities to be implemented by the seven Implementing Agencies (IAs).

The duration of the project is ten years which comprises the five-year Phase-I (Year 1 to 5) for implementing the major project activities some of which may be continued and completed in the five-year Phase-II (Year 6 to 10).

7.1. PROJECT OUTLAY – COMPONENT AND ACTIVITY-WISE

The state-wise details on budget outlay on various components are presented in Tables 7.2 onwards.

Sub-component A.1 on Plantations and Treatment Models in various landscapes

This sub-component pertains to plantations and treatment models in three types of landscapes (Natural, Agriculture and Urban/Peri-urban) in the Yamuna riverscape which have been described in detail in Chapter 5. An amount of Rs 1,730.34 crore has been provisioned for plantation in Natural landscape while Rs. 220.90 crore has been provided for agriculture and Rs. 92.39 crore for Urban and Peri-Urban landscape. The activities proposed for Agriculture landscape focus on plantation of fruit trees and forestry trees on farmlands and silvipasture on community land while activities in urban landscape include development of Eco-parks, Riverfront development, raising of avenue plantations, etc. at a cost of Rs. 1,297.29 crore.

Indexing of budget

The budget for the project has been prepared on the basis of rates applicable during April 2020. The cost of the project may be adjusted for the actual date of start of implementation of the project based on Wholesale Price Index (WPI).

Table 7.1. Component/Activity-wise Budget Allocation

S. no.	Component and/or Activity	Amount (Rs. in crore)	Allocation (%)
A.	**Implementation of Forestry Interventions in Seven States of Riverscape**	**3,620.05**	93.57
A.1	**Plantation and Treatment Models in Three types of Landscape**	**2,043.63**	
A.1.1	Natural Landscapes	1,730.34	
A.1.2	Agriculture Landscapes	220.90	
A.1.3	Urban Landscapes	92.39	
A.2	**Conservation Interventions**	**1,297.29**	
A.3	**Supporting Activities**	**279.13**	
A.3.1	Awareness generation	26.93	
A.3.2	Capacity building and value-chain development	31.14	
A.3.3	Entry point activities	15.11	
A.3.4	Nursery improvement and fire protection	36.83	
A.3.5	Research	21.91	
A.3.6	Monitoring and Evaluation	66.80	
A.3.7	Field activities, Contingency and Miscellaneous Activities	38.56	
A.3.8	Cost of PMUs of Seven State Level Implementing Agencies	41.85	
B.	**Strengthening Knowledge Management and National Capacity for Forestry Interventions and Conservation of Riverscapes**	**197.74**	5.11
C.	**Preparation of Follow-up DPR - Scaling Up and Replication of Successful Models of Forestry Interventions and Riverscape Conservation in Additional Sites**	**2.00**	0.05
D.	**National Coordination for Forestry Interventions and Riverscape Conservation**	**49.10**	1.27
Total Project Cost (A+B+C+D)		**3,868.89**	100.00

Table 7.2. Proposed budget allocation for various plantation and treatment models under different landscapes (Area in ha, cost in Rs. crore)

Landscape	State	No. of sites	Area	Phase I Cost	Phase II cost (Maint.)	Grand Total cost
Natural	Uttarakhand	117	1,116.00	27.27	27.27	27.27
	Himachal Pradesh	149	3,216.40	65.88	65.88	65.88
	Haryana	28	261.00	4.32	4.32	4.32
	Delhi	0	0.00	0.00	0.00	0.00
	Uttar Pradesh	294	15,883.92	201.12	201.12	201.12
	Rajasthan	730	59,462.07	1237.52	1237.52	1237.52
	Madhya Pradesh	281	23,407.87	194.23	194.23	194.23
	Total	**1,599**	**1,03,347.27**	**1730.36**	**1730.36**	**1730.36**
Agriculture	Uttarakhand	49	289.77	3.43	3.43	3.43
	Himachal Pradesh	2	78.00	0.57	0.57	0.57
	Haryana	41	974.46	11.24	11.24	11.24
	Delhi	0	0.00	0.00	0.00	0.00
	Uttar Pradesh	146	2,175.55	35.79	35.79	35.79
	Rajasthan	90	513.30	5.44	5.44	5.44
	Madhya Pradesh	2	15,000.00	164.43	164.43	164.43
	Total	**330**	**19,031.08**	**220.90**	**220.90**	**220.90**
Urban	Uttarakhand	17	33.00	9.73	9.73	9.73
	Himachal Pradesh	6	14.39	2.30	2.30	2.30
	Haryana	31	197.00	3.35	3.35	3.35
	Delhi	0	0.00	0.00	0.00	0.00
	Uttar Pradesh	88	1,156.38	72.22	72.22	72.22
	Rajasthan	3	8.00	2.67	2.67	2.67
	Madhya Pradesh	2	125.00	2.12	2.12	2.12
	Total	**147**	**1,533.77**	**92.38**	**92.38**	**92.38**
Grand Total		**2,076**	**1,23,912.12**	**1,788.11**	**254.73**	**2,043.64**

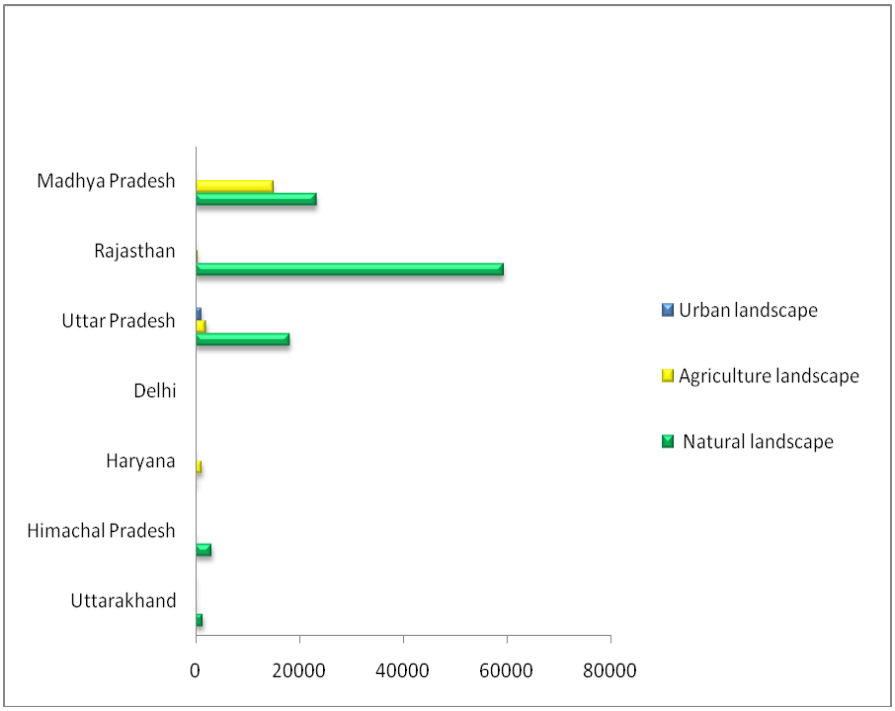


Fig. 7.1. Extent of Area (ha) of Proposed Plantations in Three Landscapes within the Yamuna Riverscape

Sub-Component A.2 on Conservation Interventions

Conservation interventions will be through soil and moisture conservation measures, riparian wildlife management, biodiversity conservation, etc. A sum of Rs. 1,297.29 crore has been allocated for these interventions on 2585 sites (Table 7.3). The highest number of sites in a state is 865 in Rajasthan. Sites for plantation and conservation models have not been proposed in Delhi due non-availability of sufficient suitable land in the riverscape, however, soil and moisture conservation measures are proposed to be rehabilitated/strengthened in the catchment of Yamuna River outside the riverscape in Delhi state on approximately 4500 ha area as conservation intervention.

The area mentioned under conservation interventions is notional area as quantities of work proposed by various states are in different units viz. volume (m^3), area (ha) and money (Rs.).

Table 7.3. Proposed budget allocation under conservation interventions for different states (Area in ha, cost in Rs. crore)

State	No. of sites	Area	Phase I Cost	Phase II cost (Maint.)	Grand Total cost
Uttarakhand	650	3,780.45	63.71	10.19	73.90
Himachal Pradesh	394	1,558.59	25.40	3.61	29.01
Haryana	83	3,458.49	41.18	2.97	44.16
Delhi	0	0.00	7.29	1.75	9.04
Uttar Pradesh	350	17,933.71	95.57	10.66	106.23
Rajasthan	865	3,62,822.99	723.84	129.67	853.51
Madhya Pradesh	243	9,515.73	167.44	14.00	181.44
Total	**2585**	**3,99,069.96**	**1,124.43**	**172.86**	**1,297.29**

As regards the total number of sites in the plantation and treatment models and conservation interventions, information about number of treatment sites, their area and their total cost are given in Table 7.4. The greatest number of sites (1,688) and area (4,22,806.36 ha) for various interventions will be in the state of Rajasthan while 183 sites have been identified for Haryana for treatment in various landscapes, including conservation interventions.

Table 7.4. Proposed budget allocation for various plantation, treatment models and conservation interventions under different landscapes (Area in ha, cost in Rs. crore)

States	No. of sites	Area	Cost
Uttarakhand	833	5,219.23	114.33
Himachal Pradesh	551	4,867.38	97.76
Haryana	183	4,890.95	63.07
Delhi	0	0.00	9.04
Uttar Pradesh	878	37,149.56	415.36
Rajasthan	1,688	4,22,806.36	2,099.13
Madhya Pradesh	528	48,048.60	542.23
Grand Total	**4,661**	**5,22,982.08**	**3,340.93**

Table 7.5. State-wise Cost Summary for various activities and PMU under sub-Component (A.3) on supporting activities (Rs. in crore)

States	Awareness generation	Capacity building and value-chain development	Entry point activities	Nursery improvement and fire protection	Research	Monitoring and evaluation	Field activities, contingency and miscellaneous activities	State PMUs	Total
Uttarakhand	0.81	0.87	0.50	1.08	0.78	2.28	1.87	1.19	9.38
Himachal Pradesh	0.72	0.74	0.40	0.73	0.45	1.96	1.45	1.00	7.45
Haryana	0.46	0.47	0.21	0.22	0.33	1.26	0.56	0.70	4.21
Delhi	0.14	0.11	0.00	0.00	0.60	0.18	0.43	0.23	1.69
Uttar Pradesh	3.20	3.75	1.50	5.40	3.35	8.30	5.00	5.92	36.42
Rajasthan	17.50	20.50	7.50	24.00	11.40	41.98	22.00	24.24	169.12
Madhya Pradesh	4.10	4.70	5.00	5.40	5.00	10.84	7.25	8.57	50.86
Total	**26.93**	**31.14**	**15.11**	**36.83**	**21.91**	**66.80**	**38.56**	**41.85**	**279.13**

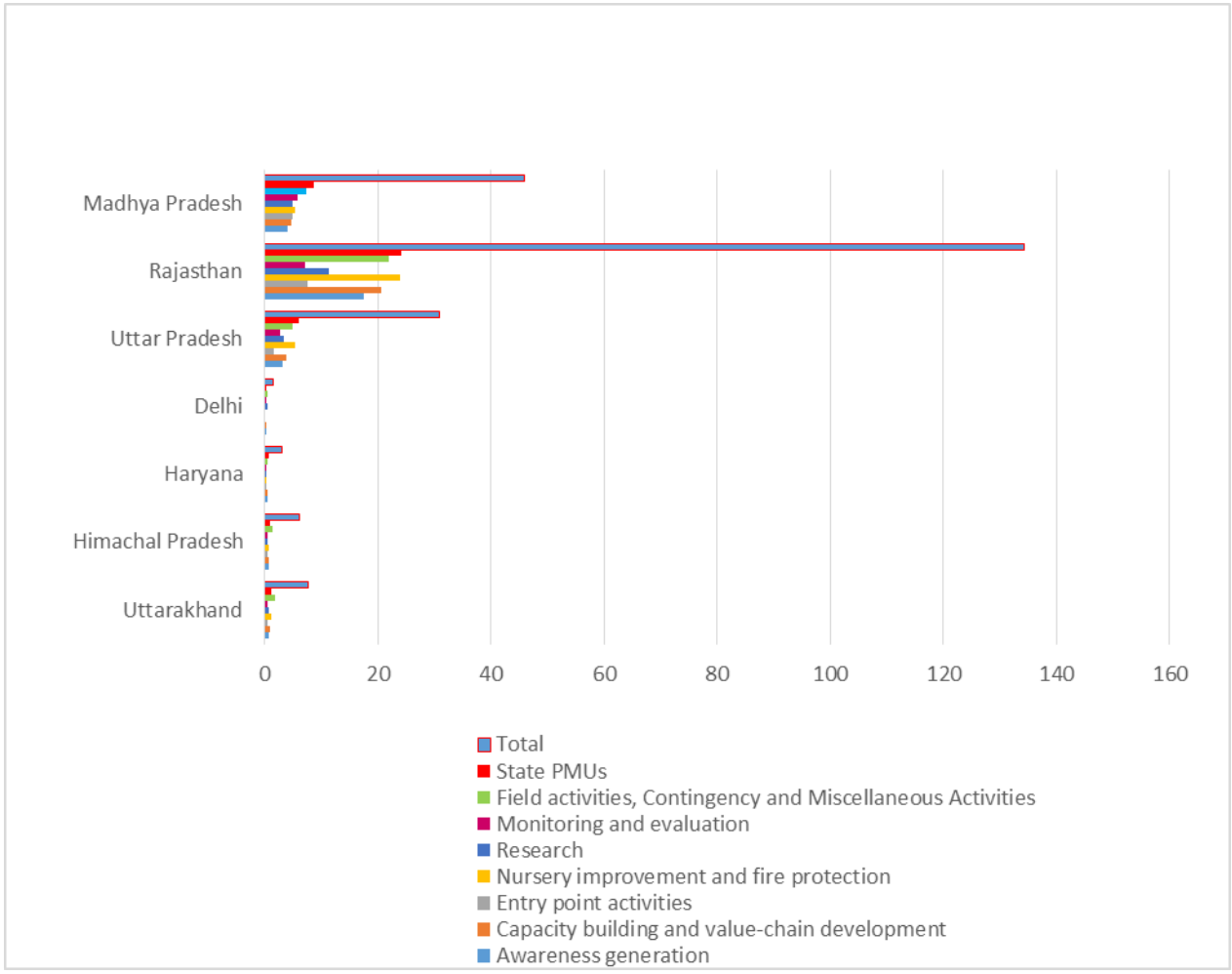


Fig. 7.2. Cost summary for various activities and PMU on supporting activities (Rs. in crore)

Sub-Component A.3 on Supporting Activities

The third Sub-component on proposed forestry interventions to be implemented by the seven IAs pertains to supporting activities which include awareness generation, capacity building and value-chain development, entry point activities, nursery improvement and fire protection, research, monitoring and evaluation, cost of PMUs in the seven states (Table 7.5). The overall budgetary provision for various supporting activities for the project period would be Rs. 279.13 crore which is 7.21% of the project cost (Table 7.1).

The seven state level IAs (SFDs) in Uttarakhand, Himachal Pradesh, Haryana, Delhi, Uttar Pradesh, Rajasthan and Madhya Pradesh will implement the programme and activities of the Project at the state and field levels. Budget outlay for each of the seven states is presented in Table 7.6. Perusal of the data in the said Table reveals that the highest amount of Rs. 2,268.26 crore or 65.87% of the total budget (Rs. 3,868.89 crore) allocated for seven states, is provisioned for Rajasthan state for extensive treatment of proposed areas in the identified watershed of Yamuna in the state. The financial allocation for Uttarakhand, Himachal Pradesh, Haryana, Delhi, Uttar Pradesh and Madhya Pradesh are Rs. 123.71 crore, Rs. 105.21 crore, Rs. 67.28 crore, Rs. 10.73 crore, Rs. 451.78 crore and Rs. 593.08 crore, respectively.

Table 7.6. Budget Allocation to Seven State's Implementing Agencies (Cost Rs. in Crore)

State	Landscape			Conservation Interventions	Supporting activities	Total
	Natural	Agriculture	Urban			
Uttarakhand	27.27	3.43	9.73	73.90	9.38	123.71
Himachal Pradesh	65.88	0.57	2.30	29.01	7.45	105.21
Haryana	4.32	11.24	3.35	44.16	4.21	67.28
Delhi	0.00	0.00	0.00	9.04	1.69	10.73
Uttar Pradesh	201.12	35.79	72.22	106.23	36.42	451.78
Rajasthan	1,237.52	5.44	2.67	1,187.06	169.12	2,268.26
Madhya Pradesh	194.23	164.43	2.12	181.44	50.86	593.08
Grand Total	**1,730.34**	**220.90**	**92.39**	**1,297.29**	**279.13**	**3,620.05**

*Implementation, ~~research and monitoring costs,~~ cost of awareness generation, research activities, capacity building, development of value chain, nursery establishment/improvement, fire protection, monitoring and evaluation, Field activities, contingency and miscellaneous activities

Component B. Strengthening Knowledge Management and National Capacity for Forestry Interventions and Conservation of Riverscapes

As indicated in Table 7.1. budget outlay of Rs. 197.74 crore (5.11% allocation of the overall project budget outlay) has been made for National level partner organization towards implementation of various priority activities for strengthening knowledge management and national capacity for forestry interventions and conservation of riverscape. Activity-wise budget allocation for the national level partner organization has been detailed in Table 7.7.

It is evident that the highest amount of budget allocation (Rs. 54.55 crore) has been made for concurrent research and development on priority thrust areas for strengthening knowledge management and capacity enhancement for forest river subtleties and riverscape conservation. Budget for other important activities *viz.* policy level interventions, capacity enhancement and awareness generation has also been provisioned which is 4.35 crore, 8.15 crore and 8.72 crore, respectively.

Table 7.7. Broad Activities and Costs for Implementation of National Level Capacity Enhancement and Strengthening Knowledge Management by the National Level Partner Organization

S. no.	Particulars	1st Year	2nd Year	3rd Year	4th Year	5th Year	Cost (Rs. in Crore)
A.	**Recurring Cost**						
A.1	Cost of PMU - Salary and Wages, Equipment Office Expenses and Management, Travel, Vehicle and POL, Audits, etc	4.5	4.0	3.5	2.2	2.17	16.37
A.2	Inputs for Policy Level Interventions	1.0	1.0	0.68	0.67	1.00	4.35
A.3	Concurrent Research and Development	8.0	14.0	14.0	10.0	8.55	54.55
A.4	National Capacity Enhancement and Knowledge Management	4.0	1.50	1.00	0.85	0.80	8.15
A.5	Scientific Exchange, Exposure Visits, and Engagement of International and National Consultants	8.0	6.0	5.0	5.0	8.72	32.72
A.6	Inputs for National Level Awareness	3.0	2.0	2.0	1.0	0.72	8.72
A.7	Monitoring - Project, and Ecological and Socio-economic	2.0	5.0	6.0	8.0	6.40	27.40
A.8	Project Evaluation	0.50	0.60	0.75	1.00	1.18	4.03
Sub Total Recurring Cost (A)		**31.0**	**34.1**	**32.93**	**28.72**	**29.54**	**156.29**
B.	**Non-Recurring Cost**						
B.1	Incorporation of Advanced Technology	1.50	0.60	0.57	0.57	0.57	3.81
B.2	Permanent Equipment	1.50	1.0	0.80	0.69	0.69	4.68
Sub Total Non-Recurring Cost (B)		**3.0**	**1.60**	**1.37**	**1.26**	**1.26**	**8.49**
C.	**Total (Recurring and Non-Recurring Costs) A+B**	**34**	**35.7**	**34.3**	**29.98**	**30.80**	**164.78**
D.	**Institutional Charge @ 20%**						**32.96**
E.	**Grand Total (A+B+D)**						**197.74**

Component C on Preparation of Follow-up DPR - Scaling Up and Replication of Successful Models of Forestry Interventions and Riverscape Conservation in Additional Sites

Component C on preparation of Follow-up DPR for scaling up and replicating the forestry interventions and conservation of riverscape in additional sites has been allocated a budget of Rs.

2.00 crore which is 0.05% of the total budget outlay of the project (Table 7.1). The budgetary provision for actual implementation of the Follow-up DPR will be made in the Followu-up DPR itself.

Component D on National Coordination for Forestry Interventions and Riverscape Conservation

The fourth Component (D) on National level coordination and management of the project by the Central Nodal Ministry (MoEF&CC) would require a budget of Rs. 49.10 crore over five year project duration. This is 1.27% allocation of the overall project budget outlay. Activity-wise breakup of budget for national level coordination and project management by MoEF&CC is presented in Table 7.8.

Table 7.8. Broad Activities and Costs for Project Management by the Central Nodal Ministry – MoEF&CC

S. no.	Particulars	1st Year	2nd Year	3rd Year	4th Year	5th Year	Cost (in Crore)
A.	**Recurring Cost**						
A.1	Cost of PMU - Salary and Wages, Equipment Office Expenses and Management, Travel, Vehicle and POL, Audits, etc	1.40	1.40	1.60	1.60	1.63	7.63
A.2	Inputs for Policy Level Interventions	0.70	0.20	0.20	0.28	0.80	2.18
A.3	National Decision Support and Management Information System	3.25	2.50	2.16	2.0	1.00	10.91
A.4	Scientific Exchange, Exposure Visits, and Engagement of International and National Consultants	1.30	0.50	0.50	1.00	1.06	4.36
A.5	Inputs for National Level Awareness	2.25	2.25	1.72	1.50	1.00	8.72
A.6	Project Monitoring	1.00	0.60	0.60	2.10	2.24	6.54
	+	**9.90**	**7.45**	**6.78**	**8.48**	**7.73**	**40.34**
B.	**Non- Recurring Cost**						
B.1	Incorporation of Advance Technology	1.75	1.25	1.00	0.75	0.75	5.50
B.2	Permanent Equipment	0.75	0.75	0.60	0.58	0.58	3.26
	Sub Total Non-Recurring Cost (B)	**2.50**	**2.00**	**1.60**	**1.33**	**1.33**	**8.76**
C.	**Grand Total (Recurring and Non-Recurring Costs) A+B**	**12.40**	**9.45**	**8.38**	**9.81**	**9.06**	**49.10**

Table 7.9 provides an overall summary of budget allocation to seven state level IAs in Uttarakhand, Himachal Pradesh, Haryana, Delhi, Uttar Pradesh, Rajasthan and Madhya Pradesh, for different plantation and treatment models and conservation interventions in the various landscapes in the Yamuna catchment/riverscape.

Table 7.9. Model/Activity Wise Area and Cost for Forestry Interventions along Yamuna River

State	Landscape	Model/Activity	Area (ha)	Grand Total (Rs. in lakh)
Uttarakhand	**Natural**	YM/UK/NL/01	265.00	742.10
		YM/UK/NL/02	325.00	731.95
		YM/UK/NL/03	20.00	46.15
		YM/UK/NL/04	10.00	25.67
		YM/UK/NL/05	490.00	1,168.13
		YM/UK/NL/06	6.00	13.09
		Total	**1,116.00**	**2,727.09**
	Agriculture	YM/UK/AL/01	239.77	226.31
		YM/UK/AL/02	50.00	117.07
		Total	**289.77**	**343.37**
	Urban	YM/UK/UL/01	20.50	702.28
		YM/UK/UL/02	5.00	223.28
		YM/UK/UL/03	7.50	47.10
		Total	**33.00**	**972.66**
	Conservation Interventions	YM/UK/CI/01	329.88	178.47
		YM/UK/CI/02	798.48	438.45
		YM/UK/CI/03	620.19	5,650.80
		YM/UK/CI/04	1,991.40	1,081.50
		YM/UK/CI/05	2.00	20.54
		YM/UK/CI/06	38.50	20.50
		Total	**3,780.45**	**7,390.27**
	Grand total for state		**5,219.23**	**11,433.40**
Himachal Pradesh	**Natural**	YM/HP/NL/01	245.80	583.93
		YM/HP/NL/02	264.00	503.73
		YM/HP/NL/03	35.00	66.31
		YM/HP/NL/04	49.00	117.01
		YM/HP/NL/05	2,022.60	3,937.36
		YM/HP/NL/06	600.00	1,380.00
		Total	**3,216.40**	**6,588.34**
	Agriculture	YM/HP/AL/01	75.00	50.99
		YM/HP/AL/02	3.00	5.52
		Total	**78.00**	**56.51**
	Urban	YM/HP/UL/01	5.25	175.11
		YM/HP/UL/02	9.14	54.98
		Total	**14.39**	**230.09**
	Conservation Interventions	YM/HP/CI/01	5.40	2.91
		YM/HP/CI/02	173.03	40.48
		YM/HP/CI/03	247.04	2,227.66
		YM/HP/CI/04	990.33	533.66
		YM/HP/CI/05	2.00	20.54
		YM/HP/CI/06	140.80	75.69
		Total	**1,558.59**	**2,900.94**
	Grand total for state		**4867.38**	**9,775.88**
Haryana	**Natural**	YM/HY/NL/01	139.00	266.05
		YM/HY/NL/02	29.00	78.16
		YM/HY/NL/03	60.00	19.58
		YM/HY/NL/04	33.00	68.66

		Total	**261.00**	**432.45**
	Agriculture	YM/HY/AL/01	844.46	831.74
		YM/HY/AL/02	130.00	292.64
		Total	**974.46**	**1,124.38**
	Urban	YM/HY/UL/01	29.00	61.14
		YM/HY/UL/02	10.00	24.86
		YM/HY/UL/03	20.00	19.97
		YM/HY/UL/04	13.00	6.50
		YM/HY/UL/05	125.00	222.22
		Total	**197.00**	**334.69**
	Conservation Interventions	YM/HY/CI/01	1,637.76	109.00
		YM/HY/CI/02/A	438.46	919.28
		YM/HY/CI/02/B	1,048.73	2,208.70
		YM/HY/CI/02/C	209.69	432.83
		YM/HY/CI/02/D	88.73	183.14
		YM/HY/CI/02/E	10.63	21.93
		YM/HY/CI/02/F	22.50	46.44
		YM/HY/CI/03	0.00	473.66
		YM/HY/CI/04	2.00	20.54
		Total	**3,458.49**	**4,415.53**
	Grand total for state		**4,890.95**	**6,307.04**
Delhi				
	Natural	**Natural**	0.00	0.00
	Agriculture	**Agriculture**	0.00	0.00
	Urban	**Urban**	0.00	0.00
	Conservation Interventions	YM/DL/CI/01	0.00	904.23
		Total	**0.00**	**904.23**
	Grand total for state		**0.00**	**904.23**
Uttar Pradesh	**Natural**	YM/UP/NL/01	2,703.00	6,684.02
		YM/UP/NL/02	585.00	1,358.54
		YM/UP/NL/03	448.50	1,108.18
		YM/UP/NL/05	2,235.00	5,512.01
		YM/UP/NL/06/A	203.00	190.88
		YM/UP/NL/06/B	2,073.94	647.40
		YM/UP/NL/06/C	58.17	13.80
		YM/UP/NL/07	600.00	1,450.15
		YM/UP/NL/08	6,907.32	3,054.39
		YM/UP/NL/09	30.00	81.00
		Total	**15,883.92**	**20,112.23**
	Agriculture	YM/UP/AL/01	1,006.70	1,099.68
		YM/UP/AL/02	604.85	1,098.62
		YM/UP/AL/03	564.00	1,380.58
		Total	**2,175.55**	**3,578.89**
	Urban	YM/UP/UL/01	279.50	2,428.93
		YM/UP/UL/02	40.00	107.64
		YM/UP/UL/03	18.38	9.39
		YM/UP/UL/04	164.00	404.78
		YM/UP/UL/06	14.00	8.53
		YM/UP/UL/07	19.50	654.59
		YM/UP/UL/08	26.00	1,077.22
		YM/UP/UL/09	595.00	2,530.90
		Total	**1,156.38**	**7,221.99**

	Conservation Interventions	YM/UP/CI/01	4,519.30	298.86
		YM/UP/CI/02/A	1,252.60	674.00
		YM/UP/CI/02/B	211.48	115.34
		YM/UP/CI/02/C	2,120.55	755.23
		YM/UP/CI/02/D	1.90	0.30
		YM/UP/CI/02/F	24.00	12.52
		YM/UP/CI/02/G	2,719.36	1,437.98
		YM/UP/CI/03	71.00	296.31
		YM/UP/CI/04	77.17	246.76
		YM/UP/CI/05	6,936.35	1,554.94
		YM/UP/CI/06	0.00	5,230.99
		Total	**17,933.71**	**10,623.22**
	Grand total for state		**37,149.56**	**41,536.32**
Rajasthan	**Natural**	YM/RJ/NL/01	6,429.00	17,826.59
		YM/RJ/NL/02	3,944.00	8,171.48
		YM/RJ/NL/03	4,650.00	2,555.86
		YM/RJ/NL/04	1,860.00	3,893.35
		YM/RJ/NL/05	40,674.20	88,973.80
		YM/RJ/NL/06	462.87	168.58
		YM/RJ/NL/07	588.67	219.25
		YM/RJ/NL/08	53.33	10.11
		YM/RJ/NL/09	800.00	1,933.15
		Total	**59,462.07**	**1,23,752.16**
	Agriculture	YM/RJ/AL/01	258.79	264.04
		YM/RJ/AL/02	234.51	257.62
		YM/RJ/AL/03	20.00	22.04
		Total	**513.30**	**543.70**
	Urban	YM/RJ/UL/01	8.00	266.84
		Total	**8.00**	**266.84**
	Conservation Interventions	YM/RJ/CI/01/A	4,722.41	1,025.81
		YM/RJ/CI/01/B	13.70	2.86
		YM/RJ/CI/02/A	2.23	152.64
		YM/RJ/CI/02/B	369.55	78.95
		YM/RJ/CI/02/C	10,581.80	2,264.67
		YM/RJ/CI/02/D	270.23	57.21
		YM/RJ/CI/02/E	27,705.50	6,031.94
		YM/RJ/CI/02/F	1,500.00	326.13
		YM/RJ/CI/02/G	143.85	30.45
		YM/RJ/CI/02/H	67.20	14.28
		YM/RJ/CI/02/I	3,14,953.25	68,689.08
		YM/RJ/CI/03	1,145.00	3,763.22
		YM/RJ/CI/04	1,348.28	2,913.36
		Total	**3,62,822.99**	**85,350.60**
	Grand total for state		**4,22,806.36**	**2,09,913.31**
Madhya Pradesh	**Natural**	YM/MP/NL/01	4,212.70	9,476.59
		YM/MP/NL/02	687.50	608.24
		YM/MP/NL/03	1,583.50	2,107.16
		YM/MP/NL/04	50.00	63.64
		YM/MP/NL/05	2,034.00	2,564.38
		YM/MP/NL/06	1,200.00	274.78
		YM/MP/NL/07	100.00	18.74
		YM/MP/NL/08	288.00	156.78

		YM/MP/NL/09	6,811.00	1,057.74
		YM/MP/NL/10/A	44.44	22.97
		YM/MP/NL/10/B	5,487.58	1,206.81
		YM/MP/NL/10/C	109.14	25.49
		YM/MP/NL/11	800.00	1,840.00
		Total	**23,407.87**	**19,423.32**
	Agriculture	YM/MP/AL/01	7,500.00	8,017.69
		YM/MP/AL/02	7,500.00	8,425.71
		Total	**15,000.00**	**16,443.40**
	Urban	YM/MP/UL/01	5.00	166.77
		YM/MP/UL/02	120.00	45.21
		Total	**125.00**	**211.98**
	Conservation Interventions	YM/MP/CI/01/A	6,018.13	388.20
		YM/MP/CI/01/B	80.00	41.74
		YM/MP/CI/01/C	1,164.45	606.30
		YM/MP/CI/02/A	363.11	188.40
		YM/MP/CI/02/B	304.00	159.95
		YM/MP/CI/02/C	345.00	182.15
		YM/MP/CI/02/D	11.00	5.90
		YM/MP/CI/02/E	21.00	10.96
		YM/MP/CI/02/F	270.00	143.21
		YM/MP/CI/02/G	939.04	499.70
		YM/MP/CI/03	0.00	15,917.75
		Total	**9,515.73**	**18,144.23**
	Grand total for state		**48,048.60**	**54,222.93**
	Grand Total (All states)		**5,22,982.08**	**3,34,093.10**

7.2. BUDGET OUTLAY – FOREST DIVISIONS

Altogether, 90 Forest Divisions in seven implementing states will participate and carry out activities pertaining to forestry interventions including plantations, conservation interventions and supporting activities in different landscapes. Overall budget outlay for 90 Forest Divisions in seven states is presented in respective state DPRs (Volume II). The magnitude of budget allocation among these 90 Forest Divisions varies from Rs. 0.15 lakh (Kaushambi, Uttar Pradesh) to Rs 716.47 crore (National Chambal Sanctuary, Sawai Madhopur, Rajasthan with an average cost of Rs. 38.69 crore.

7.3. PROJECT SCHEDULE

The total proposed project period is for five years from first year of implementation.

The execution of implementation plan (IP) developed in the DPR will be for five years in phase I. Accordingly, various activities under the four project Components and different Sub-components of seven state level Implementing Agencies have been staggered during the 5-year of implementation period. The extent of plantations (in ha) under proposed forestry interventions and corresponding year-wise costs in natural/ agriculture/ urban landscapes, conservation interventions and supporting activities to be carried out by the seven state IAs are presented in Table 7.10 to Table 7.23. The spill-over areas and costs on account of maintenance works to be carried out after five years of establishment are depicted in last column of the Tables as Phase II areas and costs.

The majority of the forestry interventions including plantations, conservation interventions and supporting activities are planned in the initial three years. Thus, cost for maintenance of

plantations undertaken in third year of implementation will also spill in the subsequent years post completion of 5-year project. Since the Project (Phase I) is of 5-year duration and maintenance cost on plantations spills over in additional four years, it is proposed that a comprehensive cost towards maintenance of plantations in additional years be provisioned to seven state IAs at the end of the fifth year itself so as to ensure maintenance and management of plantations and other activities. Thus, Table 7.10 to 7.23 show the area and cost of maintenance of Phase I works in Phase II which may be allocated to the seven state IAs as Phase II area and cost towards the end of fifth year itself of implementation

As forestry interventions and field based plantation activities have been staggered over 5-year Project period, supporting activities (policy interventions, awareness generation, research activities, capacity buildingg, development of value chain, monitoring and evaluation, etc.) by the national level partner organization and seven states IAs will also be appropriately staggered in the 5-year Project period. In general, the first year of implementation would be more towards preparatory, inception, and engagement of contractual staff and initiation of various activities. The second and third year of the project will have greater quantum of activities. Fourth year onwards of implementation, most activities will gradually reduce and maintenance of the plantations would be the major activity. The mid-term and terminal evaluation of the Project has been planned in the second half of third year and the second half of the fifth year of implementation, respectively.

The first year, will be the financial year for actual execution of the IP, so as to make a provision for budget allocation to the seven state IAs and timely release of funds for establishment of PMC at the nodal ministry (MoEF&CC), PMUs at the state level, PFU at the national level partner organization and for the initiation of preparatory and actual plantation activities. Any delay in approval of the DPR/ Plan as per the APOs and subsequent release of funds to seven state IAs prior to the onset of monsoon season would impact the outputs and outcomes planned for the first year of implementation and subsequent activities.

Table 710. Detailed Summary of Area (Year wise) for Forestry Interventions in Uttarakhand (Area in ha)

Landscape/ Activity	Year 1	Year 2		Year 3		Year 4	Year 5	Phase I	Phase II
	Est.	Est.	Maint.	Est.	Maint.	Maint.	Maint.		
Natural	656.00	390.00	656.00	70.00	1,046.00	1,116.00	1,116.00	1,116.00	1,116.00
Agriculture	121.18	126.02	121.18	42.57	247.20	289.77	289.77	289.77	289.77
Urban	13.50	17.50	13.50	2.00	31.00	33.00	33.00	33.00	33.00
Conservation Interventions	2,002.63	1,015.24	2,002.63	762.58	3,017.87	3,780.45	3,780.45	3,780.45	3,780.45
Grand Total	**2,793.31**	**1,548.76**	**2,793.31**	**877.15**	**4,342.07**	**5,219.23**	**5,219.23**	**5,219.23**	**5,219.23**

Table 7.11. Detailed Summary of Cost (Year wise) for Forestry Interventions in Uttarakhand (Cost Rs. in lakh)

Landscape/ Activity	Year 1		Year 2			Year 3			Year 4		Year 5		Phase 1 Total	Phase II (Maint.)	Grand total
	Est.	Total	Est.	Maint.	Total	Est.	Maint.	Total	Maint.	Total	Maint.	Total			
Natural	713.94	713.94	564.15	368.99	933.14	119.94	261.22	381.16	180.02	180.02	152.31	152.31	2,360.57	366.52	2,727.09
Agriculture	71.23	71.23	100.32	10.87	111.18	24.78	29.10	53.88	26.07	26.07	26.95	26.95	289.33	54.05	343.37
Urban	357.50	357.50	313.69	20.41	334.10	55.13	42.27	97.39	47.72	47.72	50.10	50.10	886.81	85.85	972.66
Conservation Interventions	2,196.86	2,196.86	1,443.64	229.72	1,673.36	1,039.07	392.09	1,431.16	522.09	522.09	547.80	547.80	6,371.27	1,019.00	7,390.27
Grand Total	**3,339.53**	**3,339.53**	**2,421.79**	**629.99**	**3,051.78**	**1,238.91**	**724.68**	**1,963.59**	**775.90**	**775.90**	**777.17**	**777.17**	**9,907.98**	**1,525.41**	**11,433.40**

Table 7.12. Detailed Summary of Area (Year wise) for Forestry Interventions in Himachal Pradesh (Area in ha)

Landscape/ Activity	Year 1	Year 2		Year 3		Year 4	Year 5	Phase I	Phase II
	Est.	Est.	Maint.	Est.	Maint.	Maint.	Maint.		
Natural	1,370.50	1,487.90	1,370.50	358.00	2,858.40	3,216.40	3,216.40	3,216.40	2,616.40
Agriculture	28.00	25.00	28.00	25.00	53.00	78.00	78.00	78.00	78.00
Urban	14.39	0.00	14.39	0.00	14.39	14.39	14.39	14.39	5.25
Conservation Interventions	904.75	525.42	904.75	128.42	1,430.17	1,558.59	1,558.59	1,558.59	3,053.19
Grand Total	**2,317.64**	**2,038.32**	**2,317.64**	**511.42**	**4,355.96**	**4,867.38**	**4,867.38**	**4,867.38**	**5,752.84**

Table 7.13. Detailed Summary of Cost (Year wise) for Forestry Interventions in Himachal Pradesh (Cost Rs. in lakh)

Landscape/ Activity	Year 1		Year 2			Year 3			Year 4		Year 5		Phase I	Phase II	Grand Total
	Est.	Total	Est.	Maint.	Total	Est.	Maint.	Total	Maint.	Total	Maint. cost	Total	Total	(Maint.)	
Natural	2,010.52	2,010.52	1,364.18	437.21	1,801.39	337.06	947.10	1,284.15	438.63	438.63	293.36	293.36	5,828.05	760.30	6,588.34
Agriculture	9.71	9.71	6.93	2.54	9.47	7.28	4.00	11.28	6.11	6.11	6.29	6.29	42.86	13.65	56.51
Urban	176.95	176.95	0.00	9.14	9.14	0.00	10.85	10.85	10.07	10.07	11.97	11.97	218.98	11.11	230.09
Conservation Interventions	1,001.14	1,001.14	661.87	105.28	767.15	163.28	178.89	342.17	208.68	208.68	220.99	220.99	2,540.12	360.82	2,900.94
Grand Total	**3,198.32**	**3,198.32**	**2,032.98**	**5,54.16**	**2,587.14**	**507.62**	**1,140.84**	**1,648.46**	**663.50**	**663.50**	**532.60**	**532.60**	**8,630.01**	**1,145.87**	**9,775.88**

Table 7.14. Detailed Summary of Area (Year Wise) for Forestry Interventions in Haryana (Area in ha)

Landscape/ Activity	Year 1	Year 2		Year 3		Year 4	Year 5	Phase I area	Phase II area
	Est.	Est.	Maint.	Est.	Maint.	Maint.	Maint.		
Natural	261.00	0.00	261.00	0.00	261.00	261.00	228.00	261.00	228.00
Agriculture	778.46	186.00	778.46	10.00	964.46	974.46	974.46	974.46	285.00
Urban	152.00	45.00	134.00	0.00	179.00	179.00	179.00	197.00	148.00
Conservation Interventions	1,854.58	1,603.91	1,854.58	0.00	3,458.49	3,458.49	3,458.49	3,458.49	3,458.49
Grand Total	**3,046.04**	**1,834.91**	**3,028.04**	**10.00**	**4,862.95**	**4,872.95**	**4,839.95**	**4,890.95**	**4,119.49**

Table 7.15. Detailed Summary of Cost (Year Wise) for Forestry Interventions in Haryana (Cost Rs. in lakh)

Landscape/ Activity	Year 1		Year 2			Year 3			Year 4		Year 5		Phase I	Phase II	Grand Total
	Est.	Total	Est. cost	Maint. cost	Total cost	Est. Cost	Maint. cost	Total cost	Maint. cost	Total	Maint. cost	Total	Total	(Maint.)	
Natural	197.32	197.32	0.00	49.53	49.53	0.00	71.98	71.98	42.40	42.40	24.88	24.88	386.10	46.34	432.45
Agriculture	429.48	429.48	112.37	106.33	218.70	10.50	157.62	168.12	139.55	139.55	109.04	109.04	1,064.89	59.49	1,124.38
Urban	114.96	114.96	35.27	39.31	74.58	0.00	48.18	48.18	42.78	42.78	37.99	37.99	318.48	16.20	334.69
Conservation Interventions	2,338.60	2,338.60	1,001.96	141.94	1,143.90	0.00	201.64	201.64	211.72	211.72	222.31	222.31	4,118.16	297.37	4,415.53
Grand Total	**3,080.37**	**3,080.37**	**1,149.60**	**337.11**	**1,486.71**	**10.50**	**479.41**	**489.91**	**436.44**	**436.44**	**394.21**	**394.21**	**5,887.64**	**419.40**	**6,307.04**

Table 7.16. Detailed Summary of Area (Year Wise) for Forestry Interventions in Delhi (Area in ha)

Landscape/ Activity	Year 1	Year 2		Year 3		Year 4	Year 5	Phase I	Phase II
	Est.	Est.	Maint.	Est.	Maint.	Maint.	Maint.	Area	
Natural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urban	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conservation Interventions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Soil and moisture conservation structures will be rehabilitated on 4,500 ha area in Aravalli ridge outside the riverscape

Table 7.17. Detailed Summary of Cost (Year Wise) for Forestry Interventions in Delhi (Cost Rs. in lakh)

Landscape/ Activity	Year 1		Year 2			Year 3			Year 4		Year 5		Phase I	Phase II	Grand Total
	Est.	Total	Est.	Maint.	Total	Est.	Maint.	Total	Maint.	Total	Maint.	Total	Total	(Maint.)	
Natural	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urban	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conservation Interventions	180.00	180.00	189.00	47.25	236.25	0.00	99.23	99.23	104.18	104.18	109.40	109.40	729.05	175.17	904.23
Grand Total	**180.00**	**180.00**	**189.00**	**47.25**	**236.25**	**0.00**	**99.23**	**99.23**	**104.18**	**104.18**	**109.40**	**109.40**	**729.05**	**175.17**	**904.23**

Table 7.18. Detailed Summary of Area (Year Wise) for Forestry Interventions in Uttar Pradesh (Area in ha)

Landscape/ Activity	Year 1	Year 2		Year 3		Year 4	Year 5	Phase I	Phase II
	Est	Est	Maint.	Est	Maint.	Maint.	Maint.	Area	
Natural	12,775.13	2,808.54	12,775.13	300.25	15,583.68	15,883.92	15,883.92	15,883.92	8,719.76
Agriculture	1,546.00	569.55	1,546.00	60.00	2,115.55	2,175.55	2,175.55	2,175.55	1,609.55
Urban	928.30	228.08	918.00	0.00	1,138.00	1,138.00	1,138.00	1,156.38	534.00
Conservation Interventions	13,612.15	3,543.95	13,612.15	777.61	17,156.10	17,933.71	17,933.71	17,933.71	10,997.36
Grand Total	**28,861.59**	**7,150.12**	**28,851.29**	**1,137.85**	**35,993.33**	**37,131.18**	**37,131.18**	**37,149.56**	**21,860.67**

Table 7.19. Detailed Summary of Cost (Year Wise) for Forestry Interventions in Uttar Pradesh (Cost Rs. in lakh)

Landscape/ Activity	Year 1		Year 2			Year 3			Year 4		Year 5		Phase I	Phase II	Grand Total
	Est.	Total	Est.	Maint.	Total	Est.	Maint.	Total	Maint.	Total	Maint.	Total	Total	(Maint.)	
Natural	4,587.08	4,587.08	2,018.73	2,058.59	4,077.32	539.45	3,279.09	3,818.54	2,904.46	2,904.46	2,400.69	2,400.69	17,788.09	2,324.14	20,112.23
Agriculture	860.34	860.34	315.25	426.32	741.57	33.08	589.70	622.77	494.02	494.02	429.03	429.03	3,147.73	431.16	3,578.89
Urban	3,766.39	3,766.39	632.52	758.59	1,391.11	0.00	797.64	797.64	556.79	556.79	440.15	440.15	6,952.08	269.91	7,221.99
Conservation Interventions	5,273.88	5,273.88	1,716.02	373.28	2,089.31	226.93	548.79	775.72	752.62	752.62	665.34	665.34	9,556.87	1,066.34	10,623.22
Grand Total	**14,487.68**	**14,487.68**	**4,682.52**	**3,616.78**	**8,299.31**	**799.46**	**5,215.22**	**6,014.68**	**4,707.89**	**4,707.89**	**3,935.21**	**3,935.21**	**37,444.76**	**4,091.56**	**41,536.32**

Table 7.20. Detailed Summary of Area (Year Wise) for Forestry Interventions in Rajasthan (Area in ha)

Landscape/ Activity	Year 1	Year 2		Year 3		Year 4	Year 5	Phase I	Phase II
	Est.	Est.	Maint.	Est.	Maint.	Maint.	Maint.	Area	
Natural	24,428.02	21,649.05	24,428.02	13,385.00	46,077.07	59,462.07	57,852.07	59,462.07	56,022.07
Agriculture	337.80	157.50	337.80	18.00	495.30	513.30	513.30	513.30	182.50
Urban	8.00	0.00	8.00	0.00	8.00	8.00	8.00	8.00	8.00
Conservation Interventions	1,41,189.08	1,27,076.90	1,41,189.08	94,557.01	2,68,265.98	3,62,822.99	3,62,822.99	3,62,822.99	1,60,445.49
Grand Total	**1,65,962.90**	**1,48,883.45**	**1,65,962.90**	**1,07,960.01**	**3,14,846.35**	**4,22,806.36**	**4,21,196.36**	**4,22,806.36**	**2,16,658.06**

Table 7.21. Detailed Summary of Cost (Year Wise) for Forestry Interventions in Rajasthan (Cost Rs. in lakh)

Landscape /Activity	Year 1		Year 2			Year 3			Year 4		Year 5		Phase I	Phase II	Grand Total
	Est.	Total	Est.	Maint.	Total	Est.	Maint.	Total	Maint.	Total	Maint.	Total	Total	(Maint.)	
Natural	14,252.93	14,252.93	13,813.51	8,725.03	22,538.54	8,705.01	17,907.75	26,612.76	22,961.65	22,961.65	19,863.27	19,863.27	1,06,229.15	17,523.01	1,23,752.16
Agriculture	196.72	196.72	84.87	45.52	130.39	9.57	63.35	72.93	60.81	60.81	54.56	54.56	515.41	28.29	543.70
Urban	200.00	200.00	0.00	12.10	12.10	0.00	12.70	12.70	13.34	13.34	14.00	14.00	252.13	14.70	266.84
Conservation Interventions	24,524.85	24,524.85	22,779.32	121.72	22,901.04	17,612.46	195.72	17,808.18	3,657.07	3,657.07	3,492.49	3,492.49	72,383.64	12,966.96	85,350.60
Grand Total	39,174.49	39,174.49	36,677.70	8,904.36	45,582.07	26,327.04	18,179.53	44,506.57	26,692.87	26,692.87	23,424.33	23,424.33	1,79,380.34	30,532.97	2,09,913.31

Table 7.22. Detailed Summary of Area (Year Wise) for Forestry Interventions in Madhya Pradesh (Area in ha)

Landscape/ Activity	Year 1	Year 2		Year 3		Year 4	Year 5	Phase I	Phase II
	Est.	Est.	Maint.	Est.	Maint.	Maint.	Maint.	Area	
Natural	15,814.30	6,778.37	15,814.30	815.20	22,592.67	23,407.87	23,119.87	23,407.87	17,233.87
Agriculture	4,000.00	6,000.00	4,000.00	5,000.00	10,000.00	15,000.00	15,000.00	15,000.00	11,000.00
Urban	125.00	0.00	125.00	0.00	125.00	125.00	125.00	125.00	5.00
Conservation Interventions	8,887.69	694.54	8,887.69	0.00	9,515.73	9,515.73	9,515.73	9,515.73	9,515.73
Grand Total	**28,826.99**	**13,472.91**	**28,826.99**	**5,815.20**	**42,233.40**	**48,048.60**	**47,760.60**	**48,048.60**	**37,754.60**

Table 7.23. Detailed Summary of Cost (Year Wise) for Forestry Interventions in Madhya Pradesh (Cost Rs. in lakh)

Landscape/ Activity	Year 1		Year 2			Year 3			Year 4		Year 5		Phase I	Phase II	Grand Total
	Est.	Total	Est.	Maint.	Total	Est.	Maint.	Total	Maint.	Total	Maint.	Total	Total	(Maint.)	
Natural	7,029.83	7,029.83	2,551.93	1,489.55	4,041.48	573.76	2,548.81	3,122.57	2,022.51	2,022.51	1,642.06	1,642.06	17,858.45	1,564.87	19,423.32
Agriculture	2,250.00	2,250.00	3,543.75	525.00	4,068.75	3,100.78	1,323.00	4,423.78	1,967.92	1,967.92	1,838.44	1,838.44	14,548.90	1,894.50	16,443.40
Urban	126.18	126.18	0.00	32.85	32.85	0.00	16.51	16.51	13.65	13.65	13.60	13.60	202.79	9.19	211.98
Conservation Intervention	12,028.73	12,028.73	263.78	991.64	1,255.42	0.00	1,041.68	1,041.68	1,232.71	1,232.71	1,185.34	1,185.34	16,743.88	1,400.35	18,144.23
Grand Total	**21,434.74**	**21,434.74**	**6,359.46**	**3,039.04**	**9,398.50**	**3,674.54**	**4,930.00**	**8,604.55**	**5,236.79**	**5,236.79**	**4,679.45**	**4,679.45**	**49,354.02**	**4,868.91**	**54,222.93**

Chapter 8
POTENTIAL BENEFITS OF PROPOSED INTERVENTIONS

8.1. FOREST AND WATER

Water is essential to life, the environment, and human development. Flora and fauna depend on water for growth, development, and survival, and water sustains human societies; environments without water are hot, dry, uncomfortable, and unsuitable for living. Water and forests are two of the most important resources on Earth and both cover large portions of Earth and both are crucial to lives and the environment. As a consequence, loss of forests and increasing human use of water are two important trends in natural resources (Cohen, 2008). This makes water and forests two of the most important issues in the twenty-first century.

Water and forests both provide food, energy, habitat, and many other biological, chemical, physical, and socioeconomic functions and services to living beings and the environment. Without water, there would be no forests. With forests, the occurrence, distribution, and circulation of water are modified, the quality of water is enhanced, and the timing of flow is altered. Indeed, water and forests impact each other greatly.

8.1.1. Significance of Forested Watershed

Water and forests both cover large portions of Earth and water resources are highly dependent on forests. Forests cover about 30% of the land, yet this 30% forested land generates 60% of total runoff. In other words, most of our drinking water supplies originate from forested areas. Forested watersheds provide an estimated 75% of the world's accessible freshwater resources for agricultural, domestic, industrial and environmental uses, with 90 % of the world's cities relying on forested watersheds for their water supply. Forests have long been seen as important sources of clean drinking water (FAO, 2011; Chang, 2013).

Forests minimize erosion through stabilization of soil and hence reduce the impairment of water quality due to sedimentation. Woodlands protect water bodies and watercourses by trapping sediments and pollutants from other up-slope land use and activities. At the same time, forests may influence the timing of water delivery by maintaining and improving soil infiltration and the soil's water-storage capacity. Riparian vegetation has an important role in filtering sediment and pollutants. Bamboo is sometimes planted in tropical riparian areas to conserve soil and water. However, in a study it was found that bamboo was less effective for this purpose than native grass and they recommend a grass strip alongside bamboo stands to enhance the trapping of sediments. Annually, forests reduce 61% delivery of sediment load in dense forested watershed. Forest and forest plant roots prevent run-off from heavy rains and with it soil erosion. Forests reduce about 34% of total runoff in dense forested watershed than degraded micro-watershed.

Forest ecosystems are fundamental to maintaining the water cycle. They influence the amount of water available and control surface and groundwater flows while maintaining high water quality. Forested areas provide environmental stability and supply a high proportion of the world's accessible fresh water for domestic, agricultural, industrial and ecological needs. Forests are also major water users, utilizing water for the generation of biomass, storing water in soils and displacing water from one location to another through evapotranspiration and subsequent precipitation. The ratio of water used versus water conserved, purified and delivered downstream by forests varies over time and is influenced by climate, topography, soil, forest structure (age, density, leaf area index, species composition, etc.) and forest management practices (FAO, 2014).

8.1.2. Findings from Experiments on Forest Hydrology

The forested areas in lower western Himalayan ranges in India which constitute the head water catchments for many hill streams have seen a large degradation in forest cover due to grazing, deforestation and other human activities over the years. The change in forest cover is likely to alter the soil moisture regime and consequently, the flow regime in the streams. Forest Research Institute, Dehradun undertook a study on hydrological aspects with the aim to establish relationship amongst the hydrogeological, and vegetation characteristics and other site parameters at micro- watershed level to assess the impact of forest on hydrological behaviour.

Soil moisture is an integral component of the hydrologic cycle that affects various processes, including evapotranspiration, infiltration, and runoff. Thus, efforts were made through this study to understand the influence of forest cover on soil moisture regime, rainfall-runoff relationship and soil erosion rate, in two micro-watersheds i.e. Arnigadas Dense Oak Forest (83% forest) and Bansigadas Degraded Oak Forest in the Mussoorie Forest Division. Annual rainfall in Mussoorie is approximately 2,100 mm of which 70%–85% is received during monsoon season (June to September).

The runoff response was not only influenced by rainfall amount but also by other factors such as rainfall intensity, rainfall duration, soil properties, soil moisture condition and vegetation. During Monsoon, dense forested micro-watershed reduced 34% more total runoff than the degraded micro-watershed. Annual mean runoff from forested micro-watershed was less (13%) as compared to the micro-degraded watershed. Stream discharge of the dense forested micro-watershed (Arnigad) declined slowly during post monsoon and 55% of the average annual precipitation reached the stream as either base flow (38%) or direct runoff (17%). Annual base flow, direct runoff and total flow was 19%, 45% and 13% more in dense forested micro-watershed respectively than degraded micro watershed. Annual Suspended Sediment Load was 61% less in dense forested micro-watershed than degraded one indicates that forest controls excess suspended sediment load. Annual total dissolved solid was 43% more in dense forested micro-watershed than degraded one and annual bed load was 83% less in dense forested micro-watershed than degraded one. The average annual total sediment load was approximately two times lesser in dense forested micro-watershed than degraded micro-watershed emphasising role of forest in erosion regulation. Soil moisture in dense forested watershed was found 3% more than the degraded forest during all the seasons. A high positive correlation was found between tree density and soil moisture content. The mean soil moisture content over the entire period of study was found higher in dense forest than the degraded forest (Tiwari *et al*., 2011; Tyagi *et al.,* 2013).

Overall, the study showed that the forest cover may be considered as key factor for variations in soil moisture regime, infiltration rate, runoff, sediment load and other hydrological parameters of micro-watersheds. The study suggests that dense forested micro-watershed plays significant role by regulating several hydrological parameters as compared to degraded micro-watershed.

8.2. FORESTRY INTERVENTIONS AND AREA UNDER TREATMENT MODELS

Forestry interventions include procedures of afforestation, reforestation, regeneration and conservation of forest including forest components viz. plants, wildlife, biodiversity, soil and water. The area proposed in the DPR for treatment under three landscapes and conservation interventions is given in Table 8.1. The three landscapes, viz., natural, agriculture and urban/ peri-urban primarily involve plantation activities. Soil and moisture conservation activities together with riparian wildlife management and wetland management are mainly prescribed under conservation interventions. Plantation activities are not confined to the models under three landscapes since some plantation activities are also prescribed under conservation interventions viz. riparian wildlife management and wetland management. On the converse, soil and moisture conservation measures such as construction of check dams, contour trenches, ponds, etc. are integral part of few models under three landscapes. The various models under a landscape may contribute in different magnitudes to benefits such as

biomass, carbon sink, lean flow, sediment load, non-timber forest produce, etc. Benefit from grassland development and assisted natural regeneration may differ from tree plantation. Rehabilitation of a heavily weed-infested forest area would provide greater benefit than rehabilitation of a sparsely weed-infested forest area. All these considerations were used to work out the effective treatment areas from point of view of estimation of potential benefits.

Table 8.1. Area proposed for treatment under different models

State	Riverscape area (ha)	Area proposed for treatment under models				
		Natural	Agriculture	Urban/ peri-urban	Conservation	Total
Uttarakhand	5,08,784	1,116	290	33	3,780	5,219
Himachal Pradesh	5,66,036	3,216	78	14	1,559	4,867
Haryana	1,63,456	261	974	197	3,458	4,891
Delhi NCT	34,279	0	0	0	0	0
Uttar Pradesh	12,64,077	15,884	2,176	1,156	17,934	37,150
Rajasthan	6,75,530	59,462	513	8	3,62,823	4,22,806
Madhya Pradesh	11,94,915	23,408	15,000	125	9,516	48,049
Total	**44,07,077**	1,03,347	19,031	1,534	3,99,070	5,22,982

8.3. POTENTIAL BENEFITS ON QUANTITY AND QUALITY OF RIVER WATER

The benefit assessment framework for water under the DPR has two components viz. water quantity and water quality (Fig. 8.1).

i. The component on quantity of water pertains to improvement of lean flow or green water benefits of the proposed plantation, soil and water conservation works using Soil Conservation Service (SCS), Curve Number Method (USDA, 1986) and Groundwater Resource Estimation Committee Methodology, 2015 (CGWB, 2017), respectively.

ii. The component on water quality pertains to quantification of the reduction of sedimentation load.

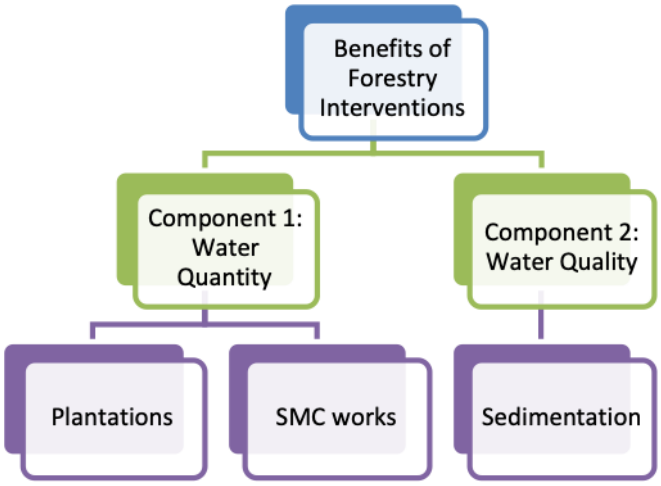


Fig. 8.1. Potential benefits of forestry interventions
(*Source:* **Project Team**)

8.4. WATER QUANTITY BENEFIT ASSESSMENT

Under this component, the proposed forestry interventions/catchment area treatment (CAT) plan has two major parts, namely, i) plantations and ii) SMC structures in Yamuna riverscape area. The quantitative benefits of the activities are assessed in the following sections:

The water balance of a forest basin can be determined by calculating the input, output and storage changes of water from interventions under catchment area treatment (CAT). The major input of water is from precipitation and major output is runoff. A complete water balance model (Fig. 8.2) may contain four sub-modelling systems describing the hydrologic cycle, namely, an atmospheric water balance sub-system; a surface water balance sub-system; a soil water balance sub-system; and a groundwater balance sub-system. Depending upon the focus of the analysis, each sub-system can be modelled separately.

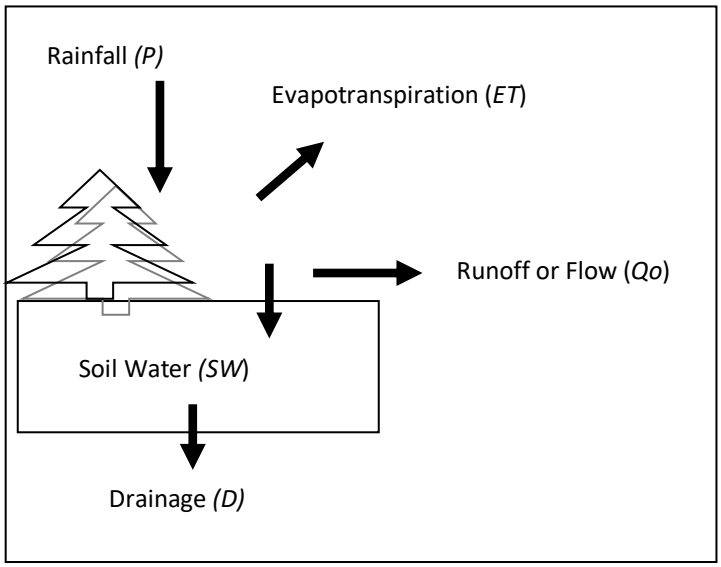


Fig. 8.2. Water Balance Model
(*Source:* **Project Team**)

8.4.1. Contribution to Base Flow from Plantation Works

The general water balance equation is of the following form:

Equation 1 $\boldsymbol{P+G = Q_{dsro}+Q_b + ET+ \Delta S_g}$

Where, P = rainfall; G= 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)

Equation 2

Changes in Water Balance = (Without CAT interventions) – (With CAT interventions)

Changes in surface runoff (Without CAT Q_{dsro}– With CAT Q_{dsro}) = Changes in base flow (With CAT Q_b–Without CAT Q_b)

Estimating Changes in Surface runoff (Without CAT Q_{dsro} -– With CAT Q_{dsro})

The surface water outflow from the catchment area will be estimated by the Soil Conservation Service Curve Number (SCS-CN) model. The SCS-CN model is based on the single parameter

Curve Number (CN) which depends on the land use and cover, soil type and the antecedent moisture conditions prevailing in the catchment. The direct surface runoff has been estimated using the SCS-CN model given in Equation 3 and 4.

Equation 3 $$Q = \frac{(P - I_a)^2}{(P - I_a + S)} \; for P > I_a \; ; \text{and } Q = 0, for P \le I_a$$

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

Steps:

Annual Rainfall

The annual rainfall (P) varies from 600 to 1,200 mm in the Yamuna Basin (CWC, 2015, 2019). The rainfall is in between 600-700 mm in the southern part of the basin and northern basin receives about 1,000-1,200 mm rainfall. In this study, weighted average method applies based on the stage of contribution in order to determine average depth of rainfall of the drainage basin. The weighted average rainfall computed was 897 mm.

Assessing Curve Number

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 (AMC-III) are as follows: 45 for forest and 76 for barren/waste/agriculture land.

Calculation of (S) Potential Retention (mm)

It is defined as the potential maximum retention after runoff begins. The values of 'S' are 310.4 with CAT and 75.87 without CAT.

Initial Abstraction

The initial abstraction (I_a) consists mainly of interception, infiltration during early parts of the storm and surface depression storage. I_a was taken as 62 mm with CAT and 15.174 mm without CAT.

Direct Surface Runoff

Direct surface runoff is the rain that runs off during the rain event as overland flow or in the vegetation cover above a soil. Its values were 609 with CAT and 812 without CAT.

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 changes in the base flow caused by plantation activity can also be called as 'green water'. Base flow contribution implies change in base flow.

The values for base flow contribution from plantation works are calculated in Table 8.2. Base flow or green water from plantation models = 42476126 ha mm or 424.76 MCM

8.4.2. Contribution to Base Flow from Groundwater Recharge through SMC Measures

Estimating groundwater recharge is important to measure effectiveness for water conservation measures. It is generally not possible to physically observe groundwater recharge activities spreading over large areas. The methodology of Ground Water Resource Estimation Committee (CGWB, 2017) was employed to project groundwater recharge from the proposed SMC activities.

Assessment Framework

Recharge due to water conservation structures has been estimated on the basis of the following formula (Equation 5):

Table 8.1. Base flow contribution expected from plantation works

S. no.	Name of state	Total catchment area (km^2)	Rainfall ($mm\ yr^{-1}$)	Effective area contributing to base flow (ha)	Base flow contribution (ha mm)
1	Uttarakhand	3,771	1,176	1,476	2,99,628
2	Himachal Pradesh	5,799	1,251	2,803	5,69,009
3	Haryana	21,265	617	6,199	12,58,397
4	Delhi NCT	1,485	617	225	45,675
5	Uttar Pradesh	70,437	1,025	92,804	1,88,39,212
6	Rajasthan	1,02,883	675	40,101	81,40,503
7	Madhya Pradesh	1,40,208	1,017	65,634	1,33,23,702
	Total			**3,12,310**	**4,24,76,126**

Base flow contribution (ha mm)= Afforestation area (ha) x (Runoff without CAT-Runoff with CAT)

Equation 5: ***RWCS =GS×RF ……(CGWB, 2015)***

Where

- RWCS = Recharge due to Water Conservation Structures
- RF = Recharge Factor
- GS= Gross Storage = Storage Capacity × No. of Fillings

Gross storage capacity= AWSA × H × Efficiency of structures × Number of fillings during the rainy season

The values for base flow contribution from soil and moisture conservation works are calculated in Table 8.3.

Ground water recharge due to water conservation structures: 27.62 MCM (1 MCM = 10^6 m^3)

8.4.3. Total Base Flow Contribution

Total ground water recharge computed is as under

Plantation works:	424.76 MCM
Soil and moisture conservation works:	27.62 MCM
Total:	**452.38 MCM**

8.5. REDUCTION IN SEDIMENT LOAD

Due to geomorphology and faulty land use practices, the Yamuna Basin is eroding at a higher rate than that of any river basin in the world. For this study, only sedimentation parameter is considered due to data unavailability and relevance to the project activities. 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).

Equation 6:

Sediment load= Catchment area* × *Sediment factor* × *Trap efficiency

The projections of reduction in sediment load due to forestry interventions are presented in Table 8.4.

Table 8.4. Reduction in sediment load due to forestry interventions

State	Effective treatment area contributing to sediment reduction (ha)	Excavation for SMC structures (m^3)	Sedimentation rate (x1000 $m^3 km^{-2} y^{-1}$)	Trap efficiency	Total CAT intervention area (km^2)	Sediment load reduction ($m^3 yr^{-1}$)
Uttarakhand	1,476	16,991.86	1.93	0.9	14.76	25,638.12
Himachal Pradesh	2,803	6,309.41	1.93	0.9	28.03	48,688.11
Haryana	6,199	1,290.41	0.986	0.9	61.99	55,009.93
Delhi NCT	225	540.00	0.986	0.9	2.25	1,996.65
Uttar Pradesh	92,804	2,11,194.46	0.86	0.9	928.04	7,18,302.96
Rajasthan	40,101	11,487.13	0.551	0.9	401.01	1,98,860.86
Madhya Pradesh	65,634	21,025.49	0.551	0.9	656.34	3,25,479.01
Total	**3,12,310**	**2,68,838.75**			**3,123.10**	**13,73,975.63**

The CAT activities are expected to reduce sediment load every year by **13,73,975.63 $Mt^3 yr^{-1}$**.

Table 2.3. Ground water recharge due to soil and water conservation structures

State	Structures other than pond (x1000 m^3)	Recharge efficiency (%)	No. of fillings	Recharge from structures other than pond	Storage potential through ponds (x1000 m^3)	Recharge through ponds (x1000 m^3) (1.4 mm/day)	Gross Storage (x1000 m^3)	Recharge factor (%)	Recharge due to water conservation structures (MCM)
Uttarakhand	2,427.41	50	14	16,991.86	72.77	25.47	17,017.33	10	1.70
Himachal Pradesh	1,051.57	50	12	6,309.41	6.64	2.32	6,311.73	10	0.63
Haryana	430.14	50	6	1,290.41	106.14	37.15	1,327.55	16	0.13
Delhi NCT	270.00	50	4	540.00	0.00	0.00	540.00	16	0.05
Uttar Pradesh	52,798.61	50	8	2,11,194.46	1,604.50	561.58	2,11,756.03	1	21.18
Rajasthan	11,487.13	50	2	11,487.13	9,062.86	3,172.00	14,659.13	7	1.47
Madhya Pradesh	5,256.37	50	8	21,025.49	10,291.67	3,602.08	24,627.58	7	2.46
Total	**73,721.23**			**2,68,838.75**	**32,634.51**	**11,422.08**	**2,80,260.83**		**27.62**

8.6. CARBON SEQUESTRATION

8.6.1. Carbon services of India's forests

The National Forest Policy of India envisages 33% of its geographical area under forest and tree cover. With its focus on sustainable management of forests, afforestation and regulating diversion of forest lands for non-forest purposes, India has been successful in improving carbon stock in its forests. In 2015, estimated carbon stock in forest was 7,082 Mt (FSI, 2017) while in 2013 it was 7,044 Mt (FSI, 2015) indicating a net increase of 38 Mt in country's carbon stocks within two years. Various national programmes and policies have converted India's forests into net sink of CO_2. The land use land use change and forestry (LULUCF) sector was source of CO_2 in the year 1994 accounting for 1.16% of CO_2 eq emissions when India submitted its first National Communication (NATCOM) to UNFCCC in 2000 (MoEF, 2004). In its second National Communication, LULUCF sector was a net sink of 17% of total national emissions (MoEF&CC, 2012). India's first biennial update report to UNFCCC has reported that the LULUCF sector was a net carbon sink offsetting 252.5 Mt of CO_2 e which is 12% of India's total GHG emission (MoEF&CC, 2015). LULUCF sector was a net sink of 301,193 Gg CO_2e during 2014, registering an increase in the sink activity of the sector. Cropland dominates the CO_2 emissions /removal estimates for India for the year 2014. Forest land were net sinks and about 12% of India's GHG emissions were offset by the LULUCF sector. Thus, forestry sector in India is making positive contribution for climate change mitigation. The carbon stock present in the forests in the seven states in Yamuna basin is show in Table 8.5.

Table 8.5. Forest carbon stocks in India's forests (in Mt) and relative percentage proportion of carbon in different pools in forest riverscape state of Yamuna

Carbon pool	National (%)	Uttarakh-and (%)	Himachal Pradesh (%)	Haryana (%)	NCT Delhi (%)	Uttar Pradesh (%)	Rajasthan (%)	Madhya Pradesh (%)
1. Aboveground biomass	2,101 (32)	106.35 (37)	63.44 (39)	3.94 (31)	0.198 (24)	41.68 (37)	32.72 (37)	260.3 38
2. Belowground biomass	663 (10)	27.5 (10)	16.72 (10)	1.36 (11)	0.045 (6)	12.62 (11)	1.29 (14)	99.4 15
3. Litter	121 (1)	5.65 (2)	2.37 (2)	0.074 (1)	0.009 (1)	1.57 (1)	0.64 (1)	6.99 1
4. Dead wood	25 (--)	1.26 (--)	0.525 (--)	0.021 (--)	0.001 (--)	0.39 (--)	0.2 (--)	1.53 (--)
5. Soil organic carbon	3753 (56)	144.93 (51)	78.18 (49)	7.29 (57)	0.563 (69)	57.36 (51)	42.75 (48)	314.23 (46)

(Figures in parenthesis are percentage contribution; ***Source:*** FSI, 2019)

8.6.2. Fulfilling International Commitments on Climate Change

Fulfilling emission reduction commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and Paris Agreement on Climate Change, Government of India, launched India's National Action Plan on Climate Change (NAPCC) in 2008. In 2015, Government of India Nationally Determined Contributions (NDC) under Paris Agreement committed to create an additional carbon sink of 2.5 to 3 Bt of CO_2 equivalent through additional forest and tree cover by 2030.National Action Plan on Climate Change, National Mission for a Green India (GIM) and Nationally Determined contribution (NDC) for Forestry sector are some of the major initiatives/targets of India in this area.

India is signatory to the UNFCCC and its Paris Agreement. Under Paris Agreement, India

has committed to meet its Nationally Determined Contribution (NDC). The forestry sector goal of NDC beside other goals commits to create an additional carbon sink of 2.5 to 3 Bt of CO_2 equivalent through additional forest and tree cover by 2030. To achieve this, India is determined to continue with its on-going interventions, enhance the existing policies and launch new initiatives in the priority areas *inter alia* full implementation of Green India Mission and other programmes of afforestation. Planned afforestation has been seen as a major mitigation strategy in forestry sector. India is one of the few countries where forest and tree cover has increased in recent years transforming country's forests into a net sink owing to national policies aimed at conservation and sustainable management of forests.

India's efforts to increase the forest and tree cover have been further augmented by policies like National REDD-plus Strategy (2018), National Agroforestry Policy (2014), Joint Forest Management Guidelines 1990; National Afforestation Programme, *Namami Gange* programme and afforestation along the river sides, Green Highways Mission and afforestation under Compensatory Afforestation Fund Management and Planning Authority Act (UNFCCC, 2015). The initiative of rejuvenation river Yamuna through forestry interventions will further contribute to additional carbon sequestration through afforestation activities.

8.6.3. Forest Productivity in India

India has 10 different bio-geographic zones and 26 biotic provinces (WII, 2000). There is a huge variation in land productivity and many attempts have been made to categorize these lands in terms of their potential forest productivity. One of these is the Paterson's productivity Index, also called the CVP (Climate, Vegetation, and Productivity) Index. Paterson argued that the optimal productivity is a function of light, temperature and moisture conditions. His formula estimates forest productivity in ideal sites under ideal conditions of management (Champion and Seth, 1968 Lal, 1992). The potential yield from natural forest in India is 6 m^3/ha/yr estimated from Peterson's table. The comparison between actual permanent sample plot (PSP) data and actual yield for some of the plantation species have been made by Pande (1995). The actual yield from sample plots has been obtained almost in the range of potential yield. However, well managed plantations are expected to gain much higher than potential yield of natural forests. It is expected that correct site and species matching genetic improvement and correct tending operations can improve the growth rate of plantation species much higher than the Paterson (1956) potential productivity.

Despite commendable efforts made in the country towards improvement of planting stock material productivity of plantation is still much low much less (5-10 m^3ha^{-1} yr^{-1}) than the potential (10-20 m^3ha^{-1} yr^{-1}). This is attributed to use of unimproved seed/clonal planting material, not matching with site and poor management practices. The productivity of fast growing tree species has increased from 10 m^3ha^{-1} $yr^{-1}$to more than 40 m^3ha^{-1} $yr^{-1}$by the use of improved clones, adoption of clonal technology site matching with clones and proper management practices (Kumar *et al.*, 2016). Kant (2005) has reported tree productivity of *Gmelina arborea* in North-eastern bio-geographic zone is estimated up to m^3ha^{-1} yr^{-1}. Kant (2005) applied Paterson productivity index to the 10 bio-geographic zones in the country and developed different scenarios (Table 8.6).

Table 8.6. Potential productivity of different bio-geographic zones of India

S. no.	Bio-geographic zone	Description	Potential ecosystem productivity (m^3ha^{-1} yr^{-1})
1	Trans-Himalayan	Ladakh and high altitude zones abutting Tibet; very cold and arid; sparse alpine vegetation	Unproductive
2	Indian Desert	Thar and Kutch in western India, sandy deserts; seasonal marshes; sparse thorn forests	1-3
3	Semi-arid zone	Plains of Punjab, Haryana, Gujarat, Eastern Rajasthan, west-central UP, western MP; most lands under agriculture; limited forested area	3-6
4	Himalayan bio-geographic zone	Four distinct biotic provinces of north, west, central and eastern Himalayas; sharp altitudinal differences; well forested and also degraded in places; also rich biodiversity; tea cultivation in eastern part.	6 except on very high elevations
5	Deccan Peninsula	Raised land covering 40% of India; bound by Satpura, western and eastern ghats; elevation ranges from 300 to 1,000 m in east; covered by tropical dry and moist forests	6-9
6	Gangetic Plains	Plains of UP, Bihar, West Bengal; most fertile alluvial soils, mostly under crop; very little forest cover	6-9
7	Northeastern bio-geographic zone	Brahmputra and Barak river valleys and north eastern hills; evergreen and moist deciduous forests; heavily subjected to shifting cultivation and encroachment	9-12
8	Coastal region	Coastal belts of west and east coasts; higher rainfall in west, exposure to cyclones in east; extensive casuarina plantations on eastern coast	>12 on west coast, 9 -12 on east coast
9	Western Ghats	Moderately high hill range along west coast; eastern side under rain shadow; very rich in bio-diversity and forest cover; large extent under tea, rubber, coffee, cardamom, tapioca; significant area under protected category $m^3ha^{-1}yr^{--1}$ for wild life	>12 on west side, 9-12 on east
10	Indian Islands	Group of 325 islands in Andaman sea and also Lakshadweep along west coast; heavy rainfall, warm and humid climate and extensive forest cover	>12

Source: Champion and Seth (1968), Kant (2004), Lal (1992) and WII (2000).

8.6.4. Reduction of CO_2 anticipated from ongoing projects in Yamuna Basin

Rejuvenation efforts of the river Yamuna through forestry interventions in the five Yamuna Basin states i.e., Haryana, Himachal Pradesh, Madhya Pradesh, Rajasthan Uttarakhand and Uttar Pradesh will attempt to plant trees in the identified diverse landscapes on both sides of the river. The expected CO_2 mitigation benefits from the proposed forestry interventions have been calculated 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 (t C)
V= Stand volume (m^3 ha^{-1})
D= basic wood density (t dry mater m^{-3}). These values have been taken from Kaul *et al.* (2010)
BEF= Biomass expansion factor (Default). These values have been taken from Kaul *et al.* (2010)
R= Root shoot ratio (Default). These values have been taken from Kaul *et al.* (2010)
CF= Carbon fraction (Default value of 0.47 (IPCC, 2006) has been considered
Carbon in the biomass has been converted into CO_{2eq} by multiplying with 44/12.

The projected reduction of CO_2 by registered CDM forestry projects in the state of Himachal, Haryana, Delhi and Uttar Pradesh are presented in Table 8.7.

8.6.5. Projected Biomass Production by forestry intervention

The estimates of biomass production from the proposed forestry interventions are presented in Table 8.8.

Table 8.7. Reduction of CO_2 anticipated from registered CDM forestry projects in the state of Himachal, Haryana, Delhi and Uttar Pradesh

S.no.	Name of project	Area (ha)	Reduction (t CO_2 eq yr^{-1})	Reduction (t CO_2 eq ha^{-1} yr^{-1})
1	Small Scale Cooperative Afforestation CDM Pilot Project Activity on Private Lands Affected by Shifting Sand Dunes in Sirsa, Haryana	369.87	11,596.00	31.35
2	India: Himachal Pradesh Reforestation Project – Improving Livelihoods and Watersheds	4,003.07	41,400.00	10.34
3	Rehabilitation of Degraded Wastelands at Deramandi in Southern District of National Capital Territory of Delhi through Reforestation	358.5	12,138.00	33.86
4	Small Scale Allahabad JFM A/R CDM Project on Degraded Lands in Allahabad Forest Division, Uttar Pradesh, India	506.63	3,794.00	7.49
5	Small Scale Chitrakoot JFM A/R CDM Project on Degraded Lands in Chitrakoot Forest Division, Uttar Pradesh, India	287.32	3,743.00	13.03
6	Small Scale Obra JFM A/R CDM Project on Degraded Lands in Obra Forest Division, Uttar Pradesh, India	326.72	5,571.00	17.05
7	Small Scale Renukoot JFM AR CDM Project on Degraded Lands in Renukoot Forest Division, Uttar Pradesh, India	284.04	7,670.00	27.00
8	Small Scale Sonbhadra JFM A/R CDM Project on Degraded Lands in Sonbhadra Forest Division, Uttar Pradesh, India	337.45	8,721.00	25.84
9	Small Scale Jhansi JFM A/R CDM Project on Degraded Lands in Jhansi Forest Division, Uttar Pradesh, India	268.87	3,376.00	12.56
10	Small Scale Lalitpur JFM A/R CDM Project on Degraded Lands in Lalitpur Forest Division, Uttar Pradesh, India	416.09	5,375.00	12.92
11	Small Scale Mirzapur JFM A/R CDM Project on Degraded Lands in Mirzapur Forest Division, Uttar Pradesh, India	763.79	10,667.00	13.97
12	Small Scale Kashi JFM A/R CDM Project on Degraded Lands in Kashi Forest Division, Uttar Pradesh, India	320.51	4,694.00	14.65
13	Small Scale Mahoba JFM A/R CDM Project on Degraded Lands in Mahoba Forest Division, Uttar Pradesh, India	265.46	4,356.00	16.41
Average estimated reduction (t CO_2 eq$ha^{-1}yr^{-1}$)				**18.19**

Source: https://cdm.unfccc.int

Table 8.8. Estimated biomass production by the plantations raised under forestry interventions in the Yamuna Riverscape

S.no.	State	Effective treatment area contributing to C sequestration (ha)	Projected biomass production (t yr^{-1})	
			After 10 years	After 20 years
1	Uttarakhand	2,763	37,060.41	46,325.51
2	Himachal Pradesh	3,325	44,601.71	55,752.13
3	Haryana	2,241	49,131.14	61,413.92
4	Delhi NCT	225	4,151.49	5,189.36
5	Uttar Pradesh	21,881	4,03,725.05	5,04,656.31
6	Rajasthan	90,324	20,17,109.06	25,21,386.33
7	Madhya Pradesh	45,478	10,49,664.29	13,12,080.37
	Total	1,66,237	36,05,443.15	45,06,803.94

The biomass estimated to be produced as a result of the forestry interventions is 45,06,803.94 t yr^{-1} at an age of 20 yrs.

8.6.6. Projected Reduction of CO_2 in atmosphere by forestry intervention in Yamuna Riverscape

The estimated carbon dioxide capture by the plantations raised under forestry interventions in the Yamuna riverscape are presented in Table 8.9.

Table 8.9. Estimated carbon dioxide capture by the plantations raised under forestry interventions in the Yamuna Riverscape

S.no.	State	Effective treatment area contributing to carbon sequestration (ha)	CO_2 reduction rate (tCO_2 eq $ha^{-1}yr^{-1}$)	Projected CO_2 reduction (tCO_2 eq yr^{-1})	
				After 10 years	After 20 years
1	Uttarakhand	2,763	7.88	17,418.39	21,772.99
2	Himachal Pradesh	3,325	7.88	20,962.80	26,203.50
3	Haryana	2,241	12.88	23,091.63	28,864.54
4	Delhi NCT	225	10.84	1,951.20	2,439.00
5	Uttar Pradesh	21,881	10.84	1,89,750.77	2,37,188.47
6	Rajasthan	90,324	13.12	9,48,041.26	11,85,051.57
7	Madhya Pradesh	45,478	13.56	4,93,342.22	6,16,677.77
	Total	1,66,237	12.57	16,94,558.28	21,18,197.85

Biomass expansion factor, wood density and ratio of below ground biomass to above ground biomass suggested by Kaul *et al.* (2010) were used for estimation of carbon sequestration.

A conservative productivity rate of 5 $m^3ha^{-1}yr^{-1}$ has been considered assuming that the plantations will be maintained for at least 30 years with usual harvesting/rotation schedule.

8.7. EMPLOYMENT GENERATION THROUGH PROJECT IMPLEMENTATION

Average 85% cost of the project activities is estimated to be incurred on hiring of manpower, mostly unskilled in nature. Based on this, a total of 7.46 crore mandays employment is expected to be generated during implementation of the project activities.

Table 8.10. Number of mandays projected be generated through implementation of prescriptions of the DPR.

State	Cost of treatment models and supporting activities	Average rate (Rs. d^{-1})	No. of mandays
Uttarakhand	11,433	330	17,32,273
Himachal Pradesh	9,776	250	19,55,200
Haryana	6,307	330	9,55,606
Delhi NCT	904	450	1,00,444
Uttar Pradesh	41,536	175	1,18,67,429
Rajasthan	2,09,913	213	4,92,75,352
Madhya Pradesh	54,223	308	88,02,435
Total	3,34,093		**7,46,88,739**

8.8. INCOME GENERATION THROUGH NTFP COLLECTION

In India, NTFPs have socio-economic and cultural values associated with the life of forest dependent communities which inhabit wide ecological and geo-climatic conditions throughout the country. An estimate suggests that more than 275 million poor rural people of the country depend on NTFPs for some part of their subsistence and cash livelihoods (Pandey *et al*., 2016). Himalayan region acts as an ecological guardian to large part of India serving it with ecological assets and also ensuring the fertility of landscape for the socioeconomic development of people living downstream of rivers arising here.

Forest based livelihood is of great economic and ecological significance for the people due to large variety of forest based products and services. Many NTFPs provide large livelihood opportunities in form of medicinal plants, resins, gums, wild edible plants, lichens, wild flowers and vegetables besides fodder and fuel wood. NTFPs are used for self-consumptions and largely for trade to supplement their annual income. In this section the description of potential NTFPs and their case studies for livelihood opportunities and trade is mentioned here.

8.8.1. Minimum support price of the NTFPs and Medicinal Plants:

The Ministry of Tribal Affairs has notified the following minimum support price (MSP) for NTFP on May 1, 2020 (Table 8.11).

Table 8.11. Minimum support price of NTFPs declared by Ministry of Tribal Affairs in May 2020

S. no.	NTFP item	MSP price Rs./kg on 01.05.2020
1	Tamarind (with seeds) *Tamarindus indica*	36
2	Wild Honey	225
3	Gum Karaya *Sterculia urens*	114
4	Karanj seeds *Pongamia pinnata*	22
5	Sal seed *Shorea robusta*	20
6	Mahua seed *Madhuca longifolia*	29
7	Sal leaves *Shorea robusta*	35
8	Chironji pods with seeds *Buchanania lanzan*	126
9	Myrobalan *Terminalia chebula*	15
10 (A)	Rangeeni Lac	200
10 (B)	Kusumi Lac	275
11	Kusum seeds (*Schleichera oleosa*)	23
12	Neem seeds (*Azadirachta indica*)	27
13	Puwad seeds (*Cassia tora*)	16
14	Baheda(*Terminalia bellirica*)	17
15	Hill Broom Grass (*Thysanolaena maxima*)	50
16	Dry Shikakai Pods (*Acacia concinna*)	50
17	Bael pulp (Dried) (*Aegle marmelos*)	30
18	Nagarmotha (*Cyperus rotundas*)	30
19	Shatavari Roots (Dried) (*Asparagus racemosus*)	107
20	Gudmar / Madhunashini (*Gymnema sylvestre*)	41
21	Kalmegh (*Andrographis paniculata*)	35
22	Tamarind (De-seeded) (*Tamarindus indica*)	63
23	Guggul (*Sterculia urens*)*	812
24	Mahua Flowers (dried) (*Madhuca longifolia*)	30
25	Tejpatta (dried) (*Cinnamomum tamala* and *Cinnamomum* sp.)	40
26	Jamun dried seeds (*Syzgium cumini*)	42
27	Dried Amla Pulp (deseeded) (*Phyllanthus emblica*)	52
28	Marking Nut (*Semecarpus anacardium*)	9
29	Soap Nut (dried) (*Sapindus emarginatus*)	14
30	Bhava Seed (Amaltas) (*Cassia fistula*)	13
31	Arjuna Bark (*Terminalia arjuna*)	21
32	Kokum (Dry) (*Garcinia indica*)	29
33	Giloe (*Tinospora cordifolia*)	40
34	Kaunch Seed (*Macuna pruriens*)	21
35	Chirata (*Swertia chirata*)	34
36	Vaybidding / Vavding (dry seeds) (*Embelia ribes*)	94
37	Dhavaiphool dried flowers (*Woodfordia floribunda*)	37
38	Nux Vomica (*Strychnos nux vomica*)	42
39	Ban Tulsi Leaves (dried) (*Ocimum tenuiflorum*)	22
40	Kshirni (*Hemidesmus indicus*)	35
41	Bakul (dried bark) - (*Mimusops elengii)*	46
42	Kutaj (dried bark) - (*Holarrhena pubescens / H. antidysenterica*)	31
43	Noni / Aal (dried fiuits) - (*Morinda citrifolia*)	17

44	Sonapatha / Syonak pods - (*Oroxylum indicum*)	21
45	Chanothi seeds - (*Abrus precatorius*)	45
46	Kalihari (dried tubers) - (*Gloriosa superba*)	31
47	Makoi (dried fiuits) - (*Solanum nigrum*)	24
48	Apang plant - (*Achyranthes aspera*)	28
49	Sugandhmantri roots/tubers - (*Homalomena aromatic*)	38

MSP of more NTFPs have been declared (Table 8.12) by Ministry of Tribal Affairs, GoI on May 26, 2020 (https://tribal.nic.in/writereaddata/Schemes/MSPforMFPMoTA26052020.pdf)

Table 8.12. List of NTFP included in MSP list by Ministry of Tribal Affairs, GoI on May 26, 2020

S. no.	Minor forest produce	MSP (Rs./kg)	Category	Applicability as MFP item
1.	Van Tulsi seeds (*Ocimum gratissimum*)	16	Forest	All India
2.	Van Jeera (*Vernonia anthelmintica*	70	Forest	All India
3.	Betel nut raw (*Areca catechu*)	30	Agriculture	N.E. states
4.	Betel nut raw (*Areca catechu*)	30	Agriculture	N.E. states
5.	Tamarind seed (*Tamarindus indica*)	11	Forest	All India
6.	Bamboo brooms (*Thysanolaena maxima*)	60	Forest	All India
7.	Perilla dry (*Perilla frutescens*)	140	Agriculture	N.E. states
8.	Nutgall (*Rhus chinensis*)	150	Agriculture	N.E. states
9.	Zanthoxylum Dried (*Zanthoxylum armatum*)	200	Agriculture	N.E. states
10.	Jack Fruit Seed (*Artocarpus heterophyllus*) (Seeds)	45	Agriculture	N.E. states
11.	Dry Aonla (*Phyllanthus emblica*) (Dry)	60	Forest	All India
12.	Kachri Baheda (*Terminalia bellerica*)	20	Processed	All India
13.	Kachri Harra (*Terminalia chebula*)	23	Processed	All India

8.8.2. Economics of Cultivation of NTFPs species

The economics of NTFPs and Medicinal Plants are given below for the livelihood of the people to be used in DPR of Yamuna (Source- A manual on Cultivation of Selected NTFPs).

Table 8.13. Economics of cultivation of *Terminalia chebula* (Harar)

Total no. of plants at 8m × 8m spacing	150 ha^{-1}
Production of fruit after 10 years	100 kg $plant^{-1}$
Production of dry fruit	30 kg $plant^{-1}$
Production of fruit	15.0 t fresh fruit ha^{-1}, .5 t dry fruit ha^{-1}
Price	Dry fruit- Rs. 60/kg
Cost of cultivation for 10^{th} year	Rs. 30,000
Total returns at Rs. 60 kg^{-1}	Rs. 2,70,000
Net profit	Rs. 2,40,000 after 10 years
Production period	5-80 years

Table 8.14. Economics of cultivation of *Podophyllum hexandrumn* (Ban kakri)

Estimated Production of dry roots and rhizomes after 3 years	2 quintals/acre
Latest rates of market	Rs. 450 kg^{-1}
Income from dried shoots	Rs. 90000
The number of new plants produced In the nursery from seeds/ vegetative propagules- 2000 × 3 yrs	6,000
Income from selling plants (Rs. 5.0/plant)	Rs. 30,000
Total income	Rs. 1,20,000
Total expenses (Irrigation, Hoeing, Weeding, Planting material, Harvesting, Drying and Transport expenses)	Rs. 73,564
Net profit after 3 years	Rs. 46,436

Table 8.15. Economics of cultivation of *Picrorhiza kurroa* (Kutki)

Estimated Production of dry roots and rhizomes after 3 years	4 q ac^{-1}
Latest rates of market	Rs. 600 kg^{-1}
Income from dried shoots	Rs. 2,40,000
The number of new plants produced through Macro Proliferation Technique- 30000 × 8	2,40,000
Income from selling plants(Rs. 1.0/plant)	Rs. 2,40,000
Total income	Rs. 4,80,000
Total expenses (Irrigation, Hoeing, Weeding, Planting material, Farm preparation, Harvesting, Drying and Transport expenses)	Rs. 2,50,000
Net profit	Rs. 2,30,000
Net profit per year	Rs. 76,667

Table 8.16. Economics of cultivation of *Aconitum heterophyllum* (Atish)

Estimated Production of dry roots and rhizomes after 3 years	120 kg $acre^{-1}$
Latest rates of market	Rs. 6,000 kg^{-1}
Income from dried roots	Rs. 7,20,000

Total income	Rs. 7,20,000
Total expenses (Irrigation, Hoeing, Weeding, Farm preparation, FYM, Fungicides, Harvesting, Drying and Transport expenses)	Rs. 79,421
Total net profit after 3 years	Rs. 6,40,579
Yearly profit/ income	Rs. 2,13,526

Table 8.17. Economics of cultivation of *Thysanolaena maxima* (Broom grass)

Cost of 1 kg	Rs. 20-25
Average broom grass price	Rs. 55,000 t^{-1}
Top grade material	Rs. 80,000 t^{-1}
Average annual cost for first year of cultivation	Rs. 32,000
Average annual income for first year of cultivation	Rs. 44,000
Average annual cost for second year of cultivation	Rs. 10,000
Average annual income for second year of cultivation	Rs. 1,50,000

Table 8.18. Economics of cultivation of bamboo species (Baans)

No. of individual bamboo harvested from 1 clump	5-6 no. yr^{-1}
Total no. of individual bamboos from one hectare of land	2500 no yr^{-1}
Cost of one bamboo (say)	Rs. 50
Cost of 2500 bamboo	Rs. 1,25,000 yr^{-1}
Expenditure (Land preparation, FYM, Fertilizer, fencing, labour charge etc.)	Rs. 25,000- Rs. 30,000
Net Profit	Rs. 1,00,000 – Rs. 95,000 yr^{-1} ha^{-1}

Table 8.19. Economics of cultivation of *Aloe barbadensis* (Ghikanvar)

1st year expenditure	Rs. 2,25,000
2nd year cost	Rs. 75,000
3rd year cost	Rs. 75,000
Total cost	Rs. 3,75,000
Estimated income in 3 years (Price Rs. 15/kg)	Rs. 25,59,000
Profit at the end of 3 years (estimated)	Rs. 21,84,300
Profit /yr/ha (average)	Rs. 7,19,766

Table 8.20. Economics of cultivation of *Angelica glauca* (Chora)

After two years of crop duration	Production of 23 q ha^{-1}
Market rate	Rs. 60-100 kg^{-1}
Intercropping of Chora with Apple yields	Rs. 80000-1,30,000 ha^{-1}

Market rate of *Tinospora cordifolia* (Giloy)

Market rate for one kg of dried stem= Rs. 15-20

Market rate of *Ocimum sanctum* (Tulsi)

Market rate of Oil= Rs. 800-3000 per litre

8.8.3. Value addition of NTFPs

The value and market rate of the raw material is a small fraction of the finished produce. Value-addition may provide greater economic returns to growers and collectors of the NTFPs. The economics of value addition of some of the produce is shown in Table 8.21. to 8.26.

Table 8.21. Economics of making edible products from *Schleichera oleosa* (Kusum) fruits

S. no.	Name of products	Fruit pulp		Overhead charges (Rs.)	Cost for total weight generated	Price of product per kg (Rs.)	Packaging charges per kg (Rs.)	Total cost per kg (Rs.)
		Quantity (kg)	Cost (Rs.)					
1.	Vati (laddoo)	1.0	60.34	235	295.34 for 1.6 kg	185	60	245
2.	Jam	0.5	30.17	21.75	51.92 for 0.75 kg	69	60	129
3.	Murabba	0.68	41.33	27.49	86.56 for 0.80 kg	87	60	147
4.	Sharbat	1.0	60.34	38.50	98.84 for 1.7 kg	58	20	78
5.	Squash	0.5	30.14	29.50	59.67 for 1 kg	60	20	80
6.	Chutney	1.0	60.34	66.50	126.84 for 1.95 kg	65	20	85
7.	Thandai	1.0	60.34	80.80	141.14 for 2.2 kg	64	20	84

(***Source:*** Technology outreach for livelihood improvement- A technical manual, ICFRE 2020)

Table 8.22. Economics of preparation of amla candy

Fixed cost	Rs. 86800
Operational cost	Rs. 67750
Misc. expenses/ transport	Rs. 2000
Total operating cost	Rs. 69750
Avg. selling price	Rs. 85000
Total profit	Rs. 15250

Table 8.23. Economics of preparation of *Moringa oleifera* powder from drumstick tree

Fixed cost	Rs. 84,500
Operational cost	Rs. 54,100
Selling of *Moringa* powder (wholesale)150 kg@ 600Rs. kg^{-1}	Rs. 90,000
Total Profit	Rs. 35,900

Table 8.24. Economics of processing of saponin based material from *Sapindus mukorossi* and *Grewia optiva* (for 200 days per year per unit)

Cost of material	Rs. 5,76,000
Cost of packaging	Rs. 8,06,400
Marketing cost	Rs. 7,39,200
Amortisation cost	Rs. 1,47,840
Depreciation	Rs. 1,47,840

Labour	Rs. 1,80,000
Utilities	Rs. 5,760
Total cost	Rs. 26,03,040
Provision for taxation	Rs. 80,000
Contingencies	Rs. 2,60,304
Total expenses	Rs. 29,43,344
Total sales	Rs. 33,76,608
Surplus Generation (estimated)	Rs. 4,33,264

Table 8.25. Cost-Benefit analysis (Rs ± SE/day) of edible products prepared from a variety wild fruits/ flowers/soft stem/petiole in the central Himalaya (Negi *et al.*, 2011)

Plant species	Juice		Squash	
	Input	Output	Input	Output
Spondias pinnata	190 ± 5.8	480 ± 8.8 (290 ± 5.8)	620 ± 7.3	1000 ± 8.8 (380 ± 8.3)
Pyracantha crenulata	140 ± 8.8	280 ± 8.8 (140 ± 5.8)	384 ± 2.9	600 ± 14.5 (216 ± 11.6)
Viburrnum mullaha	165 ± 7.6	350 ± 5.8 (185 ± 2.9)	495 ± 7.3	750 ± 5.8 (255 ± 1.7)
Berberis asiatica	150 ± 7.3	280 ± 7.3 (130 ± 1.7)	415 ± 5.8	600 ± 7.6 (185 ± 6.0)
Elaeagnus latifolia	175 ± 4.4	350 ± 5.8 (175 ± 1.7)	495 ± 7.3	750 ± 11.5 (255 ± 3.3)
Hippophae salicifolia	290 ± 8.8	700 ± 5.8 (360 ± 13.3)	1170 ± 11.6	2000 ± 20.3 (830 ± 11.5)
Zizyphus species	140 ± 8.8	280 ± 3.3 (140 ± 8.8)	390 ± 8.8	600 ± 11.5 (210 ± 3.3)
Aegle marmelos	180 ± 5.8	350 ± 3.3 (170 ± 2.9)	450 ± 7.3	750 ± 5.8 (300 ± 1.7)
Rosa webbiana	170 ± 5.8	350 ± 2.9 (180 ± 2.9)	550 ± 4.4	750 ± 7.6 (200 ± 4.4)
Rosa macrophylla	140 ± 5.8	280 ± 5.8 (140 ± 6.7)	400 ± 4.7	600 ± 7.3 (200 ± 21.7)
Rhododendron arboreum	185 ± 4.4	490 ± 5.8 (305 ± 4.4)	490 ± 8.8	900 ± 10.1 (370 ± 14.2)
Emblica officinalis	160 ± 8.8	420 ± 3.3 (260 ± 3.3)	560 ± 11.5	900 ± 8.8 (320 ± 6.7)
Myrica esculenta	165 ± 8.8	280 ± 5.8 (115 ± 3.3)	430 ± 8.8	720 ± 7.3 (290 ± 2.9)

Note: Values in parentheses are net return.

Table 8.26. Cost-benefit analysis of edible products prepared from wild fruits/flowers/soft stem/petiole in the Central Himalaya (Negi *et al.*, 2011)

Plant species	Input (Rs ± SE/day)	Output (Rs ± SE/day)
Pickle		
Diplazium esculenta	520 ± 7.3	840 ± 4.4 (320 ± 1.6)
Ficus auriculata	880 ± 4.4	1500 ± 10.1 (620 ± 8.8)
Bauhinia purpurea	390 ± 7.3	600 ± 8.8 (210 ± 6.0)
Bombax ceiba	570 ± 7.3	900 ± 13.0 (330 ± 13.0)
Ficus glomerata	400 ± 8.8	600 ± 10.4 (200 ± 1.7)
Ficus palmata	400 ± 8.8	600 ± 10.4 (200 ± 7.6)
Ficus semicordata	690 ± 8.8	1080 ± 5.2 (390 ± 2.67)
Zizyphus species	430 ± 8.8	550 ± 4.7 (120 ± 2.9)
Emblica officinalis	1500 ± 14	1800 ± 13.5 (300 ± 3.2)
Jam		
Pyracantha crenulata	600 ± 8.8	840 ± 7.3 (240 ± 10.1)
Benthamidia capitata	496 ± 8.5	700 ± 7.6 (204 ± 1.5)
Rubus ellipticus	203 ± 5	420 ± 5.2 (217 ± 5)
Sauce		
Spondias pinnata	611 ± 6.6	780 ± 5.8 (169 ± 10.8)
Pyracantha crenulata	540 ± 10.1	720 ± 2.9 (180 ± 9.3)
Murabba		
Zizyphus jujuba	456 ± 5.8	600 ± 9.3 (144 ± 10.4)
Emblica officinalis	1200 ± 17.6	1500 ± 14.5 (300 ± 3.3)

Note: Values in parentheses are net return; based on survey of about 375 households.

8.8.4. Major herbal and nutraceutical industries situated in the Yamuna basin

There are many major and a very large number of minor industries in the Yamuna basin that are engaged in processing of herbal produce from species that are found in the forest or grown in agroforestry. Such industries may be approached from beginning of DPR implementation to develop a synergy with the. A list of important units manufacturing medicinal and nutraceutical products is presented in Table 8.27.

Table 8.27. Major Herbal companies in cities situated in Yamuna Basin

S. no.	Major herbal industries	Location
1	Patanjali Food & Herbal Park Ltd.	Haridwar
2	Himalayan Mega Food Park	Udham Singh Nagar, U.K.
3	Patanjali Ayurved	Haridwar
4	Forest Essentials	Source raw material from Uttarakhand
5	Dabur India	Ghaziabad
6	M/S. Ayushman Ayurved Pharmacy	Chhatarpur, M.P.
7	M/S. Aura Herbal Products	Shivpuri, M.P.
8	Hindustan Ayurvedic Company	Gwalior, M.P.
9	Som Bioherb Products Pvt Ltd.	Kota
10	Hamdard (Wakf) Laboratories	New Delhi

A list of important units that process fruit, horticultural or wild fruit, is given in Table 8.28.

Table 8.28. Major food processing industries located in cities in Yamuna Basin

S. no.	Company	Location	Species processed
1	Progressive Growers Association (PGA	Shimla, Rohru, Jubbal, Kotkhai, Chopal,	Apple
2	HP Horticultural Produce Marketing and Processing Corporation Ltd. (HPMC)	Parwanoo (Solan)	Apple, Plums, Apricots Juices, Jams, etc.
3	Yamunagiri Devbhoomi Private Ltd.	Sirmaur	Apple, Plums, Apricots, Seasonal fruits, Juices, Jams, etc.
4	Himalayan Vegefruit Ltd.	Solan	Apple, Plums, Apricots Juices, Jams, etc.
5	Himjoli	Uttarakhand	Apple, Orange (Malta), Kaphal, Apricots, etc.
6	Uttarakhand Food Processing Unit	Uttarkashi	Temperate and Tropical fruits

8.8.5. Projection of NTFP Benefits from Forestry Interventions in the DPR

Assuming 500 trees per ha of which 75% will be NTFP trees, 60% survival and annual returns from NTFP at a rate of Rs. 20 per tree, the returns per unit plantation area would be Rs. 4500 $ha^{-1}yr^{-1}$. Assuming 300 shrubs/herbs per ha comprising about 80% NTFP plants, achieving 60% survival and annual returns from sustainable extraction of NTFP at a rate of Rs. 6.67 per plant, the returns per unit plantation area would be Rs. 960 $ha^{-1}yr^{-1}$. In hilly states of Uttarakhand and Himachal Pradesh, the sustainable extraction may be 66% and 77% of the above for trees and shrubs/herbs respectively thereby providing Rs. 3000 $ha^{-1}yr^{-1}$ and 720 $ha^{-1}yr^{-1}$ for the two types of plants . The ages for extraction are taken as 30 years and 5 years for trees and shrub/herbs respectively. The benefits that are likely to be incurred in terms of production of NTFPs from implementation of the DPR are displayed in Table 8.29.

Table 8.29. Projected benefits from NTFP production

State	Area under plantation (ha)	Returns (Rs. ha^{-1} yr^{-1})		Returns from proposed area (Rs. in lakh)		
		Tree	Shrubs and herbs	Tree	Shrubs/ herbs	Total
Uttarakhand	1,439	3000	720	43.17	10.36	53.53
Himachal Pradesh	3,309	3000	720	99.27	23.82	123.09
Haryana	1,432	4500	960	64.44	13.75	78.19
Delhi NCT	0	4500	960	0.00	0.00	0.00
Uttar Pradesh	19,216	4500	960	864.72	184.47	1,049.19
Rajasthan	59,983	4500	960	2,699.24	575.84	3,275.07
Madhya Pradesh	38,533	4500	960	1,733.99	369.92	2,103.90
Total	**1,23,912**			**5,504.82**	**1,178.16**	**6,682.98**

Based on the above, the returns from trees, shrubs, herbs would be around 6,682.98 lakh yr^{-1} at age of 30 years. Of this, sum of Rs. 5,504.82 lakh yr^{-1} would annually accrue from trees in the plantations by way of NTFP at 30 years of age. Shrubs and herbs would provide 1,178.16 lakh worth NTFP from age of 6 years.

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ANNEXURE 1

LOGICAL FRAMEWORK ANALYSIS/PLANNING

(Refer section 1.13.4 of Chapter 1 Vol. 1)

Logical Framework Analysis (LFA) is an analytic tool for result-based management that offers a systematic and logical approach for designing projects. LFA provides a structure which allows project or programme planners and evaluators to stipulate the components of their activities and identify the logical linkages between a set of means and ends and also by incorporating all the possible factors in planning to make a successful project (Table A1.1.). Thus, the LFA is an aid to logical thinking and a means by which a project may be structured and described for analytical purposes (Coleman, 1987). LFA ensures that the basic premises are probed extensively and the interrelated key elements are analyzed systematically, so that, necessary, significant and relevant information is provided to decision-makers for arriving at a well-designed project.As an effective management tool, it has now been utilized in a variety of modified forms by many development agencies.

Table A1.1. Logical framework planning matrix

Project Strategy/ Narrative summary	**Objectively verifiable indicators**	**Means of verification**	**Important assumptions**
Goal	Measurement of goal achievement	Sources of information. Methods used	Assumptions affecting Purpose-Goal linkage
Purpose	End of project status	Sources of information. Methods used	Assumptions affecting Output-Purpose linkage
Outputs	Magnitudes of outputs. Planned completion date	Sources of information. Methods used	Assumptions affecting Inputs-Outputs linkage
Inputs	Nature and level of resources necessary. Cost. Planned starting date	Sources of information. Methods used	Initial assumption(s) about the project

LFP operates as a 4 x 4 matrix. The narrative summary describes an activity or intervention; it allows the identification of 'inputs' that lead to a set of 'outputs' which should accomplish a 'purpose' that is an integral to achieving the ultimate 'goals' of a project (Coleman, 1987). Each of these four stages needs to be subjected to a concrete means of verification. 'Assumptions' are factors one assumes will (or must) take place in order for the narrative summary to run its course and achieve its aim. The middle two columns of the matrix describe the ways in which one may measure what could happen as well as what actually happens. 'Objectively verifiable indicators' are means by which one can verify whether a given activity actually led to an output. The 'Means of verification' column describes the precise method by which this verification can be measured.

Humans interact with water in a wide variety of ways which impact the water environment. In order to protect and utilise the water sustainably, diverse and complex relationships with other components of environment need to be taken into consideration while planning river basin development.Therefore, any effective tool or technique used for river basin planning should integrate physical, ecological, social and economic aspects of river basins through active involvement of stakeholders for transparent and accessible processes of analysis and decision making. Logical framework involves analysis of problems, objectives, alternatives, stakeholders and development of 'logframes' (Puranik and Dhadwad, 2015). Integrated river basin management, due to the spatial dimension of water and the interconnected nature of different land and water uses within basins, has been increasingly well understood. But given the complexity of their interconnectedness, result-oriented planning and implementation on a basin scale is seldom achieved effectively. Typically, river basins represent different components of natural resources which prominently include ecology and environment, water resources, agriculture, social, organizational and economical sub systems. All these systems are continuously interacting within themselves and also between each other. Interventions carried out in any of these sub systems to manage the river basins have either positive or negative impact over the other sub system.

The LFA provides a structure which allows project or programme planners and evaluators to stipulate the components of the river basin planning and management activities and identify the logical linkages between a set of means and a set of ends. As a planning device, the LF helps to place monitoring and evaluation (M&E) within a wider policy/programme/project framework. Table A1.2. describes four levels of the LFPmatrix – inputs, outputs, purpose and goal for rejuvenation of Yamuna River through forestry interventionsin the DPR.

Table A1.2. LFP matrix for the rejuvenation of Yamuna River through forestry interventions

Project/DPR Strategy	Narrative summary	Objectively verifiable indicators	Means of verification	Important assumptions and risks	
				Assumptions	Risk
Goal	Improvement in quantity and quality of water in Yamuna River and its tributaries	Scientific evaluation of Yamuna River and its tributaries for green cover, soil erosion, sedimentation, surface and groundwater and land degradation	Annual review by the implementing agencies and midterm and final review by third party for objectively verifiable indicators	Increase in E-flow and decrease in sedimentatio n load in Yamuna River and its tributaries	The long gestation period of forestry interventions and inadequacy and uncertainty of adequate funding
Purpose	Restoration of Yamuna River and its tributaries to existing national standards	To compare the status of changed green cover, soil erosion, sedimentation load, surface and groundwater, soil moisture and land degradation in the	Quantification of change in green cover, soil erosion, sedimentation load, surface and groundwater, soil moisture	Improvement and management of forest/vegetat ion cover including low cost moisture	Limited and delayed target achievements due to natural calamities/pest outbreaks and poor financial allocation

		watershed with existing national standards	and land degradation annually through monitoring	conservation and riverbed protection measures in watershed of Yamuna River and tributaries	
Output	Scientific river management through forestry interventions, soil and moisture conservation measures with the participation of various governmental agencies, communities and NGOs.	Assessment of multi-sector convergence and integration of proposed forestry interventions for implementation for rejuvenation of Yamuna River and its tributaries.	Activity based/periodic reports on proposed forestry interventions by the field functionaries	Restoration of streams, banks, flood plain, buffer zones, etc. of Yamuna River and tributaries	Varied apprehensions of stakeholder departments and communities due to lack of awareness may lead to poor participation
Input	Application of mutually evolved scientific forestry interventions (models) and allied activities in specified landscapes as detailed below:	Quantification of various forestry interventions in different landscapes of seven stakeholder states	Monitoring of approved annual plan of work (APO) along with desired outputs.	APOs should be framed as per proposal in DPR and activities must be executed as per approved APOs.	The inputs may not be delivered in time and space due to non-participation of other sectors, for example, Agriculture and Public Works Department, etc.
	i. Natural	Improvement in forest cover and augmentation of waterand decrease in sedimentation after plantations	Periodic reports on use of quality seed, good planting material along with prescribed planting and maintenance practices	Increase in forest cover, carbon sequestration etc. in the project area leading to improved quantity of water in streams	Non availability of desired species and quality material for plantations. Dumping of waste/debris of developmental activities in forests.
	ii. Agriculture	Improvements in tree cover and soil	Periodic reports on agro-forestry	Decrease in soil erosion	Non availability of

		moisture on farmer's fields and community lands after agroforestry plantations	plantations	and surface run off	land and change in land use due to priorities of cultivators, occurrences of drought, etc.
	iii. Urban	Improvements in TOFs after plantations and condition of river banks in urban areas.	Periodic reports on TOFs	Decrease in surface run off and waste water in streams	Poor regulation of urban waste that may contaminate streams and rivers
	iv. Conservationinterventions (SMC, bioremediation, wetlands, riparian wildlife management, etc.)	Improvement in soil moisture/ ground water, wetland status, riparian wildlife in Yamuna River and its tributaries. .	Appraisal reports on soil and water conservation and other related activities	Increase in soil moisture and decrease in soil erosion and sedimentation load in stream/rivers	Occurrences of natural calamities like cloud burst, etc. and overexploitation of ground water
	v. Supportingactivities (Public awareness, capacity building, monitoring and evaluation, research, etc.)	Assessment of improvement in public awareness, their changed capacities through monitoring and evaluation and identification of research areas	Assessment of impact of trainings/demonstrations conducted on awareness of water and river conservation including research reports	Public awareness on river conservation is crucial for their rejuvenation	Lack of receptivity, interest and support for river restoration initiative in public

ANNEXURE 2

LEGISLATIONS, POLICIES, AUTHORITIES AND DEFINITIONS IN CONTEXT OF RIVER ECOSYSTEM MANAGEMENT

Table A2.1. List of various legislations, policies, authorities and definitions in context of river ecosystem management
(Refer section 1.12.2 of Ch. 1 Vol. 1)

S. no.	Applicable Law/ Policy	Relevant provisions to river management	Implications in context of river management
1.	Constitution of India	Article 21 – Right to life. Article 48A – Directive Principle of State Policy for protection and improvement of environment. Schedule VII – Legislative competence of Union and State governments.	Interpreted to include the right to clean water and the right to clean environment. The government should aim towards improvement of the environment and natural resources. The Union government has the power of regulation and development of inter- state rivers; and to implement obligations under international agreements (including agreements for the protection of the environment and biodiversity). The state government has the power to make laws relating to land use, water and water bodies. Forests and the protection of wildlife are the subject of the Concurrent List.
2.	Environment (Protection) Act, 1986	Umbrella legislation enabling the central government to develop rules and policies for the protection of environment. The central government can impose restrictions of areas in which any industries/ activities may be carried out. It can also appoint authorities for the appropriate implementation	The Rules on specific aspects are discussed below. The central government has powers to designate an area / stretch for restriction of activities, and an appropriate authority may be appointed for the protection of the region.

		of laws or protection of certain regions.	
	Environment Impact Assessment Notification, 2006	Outlines the process of conducting the environment impact assessment and obtaining environment clearance. Category A projects (with hydroelectric component ≥ 50 MW and or irrigation component ≥10,000 ha) need the clearance of the MoEFCC (after being appraised and recommended by the Expert Appraisal Authority (EAC). Category B projects (with hydroelectric component < 50 MW and ≥ 25 MW and or irrigation component <10,000 ha) require the clearance of the State Environment Impact Assessment Authority (SEIAA).	The clearance granted usually contains a list of management and mitigation measures. For river valley projects, this could be minimum flows, catchment area treatment and other management and mitigation measures.
	Wetlands (Conservation and Management) Rules, 2010	The State Government has to identify the 'protected wetlands' in the state and prepare a 'brief document' on its status. The 'protected wetlands' are ultimately notified by the Central Government on the recommendation of the Central Wetlands Regulatory Authority.	Wetlands form a critical part of river basins and affect the drainage and water quality. The wetlands along the river system should be identified and notified as 'protected wetlands'.

	Municipal Solid Waste (Management and Handling) Rules, 2000	Provides for collection, segregation and appropriate disposal of solid waste. The State Pollution Control Board is responsible for monitoring the compliance of standards of groundwater, leachates, etc.	The disposal of untreated municipal and industrial waste deteriorates the water quality. This has to be prevented, and compliance with the standards have to be strictly monitored.
	Coastal Regulation Zone Notification, 2011	Restricts activities along the coast, depending on the nature of the activity, distance from the high tide line and the level of development of the region.	A similar approach can be adopted in the case of zoning of activities along the river/stream.
3.	Indian Forest Act, 1927	Establishes the rights and powers of government authority over forests and forest products.	Applicable to the reserved forests and protected forests around the river banks. Also applicable in the context of the utilization and transportation of forest produce in these areas.
4.	Forest (Conservation) Act, 1972	No forest land can be diverted for non-forest purpose by the state government without the prior approval of the central government.	The hydrological impact for the change in land-use; especially for sensitive and vulnerable areas along river banks should be reflected in the decision-making in respect of forest clearance. Where granted, adequate management and mitigation measures should be prescribed, and strictly implemented and monitored.
5.	Wildlife (Protection) Act, 1972	Provides for protection to all species of plants and animals with special provisions of higher level of protection for specific species. Also provides for the demarcation of 'Protected Areas' for the protection of wildlife and their habitat.	The definition of 'wildlife' includes not only the identified species, but also any animal and vegetation (aquatic and terrestrial) which forms part of any habitat. The provisions of this Act could be used to demarcate and plan protection for critical stretches of the Yamuna and its tributaries for the protection of endangered species and their habitats.

6.	Water (Prevention and Control of Pollution) Act, 1974	Powers of the Central Pollution Control Board include providing guidance and technical assistance to states on prevention, control and abatement of water pollution. All industries / operations involving any sewage or waste require to obtain a consent to establish and consent to operate from theState Pollution Control Board.	Forestry interventions should be recognized as an integral approach for the improvement of water quality of the river system. Effluents and discharges from industrial and sewage units should be adequately treated and strictly monitored.
7.	Biological Diversity Act, 2002	The central government can develop strategies / plans for the conservation and sustainable use of biological resources. For areas rich in biological diversity / habitats threatened by overuse, abuse or neglect, the central government can direct the state governments to take appropriate measures. The Act also provides for cross-sectoral plans, programmes and policies. The Act provides for protection of intellectual property rights and appropriated access and benefit sharing mechanisms.	The biodiversity of the Yamuna is threatened by over-use and unregulated pollution. The Central Government may utilize the broad mandate under the Act to integrate forestry interventions for conserving the overall river biodiversity in Yamuna. Cross-sectoral plans, incorporating the forestry, hydrology, wildlife issues, and other relevant sectors to the basin should be developed Use of biodiversity resources at different levels (national, state, and local) must consider aspect of IPR and ABS for compliance.

8.	National Forest Policy, 1988	Articulates the strategies and principles of forest conservation in India. Objectives include checking soil erosion in catchment areas of rivers; soil and water conservation, controlling floods and mitigating droughts and reducing siltation of reservoirs. Recognizes that forest cover should be increased rapidly on hill slopes, in catchment areas of rivers, lakes, etc.	The policies constitute an important recognition of the close relationship between river systems and forests. The principles and strategies of the Policy should be articulated in legal and executive action.
9	National Water Policy, 2012	Acknowledges that characteristics of catchment areas of streams, rivers and recharge zones of aquifers are affected by land use and land cover changes, affecting water resource availability and quality.	
10.	Guidelines on Sustainable Sand-mining, 2015	The guidelines suggest a mandatory cumulative impact of all mining proposals. It also provides for monitoring, *inter alia*, changes in river bed, channel morphology, aquatic and riverine habitat.	The components of a river bed, like sand, boulder and gravels in the river bed play a significant role in maintaining the ecology of a river system.
11.	Guidelines on Felling and Transit Regulations for Tree Species Grown on Non-Forest Private Lands, 2014	States should develop a simple and uniform regulatory procedure of tree felling and transit pass. It also provides for a simple and decentralized methodology for maintenance of records of tree plantation, and the use of information technology to regularly update verification of plantation and felling of trees.	This will be crucial for implementation of forestry interventions along the Yamuna river and the utilization of forest produce by communities in its basin, in a sustainable manner.

12.	Guidelines for Conservation, Development and Management of Urban Greens, 2013	Integration of green areas in master plans of cities; guidelines for maintaining and enhancing tree cover; felling / removal of trees only after scientific assessment.	Relevant for mainstreaming forestry interventions for the Yamuna in urban areas.

Source: FRI (2016).

ANNEXURE 3

Letters from SFDs in Confirmation of Availability of land for DPR

OFFICE OF THE ADDITIONAL PRINCIPAL CHIEF CONSERVATOR OF FORESTS, PROJECTS & COMMUNITY FORESTRY, UTTARAKHAND

85-Rajpur Road, Dehradun.

Phone/Fax : 0135-2743604, E-mail: pccfproject-forest-uk@nic.in

Letter No. 291 / 19-1 **Dehradun, Dated,** 16 **December, 2020**

To,

Director General,
ICFRE,
P.O. New Forest,
Dehradun-248006.

Sub: **Feedback and comments on availability of land for Forestry Interventions proposed in the DPR for Rejuvenation of Rivers.**

Ref: **Your letter F.No. 41-58/2019/ADG (M&E)/ICFRE/DPR/Vol.II/113 dated 12-10-2020.**

Sir,

A discussion was held on 14th December, 2020 with the Principal Chief Conservator of Forests (HoFF), Uttarakhand, Conservator of Forests, Yamuna Circle, Dr. Dinesh Kumar, Scientist, Silviculture and Forest Management Division, FRI regarding the DPR submitted by your institution. Based on the deliberations, the following points are being placed before you for incorporation in DPR.

1- The following areas are not found suitable for implementation of described activities:-

S.No.	Name of Division	Plantation areas	soil and water conservation
1	Mussoorie Division	UID, UK-1012, UK-1112, UK-1108, UK-1219, UK-1202, UK-1298, UK-1227, UK-1180	UID, UK-1214, UK-1183, UK-1173,UK-1168, UK-1679, UK-1164, UK-1182, UK-1179, UK-1683, UK-1684
2	Chakrata Division	UID, UK-02, UK-27, UK-28, UK-30, UK-120	UID, UK-296, UK-308, UK-512, UK-306, UK-327, UK-355, UK-341, UK-326
3	Tons Division	UID, UK-56, UK-47, UK-10	-
4	Apper Yamuna Division	UID, UK-377	UID, UK-93, UK-99, UK-2300

This is based on information provided by the respected divisional forest officers.

2- It is suggested that the Decision Support System (DSS) of the MoEF & CC should also be used for selection of sites for this project.

3- The DPR should not prescribe any implementing agency for carrying out works under this project. This decision is best left for the State Govt. and the Forest Department.

4- Quantum of soil and moisture conservation works as prescribed in the DPR should be considered as indicative. The actual quantum and area of works should be arrived at based on field level hydrological assessments. The spring shed Consortium Model as is being adopted by Uttarakhand Govt. should be extended to SMC works under this project.

5- For plantation in the hills, Assisted Natural Regeneration (ANR) should be considered as the first option. In case the ANR Model cannot be adopted for any specific set of reasons, then only other models should be consider for implementation.

6- The use of pine needles for activities such as creation of check dam should be encouraged. They not only provide a effective way of conserving water and soil but also reduce the probability of forest fire and generate local livelihood opportunities.

7- The project should consider incorporating new techniques of conservation as pilot projects. This should include use of seed balls, Miyawaki technique, improved nursery techniques etc. which could serve as demonstration models for the future.

8- In addition there are certain areas provided by the Divisional Forest Officer of Mussoorie and Barkot which are enclosed for inclusion in the DPR.

You are kindly requested to incorporate the same in DPR prepared by you.

Enclosures:- As above.

Your Sincerely,

16/12/20

(Dr. Samir Sinha)
Additional Principal Chief Conservator of Forests Projects & Community Forestry, Uttarakhand

CC: -

1- Principal Chief Conservator of Forests (HoFF), Uttarakhand, Dehradun.

2- Conservator of Forests, Yamuna Circle, Dehradun with reference to your letters No. 936 dated 04-12-2020 and 993 dated 16-12-2020.

16/12/20

(Dr. Samir Sinha)
Additional Principal Chief Conservator of Forests Projects & Community Forestry, Uttarakhand

Office of
Principal Chief Conservator of Forests
(Head of Forest Force)
Himachal Pradesh Forest Department Headquarters, Talland, Shimla-171 001

No. Ft.15-642/2019(D)DPR/IRB
Himachal Pradesh Forest Department

Dated Shimla-1, the - 6 NOV 2020

To

The Director General,
Indian Council of Forestry Research & Education,
Post Office New Forest, Dehradun-248006,
Uttarakhand.

Subject: Feedback and comments on availability of land for Forestry Interventions proposed in the DPR for Rejuvenation of Rivers.

Sir,

Kindly refer to your office letter No. 41-58/2019/ADG(M&E)/ICFRE/DPR/Vol-II/113 dated 12.10.2020 on the subject cited above.

2. In this regard it is certified that land is available in the concerned Forest Divisions for proposed forestry inventions as mentioned in the Draft Detailed Project Reports (DPRs) for rejuvenation of river Yamuna prepared/finalized by the ICFRE Institute in consultation with the field officers of this department as per sites mentioned in the DPR.

Yours faithfully,

Chief Conservator of Forests (Finance) &
O/o Pr. CCF(HoFF) HP

Tel.No. 0177-2624207, 2623147, 2624186, Fax: 0177-2624192, E-mail: pccf-hp@nic.in

वन विभाग, हरियाणा सरकार
कार्यालय मुख्य वन संरक्षक, उत्तरी परिमण्डल, हरियाणा, अम्बाला।

एफ–7, वन परिसर, कम्पनी बाग, अम्बाला, दूरभाष/फैक्स +91 171 2444237, E-mail : cfnj12345@rediffmail.com

कमांक 1123 दिनांक:– 8/12/2020

सेवा में,

Sh. A.S. Rawat, IFS
Director FRI, Dehradun.

विषय : – DPR preparation for Yamuna River Through Forestry Intervention: Confirmation of availability of Land for treatment models in Haryana.

****

आज दिनांक 08.12.2020 को प्रधान मुख्य वन संरक्षक, हरियाणा का दूरभाष पर संदेश प्राप्त हुआ है कि दिनांक 03.12.2020 को उनको भेजी गई रिपोर्ट की प्रति आपको आगामी कार्यवाही हेतु भेजे जाने के लिए कहा है। इन आदेशों के निरन्तर में रिपोर्ट आपको आगामी आवश्यक कार्यवाही हेतु भेजी जाती है।

उपरोक्त/प्रति संलग्न

मुख्य वन संरक्षक, उत्तरी परिमण्डल,
हरियाणा अम्बाला।

पृ0 कमांक :– दिनांक:–

एक प्रति प्रधान मुख्य वन संरक्षक, हरियाणा, पंचकूला को सूचनार्थ प्रेषित है।

Dr. Dinesh Kumar, coordinator, Yamuner River

मुख्य वन संरक्षक, उत्तरी परिमण्डल,
हरियाणा अम्बाला।

16/12

निदेशक कार्यालय
संख्या 2822
दिनांक 16.12.20
वन अनुसंधान संस्थान, देहरादून

हरियाणा सरकार
कार्यालय वन मण्डल अधिकारी, फरीदाबाद
बाई पास रोड, नजदीक रोज गार्डन, सैक्टर–14, फरीदाबाद, दूरभाष 0129–2286760

क्रमांक 715 दिनांक 13-11-2020

सेवा में

मुख्य वन संरक्षक,
उत्तरी परिमण्डल, अम्बाला।

विषय **DPR preparation for Yamuna river through Forestry Interventions: Confirmation of availability of land for treatment models in Haryana.**

संदर्भ आपक पत्र क्रमांक 8429–8434 दिनांक 28.10.2020

उपरोक्त विषय के सम्बन्ध मे आपकों जो डी0पी0आर0 भेजी गई थी के संदर्भ में अवगत कराया जाता हैं कि उन साईट व मॉडल की टेबल में यू0आई0डी0 नं0 3311, 3295 व 3313 में फील्ड रिपोर्ट अनुसार इतनी भूमि उपलब्ध नहीं हैं, जो डी0पी0आर0 में दी गई थी तथा यू0आई0डी0 नम्बर 3289 अल्लीपुर में केवल 15 है0 जगह उपलब्ध हैं। अतः आपको इस वन मण्डल में उपलब्ध साईट वाईज भूमि की सूचि सलंग्न करके आगामी आवश्यक कार्यवाही हेतू प्रेषित हैं।

सलंग्न / उपरोक्त

उप वन संरक्षक,
फरीदाबाद।
13/11/20.

पृ0 कमांक 716 दिनांक 13-11-2020

इसकी एक प्रति वन संरक्षक दक्षिणी परिमण्डल को सूचनार्थ मुख्य वन संरक्षक, उत्तरी परिमण्डल, अम्बाला के पृ0 कमांक 8435–8441 दिनांक 28.10.2020 के संदर्भ में सूचनार्थ एवं आवश्यक कार्यवाही हेतू प्रेषित है।

उप वन संरक्षक,
फरीदाबाद।
13/11/20.

वन विभाग हरियाणा सरकार
कार्यालय उप वन संरक्षक, पलवल

भंगूरी रजवाहा निकट जवाहर नगर, कैम्प पलवल–121102
दूरभाष नं0 01275 248978, Email - dfopalwal@gmail.com

क्रमांक 617 दिनांक 13/11/2020

सेवा में,

वन संरक्षक दक्षिणी परिमण्डल
गुरुग्राम।

विषय: DPR preparation for Yamuna river through forestry interventions: confirmation o availability of land for treatment models in Haryana.

संदर्भ: मुख्य वन संरक्षक, उत्तरी परिमण्डल, अम्बाला का पत्र कमांक 8429–7434 दिनांक 28.10.2020

उपरोक्त विषय के सम्बन्ध में सदर्भांकित पत्र द्वारा मांगी गई सूचना आपको निम्न प्रकार से आगामी आवश्यक कार्यवाही हेतु प्रेषित है –

UID.	Treatment site Name	Name of Division/Range	Model Code	Model Qty.	Modal Unit	Landscape	Remark
3291	Hassanpur Un-Classed Forest	Palwal/ Hodal	YM/HY/UL-03	10	Ha.	3UL	Land available
3294	SYM/MP/Sultanpur RF.	Palwal/ Palwal	YM/HY/UL-03	10	Ha.	3UL	Land available
435	Mohna College	Palwal/ Palwal	YM/HY/UL-04	1	Ha.	3UL	Land available
442	Hassanpur Un-Classed Forest	Palwal/ Hodal	YM/HY/CI/02/B	805	M^3	4CI	Land available
441	SYM/MP/Sultanpur RF.	Palwal/ Palwal	YM/HY/CI-02/B	805	M^3	4CI	Land available

13/11
उप वन संरक्षक,
पलवल।

End/ No 918 Dated 13/11/2020
A copy is forwarded to Chief Conf. of forests, Nor. H circle, Ambala with ref. to his offi letter No 8429-8434 Dated 28/10/2020 for necessa action.

13/11
D.C.F Palwal

Acco- 885 -

कार्यालय
वन मण्डल अधिकारी, सोनीपत
वन विभाग, हरियाणा सरकार

गोहाना रोड, लघु सचिवालय सोनीपत, आपदा भवन के साथ, , दुरभाष/फैक्स : 0130–2222933, E-mail : dfosonipat@yahoo.co.in

क्रमांक 923 दिनांक 02/12/2020

सेवा में : प्रधान मुख्य वन संरक्षक (HoFF)
हरियाणा, पंचकूला।

विषय: **DPR preparation for Yamuna river through Forestry Interventions: Confirmation of availability of land for treatment models in Haryana.**

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उपरोक्त विषय के सम्बन्ध में आपको अवगत करवाया जाता है कि विषयांकित के सम्बन्ध में मांगी गई सूचना इस कार्यालय द्वारा दिनांक 19–11–2020 को मुख्य वन संरक्षक, मध्य परिमण्डल रोहतक की ई–मेल आई0डी0 **cfrohtak601@gmail.com** पर तथा वन संरक्षक, उत्तरी परिमण्डल अम्बाला की ई–मेल आई0डी0 **cfnorth@rediffmail.com & cfnotrh@yahoo.com & cfnj12345@rediff.com** पर मेल कर दी गई थी। अतः उक्त सूचना **papccf@gmail.com & cfnorth@rediffmail.com & cfnotrh@yahoo.com & cfnj12345@rediff.com & cfrohtak601@gmail.com** पर पुन: ई-मेल द्वारा भेजी जाती है।

संलग्न/उपरोक्त

वन मण्डल अधिकारी,
सोनीपत।

पृ0क्रमाक : 924 दिनांक : 02/12/2020

इसकी एक प्रति मुख्य वन संरक्षक उत्तरी परिमण्डल, अम्बाला को सूचनार्थ एवं आगामी आवश्यक कार्यवाही हेतु प्रेषित है।

वन मण्डल अधिकारी,
सोनीपत।

Dr Divisha

OFFICE OF
DEPUTY CONSERVATOR OF FORESTS, PANIPAT
Forest Department, Government of Haryana

Forest Complex, Arya Nagar Near Assandh Road, Panipat, Ph./Fax 0180-2650331 E-Mail dfopanipat04@yahoo.co.in

No. 1028 Dated 02-12-2020

To

The Chief Conservator of Forests,(Nodal Officer)
North Circle, Ambala.

Sub.: DPR preparation for Yamuna River Trough Forestry Interventions: Confirmation of availability of Land for treatment models in Haryana.

Ref. Your Letter No. 8429-8434 dated 28/10/2020

Reference to the subject cited above it is informed that the availability of land for treatment models in Samalhka Range of Panipat Forest Division under Agriculture Landscape & Natural Landscape is as follows:-

Agriculture Landscape

Sr.No.	Village_Name	Initially Proposed	Present Scope
1	Hathwala	111Ha.	10 Ha.
2	Rakshera	71Ha.	0 Ha.
3	SanoliKhurd	18Ha.	2 Ha.
4	RanaMajra	19Ha.	2 Ha.
5	Nawada-R	16Ha.	7 Ha.
6	Goyala&MirjaPur	20Ha.	5 Ha.
7	Nanera	16Ha.	5 Ha.
8	GoyalaKhurd	20Ha.	5 Ha.
9	Adhmi	16Ha.	4 Ha.

Natural Landscape

Sr.No.	Name of Site	Initially Proposed	Present Scope
1	DikadlaKurkul to Yamuna River Road	7Ha.	0 Ha.
2	Yamuna Bund RanaMajra to Drain No.2	18Ha.	0 Ha.

Deputy Conservator of Forest,
Panipat.

Endst No. Dated

A copy is forwarded to Chief Conservator of Forests, Central Circle, Rohtak for information and necessary action.

Deputy Conservator of Forest,
Panipat.

Forest Department, Govt. of Haryana

O/o : Divisional Forest Officer (T), Karnal,

Forest Complex, Near Railway Station, Karnal, Tel./Fax No. : 0184-2241417, E-mail : dfokarnal@yahoo.co.in

Letter No. :- 1632 Dated :- 26/11/2020

To,

Chief Conservator of Forests,
North Circle Ambala.

Subject :- DPR preparation for Yamuna river through Forestry Interventions: Confirmation of availability of land for treatment models in Haryana

Ref:- Your Office letter no. 8429-8434 dated 28-10-2020.

----------X----------

With reference to the above citied subject that DPR produce in orginal & confirm. There is no change in the site & target. This is for your kind information.

ADFO
Dy. Conservator of Forests,
Karnal.

वन विभाग हरियाणा
कार्यालय : उप वन संरक्षक, क्षेत्रीय वन मण्डल,
वन परिसर, यमुनानगर दूरभाष न0 01732–237821

कमांक 1905 दिनांक 17-11-2020

सेवा में

मुख्य वन सरक्षक, उत्तरी परिमण्डल,
अम्बाला ।

विषय:– DPR Prepparation for Yamuna River through Forestry Intervention : Confirmation of availability of land for treatment models in Haryana.

संदर्भ आपका पत्र कमांक 8429–8434 दिनांक 28.10.2020 ।

उपरोक्त संदर्भाकित पत्र के सम्बन्ध में आपको अवगत करवाया जाता है कि सदर्भाकित पत्र द्वारा भेजी गई डी0पी0आर0 में सढौरा, छछरौली तथा कलेसर की साईट सही पाई गई है । इन रेजों की साईट में किसी प्रकार का कोई बदलाव नही है । जगाधरी रेज के केवल दो माडल के कार्य ही डी0पी0आर0 में सम्मलित है । जगाधरी रेज के शेष कार्य सलग्न विवरणी अनुसार डी0पी0आर0 में सम्मलित कर लिये जाये । उपरोक्त कार्यों के लिये खाली जगह उपलब्ध है ।

17/11

उप वन सरक्षक
यमुनानगर

दूरभाष कमाक दिनाक 17-11-2020

एक प्रति सर्व वन राजिक अधिकारी, को इस कार्यालय के पत्र कमांक 2782–85 दिनांक 13.11.2020 के संदर्भ में सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित है।

उप वन सरक्षक
यमुनानगर

E-mail : apccfproject123@gmail.com

कार्यालय अपर प्रधान मुख्य वन संरक्षक, परियोजना, उत्तर प्रदेश, लखनऊ

पत्रांक– 59 दिल्ली/31–1 (यमुना), लखनऊ, दिनांक 28 दिसम्बर, 2020

सेवा में,

निदेशक, वन अनुसंधान संस्थान,
देहरादून, उत्तराखण्ड।

विषयः– **DPR Preparation for Yamuna River through Forestry Interventions: Confirmation of avialablity of land for treatment models in Uttar Pradesh.**

संदर्भः– वन अनुसंधान संस्थान, देहरादून का पत्रांक– 3–30/19/पी0एस0अई0यू0/सिल्वा, दिनांक 04.12.2020 एवं इस कार्यालय का पत्रांक– 08/31–1 (यमुना), दिनांक 09.12.2020 तथा वन अनुसंधान संस्थान, देहरादून के ई–मेल दिनांक 18.12.2020 एवं ई–मेल दिनांक 24.12.2020।

महोदय,

उपर्युक्त विषयक वन अनुसंधान संस्थान, देहरादून के संदर्भित पत्र दिनांक 04.12.2020 द्वारा की गयी अपेक्षा के क्रम में 11 वन प्रभागों (आगरा, इटावा, औरैया, कानपुर देहात, फतेहपुर, गौतमबुद्धनगर, गाजियाबाद, झाँसी, ललितपुर मेरठ तथा उरई (जालौन)) द्वारा भूमि की उपलब्धता पुष्टि एवं जी0पी0एस0 कोआर्डिनेट्स के सम्बन्ध में अपेक्षित सूचना सीधे आपको प्रेषित करते हुए इस कार्यालय को भी अवगत कराया गया है इस कार्यालय के संदर्भित पत्र दिनांक 09.12.2020 द्वारा उक्त 11 वन प्रभागों की भूमि की उपलब्धता पुष्टि एवं जी0पी0एस0 कोआर्डिनेट्स के सम्बन्ध सूचना आपको प्रेषित की गयी है।

वन अनुसंधान संस्थान, देहरादून के उपरोक्त ई–मेल दिनांक 18.12.2020 द्वारा अवगत कराया गया है कि सभी वन प्रभागों से यमुना नदी के प्रस्तावित डी0पी0आर0 के अन्तर्गत उपचार (Treatment) हेतु भूमि की उपलब्धता का पुष्टिकरण (Confirmation of Avialablity of Lanc) सम्बन्धी सूचना प्राप्त हो गयी है। परन्तु अपेक्षा की गयी है कि भूमि की उपलब्धता का पुष्टिकरण (Confirmation of Avialablity of Land) के सम्बन्ध में एक पुष्टिकरण पत्र (Confirmation Letter) प्रेषित किया जाये।

अतएव उक्त ई–मेल दिनांक 18.12.2020 एवं दिनांक 24.12.2020 के क्रम में यमुना नदी के प्रस्तावित डी0पी0आर0 के अन्तर्गत उपचार (Treatment) हेतु सभी वन प्रभागों से प्राप्त सूचना के आधार पर भूमि की उपलब्धता के सम्बन्ध में पुष्टि की जाती है। तदनुसार सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित।

भवदीय

28/12/2020
(के0 पी0 दूबे)
अपर प्रधान मुख्य वन संरक्षक, परियोजना,
नोडल अधिकारी (यमुना),
उत्तर प्रदेश, लखनऊ।

पत्रांक– 59 /उक्तदिनांकित।

प्रतिलिपि निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषितः–

3. निदेशक, Forest Research Center For Ecorehabilitation, प्रयागराज।
4. डॉ0 कुमुद दूबे, वैज्ञानिक (ई), Forest Research Center For Ecorehabilitation, प्रयागराज/ नोडल अधिकारी, DPR Preparation for Rejuvenation of Yamura River Thorugh Forestry Interventions, FRI, Dehradun को सूचनार्थ प्रेषित।

28/12/2020
(के0 पी0 दूबे)
अपर प्रधान मुख्य वन संरक्षक, परियोजना,
नोडल अधिकारी (यमुना),
उत्तर प्रदेश, लखनऊ।

पत्रांक– 59 /उक्तदिनांकित।

प्रतिलिपि निम्नलिखित को सूचनार्थ प्रेषित –

1. प्रधान मुख्य वन संरक्षक और विभागाध्यक्ष, उत्तर प्रदेश, लखनऊ।
2. प्रधान मुख्य वन संरक्षक, वन्यजीव, उत्तर प्रदेश, लखनऊ।

28/12/2020
(के0 पी0 दूबे)
अपर प्रधान मुख्य वन संरक्षक, परियोजना,
नोडल अधिकारी (यमुना),
उत्तर प्रदेश, लखनऊ।

E:\DESKTOP SHORTCUT\NAMAMI GANGE\Namami Gange Document\Namami Gange APCCF Letter

Tel.No. 0177-2624207, 2623147, 2624186, Fax: 0177-2624192, E-mail: pccf-hp@nic.in

कार्यालय मुख्य वन संरक्षक, भरतपुर

कमांक एफ ( ) विकास/यमुना डीपीआर/मु.व.सं.भ./20–21/4506 दिनांक 29.10.2020

निमित्त,

निदेशक,
वन अनुसंधान संस्थान,
पो.ऑ. न्यू फॉरेस्ट, देहरादून
पिन –248006

विषय :– Preparation of Detailed Project Report (DPR) for Rejuvenation of Yamuna through Forestry Interventions.

संदर्भ :– आपका पत्र कमांक 3–30/19–पीएसआईयू/सिल्वा दिनांक 16.10.2020

महोदय,

उपरोक्त विषयान्तर्गत निवेदन है कि संदर्भित पत्र द्वारा यमुना नदी के कायाकल्प के कार्यान्वन के लिए वन भूमि पर प्रस्तावित कार्यो के सम्बन्ध में भूमि उपलब्धता की सहमति चाही गयी है। डी.पी.आर. में सम्मिलित उक्त प्रस्तावित कार्य वन अनुसंधान संस्थान, देहरादून से दिनांक 25 मई, 2020 को प्राप्त यमुना डी.पी.आर. प्रारूप (पार्ट राजस्थान) में सम्मिलित हैं।

अतः यमुना नदी कायाकल्प प्रोजेक्ट हेतु चाही जा रही भूमि उपलब्धता बाबत वनमण्डलवार निम्न तालिका अनुसार सहमति (Conset) प्रदान की जाती है :–

क्र.सं.	जिला	वनमण्डल	भूमि	क्षेत्रफल(हे0)	साईट(ना0)
1	बांरा	उप वन संरक्षक, बारॉ	कृषि	300	17
2	बांरा	उप वन संरक्षक, बारॉ	वन	7744.15	68
3	भीलवाडा	उप वन संरक्षक, भीलवाडा	कृषि	11.30	24
4	भीलवाडा	उप वन संरक्षक, भीलवाडा	वन	660.71	254
5	बूंदी	उप वन संरक्षक, बूंदी	वन	1450	14
6	धौलपुर	उप वन संरक्षक, धौलपुर	वन	1460	26
7	झालावाड	उप वन संरक्षक, झालावाड	वन	3230	19
8	करौली	उप वन संरक्षक, करौली	वन	400	68
9	बूंदी	उप वन संरक्षक, मुकंदरा हिल्स टाईगर रिजर्व, कोटा	वन	100	6
10	कोटा	उप वन संरक्षक, मुकंदरा हिल्स टाईगर रिजर्व, कोटा	वन	25	9
11	झालावाड	उप वन संरक्षक, मुकंदरा हिल्स टाईगर रिजर्व, कोटा	वन	400	3
12	चित्तौडगढ	उप वन संरक्षक, कोटा (वन्यजीव) भैंसरोडगढ अभ्यारण	वन	650	18
13	बूंदी	उप वन संरक्षक, कोटा (वन्यजीव) रामगढ अभ्यारण	वन	0	5
14	बांरा	उप वन संरक्षक, कोटा (वन्यजीव) शेरगढ अभ्यारण	वन	150	4
15	राजसमंद	उप वन संरक्षक, राजसमंद (वन एवं वन्यजीव)	वन	999	156

16	राजसमंद	उप वन संरक्षक, (राजसमंद वन एवं वन्यजीव)	कृषि	20	1
17	राजसमंद	उप वन संरक्षक, (राजसमंद वन एवं वन्यजीव)	शहरी (Urban)	8	3
18	सवाईमाधोपुर	उप वन संरक्षक, बनास नदी परियोजना, सवाईमाधोपुर	वन	0	12
19	सवाईमाधोपुर	उप वन संरक्षक, सवाईमाधोपुर	वन	2500	84
20	टोंक	उप वन संरक्षक, टोंक	वन	0	13
21	टोंक	उप वन संरक्षक, टोंक	कृषि	48	38
22	टोंक	उप वन संरक्षक, भू-संरक्षण परियोजना, टोंक	कृषि	51	51
23	कोटा	उप वन संरक्षक, राष्ट्रीय चम्बल अभ्यारण, सवाईमाधोपुर	वन	2747	59
24	बूंदी	उप वन संरक्षक, राष्ट्रीय चम्बल अभ्यारण, सवाईमाधोपुर	वन	2660	54
25	सवाईमाधोपुर	उप वन संरक्षक, राष्ट्रीय चम्बल अभ्यारण, सवाईमाधोपुर	वन	3000	60
26	करौली	उप वन संरक्षक, राष्ट्रीय चम्बल अभ्यारण, सवाईमाधोपुर	वन	3500	70
27	धौलपुर	उप वन संरक्षक, राष्ट्रीय चम्बल अभ्यारण, सवाईमाधोपुर	वन	5500	110
28	करौली	उप वन संरक्षक, उप क्षेत्र निदेशक, बाघ परियोजना, रणथम्भौर (द्वितीय), करौली	वन	220	7

भवदीय

(जी. वी. रेड्डी)
प्रधान मुख्य वन संरक्षक (हॉफ)
राजस्थान, जयपुर

क्रमांक एफ ( ) विकास/यमुना डीपीआर/मु.व.सं.भ./20–21/4507–31 दिनांक 29.10.2020

प्रतिलिपी :– निम्न को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित है :–

1. अति. प्रधान मुख्य वन संरक्षक, (विकास)/(भू–संरक्षण), राजस्थान, जयपुर।
2. मुख्य वन संरक्षक, अजमेर/एफपीआरपी, जयपुर/उदयपुर/कोटा/कोटा (वन्यजीव)/आर.टी.आर. सवाईमाधोपुर।
3. उप वन संरक्षक, बांरा/भीलवाडा/बून्दी/धौलपुर/झालावाड/करौली/मुकन्दरा हिल्स टाईगर रिजर्व, कोटा/कोटा (वन्यजीव) /राजसमंद (वन्यजीव)/बनास नदी परियोजना, सवाईमाधोपुर /टोंक /सवाईमाधोपुर/भू-संरक्षण, टोंक/एनसीएस, सवाईमाधोपुर/आर.टी.आर. ॥ सवाईमाधोपुर

को प्रेषित कर लेख है कि आप द्वारा निदेशक, वन अनुसंधान संस्थान, देहरादून को यमुना प्रोजेक्ट हेतु प्रेषित प्रस्तावों के कम में वन/कृषि/शहरी भूमि पर कार्य हेतु प्रोजेक्ट सहमति प्रदान की जा रही है। अतः यह सुनिश्चित करावें कि आप द्वारा उक्त योजना में प्रेषित प्रस्तावित वन/कृषि/शहरी भूमि को अन्य किसी योजना में प्रस्तावित नहीं किया जावे एवं कार्य भी नहीं किया जावे।

प्रधान मुख्य वन संरक्षक (हॉफ)
राजस्थान, जयपुर

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Phone:0755-2674216, Fax:2674339, Email:apccfdev@mp.gov.in

No./ 3723 Dated 13/11/2-20

To,

Shri Arun Singh Rawat, I.F.S.
Director, Forest Research Institute
and Vice Chancellor,
FRI Deemed to be University
P.O. New Forest Dehradun-248003

Sub.: DPR preparation for Yamuna river through Forestry Interventions: Confirmation of availability of land for treatment models in Madhya Pradesh.

Ref.: Your letter No.3-30/19-PSIU/Silva dated 22-09-2020.

This is with reference to MOEF&CC sponsored project on Preparation of DPR on forestry interventions for the rejuvenation of river Yamuna. It is hereby confirmed that the lands of various divisions included in Detailed Project Report prepared by Forest Research Institute, Dehradun for forestry interventions are available, as per the reports received from the field units.

Dr. Dinesh Kumar, Coordinator, Yamuna DPR

2/11/2020

(Chitranjan Tyagi)
A. P.C.C.F, (Development)
Madhya Pradesh, Bhopal

6/11/2020



ADDENDUM

(To be incorporated in chapters in the final DPR)

A. Other important considerations during implementation of DPR (to be included in Chapter 5. Section 5.13)

- The priority of species in a model may vary with micro environment. The species may, therefore, be selected based on local site conditions, objective and availability of planting material. Hence, the species under various models are not listed in order of priority. A species not listed under a model can also be planted if it is expected to perform well based on experience or technical literature.
- In Uttar Pradesh, *Dendrocalamus strictus* may not be planted in natural landscape owing to its poor performance in many areas. Other species of namoo such as *Bambusa balcooa, B. nutans, Dendrocalamus hamiltonii, D. giganteus,* etc. that are being planted under National Bamboo Mission, may be planted.
- Assisted natural regeneration (ANR) model may be considered as the principal treatment model for plantation activities in hills of Uttarakhand state and, as far as possible, this model may be adopted as first option in the forest areas. Other plantation models may be adopted only in such areas where ANR cannot be implemented.
- Decision support system of MoEF&CC may be used for finalisation of sites during implementation of the project.
- The quantum of soil and moisture conservation (SMC) works in the DPR may be considered as indicative. The area mentioned in the DPR under SMC works is purely notional in all states. The actual quantum and area of works in Uttarakhand should be decided on the basis of field level hydrological assessments. The spring shed Consortium Model as is being used by Uttarakhand government should be extended to the SMC works in this state under the project. GIS mapping may be done for designing and mapping of SMC works.
- Use of pine needles for making check dams may be encouraged in the hills of Uttarakhand and Himachal Pradesh. This provides an effective may of conserving soil and water, reduces probability of forest fire and generates local livelihood opportunities.
- Inaccessible and difficult areas may be identified for assigning to Eco Task Force for treatment. Model and geo-location of suitable site may be suggested.
- For urban landscape, detailed specifications such as design and implementation of models may be prescribed with indicative percentage of parts of work. The use of cement concrete will be minimised, stone would be preferred to RCC wherever stone can replace RCC. The RCC work would not cover more than 15 per cent area. Green spaces and water bodies would occupy at least 70 per cent area.



Fig. A specimen Eco-park (https://ta.m.wikipedia.org/wiki, Longwanqun National Forest Park Creek, China)

- For check dam, pond and wetland development, local, low-cost material must be used.
- For wildlife management and wetland management models, detailed diagram and design with indicative percentage of parts of work may be provided.



Fig. Components of Chambal Wildlife Sanctuary

In riparian wildlife management, the land area and water bodies may constitute about 50-80 percent and 20-50 of the treated area respectively. In wetland management, the land area and water bodies may constitute about 10-40 percent and 40-90 of the treated area respectively. Built up area will not be created in these two models under the project.

- Use of improved water management technologies such as sprinkler system, drip irrigation, etc. may be suggested in agricultural land for agroforestry.
- Species with high water use efficiency may be used for planting in forest and non-forest areas.

B. Ongoing and Proposed Schemes in Delhi NCT (To be included in Chapter 3, Section 3.3)

Delhi Development Authority (DDA) has already taken up the restoration and rejuvenation of floodplain of Yamuna in areas falling under the jurisdiction of DDA from Wazirabad barrage to Okhla barrage. A total of ten projects (Table 1) have been taken up and work is being carried out on directions and guidelines of the Principal Committee of experts constituted by the Hon'ble National Green Tribunal (reference letter no. PS/PC (Pers./Hort./LS)2020/DDA/28 dated 27 January 2020 of Principal Commissioner (Pers./Horticulture/Landscape), DDA, New Delhi). 300 m wide green buffer of plantation of riverine ecology of Riparian species. 150 m wide greenway where some recreational activities are permitted is being developed for public interface with kachcha walkways and open spaces. The existing depressions and detention basins are being restored and deepened for water augmentation and ground water recharge. The areas having potential to be developed as Biodiversity parks are being developed as Biodiversity parks on the line of Yamuna Biodiversity park, upstream of Wazirabad. Work has been entrusted to Prof. C.R. Babu and his team from CEMDE. The wetlands will be treated for the cleansing of waste water passing in the drains through floodplains of River Yamuna, Prof. Gauhar Mehmood, Wetland expert from Jamia Millia Islamia University has been taken on board for the consultancy. Indigenous species are only proposed in the total stretch to control the soil erosion and to improve the ecology and micro climate in the catchment areas of Yamuna.

Table 1. Summary of projects taken up by DDA on directions and guidelines of the Principal Committee of experts constituted by the Hon'ble National Green Tribunal

Sr No	Project	Area	Proposal/Design Intent
1.	Old Railway Bridge to ITO Barrage (Western Bank)- **Asita West**	200 Hectares	1. The proposal of the area of 100-150 m of greenway that consists of cycle track, pedestrian pathways are proposed to be restored as water nodes and the area along the river is to developed as green buffer up to 50 to 300 m. 2. A separate zone for the treatment of the waste water from the Shantivan Drain has been proposed by the means of constructed wet lands and phytoremediation.
2.	Geeta Colony Bridge to ITO Barrage (Western Bank) **Eco-Tourism Bundh**	30 Hectares	1. It was recommended by the Principal Committee of Hon'ble NGT that the fly ash dumps of the Rajghat Power Plant have to be completely removed and the area should be detoxified. 2. DDA suggests in its proposal to use the existing low lying area to be capacitated into a waterbody collecting water from surface

			runoff and treated water from the drain entering from Memorial complex side connecting to River through underneath the bridge, to develop them for recreational purpose like boating. 3. The area falls outside 1 in 25 years floodplains, DDA also proposes to setup a River museum and an Oceanarium in this area for promoting education, public awareness and Eco-Tourism. 4. The land area is proposed to be a compliment to the ecological aspect of the site as the idea is to develop it into a domain of Eco-tourism for the city people to enjoy the natural landscape design features by way of Eco-tourism activities. 5. To verify the justification of detoxification, soil testing in a ash dyke vis-a-vis on filled up good earth has been taken up on experimental basis on one acre piece of land respectively. The results will be submitted to Wetland Consultant for suggesting the remedial measures/suggestion(s) for further treatment and testing for its efficiency accordingly the work for construction of water body will be taken up.
3.	Old Railway Bridge (Eastern Bank)- **Asita East**	**PART A:** 90 Hectares land within DDA's jurisdiction **PART B:** 107 Hectare with UP irrigation Department	**PART A:** This site has been divided into four zones namely — ecological zone, human-nature interactive zone, public recreational zone and eco-urban linkage. **Ecological zone** proposed along the river edge would comprise of 20-25mts of marsh area adjoining which would be floodplain forests and grasslands. It also aims to restore the existing depressions and restore them as catchment wetlands to store the flood waters and also to improve the groundwater recharge. These wetlands have been kept natural and no construction has been allowed on the floodplains as per the directions of the Hon'ble NGT. **Human-nature interactive zone** would comprise of congregational spaces with bamboo shelters and floodplain forest and grasslands.

			Public recreational zone will have facilities like kid's play areas, recreational waterbodies with cross-over bridges, watch towers made of bamboo. **The Eco urban linkage** would serve as the link between the river, floodplains and the zone beyond the floodplains. **PART B:** Financial bids have been opened and L-l decided but the award of work is held up for deposition of fund by U.P. irrigation department.
4.	NH24 to DND Flyway **(Western Bank)**	**PART A:** Approx. 100 Hectares (Incl. 25 Ha Art of Living area **PART B:** Remaining area is presently occupied by construction activities for DMRC & PWD and other	**Part A:** Sludge forming due to the water from the drains mixing with the rainwater is found to be maximum in this stretch. Thus the 300 m along the River Yamuna will be developed as a **green buffer** with its edge planted with species of riverine ecology and species that can sustain the prevailing sub-surface conditions. The connection between the Barapullah drain with River Yamuna will be revived once the pilot project for the treatment of the waste water in the Barapullah Drain is treated. Thus a **wetland system** has been proposed spreading throughout the site which would collect treated water from the Barapullah drain and then flow from this wetland system and finally into River Yamuna. Approximately 150mts along the DND Flyway has been proposed that includes the greenway with vehicular access way and cycleway in rammed earth and pathways in murram lined with trees and grasses suitable for the soil and conditions. Adjoining the Groundwater greenway interactive spaces for multi-functional activities are arranged along the proposed wetland system. **Part B:** Permanently and temporarily allotted to various agencies like DMRC, PWD, and Delhi Transco, etc. for infrastructure projects. Need to be restored to its original condition first after repossessing of the allotted land since a-lot of concretization and damage to the floodplains has taken place due to batching plants and other related construction activities.

		agencies.	
5.	DND to proposed Kalindi By-pass **(Western Bank)-Khijrabad**	115 Hectares Entrusted to CEMDE	The work is being executed in the supervision of Prof. C.R. Babu. The construction of constructed wetlands for treatment of sewage water from incoming drains. Water hyacinth and *Alternanthera* has been removed from wetlands covering an area of 25 ha. The de-weeding of waterbodies has reduced the mosquito populations. In some wetlands, after removal of water hyacinth, lemna has been growing and removing high levels of nitrates and phosphates from the sewage water and hence improvement in the quality of polluted water. This also serves as a food material for aquatic birds. In these wetlands fish that feed on detritus has also been recorded. Some of the wetlands, where Water hyacinth was removed, has already been attracting birds. **Greenway and recreational park development** A small stretch of 500 m long and 10 m wide strip along the Ashram Road has been planted with 300 plants. A large solid waste dump behind the Kalindi Colony has been landscaped and this is being developed into a recreational park. **Development of Nature Trails** Two nature trails - one trail from Ashram Road to DND Flyover has been made; both sides of this nature trail would be developed into a greenway. **Development of Terrestrial Communities** About 20 ha of elevated portion beneath the DND flyover has been prepared for planting 15000 saplings of native trees.
6.	NH-24 to DND Flyway **(Eastern Bank) Part Area-1**	**PART A:** 28 hectares approx. of land has been allotted for compensato	**PART A:** 28 hectares approx. of land has been allotted for compensatory plantation 1. Site analysis and studies carried out. Design development under progress.

		ry plantation 1. Site analysis and studies carried out. Design developmen t under progress. **PART B:** Request for release of funds has been sent to the UP Irrigation Department for 162.75 Ha of land on the basis of thumb rule (tentative) costing	**PART B:** Request for the release of funds has been sent to the UP Irrigation Department for 162.75 Ha of land on the basis of thumb rule (tentative) costing,
7.	NH-24 to DND Flyway **(Eastern Bank) Part Area-II-Hindon Cut Wetlands I&II**	45 Hectares (15 Ha with DDA+30 Ha with UP) Entrusted to CEMDE	Water hyacinth from both the wetlands has already been removed.
8.	Wazirabad Barrage to ISBT Bridge **(Eastern Bank)** around Garhi Mandu Village & Usmanpur Village	236.5 Hectares	1. The entire area remains inundated for long periods of time after the monsoons. 2. DDA has already planted trees in 25 Ha. of an area near Signature Bridge, and two wetlands have been cleared of hyacinths. 3. The design development of the entire area is under process.
9.	Wazirabad to Old Railway Bridge **(Western Bank)**	66 Hectares	1. As recommended by the Principal Committee of Hon'ble NGT, the area entrusted to INTACH, as the area has historical and cultural significance. 2. Drawings for Qudsia Ghat of an area 16.4 Ha

			has been issued and the estimate is under preparation and the work is proposed to be completed by June 2020. 3. Area of Sur Ghat (13.6 Ha) is being taken up and which will be submitted for estimation purpose soon. 4. The area along the River edge to be afforested and proposed for River walk and Eco-Trail, will also be submitted at the earliest. 5. The area of 32 Ghats involving interdepartmental coordination and demolition of encroachments and unauthorized structures, revival of cultural activities and redevelopment of Ghats is under study and analysis.
10.	ITO to NH-24 **(Eastern Bank)** - Area south of Commonwealth Games Village Area	90 Hectares	1. The comprehensive master plan was developed to create ecological green infrastructure by creating a series of wetlands for water augmentation and planting riparian community of riverine ecology. 2. To increase the water augmentation, receding time f flood water is reduced by creating areas of recharge zones which eventually would turn into an ecological pockets with indigenous species. 3. The flowing water channels will also have Gabion walls and phytoremediation methodology for the treatment of water. 4. Boardwalks have been strategically designed that would give the public a controlled access throughout the site to provide connect to the River without hampering the ecology (flora and fauna) at site. The elevated Boardwalks will be taken up in the second phase on account of high expenditure and maintenance involved.

The total recorded forest area in Delhi is 102 km^2 i.e. 6.88% of the geographic area of which the Reserved and Protected Forests constitute 76.48% and 23.52% of the total forest area respectively. The forest cover of Delhi has increased from 192.41 km^2 to 195.44 km^2 during 2017-2019. The Forest department is working to increase the forest and tree cover in Delhi to 371 km^2 by the end of 2022.

Hence, additional works are not proposed by Delhi NCT under the DPR on rejuvenation of Yamuna river through forestry interventions. However, work on rehabilitation of existing water and soil conservation structures is proposed by the DPR in the catchment area of Yamuna in Delhi state.



For Further Details,
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