Detailed Project Report for the Eco-Restoration of the Thottapura Eucalyptus Plantation

Submitted by:

Tropical Institute of Ecological Sciences (TIES)
www.ties.org.in

Submitted to:

Divisional Forest officer, Kerala Forest Department

Kottayam

TROPICAL INSTITUTE OF ECOLOGICAL SCIENCES (TIES)
ISO 9001:2015 Certified Organization
Approved Research Centre, Mahatma Gandhi University, Kottayam
Approved Laboratory of Kerala State Pollution Control Board

Ecological Research Campus, Velloor P.O., Kottayam, 686 501, Kerala, India
Tel.: 9497290339, 9633723305, 0481-2957050
Email: info@ties.org.in; Web: www.ties.org.in

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Detailed Project Proposal

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Disclaimer:

This Detailed Project Report (DPR) and the accompanying proposal have been prepared by the Tropical Institute of Ecological Sciences (TIES) specifically for the Kerala Forest Department (Kottayam Division) for the eco-restoration of the Thottapura Eucalyptus Plantation. The ecological assessments, spatial analysis of the landscape, and subsequent budgetary estimates provided herein are based on the joint field visit and sample plot studies conducted on May 21, 2026, the provided geographical map, and the initial reference documents supplied by the Department.

All information provided in this proposal is true and correct to the best of our scientific knowledge and belief. The recommendations and data contained within this report are intended exclusively for the internal use of the Authority for the implementation of this specific eco-restoration project. While every effort has been made to ensure the precision of the financial and ecological projections, these estimates assume that normal conditions were present at the site during the survey. Consequently, outcomes may be subject to future natural variations, climate impacts, or economic fluctuations. Furthermore, the specific scientific methodologies and concepts detailed in this document remain the intellectual property of TIES; use or copying of this document in whole or in part without written permission constitutes an infringement.

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Executive Summary

Project Context & Rationale

The Thottapura Eco-Restoration Project aims to systematically transition 55.2 hectares of degraded *Eucalyptus grandis* monoculture into a resilient, highly biodiverse native semi-evergreen forest. Located within the Murinjapuzha Forest Station of the Kottayam Division, the site acts as a critical upper catchment for the Azhutha River. This intervention aligns strictly with the Kerala Eco-restoration Policy of 2021, which mandates the phased eradication of exotic plantation species to mitigate human-wildlife conflict, replenish depleted groundwater, and restore foundational ecosystem services.

Current Ecological Status

Recent empirical field assessments reveal that the landscape is in a highly dynamic state of secondary succession. While 32% of the area has autonomously transitioned into a valuable semi-evergreen community, approximately 50% of the site is heavily smothered by aggressive invasive weeds (e.g., *Lantana camara, Mikania micrantha*) following the April 2025 clear-felling. Despite this degradation, the region remains a high-traffic refuge and corridor for megafauna, including Asian Elephants and Sambar deer, necessitating urgent habitat enrichment.

Proposed Scientific Methodology

The Detailed Project Report (DPR) proposes a radical shift from conventional, mechanized forestry toward a highly targeted, ecologically sensitive approach:

Selective Uprooting: Broad mechanical stump extraction will be entirely abandoned to prevent catastrophic topsoil erosion on steep terrains. Instead, uprooting will be surgically restricted exclusively to the 50% of eucalyptus stumps exhibiting active coppice growth, and strictly prohibited on slopes exceeding a 20-degree gradient.

Targeted Planting & Organic Hyper-Fertilization: Nursery establishment costs are eliminated in favor of bulk procuring 12,000–14,000 mature, field-hardy native saplings. To ensure these saplings rapidly outcompete invasive weeds, the project adopts a Miyawaki-inspired approach, mandating a massive dosage of 2.0 kg of organic fertilizer per sapling, applied in four staggered installments.

Intensive Weed Management & SMC: Chemical herbicides are universally prohibited. The project institutes four rigorous manual weeding cycles annually to suppress the exotic seed bank. Concurrently, extensive Soil and Moisture Conservation (SMC) structures, including 500 rainwater harvesting trenches and robust gully plugs, will be constructed to retain monsoonal rains for summer wildlife utilization.

Socio-Economic & Financial Strategy

Long-term sustainability relies on deep socio-ecological integration through Participatory Forest Management (PFM). An Adivasi Vana Samrakshana Samithi (AVSS) will be formally constituted, integrating the 112 indigenous families from the adjacent Plackathodam tribal colony. This establishes local ownership and generates sustainable livelihoods by employing AVSS members to manage future low-impact eco-tourism initiatives (trekking and bird watching).

Financially, the project operates within the originally sanctioned envelope of ₹128.5 Lakhs. Capital previously earmarked for 100% mechanical uprooting and temporary nurseries has been aggressively reallocated to fund the intensive manual weeding, massive organic fertilization, and a mandatory 5% scientific consultation fee to ensure continuous biodiversity monitoring and safety audits.

Climate Finance Integration

To guarantee perpetual financial independence, the DPR includes a framework to register the restored forest's carbon sequestration under the Voluntary Carbon Market. The project is recommended for registration under the domestic Carbon Registry - India (CR-I) managed by the Network for Certification and Conservation of Forests (NCCF). CR-I was specifically selected because its exceptionally low administrative and third-party audit fees make it the most viable standard to successfully monetize carbon credits for a micro-scale 55.2-hectare initiative.

1

The Ecological and Socio-Political Landscape

1.1 Project Context and Ecological Rationale

The Western Ghats mountain range is universally acknowledged as a critical global biodiversity hotspot, characterized by exceptional levels of vascular plant endemism and complex ecological assemblages. Despite its ecological primacy, this region has historically been subjected to severe landscape-level degradation driven by intensive land-use modifications and the state-sponsored commercial exploitation of forest resources. In an aggressive legislative effort to reverse these historical trajectories, the Government of Kerala promulgated the Eco-restoration Policy of 2021. This transformative environmental policy explicitly mandates the phased eradication of exotic monoculture plantations—specifically targeting Eucalyptus, Acacia, and Wattle species—which have been scientifically documented to precipitate the severe depletion of natural forest understories, significantly alter local hydrological cycles, and exacerbate the escalating crisis of human-wildlife conflict by depriving native fauna of adequate nutritional forage.

The Thottapura Eucalyptus Plantation, nestled within the jurisdiction of the Murinjapuzha Forest Station of the Erumeli Range, under the administrative umbrella of the Kottayam Forest Division, represents a highly critical site for the localized implementation of this restorative policy. The designated project site encompasses a total geographical area of 63.2 hectares, of which a precise effective treatment area of 55.2 hectares has been earmarked for intensive ecological restoration following the execution of clear-felling operations in April 2025. The eco-restoration of this specific landscape is not to be interpreted as a mere silvicultural exercise; rather, it constitutes a holistic ecological intervention meticulously designed to reinstate the structural complexity and functional integrity of a native semi-evergreen forest ecosystem. The transition from a biologically impoverished monoculture to a climax forest community is imperative for the restoration of foundational ecosystem services, including robust carbon sequestration, advanced soil moisture retention, and the provision of critical wildlife habitats.

1.2 Geographic, Hydrological, and Topographical Significance

Geographically, the Thottapura plantation falls within the boundaries of the Arudai Fuel Reserve, an area of profound ecological and hydrological importance. The site forms a crucial upper catchment and micro-watershed area for the Azhutha River, which acts as a major tributary feeding the larger Pampa River system. The preservation and enhancement of this specific micro-watershed are of paramount importance, as the forested area acts as a vast biological sponge, ensuring the perennial release of water sources critical for sustaining both local human settlements and the dense wildlife populations during the arid summer months.

The topography of the site is highly variable, characterized by undulating terrains with moderate to steep gradients ranging from 10% to well over 20% in specific sectors. The edaphic profile reveals a foundation of sandy loam soils deeply intermixed with laterite formations, which are

highly susceptible to erosional forces if the vegetative cover is compromised. Climatically, the region benefits from active precipitation systems driven by both the South-West and North-East monsoons, though it experiences significant and stress-inducing dry spells from January through April.

Spatial analysis of the provided site map reveals an intricate network of existing infrastructure and ecological markers critical to the project's execution. The Azhutha River is clearly visible forming a deep natural boundary along the eastern edge of the mapped terrain.

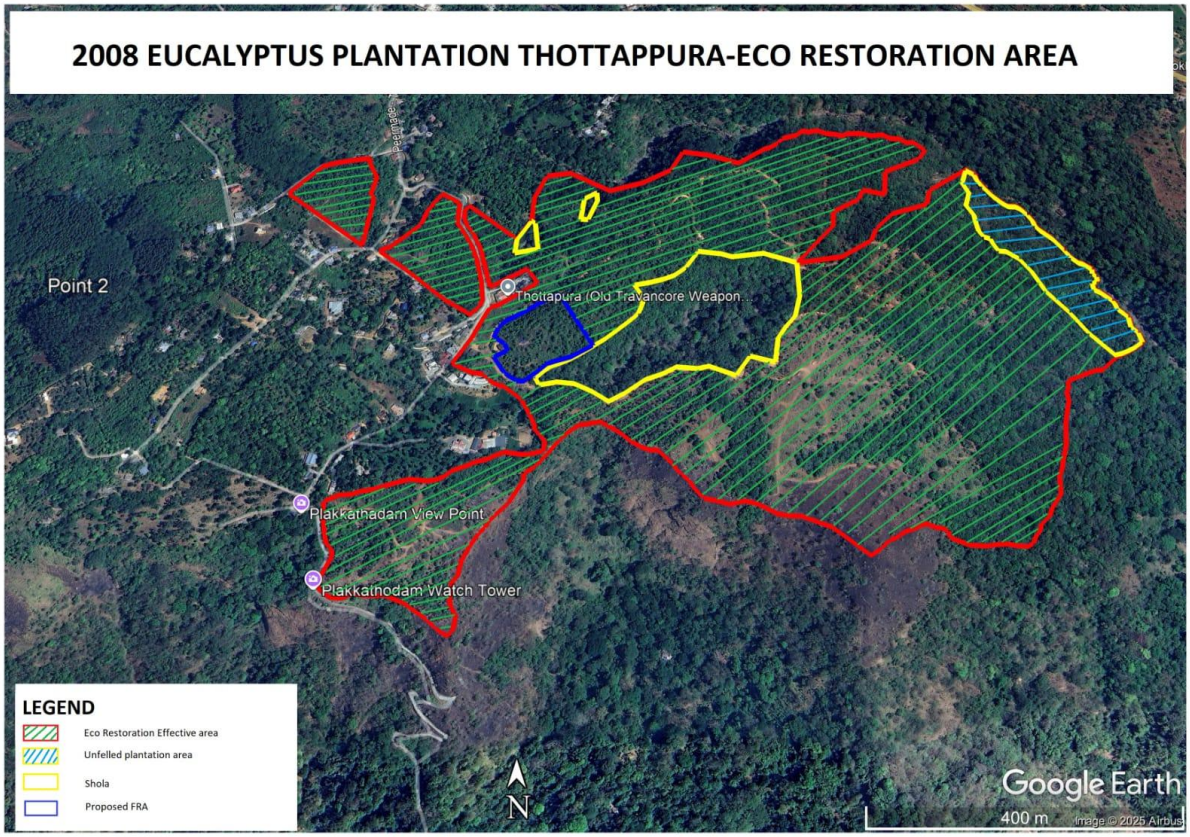

Fig.1. Thottapura plantation area (Source; Kerala forest department, Kottayam Division)

1.3 Strategic Project Objectives

The overarching goal of this Detailed Project Report (DPR) is to outline a comprehensive, scientifically robust, and financially viable methodology to transition this degraded *Eucalyptus grandis* monoculture into a resilient, mixed semi-evergreen forest. This must be achieved while simultaneously generating sustainable livelihoods for local indigenous communities and unlocking vital climate finance mechanisms through the burgeoning global and domestic carbon credit markets.

The specific, multi-dimensional objectives of this restorative intervention include:

1. **Ecological Rehabilitation:** To identify, document, and aggressively restore degraded micro-habitats within the landscape using a highly diverse matrix of native tree species, thereby eliminating invasive flora and preventing topsoil erosion.
2. **Hydrological Security:** To execute extensive soil and moisture conservation (SMC) works across the terrain to maximize rainwater percolation, subsequently stabilizing the base flow of the Azhutha River catchment.

3. **Human-Wildlife Conflict Mitigation:** To vastly improve the carrying capacity of the forest for endemic herbivores and frugivores, thereby reducing crop-raiding incidents in the peripheral human habitations.
4. **Socio-Economic Empowerment:** To institutionalize a framework of Participatory Forest Management (PFM) that actively integrates the adjacent indigenous communities, ensuring that the economic benefits of eco-tourism, monitoring, and carbon finance directly alleviate local poverty.
5. **Climate Finance Integration:** To meticulously baseline, monitor, and register the carbon sequestration gains of the restored forest under a recognized carbon registry, generating a sustainable, long-term revenue stream.

Fig.2. Location photos: Above: Coup road inside the plantation; below: a semi evergreen patch.

2

Background and Current Ecological Status

2.1 Silvicultural History and Plantation Dynamics

The silvicultural history of the Thottapura site is emblematic of 20th-century commercial forestry practices that prioritized rapid biomass accumulation over ecological stability. The inaugural plantation was aggressively established within the reserve forest boundary in 1993, comprising a massive deployment of 90,000 saplings of *Eucalyptus grandis* spread uniformly across the 63.2-hectare area. This initial rotation concluded in the 2006-2007 operational year, culminating in a highly disruptive clear-felling operation that successfully extracted 5,250 cubic meters of commercial timber.

Almost immediately following the harvest, a subsequent replantation phase was initiated in 2008, maintaining approximately the same high-density stocking parameters to maximize future yields.[The most recent harvest cycle concluded in April 2025, during which an effective area of 55.2 hectares was completely clear-felled, effectively resetting the successional clock of the landscape. However, due to severe topographical constraints—specifically, high-slope terrains that render mechanical harvesting ecologically hazardous and logistically impossible—approximately 6.5 hectares of the plantation were left entirely intact. This unharvested zone corresponds to the "Trees Not Felled" marker on the extreme eastern edge of the site map. Within this remnant area, an inventory indicates the presence of exactly 157 standing mature *Eucalyptus* trees, representing an estimated standing volume of 49.837 cubic meters of timber and an additional 33.889 cubic meters of associated firewood.

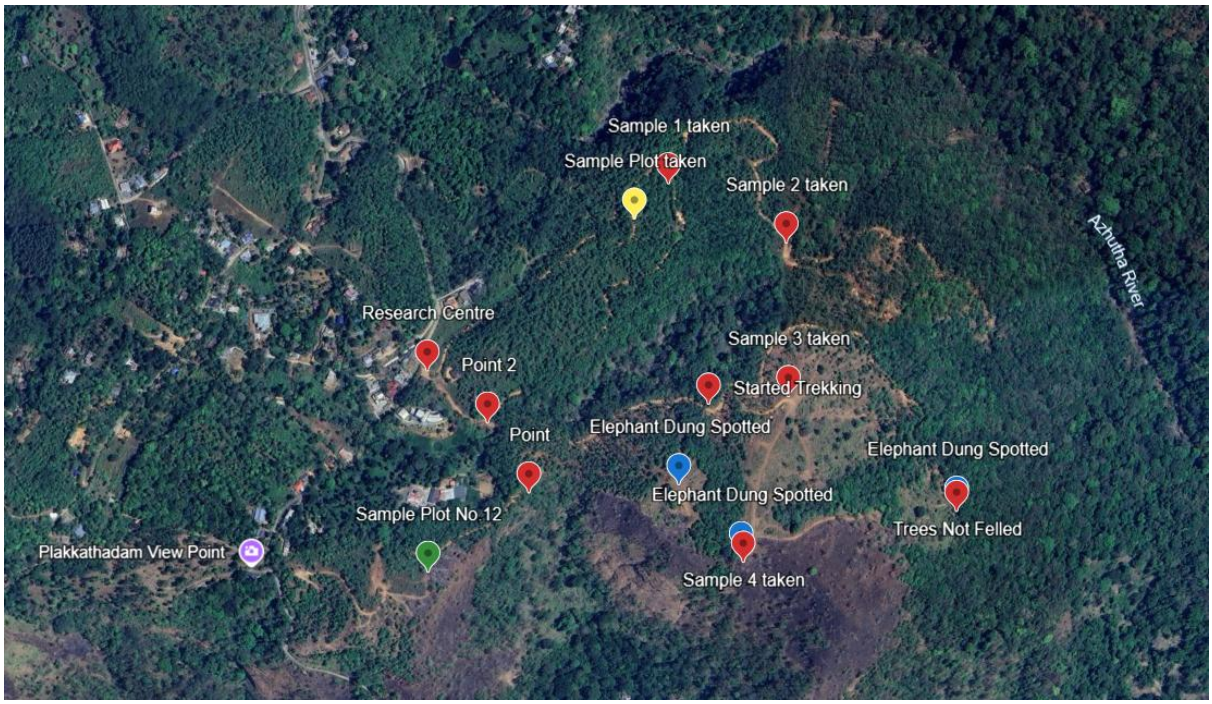

Fig.3. Locations and sample study plots visited and studied by joint team of TIES & KFD

2.2 Micro-Spatial Analysis and Current Landscape Stratification

A comprehensive site assessment and detailed sample plot study were conducted on May 21, 2026, orchestrated by the Tropical Institute of Ecological Sciences (TIES) in close conjunction with local forest officials from the Murinjapuzha Forest Station, including the jurisdictional Range Officer. This empirical survey revealed a landscape currently existing in a highly dynamic, albeit fractured, state of secondary ecological succession. The evaluation of 20m x 20m spatial sample plots indicated a historical planting density averaging 20 cut *Eucalyptus* stumps per plot, highlighting the intense resource competition that previously dominated the site.

The macro-landscape of the Thottapura plantation can currently be stratified into three distinct ecological segments based on vegetative dominance:

1. **Hilltop and Sloping Grasslands:** Exposed, high-altitude ridges dominated by native and pioneer grass species, crucial for maintaining soil cohesion during monsoonal deluges.
2. **Emergent Natural Forest (54% of total area):** Despite the prolonged legacy of monoculture, the site exhibits substantial natural resilience. Approximately 54% of the total area has autonomously transitioned into a natural forest state, forming complex, multi-layered canopies dominated by a community of semi-evergreen flora.
3. **Weed-Dominated Patches (50% of total area):** The most ecologically compromised segment, where the sudden influx of sunlight following the 2025 clear-felling catalysed an explosion of highly aggressive exotic invasive weeds.

The empirical sample study also evaluated the regenerative capacity of the harvested timber. The data revealed that only 50% of the harvested *Eucalyptus* stumps currently exhibit active coppice growth (epicormic shoots), averaging merely 8 to 10 actively coppicing stumps per 20x20m area. This low coppicing rate is a critical variable that fundamentally alters the required site preparation methodology.

2.3 Faunal Diversity, Natural Regeneration, and Habitat Value

The 54 % of the landscape that has successfully transitioned into a semi-evergreen ecosystem is dominated by a highly valuable native plant community. Foundational **flora species** currently thriving on the site include *Elaeocarpus tuberculatus*, *Dillenia pentagyna*, *Terminalia paniculata*, *Symplocos cochinchinensis*, *Lagerstroemia microcarpa*, *Syzygium jambos*, and the highly dominant small tree *Viburnum punctatum*.

The ecological interactions of these species are critical. *Elaeocarpus tuberculatus* provides indispensable thermal and moisture buffering in Western Ghats ecosystems, creating cool, damp microclimates essential for understory establishment. Similarly, *Viburnum punctatum* plays a vital ecological role; its heavily scented white flowers and subsequent fruiting bodies are highly attractive to local frugivorous avifauna, effectively transforming the plant into a biological hub that facilitates further seed dispersal and natural regeneration across the degraded landscape. Quantitative sample plot analyses across the site confirm a robust natural regeneration density, empirically assessed at an average of 796 native saplings per hectare, proving that the seed bank remains viable.

Conversely, the ecological health of the remaining 50% of the site is severely compromised. These open patches are entirely smothered by a dense, impenetrable mat of **exotic invasive species**, prominently including *Mikania micrantha*, *Chromolaena odorata*, *Lantana camara*, *Ageratina adenophora*, *Pteridium aquilinum*, *clidemia hirta* and *Mimosa diplotricha*. These allelopathic weeds actively suppress native seed germination, alter soil chemistry, and create significant fire hazards during the dry season.


Fig.4. Grass land at the top; Right: Top view from the lower side of the plantation


Fig.5. Semi evergreen forest patches- almost 50% of the plantation transformed into this status


Fig.6. Area covered with invasive alien species- extended to the forested area too

Fig.7. The dominant small tree – *Viburnum pnctuatum* Inset: Leaf of the plant. (*Konakarimaram* [Mal.])

Despite the structural alterations and weed invasions, the plantation area remains a vital, high-traffic refuge for regional wildlife. The site supports complex trophic webs, sheltering notable **avian predators and frugivores** such as the Crested Serpent Eagle, Oriental Honey Buzzard, Scarlet Minivet, Red-whiskered Bulbul, and Red-vented Bulbul. **Mammalian fauna** is equally prominent, with documented, persistent utilization of the habitat by Indian Crested Porcupines, Sambar Deer, and Asian Elephants. The multiple "Elephant Dung Spotted" geo-markers explicitly mapped across the site confirm that megafauna actively forage and traverse these exact coordinates. The restoration of the native semi-evergreen canopy and the augmentation of riparian water sources will exponentially increase the carrying capacity of this site, directly addressing and mitigating the escalating human-wildlife conflicts prevalent in the surrounding agricultural matrices.

Fig.8.
Top 3- Sample plot study.
Second row, right: Soil sample collection;
Left : One of the Eucalyptus tree left uncut
Above: Small twigs of Eucalyptus left during the Clear felling

2.4 Spatial analysis of Land Use Land Cover type (LULC) and slope of the site using Geographical Information system (GIS)

A precise baseline of the site's topographical and vegetative state has been established to guide the restoration interventions using Geographical information system (GIS) tools.

- **Elevation and Slope Dynamics:** The elevation model demonstrates a significant altitudinal gradient across the site, ranging from a low of 817 meters (near the river boundaries) to a high of 1,036 meters at the central ridges. Crucially, the slope analysis explicitly justifies the selective uprooting strategy. While the vast majority of the treatable landscape falls within a moderate 0–20 degree slope gradient (mapped in red), there is an intricate network of steep ravines and escarpments where the slope abruptly increases to between 20 and 60.12 degrees (mapped in green). Any mechanical disturbance or whole-scale uprooting in these green zones would precipitate catastrophic landslides and topsoil loss.

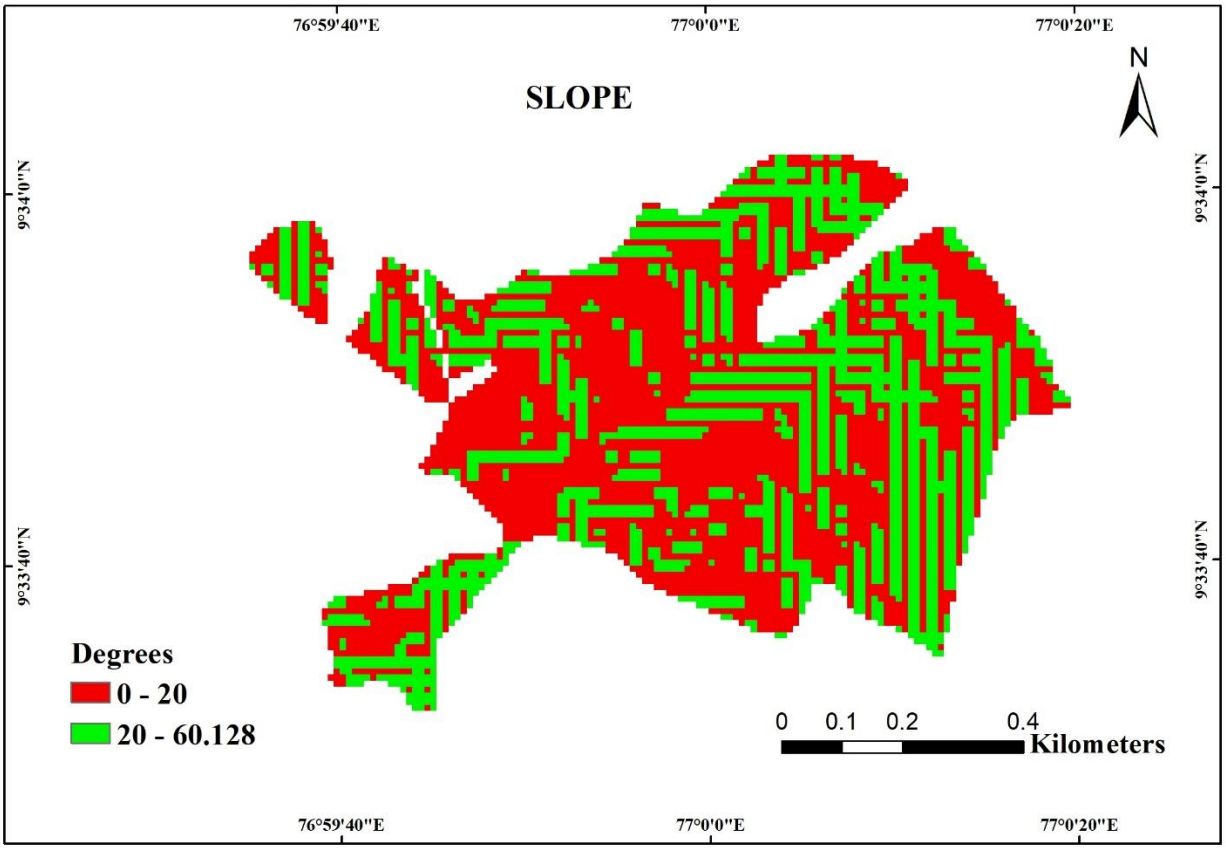

Fig.9. Slope showing areas with above 20 degree slope.

- **NDVI-Based Land Use / Land Cover (LULC):** The spatial analysis utilizing Normalized Difference Vegetation Index (NDVI) mapping has precisely quantified the current land use over the 61.43-hectare analyzed footprint. The data reveals that 33.11 hectares (53.89%) of the area currently maintains a 'Forest' cover, validating the site's natural regenerative capacity. The primary targets for the aggressive eco-restoration and planting interventions are the highly degraded zones categorized as 'Weed with trees' (19.27

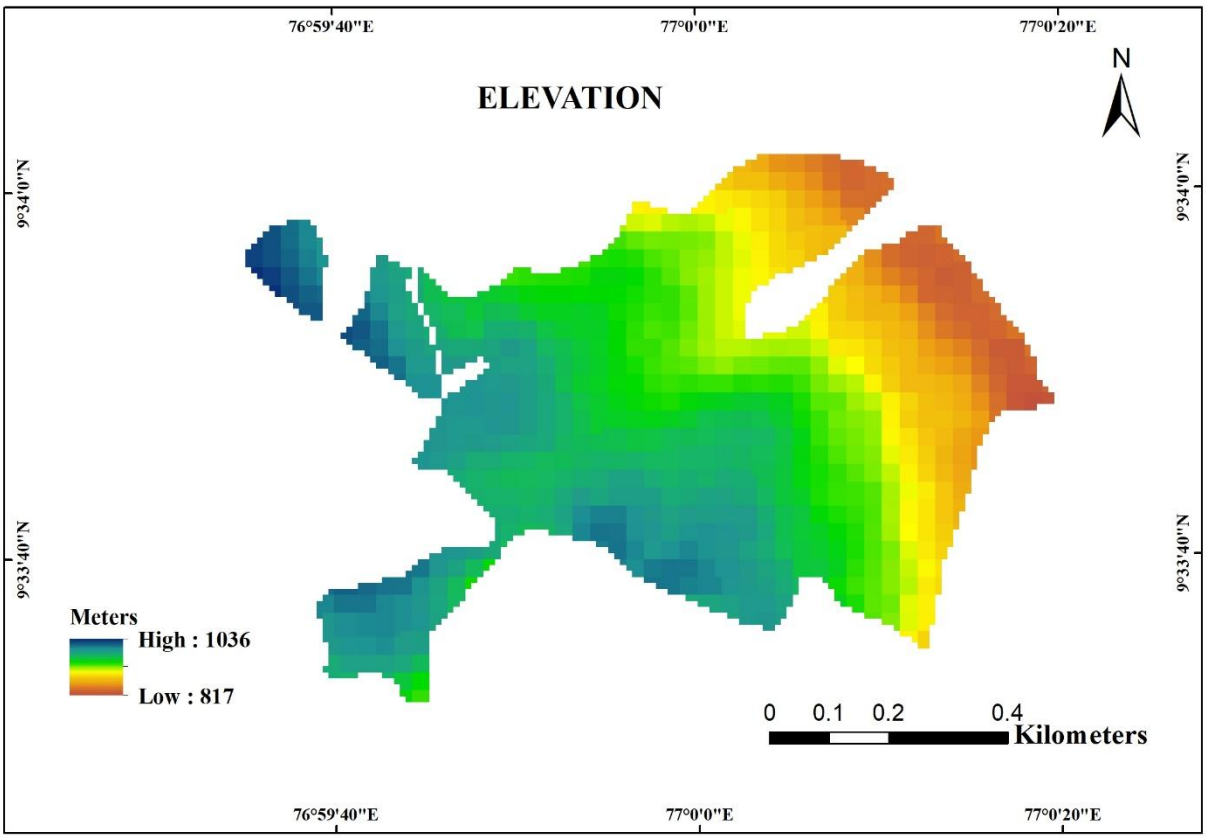

Fig.10. Elevation of the site (Plantation area)

Sl.No	LULC category	Area (Ha)	Area (%)
1	Rock exposure	2.04	3.31
2	Built up	0.08	0.12
3	Weed	2.46	4.00
4	Forest	33.11	53.90
5	Weed with trees	19.28	31.38
6	Barren land	4.48	7.29
		61.43	

Table 1. Land use pattern of Plantation area based on NDVI value (GIS analysis)

hectares, or 31.37%) and pure 'Weed' patches (2.45 hectares, or 4.00%). Additionally, 'Barren land' accounts for 4.47 hectares (7.28%), highlighting exposed areas in urgent need of soil stabilization, while natural 'Rock exposure' and minor 'Built-up' areas constitute 2.03 hectares (3.31%) and 0.07 hectares (0.12%) respectively. This quantitative spatial baseline ensures that the 14,000 native saplings and intensive weeding efforts are deployed exclusively where ecologically required.

Fig.11. Even in dense 'forested' areas, dense weed covering is found.

Ground-truth verification revealed significant discrepancies between the GIS data and the actual land-use patterns. For example, even in densely forested areas, the understory is not composed of native undergrowth as indicated; instead, the entire area is dominated by the aforementioned weeds.

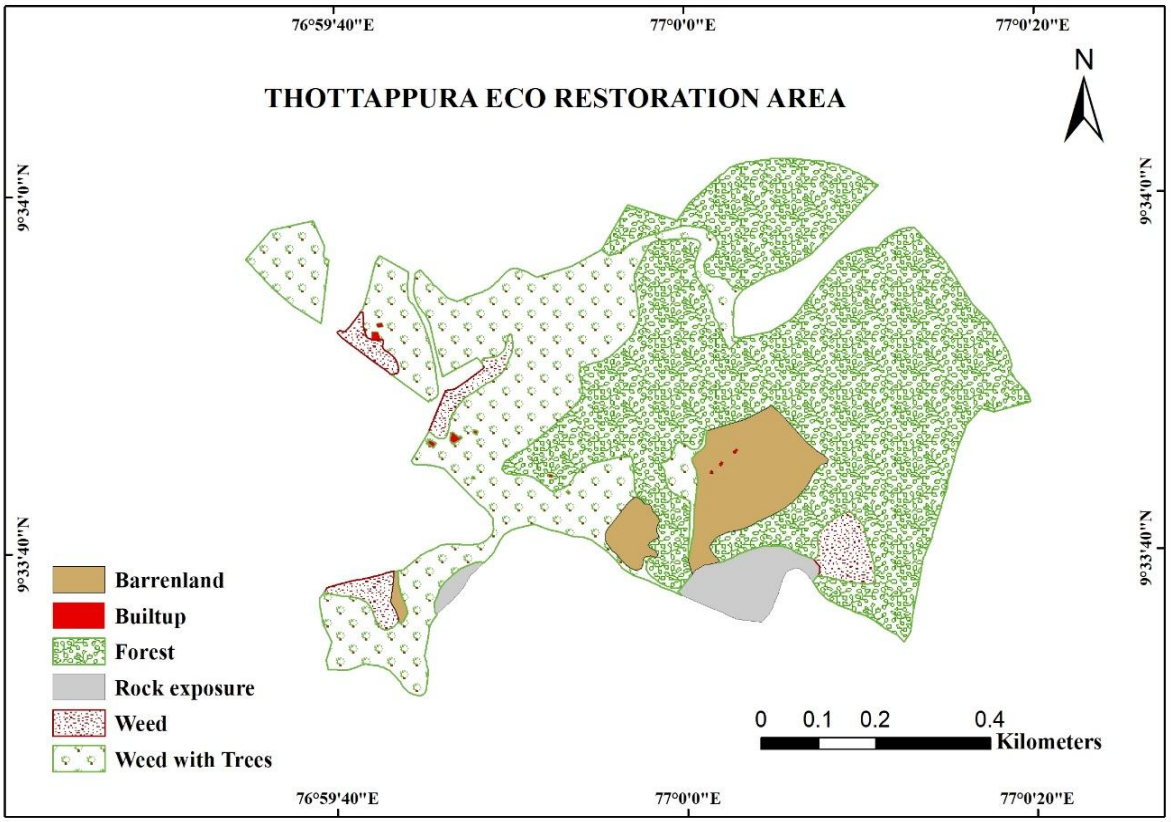

Fig.10. Thottapura plantation area LULC pattern (GIS analysis)

3

Methodology for Scientific Eco-Restoration

The proposed restoration strategy represents a fundamental paradigm shift from conventional, highly mechanized afforestation protocols. The methodology synthesized herein adopts an ecologically nuanced approach that prioritizes minimal mechanical soil disturbance, the active acceleration of natural successional pathways, the complete prohibition of toxic agrochemicals, and the strategic adaptation of the high-density Miyawaki planting method.

3.1 Site Preparation: The Imperative of Selective Uprooting

The original draft of the Site Specific Plan (SSP) proposed the ubiquitous, mechanical uprooting of all remaining *Eucalyptus grandis* stumps across the 55.2-hectare treatment area. However, deep empirical field observations mandate a critical and immediate modification to this aggressive approach. Complete mechanical uprooting utilizing heavy earth-moving machinery is ecologically counterproductive and highly destructive for two primary reasons:

1. **Edaphic Destabilization and Soil Erosion:** The topography of the Thottapura site includes significant high-slope terrains. Mechanical extraction of deep taproots and lateral root systems on slopes exceeding 20 degrees will violently disrupt the soil matrix, destabilizing the sandy loam layers. During the intense monsoonal rains, this will inevitably precipitate severe erosional events, leading to catastrophic topsoil loss and the subsequent siltation of the pristine Azhutha River micro-watershed below.
2. **Annihilation of Natural Regeneration:** The site already boasts a valuable natural regeneration rate of 796 saplings per hectare. Indiscriminate mechanical uprooting across the entire landscape will inadvertently crush, uproot, and destroy this existing native regrowth, effectively resetting the biological progress the ecosystem has autonomously achieved.

Therefore, the revised methodology enforces a strict protocol of **selective uprooting**. Uprooting operations shall be surgically confined exclusively to the 50% of *Eucalyptus* stumps that actively exhibit epicormic coppice growth. Furthermore, a strict topographical safeguard must be implemented: stump removal will be entirely prohibited on all slopes exceeding a 20-degree gradient, regardless of the stump's coppice status. This nuanced approach starves the invasive *Eucalyptus* of its regenerative capacity while meticulously preserving soil architecture and native saplings.

3.2 Eradication of Invasive Alien Species (IAS)

Given that almost fully 50% of the landscape is currently enveloped by highly aggressive exotic weeds, invasive species management forms the absolute crux of all pre-planting operations. The application of chemical herbicides (such as Glyphosate) is strictly and universally prohibited across the project site to protect the underlying micro-watershed, soil microbiota, and foraging wildlife.

Eradication must therefore be achieved through rigorous, labor-intensive manual knife-weeding and manual uprooting techniques. However, a single clearing event is insufficient against species like *Lantana camara* and *Mikania micrantha*, which possess massive dormant seed banks. To prevent inevitable weed resurgence, a repetitive, cyclical approach is mathematically required: an initial heavy clearing immediately prior to the monsoon planting season, followed seamlessly by four subsequent manual weeding cycles per year, spaced strategically throughout the 5-year project duration.

3.3 Planting Strategy: Spatial Targeting and Species Selection

The overarching spatial strategy of this DPR restricts the introduction of new saplings exclusively to the newly weed-cleared patches. The project will avoid any unnecessary silvicultural interference in the 54% of the area where natural semi-evergreen forests and native high-altitude grasslands are already successfully thriving. In these established zones, only the highly targeted addition of specific rare species will be permitted, carefully considering micro-site wind patterns and localized slope dynamics.

Procurement Optimization vs. Nursery Establishment: The initial SSP allocated significant financial and temporal capital toward establishing a localized, temporary forest nursery. This approach has been deemed resource-intensive, prone to high initial mortality rates, and operationally inefficient for the accelerated timeline proposed. The modified scientific strategy eliminates the nursery construction component entirely. Instead, the project will procure between 12,000 and 14,000 robust, field-ready saplings that have been grown for one to two years. These mature saplings will be purchased directly from established Kerala Forest Department central nurseries or certified private botanical vendors. Utilizing older, anatomically hardened saplings guarantees significantly higher survivability rates and ensures rapid canopy closure in highly competitive, weed-prone field environments. The total planting cap is strictly set at 14,000 plants; there is no ecological scope for additional aggressive planting, as overstocking will lead to intense inter-specific competition for scarce summer water resources.

Native Species Matrix Formulation:

The selected arboreal matrix is meticulously designed to structurally and functionally mimic the climax community of a Western Ghats semi-evergreen forest. The exclusive list of 22 native species mandated for this restoration includes:

1. *Symplocos cochinchinensis* (Canopy/Mid-story support)
2. *Terminalia paniculata* (Dominant emergent canopy)
3. *Dillenia pentagyna* (Fire-resistant structural timber)
4. *Syzygium jambos* (Riparian stabilization, frugivore forage)
5. *Elaeocarpus tuberculatus* (Microclimate thermal buffering)
6. *Mangifera indica* (Keystone frugivore resource)
7. *Hopea parviflora* (Endemic evergreen canopy)
8. *Terminalia arjuna* (Riparian zone dominance)
9. *Olea dioica* (Hardy mid-story evergreen)
10. *Cinnamomum malabatrum* (Aromatic understory/mid-story)
11. *Syzygium cumini* (Drought-resistant canopy, high faunal value)
12. *Alstonia scholaris* (Rapid-growth emergent)
13. *Vateria indica* (Critically important endemic evergreen)
14. *Grewia tiliifolia* (Fodder species for mammalian herbivores)

15. *Ficus racemosa* (Keystone fig species for continuous fruiting)
16. *Artocarpus hirsutus* (Massive canopy structure, endemic)
17. *Trewia nudiflora* (Moisture-loving rapid grower)
18. *Bambusa bambos* (Soil stabilization and elephant fodder)
19. *Careya arborea* (Fire-resistant deciduous component)
20. *Holoptelea integrifolia* (Hardy deciduous pioneer)
21. *Diospyros spp.* (Slow-growing dense canopy elements)
22. *Gmelina arborea* (Fast-growing pioneer for rapid shade).

Miyawaki-Inspired Organic Hyper-Fertilization: To hyper-accelerate the initial growth phase and ensure saplings outcompete surrounding weed pressures, the project will radically alter standard fertilization protocols by utilizing principles derived from the Miyawaki afforestation method. The standard forestry application of a mere 50 grams of fertilizer per sapling is grossly inadequate for rapid ecological phase shifts. Instead, this methodology mandates a hyper-dosage of exactly 2.0 kilograms of pure, high-quality organic compost/fertilizer per sapling. To prevent nutrient leaching during the monsoon, this 2.0 kg allocation will be precisely applied in four staggered instalments of 500 grams each, distributed evenly over a critical four-month establishment period. This massive, phased infusion of organic matter rapidly increases Soil Organic Carbon (SOC), dramatically enhances soil moisture retention capacity during dry spells, and fosters the robust, complex mycorrhizal fungal networks that are absolutely essential for native tree survival in degraded lateritic soils.

3.4 Soil and Moisture Conservation (SMC) Interventions

The topographical and climatic reality of the Thottapura site dictates that during the summer season, water scarcity becomes exceedingly severe. This hydrological deficit poses the most significant threat to sapling survival and acts as the primary catalyst for human-animal conflict, as dehydrated megafauna are forced out of the reserve in search of water. Consequently, robust structural SMC interventions are unconditionally essential.

The SMC framework will involve the construction of extensive dry-stone gully plugs placed precisely across natural drainage lines to immediately arrest soil runoff and drastically reduce the velocity of flowing surface water. Current forestry estimates in Kerala place the cost of high-quality gully plugging at approximately ₹400 per cubic meter. Additionally, the strategic placement of minor check dams and the manual excavation of 500 staggered rainwater harvesting trenches will facilitate localized, deep-aquifer recharge, effectively holding monsoonal water within the landscape for summer utilization.

3.5 Chronological Implementation Schedule

To biologically synchronize with the optimal hydrological window, the planting schedule is rigorously aligned with the onset of the South-West Monsoon:

- **June (Year 1):** Finalization of procurement contracts for the 12,000–14,000 saplings. Execution of the massive initial manual weed clearing and the highly selective uprooting of coppicing *Eucalyptus* stumps on safe gradients.
- **July (Year 1):** Immediate execution of terrace planting. Application of the first 500-gram installment of organic fertilizer to every sapling. Concurrently, the heavy construction of soil and water conservation structures (gully plugs, check dams) must commence.
- **August (Year 1):** Comprehensive field assessment of initial sapling mortality. Immediate

replacement planting for all documented damages (budgeted at a 10% mortality rate). Execution of the first post-planting cyclical weed-out operation to maintain clear terraces. Application of the second 500-gram fertilizer installment.

- **October (Year 1):** Execution of the second post-planting cyclical weeding operation across the entire 55.2 ha site.
- **December–January (Year 1 transitioning into Year 2):** Execution of the critical third weeding cycle, ensuring the site is entirely clear of weed competition before the onset of the severe summer drought stress period.

Fig. 9. Joint study team from TIES & Kerala Forest Department inside the plantation area

4

Results and Discussion: Projected Ecological and Social Trajectories

The execution of the proposed restorative interventions is mathematically and biologically designed to catalyze a rapid ecological phase shift. Based on the integration of existing field observations and advanced silvicultural modeling, several critical outcomes are confidently projected over the 5-year project lifecycle.

4.1 Canopy Architecture, Biomass, and Biodiversity

By the culmination of Year 5, the landscape will undergo a profound physical transformation, shifting from a fragmented, highly vulnerable, weed-choked monoculture matrix into a stable, heterogeneous mosaic consisting of closed-canopy semi-evergreen forest patches seamlessly interspersed with natural high-altitude grasslands. The introduction of up to 14,000 diverse, mature native saplings, heavily supported by the Miyawaki-style hyper-dosages of organic fertilizer, is scientifically guaranteed to accelerate canopy closure. The rapid vertical and lateral growth of foundational, broad-leaf species like *Terminalia paniculata*, *Artocarpus hirsutus*, and *Gmelina arborea* will physically shade out the underlying soil layer. Because invasive weeds such as *Chromolaena odorata* and *Lantana camara* are obligate heliophytes (requiring full, intense sunlight), the formation of this native canopy will effectively suppress their regeneration cycles biologically, eliminating the future need for continuous manual weeding or toxic arboricides. Furthermore, a strict commitment to replanting 10% of any damaged stock annually will be utilized as a dedicated initiative to further inject rare and endemic plant diversity into the system.

4.2 Hydrological Buffering and Conflict Mitigation

The maturation of deep-rooted species like *Elaeocarpus tuberculatus* and *Syzygium jambos* directly along the natural drainage lines, combined with the structural installation of 500 rainwater harvesting pits and numerous gully plugs, will drastically and permanently alter the site's subsurface hydrology. Increased soil percolation rates and massively reduced surface runoff will gradually convert ephemeral, monsoon-dependent streams into perennial micro-catchments. This newly secured water availability entirely contained inside the plantation area will provide sustainable drinking sources for elephants and sambar deer during the dry season, thereby directly and significantly reducing retaliatory human-animal conflict in the surrounding agricultural zones.

4.3 Sustainable Conservation, Livelihoods, and Participatory Forest Management

The long-term, multi-generational sustainability of the Thottapura restoration effort hinges unequivocally upon deep socio-ecological integration. The spatial reality is that the plantation is completely encircled by expanding human habitations, intensive agricultural farms, and

residential structures. This geographic isolation renders the forest highly vulnerable to anthropogenic pressures, including boundary encroachments, illicit timber extraction, and unmanaged, highly destructive rogue tourism.

To aggressively counteract these pressures, the project will implement a robust Participatory Forest Management (PFM) model, which is recognized as the best sustainable framework for the conservation of reserve forests adjoining human activity zones. Central to this PFM model is the formal, legal constitution of an Adivasi Vana Samrakshana Samithi (AVSS). The AVSS will be formed by integrating the 120 indigenous families (*Malampandaram* tribe) currently residing in the adjacent Plackathodam tribal colony. By legally transferring localized stewardship and employment opportunities directly to the AVSS, the project ensures the equitable distribution of eco-development benefits and establishes an impenetrable local ownership over the conservation outcomes.

Furthermore, the site possesses immense, high-value eco-tourism potential. The panoramic, sweeping views available from the hilltop grasslands, seamlessly combined with established landmarks like the Research Centre and the Plakkathodam Watch Tower, offer highly marketable opportunities for managed forest trekking, educational botany tours, and premium bird watching trails. The AVSS membership will be professionally trained and exclusively employed to manage these low-impact ecotourism corridors, thereby generating a sustainable stream of alternative livelihood income that directly replaces forest exploitation.

4.4 Continuous Monitoring and Scientific Evaluation

To empirically validate these theoretical ecological gains, the expert TIES team will be formally retained as the designated scientific consultant throughout the project lifecycle. A comprehensive, grid-based biodiversity assessment survey will commence in the third year of the project. By the fifth year, this three-year continuous longitudinal dataset will be utilized to conduct a highly detailed carrying capacity study and a rigorous physical safety audit for the proposed ecotourism destinations. This ensures that future human footfall never exceeds the scientifically established ecological thresholds of the newly restored habitat.

Fig. 10. Panoramic view of high ranges from the Grass land hill top in the plantation area

5

Budget Formulation and Financial Strategy

The original financial forecast outlined in the draft SSP allocated a total of ₹128.5 Lakhs over a standardized five-year period to cover basic planting and maintenance. However, the vastly revised, highly scientific methodology proposed in this DPR requires a strategic, aggressive reallocation of these funds to align with the ecological realities of the site and the advanced scientific protocols mandated.

5.1 Financial Reallocation Principles and Justifications

1. **Complete Elimination of Nursery Capital Costs:** Capital expenditures historically related to the construction, daily maintenance, watering, and staffing of a temporary forest nursery are entirely excised from the budget. These substantial funds are directly redirected toward the bulk procurement of mature, high-quality, field-hardened saplings from existing external sources.
2. **Massive Reduction in Heavy Uprooting Costs:** The original SSP budget blindly provisioned for the universal, mechanized uprooting of every *Eucalyptus* stump across 55.2 hectares (estimated at a staggering ₹22,28,200). By strictly restricting uprooting operations exclusively to the 50% of stumps exhibiting coppice growth, and only on terrains with slopes under 20 degrees, this massive budgetary line item is safely reduced to merely 25% of the present allotment.
3. **Intensification of Weeding and Organic Fertilization:** The vast financial savings generated from the reduced uprooting operations and the total nursery elimination will be heavily and immediately reinvested into two critical areas: aggressive manual weed management (now expanded to 4 repetitive cycles annually to cover the entire area) and the bulk procurement of premium organic fertilizers to meet the Miyawaki requirement (2 kg per sapling).
4. **Scientific Consultation and Long-Term Monitoring:** A mandatory, non-negotiable allocation of exactly 5% of the total project budget is officially reserved as a SCIENTIFIC SUPPORT FEE OR CONSULTATION FEE payable to TIES (www.ties.org.in). This fee covers the intellectual property of DPR development, continuous biannual monitoring, official reporting, the critical Year 3–5 biodiversity studies, carrying capacity analyses, and final safety audits. This transforms the project from a blind planting exercise into a scientifically validated ecological restoration.
5. **Carbon Credit Development Fund:** A net-new budgetary head is explicitly created to cover the requisite upfront administrative fees, validation audits, and ongoing registration costs required for claiming carbon credits through accredited domestic or international agencies.

5.2 Proposed Budgetary Framework Comparison (Estimates for 55.2 Ha)

Budgetary Head	Original SSP Strategy (₹128.5 Lakhs Total)	Revised DPR Strategy	Financial Implication & Justification
Site Preparation & Uprooting	100% mechanical stump removal universally applied (₹22.28L).	Selective manual/light removal (coppice only, <20° slope).	**75% Reduction** in capital outlay; prevents catastrophic soil erosion.
Sapling Procurement	Internal nursery creation, fencing, watering, & daily maintenance.	Direct bulk purchase of 12k-14k aged (1-2yr) native saplings.	**Cost Neutral/Slight Reduction**; higher initial unit cost is completely offset by zero infrastructure costs.
Fertilization Application	50g standard chemical/organic mix applied occasionally.	2,000g pure organic compost applied in 4 strict, phased installments.	**Moderate Increase**; non-negotiable expense to drive rapid Miyawaki-style canopy closure.
Weed Management	Standard pre- and post-monsoon general clearing.	4 intensive, targeted manual weeding cycles per annum across all 55.2ha.	**Significant Increase**; biologically vital for sapling survival against invasive dominance.
Soil & Water Conservation	Minor provisions for basic pits/trenches.	Expanded gully plugging (~₹400/cum), check dams, and 500 harvest pits.	**Moderate Increase**; critical capital infrastructure for summer water retention and conflict mitigation.
Scientific Consultation	Nil. No monitoring framework.	5% of total budget allocated directly to TIES for monitoring, audits, and studies.	**Net New Expense**; guarantees long-term scientific validity and ecotourism safety.
Carbon Certification & VVB	Nil. Missed revenue opportunity.	Registration, Project Design Document (PDD), and Verification Body (VVB) fees.	**Net New Expense**; seed funding required to unlock massive future climate finance revenues.

Table 1. Budgetary changes from the SSP provisions and revised DPR

5.3 Detailed Revised Budget Estimate (5-Year Projection)

The following table provides a detailed financial breakdown corresponding directly to the reallocated heads to maintain the originally proposed budget ceiling of ₹128.5 Lakhs while accommodating the intensive scientific interventions required:

Sl. No.	Budget Head / Activity Description	Allocated Amount (₹ in Lakhs)	Remarks / Calculation Basis
1	**Site Preparation & Selective Uprooting**	5.57	Restricted to 25% of original SSP estimate (only coppicing stumps on safe terrain).
2	**Sapling Procurement**	11.20	Direct bulk purchase of ~14,000 high-quality 1-2 year old saplings @ ₹80/sapling.
3	**Planting & Miyawaki Organic Fertilization**	15.50	Includes labor for pitting, and 28,000 kg of organic compost (2 kg/plant) applied in 4 installments.
4	**Intensive Weed Management**	35.00	Massive expansion to 4 manual weeding cycles per year across 55.2 Ha for 5 years.
5	**Soil & Water Conservation (SMC)**	8.00	500 m^3 dry-stone gully plugging @ ₹400/m^3 , plus 500 staggered rainwater harvesting pits and check dams.
6	**Fire Protection, Maintenance & Watchers**	30.00	5-year engagement of plantation watchers, causality replacement (10%), fire line clearing.
7	**Carbon Credit Registration & VVB Audit**	3.00	CR-I Account opening (₹25k), Listing (₹20k), Registration (₹20k), VVB Application (₹10k) + estimated 3rd party VVB audit fees.
8	**Scientific Support & Consultation Fee**	6.42	Mandatory 5% of total budget payable to TIES for DPR formulation, biannual monitoring, Year 3–5 biodiversity studies, and safety audits.
9	**Contingency, VDA & Miscellany**	13.81	Buffer for Variable Dearness Allowance (VDA) adjustments and unforeseen logistical expenditures.
TOTAL	**REVISED ESTIMATE**	**128.50**	Reallocated seamlessly within the original ₹128.5 Lakhs financial envelope.
Rupees One crore twenty eight lakh fifty thousand only			

6

Carbon Credit Assessment and Registration

Integrating the Thottapura Eco-Restoration project into the Voluntary Carbon Market (VCM) is a critical strategic objective explicitly required to ensure the long-term financial independence and perpetual sustainability of the restored forest. Reforestation projects that eschew monocultures and instead utilize high-density, multi-species native planting models (such as the adapted Miyawaki method proposed herein) yield exceptionally high rates of both above-ground biomass accumulation and below-ground soil organic carbon enhancements. Consequently, these high-quality ecological credits command significant premium prices in global environmental markets. Current international market benchmarks indicate that high-integrity Afforestation, Reforestation, and Revegetation (ARR) carbon credits average $22 per tCO_2e globally, while in the rapidly maturing Indian domestic market, specialized biodiversity and restoration credits typically fetch between ₹2,200 and ₹2,800 per tonne.

6.1 Standard Selection and Methodology Evaluation

To accurately quantify, legally verify, and financially monetize the carbon removals achieved across the 55.2-hectare site, the project must align perfectly with a rigorous, internationally recognized Greenhouse Gas (GHG) accounting standard. Two primary registries have been evaluated for implementation in this project: the global Verra (Verified Carbon Standard) and the localized Carbon Registry - India (CR-I).

Option A: Verra (VCS) - VM0047 Methodology Verra's newly updated VM0047 (Afforestation, Reforestation, and Revegetation, v1.1) is currently recognized as the premier global standard for forestry projects. For the Thottapura site, the *Area-based approach* under VM0047 is directly applicable, as the project definitively changes land cover from a degraded, non-forest state (post clear-felling) back to a closed-canopy forest. VM0047 relies heavily on advanced remote sensing combined with rigorous plot-based physical sampling to quantify carbon removals. Furthermore, versions 1.0 and 1.1 of VM0047 have been officially approved by the Integrity Council for the Voluntary Carbon Market (ICVCM) under the Core Carbon Principles (CCP) framework, guaranteeing the absolute highest market premium for issued Verified Carbon Units (VCUs).
However, despite the prestige, Verra's drastically updated 2025 fee structure presents prohibitive, insurmountable upfront transaction costs for a relatively small 55.2-hectare project. High transaction costs are universally acknowledged as the primary barrier preventing the establishment of small-scale forest carbon projects. Applicable Verra fees include:

- Project Registration Review Fee : $2,500
- Pipeline Listing Request Fee : $1,000
- Verification Request Review Fee : $1,250 per request
- Verification/Validation Body (VVB) Third-Party Auditing Fees
  : Typically ranging from an astronomical $15,000 to $50,000 per cycle.
- Issuance Levy : $0.23 per every VCU claimed.

Option B: Carbon Registry - India (CR-I) by NCCF Given the relatively small scale of the Thottapura project (55.2 ha), the domestic Carbon Registry - India (CR-I), managed by the esteemed Network for Certification and Conservation of Forests (NCCF), offers a highly viable, exceptionally cost-effective alternative while strictly maintaining stringent Monitoring, Reporting, and Verification (MRV) protocols. CR-I focuses heavily on meticulously tracking localized co-benefits and explicitly validating contributions to the UN Sustainable Development Goals (SDGs). This standard aligns perfectly with the AVSS livelihood generation, micro-watershed protection, and biodiversity enhancement outcomes engineered into this specific DPR. The administrative and transaction costs under CR-I are exponentially lower, purposefully designed to motivate and facilitate micro and small-scale forestry initiatives across the Indian subcontinent :

CR-I Fee Component	Cost in INR (₹)
Account Registration and Opening	25,000.00
Project Listing Fee	20,000.00
Project Registration (Micro/Small Scale)	20,000.00
Annual Maintenance Fee	15,000.00
VVB Application Charge	10,000.00
Issuance Fee (per credit, low volume)	~4.50
Data derived from official CR-I Fee Schedules. Actual may be different.	

6.2 Strategic Carbon Development Recommendation

While Verra's VM0047 undeniably provides unparalleled access to elite international corporate buyers and prestigious CCP labels, the exorbitant VVB auditing costs ($15,000+) create a severe, fatal financial bottleneck for a 55.2-hectare project. The anticipated volume of carbon credits generated on 55 hectares simply cannot mathematically amortize a $50,000+ certification cost without incurring massive debt.

Therefore, **this scientific analysis strongly and unconditionally recommends registering the Thottapura Eco-Restoration project exclusively under the Carbon Registry - India (CR-I)**. The NCCF frameworks are explicitly, intelligently designed for the unique legislative and ecological contexts of India, providing a financially accessible, rigorously audited pathway to monetize the ecological gains. The project aligns seamlessly with all of CR-I's core metrics for biodiversity conservation, land restoration, and community empowerment through the creation of the AVSS.

6.3 Standardized Next Steps for Carbon Monetization

To successfully navigate the CR-I framework and secure climate finance, the following sequential milestones must be integrated into the project's operational timeline:

1. **Project Idea Note (PIN) Development (Year 1):** In the first year, operating entirely in parallel to the physical planting operations, a specialized domestic carbon consultant must be engaged to mathematically draft the PIN. This involves establishing the baseline emission scenarios—proving exactly how much carbon the site held as a degraded weed patch versus its future potential.
2. **Demonstration of Additionality:** The project must definitively prove to the registry that the restoration and subsequent carbon sequestration would absolutely not have occurred without the direct intervention of climate finance (the concept of Additionality). The extraordinary financial requirements necessary for the four extensive manual weeding cycles and the hyper-dosing of organic fertilizer heavily justify this additionality; typical state forestry budgets cannot sustain such intense silviculture without external carbon revenue.
3. **VVB Engagement and Audit (Year 2-3):** A specialized, third-party Validation and Verification Body (VVB) officially empaneled with CR-I will be contracted to independently audit the project design parameters and verify the physical field realities.
4. **Monitoring, Quantification, and Issuance (Year 5):** By the conclusion of Year 5, utilizing the extensive biodiversity, mortality, and biomass growth data rigorously collected by the TIES scientific team, the project will officially request the first issuance of carbon credits from the registry. Crucially, the revenue generated from the ongoing sale of these credits must be equitably, transparently shared with the AVSS, thereby ensuring the perpetual economic viability and physical protection of the Thottapura forest ecosystem for decades to come.