National Green Highways Mission

Best Management Practices Manual for

GREEN HIGHWAYS

सत्यमेव जयते
Ministry of Road Transport and Highways
Government of India

National Green Highways Mission
National Highways Authority of India
Ministry of Road Transport & Highways

नितिन गडकरी
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सत्यमेव जयते

मंत्री
सड़क परिवहन, राजमार्ग
एवं पोत परिवहन
भारत सरकार
नई दिल्ली–110 001

MINISTER OF ROAD TRANSPORT,
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MESSAGE

National Highways are the lifeline of Indian road infrastructure. These are valued and shared assets which promote tourism, facilitate trade and bridges geographical divide. Therefore it becomes responsibility of government and people to join hands to keep the highways green, clean and pollution free. To address this, Ministry of Road Transport and Highways has recently promulgated the **Green Highways (Plantations, Transplantations, Beautification and Maintenance) Policy – 2015** for developing green corridors along the National Highways contributing towards better environment and meeting the CoP 21 commitment of India.

Roadside plantation is a worldwide phenomenon due to growing awareness amongst masses on environmental degradation and pollution. Several countries in the world have practiced diverse ways to protect highways of damaging effects of climate change and have been able to institutionalize it. A wide range of best practices are prevalent globally with respect to roadside plantations. These practices have been in execution for many decades and have been vital in preserving the environment around National Highways.

The Green Highways Policy 2015 provides an institutional approach for undertaking highways plantations. I am pleased that National Green Highway Mission has taken the initiative to collate best practices on greening of highways across the world in one document. This is a great step towards building collective knowledge base. I am also happy to learn that NGHM would review these documented and existing best practices worldwide for green corridor development, adapt and test these practices in Indian context. The manual on Best Management Practices for Greening Highways is a commendable effort which nicely captures the global best management practices with respect to the roadside plantations.

I would congratulate the Mission leadership and staff for this endeavor and would look forward to its being widely disseminated across India and across the globe to facilitate mutual learning and sharing.

(Nitin Gadkari)

PREFACE

Highways are acknowledged as the growth engine of economic development. National Highways account for only 2% of Indian road network but carries 40% of the automobile traffic which signifies its importance in the country's economy. They are an integral part of the physical environment and socio-economic milieu.

Clearance of forest and tree felling activities for highways development along with incessant movement of vehicles contribute towards environmental degradation. Considering the importance of road network in our lives and at the same time damage caused to the environment due to overuse of road network, Ministry of Road Transport and Highways (MoRTH), Government of India promulgated **Green Highways (Plantations, Transplantations, Beautification and Maintenance) Policy 2015** to develop green corridor along National Highways. **National Green Highways Mission (NGHM)** under National Highways Authority of India (NHAI) has been entrusted with the task of planning, implementation and monitoring roadside plantations along one lakh km network of National Highways.

However in India, GHP 2015 and approach of green corridor development is a new concept but in many countries this concept is being practised in more institutionalised way to combat environmental degradation and pollution. Therefore, it was decided that instead of reinventing the wheel, NGHM would review existing best practices worldwide for green corridor development, localize & test them and finally scale them up. As first step in this direction, NGHM decided to prepare a manual of Best Management Practices worldwide including India and develop Green Highways Management Charter to be followed for green corridor development. Manual has been developed by NGHM team with consultations and inputs from specialised organizations including ICFRE, NEERI, IIFM, NHAI, Forest Departments etc.

This manual will support and give direction to the NGHM team, NHAI officials and Plantation Agencies on suitable best practices for green highways projects in their area undertaking good plantation and management through the given approaches.

This document is just the beginning of the process and in the coming years, extensive research and testing of innovations will be done by NGHM. Some of the innovations might be replicated in large scale across the world. This document will be updated on regular basis and NGHM would always be open to incorporate any new practice or innovation in the manual and as part of the Green Highways Management Charter.

It is my pleasure to bring out the Best Management Practices Manual for Green Highways in the public forum. I hope that it will be a well-read addition to the documents on bringing together BMPs across worldwide at one place for easy reference. This document will essentially redefine the way forward for green corridor development.

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Author's Disclaimer:

The Authors have generously borrowed, quoted and adapted from cited references. Any unintended errors are regretted.

Any feedback / suggestion to this BMP manual are welcome.

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ABBREVIATIONS

- BMP: Best Management Practices
- CA: Compensatory Afforestation
- CCPs: Coal Combustion Products
- CIBRC: Central Insecticides Board and Registration Committee
- COEHD: Center for Community Health and Development
- CoP: Conference of Parties
- CSA: Canopy Surface Area
- DPR: Detailed Project Report
- FHWA: Federal Highway Administration
- FD: Forest Department
- FDC: Forest Development Corporation
- FSSAI: Food Safety and Standards Authority of India
- GHG: Green House Gases
- GHP: Green Highways Partnership
- GHP 2015: Green Highways Policy 2015
- GCRS: Green Corridor Rating System
- GoI: Government of India
- ICOMOS: International Council on Monuments and Sites
- IHMCL: Indian Highways Management Company Limited
- IRC: Indian Road Congress
- IRVM: Integrated Roadside Vegetation Management
- JFMCs: Joint Forest Management Committees
- LID: Low Impact Development
- MGNREGA: Mahatma Gandhi National Rural Employment Guarantee Act
- MnDoT: Minnesota Department of Transport
- MoRTH: Ministry of Road Transport and Highways

- MoEF: Ministry of Environment and Forests
- MoRD: Ministry of Rural Development
- NHAI: National Highway Authority of India
- NHM: National Horticulture Mission
- NGHM: National Green Highways Mission
- NGOs:: Non Government Organisations
- PennDoT: Pennsylvania Department of Transportation
- PSU: Public Sector Unit
- RO: Regional Officer
- RET: Rare Endangered & Threatened
- RMS: Road and Maritime Studies
- ROW: Right Of Way
- SHGs: Self Help Groups
- SI: Stomatal Index
- SoR: Schedule of Rates
- SPM: Suspended Particulate Matter
- TMPs: Tree Management Plan
- TPC: Topmix Permeable Concrete
- Usar: Alkaline soil

1. INTRODUCTION

Trees provide various ecosystem services such as biodiversity conservation, abetment of pollutants, oxygen generation, noise reduction, mitigation of "heat islands" effects, micro climate regulation, soil stabilization, ground water recharge, prevention of soil erosion, carbon sequestration, aesthetic appearance, and many more (Hosur, 2016). Trees are capable of providing a temperature difference of 4-10°C from heat waves of summers (Pradines, 2009).

Highways development projects in India have overlooked and undervalued the environment specifically plantations which have long term intangible benefits which are shared globally. Number of vehicles has been growing at an average pace of 10.16% per annum (National Highway Authority of India, 2016). Though plantation is one of the elements of highway constructions & expansion projects but so far Detailed Project Reports (DPRs) were focused on widening of roads to accommodate the ever increasing vehicles compromising on the quality of plantations. Most of the plantations done so far were neither of the expected quality nor had been managed properly due to many reasons viz. lack of funds, untrained staff, absence of standard framework, etc. Considering the importance of road network in our lives and at the same time damage caused to the environment and nearby surroundings due to overuse of the road network, it becomes responsibility of government, corporates and people to join hands to keep the highways green and beautiful negating ill-effects of vehicular pollution & felling of trees to build new highways.

To address this, in September 2015, Ministry of Road Transport and Highways (MoRTH), Government of India promulgated Green Highways (Plantations, Transplantations, Beautification & Maintenance) Policy - 2015 to develop green corridors along National Highways for sustainable environment and inclusive growth. National Green Highways Mission (NGHM) under National Highways Authority of India (NHAI) has been entrusted with the task of planning, implementation & monitoring plantations along one lakh km network of National Highways.

With the development of green corridor, travelers would be able to enjoy the beauty and extensive benefits of the vegetation, while experiencing safer driving environments. Green corridor development will also help in achieving the goal of maintaining one third of geographical area of the country under tree cover (National Forest Policy, 1988). Thus, by taking substantial measures to abate emissions along national highways, the National Green Highways Mission (NGHM) can contribute substantially to conserve and protect the environment and fulfill the commitment made by India during **CoP 21 Summit**.[1]

[1] *21st yearly session of Conference of Parties (CoP 21) of United Nations Climate Change Conference held in Paris, 2015.*

2. RATIONALE & IMPORTANCE OF BMPs

The concern for neutralizing ill effects of pollutions is shared globally and many countries are doing exemplary work in green corridor development along roadside. India could learn from their examples and build up its own customized operation framework for Highways plantations. It was proposed to review global best examples of selected countries for understanding uniqueness of their model. Technological interventions and Innovations related to the plantation and establishment of the vegetation have also been reviewed.

Best Management Practices (BMPs) are important for enhancing the management of existing and new highways plantations while at the same time reducing environmental impacts especially Green house gases (GHG) emissions and vehicular pollution. This BMP Manual will be a guiding document for plantations across all highways in India.

Why review of global best practices important?

Various countries have developed and documented best practices for the plantations and management of roadside vegetation addressing the issues involved. Reviewing and learning from the unique experiences and proven practices will be less time consuming & cost effective way to develop best practices for our country. Listing out global best practices and documenting Green Highways Vegetation Management Charter will be a logical application of good information, communication, technology, planning and research in the area of roadside management .

Why we need a Green Highways Vegetation Management Charter?

Majority of the projects/policies fail due to lack of implementation and management guidelines so there is a need for proper framework which can be used and referred as standard for undertaking plantations along the highways. Therefore, there is a need for Green Highways Vegetation Management Charter which is developed after reviewing global best practices and analyzing them in the context of India. Besides addressing the technical plantation concerns, the Charter would develop a shared understanding among all stakeholders from implementers to community to common citizenry which would help in effective implementation and management. The charter would clearly define roles and responsibilities, authority, best management practices for implementation and maintenance, non-negotiable conditions and sharing of resources, manage roadsides for safety, environmental health, and visual quality. It would also serve as a guiding document for the NHAI / NGHM staff, plantations agencies and other concerned stakeholders.

The Green Highways Vegetation Management Charter will continue to evolve by conducting regular research and communications with the specialists and experts as well as learnings from implementation of the best practices on ground.

Global best management practices will give the direction and the Green Highways Vegetation Management Charter will provide directives to take the mission forward and achieve the set objectives.

3. AIM & OBJECTIVES

This manual aims to document the global best management practices for highways plantations and develop a Green Highways Vegetation Management Charter for India which will provide a set of practical guidelines for undertaking the greening / plantations along highways.

The objectives of the manual are to:

- review the existing global best practices of roadside plantation.
- document unique models of roadside plantation of different countries
- compare and analyze Indian roadside plantation with global examples of roadside plantation to establish practices and methods that might be applied in India
- develop Green Highways Vegetation Management Charter for India

4. METHODOLOGY

The development of Green Highways Vegetation Management Charter is an integrated approach which includes an assessment of the existing practices & conditions and determination of desired roadside environment. Practices developed and adopted by some countries, technical practices and few related innovations are reviewed with their scope for the development of Vegetation Management Charter in Indian context. The Green Highways Vegetation Management Charter needs to be updated and improved on regular basis as development of green corridor and sustainable vegetation is a site specific methodology. So regular updates and changes are required according to the field experiences.

5. BEST MANAGEMENT PRACTICES DEFINED

Best Management Practices (BMPs) provide a platform which is mutually agreeable and beneficial to all stakeholders and contributes towards better ecosystem development, while at the same time increasing the competitive edge for each stakeholder in holistic development.

Development and implementation of BMPs for roadside plantation has been identified by NGHM as a priority area for engagement with the stakeholders and therefore this manual has been commissioned as a project to develop a standard framework for development of BMPs. The BMPs identified as suitable for Indian context will be part of the Green Highways Vegetation Management Charter and will be model tested.

BMP with regard to this project means a practice, or combination of practices, that is determined to be an effective and practicable (including technological, economic, and institutional considerations) means for green corridor development along the highways through greening and allied activities while reducing the impact of greenhouse gases (GHG) and vehicular emissions.

6. BEST MANAGEMENT PRACTICES ADOPTED GLOBALLY

The practices adopted in various parts of the world for highways plantations and vegetation management have been reviewed. Some of the practices which could be categorized as best management practices have been documented and analyzed assessing their feasibility in Indian context. The BMP have been categorized in three sections:

- Traditional Plantations and Vegetation Management Practices
- Technical Practices
- Innovations

Few case studies which can be implemented in Indian scenario are discussed below based on the literature reviewed. Countries were selected on random basis.

6.1. Traditional Plantation and Vegetation Management Practices

BMP 1: Tree Management Plan of Kings Highway Braidwood, Australia

(Corkery Consulting Pty Ltd, Australia, 2013)

In response to the frequent crashes along Kings Highway near Braidwood, Australia, a Tree Management Plan (TMP) was prepared by Road and Maritime Studies (RMS), a Government agency managing operations and programs of roads and waterways. The TMP provides guidelines for long term management and maintenance of existing and new avenue plantations along the Kings Highway while considering road safety issues. Other factors that were considered: Transport routes (e.g. for stock), Fire control lines, Carbon sinks, Places of Indigenous culture and heritage, Sites of historic heritage, Geological heritage, Aesthetic appeal and recreational opportunities and Sites for research and education. The avenue of trees which were already present on the highway were Golden Poplars (Populus x canadensis 'Serotina Aurea') inter-planted with Lombardy Poplars (Populus nigra var. italica) and Pin Oaks (Quercus palustris).

Figure 1: Avenue of Lombardy Poplars (Corkery Consulting)

The objectives of this Tree Management Plan are:

- Conserve the avenues of trees retaining their cultural heritage values in accordance with the provisions of the Australian ICOMOS (International Council on Monuments and Sites), Burra Charter[2] .
- Provide a design for replacement planting and avenue realignment over the longer term as the existing avenue trees reach the end of their life cycle.
- Provide guidance for maintenance of existing as well as newly planted avenue trees.
- Consider road safety and operational requirements while implementing

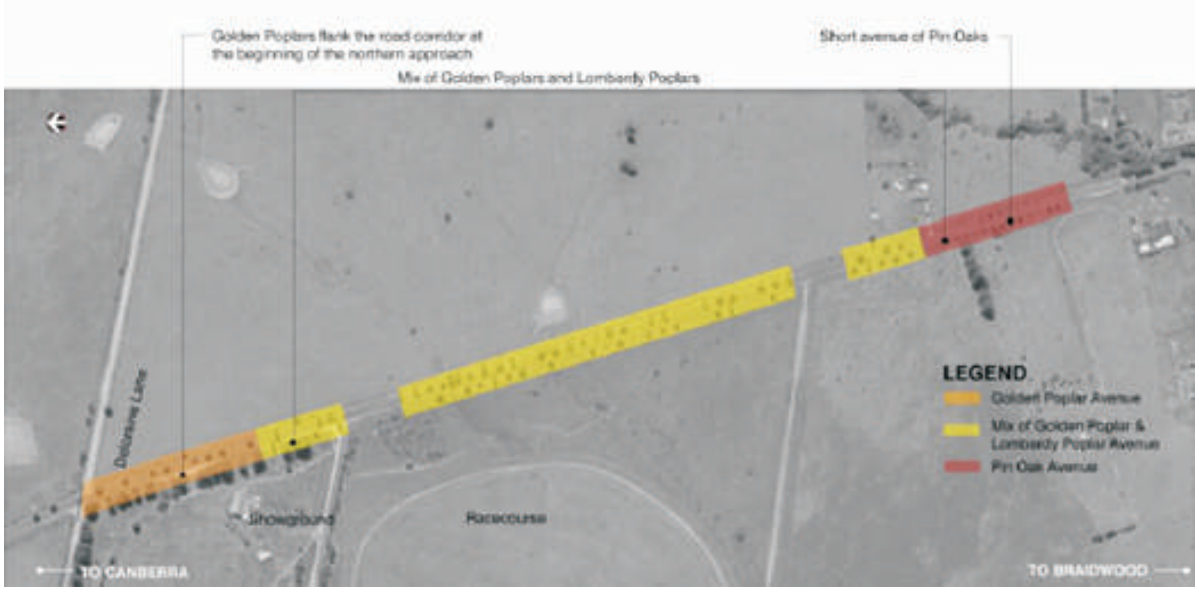


Figure 2: Location of existing trees on the Kings Highway northern approach to Braidwood

[2]*The Burra Charter defines the basic principles and procedures to be followed in the conservation of Australian heritage places*

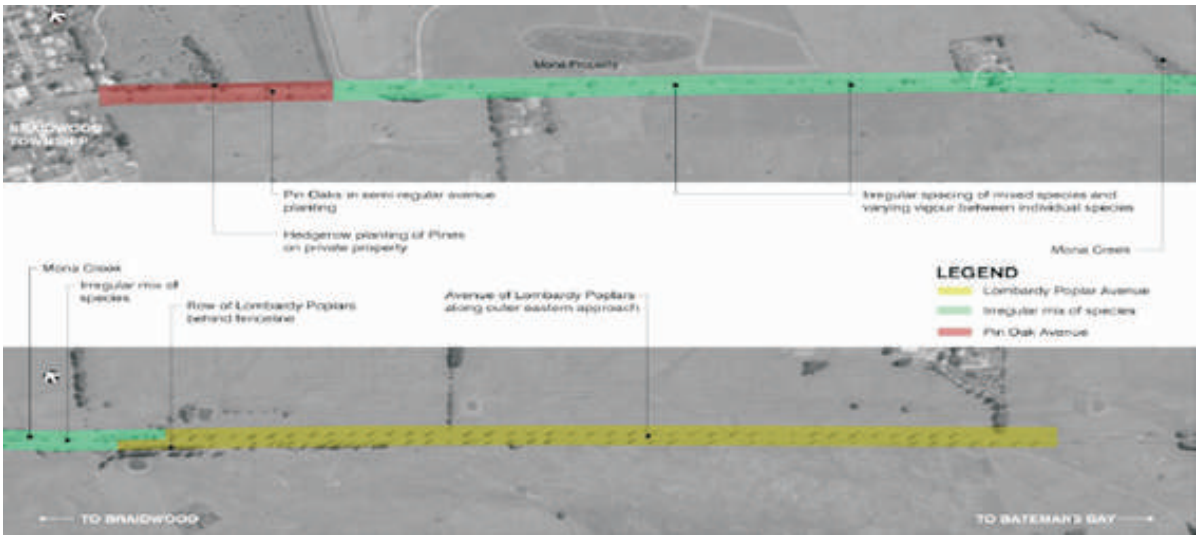


Figure 3: Location of existing trees along the eastern approach to Braidwood

The key features of Tree Management Plan are:

1. **Consistency with Road Safety**: First step was to define the project area according to the utility of the road, considering safety aspects. As per road safety standards, any new trees to be planted outside defined clear zones (generally 9m away from road, where speed limit is 100km/h).

2. **Tree Avenue Structure**: The key principle of this plan is to maintain the landscape character of the tree avenues by implementing a program of tree management and replacement. The key value with which local community associate with these trees are the avenue structure and seasonal effects. Following aspects were considered for tree avenue structure:

    - New avenue plantations will have trees of similar species, age and size (relative to each other) planted in a symmetrical arrangement to retain the avenue structure. This will require inter-planting offset from existing avenue trees so that the planted trees have space to grow to sufficient height before removing existing trees.
    - The alignment of the new avenues consider adjacent infrastructure that may prevent a satisfactory length, spacing or lateral placement of trees.
    - Opportunities for continuous linear plantings of trees that are not affected by overhead or underground services, property accesses or other infrastructure

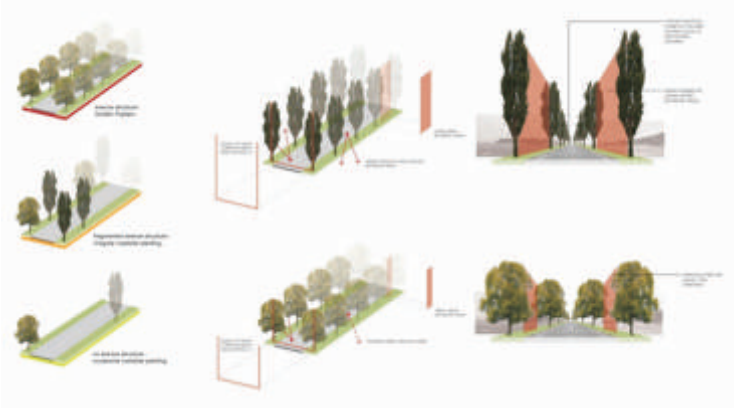


Figure 4: Structure of Ideal Avenue Plantation and Tree type (Corkery Consulting)

3. **Tree Species Selection**: Selection of tree species was based on following characteristics:

   - Suitability to climate, microclimate and soils (which are generally low fertility sandy loams derived from Braidwood granites)
   - Longevity of the species growing in difficult conditions at road corridors
   - Suitable scale and form without additional maintenance requirements
   - Low susceptibility to pests and diseases
   - Competition with other species

4. **Planting Stock Propagation**: Points considered while propagating the plants are:

   - Propagation and nursery production of tree stock is carefully managed. Ensure availability of healthy stock of selected species / cultivars of required size
   - Uniform size and form of trees to be supplied. Tree stock used for each stage is to be supplied from single propagation batch if possible. Propagation batches should only be split if there is long period between stages of planting works making it impractical to hold and manage tree stock from single batch. A nominated planting stock size of 100-150 liters will ensure that the trees are able to provide immediate visual and amenity benefits and have adequate resistance to damage while ensuring the transport and planting costs are reasonable.
   - Indicative height of a 100L (container grown) tree should be 2.5 – 3.5 meters and a 150L tree should be 3 - 4 meters depending on the species.
   - Planting trees from 100 -150L requires mechanical assistance to move and position the tree stock.

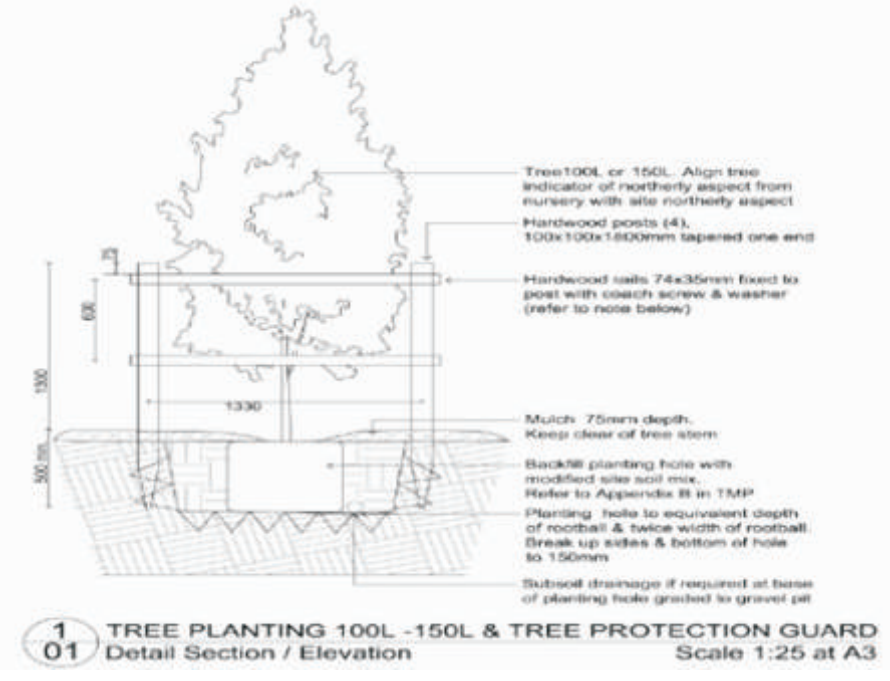


Figure 5: Planting and Tree Protection detail

[3] *Volume of plant container is considered in liters*

5. Tree Planting: Attention was given to the planting process to ensure successful replacement of trees that will form the avenues along the northern and eastern approaches to Braidwood. Soil testing was done to determine soil conditioning and improvements required to allow successful establishment of the planted trees. This ensured that the planted trees achieve the optimum growth rate and habit for the species in this location. Surface and subsoil drainage is essential for optimum plant growth. Therefore, trees were not planted in situations where the soil remains waterlogged for extended periods without adequate drainage treatment. It is recommended that trees are planted at the sides and not at the lowest level of drainage swales. If proposed tree planting locations coincides with impeded subsoil, surface ponding or water-logging and no other options are available, then drainage works are recommended to ensure the visual and structural integrity of the tree avenue is maintained. In all instances each tree planting location must be verified on site for site specific recommendations. Tree planting information was to be provided to Palerang Council (a local government) for inclusion in the Council's asset inventory.

6. Maintenance: Under TMP, ongoing maintenance covers scheduled inspections and tree maintenance by skilled people. An arborist provides expert advice on pruning and maintaining trees at an acceptable level of health and safety. Other maintenance programs and procedures such as weed and sucker management; work in vicinity of existing trees; infrastructure protection and Pest and disease control were also considered.

7. Community Involvement: Kings Highway Braidwood considered the community involvement as an important aspect and preference was given to local communities, management trusts and property owners along the roadside.

8. Tree Removal: Existing Trees were replaced with new trees after consulting with arboriculturist[4] and considering road safety requirements, health and status of trees and growth rate of existing trees. Removal of existing trees at the end of their effective safe life is coordinated with replacement tree planting program. The assessment of each tree's health and ability is done by a qualified arboriculturist in accordance to tree inspection program by Palerang Council.

BMP 2: Pennsylvania Department of Transportation (PennDOT)

[(Larry Kuhns, 2004), (Pennsylvenia Department of Transportation, 2003)]

Trees and shrubs plantings along roadside are considered to be better than ornamental plantings by PennDOT. The PennDOT maintains over 40,000 miles of highways. Landscaping is taken as an opportunity to have a better first impression of Pennsylvania to tourists and prospective business investors which could invest in the state.

Figure 6: PennDoTHighway Plantations (PennDoT)

Figure 7: PennDoTHighway Maintenance (Facebook PennDoT)

[4]Arboriculturist is a person who practices arboriculture which is the study of growth of plants and cultural practices according the nearby environment.

Advantage of trees and shrubs plantations along roadside are:

- Long life span
- Large in size
- Visual impacts for long time
- To improve community relations
- Long term maintenance requirements for trees and shrubs are much lower than for herbaceous ornamental plantings

Figure 8: Primary Planting Opportunities

Figure 9: Benefits of Plantation along roads

Primary issues considered by the PennDOT for the improvement in survival, growth and visual impact of trees and shrubs plantation along roadside after the road is built are plant selection and handling; Site preparation; Maintenance; Litter Abatement and Community Engagement.

1. Plant selection & handling: Characteristics of plants considered by PennDOT for roadside plantation are:

- Act as wind tunnels
- Salt resistant (for winters)
- Hardiness
- Size
- Form
- Leaf color
- Fall coloration
- Seed tree species native to the area
- Able to withstand harsh roadside conditions: temperature, vehicular pollution

Along with tree and shrub species, wildflowers are also used for landscaping and beautification of highways. Prime importance is given to the road safety while planning for landscaping of road. For landscaping, experts preferred:

- Assistance in inspection for high quality plants and best care were considered to be an important factor during procurement from nurseries and also at proposed site.
- Minimize the loss of water from the plant to the soil by minimizing the time between digging of plant from nursery and planting at the site
- Plants should not be delivered to the planting site more than two days prior to planting.
- All plants should be in an enclosed, ventilated truck box or entirely covered with tarps during shipping.
- If planting is delayed, place the plants in a holding area where they can be irrigated, and cover the root balls with mulch to reduce water loss.
- Check water availability for irrigation at the site before planting.
- The plant material used for plantings along roadside-
  - ✓ Balled-and-burlap, or B&B - most commonly used
  - ✓ Bare-root: In spite of lower cost, it is not commonly used for roadside planting projects because their handling is extremely time-and-method sensitive
  - ✓ Container-grown: Require more watering after planting

2. Site Preparation : Points which were considered for the preparation of the site are -

- Eliminate weeds and other unwanted plants grown on the selected site
- Improve the soil quality and condition - add organic matter for providing biological and chemical stability to the soil
- Restore topsoil function
- Loosen the soil for air balance

Figure 10: Roto-tiller used for loosening of soil along roadside

Shared Spaces or Cluster Plantings is an approach used for planting purpose in which the planting area is treated as a large bed, and the plants are spaced close enough so that they grow together, both above and belowground. The key benefits are -

- Grouped plants begin to modify and improve the environment in their immediate vicinity.
- Preparing large bed for planting provides more soil volume for roots to explore water & nutrients
- Closer canopies shade more soil surface and moderate temperature extremes
- Moderated temperature helps soil to retain moisture better, and a more complex spectrum of soil microorganisms develops around the roots.
- Cluster plantations are easier to maintain because they occupy less acreage and as they mature there is less space and light to support weed growth.

3. Maintenance: Necessary resources for maintenance are as follows-

- Water
- Fertilization: Adequate topsoil and control weeds
- Pruning: Occasional removal of dead, crossing, or parallel branches. Some species may never need to be pruned like Junipers
- Remove bracing: After first growing season to reduce the possibility of plant damage
- Mulch: Best mulch is a 2-4 inch layer of wood chips
- Weed Control: Weed can be pulled or spot-treated with herbicide product containing glyphosate. At least one annual application of herbicide &weed removal.

4. Litter Abatement- "Adopt-A-Highway Program" concentrates on litter abatement along highways in which people can volunteer. Prior training is also provided by the contractor under this program by taking care of all the safety aspects on the road.

Figure 11: Team of adopters under Adopt A Highway Program for Litter Abatement (AVA_Adopt a Highway)

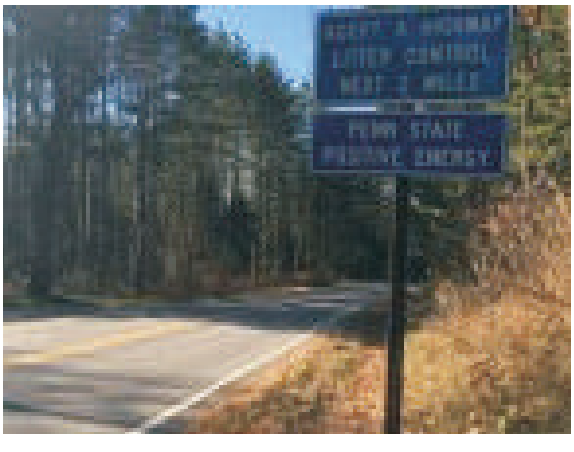


Figure 12: Adopt A Highway Program for Litter Abatement in Pennysylvia State (Penn_Litter Abatement)

5. Community Involvement- "Adopt-And-Beautify Program" is the extension of Adopt-A-Highway Program in which communities are involved in the planting and beautification of highways along with litter pickup in partnership with PennDOT.

BMP 3: Tree Avenues in the Landscape, Europe

Europe is known for its tree-lined roads and streets. Compared with tree-lined roads in the open countryside, the situation of tree-lined urban streets was more varied because of the space availability. Apart from roadside, trees were also planted in streets, garden cities, private avenues. Trees were considered to have a positive impact on property values, adding an extra 5 to 20% value. Trees along roadside were not considered for the timber harvesting. The main purpose for roadside plantation was:

- Landscaping
- Heritage value
- Environmental Benefits
- Shelter from the wind
- Prevent soil erosion
- Reduce the risk of landslides
- Trees stabilize the highway and verges in marshy areas

Figure 13: Spring landscape in Europe (CEP-CDPATEP)

Figure 14: Autumn colours tree-lined roads in Europe (CEP-CDPATEP)

Tree Plantations

- Trees planted along country roads were set at regular intervals in proportion to the road
- Safety zone was maintained while planning for tree plantations along roadside
- Safety measures were considered
- Different trees were planted according to region or country to set different mood and accent
- Geometrically varied plantations like square planting was also done as was the norm in France

- Varied number of rows of trees from one to multiple rows. In the Netherlands, roads lined with two rows of trees on either side are common; while in Belgium single row of trees on either side is common
- Mixed species was also planted at some locations
- Existing trees were saved and new trees were planted
- Policy on gap filling of the areas where some part was planted and some not.

Species selection was done on the basis of following characteristics:

- Geography
- Climate
- Soil type
- Shape
- Texture
- Color
- Native species
- Fruit bearing trees preferred

Community Engagement

- Plantations were done by local farmers, landlords, etc
- Community was involved as nursery operators, arborists & arboriculture consultants
- Low qualified personnel were preferred for the collection of dead leaves and fruit, watering, etc.
- Involvement of concerned third parties (farmers, utility companies, civil engineering companies) and public (residents, tourists, associations) was considered important.

Procurement of planting material: Procurement of planting material was preferred from nearby nursery. Nursery was setup for maintaining quality of plants. In Brandenburg, Germany a decree of 1814 ordered creation of nurseries at intervals of 15kms.

Tree felling along roadside was discouraged by the government. Showing the importance of tree preservation, Norway Road Department posted in its brochure that it takes 100 years to make a tree but just five minutes to cut it down.

Figure 15: Importance of mature trees by Norway Road Department

Factors considered for successful plantings:

- transport conditions
- planting pits
- soil quality
- staking
- mulching
- hoe-weeding
- watering
- formative pruning to create a balanced structure and gradually
- raise the crown

In order to ensure that the efforts for tree planting and maintenance are not wasted, the trees were protected from all sources causing fatal damage. Cleaning tools after working on one tree before moving on to the next is basic plant health good practice to help prevent the spreading of disease.

BMP 4: Roadside Tree Planting through Cooperative Approach, Bangladesh

(Bangladesh Conservation Approaches and Technologies, 2008)

100 landless and local unemployed young people in Gaibanda, Bangladesh planted 8000 saplings of Eucalyptus (Eucalyptus camaldulensis) voluntarily on a road stretch of 4km along both sides (around 0.1 sq. Km) after taking permissions. Land was taken on lease for some time from local government and community had usufruct right.

Objectives of the Plantation

- create an alternative income source through establishment of roadside plantation to uplift the socio-economic condition of the poor landless unemployed labor
- utilize the roadside land
- reduce soil and wind erosion
- increase aesthetic value of road

Tree Species Selection

Species was selected on the basis of timber value (maximum return by harvesting), climate, fast growth, survival rate, less establishment and management cost. From initiation to planning and implementation every aspect was managed by the volunteers. No training, advisory service or research was provided.

Tree Planting

- Planting pit was prepared using spade or hoe
- Seedlings were procured from the nursery
- Staking was done using bamboo sticks

Profit Sharing: Profit sharing ratio was decided as 70:30 between the users and local government (Union Council).

Maintenance: Watch and ward by the volunteers.

Major problems faced:

- Lack of technical knowledge
- Lack of women participation
- Conflicts over resource use
- No support from NGO or government

Results of this program are:

- Motivated and set an example for other people of the district who later adopted similar practice
- Improved livelihood, human well-being and overall situation of disadvantaged group
- Poverty alleviation
- Increased soil cover
- Reduction in wind velocity
- Reduced downstream flooding

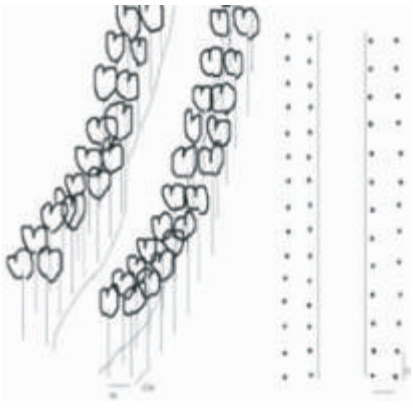


Figure 16: Spacing between rows (1.0m) and plants (0.5m)

BMP 5: Best Practices for Roadside Vegetation Management by Minnesota Department of Transportation

(IRRB) and (Ann M. Johnson, Best Practices Handbook for Roadside Vegetation Management, July, 2008)

Best Practices Handbook of Minnesota Department of Transport (MnDoT) provides guidelines for effective management of roadside vegetation for local agencies and highlights eight Best Management Practices which were identified through research, series of surveys and discussion with industry experts by Technical Advisory Committee of Minnesota, US.

The Eight best management practices for roadside vegetation are as follows:

1. Develop an Integrated Roadside Vegetation Management (IRVM) plan

IRVM is an overall plan for unified management and coordination of social & cultural elements, biological concerns, mechanical treatments, roadside safety, environmental health and visual quality. It can be used as decision-making and quality management tool for maintaining roadside vegetation. Benefits of implementing Integrated Vegetation Management Plan are:

Criteria	Benefits
Safety	• Creation of adequate sight distances and hazard-free zones • Minimized effects of rain, blowing & drifting snow and ice formation • Reduced hazardous conditions for maintenance staff
Economic	• Increased productivity from planning versus reacting to problems • Economical and environmentally sustainable outcomes • Increased tourism due to aesthetic appeal contributing to rural livelihood
Flexibility	• Efficient use of staff, time, and equipment through planning • Variety of management tools & techniques to choose from
Environmental	• Improved water & air quality and protected soil • Increased biodiversity and desirable native plant communities • Improved safety for wildlife • Newly created habitat • Reduced impact of roadway projects • Increased carbon monoxide absorption & carbon dioxide sequestration
Aesthetic	• More healthy and diverse vegetation appropriate for the area without undesirable vegetation • Improved appearance of roadway & pleasant experience for travelers
Public Relations	• Shared expertise between agencies and establishment of partnerships • Increased public awareness of maintenance activities

2. Develop a Public Relations Plan (capacity building plan/ public engagement plan)

Effective public relations plan is crucial for successful implementation of roadside plantations and depends on user awareness, public awareness, media relationships, response to complaints, crisis management and cooperation with other agencies

3. Develop a Mowing Policy and improved procedures

Since mowed areas are visible to the public and also expensive, mowing is an important vegetation maintenance operation. A mowing policy should be developed considering safe operating practices, prioritization of mowed and unmowed areas, the use of herbicides, and expected or required cost reductions. Areas that require periodic mowing to maintain safe right-of-way are intersections, bridges, sharp curves, and farm and field entrances.

4. Establish Sustainable Vegetation

Planting and establishing sustainable vegetation along roadsides that is suitable for a particular area or condition is very important for effective use of time, resources, energy and money. Sustainable vegetation requires less maintenance and thrives wherever it is planted. The keys to a sustainable roadside environment include:

- Using native grasses and wildflowers
- Using salt tolerant species
- Staging planting
- Controlling erosion
- Selecting appropriate shrubs and trees for a given area
- Strategically managing woody vegetation and trees

5. Control Noxious Weeds and Prevent the Establishment of New Invaders

Mn/DOT's goal is to take out target weeds without harming desirable vegetation, plant stabilized slopes and waters of the state. Plants identified as "noxious" should be controlled and its use should be prohibited in accordance with Minnesota's Noxious Weed Law. Minnesota Invasive Species Advisory Council looks after the invasive species management and control. Updated list of unwanted species should be referred for control purposes covering noxious, restricted, secondary and offensive weeds. Least toxic and economical methods and options should be considered for weed treatment. Different approaches for controlling noxious weed are:

- **Biological Control** includes use of insects / pathogens inhibiting growth & reproduction of weeds and reducing their ability to compete with desirable native range plants
- **Cultural Control** includes planting native grasses or competing plant species to force out noxious weeds
- **Physical Control** includes tilling, mowing, and burning areas to control weeds
- **Chemical Control** includes use of herbicides

Best practices for weed control are:

- Spraying only the weeds
- Spraying at the right times
- Spraying with most effective herbicides
- Spraying with latest technology
- Spraying with better trained personnel
- Prioritizing and spraying proactively
- Planting self-sustaining vegetation
- Reducing disturbance to healthy vegetation

Figure 17: Spot spraying of herbicides minimizes drift

6. Manage Living Snow Fences

Living snow fences are designed plantings of the trees species, shrubs and native grasses located along roads or around communities and farmsteads. These are properly designed and placed to act as a barrier to trap snow as it blows across fields. Living fences pile up the snow before it reaches a road, waterway, farmstead or community. These fences improve the driver visibility and reduce vehicle accidents, reduces the plow time thus cost effective, lessen the environmental impact with less salt use, results in the increase of crop yields by 10% or more. It also controls soil erosion and reduces spring flooding. Snow fences help in beautification of the road and at the same time serve as visual clues to help drivers find their way. (Ann M. Johnson, Best Practices Handbook for Roadside Vegetation Management, July, 2008)

There are four types of living snow fences: twin shrub row, community shelterbelt, deciduous tree windbreak, and standing corn rows.

Figure 18: Twin Shrub Row Snow Fence

Figure 19: Community Shelterbelt

Figure 20: Standing Corn Row Snow Fences

Figure 21: Structural Snow Fence

7. Use Integrated Construction and Maintenance Practices

While designing a project, roadside vegetation should be incorporated through provisions for soil conservation, erosion control, topography, and aesthetics. Unless elements of roadside vegetation are considered in design and planning stage, implementation will be cost and resource intensive with challenging conditions for the staff.

8. Manage Roadside Vegetation for Wildlife and Vehicle Safety

This practice aims to promote vehicle safety while enhancing safety on roadsides for wildlife. (Ann M. Johnson, Best Practices Handbook for Roadside Vegetation Management, July, 2008). This is important to reduce the human-animal conflicts. According to the research conducted on deer-motor vehicle collision in Minnesota, wildlife is more likely to use a road underpass or overpass if there are lead fences that funnel deer toward the passage. Greater vegetative cover near the passage and along fences will encourage wildlife if there are greater amounts of vegetation in and around the underpass, if there is an earthen floor, and if the underpass is short and more open, having a height and width of at least 15 feet. (Reed, 1981;Putman 1997)

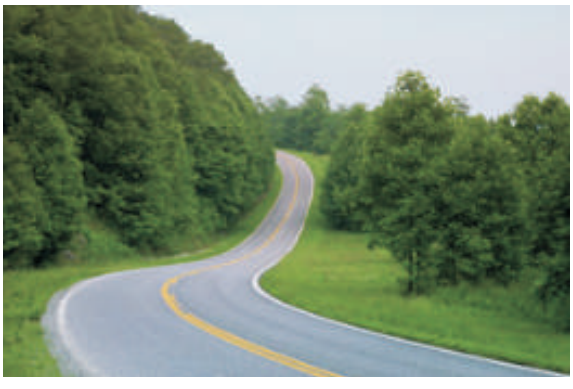


Figure 22: Biological Diversity - results from native seedings in Clinton County, Iowa.
(Photograph: Clinton County, Iowa, IRVM)

Figure 23: Woody Vegetation in Roadsides – provides cover for deer and increases the risk of deer-vehicle collisions
(Photograph: BASF Professional Vegetation)

Example of implementation of IRVM discussed is described below:

Mn DOT Maintenance Area 3B IRVM Plan: MnDOT developed its integrated roadside vegetation management (IRVM) plan as a proactive way to address roadside management in Maintenance Area 3B, Minnesota. (Ann M. Johnson, Best practices handbook on Roadside Vegetation Management, 2000). Roadsides in Area 3B fall are categorized into three types as Minimal mowing, 50/50 mowing & High frequency mowing based on the management practices needed to keep them safe and aesthetically pleasing.

Figure 24: Covered Mowing clippings (IRRB)

Figure 25: Mowing clippings covering mower decks (IRRB)

The plan also includes a mapping and communication plan that states that roadsides of each type will be indicated on maps so that maintenance personnel and public are well informed and work within overall program. The plan resulted into the following:

- Reduction of Roadside Hazards
- Efficiently Reducing Mowing
- Reduction of Noxious Weeds with Herbicides
- Burning Native Prairie Areas
- Implementation of a Uniform Maintenance Area Mapping System
- Increase Areas of Native Vegetation

For selection of tree species and site, following characteristics are covered (Minnesota Department of Transportation):

- Plant form, height, spread, summer & winter texture, overhead utility compatibility, growth rate, life expectancy, and root type.
- Flower colors and seasons and fruit types, colors and seasons.
- Spring, summer, fall, and winter foliage colors.
- Place of origin, plant community association, succession occurrence, sun requirements, site orientation, and topography.

- Tolerances associated with soil pH, compaction, salt spray, soil salt, moisture regimes, flooding, depth to water table, soil drainage, drought, oil water holding capacity, soil texture, herbicides, and pollutants.
- Maintenance implications, planting ease, and windbreak suitability groups.
- Insect, disease & animal damage concerns, wildlife benefit, plant toxicity, cold injury, storm damage susceptibility, and invasiveness.
- Allergy intensity for different varieties of plants

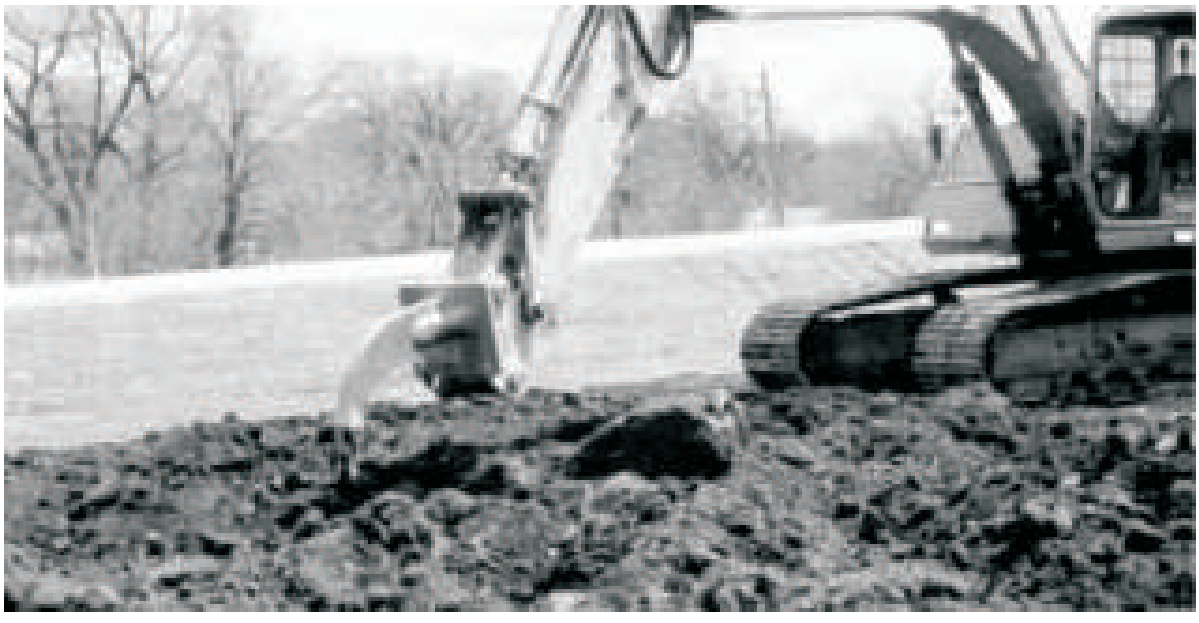


Figure 26: Scarifying the Soil - during construction significantly improves the chances of any vegetation establishment

IRVM plans are broadly applied and adopted across the United States of America. (Venner Consulting and Parsons Brinckerhoff, 2004)

To conclude, successful roadside vegetation management depends on integrated approach which includes an assessment of the existing conditions and determination of the type of roadside environment desired.

BMP 6: Community based Bio-Engineering for eco-safe roadsides in Nepal.

(Devkota S. S.-R., 2014) and (Howell, 1999)

Bio-engineering or use of vegetation for slope stabilisation, and control of run off and its effects (soil erosion and transportation of sediments), is a cost- effective and locally adapted method along road side slopes, river banks or on cultivated terraces. Bio-engineering methods range from simple plantation of appropriate deep-rooted species, to a combination of vegetation and more elaborate civil engineering. In addition to cost effectiveness, advantages beyond slope stabilization include benefits obtained from vegetation for livelihoods, and inter-cropping. Some of the main requirements for successful bio-engineering include proper roadside drainage to divert heavy run-off from fragile slopes to a safer place, early plantation maintenance to keep weeds from competing with plants and keeping livestock away from slopes.

Rural earthen road common problems and low cost bio-engineering methods along with drainage techniques are:

S. No	Problems	Solutions	Details
1.	Surface erosion Control of run-off	Turfing	Shallow rooting grass and the soil it is growing in, is placed on the slope. It is normally used on well-drained materials, where there is a minimal risk of slumping
		Jute netting along with seedlings	Locally made geotextile of woven jute netting of standard mesh size 40 x 40 mm to protect slope surface and allowing seeds to hold and germinate
		Grass plantations	Rooted stem cuttings or clumps grown from seeds are planted over the slope in different ways (e.g. along contour lines, vertically, diagonally or randomly). They protect the slope with their roots and provide surface cover, reduce surface runoff and catch the debris
		Facines	Bundles of live branches are laid in shallow trenches later put out roots and shoots forming a strong line of vegetation. It is sometimes also called live contour wattling. They can be established along contours or diagonally depending on the drainage requirement
2.	Gullies	Live check dams	Woody cuttings of shrubs or large tree species are planted across a gully, usually following the contours. These form a strong barrier and trap sediments moving downwards. As time passes a small step-like terrace will develop in the floor of the gully
		Vegetative stone pitching	Strengthening of slopes by combination of dry stone walling or cobbling and vegetation planted in the gaps between the stones. It is a stronger form of normal stone pitching
3.	Shallow landslides	Palisades	Woody cuttings planted in lines across the slope following the contour. These cuttings form a strong barrier and trap earth materials moving down the slope. In the long run, a small terrace will develop and stabilise the slope. Palisades can also be installed at an angle if drainage is a problem
		Brush layering	Woody cuttings are laid in lines across the slope following the contour. It can be used for the slope of less than 45° and the slope shall be well-drained. Technique is effective for debris flows, to fill slopes and high embankments. A strong barrier is formed preventing the slope from rill formations while trapping materials moving down the slope.
		Gabion walls combined with vegetation	Stone filled gabion walls have special properties of strength, flexibility and free drainage. It can be used up to 10 meters of height for retaining walls, cascade channels and check dams. Gabions can allow protection for vegetation and vegetation may provide additional stability once gabion walls begin to deteriorate.
		Dry stone walls combined with vegetation	Dry stone walls are low cost options for slope and road side slope protection. They can be used up to 2 meters high as retaining walls, cascade channels and check dams. Dry walls are for immediate protection of shallow slopes whereas vegetation provides additional stability as time passes.

S. No	Problems	Solutions	Details
4.	Secondary impacts on waterways from road construction	Live check dams combined with vegetation and boulders	Degraded watersheds due to soil erosion, landslides, poorly constructed roads and accumulation of roadside water, lead to transportation of sediments downstream - and often - reduced water quality and quantity. The situation can be improved by applying bioengineering and simple civil engineering structures. It is extension of "live check dams" discussed in method 5 above. Live check dams are further reinforced by vegetation on either side of the failure or gully slope. Sometimes if the gully or the slope is shallow and the slope is less steep, dry stone check dams with vegetation alone is also effective (e.g. check dams) .
5.	River bank protection	Sandbags, bamboo vans & vegetation	This is most the simple and low cost method for bank protection in the plain area, mostly for meandering rivers in the Nepal Terai. It can also be used in the inner river valley basin where flash floods are common and where stone / boulders are not easily available. If the problem is bigger gabion or stone / boulder retaining wall might be good

6.2. Technical Practices

BMP 7: Tree Transplantation

To prevent the felling of trees for roads expansion and construction projects, a bioengineering technique called transplantation can be used to relocate trees ideally of diameter 40-50 cm to 100 cm successfully with required equipment, techniques and experts. It is a technique of moving a plant from one location to another, ensuring no damage to the plant so that it can re-establish at the new place with the same vigour. Some species show better results than others with this technique. It needs to be noted that result of this technique varies from tree to tree depending on species, location, climate, tree age, tree health, treatment while transplanting, etc.

Advantages of transplantation:

- Can act as a savior for the plants which are a hindrance for the construction or expansion project requiring cutting of trees
- Environment is not compromised at the cost of development
- Aesthetic of the area is maintained
- Trees with sentimental and religious values can be saved
- Livelihood opportunities for skilled and unskilled labor involved in transplantation
- Large trees provide cooling effect which reduces energy cost
- Mature landscape in less time (as compared to growing of tree from seedling)
- Any particular mature tree which has outgrown in its present location and is a risk to road safety can be saved by transplantation

Figure 27: Steps of Tree Transplantation Process (Tree Transplantation)

Methodology:

Tree transplantation follows a phased approach. Steps of a successful transplantation are as follows:

1. Digging or preparation of the root ball
2. Moving or transporting the tree on the preplanned route with minimal damage and disruption. If root ball breaks, it will break the roots inside and may lead to plant death
3. Digging and preparing the tree pit which should be of same size as the root ball
4. Planting the tree: Transplanted tree is not strong enough to stand by itself because of the stress and weight of tree trunk therefore after transplantation the tree it is tied up with the help of sticks
5. Clean up the area after transplantation. Waste generated after pruning can be used as firewood. (Rae W. , 1976)

Figure 28: Photographs showcasing Transplantation (Dorian Drake)

Factors affecting the cost of transplantation:

1. Size of the Tree: Requirement of labor for bigger trees will be more
    - Trees with DBH less than 8" can be relocated with hand
    - Trees with DBH 8-10" can be relocated with traditional methods like tree spade
    - Trees with DBH 10-24" require highly mechanized instruments like hydraulic tree spade, etc.

2. Distance and Access to Transplanting Site: more the distance of relocation more will be the cost
3. Digging Conditions: leveling will increase the cost
4. Tree species
5. Number of Trees

Factors to be considered while tree transplanting:

1. Feeder roots should be preserved as much as possible
2. Maintain root shoot balance (reduce crown by 20%)
3. Favorable time varies from species to species. Usually monsoon is considered as the most suitable season for majority species as transpiration loss is the least.
4. Dormant season for pruning of roots
5. Public safety issues: While transporting the tree from old location to new there should be no risk or harm to the public.
6. Tree is disease free and worth transplanting
7. Tree is accessible to equipment
8. Condition of soil is conducive to dig proper root ball without damaging the roots of the tree. Root ball preparation of sandy soil is very difficult.
9. Treat all transplants with hormones to enhance their ability to survive
10. Adequate water supply in the transplanted location assures survival

BMP 8: Hydro-Seeding

Hydro-seeding or hydro-mulching is a bioengineering technique to develop quick natural green surface where seed (usually grass seeds), fertilizer, hydro-mulch and water are mixed homogeneously to form a slurry and sprayed uniformly using truck or trailer mounted tank with jet or mechanical agitation system (Earth Groomers Inc.). The mulch layer holds the moisture, soil and nutrients which results into quick germination of seeds. Though this technique is popular in gardening purposes but many countries are using this as an effective technique for soil erosion control. Countries like USA (Pennsylvania, Delaware, North Carolina), UK (London) and Canada have adopted this technique for landscaping and soil erosion control along roadside also. Not only grasses but wild flowers can also be planted using this technique.

Figure 29: Hydroseeding to prevent erosion
(Kulig Contracting)

Figure 30: Aerial Hydroseeding
(Polymer Innovations)

In 2011, after Sarnia Road bridge replacement took place in London, Ontario hydro-mulching or hydro-seeding technique was used to re-vegetate the area (Tara Beecham, 2016) by a London based company, JK Landscape Inc.

Advantages over conventional seeding process

- Faster technique
- Cost effective way
- More uniform germination
- Reduced labor costs
- Superior erosion control

Figure 31: Site Situation at the time of Hydro-seeding and sometime after Hydro-seeding
(Bluetgarden)

BMP 9: Soil Bioengineering: Vegetated Bamboos Crib Walls – Nepal

(Acharya)

Soil-bioengineering has emerged as an alternative engineering discipline to the conventional geotechnical or civil engineering which is affordable and sustainable. It is the use of plant materials, living or dead, in geotechnical problems such as landslide, eroding slopes and riverbank protection. It is a novel, but proven approach to improve sustainability of infrastructure projects through use of natural, locally available materials as an alternative to lower the use of steel and concrete usage in construction. As an appropriate solution to the road infrastructure development problem in Nepal, a **new soil bioengineering technique called vegetated bamboos crib walls** was tested.

Considering the wide availability and diversified utility of bamboo in Nepal, bamboos were used in earth retaining structure (crib walls) to stabilise landslides. Crib walls can be described as a specialized form of gravity-retaining structure using on-site fill material, held within a constructed framework.

Results show that this old technique of making crib wall using the locally available material (bamboo) in stabilising slopes might be an alternative to conventional gabion walls. The use of bamboos in crib wall construction for stabilising roadside slopes will have following benefits:

- Simple and fast construction.
- No need of qualified technical workforce
- Plantation and sale of bamboos will increase, which will derive income of local people.
- It is labour intensive work, which will generate employment for the rural people.
- Bamboos and vegetative cuttings are renewable resources which can be easily grown in surrounding area and is environment friendly and sustainable.
- Can be applied everywhere.
- These walls look like invisible construction after certain time and add to aesthetic beauty and improve environment of surrounding area.

Figure 32: Construction steps of a vegetated bamboo crib wall

Figure : 33 Environmental sustainability (improvement in surrounding environment one year after construction of Bamboo Crib Walls

BMP 10: Storm Water Management

Innovative BMPs by Green Highways Partnerships (GHP) & Low Impact Development (Partnership, 2010) (www.lid-stormwater.net/background.htm)

When storm water is not properly managed, negative impacts to local ecosystems and communities can take the form of flooding and/or toxin leaching. GHP has compiled an innovative storm water "Best Management Practices" system with feasibility aspect.

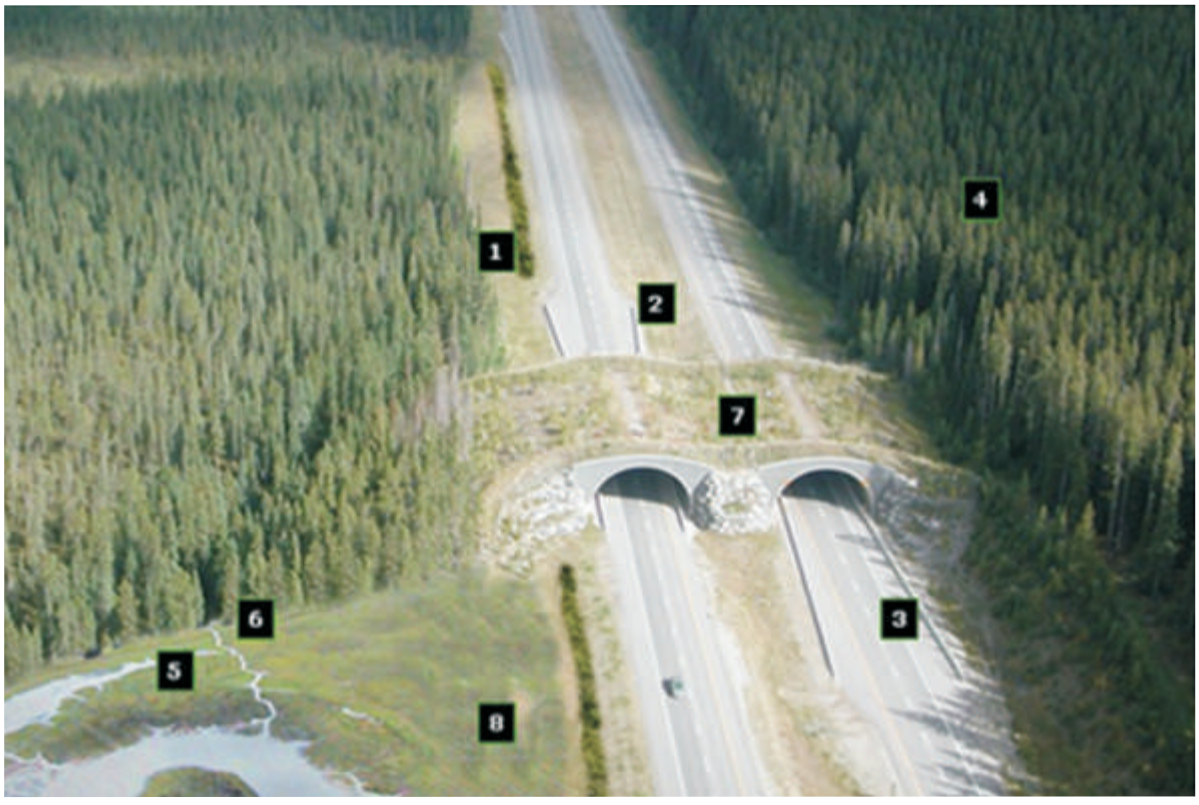


Figure 34: Intervention location for Storm water Management BMP

1. Bio-retention Swale
2. Pervious Pavement Shoulder
3. Environmentally Friendly Concrete
4. Preserved Forest Buffer
5. Restored and Storm water Wetlands
6. Stream Restoration
7. Wildlife Crossing
8. Soil Amendments

Low Impact Development (LID) is an innovative storm water management approach with a basic principle that is modeled after nature: Manage rainfall at the source using uniformly distributed decentralized micro-scale controls. (www.lid-stormwater.net/background.htm)

LID's goal is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Techniques are based on the premise that storm water management should not be seen as storm water disposal. Instead of conveying and managing / treating storm water in large, costly end-of-pipe facilities located at the bottom of drainage areas, LID addresses storm water through small, cost-effective landscape features located at the lot level. (www.lid-stormwater.net/background.htm)

BMP	Details
BIORETENTION	It was developed in early 1990's by the Prince George's County, MD, Department of Environmental Resources (PGDER). It utilizes soils and both woody and herbaceous plants to remove pollutants from storm water runoff. Runoff is conveyed as sheet flow to the treatment area, consisting of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants. Runoff passes first over or through a sand bed, which slows the runoff's velocity, distributes it evenly along the length of ponding area, consisting of a surface organic layer and/or ground cover and the underlying planting soil. Bioretention area is graded to divert excess runoff away from itself. Stored water in the bioretention area planting soil exfiltrates over a period of days into the underlying soils.
STORMWATER WETLANDS	Stormwater wetlands or Constructed wetlands are structural practices similar to wet ponds that incorporate wetland plants in a shallow pool. Wetlands are most effective stormwater practices for pollutant removal and enhance aesthetic value. Stormwater wetlands are fundamentally different from natural wetland systems. They are designed specifically for treating stormwater runoff and have less biodiversity than natural wetlands both in terms of plant and animal life. There are several design variations of the stormwater wetland differing in relative amounts of shallow & deep water and dry storage above the wetland.
WETLAND RESTORATION	This method has two approaches: active and passive. Passive approach allows natural regeneration of wetland plant communities, re-colonization by animals and re-establishment of wetland hydrology and soils. It is most appropriate when the degraded site still retains basic wetland characteristics and source of degradation is an action that can be stopped. Success of passive methods usually depends on an accessible source of water, close proximity of wetland plants and animals and a mechanism for bringing species to the restoration site. It is low cost and has high degree of certainty that the resulting wetland will be compatible with the surrounding landscape. Active approach involves physical intervention in which humans directly control site processes to restore, create, or enhance wetland systems. It include re-contouring a site to the desired topography, changing the water flow with water control structures (i.e., weirs or culverts), intensive planting and seeding, intensive non-native species control, and bringing soils to the site to provide proper substrate for native species. Design, engineering, construction and costs for such work can be significant.
RIPARIAN FOREST BUFFERS	Riparian forest buffers are areas of forested land adjacent to streams, rivers, marshes or shoreline that form transition between land and water environments. Although riparian areas comprise only about 5 to 10 percent of the land in the watershed, they play an important role in maintaining the health of watersheds. Forests are most effective riparian buffer available. It improves water quality while providing habitat for wildlife and fish. Riparian buffers are key to controlling non-point source pollution. Type, size and effectiveness of riparian buffers vary based on location, environmental management needs and landowner needs. Width of each zone is determined by specific site conditions and landowner objectives.

BMP	Details
STREAM RESTORATION	First and most critical step in implementing restoration is to halt disturbance activities causing degradation or preventing recovery of the ecosystem. Restoration actions may range from passive approaches that involve removal or attenuation of chronic disturbance activities to active restoration that involves intervention and installation of measures to repair damages to the structure of stream corridors. Restoration practitioners involved with stream corridors take one of 3 approaches: 1. **Non intervention and undisturbed recovery**: where stream corridor is recovering rapidly and active restoration is unnecessary and detrimental 2. **Partial intervention for assisted recovery** where a stream corridor is attempting to recover but is doing so slowly or uncertainly. In such a case, action may facilitate natural processes already occurring 3. **Substantial intervention for managed recovery**: where recovery of desired functions is beyond the repair capacity of the ecosystem and active restoration measures are needed.
POROUS PAVEMENTS	Porous pavement is a permeable pavement surface with an underlying stone reservoir that temporarily stores surface runoff before infiltrating into the subsoil. This porous surface replaces traditional pavement, allowing parking lot runoff to infiltrate directly into the soil and receive water quality treatment. There are several pavement options, including porous asphalt, pervious concrete, and grass pavers. Porous asphalt and pervious concrete appear same as traditional pavement from surface but are manufactured without "fine" materials and incorporate void spaces to allow infiltration. Grass pavers are concrete interlocking blocks or synthetic fibrous grid systems with open areas designed to allow grass to grow within void areas. Other alternative paving surfaces can help reduce runoff from paved areas but do not incorporate stone trench for temporary storage below pavement
ENVIRONMENTALLY FRIENDLY CONCRETE	Traditional concrete has many problems including leaching of toxins into surrounding ecosystems through Highways constructed using them. But Green Highways technologies have potential to solve these challenges Utilizing slag cement and Coal Combustion Products (CCPs) such as fly ash, bottom ash, boiler slag and flue gas desulfurization gypsum can save virgin resources, reduce energy consumption and greenhouse gas emissions, and reduce need for landfill space and new landfills. To eliminate toxic leaching, green highway uses porous concrete pavement technology. This technology utilizes a permeable pavement surface with an underlying stone reservoir that temporarily stores surface runoff before infiltrating into the subsoil. Runoff infiltrates directly into the soil and receives water quality treatment. Since the reservoir area underneath porous pavement stores and infiltrates surface runoff, using porous concrete pavement will significantly reduce the amount of land needed for traditional stormwater management measures. Porous pavement increases groundwater recharge, reduces pollutants in stormwater runoff, and helps alleviate flooding and contamination to streams. Current standards for concrete production are not sustainable. Production of each ton of cement is accompanied with one ton of carbon dioxide emissions--one of the greenhouse gases primarily responsible for global warming.

BMP	Details
SOIL AMENDMENTS	By restoring or improving the physical and therefore hydrological characteristics of a soil, that soil can then best be utilized for stormwater management purposes. Compared to compacted, unamended soils, amended soils provide greater infiltration and subsurface storage and thereby help to reduce a site's overall runoff volume, helping to maintain the predevelopment peak discharge rate and timing. Soil amendments also address water quality by increasing the spacing between soil particles so that soil can absorb and hold more moisture. This in turn reduces runoff and damaging effects of excessive runoff on local streams. Amendment of soils changes various other physical, chemical and biological characteristics so that the soils become more effective in maintaining water quality.

6.3. Innovations

Some of the innovations with respect to the roadside plantation are covered below:

BMP 11: System of Vegetation Strips for Protection of Slopes against Erosion

(Subic, 1992)

The United States Patent and Trademark Office is the federal agency in the U.S. Department of Commerce for granting U.S. patents to inventions and registering trademarks (USPTO, 2016). This innovation is related to the development of a system of vegetation strips at steep slopes and to make vegetation cover to develop full growth. This can be used in the areas with very steep slope from 45o to 65o.

Description of the drawing

The base wire netting 1 is shown in Figure 35. On the base wire netting 1 whose mesh is shown in detail "a", wire netting strips 2 are mixed at similar distances (between 1-3 m). The mesh of the wire netting 2 is shown in detail "b". Wire netting strip 2 is mixed to the base wire netting 1 with a wire 3 which is twisted around the base netting 1 and the bottom edge of the wire netting strip 2. Fixed on the upper edge of the wire netting strip 2 are wires which are mixed to the base netting 1 at points 4. The above structure can be prefabricated, made on site or combined.

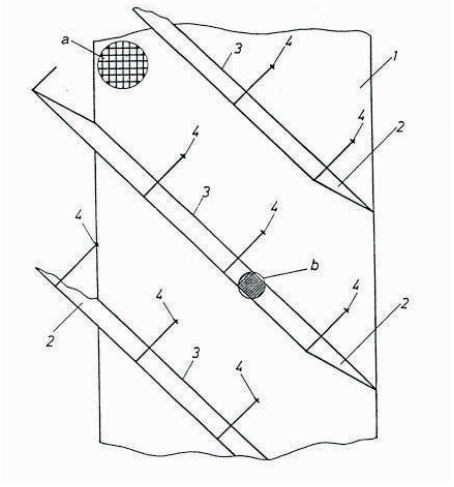


Figure 35: Base wire netting 1 with fixed wire netting strips 2

The vegetation strip system under the invention is installed as follows:

Base wire netting 1 is spread on the slope and fastened at the top of the slope. In case of uneven slope configuration base wire netting 1 must be mixed by rock bolts also at the uneven points to adhere to the ground. Individual strips of base wire netting 1 are also mixed to each other, so the slope is completely covered with base wire netting 1, with the bottom edge of wire netting 2 mixed to the base wire netting I with wire 3. As shown in Figure 35 and Figure 36, the strips of wire netting 2 are mixed to the base wire netting 1 slantwise, under an angle of 20° to 40° to the bottom line of the slope. Such

installations are usually furrows going down the slope in the direction of the roadway and each strip of wire netting 2 ends at the bottom of the slope. Then, upper edges of wire netting strips 2 are mixed with wire to the points 4 on the base wire netting 1. The channel so formed is set apart with special spacers and then installed with earth, turf or other similar material. If necessary, the front side of this channel is closed with synthetic material, jute or similar material to prevent the wash away of earth. This procedure starts at the top of the slope and continues slowly downwards to the bottom. The vegetation strip is then completed.

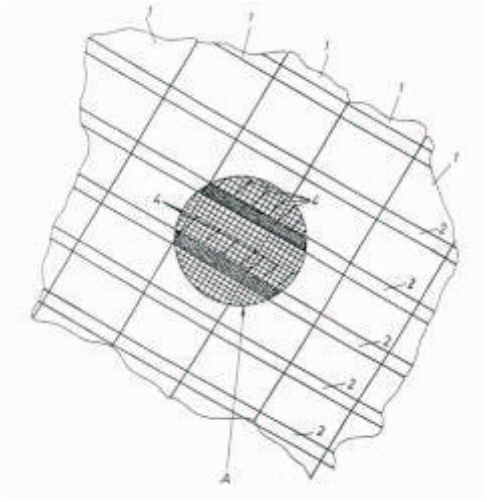


Figure 36: Complete system of vegetation strips for protection of slopes against erosion

Small trees and shrubs are then planted or seeded into the vegetation strips to ensure continued development of vegetation which will protect the slope. Vegetation strips hold erosion material; whereas the filling material is held first by the force of friction between the base wire netting 1 and the surface of the slope and later by the roots of the plants.

Advantages

- Steep slopes of Slopes 45°- 65° can be protected with no height limit
- The protection system is adhered tightly to uneven configuration of any slope
- Planting or seeding does not depend on the vegetation period as it is the case with the "slope mesh"; this operation can be done subsequently
- The slope protection system has unlimited life unlike inorganic materials
- The slope protection system meets all environmental requirements as it can be regenerated

BMP 12: Bottle Seedling/Nursery House turns bamboo and plastic bottles into shelter for Vietnamese farmers

(The Centre for Community Health and Development , 2014)

A bamboo house was designed by 1+1>2 International Architecture JSC architects, in Haiphong, Vietnam in collaboration with the Center for Community Health and Development (COEHD). It developed the Bottle Seedling House in 16sq.m. area (Xuanson, 2016). COEHD is a Vietnamese non-profit organization which works to improve the vulnerable communities and individuals of Vietnam (The Centre for Community Health and Development , 2014). With concrete foundation and cross bracing bamboo frame, this structure is strong enough to withstand in the fields. Bottles and air gap in the structure maintains temperature inside the house. Bottles can be used for rain water harvesting so similar technique can be explored in India.

Figure 37: Bottle Seedling / Nursery house roof

Figure 38: Base of house is made up of concrete

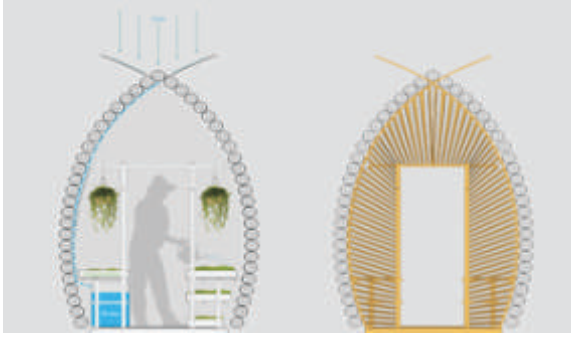


Figure 39: Rain Water Collection
(Arch Daily 4)

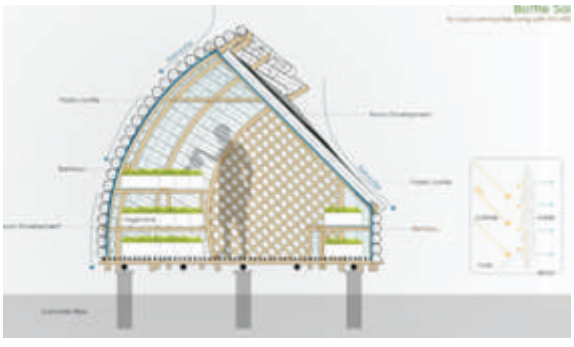


Figure 40: Establishment of seedlings in Bottle Seedling/nursery house
(Arch Daily)

Benefits of the Seedling House:

- Similar setup can be suggested for the temporary nursery during corridor development
- Can be used as a shelter in the fields during inspection or for farmers working in fields
- Increase the aesthetics of the area
- Use of recyclable material
- Can be used for the promotion of bamboo
- Water harvesting technique
- Can attract birds for water during hot summer.

BMP 13: Topmix Permeable Concrete by Tarmac

(Gray, 2015); (Matchar, 2015); (Weller, 2015)

Topmix Permeable Concrete (TPC) is a fast draining concrete designed to be a super-absorbent surface covering that allows water to seep through it in an attempt to combat flooding. It can absorb upto 1,000 liters of water per minute per square meter. The concrete could help to tackle and reduce flood damage, take pressure off aging storm water drainage systems and even reduce risk of water shortages by redirecting rainwater into natural aquifers. In times of extremely heavy rain, the pavement acts as a reservoir, its under-layer holding on to water and releasing it slowly at a pace the ground can handle. The system can also help filter contaminants, such as motor oil, out of water—the multiple layers of porous stone essentially act as a giant filter.

It works by having a permeable layer of concrete on top that allows water to drain through a matrix of relatively large pebbles into a loose base of rubble beneath. Besides helping in tackling flash floods in urban areas it may also help to reduce the heating of tarmac in hot weather. Permeable concrete allows surface water to freely drain through the wearing surface to the underlying ground with the ability to act as a reservoir during periods of high downfall. During these periods this characteristic can aid in delaying the discharge of surface water into water courses or drainage systems reducing the risk of overwhelming systems and causing flash flooding. During periods of rising temperatures and intense rainfall, water stored within the system evaporates creating a cooling effect reducing surface temperatures. Permeable concrete is ideal for large areas of concrete where water can be a problem, such as car parks or driveways. By adding drainage systems into the aggregate beneath Topmix Permeable layer, it can increase the amount of water it is able to absorb.

The system can accommodate three designs: full infiltration, partial infiltration, and full attenuation:

- **Full infiltration** refers to a system where all water goes through Topmix to flow into the soil underneath. It is particularly useful in wet areas that do not need to collect the rainwater.
- **Partial infiltration** involves a semi-permeable barrier beneath Topmix that acts as a drainage system into nearby sewers or waterways — useful when the layer beneath Topmix can't pass the water through on its own.
- **Full attenuation** uses a capture system to store all the water that flows through Topmix. This option is most useful in areas with unclean water and high recycling rates, since the captured water can be reused later.

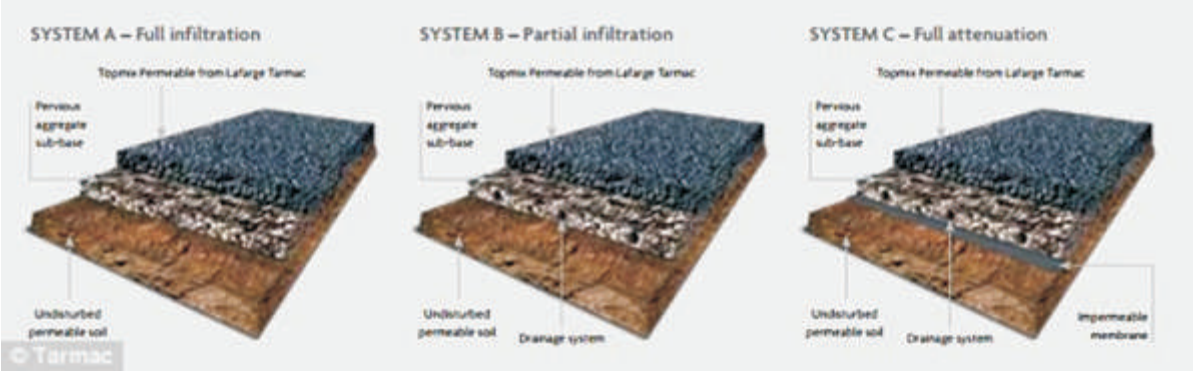


Figure 41: Graphic showing how the system works in 3 design options using TPC

However, in areas that suffer extreme cold, the concrete is likely to be damaged as the water beneath freezes and causes the surface above to buckle and crack. Topmix is currently limited to sales in the UK and has already been used in a car park in High Wycombe and on Worksop Golf Course.

BMP 14: Plastic Roads – Madurai, India

(Menon, 2016)

In 2006, the Thiagarajar College of Engineering, Madurai in India received the patent for this technology which uses plastic waste in creation of roads. In 2002, use of plastic waste in road construction was tested in the premises of the college and this stretch of road is still going strong.

Prof Rajagopalan Vasudevan, Professor of Chemistry at Thiagarajar College of Engineering, Madurai who is the brain behind this is also called as 'Plastic Man' of India for his innovative thought. The plastic waste items that can be used for road construction are various items like plastic carry bags, plastic cups, plastic packaging for potato chips, biscuits, chocolates, etc. Plastic waste helps increase the strength of the road, reducing road fatigue. These roads have better resistance towards rain water and cold weather. Since a large amount of plastic waste is required for a small stretch of road, the amount of waste plastic strewn around will definitely reduce. This process has generated an additional job for rag pickers.

Figure 42: A road made of waste plastic (Walk Ability Asia)

The entire process is very simple. Plastic waste material is first shredded to a particular size using a shredding machine. The aggregate mix is heated at 165°c and transferred to the mixing chamber, and the bitumen is heated to 160°c to result in good binding. It is important to monitor the temperature during heating. The shredded plastic waste is then added to the aggregate. It gets coated uniformly over the aggregate within 30 to 60 seconds, giving an oily look. The plastic waste coated aggregate is mixed with hot bitumen and the resulting mix is used for road construction. The road laying temperature is between 110°c to 120°c. The roller used has a capacity of 8 tons.

Advantages of using waste plastics for road construction are many. Process is easy and does not need any new machinery. For every kilo of stone, 50 gms of bitumen is used and 1/10th of this is plastic waste; this reduces the amount of bitumen being used. Plastic increases the aggregate impact value and improves the quality of flexible pavements. Wear and tear of the roads has decreased to a large extent. This road construction process is extremely eco-friendly, with no toxic gases being released.

7. COMPARATIVE ANALYSIS

The guidelines for Green Highways development projects practiced in various parts of the world have been compared with guidelines of Green Highways Policy 2015 of India to understand and analyze the uniqueness of each of the strategies adopted worldwide. Evaluating the feasibility of these practices in Indian context, some of these practices have been included in the Green Highways Vegetation Management Charter of NGHM, India. A comparison matrix has been developed for the different global practices/strategies/technologies discussed above.

Best Management Practices for Green Highways can be defined as the combination of practices, tools and techniques which

- do not pose risk to travelers
- ensure quality seedlings from certified nurseries
- involve restoration of topsoil
- encourage self-sustaining vegetation
- require minimum use of herbicide / weedicide / pesticide / fertilizers
- require limited use of mowing of grasses and/or trimming, cutting, pruning and thinning of shrubs/trees
- naturally discourage growth of unwanted vegetation
- poses minimum risk of collision of vehicles with wildlife along roadside
- improves aesthetics of highways
- controls soil water and noise pollution
- all other objectives as laid in GHP -2015

Best management practices take hold over time and result into minimum maintenance requirements (need and cost) and evolved through practical application. They also include other aspects of soil erosion control, slope stability, conservation of natural habitat. Best Planting Practices include all factors related to Pre-plantation, Plantation and Post-plantation phase which are responsible for the growth and survival of plants along roadside. Tools can be the suitable instruments for management like use of weed eater for cutting of weed, hand pruner for tree pruning, rake for uniform spreading of soil, spade and pick mattock for earth digging, etc.

On the basis of literature review and comparison matrix it is clear that though many countries have policies for highways plantations but not all have as detailed and comprehensive as GHP 2015 guidelines. United States has given importance to after care and maintenance whereas other countries are focused on planting and initial phase of the plantations. Objectives of plantations along roadside vary from one country to another but majority follow voluntary approach of plantation along roadside and have shown good results also. Objective of roadside plantations in Bangladesh was timber harvesting whereas in Pennsylvania was beautification and aesthetics of roadside. Every country has followed site by site approach for species selection but majority chose native species for plantation by giving priority to road safety for travelers. While planting, special attention was given to invasive species which could affect the presence and growth of the newly planted species.

S.No.	Particulars	GHP,2015 Guidelines	Australia	Pennsylvania	Europe	Bangladesh	Minnesota
1	Plantation policy on ROW	Yes	Yes	Yes	Yes	No, plantations carried out voulunta rily under forest policy	Yes
2	Planting material	Saplings	Ball and burlapped, Bare root saplings, Container plants	Ball and burlapped, Bare root saplings, Container plants	Saplings	Saplings	Seedlings for trees & shrubs; seeds for wild flower & grasses
3	Plant species	Native tree and shrub	Native species	Native species with seeds collected from the country	Native species, Fruit bearing species	Fast grwoing timber value species	Native tree, wild flower, grasses & shrubs
4	Transplantation	Mature tree transplantation	Yes	Yes	Yes	Yes	Yes
5	Landscaping policy	Yes	Yes	Yes	Yes	NA	Yes
6	Validation	Survival rate & average increase in height and girth	NA	NA	NA	NA	NA
7	Payment System	In phases / instalments	NA	NA	NA	NA	NA
8	Community participation	Yes	Yes	Yes	Yes	Yes	Yes
9	Litter control	NA	NA	Adopt-A-Highway Program	NA	Through community work	Adopt-A-Highway Program

S.No.	Particulars	GHP,2015 Guidelines	Australia	Pennsylvania	Europe	Bangladesh	Minnesota
10	Nursery establishment	Provision for nursery establishment	Provision for nursery establishment	Provision for nursery establishment	Establish ment of nursery at every 15 Km of	No rovision as such but seedlings procured from nursery	Provision for nursery establishment
11	Training for plantation	NA	Yes	Yes	Yes	No	Yes
12	Voluntary/ mandatory approach	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary	Voluntary
13	Government support	Yes	Yes	Yes	Yes	No	Yes

Figure 43: Comparison Matrix

For successful tree establishment, major focus was given on species selection and attention during root establishment with watering, mulch, fertilization and pruning.

Plant material can be used for plantation in following forms:

1. Ball & Burlapped
2. Bare-root
3. Container grown

Figure 44: Bare-root, Container Grown & Ball & Burlapped planting material
(Buffalo Green Fund)

Ball & Burlapped is used widely. Transplantation is carried out not only for mature trees but also for young plants grown in nurseries. It is also considered as one of the most efficient and quick way of tree establishment along roadside.

Figure 45: Factors to be considered in successful tree establishment along roadside

Factors that should be considered for the selection of species are flower colors, root type, natural tendency to repel pests, less susceptible to disease damage, tolerances associated with compaction, soil salt, moisture regimes, flooding, depth of water table, soil drainage, drought, soil water holding capacity, soil texture, herbicides, maintenance implications, planting ease, windbreak suitability groups, wildlife benefit, plant toxicity, cold injury, storm damage susceptibility, invasiveness and allergy intensity for different varieties of plants. Majority of these factors have been covered in the Species Matrix developed by NGHM but species selection for each project might vary even for same region might depending on which factors to be given more weightage. NGHM Species matrix has incorporated the Indian Road Congress (IRC) SP 21:2009 guidelines for development of the species matrix. Unlike Europe, roadside trees in India will also be considered for timber harvesting which increases the scope of roadside plantation.

Best practices that are being adopted globally for successful plantings along roadside and can be used in Indian context are categorized as follows-

1. **Pre-Plantation**: All practices that are considered before initiating plantation along a highway stretch including planning, tree species selection, procurement of seedlings, etc.
2. **During-Plantation**: Practices that are taken care of during the plantation on the selected site and will include handling of saplings, planting pit preparation, etc.
3. **Post-Plantation**: After care and monitoring practices for the regular growth of plant species including watering of plants, guying or stalk removal after one growth season, fertilizer application, pruning, etc.
4. **Others**: All those miscellaneous points not covered above but which will be responsible for the successful growth and establishment of the plants along ROW.

8. GREEN HIGHWAYS VEGETATION MANAGEMENT CHARTER

The **Green Highways Vegetation Management Charter** for the plantations along the National Highways will be used by Plantation Manager under each RO/PD of NHAI to implement the plantations work along the national highways as well as determine the applicability of the Best Management Practices including tools, techniques and timing to develop site specific detailed plan and prioritize the practices according to area.

The Green Highways Vegetation Management Charter will engage all the stakeholders at various stages for developing shared ownership and understanding of the Charter. Inputs from the stakeholders will be sought and incorporated after review by the Charter core committee. Engagement of stakeholders will help in enhancing the quality of the Charter and its implementation.

The Green Highways Vegetation Management Charter covers best management practices for roadside plantations used worldwide that can be adopted or tested in India, roles and responsibility of stakeholders; do's & don'ts, roadside safety and sharing of resources. The Charter has been developed consulting the IRC SP 21:2009 guidelines and wherever possible guidelines have been adopted as it is in various sections of the Charter. IRC SP 21:2009 guidelines serve as the basis for all highways plantations in India giving a guiding framework with respect to type of plantation, distance from road, road safety, wildlife corridor management, post plantation maintenance, etc.

Green Highways Vegetation Management Charter for India

8.1. Planning / Pre-plantation Phase

Best practices and guidelines to be considered while planning for tree plantation on highways are:

i. Area Selection

- Whether area along roadside is available for plantation under NHAI or not
- Available soil depth for proper root germination should be minimum 6 inches.
- Surface should have sufficient layer of good quality soil (upto 45cm) for better growth and survival of grasses & shrubs
- Weather conditions of the area
- Number of rows of trees that can be planted according to the Guidelines for Green Highways Project

- Cultural and heritage importance of the area
- Proximity to Wildlife corridor
- To maintain visual characteristics & uniformity in terms of landscape, the entire stretch of the project corridor shall be divided into homogenous landscape sections based on similarity in terms of available width, soil conditions, climate (temperature and rainfall) and topography

ii. Integrated Green Corridor Development through inclusive Detailed Project Reports (DPRs)

For effective implementation of the GHP detailed planning should be done at the respective PIU level at the time of project conceptualization. It should clearly lay out role of different NHAI and NGHM officials, implementing agency and donors wherever applicable. DPRs would be developed by the Plantations Manager in consultation with the Project Director of the PIU after conducting an extensive recce of the prospective project site. It would cover factors such as existing vegetation at the project site and suggested plant species according to NGHM Plantations Species Matrix. Besides plantations, allied and maintenance activities such as irrigation plan, fertigation plan, weeding, etc should be clearly stated.

iii. Role clarity & setting up of performance indicators

Before initiation of the project implementation, expected roles of NGHM, donor, implementing agencies and / or any other concerned stakeholder should be clearly outlined against output based indicators for impact evaluation of project. For example, quality planting material for each project should state expected girth, age and height of tree. Similarly presence of qualified personnel as desired during empanelment stage must be ensured during project implementation

iv. Tree / Shrub Species Selection

- Species would be selected according to the **Species Matrix (Annex III)** prepared by NGHM. This matrix compares plant species for different agro climatic zones on three fundamental principles: Ecological, Economic and Aesthetics.
- Key characteristics of tree/shrub species that should be considered for selection (majority characteristics already covered in Species Matrix) :
    - Suitability to climate, microclimate and soils
    - Soil type and associated tolerance
    - Shape, Size & Form
    - Texture
    - Color / Leaf color
    - Native species with ecological importance contributing towards higher GHG sequestration, soil-water conservation, nitrogen fixation, etc.
    - Growth rate, Survival rate and life expectancy
    - Longevity of the species to withstand harsh roadside conditions: temperature, vehicular pollution
    - Low susceptibility to pests, diseases and animal damage

- Less planting and Maintenance cost
- Tree / shrub species with economic benefits such as fuel, fodder, flower, fruit and timber value
- RET (rare, endangered & threatened) species to promote conservation & enhance ecosystem values
- Plant toxicity, invasiveness and allergy intensity for different plants
- Staging planting in areas with slope to control soil erosion.

- For roadside areas notified as Forest (Protected/Reserved/PAs), the planting list would be approved by the Forest Department.
- Special attention would be given to the areas where highways pass through the notified Protected/Reserved areas along the underpass or overpass for animals by following special protection measures for the forests and wildlife. Specially designed wildlife corridors would be developed with the scientific inputs of specialized organizations and departments.
- For beautification, same species would be selected along a stretch of highway with different flower colors if possible. This can reduce the maintenance of trees as it is easier to maintain similar species trees.
- Allelopathy[5] property of the species would be considered to avoid harmful effect of the phenomenon.

v. Agency / Person Responsible for Plantation

- Forest Departments / Private Company/ Proprietorship Firm/ Cooperatives/ NGOs/ Registered Society/ SHGs/ JFMCs/ Watershed committees empanelled with NGHM
- Concessionaires as per the contract but should abide by GHP 2015 guidelines

vi. Maintenance

- Maintenance work at the time of plantation and upto five years post plantation would be the responsibility of the agency which undertakes plantation along with RO NHAI and Plantations Manager, NGHM.
- Post five years contractual maintenance period, the maintenance will be done by:
  - ✓ Local community who maintain the plantation on one hand, and enjoy usufruct right for sustainable harvest of the products from the plantations
  - ✓ Adoption by any corporate / PSU or donor to maintain the plantations under CSR with branding benefit
  - ✓ Maintenance by NGHM / NHAI wherever above two conditions do not apply

[5] *The phenomenon of chemical inhibition by one plant (or other organism) to another, due to the release of substances acting as germination or growth inhibitors into the environment.*

vii. Funding Source

- NGHM head office will coordinate and finalise funding source for a project site: NGHM corpus fund or donor agency under CSR or PPP initiative or Concessionaires.
- If work is within the scope of Concessionaires then plantation will be done by Concessionaires as per Concession Agreement following NGHM guidelines in a time bound manner or by NGHM if Concessionaire agrees and diverts funds to NGHM
- If the plantation work is beyond the scope of Concessionaire, NGHM would undertake plantations after proper consultation with the concerned RO and the Concessionaire from the corpus funds
- In case of a company or PSU or a donor adopting a particular site under Adopt a Green Highway Program, plantation work would be undertaken either by the adopting company or NGHM, if adopting company gives funds to NGHM to undertake plantation on its behalf

viii. Empanelment and Finalization of Plantation Agency

- Plantation Agency would be finalized jointly by RO NHAI and NGHM head office
- **NGHM Empanelment Guidelines (Annex II)** would be followed for empanelment of plantation agencies considering their work experience, experienced staff and registration.

ix. Soil Characteristics Assessment

- Soil testing to be done by the planting agency/Cooperatives/ NGOs/ SHGs/ JFMCs etc to do the soil characteristics assessment. Soil testing report would be submitted NGHM which should at least include macronutrients level i.e., N (Nitrogen), P (Phosphorous) & K (Potassium)
- Improve the soil quality and condition by adding organic matter or fertilizer for providing biological and chemical stability to the soil.
- Tolerances associated with soil pH, compaction, salt spray, soil salt, moisture regimes, flooding, depth to water table, soil drainage, drought, oil water holding capacity, soil texture, herbicides, and pollutants would also be tested depending on the area, agro climatic zone and species
- Soil testing should be done to determine soil conditioning and improvements required to allow successful establishment of the planted trees.
- Surface and subsoil drainage is essential for optimum plant growth.

x. Planting Material

- Saplings would be procured from certified nurseries (under NGHM / National Horticulture Mission / Forest Department / any other authorized agency) preferably Ball & Burlapped or bare-root or container grown
- Propagation and nursery production of tree stock should be carefully managed ensuring availability of healthy plants and stock of selected species/cultivars of required size
- Uniform size and form of trees to be supplied.

xi. Available Nurseries nearby

- Nursery should be available within 60 Km range from the planting highway stretch and should be certified under NGHM-NHAI or National Horticulture Mission (NHM).
- Nurseries must follow all the requirements for species selection according to the area and NGHM species matrix and guidelines
- In case of non-availability of nursery in vicinity, temporary private nursery can be setup by the plantation agency following NGHM and NHM guidelines.
- Temporary nurseries can be setup as "seedling house" under innovation.

Figure 46: Greenhouse Nursery (Barca Forestal)

xii. Irrigation

- Irrigation source and practice must be clearly mentioned in the plantations DPR by the plantation agency.
- Sufficient water availability will be ensured by the planting agency and inspection will be carried out by the NGHM Plantation Manager.
- In the areas with problem of water availability, innovations like "seedlings house" for nursery development and "Topmix Permeable Concrete" can be considered at the time of road construction phase for harvesting rainwater.

xiii. Scope of Employment

- Local community engagement will also be ensured by the plantation agency in all phases of the plantation.

- Concessionaire or plantation agency must ensure that in all new projects at least 80% of jobs are provided to the local communities. It might be difficult to ensure the same in case of existing Concessionaire implemented projects as they are not bound by NGHM guidelines, therefore advocacy would be done to convince them to ensure as much local participation as they can accommodate.

- Rural youths will be preferred as per the Guidelines of Green Highways Project.

xiv. Equipment Availability

- All necessary equipment and tools (such as tiller, cultivator, weeder, sub soilers, pit digging spade, pruning knife, pruning saw, tree pruner & shears, etc) for plantation must be available with the plantation agency and should be ensured prior to plantation.

xv. Consistent with Road Safety

- Plantation Plan must be prepared in accordance with the road safety following the Guidelines of Indian Road Congress (IRC) SP 21:2009, NGHM and NHAI.
- Indian Road Congress (IRC) SP 21:2009 provides exhaustive guidelines for plantation and landscaping with the point of view of maintaining aesthetic beauty of highways and also ensuring road safety.
- Avoid fast growing species in the first row to reduce risk of sight blockage for travelers.
- Special focus must be given to the turns and interchanges.
- Any particular mature tree which has outgrown in its present location and is a risk to road safety should be tried to save by transplantation
- Frequency of trimming/cutting of trees considering the road safety as paramount abiding the Guidelines for National Green Highways Policy, 2015.
- The first row of plantation shall be one metre away from the toe of embankment so that it is not a hazard to road traffic or restrict the visibility.
- Most vulnerable locations in this regard are the inside curve, median, junction corner and cut slopes. Growth of vegetation close on the road curve may lead to serious reduction of clear sight distance and may cause accidents. Tall and overgrown plants on and near the curve is not permissible.
- Trees shall be planted at a minimum distance of 14 m from the central line of extreme traffic lane to provide recovery area for the vehicle that runs of the road.
- The advertisement size, color and texture shall strictly be in accordance to the prevailing road safety guidelines. Second party shall submit their advertisement plan in project report

xvi. Tree Avenue Structure & Spacing

- Should be in accordance with Green Highways Policy, 2015 guidelines and IRC SP 21:2009 guidelines.
- Space between trees and shrubs can be planned differently as shrubs usually do not have big crown area. Spacing can be decided in consultation with the specialists like horticulturist or arborist.

- Spacing would be decided according to the species to be planted adhering to NGHM guidelines.
- Depending on the available ROW, plantation pattern should be worked out as follows: i) First row along the Highways will be of small to medium sized ornamental trees. ii) Subsequent rows, depending on the availability of width, will comprise of ornamental and/or shade bearing species, of more height than those in the first row. iii) In rural sections, the last row will always be of shade bearing tall trees.
- Multiple rows of plantation are advised for better protection against soil erosion and water purification. Plantation shall be done in a staggered manner.
- Landscape character of the tree avenues should be maintained wherever possible as local community associate with these trees due to avenue structure, religious importance and seasonal effect. New avenue plantation should have trees of similar species, age and size (relative to each other) planted in a symmetrical arrangement to retain the avenue structure. This will require inter-planting offset from existing avenue trees so that the planted trees have space to grow to sufficient height before removing existing trees.
- Technical Specification: Technical specifications given here are just for understanding Green Corridor Development approach. The site specific project report shall prescribe plantation pattern based on actual site condition.

Row I

Distance from embankment	3.3 ft away from the toe of embankment/ 55 ft away from central traffic line
Spacing between plant to plant	10 ft
Canopy Shape & Size	Preferable Cylindrical/oblong with small CSA
Size of the pits (normal soil)	60 X 60 X 60 cm
For Alkaline soil (usar)	By Auger
Water logged areas	Mounds with height varying depending on the water level
No. of plants per km on one side	333
Height of the plant	1.5 m to 2 m

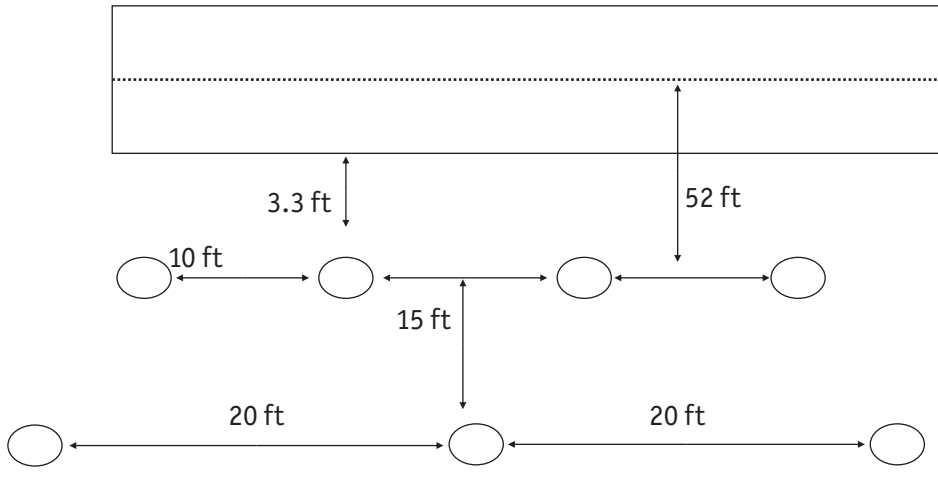
Penultimate Row (If space for III Row is available)

Distance from preceding row	15ft
Spacing between plant to plant	10ft
Canopy Shape & Size	Preferable Round/oblong with medium CSA
Size of the pits (normal soil)	60 X 60 X 60 cm
For Alkaline soil (usar)	By Auger
Water logged areas	Mounds with height varying depending on the water level
No. of plants per Km on one side	333
Height of the plant	More than 2 m

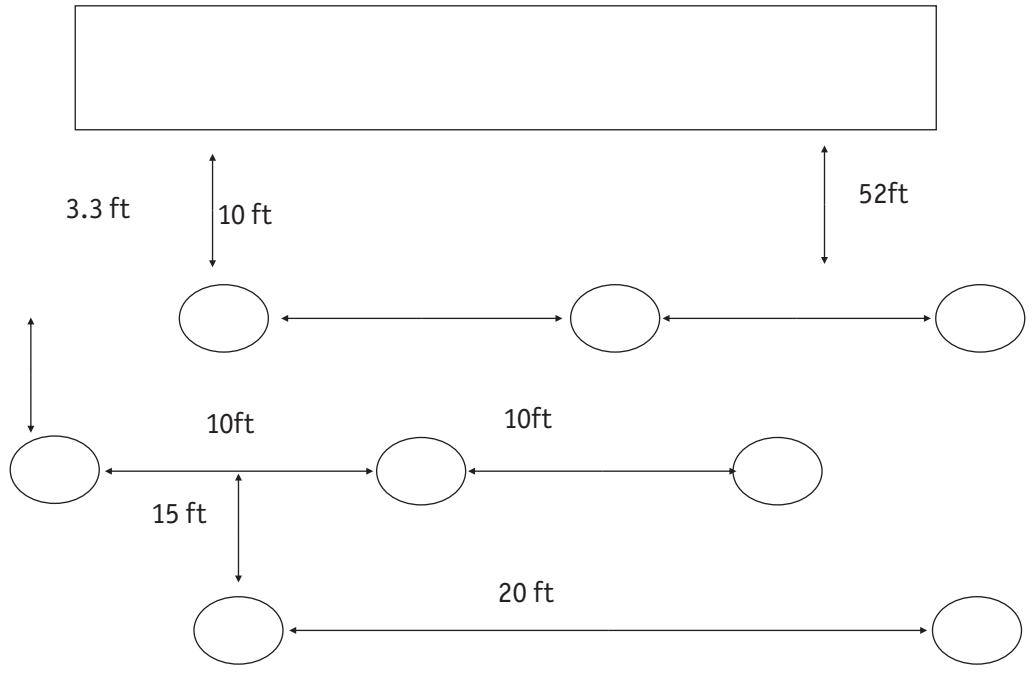
Shade Plants Last Row (II OR III row)

Distance from preceding row	15 ft
Spacing between plant to plant	20 ft
Canopy Shape & Size	Preferable spreading with medium CSA
Size of the pits (normal soil)	60 X 60 X 60 cm
For Alkaline soil (usar)	By Auger
Water logged areas	Mounds with height varying depending on the water level
No. of plants per Km on one side	166
Height of the plant	More than 3 m

(Case I)



(Case II)



xvii. Tree Median Plantation Structure and Specification

- Shrubs to be planted in the median shall be of low or medium height for prevention of headlight glare. Non-browsable flowering species like Caesalpineas should be preferred.
- One to two rows of flowering shrubs are recommended according to the varying width of the median in different sections.
- Some herbaceous species may also be planted as ground cover, not only on the medians but on special landscapes and embankment slopes also.
- Technical Specifications:
    - In sections where median width is less than 1.5 meter, only grass turf is recommended.
    - In median width of 3 meter, one row of shrub to be planted
    - In 5 meter median width, plantation of two rows of flowering shrubs at a spacing of 1.5 meter from the inner edge is recommended.
    - The plants shall be at spacing of 3 X 3 meters and size of the pits for planting shall be of 0.6 m diameter and deep.
    - The surface for the median plantation shall be well prepared.
    - The surface shall have sufficient layer of good quality soil so as to have a better growth and survival of grasses and shrubs.
    - The masses of loose debris on the median and any convexities shall be removed and similarly any concavities are to be filled with good soil.

xviii. Plantations on Vacant Land Parcels

- Captive plantations of commercial crops can be initiated on the vacant land parcels available with NHAI near flyovers and road alignments.
- User rights of these lands can be given to agro-forestry industries which can take up plantation, management and sustainable harvesting during the concession period.
- NGHM based on the project feasibility can transfer user rights based on project development fees, annual premium and profit sharing from the concessionaire.
- Pulp & paper industries, Fiber board manufacturing units and various small scale cottage industries (furniture, incense sticks, handicraft, floriculture, food processing) are some agro-forestry industries dependent on Agriculture or forest produce for their raw material and can be approached for plantation on vacant land parcels

xix. Transplantation

- Trees of age 2 years and above shall be considered for transplantation which can be transplanted both manually as well by use of appropriate technology
- Transplantation location shall be finalized during the planning stage itself and the same shall be prescribed in the project report.
- If the location of transplantation of young native trees cannot be finalized then it shall be kept in nursery with due care till the space is available on ROW.

- Transplanting Technique for trees above 5 years of age:
    - In winter when the tree is dormant or less active, it shall be pruned heavily leaving a bare framework of the large branches.
    - 40 to 50 m wide trench (1 to 2 m deep) shall be dug around the stem as much distance away from it, depending upon the stature of the specimen, cutting all the roots, big and small, in the process.
    - Location of transplantation is to be identified and preliminary treatment is to be done at least 3 months in advance before the area is ready for transplantation.
    - Specialized techniques required for transplantation with specialized equipment and machinery should be arranged
    - Transplantation of trees shall be done to the maximum extent possible on the National Highways to save the trees along ROW.
    - Transplantation site shall be within 5 km of the existing tree location.

xx. Plantation in ROW notified as Forest (Protected/Reserved/PAs)

- For sections of highways where the plantations in ROW have been notified as Forest (Protected/Reserved/PAs), permission for tree cutting is granted by Forest Department (FD) under the Forest Conservation Act, 1980.
- While granting the permission, the FD stipulates the conditions not only for compensatory afforestation (CA) but also for avenue plantation.
- Amount for avenue plantation is remitted with Forest Department and normally the work of avenue plantation is taken up by Forest Department apart from CA.
- Such plantations can also be given to Forest Development Corporation (FDC) of respective state which can sign a MoU with NGHM for plantation, maintenance activities and sharing the sustainable harvest earnings with NGHM.

xxi. Protection of Existing Trees

- Trees already existing in the highway stretch must be protected unless they are diseased or possess any safety risk to travelers or are old enough to die of their natural death.
- New tree species will be chosen in accordance to the existing trees. Possible plan that can be referred for plantation is given in the figure below.
- Any tree which can possess risk to travelers and has sentimental value should be transplanted.

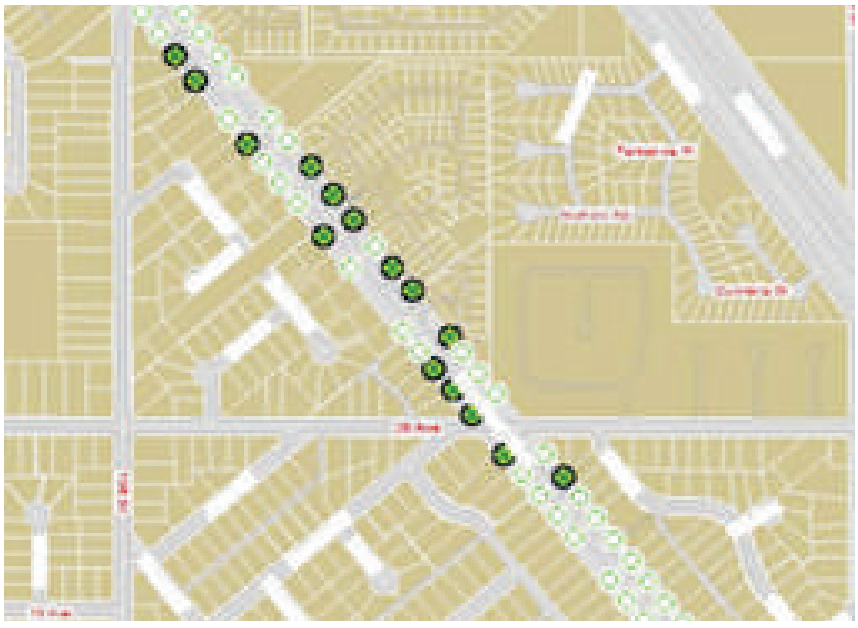


Figure 47: Planning of tree plantation on already existing highways (Surrey)

Material Handling, Inspection and Storage

- Saplings good in appearance, free from insects, wounds and plant diseases should be selected for the plantation.
- Species name and size should be tagged on the saplings for easy selection.
- Full growth of root systems and avoid J-root formation[6] .
- Keep the root balls moist using water.
- Protect root balls from water loss in summers and from freezing in winters.
- Do not drop the root ball.
- Lift the saplings with care to avoid breakage of root ball. Do not lift it by stem.
- Inspection of the trees will be done by plantation agency and NGHM Plantation Managers before and after procurement respectively.
- Plant bare-rooted plants during their dormant season to avoid stress of plantation. Dormant season is species dependent.
- Plant trees as soon as possible. In case of delay, cover it up with wood chips which will act as mulch and keep it moist and alive.
- Soak bare-root trees in water before planting along the roadside.

[6] *Roots in the form of English alphabet 'J'.*

8.2. Plantation Phase

Best practices to be adopted during the plantation phase along the highway stretch.

i. Planting Stock Propagation

- Select trees species of uniform size and form for plantation.
- Plant the seedlings procured on daily basis. Avoid storing saplings for long.
- Tree stock or saplings stock to be used for each stage of plantation should be supplied from a single batch (if possible) in a covered vehicle. Propagation batches should only be split if there is long period between stages of planting works making it impractical to hold and manage tree stock from single batch.

ii. Preparation of Plantation Area and Plantation Activity

- Eliminate weed known to the area or any type of vegetation from the selected plantation area which can affect the growth of the new plantations.
- Loosen the top 6" of the soil of the entire plantation area for proper root development. Roto-tiller can be used for loosening of soil along roadside.
- To restore the topsoil function either place topsoil from the construction area on the selected area or add organic matter like mulch made up of wood chips or composted materials. However, wood chips should be avoided in areas susceptible to termite attack
- In location where a really bad patch of alkaline soil occurs, there is a need to dig deep pits by Auger (mechanical device) and replacing it by good quality soil. The soil amender Gypsum 1 to 3 kg, depending on the pH along with 2 kg compost and sand shall be filled in the pits. The treatment helps in lowering down the pH and thus enhancing better survival of plants.
- Create small earthen berms around the trees to capture moisture and soil erosion control for planting on slopes.
- For very steep slopes (> 30°), bioengineering techniques like hydro-seeding or innovations can be used.
- Dig the pit, 3 times bigger than the root ball radius in width. The depth of the pit should be same as the root ball.
- Remove the burlapped material if it is made up of non-biodegradable material otherwise remove the burlap material from the upper surface only.
- Construct a 3" tall watering dike around pit and to remove voids apply water.
- Hormones/fertilizers (high in phosphorous) can be applied in order to reduce stress of plantation.
- In areas with geotechnical problems such as landslide and eroding slopes, soil bioengineering technique called vegetated bamboos crib walls can be used.
- Place a 4-6" layer of mulch around the tree in a minimum three foot radius for moisture, nutrient capture and protection from any weed.

- In clay soil, plant trees approximately 20% higher than usually root-ball is planted
- Guying or staking can be done if tree is unable to stand on its own.
- Plantations should be done as per the agreed Avenue and Median Plantation structure.

8.3. Post-Plantation Phase

Post-plantation care and maintenance will be taken up by plantation agency till maintenance schedule and afterwards by local communities or by NGHM.

i. Regular Maintenance and Monitoring of plantation site

- Plantation Agency would be required to submit the progress report on monthly basis to respective PIU, which shall conduct field verification on monthly basis.
- Scope of five years maintenance work and its schedule shall be prescribed in project report covering: survey, site preparation, weeding, hoeing, watering, fertigation, casualty replacement, pruning, etc.
- Follow strictly the maintenance schedule as per NGHM Guidelines for frequency of watering except monsoon season
- Pruning of trees should be done in early growth season to have a desired growth of the tree. Damaged, dead or irregular spreading branches should be removed throughout the year which can possess risk to travelers.
- Prune / trim large trees before monsoon season.
- Excessive or vigorous pruning and tree topping must be outlawed and only gentle pruning should be favored and must be carried out by trained arborists. Pruning should be done in order to increase airflow for increasing the air filtering effect and dust capture capacity of the roadside trees.
- Special types of pruning can also be practiced for beautification and aesthetics purpose like willow pollarding.
- Clean the area every time after pruning / trimming using sharp tools to avoid spreading of diseases / infections. Disinfectants or fungicide can be used to clean the equipment.
- Fertilizer requirement will depend on the soil test report. Always apply fertilizer / herbicides / weedicides after pruning / trimming. Notify the nearby public before herbicide / weedicide / pesticides / insecticides (if required) spray.
- Spot spraying of fertilizers / herbicides / weedicides should be preferred over spraying the entire ROW. Herbicide & insecticide used must not violate Indian Insecticides Act, 1968 and herbicides/weedicides or pesticides from approved agencies by Government of India (GoI).
- Use lower application rates of herbicides/weedicides for coarse-grained soils and higher rates for fine-grained soils or soils high in organic material.
- Use biodegradable methods for the control of unwanted plants on road shoulder or any other area.

- Stake the tree for one growing season so that it can develop its vigor.
- Maintain mulch at a depth of 3" and a minimum radius of 3" around the tree. Mulch can be prepared by wood chips, bark cuttings, etc.
- Monitor and remove invasive species known to the area. It can be done manually by uprooting the weed or using equipment like weed eater.
- Methods that can be used to control noxious weeds are as follows-
    - **Natural control Method**: Introduce plants and covers to control noxious weeds and other unwanted plants. Controlled burning can also be used.
    - **Mechanical methods**: Hand scythes, shovels, string trimmers, weed eaters, push mowers, pruning shears, etc. can be used as machines for weed control and desirable vegetation maintenance.
    - **Biological methods**: Use of animals, insects, bacteria or virus to control weed growth
    - **Chemical Methods**: Use of herbicide & weedicide approved by Central Insecticides Board and Registration Committee (CIBRC) and Food Safety and Standards Authority of India (FSSAI) under Food Safety and Standards Act, 2006. Though preference will be given to biological method considering the implications on the environment.

8.4. Others Management and Maintenance Activities

- **Litter control**: During the maintenance schedule of five years, litter control will be taken up by the plantation agency later NGHM-NHAI can start a program in India under Swachch Bharat Abhiyaan on similar lines as "Adopt-A-Highway" program of United States for litter management along the highways.
- **Fire-line**: Maintain a fire-line between ROW and fields nearby highways to prevent expansion of fire along highways or from highways to field.
- **Road safety**: Ensure on continuous basis, the safety of road commuters by careful pruning and management of trees as per guidelines stated in point 8.1 (xv) above
- **Tree Protection Measure**: It is responsibility of the Plantations agency to ensure that the plantations done is secured and is not damaged by human or animal intervention. The fencing of single row plantation will be done by using tree (iron / brick / bamboo) guards. The fencing of multiple row plantations shall be done preferably by barbed wire. A five strand barbed wire fencing, with cross strands, stretched on angle iron poles fixed at a distance of 4 meter from one another is recommended. Live fencing / bamboo fencing / thorn fencing / CPT may also be used wherever protection can be ensured through these. The specification for barbed wire fencing shall be as per IRC SP-21:2009.Tree guards made of locally available bio-degradable material, such as bamboo sticks wrapped by stems of Besharam (Ipomoea carnea) would be preferred as they would be economical and environment-friendly.

9. RESULTS, DISCUSSION & FUTURE RESEARCH

The Green Highways Vegetation Management Charter development is an ongoing process and regular updation is very important. Community landscaping, plantings, vegetation maintenance are majorly adopted practices in different parts of the world but countries are yet to integrate carbon potential of trees planted along highway ROW. Majority of the countries have developed Integrated Roadside Vegetation Management plan but not as holistic guidelines as India has developed under GHP, 2015. Validation of the plan apart from success rate could be done through surveys and public feedback.

Live snow fences of trees in snowfall prone areas along highways like NH 1 (J&K) can be done to protect the roads from snow and for beautification of the roads. These can also act as windshields.

Since engagement of local communities is crucial for the success of NGHM, therefore the public engagement plan that would include awareness, trainings, workshops and advertisement regarding the mission should be developed. Mowing policy can be modified into trimming / cutting policy for cutting / trimming / pruning of trees / shrubs along roadside that will include agreement with the plantation agency or local communities for carrying out the pruning / trimming / cutting practices and will also include the frequency of trimming / cutting of trees considering the road safety as paramount abiding the Guidelines for National Green Highways Policy, 2015. Assessment or baseline data collection should include current conditions of soil by soil sampling, pollution level, green cover, list of RET (Rare Endangered and threatened) species in the project area and noxious weed in the area so that specific plans for the stretch can be developed. Native grasses and wildflowers are also effective in establishment of sustainable vegetation by the MnDOT, which can be included in the Species Matrix. In the hilly areas where primary concern is to arrest soil erosion and slope stabilization hydro-seeding can prove to be effective for plantation of herbaceous species.

User and public awareness and engagement also plays crucial role in the effective implementation of the project. There is a need to carry out stakeholder analysis mapping relevant GHP stakeholders (Plantation Managers, Plantation agencies, NHAI staff, and community, etc) and other stakeholders and their training and capacity building needs. Training modules should be developed and regular training to be imparted to the stakeholders involved in the plantation and maintenance work by respective Plantations Agency / Cooperatives / NGOs / SHGs / JFMCs etc. registered under the Mission. Besides this, convergence opportunities with government initiatives such as Skill India Program should be explored.

Global BMPs in Green Highways in Indian Context

The review of the global Best Management Practices has provided a good overview of the existing best practices worldwide which are relevant to the Green Highways. India being a vast country with varied climatic zones and regional diversity, there is no single BMP that can be applied as a standard practice across the country. There is a need to contextualize the global best practices after testing them in Indian conditions. Global best practices matching a particular agro climatic zone of India should be model tested in few similar locations and then learnings from the implementation of the BMP should be collated and localized version of the BMP should be developed. Though there are alot of BMPs which are already being implemented in India but there is a need to develop a proper vegetation management plan which covers all feasible best practices as a holistic plan covering all phases: planning phase, plantation phase, technical maintenance phase and self-sustainability phase. Besides this, some of the BMPs are already being practiced in India but there is scope of improvisation with coming up of new technologies and innovations. Therefore, learnings from various parts of the world and innovations should be should be reviewed and applied in Indian context.

Limitations and Future Research

This manual largely focuses on the plantation aspect but while reviewing the global best practices, the best practices with respect to some of the non-plantation activities were also looked at. These practices should be reviewed in depth and model tested and then included in the Charter to make holistic Charter for Green Corridor development. Some of the practices that can be looked at are:

- Use of cloverleaves interchanges large space on highways can be explored for the treatment of storm water runoff like Ellicott City, Maryland and Newtown Township, Pennsylvania, United States has designed.

Figure 48: Cloverleaves and diamonds near interchanges are ideal for planting
(Static)

- Road engineering techniques which contribute towards green highways through water conservation, use of waste material in the mix, water absorbent and percolating material, underground water tanks, etc can be explored.
- Tree Protection during Design and Construction is a way to ensure that trees, brush, flowers, and grasses are not damaged during construction operations (Ann M. Johnson, Best practices handbook on Roadside Vegetation Management, 2000) and to promote the use of corrective action when damage does occur. This part can also be explored and can be included in the NGHM Guidelines.
- There is scope for further testing and development on creation of Pervious Concrete which is a mixture of 'aggregate' – small broken pieces of stone and a special grade of cement. When water flows on the pervious concrete roads, it gets absorbed into the ground below. Pervious Concrete Road technology is currently being used and tested in Netherlands and in Delhi in India. There are two advantages with this technology:
    - Rainwater is absorbed into the ground. So roads do not break down and have a longer life.
    - Rainwater directly seeps through the pores in the road and joins the groundwater, slowly resulting in the rise of groundwater levels.
- Use of green technologies such as wind energy, solar energy, biodiesel generating plants, etc can be explored on pilot basis and then included in the Charter as best practices.
- GIS based monitoring: Monitoring of plantation should be GIS based in order to expand the reach of the mission and also to take care of the maintenance work.
- Online Species Matrix and Negative List: Species Matrix and Negative List, according to the NGHM guidelines, should be online based and open to all for suggestions from experts and common people so that region wise list can be prepared and updated regularly. As India is a diverse country this way region wise or agro-climatic regions wise data can be collected easily and this will increase the public involvement in the mission.
- Development of Green corridor rating system (GCRS) assessing the performance on the basis of adherence to guidelines, innovations, use of technology, best management practices, etc.

Unless elements of roadside vegetation management are considered in design, maintenance staff will encounter difficulties in implementing the plan, especially as it relates to erosion control and the establishment of desirable vegetation. So construction and maintenance practices of roads should include proper seeding techniques, selection of the correct plant in the right area, selection of salt-tolerant seed species where needed, erosion control, topsoil placement and grading operations.

Research Need Analyses in Green Highways

The Green Highways Program is being implemented across diverse landscapes of India with varied agro-climatic zones. No particular BMP can be applied as a standard across the country. Therefore considering the varied geographies and climatic conditions, extensive research is needed for building green corridor along the highways which are capable in adapting and mitigating global warming and climate change effects. Proper research need analysis should be done and areas of potential research should be identified through stakeholder consultation. Global BMPs should be analyzed and tested for Indian context and suitable localized BMPs should be devised for varied agro climatic zones of India. Research on following themes should be undertaken on priority:

- impact of highway plantations on micro climatic conditions, pollution level
- role of bio engineering techniques for slope stabilization and controlling soil erosion
- irrigation techniques and water management including conservation
- use of green technologies and green energy
- suitable plant species, appropriate plantation / vegetation models
- GIS based monitoring
- development of green corridor rating system

ANNEXURE

I Soil Meaning and Type

Dictionary meaning of soil is 'the portion of the earth's surface consisting of disintegrated or weathered rocks, minerals and humus' in which plants can grow. Soil formation occurs in stages because of that different layers of soil have different properties. Soil profile i.e., vertical section of soil, depicts the soil fertility. Soil is composed of air, water, organic minerals and organic matter (University of Hawai'i - College of Tropical Agriculture and Human Resources, 2007-2016). Different layers of vertical section of soil profile are called horizons. Primary horizons are O, A, E, B and C.

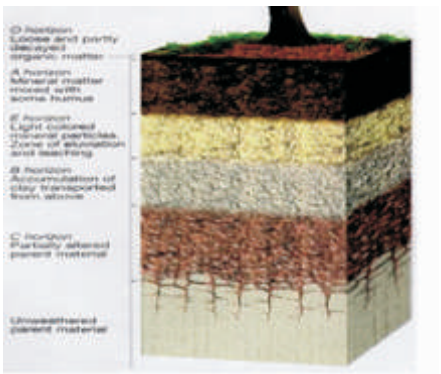


Figure 49: Forest Soil Profile
(Hawaii)

O horizon- comprised of organic material at various stages of decomposition

A horizon- consists of minerals (sand, silt, and clay) and with appreciable amounts of organic matter. Predominantly the surface layer of many soils in grasslands and agricultural lands.

E horizon- subsurface heavily leached horizon. Leaching is the process in which soluble nutrients are lost from the soil due to precipitation or irrigation

B horizon- subsurface horizon. It is a site of deposition of certain minerals that have leached from the layer(s) above.

C horizon- subsurface horizon. It is the least weathered horizon. It is unconsolidated, loose parent material.

Last horizon is the parent rock. Composition and presence of soil horizons vary from place to place or region to region these are used for the management of nutrients in the soil.

Soil classification according to the grain size by **British Soil Classification** System is shown in figure below (Atinkson, 2000).

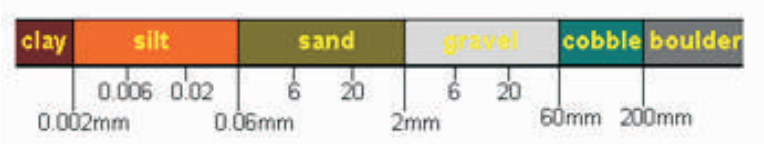


Figure 50: Soil Classification (in mm)

ANNEXURE

II Empanelment / Registration of Plantation Agencies

Agencies interested to take up plantation and allied activities shall be first registered with NGHM. Proposal of registration can be submitted in prescribed formats to respective Regional Offices or NGHM Headquarters. After due verification, agencies will be deemed empanelled and will be eligible for undertaking plantation and allied activities on behalf of NGHM. The list of empanelled agencies will be uploaded on the website of MoRTH, NHAI and IHMCL.

1. Empanelment of Plantation Agencies (Private Limited Companies, Proprietorship Firms and STARTUPs etc.)

After receiving duly filled application (format –Annexure I) from Plantation Agencies, ROs shall submit verification report in prescribed format to NGHM with their recommendations for approving or rejecting applications.

Evaluating Technical Credentials of Plantation Agencies: Plantation agencies must have following resources to be considered for empanelment

S. No	Resources	Eligibility Criteria
1	Team Leader (1)	1. Minimum 3 years of Experience in Plantation/ Transplantation/ Landscaping Activities 2. Education Qualification: Post Graduation/ Graduation in Forestry/ Agriculture/ Horticulture or other relevant stream.
2	Team Supervisor (1)	1. Minimum 2 years of Experience in Plantation/ Transplantation/ Landscaping Activities 2. Education Qualification: Post Graduation/ Graduation in Forestry/ Agriculture/ Horticulture or other relevant stream.
3	Team Members (2)	1. Minimum 1 year of Experience in Plantation/ Transplantation/ Landscaping Activities

2. Empanelment of Cooperatives / NGOs

After receiving the duly filled application from Cooperatives/ NGOs and other similar organizations, ROs shall submit verification report in prescribed format to NGHM with their recommendations for approving or rejecting applications.

Evaluating Technical Credentials of Cooperatives & NGOs: Agencies must have following resources to be considered for empanelment

S. No	Resources	Eligibility Criteria
1	Cooperative / NGO Head / Representative	1. Minimum 3 years of Experience in Plantation/ Transplantation/ Landscaping Activities 2. Technical Qualification: Graduation in Forestry/ Agriculture/ Horticulture or other relevant stream. OR Certificate from recognized govt. agency of any professional course/training in Plantation/Agriculture or other relevant stream.
2	Cooperative / NGO Members	1. Minimum 2 years of Experience in Plantation/ Transplantation/ Landscaping Activities 2. Technical Qualification: Graduation in Forestry/ Agriculture/ Horticulture or other relevant stream. OR Certificate from recognized govt. agency of any professional course/training in Plantation/Agriculture or other relevant stream.

3. Empanelment of Community Based Organizations/LSGs such as FPOs/ SHGs/ JFMCs/ Watershed Committees/ Gram Panchayats etc.

Community Based Organizations/ LSGs will be considered for empanelment based on the accreditation received from Collector/Forest Department/ Horticulture Department or RO-NHAI. Initially CBOs/LSGs will be awarded work for maximum 2 km as per plantation SoR of MoRD. Work award eligibility will be upgraded on annual basis for CBOs/LSGs on successful completion of projects awarded. Eligibility can also be upgraded earlier, in case CBOs/LSGs are able to complete to their previous project before scheduled annual upgradation.

Evaluating Technical Expertise of Applicants

- This technical team composition will be for plantation work up to 10 km. Number of technical resource persons will be increased as per the scope and requirements of the project. Same will be mentioned in MoU.
- One resource person can be part of only one agency. If duplicity of same resource person is found in more than one agency, then credentials of that particular resource person will not be considered by NGHM.

Relevant Work Experience

- Plantation agencies should have completed plantation projects of minimum Rs 5 lakh project cost.
- Plantation agencies will be eligible for getting work order equivalent to their work experience in plantation projects.
- Work order eligibility will be enhanced in proportion to amount of work completed. Same will be updated on the empanelled list on the website of MoRTH, NHAI and IHMCL

STARTUPs will be exempted from work experience qualifications, but they will be required to fulfill technical credential criteria. Initially START UPs will be awarded work for 2 km and based on their performance further works will be awarded.

Project Award Eligibility Evaluation: If any XYZ agency has completed plantation projects worth Rs 5 lakh at the time of registration and after empanelment XYZ agency completes another plantation project of Rs 2 lakh, then the eligibility of XYZ agency will be Rs 7 lakh (5 +2). Agencies can send their requests to upgrade their eligibility to respective ROs with a copy to NGHM Headquarter.

Format for Application for Empanelment of Plantation Agencies

Name of the Applicant Agency	
Type of Agency (Private Company/ Proprietorship Firm/ Cooperatives/ NGOs/ Registered Society/ SHGs/ JFMCs/ Watershed committees etc.)	
Authorized Contact Person	
Address & Contact Details	
Email ID	
Relevant Plantation/ Transplantation/ Landscaping Experience (please mention total project cost)	
Team Composition (Details of team leader, team supervisor/ members)	
Any other expertise (Availability of Transplantation machinery etc.)	

Signature of Authorized Signatory

Name

Designation

Agency Name & Seal

Documents to be enclosed along with application:

1. Please enclose certificate of registration and other relevant document such as MoA, AoA, and Income Tax return of last financial year. (CBOs/LSGs are only required to submit registration document along with accreditation from Collector/Forest Department/Horticulture Department or RO- NHAI/MoRTH)

2. Please enclose relevant document for verification such as Work Order, Work Completion and Photographs of plantation site

3. Detailed CV of Team Leader, Team Supervisor and other members along with relevant experience and education qualification documents.

4. Affidavit certifying that all the information submitted by the agency is true to best of his/her knowledge.

5. Complete application form along with covering letter on the letterhead of the agency can be submitted at PIU/RO/ NGHM Headquarters. Application can also be sent through Email or by Speed Post.

Note: CBOs/LSGs are not required to submit work experience certificate.

ANNEXURE

III Plantation Species Matrix for Roadside Plantation

Executive Summary

Highways are acknowledged as the growth engine of economic development. Interstate road infrastructure enables movement of goods, facilitates trades and bridges the geographical divide amongst cities. The fact that National Highways account for only 2 % of the paved roads but still carries 40 % of the automobile traffic signifies its importance in Indian economy. The incessant movement of vehicles on the highways emitting harmful gaseous & solid pollutants is a major source of air and noise pollution. High level of Green House Gases (GHGs) and suspended dust particles in air poses an imminent health threat for the commuters and also endangers the biodiversity of the region. Under such circumstances it is important to take proactive measure for pollution containment on highways. Various research, case studies and pilot project conducted over the years have confirmed that green corridors/belts are the effective means of pollution control. Green corridors work as vegetation buffer around the pollution source and helps in sorption of GHG gases and collection of dust particles.

Given that green corridors have to face stressed climatic conditions with intake of high level of gaseous emission (SO2, CO, CO2 & NOX and Suspendeda Particulate Matter (SPM), it is important to select the species which are tolerant and at the same time capable in effective mitigation of pollution. Plantation Species Matrix is a framework to facilitate National Green Highways Mission - NHAI in selection of suitable tree/shrub species for green corridor development.

For identification of suitable tree/shrubs an Excel based model has been developed which compares different plant species on three fundamental Principles – Ecological, Economic and Aesthetic Value. The model provides ranking of different tree/shrub species based on their suitability in a particular bio climatic zone. The criteria and indicators for the model were developed based on the Central Pollution Control Board, MoEF guidelines (ENVIS Centre, 2000)and the existing guidelines (IRC) SP 21:2009 of Indian Road Congress. Over 450 tree/shrub species were compared and assessed on this tool for identifying the best suitable species for median and avenue plantation.

There are certain species which have been considered under Negative list of species as some of them have been found invasive, toxic or performed poorly on the tool.

Introduction

India has the world's second largest road network after USA. Out of 46.80 lakh KM long road networks, National Highways account for 1 lakh km stretch which passes through urban, rural and forest areas of the country. Clearance of forest and tree felling activities are inevitable process of highway development which results in large scale environmental degradation in form of biodiversity loss and release of carbon stocked in trees. Although to counter the losses Highway projects are bundled with median and avenue plantations but they are seldom equivalent to the natural ecosystem existing before the development. The situation becomes critical with incessant movement of vehicles on these roads contributing further in release of Greenhouse gases and other suspended particulate matters. Pollutants released in air by vehicles travels to farther areas, posing an imminent health threat for humans as well as wildlife.

In this respect, Ministry of Road Transport and Highways has recently unveiled Green Highway Policy - 2015 with the vision "to develop highways for economic development and growth in a sustainable manner with participation of local self-government / private agencies / forest department".

The policy envisions participatory approach for development of green corridors along highways, which will help in sequestering GHG emissions and will also create millions of man-days' of employment. National Green Highways Mission- NHAI has been given the responsibility to implement the Green Highway project for Green Corridor development along National Highways.

The concern for neutralizing ill effects of pollutions is shared globally. Various researches, case studies and pilot projects conducted over the years identifies green belt as the effective means of pollution control. As green belts have to face stressed climatic conditions involving intake of high level of pollutants (SO2, CO, CO2 & NOX& SPM), it is important to select species with high pollution tolerance index and effective pollution sorption capacity.

Green Corridor Development

Vehicles are the mobile sources of gaseous as well as particulate pollution. Components of green corridor on roadside hence should be both absorbers of gases as well as of dust particulates including even lead particulates. The choice of plants should include shrubs of height 1 to 4 m and tree of 3 to 20 m height. The intermixing of trees and shrubs should be such that the foliage area density in vertical is almost uniform. A green belt of such a design and having width of 30 to 50 m will enable higher pollution attenuation capacity.

For any green belt development tree/shrub species shall be selected based on its ecological importance, economic value and suitability for roadside plantation. The focus shall be on planting native tree/shrub species with ecological importance contributing towards higher GHG sequestration, soil-water conservation, nitrogen fixation etc. Tree/shrub species with economic benefits such as fuel, fodder, flower, fruit and timber value shall also be given due consideration.

The objectives of roadside plantation as envisaged in Green Highways Policy-2015 are to:

- Develop a systematic framework for plantation along National Highways
- Reduce the impact of air pollution and dust
- Provide shade on glaring hot roads during summers

- Reduce the impact of noise pollution due to rising traffic
- Reduce soil erosion at embankment slopes
- Reduce the effect of wind and incoming UV radiation

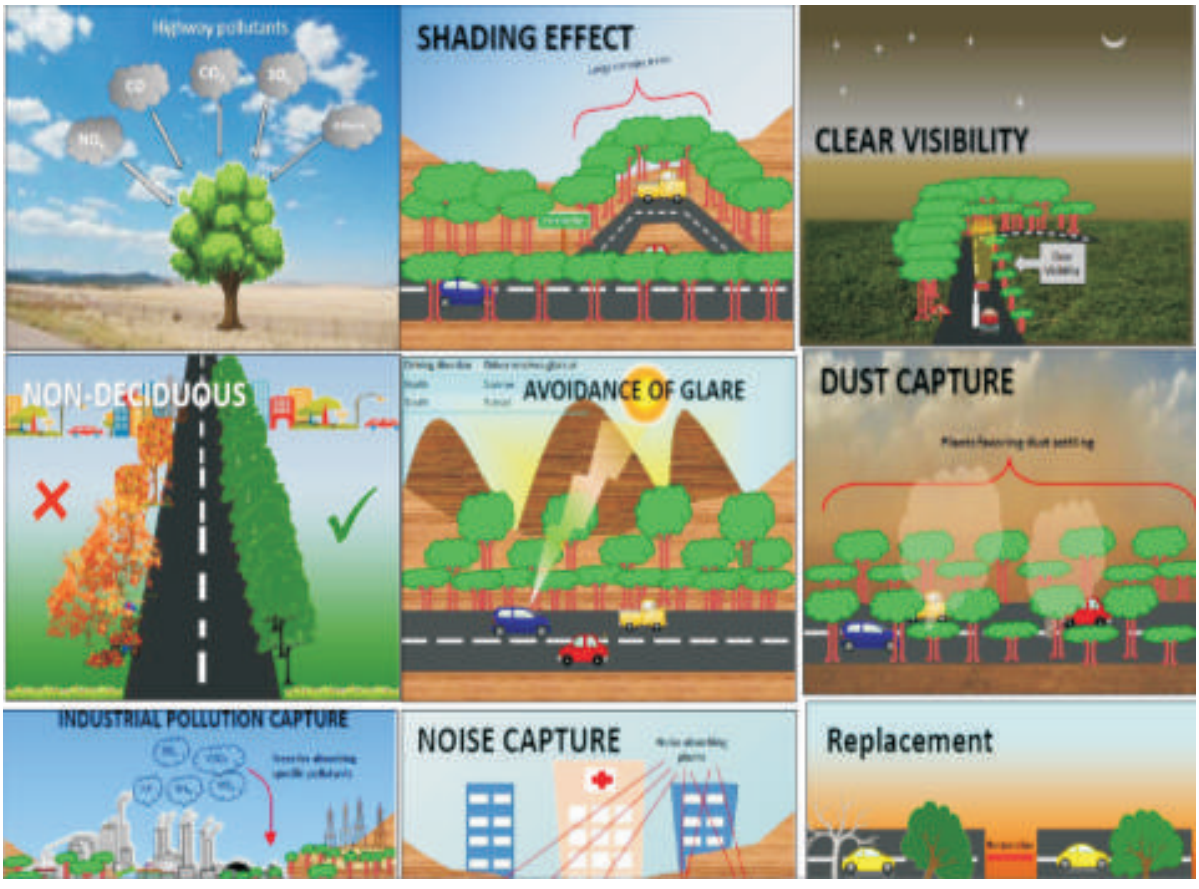


Figure 51: Benefits of Green Corridor

Plantation Species Matrix

Not every tree/shrub species is capable in fulfilling the objectives as desired for green corridor. **Plantation Species Matrix** is a mathematical decision making tool for selection of suitable tree/shrub species for roadside plantations.

For identification of suitable tree/shrub species, an Excel based model has been developed which compares different plant species on three fundamental Principles- Ecological, Economic & Aesthetics. The criteria and indicators for the model were developed based on the Central Pollution Control Board, MoEF guidelines for Green Corridor Development and in compliance to the existing guidelines (IRC SP 21:2009) of Indian Road Congress for plantation and landscaping.

Figure 52: Criteria for Tree / Shrub Selection

	Environment Conservation	Economic Sustainability	Aesthetics & Road Safety
Min. Eligibility Criteria	Suitability toAgro Climatic Zone		
Criteria-1	Pollution Attenuation Capability	Utility	Height
Criteria-2	Evergreen or Deciduous	Ease of Maintenance	Flowering Pattern
Criteria-3	Growth Rate		
Criteria-4	Tolerant/Stressed		

Environment Conservation

AGRO-CLIMATIC ZONE

It is assumed that the plantations will be managed through silviculture operations, thus enabling use of manures required to fulfill any micro nutrients deficiency found in the soil. Similarly, irrigation facility can be managed to avoid water stressed conditions. But to create a micro climate suitable for natural growth of tree/shrub is not possible on a large scale. Hence, the species suitable to particular agro-climatic conditions can be eligible for further evaluation.

Agro climatic zones provides important information about edaphic factors such as soil characteristics (texture, pH, drainage) etc. and climatic variables such as rain fall and temperature. Any species which is suitable to a particular climatic zone will be eligible for further evaluation on the mathematical model of Plantation Species Matrix.

As per the Planning Commission report, India has been divided into 15 Agro-climatic zones which are further sub divided into sub zones.

Figure 53: 15 Agro Climatic Zones of India

Pollution Attenuation Capability

Every tree/shrub species has different capability for sorption, which depends on various factors such as its Canopy Size, Leaf Area, Stomata Size, Tolerance Capability, etc. It is also important to mention that in moist condition, tree/shrub shows higher pollution sorption capacity.

The pollution attenuation factor (Af) for sources releasing at ground level is given by:

$$Af = Qwa / QB$$

Af = ratio of mass flux of pollutant reaching at distanceX1 and X2 in the absence of GB (QWB) to the mass flux reaching at the same distance in the presence of the GB (QB).

Relationship of aforesaid indicators with pollution attenuation criteria is described in detail:

Canopy Shape & Size

Dense foliage helps in better trapping of pollutants and also works as wind break. Openness in canopy allows better filtration capacity whereas large canopy surface area works as noise barrier.

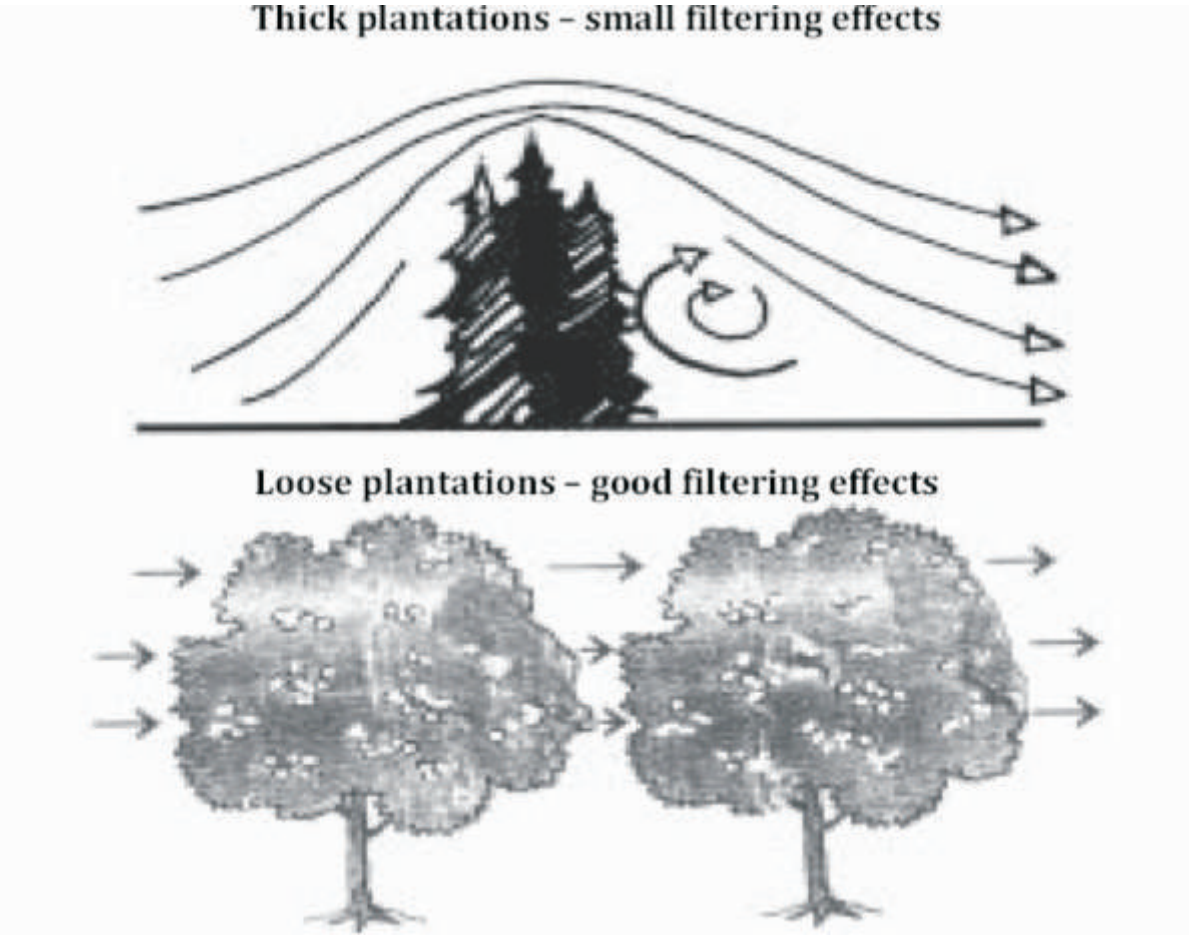


Figure 54: Impact of Thick & Loose plantations on filtration effects

Leaf Area

Larger leaf size helps in greater retention of pollutants. Leaf area density has direct correlation with pollution attenuation coefficient. Large and broad leaves with axillary hairs have better dust retention capacity; similarly leaves with complex shape and large circumference possess higher dust capture capability.

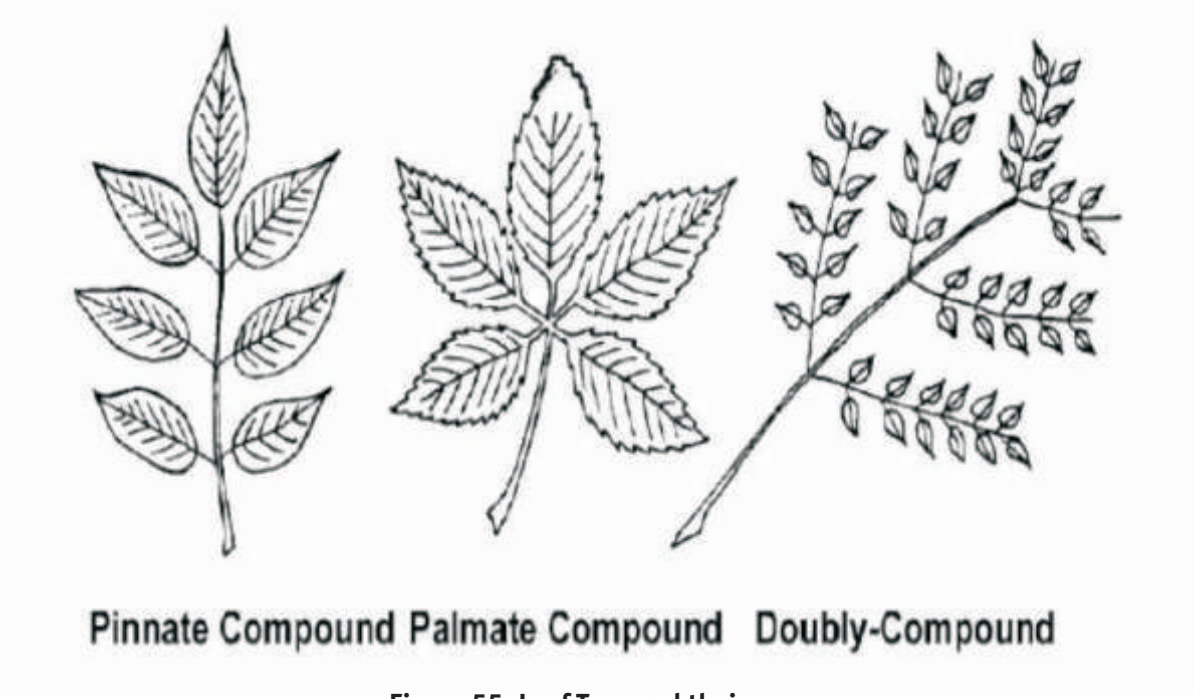


Figure 55: Leaf Type and their area

Stomatal Index

Phyllosphere is the sink site for pollutant. Stomatal apertures inside phyllosphere is the entry point for gaseous pollutants where it gets absorbed and further converted into sugar and amino acid by mesophyll cells through metabolism process. Stomatal index is deduced by measuring the size of guard cells through microscope. High stomatal density, high index and large stomata gives high transpiration rate thereby allowing higher sorption capacity.

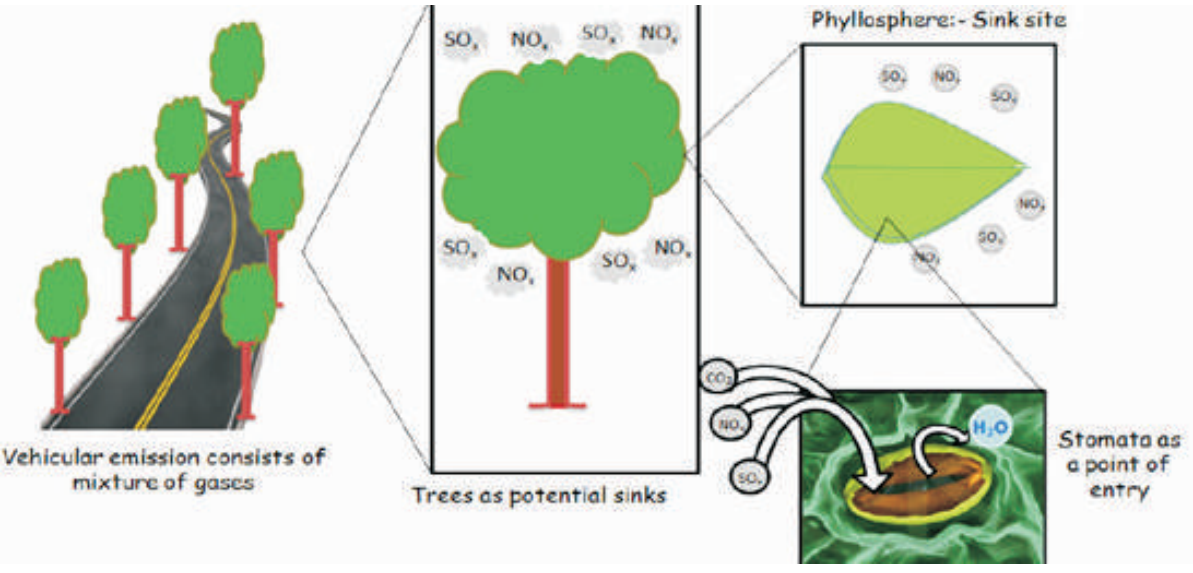


Figure 56: Stomatal Index process

Evergreen or Deciduous

Longer duration of foliage enables round the year sorption capacity. Thus, evergreen trees/shrubs will have higher pollution attenuation coefficient as compared to deciduous or semi –deciduous trees/shrubs.

Growth Rate

Trees/shrubs with higher growth rate are able to reach maturity earlier. Early formation of canopy is better for pollution sorption as well as for creating barrier for noise.

Tolerant or Stressed

Vehicles emit various kinds of pollutants. Primary pollutants are SO2 ¬, NOX, SPM and HF. There may be cases where a particular species can hold on one type of pollutant better but is sensitive towards the other, resulting in damage to the plant. Selection of species with tolerance capability for primary pollutants helps in maintaining the longevity of green belt.

Economic Sustainability

- **Ease of Maintenance**: Trees/shrubs which can survive in water stressed and micro nutrient deficient soil will have higher survival ratio. Also tree/shrub whose leaves are not palatable can survive without protection. Thus, hardy species with less monitoring requirement are expected to provide better results in remote locations.

- **Utility**: Plants have different economic and social usage Plants which can provide fruit, fodder, flower, fuel-wood or commercial timber value are likely to be conserved for inherent benefits. Sustainable harvesting of commercially desirable tree/shrub will ensure economically viability of plantation management operations.

Aesthetic & Road Safety

Indian Road Congress in (IRC) SP 21:2009 provides exhaustive guidelines for plantation and landscaping with the point of view of maintaining aesthetic beauty of highways and also ensuring road safety. Plantation of similar type of tree/shrubs in a row along the median & avenue provides homogeneity to the landscape and is also soothing to eye of the commuter. Similarly selection of tree species with appropriate height helps in reducing glare of light from the vehicles. Ornamental trees/shrubs with longer duration of flowering season can provide round the year panoramic view.

Operation Model for Plantation Species Matrix

Over 450 tree/shrub species were compared and assessed on this tool for identifying the best suitable species for green belt plantation. The weightage allotted to different edaphic and climatic characteristics of tree species have been mentioned in the Scoring Matrix.

S. No	Characteristics	Score	Remarks
1	Tolerance/ Stressed	1/0	Any species which has shown tolerance for primary pollutants of vehicular emission have been rated tolerant and sensitive species have been categorized as **Stressed. Tolerant species have been given a fixed score of 1 and stressed species have got 0.**
2	Evergreen/ Semi-deciduous/ /Deciduous	1/0.5/0	Evergreen trees/shrubs have been given 1, semi-deciduous have been given 0.5 and deciduous have got 0.
3	Growth Rate (Fast/Quick/Slow)	1/0.5/0	Growth rate of tree/shrub have been classified in 3 categories: Fast –Species which can grow in very short span of time - 1 Quick- Species which can grow in short span of time – 0.5 Slow- Species which requires longer duration to grow – 0
4	Canopy Surface Area (CSA)	1	The tree/shrub in the database having highest canopy surface area has been given 1 and others have been given score relative to the tree with highest CSA.
5	Leaf Area	1	The tree/shrub in the database having highest leaf area has been given 1 and others have been given score relative to the tree with highest LA.
6	Stomatal Index (SI)	1	The tree/shrub in the database having highest stomatal index has been given 1 and others have been given score relative to the tree with highest SI.
7	Canopy Shape (Spreading/Round /Oblong/ Flat-crown/Conical)	1/0.75/ 0.5/ 0.25/ 0	Spreading Canopy - 1, Round Canopy- 0.75, Oblong Canopy – 0.5, Flat Crown – 0.25, Conical - 0
8	Flowering Seasonality	0.5	Trees/shrubs having round the year flowering season have been given 0.5 and others have been rated relative to them.
9	Utility	1	Trees with highest recorded uses have been given 1 and others have been rated relative to the tree/shrub with highest Utility Index.
	Total	**8.5**	

Based on the above mentioned scoring methodology tree/shrub species have been given score out of 8.5 marks. Brief results of 50 top scoring tree/shrub species have been shown for reference.

Scientific Name	Common Name	Type	Stressed/ Tolerant	Growth Rate	Evergreen / Deciduous	Score
Azadirachta indica	Neem	Tree	Tolerant	Quick	Evergreen	5.71
Tamarindus indica	Tamarind	Tree	Tolerant	Quick	Evergreen	5.46
Cocosnucifera	Coconut	Tree	Tolerant	Slow	Evergreen	5.16

Scientific Name	Common Name	Type	Stressed/ Tolerant	Growth Rate	Evergreen / Deciduous	Score
Bambusa arundinacea	Thorny Bamboo	Tree	Tolerant	Fast	Evergreen	4.92
Dendrocalamus strictus	Lathi Bans	Tree	Tolerant	Fast	Evergreen	4.80
Ficus benghalensis	Indian Banyan	Tree	Tolerant	Quick	Evergreen	4.79
Ziziphus mauritiana	Indian Jujube	Tree	Tolerant	Quick	Evergreen	4.71
Caesalpinia pulcherrima	Peacock Flower	Tree	Tolerant	Quick	Evergreen	4.56
Trema orientalis	Charcoal Tree	Tree	Tolerant	Quick	Evergreen	4.53
Alstoniascholaris	Devil Tree	Tree	Tolerant	Quick	Evergreen	4.51
Peltophorum pterocarpum	Copper Pod	Tree	Tolerant	Quick	Evergreen	4.45
Samanea saman	Rain Tree	Tree	Tolerant	Quick	Evergreen	4.45
Duranta repens	Golden Dewdrop	Shrub	Tolerant	Quick	Evergreen	4.40
Annona squamosa	Custard Apple	Tree	Tolerant	Fast	Evergreen	4.40
Thespesia populnea	Indian Tulip Tree	Tree	Tolerant	Quick	Evergreen	4.39
Cassia siamea	Siamese Cassia	Tree	Tolerant	Fast	Evergreen	4.37
Anthocephalus chinensis	Kadam	Tree	Tolerant	Fast	Deciduous	4.34
Prosopis cineraria	Khejri	Tree	Tolerant	Quick	Evergreen	4.32
Acacia nilotica	Indian Gum Arabic/Babul	Tree	Tolerant	Quick	Evergreen	4.29
Ficus semicordata	Drooping Fig	Tree	Tolerant	Quick	Evergreen	4.29
Madhuca longifolia	Mahua	Tree	Tolerant	Quick	Evergreen	4.29
Barringtonia racemosa	Powderpuff Mangrove	Tree	Tolerant	Fast	Evergreen	4.27
Ficus benjamina	Weeping Fig	Tree	Tolerant	Quick	Evergreen	4.25
Pongamia pinnata	Karanj	Tree	Tolerant	Quick	Evergreen	4.23
Terminalia arjuna	Arjun	Tree	Tolerant	Quick	Evergreen	4.21
Tabernaemontana divaricate	Crape Jasmine	Shrub	Tolerant	Quick	Evergreen	4.21
Bambusa vulgaris	Golden Bamboo	Shrub	Tolerant	Fast	Evergreen	4.2
Acacia farnesiana	Sweet Acacia	Tree	Tolerant	Quick	Evergreen	4.19
Heterophragma roxburghii	Waras	Tree	Tolerant	Quick	Evergreen	4.18
Acacia tortilis	Umbrella Thorn TreeTree		Tolerant	Quick	Evergreen	4.18
Annona reticulata	Bullock's Heart	Tree	Tolerant	Fast	Evergreen	4.16
Hibiscus rosa-sinensis	China Rose	Shrub	Tolerant	Quick	Evergreen	4.15
Guazuma ulmifolia	West Indian Elm	Tree	Tolerant	Quick	Evergreen	4.14
Barringtonia acutangula	Fresh Water Mangroove	Tree	Tolerant	Quick	Evergreen	4.13
Ficus elastica	Rubber Fig	Tree	Tolerant	Quick	Evergreen	4.12
Lantana camara	Lantana	Tree	Tolerant	Quick	Evergreen	4.11

Scientific Name	Common Name	Type	Stressed/ Tolerant	Growth Rate	Evergreen / Deciduous	Score
Cassia pumila	Dwarf Cassia	Shrub	Tolerant	Quick	Evergreen	4.11
Prosopis chilensis	Chilean Mesquite	Tree	Tolerant	Quick	Evergreen	4.10
Prosopis pallida	Kiawe	Tree	Tolerant	Quick	Evergreen	4.08
Dalbergia sissoo	Sheesham	Tree	Tolerant	Quick	Evergreen	4.07
Melia azedarach	Persian Lilac	Tree	Tolerant	Quick	Evergreen	4.06
Citrus aurantium	Bitter Orange	Tree	Tolerant	Quick	Evergreen	4.04
Kigelia africana	Sausage Tree	Tree	Tolerant	Slow	Evergreen	4.04
Calophyllum inophyllum	Alexandrian Laurel	Tree	Tolerant	Quick	Evergreen	4.02
Thevetia peruviana	Yellow Oleander	Shrub	Tolerant	Quick	Evergreen	3.99
Ficus gibbosa	Dye Fig	Tree	Tolerant	Slow	Evergreen	3.98

Tree/Shrub suitable to agro climatic zone and having good score on plantation species matrix can be considered for Green Corridor development.

Selecting appropriate species for Median Plantation

The shortlisted tree/shrub species were further evaluated for their suitability for median plantation based on SP 21:2009 guidelines, pollution resistant dwarf tree/shrub species are preferred in the median to prevent glare from the vehicles moving in opposite direction during night, whereas flowering shrubs enhances the aesthetic beauty of the highway. Following 20 species have been found appropriate for median plantation.

Scientific Name	Common Name	Type	Stressed/ Tolerant	Growth Rate	Evergreen/ Deciduous	Flowering Season	Score
Duranta repens	Golden Dewdrop	Shrub	Tolerant	Quick	Evergreen	Throughout the year	4.40
Tabernaemontana divaricata	Crape Jasmine	Shrub	Tolerant	Quick	Evergreen	Throughout the year	4.21
Hibiscus rosa-sinensis	China Rose	Shrub	Tolerant	Quick	Evergreen	Throughout the year	4.15
Hamelia patens	Scarlet bush	Shrub	Tolerant	Quick	Evergreen	Oct-Jan	3.99
Bougainvillea spectabilis	Great Bougainvillea	Shrub	Tolerant	Quick	Evergreen the year	Throughout	3.97
Murrayapaniculata	Kamini	Shrub	Tolerant	Quick	Evergreen	June-Oct	3.96
Clerodendrum inerme	Glory Bower	Shrub	Tolerant	Quick	Evergreen	Nov-Jan	3.94
Acacia pennata	Climbing Wattle	Shrub	Tolerant	Quick	Evergreen	June-Aug	3.90
Clerodendrum infortunatum	Hill Glory Bower	Shrub	Tolerant	Quick	Evergreen	Oct-Jan	3.79

Scientific Name	Common Name	Type	Stressed/ Tolerant	Growth Rate	Evergreen/ Deciduous	Flowering Season	Score
Lawsonia inermis	Henna	Shrub	Tolerant	Quick	Evergreen	April-July	3.79
Grewia subinaequalis	Phalsa	Shrub	Tolerant	Quick	Evergreen	Apr-June	3.77
Ziziphus oenoplia	Jackal Jujube	Shrub	Tolerant	Quick	Evergreen	Dec-Feb	3.77
Calotropis procera	Sodom Apple	Shrub	Tolerant	Quick	Evergreen	December	3.75
Ricinus communis	Castor Bean	Shrub	Tolerant	Quick	Evergreen	Sep-Oct	3.74
Tecoma stans	Yellow Trumpet Bush	Shrub	Tolerant	Quick	Evergreen	Feb-April	3.73
Sesbania sesban	Common Sesban	Shrub	Tolerant	Quick	Evergreen	Aug-Dec	3.63
Prosopis stephaniana	Syrian Mesquite	Shrub	Tolerant	Quick	Evergreen	Dec-Feb	3.62
Ziziphus rugosa	Wrinkled Jujube	Shrub	Tolerant	Quick	Evergreen	Dec-Feb	3.57
Ziziphus xylopyrus	Kat Ber	Shrub	Tolerant	Quick	Evergreen	Apr-June	3.57

There are certain small trees with ornamental value which can also be considered for median plantations, a small list is mentioned below:

Scientific Name	Common Name	Type	Stressed/ Tolerant	Height	Evergreen/ Deciduous	Flowering Season	Score
Caesalpinia pulcherrima	Peacock Flower	Tree	Tolerant	4	Evergreen	Throughout the year	4.56
Acacia farnesiana	Sweet Acacia	Tree	Tolerant	5	Evergreen	Aug-March	4.19
Citrus aurantium	Bitter Orange	Tree	Tolerant	5	Evergreen	Sept-Nov	4.06
Acacia ferruginea	Rusty Acacia	Tree	Tolerant	4	Evergreen	Jan-Feb	3.98
Callistemon citrinus	Bottle Brush	Tree	Tolerant	5	Evergreen	Throughout the year	3.96

Selecting appropriate species for Avenue Plantation

One of the main objectives of Roadside Avenue plantation is to provide shade. These tree species should be of local significance and should be mostly evergreen in nature, which ensure no substantial leaf-fall in winters preventing the problem of blockage of roadside drains. Depending on the available ROW, plantation pattern should be worked out as follows:

- The first row along the Highways will be of small to medium sized ornamental trees.
- Subsequent rows, depending on the availability of width will comprise of ornamental and/or shade bearing species of more height than those in the first row.
- In rural sections, the last row will always be of shade bearing tall trees.

List of tree/shrub species suitable for Row I is mentioned below

Scientific Name	Common Name	Type	Stressed/ Tolerant	Growth Rate	Evergreen/ Deciduous	Utility	Row I
Caesalpinia pulcherrima	Peacock Flower	Tree	Tolerant	Quick	Evergreen	Ornamental	4.56
Trema orientalis	Charcoal Tree	Tree	Tolerant	Quick	Evergreen	Medicinal, Fuel-wood, Fiber	4.53
Duranta repens	Golden Dewdrop	Shrub	Tolerant	Quick	Evergreen	Ornamental	4.40
Tabernaemonta nadivaricata	Crape Jasmine	Shrub	Tolerant	Quick	Evergreen	Ornamental	4.21
Acacia farnesiana	Sweet Acacia	Tree	Tolerant	Quick	Evergreen	Medicinal, Fodder	4.19
Hibiscus rosa-sinensis	China Rose	Shrub	Tolerant	Quick	Evergreen	Ornamental	4.15
Citrus aurantium	Bitter Orange	Tree	Tolerant	Quick	Evergreen	Fruit, Medicinal	4.06
Hamelia patens	Scarlet Bush	Shrub	Tolerant	Quick	Evergreen	Ornamental, Medicinal	3.99
Acacia ferruginea	Rusty Acacia	Tree	Tolerant	Quick	Evergreen	Utility wood items, Gum	3.98
Murraya paniculata	Kamini	Shrub	Tolerant	Quick	Evergreen	Medicinal & Bee-keeping	3.96
Callistemon citrinus	Bottle Brush	Tree	Tolerant	Slow	Evergreen	Ornamental	3.96
Clerodendrum inerme	Glory Bower	Shrub	Tolerant	Quick	Evergreen	Medicinal, Ornamental	3.94
Saraca asoca	SitaAshok	Tree	Tolerant	Quick	Evergreen	Ornamental	3.93
Ixora coccinea	Jungle Geranium		Tree	Tolerant	Quick	Evergreen Ornamental	3.92
Ixora rosea	Giant Ixora	Tree	Tolerant	Quick	Evergreen	Ornamental	3.89
Ixora arborea	Torchwood Tree		Tree	Tolerant	Quick	Evergreen Medicinal, Ornamental	3.86
Clerodendrum infortunatum	Hill Glory Bower		Shrub	Tolerant	Quick	Evergreen Medicinal	3.79
Lawsonia inermis	Henna	Shrub	Tolerant	Quick	Evergreen	Beauty care	3.79
Gardenia jasminoides	Gandharaj	Tree	Tolerant	Quick	Evergreen	Floriculture, Dye	3.79
Ziziphus oenoplia	Jackal Jujube	Shrub	Tolerant	Quick	Evergreen	Medicinal, Dry fruit	3.77
Calotropis procera	Sodom Apple	Shrub	Tolerant	Quick	Evergreen	Medicinal, Floriculture, Fibre	3.75

Scientific Name	Common Name	Type	Stressed/ Tolerant	Growth Rate	Evergreen/ Deciduous	Utility	Row I
Ricinus communis	Castor Bean	Shrub	Tolerant	Quick	Evergreen	Medicinal, Ornamental	3.74
Tecoma stans	Yellow Trumpet	Shrub	Tolerant	Quick	Evergreen	Ornamental, Fodder	3.73
Acacia catechu	Khair	Shrub	Tolerant	Quick	Evergreen	Fuel-wood, Fodder, Food	3.69
Psidium guajava	Common Guava	Tree	Tolerant	Quick	Evergreen	Medicinal, Fruit	3.68

List of tree/shrub species suitable for Row II & Row III is mentioned below

Scientific Name	Common Name	Type	Stressed/ Tolerant	Evergreen/ Deciduous	Utility	Row II	Row III
Azadirachta indica	Neem	Tree	Tolerant	Evergreen	Fruit, Medicinal, Food, Organic Pesticide	-	5.71
Tamarindus indica	Tamarind	Tree	Tolerant	Evergreen	Fruit, Medicinal, Food	-	5.46
Cocos nucifera	Coconut	Tree	Tolerant	Evergreen	Ornamental, Fibre, Fruit	-	5.16
Bambusa arundinacea	Thorny Bamboo	Tree	Tolerant	Evergreen	Fibre, Timber, Food, Handicraft	-	4.92
Dendrocalamus strictus	Lathi Bans	Tree	Tolerant	Evergreen	Paper making, Food, Medicinal, Timber, Handicraft	-	4.8
Ficus benghalensis	Indian Banyan	Tree	Tolerant	Evergreen	Religious	-	4.79
Ziziphus mauritiana	Indian Jujube	Tree	Tolerant	Evergreen	Fodder, Fruit, Timber, Biodiesel, Medicinal	4.71	-
Alstonia scholaris	Devil tree	Tree	Tolerant	Evergreen	Medicinal and Utility Wood	-	4.51
Peltophorum pterocarpum	Copper Pod tree	Tree	Tolerant	Evergreen	Ornamental, Fodder	-	4.45
Samanea saman	Rain tree	Tree	Tolerant	Evergreen	Ornamental	-	4.45

Scientific Name	Common Name	Type	Stressed/ Tolerant	Evergreen/ Deciduous	Utility	Row II	Row III
Anona squamosa	Custard Apple	Tree	Tolerant	Evergreen	Fruit,	4.40	-
Thespesia populnea	Umbrella tree	Tree	Tolerant	Evergreen	Handicraft	4.39	-
Cassia siamea	Siamese Cassia	Tree	Tolerant	Evergreen	Food, Medicinal	-	4.37
Anthocephalus chinensis	Kadam	Tree	Tolerant	Deciduous	Ornamental, Timber, Paper making, Floriculture	-	4.34
Prosopis cineraria	Khejri	Tree	Tolerant	Evergreen	Fuel-wood, Fodder, Food	-	4.32
Acacia nilotica	India Gum Arabic/Babul	Tree	Tolerant	Evergreen	Medicinal, Fuel-wood, Fodder	4.29	-
Ficus semicordata	Drooping Fig	Tree	Tolerant	Evergreen	Fodder	4.29	-
Madhuca longifolia	Mahua	Tree	Tolerant	Evergreen	Flower, Oil, Medicinal	-	4.22
Barringtonia racemosa	Powderpuff Mangrove	Tree	Tolerant	Evergreen	4.27	-	
Ficus benjamina	Weeping Fig	Tree	Tolerant	Evergreen	Habitat	-	4.25
Pongamia pinnata	Karanj	Tree	Tolerant	Evergreen	Bio-diesel, Medicinal, Ornamental	4.23	-
Terminalia arjuna	Arjun	Tree	Tolerant	Evergreen	Medicinal, Tussar silk	-	4.21
Bambusa vulgaris	Golden Bamboo	Tree	Tolerant	Evergreen	Ornamental	-	4.2
Heterophragma roxburghii	Waras	Tree	Tolerant	Evergreen	Medicinal	-	4.18
Acacia tortilis	Umbrella Thorn Tree	Tree	Tolerant	Evergreen	Fodder, Furniture, Gum, Aromatic	4.18	-
Annona reticulata	Bullock's Heart	Tree	Tolerant	Evergreen	Fruit	4.16	-
Guazuma ulmifolia	West Indian Elm	Tree	Tolerant	Evergreen	Fodder, Fuel-wood, Medicinal	4.145	-
Barringtonia acutangula	Fresh Water Mangrove	Tree	Tolerant	Evergreen	Medicinal, Ornamental	-	4.13
Ficus elastica	Rubber Fig	Tree	Tolerant	Evergreen	Ornamental, Latex	-	4.12
Cassia pumila	Dwarf Cassia	Tree	Tolerant	Evergreen	Gum, Food, Pesticide	-	4.11

Selecting Appropriate Tree/Shrub Species for Block Plantation

There are various land parcels near flyovers and road alignments which are available with NHAI. These lands can be for block plantation of commercial agroforestry crop, which also performs well on Plantation Species Matrix. A list of possible tree species which can be considered for block plantations is mentioned below:

Scientific Name	Common Name	Type	Stressed/ Tolerant	Utility	Score
Tamarindus indica	Tamarind	Tree	Tolerant	Fruit, Medicinal, Food	5.46
Cocos nucifera	Coconut	Tree	Tolerant	Ornamental, Fibre, Fruit	5.16
Bambusa arundinacea	Thorny Bamboo	Tree	Tolerant	Fibre, Timber, Food, Handicraft	4.92
Dendrocalamus strictus	Lathi Bans	Shrub	Tolerant	Paper making, Food, Medicinal, Timber, Handicraft	4.8
Annona squamosa	Custard Apple	Tree	Tolerant	Fruit	4.40
Anthocephalus chinensis	Kadam	Tree	Tolerant	Ornamental, Timber, Paper making, Floriculture	4.34
Madhuca longifolia	Mahua	Tree	Tolerant	Flower, Oil, Medicinal	4.29
Pongamia pinnata	Karanj	Tree	Tolerant	Bio-diesel, Medicinal, Ornamental	4.23
Terminalia arjuna	Arjun	Tree	Tolerant	Medicinal,Tussar Silk,	4.21
Dalbergia sissoo	Sheesham	Tree	Tolerant	Wood, Medicinal	4.08
Aphanamixis polystachya	Rohituka tree	Tree	Tolerant	Timber, Biodiesel	3.98
Buchanania lanzan	Chironji	Tree	Tolerant	Medicinal, Dry fruit	3.775
Artocarpus heterophyllus	Jack fruit	Tree	Tolerant	Food	3.63
Eucalyptus hybrid	Mysore Gum	Tree	Tolerant	Pulpwood, Dyes, Oil,	3.63
Achras sapota	Sapota	Tree	Tolerant	Fruit	3.62
Mangifera indica	Mango	Tree	Stressed	Fruit, Medicinal	3.27
Butea monosperma	Palash	Tree	Tolerant	Ornamental, Timber, Resin, Fodder, Medicine, and Dye	3.26

This list is not exhaustive, plantation of any particular tree/shrub species which fits in the criteria of Plantation Species Matrix can be taken up.

Negative List of Tree/Shrub Species

There are certain species which have been considered under Negative list of species as some of them have been found invasive, toxic, stressed or performed poorly on the tool. These species may have detrimental effect on other species of green belt or will not fulfill the requirement for pollution sorption.

Scientific Name	Common Name	Type	Stressed/ Tolerant	Growth Rate	Height	Evergreen/ Deciduous	Score
Populus nigra	Lombardy Poplar	Tree	Stressed	Quick	20	Deciduous	0.7
Alnus nitida	West Himalayan Alder	Tree	Stressed	Quick	20	Deciduous	0.82
Alnus nepalensis	Nepalese Alder	Tree	Stressed	Quick	20	Deciduous	0.86
Populus alba	White Poplar	Tree	Stressed	Quick	15	Deciduous	1.2
Populus ciliata	Himalayan Poplar	Tree	Stressed	Quick	20	Deciduous	1.2
Populus deltoides	Eastern Cottonwood	Tree	Stressed	Quick	20	Deciduous	1.2
Populus euphratica	Euphrates Poplar	Tree	Stressed	Quick	10	Deciduous	1.2
Coriaria nepalensis	Musuri Berry	Shrub	Stressed	Quick	5	Deciduous	1.25
Acer campbellii	Campbell's Maple	Tree	Stressed	Quick	12	Deciduous	1.5
Betula alnoides	Indian Birch	Tree	Stressed	Quick	15	Deciduous	1.52
Acer negundo	Ash leaved Maple	Tree	Stressed	Quick	12	Deciduous	1.7
Corylus colurna	Turkish Hazelnut	Tree	Tolerant	Quick	10	Deciduous	1.7
Ougeiniao ojeinensis	Sandan	Tree	Tolerant	Quick	12	Deciduous	1.78
Polyalthia longifolia	False Ashoka	Tree	Stressed	Quick	15	Evergreen	2.06
Strychnos nux-vomica	Poison Nut	Tree	Tolerant	Quick	12	Deciduous	2.22
Pinus kesiya	Khasi Pine	Tree	Stressed	Slow	10	Evergreen	2.24
Haldina cordifolia	Haldu	Tree	Tolerant	Slow	20	Deciduous	2.24
Sterculia guttata	Spotted Sterculia	Tree	Tolerant	Quick	15	Deciduous	2.28
Juniperus communis	Common Juniper	Shrub	Stressed	Quick	10	Evergreen	2.33
Bauhinia acuminata	Dwarf White Bauhinia	Shrub	Tolerant	Quick	3	Deciduous	2.45
Salix fragilis	Crack Willow	Tree	Tolerant	Quick	18	Deciduous	2.52
Salix alba	White Willow	Tree	Tolerant	Quick	20	Deciduous	2.52
Bauhinia racemosa	Burmese Silk Orchid	Tree	Tolerant	Quick	5	Deciduous	2.56
Bauhinia semla	Semla	Tree	Tolerant	Quick	10	Deciduous	2.57
Salix caprea	Great Sallow	Shrub	Tolerant	Quick	5	Deciduous	2.59
Acacia mellifera	Black Thorn	Tree	Tolerant	Quick	10	Deciduous	2.60
Quercus rubra	Champion Oak	Tree	Tolerant	Quick	15	Deciduous	2.65
Aleurites fordii	Tung tree	Tree	Tolerant	Quick	8	Deciduous	2.67
Acacia leucophloea	White Bark Acacia	Shrub	Tolerant	Quick	3	Deciduous	2.67
Acacia mearnsii	Black Wattle	Tree	Tolerant	Quick	20	Evergreen	3.5
Nerium indicum	Oleander	Shrub	Tolerant	Quick	5	Evergreen	3.65
Calotropis gigantea	Gigantic Swallow Wort	Shrub	Tolerant	Quick	5	Evergreen	3.75
Thevetia peruviana	Yellow Oleander	Shrub	Tolerant	Quick	6	Evergreen	4.04
Lantana camara	Lantana	Shrub	Tolerant	Quick	3	Evergreen	4.12

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