Green Roads for Water in LGEDs Road Network

Ten Reasons for Green Roads for Water in LGEDs Road Network

1. As water is a major cause for road failure and maintenance costs, Green Road for Water reduce the spending requirements in road maintenance – starting with improving road maintenance problem spots rather than just restoring these. This will help reduce the funding gap in maintenance.
2. Disaster risk reduction is greatly enhanced by systematically mainstreaming this in road design and asset management – by raising roads and create safe shelters and by flood protection: this is important as roads are lifelines during disaster .
3. By systematically using the extensive road infrastructure for water harvesting and supporting groundwater recharge the drought crisis in the Barind can be addressed.
4. By designing roads and overflows in the Haor, so that they help retain the reclining flood, the period of available soil moisture can be extended.
5. By bio-engineering and spring shed protection around roads, erosion can be controlled and the decline in spring discharges can be reversed in the Chittagong Hill Tracts.
6. By systematically remove the blockage of natural drainage by roads and bridge sills in Riverine Areas and Coastal Zone, water logging can be greatly reduced – bringing a large boost in production and a reduction of diseases.
7. By retrofitting too narrow 'choking' bridges in SW, tidal rivers can be salvaged
8. By systematically introducing gated culverts in rice growing areas water control can be enhanced for HYV Amon Paddy, which can double yields and shorten growing season, freeing land up for an additional crop.
9. By responsible sourcing, excess sediment in low lying areas can be put to good use for local road building – giving a boost to desilting
10. By tailoring culverts and other cross drainage structure to accommodate fish passage, fish capture can be enhanced importantly.

GREEN ROADS FOR WATER

Increasing Resilience of Rural Infrastructure and Local Communities through Green Roads Concept

Green Roads for Water Hotspot: Coastal Zone

Opportunities and Challenges

1 Unblock drainage congestion and reduce water logging.

→ Systematically equip roads with adequate cross drainage structures and install additional bridges and culverts in critical areas

2 Salvage tidal rivers, prevent them from silting up.

→ Retrofit/ construct bridges with adequate spans and preferably no piers

3 Support desilting of drains.

→ Use excavation material from silted up khals for local road construction

4 Facilitate water management for high yielding Amon paddy.

→ Install gated culverts on local roads to allow field water ponding and release, when needed

5 Improve flood preparedness.

→ Construct elevated roads in lower lying polder areas (for livestock evacuation) connecting to typhoon shelters

6 Improve flood protection.

→ Built in flood protection requirements in river facing roads – adequate height, armouring, salt-tolerant vegetative cover

7 Optimize functions with well-planned roadside vegetation.

→ Vegetation planting and species selection for direct productive use, embankment stability, dust/ pollution control, noise reduction, biodiversity

Examples of techniques

Remove water logging by retrofitting adequate road cross drainage

Ensure wide bridge spans and no piers to salvage tidal rivers

Gated culverts: allowing water control for HYV Amon Paddy

Repurposing sediment from excavating khals for local road construction

GREEN ROADS FOR WATER

Increasing Resilience of Rural Infrastructure and Local Communities through Green Roads Concept

Green Roads for Water Hotspot: Flood Plains and Estuaries

Opportunities and Challenges

1 Unblock drainage congestion and reduce water logging.

→ Systematically equip roads with adequate cross drainage structures and install additional bridges and culverts in critical areas, avoid high bridge sills

2 Improve flood protection.

→ Built in flood protection requirements in river facing roads – adequate height, armouring, vegetative cover

3 Improve flood preparedness.

→ Construct elevated roads in lower lying areas (for livestock evacuation); include wide sections for temporary shelter

4 Mitigate floods in critical areas.

→ Roads may constructed in critical areas to cordon off the area from floods and compartimentalize

5 Facilitate fish migration.

→ Sufficient culverts and bridges; well-designed and well-placed culverts, i.e. culverts that are not too steep, and have low/moderate velocity; that may have roughened surfaces; that have adequate water levels in dry season; and are connected to the downstream water body

6 Optimize functions with well-planned roadside vegetation.

→ Vegetation planting and species selection for direct productive use, embankment stability, dust/ pollution control, noise reduction, biodiversity and are suitable to local soil and climate

Examples of techniques

Armouring of river facing roads

Elevated roads providing flood shelter for livestock

Sufficient cross drainage to avoid water logging

Mahogany road side tree planting for productive use and as shelter belt

GREEN ROADS FOR WATER

Increasing Resilience of Rural Infrastructure and Local Communities through Green Roads Concept

Green Roads for Water Hotspot: Chattogram Hill Tracts

Opportunities and Challenges

1 Preserve and capturing springs.

→ Develop roadside spring boxes with outlets and slope protection; also increase recharge in the spring sheds

2 Stabilize roadside hill slopes, reduce erosion.

→ Use bio-engineering techniques to reduce risk of erosion, slips and landslides – with plants and small civil engineering measures catching, erosion, and armouring, reinforcing, anchoring, supporting and draining vulnerable slopes

3 Water harvesting from roads.

→ Use road drainage system to collect run-off from road slopes and route to safe disposal recharge/ storage areas

4 Optimize multiple functions with well-planned roadside vegetation.

→ Vegetation planting and species selection for direct productive use, embankment stability, dust/ pollution control, noise reduction, biodiversity

Examples of techniques

Roadside spring capture and protection

Spring shed improvement to enhance recharge

Bio-engineering to stabilize road slopes

Develop road drainage system to capture run-off and feed water storage

GREEN ROADS FOR WATER

Increasing Resilience of Rural Infrastructure and Local Communities through Green Roads Concept

Green Roads for Water Hotspot: Barind

Opportunities and Challenges

1 **Water harvesting with roads to address water scarcity.**

→ Use variety of road water harvesting measures: routing water from drains to recharge areas or storage ponds; using porous pavement for percolation; using roadside excavation trenches for storage and recharge

2 **Responsible sourcing: avoid depleting sand and gravel from vulnerable rivers, as this will undermine their water holding and flood retention and recharge capacity.**

→ Use alternative non-sand road pavements; use crushed sand instead; or use excavation material from derelict canals and ponds

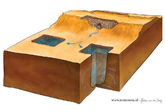
3 **Road protection against flash floods – capturing as much as possible from flash floods.**

→ Nature-based vegetative protection and armouring of exposed sections

4 **Optimize functions with well-planned roadside vegetation.**

→ Vegetation planting and species selection for direct productive use, embankment stability, dust/ pollution control, noise reduction, biodiversity

Examples of techniques



Water harvesting: guiding water from culverts to recharge areas and storage

Using porous pavement for water percolation

Responsible sourcing: use manufactured sand

Optimize roadside vegetation

GREEN ROADS FOR WATER

Increasing Resilience of Rural Infrastructure and Local Communities through Green Roads Concept

Green Roads for Water Hotspot: Haors

Opportunities and Challenges

1 Improved flood retention, enhancing post-flood soil moisture for early season crops and fish breeding and capture fisheries.

Carefully plan – even retrofit - roads, including drainage structures and overflow areas/ causeways to positively effect and flexibly manage to patterns of flood retention. Options:

- Submersible road embankments
- Road causeways with sluice gates// box culverts
- Raised roads with designed spillways – preferably leading to recharge area or wetlands
- Armoured road embankments to create water storage
- Small ponds alongside roads that slowly release water and improve soil moisture and serve as fish spawning ground

2 Improve flood preparedness.

Construct elevated roads with overflow capacity in lower lying areas (for livestock evacuation); include wide sections for temporary shelter

3 Facilitate fish migration.

Sufficient culverts and bridges; well-designed and well-placed culverts, i.e. culverts that are not too steep, and have low/moderate velocity; that may have roughened surfaces; that have adequate water levels in dry season; and are connected to the downstream water body

4 Optimize functions with well-planned roadside vegetation, protect (submerged) roads from scour.

Vegetation planting and species selection for scour control, but also direct productive use, embankment stability, dust/ pollution control, noise reduction, biodiversity and are suitable to local soil and climate

Examples of techniques

Overflow area with armouring and vegetative protection

Water reservoir created with road embankment

Vertiver grass as slope stabilizer

Fish friendly culvert

GREEN ROADS FOR WATER

Increasing Resilience of Rural Infrastructure and Local Communities through Green Roads Concept

Bridges

Key Points

1. **Bridge spans should be wide enough and preferably with no or few piers, in order to:**
   - Not restrict flood flows and cause flooding
   - Not cause upstream sedimentation
   - In case of tidal rivers, not hinder the tidal flows and disturb the riverbed load
2. **Bridge sills are important in soft underground, but should not too high, impeding drainage**
3. **Protect entrance of bridge with combination of bio-engineering measures and armouring (NBS)**

Examples of techniques

Bridge on tidal river too narrow and too many piers disturbs the tidal flow, causes riverbed to silt up and tidal effect to withdraw

Bridge sill too high and bridge too narrow: causes water logging and silting up of the stream

Bridge abutment and bridge approach vulnerable to erosion – need to solve with bio-engineering measures and armouring

Determine bridge span	Determine level of bridge sill
Calculate active water channel	Survey streambed elevation
Measure flood plain adjacent to active water channel (for 50-year flood)	Deduct expected scour depth during design floods
Make provision for debris and floatsam (1-3 meter in small streams)	Assess foundation stability requirements
Note: avoid placing pier in active water channel and if so, provide reinforcement	Avoid drainage congestion at any cost

Pavement and Construction Materials

SAFE SOURCING – suggested recommendations

Key Points

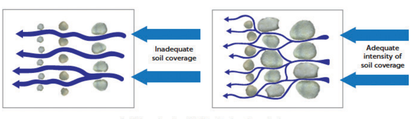
1. Phase out use of bricks for road pavement, following the Brick Manufacturing & Kiln Establishment Act, 2013 (Amended 2019)
2. Avoid use of sand and gravel, sourced from vulnerable river in drought prone areas (for instance Barind), following the Balumohal and Soil Management Act, 2010 (amended 2023)
3. Repurpose excavation material from silted up drainage canals in road development and maintenance. When the material is highly plastic, mix with cement, lime or brick dust. Asses it is not contaminated with organic or chemical material
4. Repurpose excavation material (rock rubble) from road building in CHT, for instance in water recharge and slope protection
5. Explore new road building techniques in which waste material (plastic, rubber tyres, used asphalt) can be recycled
6. Consider employment factor in road construction and maintenance – preserving importance of road construction and maintenance in rural job creation

Some recommended pavements

Zone	Surface Layer Type	Binder/ Modifier	Base Layer Type	Rationale
Coastal Zone	Uni-block Pavement / Hot Sand Asphalt / RAP	Polymer Modified Bitumen (PmB)	ETB / Steel Slag (Unbound) / Demolition Waste + Geosynthetics	Resists salinity, waterlogging, and erosion; durable in high humidity; geosynthetics enhance structural stability and erosion control.
Barind and Drought-Prone	Steel Slag Asphalt Concrete / RAP	WEP Modified Asphalt	CTB / Brick Aggregate	Handles high temperature and dry conditions; WEP enhances flexibility and sustainability; CTB provides strength in hard soils.
Haors and Flash Flood Zones	Hot Sand Asphalt / RAP	Polymer Modified Bitumen (PmB)	Demolition Waste / ETB + Geosynthetics	Performs under frequent submersion and drying; RAP adds stiffness; geosynthetics improve drainage and flood resilience.
Chattogram Hill Tracts	Double Surface Dressing / Asphalt Wearing Course	Polymer Modified Bitumen (PmB)	CTB + Geosynthetics	Suitable for steep, erosion-prone terrain; reduces emissions and improves compaction; geosynthetics aid slope stabilization.
River Systems & Estuaries	Asphalt Wearing Course / Rigid Pavement with Recycled Aggregate	Polymer Modified Bitumen (PmB)	CTB / Demolition Waste + Geosynthetics	Ensures durability in areas prone to water fluctuation and erosion; reduces carbon footprint; geosynthetics manage drainage.

Unpaved roads – recommended practice

Use rolling dips or water bars (slightly elevated hump at angle with the road) to remove water from unpaved surface



Use rocks (where available) or grasses on the road sides to dissipate water running from the unpaved road surface and avoid erosion

Planning Roadside Vegetation

Key Points

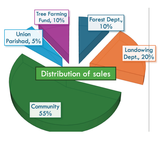
1. Plan roadside vegetation with the full scope of potential benefits in mind, to optimize them.
2. Address ownership and community management as a precondition, making use of the Social Forestry Rules.
3. Build in adequate time and community consultation to secure the roadside verges for common beneficial use.
4. Prevent and manage unplanned roadside plantation, which can have negative impacts including road safety, moisturizing, and shading of pavement.

Specific guidance:

Benefits of roadside vegetation are multiple if done well:

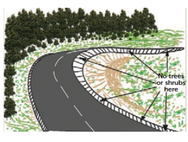
Function	Application
Productive use	Define productive use (timber, fruits, medicine, fodder, fuelwood) against preferably extended lifespan to avoid regular replanting
Protection of road surface	Prefer deep-rooted over broad-rooted species that may interfere with the road surface Roadside vegetation – in directions of sunlight - slows down heat-related wear such as softening of asphalt and thermal cracking. The effect of shade may on the other hand prolong the drying of roads after rainfall.
Stabilizing road embankments	Combination of stable roadside grasses (vetiver and others) and tree species to minimize erosion of embankments Deep-rooted trees can stabilize the roadsides
Protecting submersible roads	Use appropriate species that reduce eroding effects on submersible roads and that are adjusted to flooding conditions
Improved micro-climate and reduce heat stress	Tree planting to reduce exposure to desiccation and heat extremes High foliage, broad-leaved trees with overlapping canopies to optimize shade effects Position vegetation so as to optimize shade on the road surface Create wind tunnel effects to allow breezes to cool road surface
Dust control	Tree planting in road sections that are perpendicular to the prevailing wind directions will serve as dust barriers and windbreaks, slowing down windspeed and the uplift of dust Double-layered permeable vegetation (especially on level roads) to optimize dust capture
Pollution control	Use of bio-accumulator species in pollution-sensitive areas to convert heavy metals (see also annex 1) Vegetation captures Nox, CO_2 and other pollutants.
Sound proofing	Vegetation close to the road will reduce sound pollution Dense, layered planting, multirow vegetation is most effective Combine ground vegetation with shrubs and larger trees Evergreen is preferred
Promoting biodiversity	Create variety of habitats, integrate rocks, logs and mini wetlands in the roadside vegetation Connecting to landscape hedges to create biological corridors Selective mowing and removal of biomass to enhance plant species diversity Avoid mowing in flowering or breeding season, leave some strips totally unmowed
Carbon sequestration	Use native, fast-growing and long-lived tree species suited to local conditions. Use deep-rooted perennials, grasses, and legumes to increase soil carbon
Road safety	Roadside greenery in general improves driver alertness and tranquility – and encourages responsible traffic behaviour. Preference is for low growing shrubs and groundcovers near road edges and light-canopy trees set back from the road, allowing regular visual breaks Avoid tree planting in high-speed sections (>60 kilometres/hour). Support visibility (no tree planting in inner bends) Glaring can be avoided by planting dense evergreen trees in direction of rising or setting sun Irregular and varied spaced planting can avoid speeding behaviour
Beautification and comfort	Provide shade and space where there is much pedestrian movement Consider iconic trees for beautification and local identity
Avoiding interference	Do not grow high trees near electricity lines Avoid root penetration in culverts

Some good practices

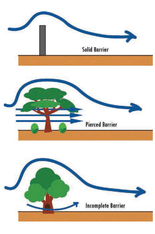


Distribution of proceeds according to Social Forestry Rules

Road safety – no trees or shrubs on the inside of cut slopes around curves



Road safety – no trees or shrubs on the inner bend of a road



Road vegetation and dust movement: pierced barriers trap most dust

GREEN ROADS FOR WATER

Increasing Resilience of Rural Infrastructure and Local Communities through Green Roads Concept

Cross drainage

Key Points

1. Cross drainage is important to evacuate water from the area around the road and avoid water logging in the landscape and prevent water accumulation around the road.

2. In many areas however roads are built with inadequate cross drainage – sometimes because of temporary funding constraints. This causes serious water logging in low lying areas, resulting in large agricultural losses and worsened public health. Such inadequate cross drainage should be corrected on priority basis.

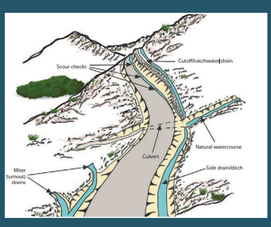
3. A well-developed and well-maintained cross drainage system will prolong the life of the road and will also make it easy to collect the run-off water and direct to areas for beneficial use, i.e. a storage reservoir or recharge areas. This is particularly important in drought affected areas, where water supply Is critical, such as the Barind.

4. Another important beneficial application is in rice growing areas, in particular where improved amon varieties are introduced. These need more water control: the timely release and ponding of water. For this often road culverts equipped with gates are most suitable. The gates are usually placed at the outlet side of the culvert.

5. Culverts are also important for fish movement – including fish migration and spawning. Culverts should not be too steep and have low/moderate flow velocity; they may have roughened surfaces (for catfish). They should have adequate water levels in the dry season as well. They should be connected to the downstream water body – so that the fish are not expected to 'jump'. A new development to be considered are 'arch culverts', which have a relatively flat bottom, facilitating movement of fish and amphibeans.

6. Cross-drainage should be self-clearing. Siltation should be avoided by having adequate clearance and minimum velocity of the flow: the latter is a function of the slope of the cross-drainage structure. For concrete culverts as minimum slope of 0.2-0.8% is recommended to allow flush out during high water events.

Examples of techniques



Well-developed drainage system collecting water and making it possible to route to areas of beneficial use

Road drainage water channelled into farm trench to irrigate root zones of the plants

Gated culvert making it possible to control water levels in rice fields for optimum production

Arched culvert – facilitating movement of fish, reptiles and amfibeans.

Road embankments

HEIGHT OF EMBANKMENT: Key Points

1. Height based on maximum flood level plus additional provision for wave action – in particular at sea fronts and river banks.
2. For roads close to rivers and sea, close coordination is needed with BWDB, to ensure road maintain width and height and are paved before the maximum height of the flood embankment has been achieved.
3. Inside low-lying flood prone area the height of roads may be increased so as to provide shelter and evacuation routes for people and livestock.
4. Also in areas prone to water logging road embankment must be raised with adequate drainage so that nearby houses are not inundated
5. Raising the height of these roads may be done with excavated material from khals and drains that is often easily available
6. In the haor areas road embankments may be made with appropriate heights that support water management and all-weather access – e.g. slightly elevated in order to influence the retreating inundation and to control soil moisture in the recession areas. Care should be taken not to interfere with the flooding patterns and deploy overflow structures, flood causeways or adequate cross drainage. When this is not possible or feasible, submersible roads may be made

SIDE SLOPE: Key Points

1. Road shoulders and embankments should follow recommended side slopes for road stability and safety and to accommodate roadside vegetation (see table). For higher embankments (4-5 mtr) more gentle side slopes apply.
2. Ownership issues of roadside side slopes should be addressed: this requires consultation and time, so as to agree on ownership by LGED and/or land use by communities of the side slopes.
3. Where it is not possible to ensure the proper side slopes, alternative reinforcement arrangement should be deployed such as (1) retaining walls properly anchored and backfilled; (2) face geotextile face wraps or geogrid bamboo matrasses with vegetation; (3) armouring with concrete block (with weepholes) or riprap with graded filter; (4) bio-engineering for short slopes, with native grasses, vertiver, creeper mats, especially on lower part of the slope; (5) toe drains.
4. One should prioritize slide slope protection by timely repair and building back better of the road embankments in case of erosion or flood damage.
5. Multi-purpose roadside ponds/trenches can be used to collect access drainage water and serve as a water storage – preferably at 3 meter from side slope. Deeper ponds/ trenches can be used for fish cultivation or aquatic crops.

Some practices

Grasses protecting side slope

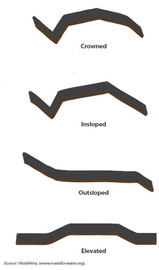
Timely repair is important

Retaining wall to be anchored (1/3) and backfilled

Damage to sideslope to be not just restored but be 'build back better'

CAMBER: Key Points

1. The road camber is important to remove standing water from road surface
2. CRELIC advises that with climate change the camber should have
   - a minimum of 3.0 % on carriageways, with increased cross falls of up to 5.0% on hard shoulders draining to filter drains.
   - longitudinal gradients should be at least 0.5% on curbed roads.
   - flat areas should be avoided, and consideration of surface water drainage is critical at rollovers, roundabouts, and junctions.
3. There are several shapes of camber. Crowned or in sloped surfaces are preferred to connect to side drains. Out sloped may discharge direct in adjacent land but should be provided by grass or dense stones to reduce erosion and facilitate infiltration of the road based on presence of roadside drain.

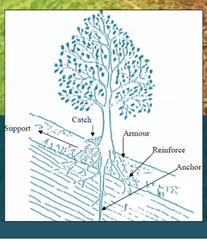


Source: MetaMeta, (www.roadsforwater.org).

GREEN ROADS FOR WATER

Increasing Resilience of Rural Infrastructure and Local Communities through Green Roads Concept

Bioengineering



Bioengineering is a subset of green infrastructure that uses vegetation (trees, shrubs, grasses) to serve engineering functions – combined with civil engineering measures. Bioengineering helps to reduce soil/slope instability and erosion, increases the slope's factor of safety, is versatile in its application and cost-effective.

Key Points

1. Integrate bioengineering systematically into rural road designs, especially in flood-prone, erosion-prone, and hilly areas.
2. Tailor the different functions of bioengineering to the specific location.
3. At sensitive / dangerous areas, strategically combine bioengineering with grey infrastructure for optimal impact of both.
4. Consider bioengineering as a Building Back Better option when the initially employed stabilization method failed or did not perform
5. Promote co-benefits.

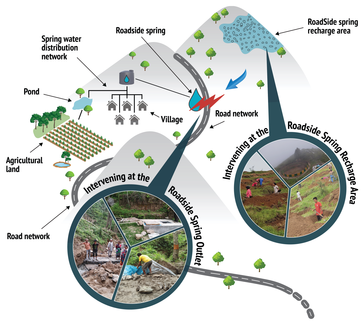
Specific guidance:

Engineering function	Bio-engineering measures	Civil engineering measures
Catch: Stop material from falling or sliding down a slope	- Contour lining of grasses, brush layers - Live check dam - Stems of shrubs and bamboo	- Check dams - Catch walls - Jute netting
Armour: Protect the surface from erosion	- Storeys of mixed plants providing complete cover - Grass carpet of clumping or spreading grass with dense and fibrous roots - Use green soil bags	- Revetment wall - Stone pitching
Reinforce: hold particles together and reduce the risk of shallow-seated movement	- Grasses, shrubs, and trees that are densely rooting - Most vegetation structures	- Soil nailing - Reinforcing earth
Anchor: reduce risk of deeper-seated movement	- Trees and shrubs that are deeply-rooting with long string roots	- Rock anchors by bolting
Support: hold material on the slope	- Large trees and bamboos having deep and dense root system	- Retaining walls - Prop walls
Reduce: reduce material and water movement	- Strong, numerous, and flexible stems - Many strong, fibrous roots	- Check dams - Catch walls
Drain: remove excess water	- Down slope and diagonal vegetation lines - Angled fascines	- Surface drains - French drains

Table 1. Bioengineering function: Bioengineering systems and civil engineering systems (based on Developing Bio-engineering Capacity for the Local Government Engineering Department Operations in the Chattogram Hill Tracts, Bangladesh, ADB)

Spring protection

1. In hilly areas springs and seeps are opened up with road development. This can cause the 'emptying' of local aquifer systems
2. We need to intervene at the new spring outlet and capture and protect the spring
3. We need to intervene in the spring shed and enhance recharge of the spring



GREEN ROADS FOR WATER

Increasing Resilience of Rural Infrastructure and Local Communities through Green Roads Concept

Selecting Roadside Vegetation

Key Points

1. Mix of trees, shrubs and grasses for full range of benefits that vegetation can provide.
2. Decide on importance of different qualities and select species accordingly: carbon sequestration, timber value, non timber value, pollution abatement, noise reduction, soil improvement wind break, biodiversity harbour, shading effect, esthetic value, and reduced storm exposure.
3. Look at suitability for the concerned hotspot region: the Coastal Zone, the Barind and Drought Prone Areas, the Haor and Flash Flood Areas, the Chattogram Hill Tracts, and the Flood Plains and Estuaries

Specific guidance:

The table below has been developed based on a review of authorative (agro)forestry and botanical references specific to Bangladesh and tropical Asia, and has been verified with experts.

Tree Species	Flood Plains and Estuaries	Coastal Zone	Haor and Flash Flood Areas	CHT Hill Tracts	Barind and Drought Prone Areas	Storm-proof (wind-firmness)	Stable Root System	Time to Maturity / End of Life	Height at Maintenance
Shorea robusta (Sal)	No	No	No	No	Yes	Moderate	Deep taproot, good for stability	15–20 yrs / up to 100 yrs	15–20m
Heritiera fomes (Sundari)	No	Yes	No	No	No	Moderate	Stilt roots, saline-tolerant	15 yrs / 70–100 yrs	15–20m
Barringtonia acutangula (Hijol)	Yes	No	Yes	No	No	Moderate	Deep-rooted, flood-tolerant	10–15 yrs / 50 yrs	8–12m
Artocarpus heterophyllus (Jackfruit)	No	No	No	Yes	Yes	No	Deep-rooted, pavement-friendly	7–10 yrs / 40 yrs	10–15m
Melocanna baccifera (Bamboo)	Yes	No	No	Yes	Yes	Yes	Fibrous root binds soil on slopes	3–5 yrs / 10–15 yrs	5–10m
Aegle marmelos (Bael)	Yes	No	No	Yes	Yes	Yes	Taproot, drought-resistant	8–10 yrs / 50 yrs	8–10m
Albizia lebbeck	Yes	No	No	Yes	Yes	No	Spreading roots, nitrogen fixer	4–5 yrs / 30 yrs	10–15m
Azadirachta indica (Neem)	Yes	No	No	Yes	Yes	Yes	Deep-rooted, low maintenance	3–5 yrs / 40 yrs	10–15m
Acacia auriculiformis	Yes	Yes	No	Yes	Yes	Yes	Fibrous roots, soil stabilizer	4–6 yrs / 30 yrs	10–12m
Ficus religiosa (Peepal)	Yes	No	No	Yes	Yes	No	Deep roots, pavement-safe	10–15 yrs / >100 yrs	20–30m
Terminalia arjuna	Yes	No	Yes	Yes	No	Yes	Strong roots for erosion control	10 yrs / 70 yrs	15–20m
Dalbergia sissoo (Sheesham)	Yes	No	Yes	No	Yes	No	Taproot, strong wood	10 yrs / 60 yrs	15–20m
Syzygium cumini (Jamun)	Yes	No	Yes	Yes	Yes	Moderate	Deep-rooted, fruit-bearing	6–8 yrs / 50 yrs	10–15m
Moringa oleifera	Yes	No	No	Yes	Yes	Yes	Light roots, fast-growing	2–3 yrs / 20 yrs	8–10m
Dipterocarpus turbinatus	No	No	No	Yes	No	No	Deep taproot, stabilizing	15 yrs / 80 yrs	25–30m
Terminalia bellirica	Yes	No	No	Yes	Yes	No	Strong root, drought-tolerant	8–10 yrs / 60 yrs	15–20m
Saccharum spontaneum	Yes	Yes	Yes	No	No	Yes	Fibrous roots, soil binder	1–2 yrs / 3 yrs	1–2m
Swietenia macrophylla (Mahogany)	Yes	No	No	Yes	Yes	Yes	Taproot, invasive risk	10 yrs / 60 yrs	20–30m
Areca catechu (Betel Nut)	Yes	Yes	No	No	No	Moderate	Fibrous roots, fairly stable	7–8 yrs / 60–100 yrs	15-20m
Palmyra palm	Yes	Yes	No	No	Yes	High	Deep anchorage	14-15 yrs / 60 yrs	25-30m

Tree Species	Carbon Seq.	Timber Value	Non-Timber Value	Windbreak Value	Shading Value	Biodiversity Harbour	Pollution Absorption	Dust Trapping
Shorea robusta (Sal)	High	High (furniture)	Resin, leaf plates	Moderate	Moderate	Supports birds, mammals, insects	Moderate	High
Heritiera fomes (Sundari)	Very High	High	Medicinal, tannin	High	Low	Nurseries for fish, birds, reptiles	High (heavy metals)	Moderate
Barringtonia acutangula (Hijol)	Moderate	Low	Flowers used locally	Low	Moderate	Attracts wetland birds, bees	High (nutrient filter)	High
Artocarpus heterophyllus (Jackfruit)	High	Medium	High-value fruit	Moderate	High	Habitat for insects, squirrels	Moderate	Moderate
Melocanna baccifera (Bamboo)	High (fast growth)	High (construction)	Crafts, shoots, fencing	Moderate	Moderate	Understory wildlife shelter	Moderate	High
Aegle marmelos (Bael)	Moderate	Low	Fruits, medicinal uses	Moderate	Moderate	Attracts bees, birds	High	Moderate
Albizia lebbeck	Moderate	Moderate	Shade, fodder, medicine	High	High	Insect and bird-attracting	Moderate	High
Azadirachta indica (Neem)	Moderate	Low	Medicinal, pest repellent	Moderate	Moderate	Habitat for beneficial insects	High (air purifying)	Moderate
Acacia auriculiformis	Moderate	Medium	Pods, firewood, gum	Moderate	Moderate	Shelter for birds	Moderate	Moderate
Ficus religiosa (Peepal)	High	Low	Shade, cultural	Moderate	High	Hosts birds, insects, epiphytes	Moderate	High
Terminalia arjuna	High	Moderate	Bark (medicinal)	Moderate	Moderate	Bird nesting, bees	High	Moderate
Dalbergia sissoo (Sheesham)	High	High	Fuelwood, shade	Moderate	Moderate	Hosts insects, birds	Moderate	Moderate
Syzygium cumini (Jamun)	Moderate	Low	Fruits, medicine	Low	High	Birds, bats	Moderate	Moderate
Moringa oleifera	Moderate	Low	Nutrient-rich leaves	Low	Moderate	Bees, insects	High	Moderate
Dipterocarpus turbinatus	Very High	High	Resin, medicinal	Moderate	Low	Birds, insects	Moderate	Moderate
Terminalia bellirica	High	Moderate	Medicinal fruits	Low	Moderate	Birds, bees	Moderate	Moderate
Saccharum spontaneum	Low	None	Fodder, erosion control	Low	Low	Hosts small wildlife	Low	Moderate
Swietenia macrophylla (Mahogany)	High	Very High	Shade	Moderate	Moderate	Limited biodiversity support	Moderate	High
Areca catechu (Betel Nut)	Moderate	Moderate	Nuts, fronds and fibers	Low	Moderate	Attracts pollinators, bees, insects	Moderate	Moderate
Palmyra palm	Moderate	Moderate	Fruit, sap, leaves	Low	Moderate	Attracts wildlife, supports local fauna	Moderate	Moderate