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Titan Vanam Afforestation Project

Monitoring Report - Feb 2026


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One-year-old ecological restoration site at Thorappalli, Tamil Nadu

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1. Introduction

1.1 Project Context

The Titan Vanam Project is a CSR-funded urban greening and ecological restoration initiative undertaken by Titan Company Limited[1], implemented by Biota Soil Foundation[2]. The project has transformed 19.1 hectares of degraded common land in Krishnagiri District into a multi-tier native forest ecosystem through high-density planting of 136 native species (completed in March 2025)[3].

The afforestation follows an organic management approach, eschewing chemical fertilizers in favor of biological nutrient cycling, organic amendments, and natural ecosystem processes. This approach prioritizes long-term ecological sustainability and the development of self-sustaining forest systems that deliver lasting environmental and community benefits.

This report covers the monitoring year 2025–2026 (Monitoring Cycle 2), representing the first formal assessment since project commencement. Field surveys, data collection, and analysis were conducted between December 2025 and January 2026.

1.2 Objectives of the Monitoring Report

The primary objectives of this monitoring report are:

- To measure and report the ecological progress of the Titan Vanam afforestation activities across both project sites (Thorapalli and Billanakuppam)
- To assess plantation establishment success, including survival rates, growth performance, and species diversity
- To evaluate ecosystem recovery indicators, including soil health regeneration and emerging biodiversity patterns
- To document environmental co-benefits observed during the monitoring period
- To identify management interventions required for continued project success

Indicators Covered:

This monitoring report assesses a comprehensive set of ecological and environmental indicators as mentioned below:

- Plantation performance metrics (survival rates, growth measurements, species distribution)
- Vegetation structure and composition (canopy development, stratification, native species establishment)
- Biodiversity indicators (flora species richness, fauna observations, invasive species presence)
- Soil health parameters (organic carbon, nutrient status, pH and EC stability)
- Ecosystem function indicators (food web integration, habitat development, pollinator activity)

[1] https://www.titancompany.in/
[2] https://biotasoil.org/
[3] The baseline report in March 2025 had mentioned 139 species, but there was some repetition, which has been corrected now. The unique species total is actually 136.

Scope Note
This monitoring report builds on previously completed technical and spatial analyses. Baseline conditions and site characterization are not repeated here.

Left to right: Visible ecological transformation between March 2025 and December 2025

1.2 Site-wise Area Coverage and Plantation Details

The below table shows the data from March 2025 (originally planted figures) -

Site Name	Location	Area (Ha)	Trees Planted	Non-tree Species	Total Saplings (as of Mar 2025)
Thorapalli	Chennathur, Krishnagiri District	11.6	130,584	27,240	157,824
Billanakuppam	Krishnagiri District	7.5	63,549	10,100	73,649
Grand Total	-	**19.1**	**194,133**	**37,340**	**231,473**

Note: *For the purpose of this report, Thorapalli is referred to as Site 1, and Billanakuppam is referred to as Site 2.*

2. Monitoring Methodology

2.1 Field-Based Monitoring

Survival assessment approach

- A quadrat sampling methodology was used to assess plantation survival and performance across two project sites: Thorapalli (Site 1; 11.6 ha) and Billanakuppam (Site 2; 7.5 ha).
- Six quadrats measuring 20 m × 20 m (400 sq m each) were randomly established at each site to ensure spatially representative coverage.
- In total, 12 quadrats were assessed across both sites.
- The quadrats collectively sampled 4,800 sqm of plot area. This represents approximately 2.5% of the total project footprint.
- The sampling intensity is consistent with standard monitoring practices for young, high-density, mixed-species plantations.

Left to right: Thorapalli and Billanakuppam quadrant locations

Field monitoring was conducted by a six-member team, divided into two sub-teams, with one team assigned to each quadrant. Monitoring followed a straightforward field-based approach. Within each designated quadrant, all planted individuals were visited and assessed.

For each individual sapling, species type and basic growth measurements were recorded, including total height and Girth at Breast Height (GBH), where applicable (only GBH>10cm was recorded). All observations and measurements were recorded manually using pen and paper during field visits and were subsequently digitised in Microsoft Excel for compilation and analysis, and field notes were scanned to keep for records.

Field team conducting species-level measurements within monitoring plots

3. Monitoring Results

3.1 Survival of Planted Stock

Overall Survival Rate

The monitoring census recorded a total of 163,750 surviving tree individuals (scaled estimate) from an original planting of 194,133 trees across the 19.1 hectares project area, yielding an **overall survival rate of 84.35%**.

Survey recorded data is presented below -

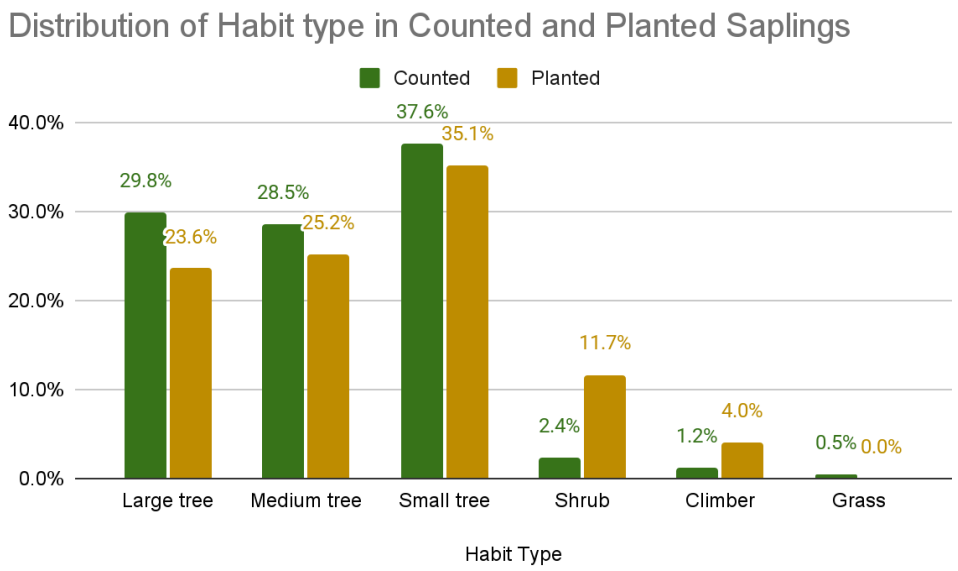
Site	Quadrant	Quadrant Area (sq m)	Trees Counted	Non-Trees Counted	Total Saplings Counted	No of Species Counted
Site 1 (Thorapalli)	1	400	349	32	381	46
	2	400	194	43	237	44
	3	400	223	17	240	43
	4	400	252	4	256	42
	5	400	254	5	259	48
	6	400	407	20	427	62
Total (Site 1)		**2,400**	**1,679**	**121**	**1,800**	**108**
Site 2 (Billenakupam)	1	400	300	19	319	58
	2	400	188	2	190	38
	3	400	157	9	166	41
	4	400	158	6	164	49
	5	400	174	10	184	34
	6	400	217	0	217	26
Total (Site 2)		**2,400**	**1,194**	**46**	**1,240**	**86**
Grand Total (Site 1 + Site 2)		**4,800**	**2,873**	**167**	**3,040**	**126**

Based on this, the statistically estimated survival rate is presented as below -

Site	Site Area (sq m)	Quadrant Area (sq m)	Trees Counted	Trees Count Scaled	Estimated BioFencing Trees	Total	Total Planted Trees	Survival %
Site 1 (Thorapalli)	116,334	2,400	1,679	81,385	27,000	108,385	130,584	83.00%
Site 2 (Billenakupam)	75,105	2,400	1,194	37,365	18,000	55,365	63,549	87.12%
Total	**191,439**	**4,800**	**2,873**	**118,750**	**45,000**	**163,750**	**194,133**	**84.35%**

Note: Commiphora berryi, the most abundantly planted species (50,000 baseline) as bio-fence, was estimated as 45,000 individuals (90.0% survival) - 27,000 in Site 1 (from 30,000 baseline) and 18,000 in Site 2 (from 20,000 baseline) is added based on the fact that it is on the boundary and hence could not be counted in quadrants-based sampling.

A comparison of the saplings distribution by habit-class (large/medius/small tree, shrub, climber, grass) in observed survey versus originally planted data is presented below -



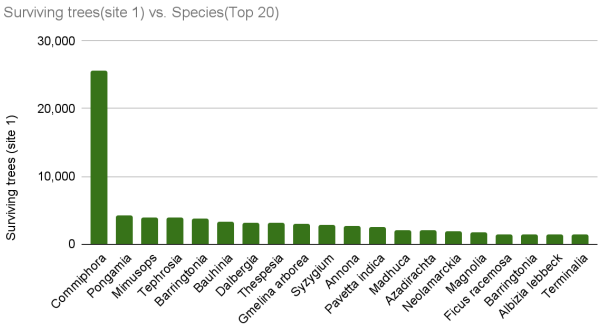
The below table shows a comparison of the number of unique species that were observed during the site-assessment in Dec 2025, versus the original planted record from March 2025.

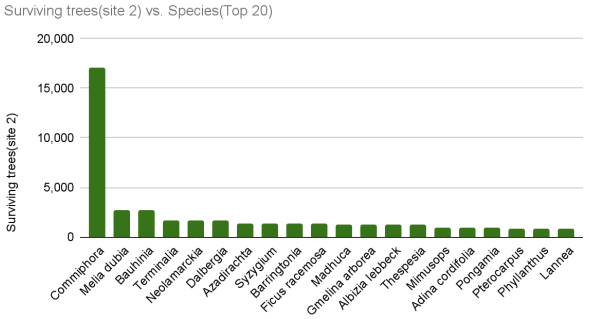
Assessment Period	Tree Species	Non-Tree Species	Total Species
March 2025	102	34	136
December 2025	100	26	126

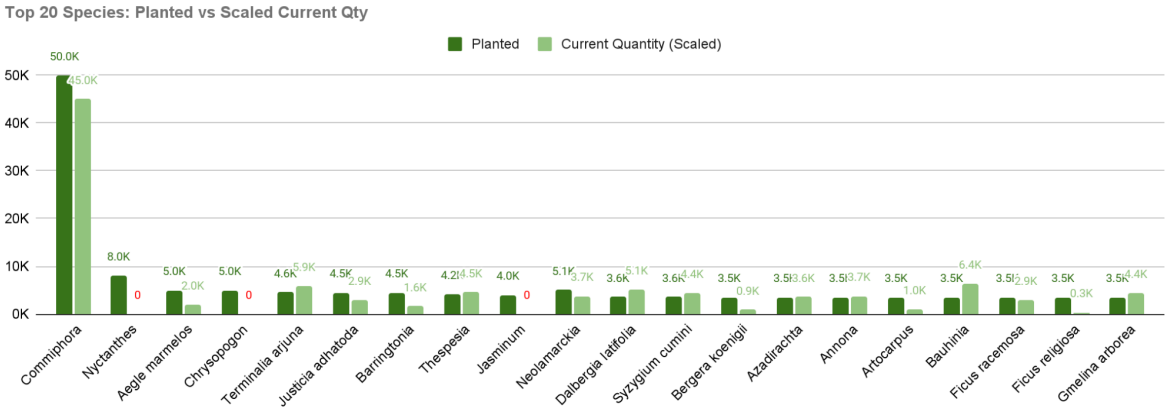
The details of the species observed and comparison with the planting species is provided in Annexure 1.

The below table shows the four tree species found in significant numbers, which were not part of the planting list. All these species are **native** species.

Significant New Trees	Quadrant Count	Scaled Count
Barringtonia asiatica	80	3878
Ficus carica	28	1357
Monoon longifolium	25	1212
Sapindus emarginatus	23	1115







Note: Out of the top 20 species which were planted, Nyctanthes arbor-tristis (8K planted), Chrysopogon zizanioides (5K planted) and Jasminum cuspidatum (4K planted) were not observed in the current survey.

3.2 Carbon Stock Monitoring

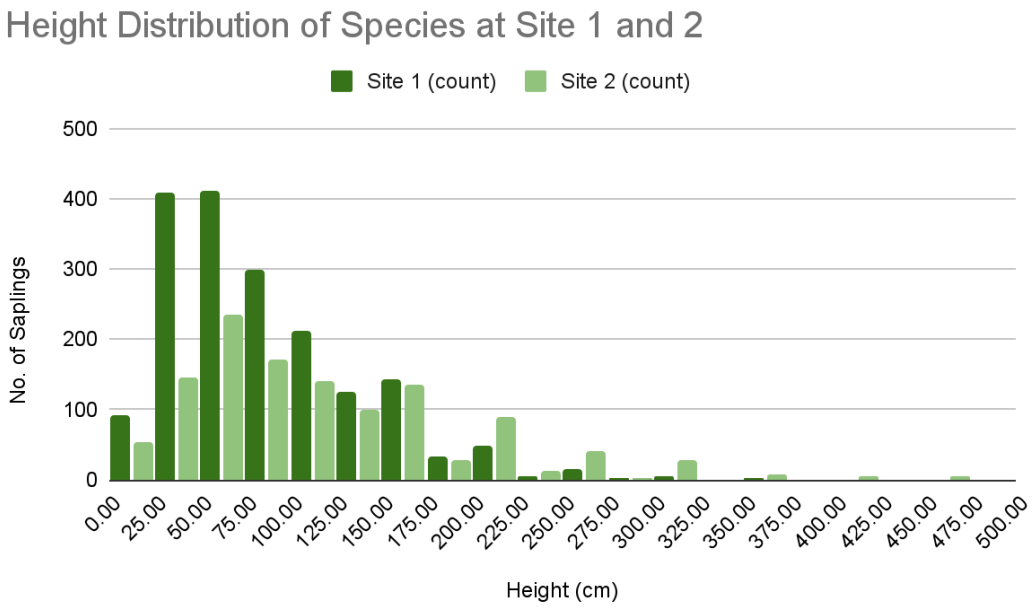
Updated tCO_2 Estimates for the Monitoring Year (2025-26)

Tree biomass was calculated using tree height and trunk size measured during the census and this was converted into carbon and CO_2 values using standard guidelines (as per IPCC). The project currently stores 44.21 tonnes of CO_2 across 19.1 hectares, with Site 2 (Billenakupam) contributing most of the carbon storage despite being smaller, mainly because it has larger trees and faster-growing species.

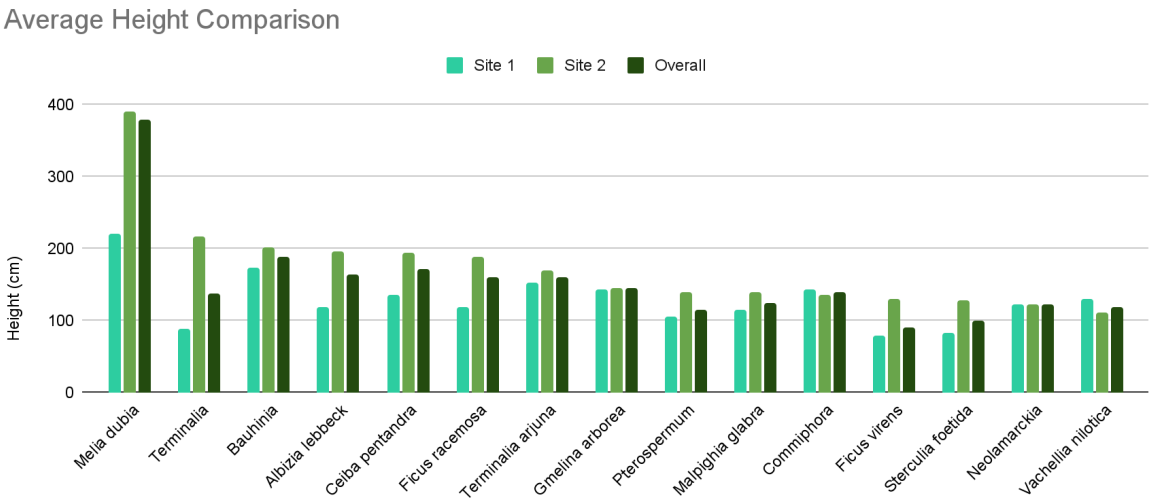
Coverage	Area (Ha)	Carbon Stock increase (tCO_2)
Site 1 (Thorapalli)	11.6	9.38
Site 2 (Billenakupam)	7.5	34.84
Overall Project	**19.1**	**44.21**

Height Growth Performance by Site

The census recorded an overall average tree height of 87cm at Site 1, compared to 133cm at Site 2. This 53% differential (w.r.t to Site 1) is concentrated in the large-canopy and fast-growing species.



Sitewise comparison of height distribution



This height gap is a direct driver of the carbon stock imbalance between the two sites. Height is an input to the allometric equations used to calculate AGB - taller trees with the same stem diameter yield a higher biomass estimate. Site 2 carries 34.84 tCO_2 of the total 44.21 tCO_2 (79.0%) despite being the smaller site by area, largely because its trees are growing taller per individual. The most likely cause is that Site 1, with its higher planting density relative to site area, is subject to more severe inter-tree competition for light, consistent with the growth suppression observations.

Survival-Adjusted Carbon Stock Projections

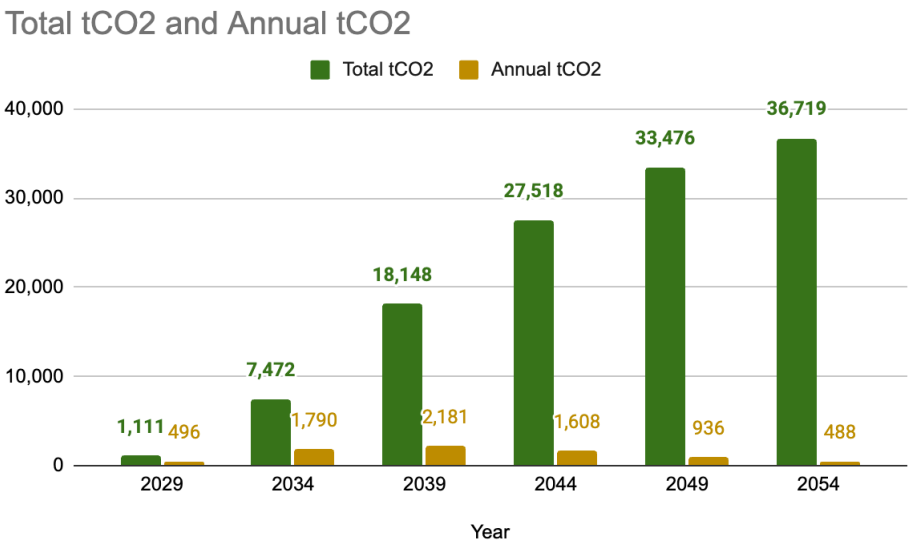
The observed survival rate of 84.35% has been applied to the original (ex-ante) carbon growth model. In addition, a 95% continued long-term survival rate has been assumed for the currently surviving individuals. Based on these adjustments, the 30-year carbon sequestration projections have been recalculated on a survival-adjusted basis.

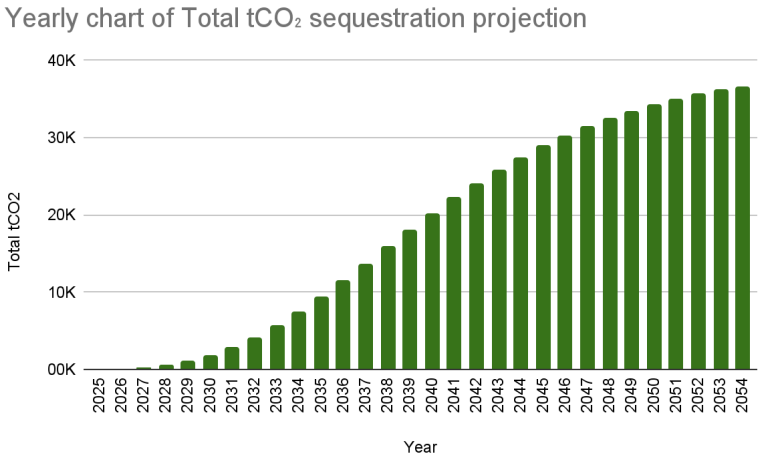
The projections use growth curves aligned with the site conditions and species mix. As expected in young, mixed-species tropical plantations, annual carbon sequestration is projected to increase rapidly in the early years (Years 1–10), peak during the mid-growth phase (Years 10–15), and gradually decline as the plantation matures and canopy closure occurs.

Detailed methodology used for the carbon projections is given in Annexure 5.

The projected 30-year cumulative sequestration, adjusted for observed survival, is estimated at **36,718 tCO_2** across the full project area (Site 1: 23,517 tCO_2; Site 2: 13,201 tCO_2).

On a per-hectare basis, this translates to a cumulative 2,021 tCO_2/ha at Site 1 and 1,885 tCO_2/ha at Site 2. For comparison, the total projected 30y sequestration figure across the two sites as reported in the March 2025 baseline report was **37,745 tCO2.** Therefore, the overall 30y sequestration potential for the project is consistent between the two studies.


Total tCO2 and Annual tCO2
Total tCO2
Annual tCO2
40,000
30,000
20,000
10,000
0
1,111
496
7,472
1,790
18,148
2,181
27,518
1,608
33,476
936
36,719
488
2029
2034
2039
2044
2049
2054
Year


Yearly chart of Total tCO₂ sequestration projection
40K
30K
20K
10K
00K
Total tCO2
2025
2026
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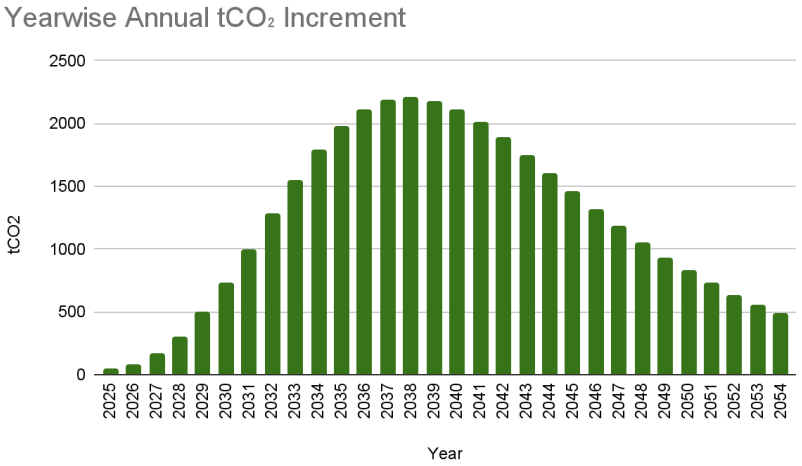
Year


Yearwise Annual tCO₂ Increment
2500
2000
1500
1000
500
0
tCO2
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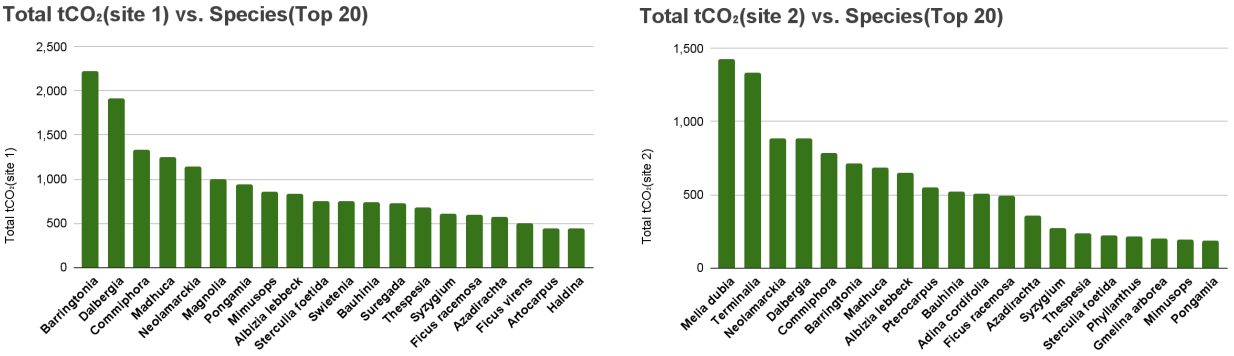
Year



Carbon sequestration per species for each site

3.3 Biodiversity Monitoring

This section presents the current biodiversity status of the Titan Vanam Afforestation Project sites (Thorapalli and Billanakuppam) based on field observations conducted during the monitoring period.

Shrub and herb cover estimation

Across the two sites, shrub species recorded included Adhatoda zeylanica, Gardenia species., Jasminum species., Justicia adhatoda, Barleria prionitis, and Aloe vera, with both Billanakuppam and Thorapalli each having one quadrant where no shrubs were observed.

Invasive Presence

Indicator	Thorapalli	Billanakuppam
Invasive Species (Baseline - Mar 2025)	21	18
New Invasive Detected (Current - Dec 2025)	None	*1 (Hydrocotyle umbellata)*

3.3.1 Distribution of Species across the two sites

A total of 126 unique species were observed on the two sites.

Site	*Nativity*	COUNT of Species	UNIQUE # of Species
Site 1	Indeterminate	1	1
	Native	1764	97
	Non-native	35	9
Site 1 Total		**1800**	**108**

Site 2	Native	1230	82
	Non-native	10	3
Site 2 Total		**1240**	**85**
Grand Total		**3040**	**126**

Shannon–Wiener Diversity Index Analysis

The Shannon–Wiener Diversity Index indicates moderate species diversity across the restoration sites.

- Site 1 (Thorapalli): 1.57, showing relatively higher species diversity.
- Site 2 (Billenakupam): 1.38, indicating moderate diversity with slightly higher species dominance.

Overall project diversity index: 1.54, reflecting a fairly balanced species composition across the landscape, which is appropriate for a developing ecological restoration site.

Top 20 species distribution (without boundary fencing, Commiphora berryi) are all Native and amount to 65% of the total species planted.

S. No	Species	Nativity	Relative Density
1	Bauhinia purpurea	Native	5.36%
2	Terminalia arjuna	Native	4.67%
3	Pongamia pinnata	Native	4.11%
4	Dalbergia latifolia	Native	4.11%
5	Barringtonia asiatica	Native	4.11%
6	Mimusops elengi	Native	3.85%
7	Thespesia populnea	Native	3.55%
8	Syzygium cumini	Native	3.52%
9	Gmelina arborea	Native	3.49%
10	Neolamarckia cadamba	Native	3.19%
11	Melia dubia	Native	3.19%
12	Azadirachta indica	Native	2.96%
13	Madhuca longifolia	Native	2.89%
14	Annona squamosa	Native	2.86%
15	Phyllanthus emblica	Native	2.76%

16	Ficus racemosa	Native	2.50%
17	Albizia lebbeck	Native	2.34%
18	Justicia adhatoda	Native	2.17%
19	Aegle marmelos	Native	1.58%
20	Magnolia champaca	Native	1.51%
	TOTAL		64.74%

3.3.2 Fauna (Opportunistic Observations)

Fauna observations were recorded concurrently during the vegetation census, along with quadrat assessments and movement along access paths between plots. No dedicated fauna sampling methods - such as systematic transects, camera trapping, call playback surveys, or time-bound observation protocols - were employed during this monitoring cycle. Accordingly, the fauna observations reported here are qualitative and indicative in nature.

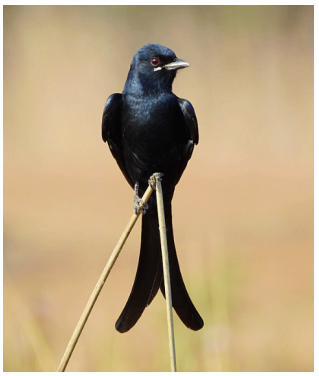
Several ecologically noteworthy observations were documented that provide early evidence of trophic integration within the planted ecosystem. Moth caterpillars were recorded feeding on foliage of Terminalia arjuna, Ficus racemosa, and Ailanthus excelsa - three native canopy-forming species that are well-established across the project area. The active utilisation of these planted species by herbivorous Lepidoptera is interpreted as a positive ecological signal, indicating that the plantation is beginning to function as a habitat resource The establishment of such plant–herbivore interactions is a foundational step in the development of local food-web linkages, and is expected to support including insectivorous birds, reptiles, and predatory arthropods - as the canopy structure continues to develop.

Moth caterpillars observed feeding on foliage

These preliminary observations will be used to inform the design of more structured fauna monitoring protocols in future assessment cycles, should formal biodiversity co-benefit reporting be required.

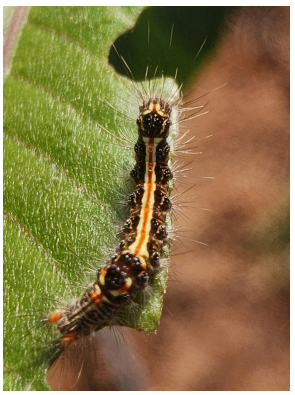
The table below summarises faunal observations recorded across the Thorapalli and Billanakuppam sites, including butterflies (9 species), birds (6 species), and moth caterpillars (3 species).

S. No.	Species	Photo	Description
	BUTTERFLY		
1	**Common mormon** (*Papilio polytes*)	 Representative Pic: Common Mormon © Ujjal Kishor De	A large swallowtail butterfly, frequently found in gardens and forest edges. Females mimic toxic species for protection. Its presence at the site indicates availability of Citrus and Rutaceae family host plants in the understorey.
2	**Common jezebel** (*Delias eucharis*)	 © Wikimedia commons	A medium-sized butterfly with bright red and yellow underwing markings. Larvae feed on *Dendrophthoe* (mistletoe) species found on host trees. Its occurrence suggests that parasitic plant–tree associations are forming within the plantation.
3	**Common castor** (*Ariadne merione*)	 © Wikimedia commons	A small, fast-flying butterfly associated with castor (*Ricinus communis*) and other Euphorbiaceae. Commonly found in disturbed and regenerating habitats, its presence is typical of early-successional sites.
4	**Common grass yellow** (*Eurema hecabe*)	 © Wikimedia commons	One of the most widespread butterflies in peninsular India. Larvae feed on leguminous plants. Its abundance is a general indicator of herbaceous ground cover and legume availability at the site.

5	**Plain tiger** (*Danaus chrysippus*)	 Representative Pic: Plain Tiger Butterfly © Yinglun Li	A medium-sized, conspicuously orange butterfly that is toxic to predators. Larvae feed on milkweed (*Calotropis* spp.). Its presence confirms that ruderal milkweed plants are available, which is common in open and semi-restored landscapes.
6	**Lemon pansy** (*Junonia lemonias*)	 © Wikimedia commons	A ground-level butterfly with prominent eyespots on the wings. Breeds on *Hygrophila* and other Acanthaceae. Frequently seen basking on bare soil or leaf litter in open patches within plantations.
7	**Tawny coster** (*Acraea terpsicore*)	 Representative Pic: Tawny Coster © Ujjal Kishor De	A slow-flying, aposematic butterfly with orange wings and dark spots. Larvae feed on *Passiflora* species. Originally restricted to southern India, this species has expanded its range northward over recent decades and is now common in disturbed and restored habitats.
	BIRDS		
1	**Black drongo** (*Dicrurus macrocercus*)	 © Wikimedia commons	An aggressive, insectivorous bird that perches on exposed branches to hawk flying insects. It is one of the earliest bird species to colonise young plantations and open woodlands. Its presence indicates a sufficient aerial insect population to sustain resident insectivores.

2	**Ashy prinia** (*Prinia socialis*)	 Representative Pic: Ashy prinia © VarmaX	A small, resident warbler that inhabits dense shrub and low scrub. It nests close to the ground in thick vegetation. Its occurrence confirms that the shrub layer at the site is developing to a density suitable for nesting by understorey bird species.
3	**Red-whiskered bulbul** (*Pycnonotus jocosus*)	 Representative Pic: Red-whiskered bulbul © mylenevitry	A frugivorous and insectivorous bird common in forest edges and gardens. It feeds on berries, small fruits, and insects. Its presence indicates that fruiting resources - from planted or naturally recruited species - are becoming available at the site.
4	**Green bee-eater** (*Merops orientalis*)	 © Wikimedia commons	A small, brightly coloured insectivore that hunts flying insects (bees, wasps, dragonflies) from low perches. Typically found in open habitats with scattered trees. Its presence confirms active aerial insect populations across the site.

5	**Indian roller** (*Coracias benghalensis*)	 Representative Pic: Indian Roller © Marc Faucher	A large, conspicuous bird that feeds on ground-level invertebrates, small reptiles, and insects flushed from grass. It requires open ground with nearby perching trees - a habitat structure consistent with the current state of the plantation, where canopy gaps and open patches persist between planting zones.
6	**White-browed wagtail** (*Motacilla maderaspatensis*)	 © Wikimedia commons	A ground-foraging insectivore associated with waterbodies and moist open areas. It feeds on small invertebrates picked from soil and leaf litter. Its presence at the site indicates healthy ground-level invertebrate populations and suggests that moist microhabitats exist within or adjacent to the plantation area.
	MOTHS		
1	**Ailanthus defoliator moth** (*Atteva fabriciella*)		Caterpillars of this species were observed feeding on *Ailanthus excelsa* foliage at the site. This is a native moth whose larvae are specialist feeders on Ailanthus. While heavy defoliation by this species can temporarily stress individual trees, it is not a cause for management concern at the levels observed. The caterpillars themselves are a food source for insectivorous birds and parasitoid wasps, contributing to food web development at the site.

2	**Monkey moth** (*Eupterote sp.*)	 Pic: Monkey moth caterpillar with orange-black banding observed feeding on Terminalia arjuna	Caterpillars of this species were observed feeding on *Terminalia arjuna* foliage. This is a native moth whose larvae are known defoliators of various trees, with *Terminalia arjuna* being a primary host in peninsular India. The larvae are characterized by a brownish body covered in dense tufts of hair and a distinct reddish head. These caterpillars serve as an essential food source for insectivorous birds, helping to integrate the planted trees into the local food web.
3	**Yellow-tail moth (*Orvasca subnotata*)**	 Pic: Yellow-Tail moth caterpillar within silk shelter on Ficus racemosa leaf	This species was recorded on *Ficus racemosa*, easily identified by its striking orange-and-black dorsal banding and long white hair tufts. These caterpillars are known for constructing loosely woven silk shelters on the leaf surface, which was observed at the site. This native moth frequently utilizes *Ficus* species as a larval food source. The presence of a resident, shelter-building population indicates that these trees are sufficiently established to support specialist herbivores. Like other native lepidopterans, these larvae are a vital ecological resource, providing prey for birds and parasitoid wasps.

4. Soil and Water Quality

Soil quality assessment was conducted at both project sites - Thorapalli (Chennathur) and Billanakuppam (Krishnagiri) - to monitor changes in soil health parameters over the monitoring period.

Comparative analysis of 2025 and 2026 soil test results provides insight into nutrient dynamics, organic matter accumulation, and early indicators of ecological restoration.

4.1 Key Soil Parameters and Interpretation

Comprehensive soil testing was performed to evaluate primary nutrients (nitrogen, phosphorus, potassium), secondary nutrients (calcium, magnesium, sulphur), and micronutrients (zinc, iron,

copper, manganese, boron), along with fundamental soil health indicators including pH, electrical conductivity (EC), and organic carbon content.

4.2 Thorapalli (Chennathur) – Soil Test Results

- Soil conditions at Thorapalli indicate strong early-stage soil regeneration.
- Organic carbon increased by 44%, from 0.41% to 0.59%, improving from Low to Medium status, indicating enhanced soil biological activity.
- Available nitrogen increased significantly, from 87 to 135 kg/ac, suggesting the establishment of an active biological nitrogen cycle.
- Phosphorus and potassium levels declined, a pattern typical of young, high-density forest systems, where nutrients are rapidly immobilised in plant biomass and microbial pools.
- Secondary nutrients showed marked improvement, with calcium and sulphur shifting from deficient to sufficient levels.
- Micronutrients such as iron, copper, and manganese remain within adequate ranges.
- Zinc and boron levels require continued monitoring in subsequent assessment cycles.

Parameter	Range	2025 Result	Status	2026 Result	Status	Trend
Primary Indicators						
pH	6.3–8.3	7.2	N	6.9	N	Stable
EC (dS/m)	0.01–1.0	0.05	N	0.13	N	Stable
Organic Carbon (%)	0.5–0.75	0.41	L	0.59	M	↑ Improved
Macronutrients						
Nitrogen (kg/ac)	112–224	87	L	135	M	↑ Improved
Phosphorus (kg/ac)	10–25	7	L	5	L	Biological uptake
Potassium (kg/ac)	61–120	69	M	54	L	Biological uptake
Secondary Nutrients						
Calcium (mg/kg)	>301	270	D	408	S	↑ Improved

Magnesium (mg/kg)	>120	165	S	164	S	Stable
Sulphur (mg/kg)	>10	8.0	D	15	S	↑ Improved
Micronutrients						
Zinc (mg/kg)	>1.0	0.32	D	0.08	D	Monitor
Iron (mg/kg)	>4.51	5.91	S	5.82	S	Stable
Copper (mg/kg)	>0.21	1.91	S	0.89	S	Stable
Manganese (mg/kg)	>2.01	5.8	S	5.3	S	Stable
Boron (mg/kg)	>0.5	0.25	D	0.31	D	Slight improvement

Status Legend: *N = Normal | L = Low | M = Medium | D = Deficient | S = Sufficient*

4.3 Billanakuppam (Krishnagiri) – Soil Test Results

- Billanakuppam shows clear signs of ecological recovery, **with a 50% increase in organic carbon from 0.32% to 0.48% within one year.**
- Available nitrogen improved substantially from Low (77 kg/ac) to Medium (128 kg/ac), indicating establishment of a functioning nitrogen cycle.
- Phosphorus and potassium levels declined sharply (phosphorus from 17 to 2 kg/ac; potassium from 62 to 24 kg/ac), reflecting rapid biological immobilisation typical of early-stage afforestation rather than nutrient loss.
- Secondary nutrients exhibited strong recovery, with calcium, magnesium, and sulphur transitioning from deficient to sufficient status.
- Improvements in secondary nutrients suggest enhanced soil structure and mineral weathering processes.
- Micronutrients remain within adequate ranges to support essential plant physiological functions.

Parameter	Range	2025 Result	Status	2026 Result	Status	Trend
Primary Indicators						
pH	6.3–8.3	7.3	N	7.1	N	Stable

EC (dS/m)	0.01–1.0	0.06	N	0.06	N	Stable
Organic Carbon (%)	0.5–0.75	0.32	L	0.48	L	↑ 50% increase
Macronutrients						
Nitrogen (kg/ac)	112–224	77	L	128	M	↑ Improved
Phosphorus (kg/ac)	10–25	17	M	2	L	Biological uptake
Potassium (kg/ac)	61–120	62	M	24	L	Biological uptake
Secondary Nutrients						
Calcium (mg/kg)	>301	254	D	318	S	↑ Improved
Magnesium (mg/kg)	>120	92	D	190	S	↑ Improved
Sulphur (mg/kg)	>10	6.4	D	16	S	↑ Improved
Micronutrients						
Zinc (mg/kg)	>1.0	0.16	D	0.30	D	Slight improvement
Iron (mg/kg)	>4.51	5.78	S	6.40	S	Stable
Copper (mg/kg)	>0.21	1.32	S	1.30	S	Stable
Manganese (mg/kg)	>2.01	5.7	S	7.4	S	Stable
Boron (mg/kg)	>0.5	0.22	D	0.36	D	Slight improvement

Status Legend: *N = Normal | L = Low | M = Medium | D = Deficient | S = Sufficient*

4.4 Comparison to Acceptable Ecological Thresholds

All soil parameters were evaluated against established ecological thresholds for forest ecosystem health. The following summary highlights compliance with acceptable ranges:

Parameter Category	Ecological Threshold	Current Status (Both Sites)	Assessment
Soil pH	6.3–8.3	6.8–7.2	Within optimal range
Electrical Conductivity	<1.0 dS/m	0.06–0.13 dS/m	No salinity stress
Organic Carbon	>0.5% (optimal)	0.48–0.59%	Improving trend
Nitrogen Availability	>112 kg/ac	128–135 kg/ac	Biological cycle active
Heavy Metal Contamination	Not detected	Not detected	Site safe for restoration

All primary soil health indicators remain within acceptable ecological thresholds, confirming chemical stability and absence of environmental stress factors that could impede forest establishment. The observed nutrient dynamics are consistent with early-stage forest ecosystem development.

4.5. Water Quality Assessment

Irrigation Water Quality Monitoring – Thorapalli & Billanakuppam

Baseline water sampling was conducted in March 2025, followed by monitoring in February 2026 at the Thorapalli and Billanakuppam sites.

Comparative analysis indicates:

- pH levels have improved at both sites and are now within the ideal irrigation range (6.0–8.0).
- Electrical Conductivity (EC) and TDS show a moderate increasing trend, particularly at Thorapalli; however, values remain within acceptable limits for plantation.
- Bicarbonate levels have increased at both sites but remain within permissible irrigation limits.
- Sodium hazard indicators (SAR) remain low across both sites, indicating no sodium dispersion risk.
- RSC values are safe or negative, confirming no risk of sodicity buildup or soil structural degradation.

Overall, irrigation water at both Thorapalli and Billanakuppam is classified as low to moderately saline with low sodium hazard, and remains suitable for afforestation. No corrective measures are currently required; however, continued periodic monitoring is recommended to track salinity trends.

Comparative Water Quality Table

Parameter	Thorapalli Baseline (2025)	Thorapalli Feb 2026 (Range)	Billanakuppam Baseline (2025)	Billanakuppam Feb 2026	Normal Irrigation Range	Interpretation
pH	7.7–7.8	7.2	7.9–8.0	7.3	6.00 – 8.00	Improved and within ideal range
EC (dS/m)	0.92–0.94	1.21–1.47	0.56–0.58	0.82	0.00 – 2.00	Increased but within acceptable limit
TDS (approx.)*	~600 mg/L	~770–940 mg/L	~338 mg/L	~525 mg/L	<450 mg/L (450–2000 moderate)	Moderate salinity rise
Bicarbonates	316–334 mg/L	~439–451 mg/L	227–230 mg/L	~317 mg/L	0.00 – 10.00 meq/L	Increased but within limit
Carbonates	BDL	BDL	BDL	BDL	0.00 – 10.00 meq/L	Safe
SAR	1.3	1.0–1.85	~1.0	2.09	0.01 – 10.00	Low sodium hazard
RSC	BLQ	-2.63 to -1.42	BLQ	0.50	0.01 – 2.50 meq/L	Safe; no sodicity buildup risk

*TDS approximated from EC × 640
BDL = Below Detection Limit (< 1 mg/L)
BLQ = Below Laboratory Quantification Limit

5. Ambient Air Quality and Noise

Assessment of ambient air quality (AQI) against CPCB standards and ambient noise levels against WHO benchmarks was included in the agreed scope of work. **However, this assessment could not be undertaken during the current monitoring cycle.**

These parameters are therefore not reported in the present assessment and will be taken up in a subsequent monitoring phase. In the March 2025 assessment, neither of these factors were an area of concern. In the December site-survey also, there were no concerns observed on these parameters given the rural nature of the two sites.

6. Satellite Based Analysis

6.1 Historical land use

The land use for the two sites has not changed in the past 10 years and vegetation growth has remained constant (likely given anthropogenic factors).

Site 1: Thorapalli, Hosur

Image 1: 16 Jan 2015

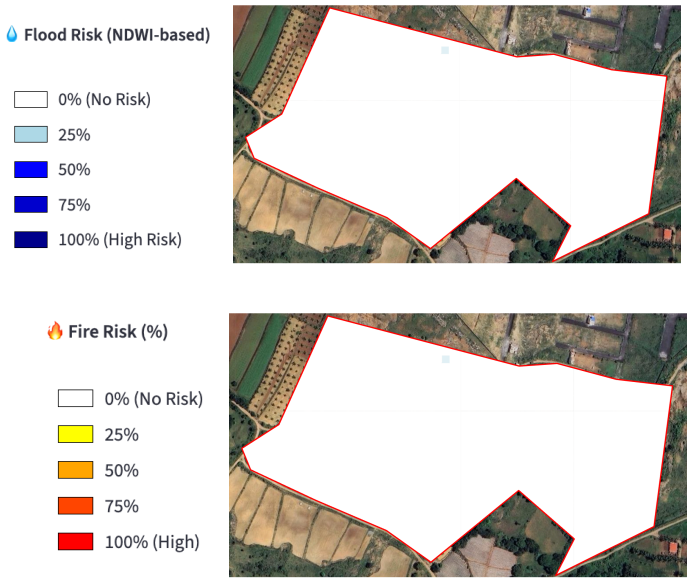
Image 2: 11 Feb 2024

Image 3: 1 June 2025

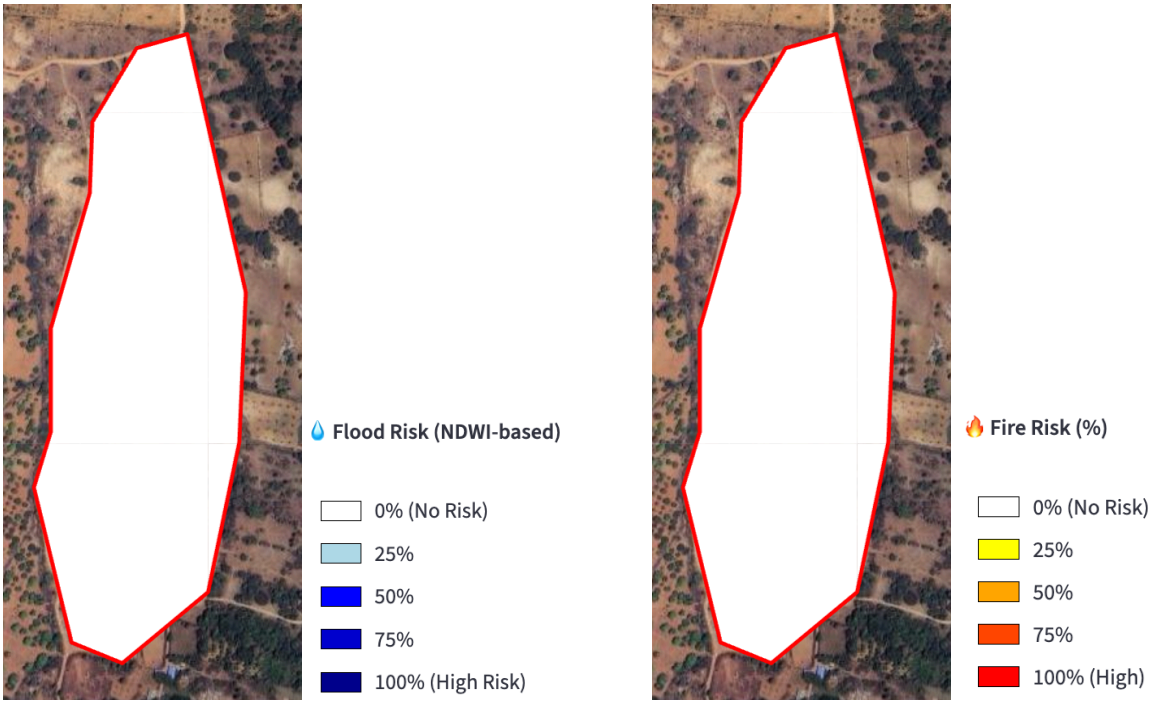
Site 2: Billanakuppam

Image 4: 20 Aug 2012 Image 5: 26 Apr 2024 Image 6: 12 Apr 2025

6.2 Natural Risk



Site 1: Thorapalli



Site 2: Billanakuppam

The map shows the Flooding risk, based on 10 years historical NDWI analysis and Fire risk based on 10 years historical FIRMS daily fire instances where:

- Flood Risk: White indicates low risk, showcasing that historically there was <5% flooding/water accumulation observed. Blue/green or darker zones indicate the area of high flow accumulation or sinks. These are the low-lying areas where water is likely to accumulate. For both sites, the calculated flood risk lies in the category of **No Risk**

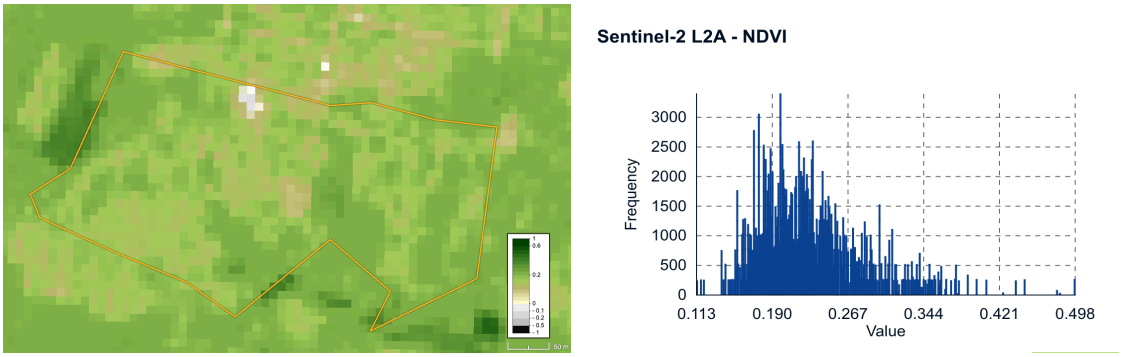
- Fire Risk: White represents very low risk, Yellow zones represent areas with small, with risk increasing to dark red colour, showing high fire risk. For both sites, the calculated fire risk lies in the category of **No Risk**

6.3 NDVI Map (Enhanced Vegetation Index) (Site 1, Thorapalli)

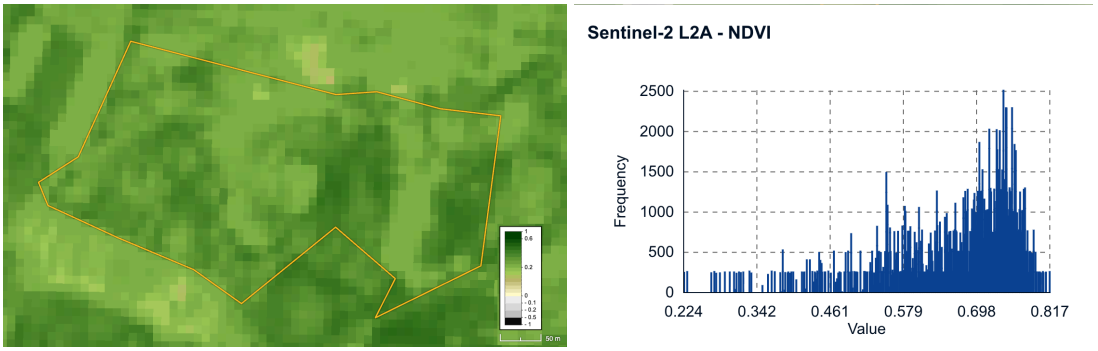
Overall, the pre-intervention site shows low to sparse vegetation. This aligns with the physical site observations, which indicate sparse vegetation primarily consisting of scattered individual trees and some invasive shrub cover.

NDVI Map (Enhanced Vegetation Index) (Site 1, Thorapalli)

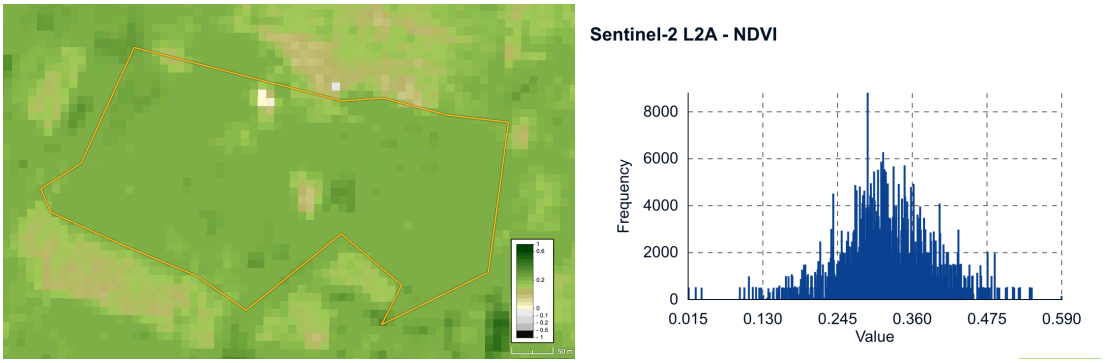
The NDVI values at the site have increased after the intervention. Compared to the baseline image from March 2025, the November image shows improved vegetation growth, which is further supported by the February 2026 NDVI results. The rightward shift in the NDVI histogram clearly indicates a consistent increase in vegetation greenness following the intervention.



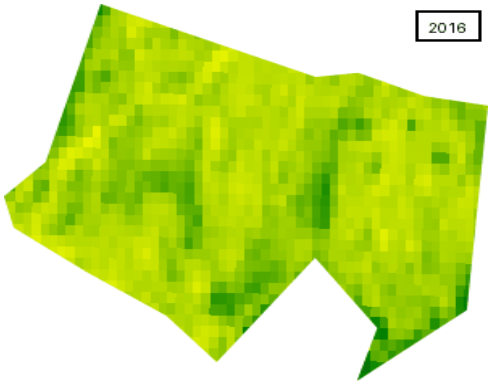
NDVI in March 2025



NDVI in November 2025



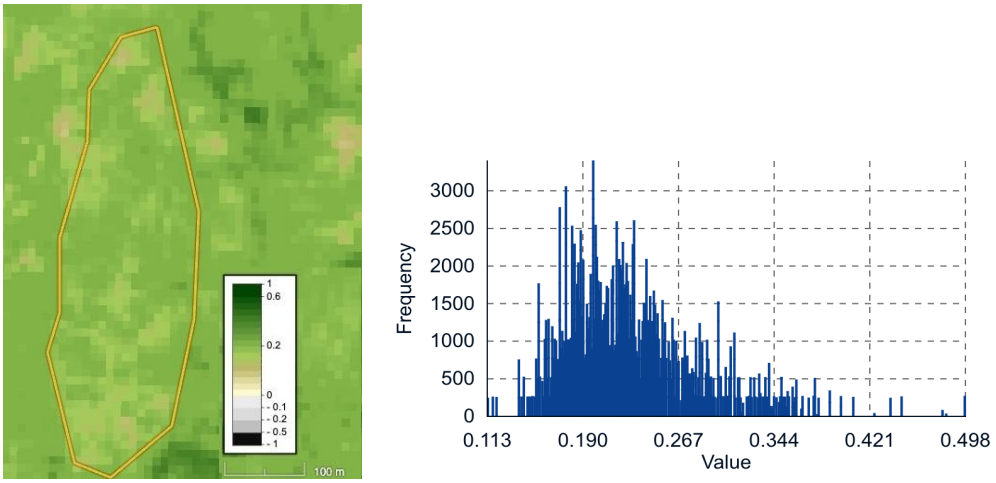
NDVI on 1 Feb 2026



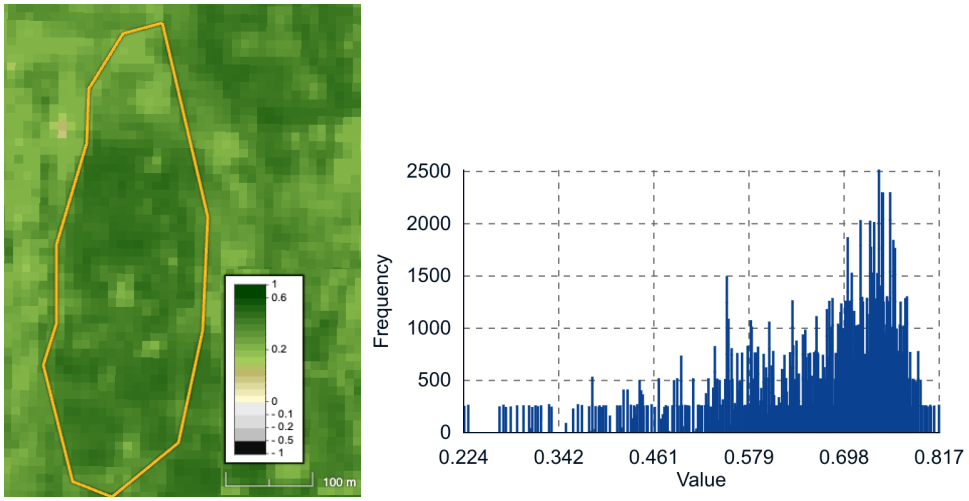
NDVI pattern over years

NDVI Map (Normalized Difference Vegetation Index) (Site 2, Billanakuppam)

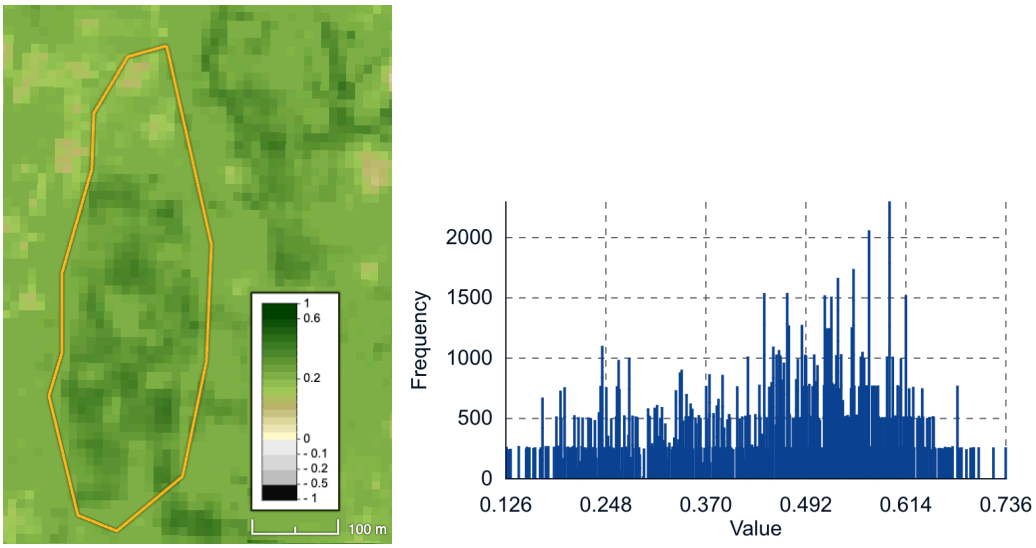
The November 2025 post-intervention imagery shows a clear increase in NDVI compared to the pre-intervention baseline from March 2025. This improvement is further confirmed by the February 2026 NDVI results. The rightward shift in the NDVI histogram from the baseline indicates a steady increase in vegetation greenness following the intervention.



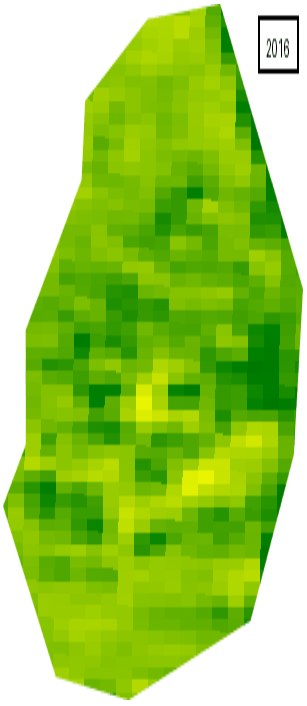
NDVI in March 2025



NDVI in November 2025



NDVI on 1 Feb 2026



NDVI change over time

7. Observations and Recommendations

Based on field observations, 65 species from the original planting list (of 136 species) were not recorded at the site during the monitoring exercise. In parallel, the team documented 58 species that were observed in the field but were not part of the original planting list. Of these 58 species, 9 were identified as non-native which is provided in the table below. The detailed observation for all the species observed is given in Annexure 2.

List of Non-Native Species Observed
Areca catechu
Ceiba pentandra
Magnolia acuminata
Morinda citrifolia
Olea europaea
Pimenta dioica
Psidium guajava
Simarouba glauca
Carica papaya

Significant New Trees Found
Barringtonia asiatica
Ficus carica
Monoon longifolium
Sapindus emarginatus

Out of the top 20 species which were planted, Nyctanthes arbor-tristis (8K planted), Chrysopogon zizanioides (5K planted) and Jasminum cuspidatum (4K planted) were not observed in the current survey.

1. Growth Suppression from Overcrowding

The plantation is currently being dominated by a few fast-growing species, such as Melia dubia and Sterculia foetida, which is limiting the growth of other species. Due to increased competition, a majority of saplings have not yet attained a girth of 10–14 cm, indicating growth suppression associated with high planting density. However, as is expected in a high-density planting method, the height growth is rapid. Overall, growth is better on Site 2 (Billanakuppam) than Site 1 (Thorapalli), as was also noted in Section 3.2.

2. Water Management Deficiency

The formation of mounds around saplings is promoting surface runoff rather than water retention, which may be contributing to plant stress, particularly among suppressed individuals. Creating basins around saplings is recommended, as this would improve water retention and facilitate more effective delivery of moisture to the root zone.

3. Invasive Species - Hydrocotyle umbellata at Billanakuppam

Hydrocotyle umbellata was recorded at the Billanakuppam site and is likely to have been introduced through nursery stock. If unmanaged, it may spread and form dense mats that compete with native groundcover and increase stress on young saplings.

4. Tree Form and Pruning

Lower branches of species such as Bauhinia purpurea, Terminalia arjuna, and Albizia lebbeck have not yet been pruned. Pruning these branches could support improved vertical growth and overall tree form.

5. Ecological Interactions.

The presence of moth caterpillars on Terminalia arjuna, Ficus racemosa, and Ailanthus excelsa observed during the survey is a positive ecological indicator. This suggests that these species are beginning to integrate into the local food web and provide forage for insect life.

Note: These observations were recorded during vegetation surveys and along access paths between quadrats. No dedicated fauna sampling (transects, trapping, call playback) was conducted, so the **findings are qualitative** in nature.

Annexure 1 - Species from Original Planting List not observed in December 2025 survey

S. No.	Tree Species	Non Tree Species
1	Abrus precatorius	Anisomeles indica
2	Acacia concinna	Asparagus racemosus
3	Acacia ferruginea	Barleria cristata
4	Acacia leucophloea	Calycopteris floribunda
5	Alangium salvifolium	Carissa carandas
6	Albizia amara	Cissus quadrangularis
7	Atalantia monophylla	Clematis gouriana
8	Bamburus missionis	Clerodendrum phlomidis
9	Boswellia serrata	Coleus zeylanicus
10	Butea monosperma	Crateva magna
11	Caryota urens	Crinum asiaticum
12	Catunaregam spinosa	Desmodium gangeticum
13	Clitoria ternatea	Dodonaea viscosa
14	Diospyros buxifolia	Euphorbia tirucalli Linn
15	Diospyros montana	Gymnema sylvestris
16	Dolichandron atrovirens	Jasminum rigidum
17	Drypetes sepiaria	Kalanchoe pinnata
18	Ficus microcarpa	Myxopyrum smilacifolium
19	Gyrocarpus americanus	Nyctanthes arbor-tristis L.
20	Hardwickia binata	Ocimum gratissimum
21	Lagerstroemia indica	Rubia cordifolia
22	Melia azedarach	Senna auriculata
23	Memecylon umbellatum	Solanum indicaum
24	Morinda coreia	Spermadictyon suaveolens
25	Morinda pubescens	Vallaris solanacea
26	Nyctanthus arbor-tristis	Veteveria zizanioides
27	Pamburus missionis	
28	Persea macrantha	
29	Phoenix pusilla	
30	Polyalthia korinti	
31	Polyalthia suberosa	
32	Salix tetrasperma	
33	Saraca asoka	
34	Scaevola taccada	
35	Sterblus asper	
36	Streblus asper	
37	Strychnos nux-vomica	
38	Tricalysia sphaerocarpa	

39	Vitex leucoxylon	

Annexure 2 - Species List that were Observed in the survey but were not in the Original Planting List

S. No.	Tree Species found in Survey, not in planting list	Native/Non Native	Non-Tree Species found in Survey, not in planting list	Native/Non Native
1	Adina cordifolia	Native	Barleria prionitis	Native
2	Areca catechu	Non-native	Carica papaya	Non-native
3	Atalantia monophylla	Native	Crateva magna	native
4	Barringtonia asiatica	Native	Gardenia jasminoides	Native
5	Ceiba pentandra	Non-native	Ipomoea pes-caprae	Native
6	Commiphora caudata	Native	Ixora coccinea	Native
7	Cordia obliqua	Native	Jasminum sambac	Native
8	Dalbergia sissoo	Native	Justicia gendarussa	Native
9	Diospyros ferrea	Native	Kalanchoe pinnata	Native
10	Eugenia uniflora	Native	Nerium oleander	Native
11	Ficus carica	Native	Pavetta indica	Native
12	Haldina cordifolia	Native	Rauvolfia serpentina	Native
13	Khaya senegalensis	Native	Tephrosia purpurea	Native
14	Magnolia acuminata	Non-native	Artabotrys hexapetalus	Native
15	Malpighia glabra	Native	Helicteres isora	Native
16	Melia dubia	Native	Indigofera tinctoria	Native
17	Monoon longifolium	Native		
18	Morinda citrifolia	Non-native		
19	Nothapodytes nimmoniana	Native		
20	Olea europaea	Non-native		
21	Pimenta dioica	Non-native		
22	Prunus species	Indeterminate		
23	Psidium guajava	Non-native		
24	Psydrax dicoccos	Native		
25	Pterocarpus santalinus	Native		
26	Pterospermum suberifolium	Native		
27	Punica granatum	Native		
28	Sapindus emarginatus	Native		
29	Senegalia senegal	Native		
30	Simarouba glauca	Non-native		
31	Terminalia catappa	Native		
32	Terminalia paniculata	Native		
33	Ziziphus jujuba	Native		

34	Citrus limon	Native		
35	Ficus hispida	Native		
36	Gardenia resinifera	Native		
37	Lagerstroemia speciosa	Native		
38	Mangifera indica	Native		
39	Oroxylum indicum	Native		
40	Phylanthus emblica	Native		
41	Sapindus laurifolius	Native		
42	Sesbania grandiflora	Native		

Annexure 3 - Quadrant-wise Summary statistics and Carbon Estimation

Site	Quadrant	Area (sq m)	Trees Counted	Non-Trees Counted	Saplings Counted	Species Counted	tCO_2
Site 1	1	400	349	32	381	46	0.047
Thorapalli	2	400	194	43	237	44	0.019
	3	400	223	17	240	43	0.025
	4	400	252	4	256	42	0.024
	5	400	254	5	259	48	0.023
	6	400	407	20	427	62	0.057
Total (Site 1)		**2,400**	**1,679**	**121**	**1,800**	**108**	**0.193**
Site 2	1	400	300	19	319	58	0.061
Billanakuppam	2	400	188	2	190	38	0.066
	3	400	157	9	166	41	0.312
	4	400	158	6	164	49	0.051
	5	400	174	10	184	34	0.476
	6	400	217	0	217	26	0.147
Total (Site 2)		**2,400**	**1,194**	**46**	**1,240**	**86**	**1.113**
Grand Total (Site 1 + Site 2)		**4,800**	**2,873**	**167**	**3,040**	**126**	**1.307**

Annexure 4 - Table showcasing 30 year Carbon sequestration projections

Year	Total tCO_2(site 1)	Total tCO_2(site 2)	Total tCO2	Annual tCO2	Annual tCO_2(Site1)	Annual tCO_2(Site 2)
2025	33.9	19.12	53.02	53.02	33.9	19.12
2026	87.57	49.36	136.93	83.92	53.68	30.24
2027	196.88	110.9	307.78	170.85	109.31	61.54
2028	393.4	221.48	614.88	307.11	196.52	110.59
2029	711.14	400.21	1111.35	496.46	317.74	178.72
2030	1,180.46	664.09	1,844.55	733.2	469.32	263.88
2031	1,822.20	1,024.80	2,847.00	1002.45	641.74	360.71
2032	2,643.72	1,486.43	4,130.15	1283.15	821.52	461.63
2033	3,637.75	2,044.86	5,682.61	1552.45	994.03	558.42
2034	4,783.86	2,688.58	7,472.44	1,789.83	1,146.11	643.72
2035	6,051.82	3,400.61	9,452.43	1,979.99	1,267.96	712.03
2036	7,405.79	4,160.82	11,566.61	2,114.18	1,353.97	760.21
2037	8,808.36	4,948.21	13,756.57	2,189.96	1,402.57	787.39
2038	10,223.91	5,742.79	15,966.70	2,210.14	1,415.56	794.58
2039	11,620.99	6,526.92	18,147.91	2,181.20	1,397.07	784.13
2040	12,973.60	7,286.03	20,259.63	2,111.72	1,352.61	759.11
2041	14,261.75	8,008.91	22,270.66	2,011.03	1,288.15	722.88
2042	15,471.26	8,687.61	24,158.87	1,888.21	1,209.51	678.7
2043	16,593.18	9,317.13	25,910.31	1,751.44	1,121.92	629.52
2044	17,623.02	9,894.95	27,517.97	1,607.68	1,029.85	577.83
2045	18,559.89	10,420.59	28,980.48	1462.49	936.86	525.63
2046	19,405.59	10,895.06	30,300.65	1320.17	845.7	474.47
2047	20,163.95	11,320.51	31,484.46	1183.81	758.36	425.45
2048	20,840.10	11,699.83	32,539.93	1055.47	676.15	379.32
2049	21,439.99	12,036.37	33,476.36	936.44	599.9	336.54
2050	21,969.99	12,333.69	34,303.68	827.31	529.99	297.32
2051	22,436.52	12,595.40	35,031.92	728.24	466.53	261.71
2052	22,845.91	12,825.05	35,670.96	639.04	409.39	229.65
2053	23,204.19	13,026.03	36,230.22	559.26	358.28	200.98
2054	**23,517.00**	**13,201.50**	**36,718.50**	**488.3**	312.82	175.48

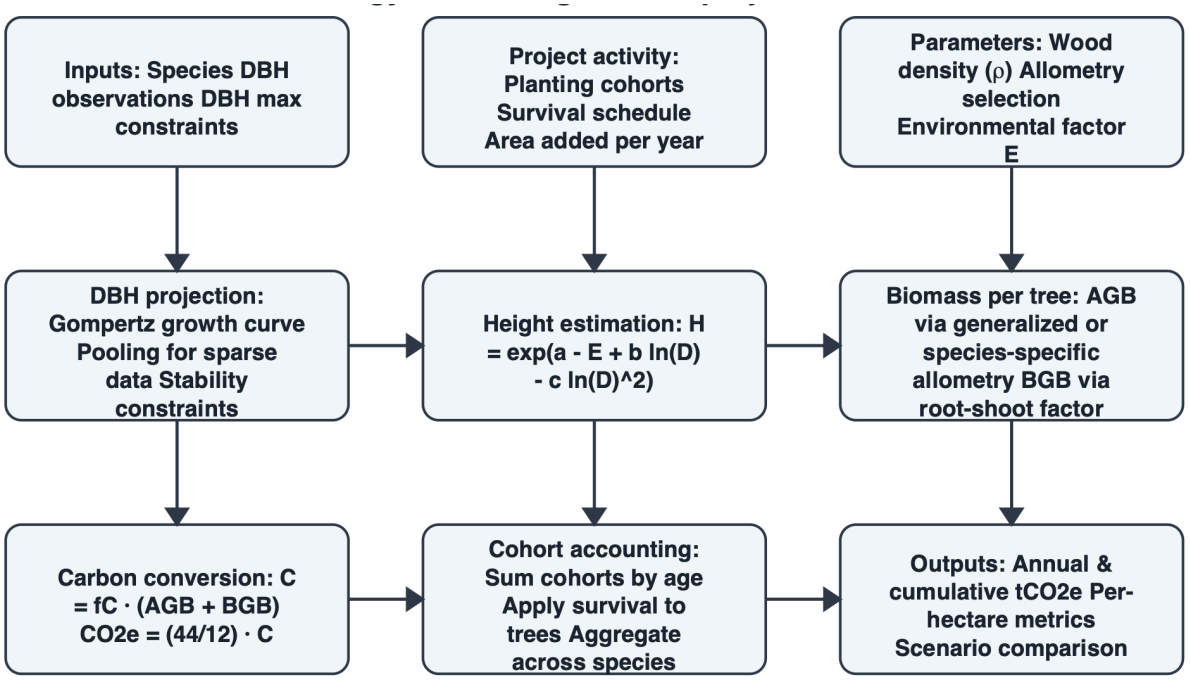
Annexure 5 - Carbon Sequestration Estimation Methodology

This section documents the carbon accounting methodology implemented to estimate ex-ante carbon sequestration from tree planting over a multi-decade time horizon. The design follows the biomass stock-change logic typically applied in Verra VM0047-aligned ARR quantification, with a computational chain that starts at tree growth and ends at annual and cumulative project-level CO2-equivalent outputs.

The chain proceeds from diameter growth to biomass, from biomass to carbon stock, from carbon stock to CO2-equivalent, and finally to aggregation across species, planting cohorts, survival schedules, and planted area expansion over time. The carbon sequestration calculator is scoped to the core stock-change quantification engine, while baseline definition, leakage, non-permanence risk and buffer contributions, uncertainty and conservativeness deductions, and monitoring and verification procedures must be addressed in the full VM0047 project documentation and verification workflow.

Methodology overview

The diagram summarizes the sequence of inputs, transformations, and aggregation steps used in calculation.



Key inputs and data handling

The application ingests species-identified diameter-at-breast-height (DBH) observations provided as a time series by project year. These observations parameterize a smooth growth trajectory for each species, and DBH inputs are expected to be consistent in units across the entire run, commonly centimeters. A species-level maximum or upper diameter is provided to constrain long-term extrapolation and prevent implausible asymptotic behavior during projection.

Project activity data are represented through cohort accounting. For each planting year, the calculator records the number of trees introduced as a cohort and tracks that cohort's surviving tree count in subsequent years using an age-specific survival schedule. In parallel, the calculator reads the planted area added each year and accumulates this to a cumulative planted area time series, enabling reporting of both total sequestration and per-hectare sequestration over time.

Species-level allometric parameters include wood density and optional species-specific volume or biomass expressions, allowing the calculator to operate in a standardized generalized allometry mode or a project-specific equation mode. The height-diameter relationship includes an environmental factor E supplied as an input constant; in the project workflow, E is taken from the GlobAD dataset published by Chave and applied consistently within a run unless updated.

Growth modelling: projecting DBH by year

Diameter growth is projected using a Gompertz curve, supporting early acceleration, a mid-stage rapid growth phase, and tapering toward an asymptote that represents a plausible species maximum. The asymptote is constrained using the species-level maximum diameter input, and remaining parameters are fit to minimize mismatch between observed and predicted DBH across years with observations.

To stabilize projections where measurement data are sparse, the calculator supports pooling by grouping species into broad size classes based on maximum diameter and fitting a representative curve shape using combined information. Fitting is constrained within reasonable parameter bounds to avoid unrealistic early-year growth; if numerical optimization fails for a given species or group, the calculator falls back to robust starting values so a traceable projection is still produced.

Estimating height from diameter and the role of Factor E

Because most biomass allometry requires tree height, the calculator estimates height from projected DBH using a log-quadratic height-diameter relationship of the form $H = \exp(a - E + b \ln(D) - c (\ln(D))^2)$, where
D is DBH and E is the environmental factor input. E shifts the height predicted for a given diameter to reflect environmental context embedded in the global calibration, and is intended to be sourced from Chave's GlobAD environmental calibration dataset for the relevant project setting.

Biomass estimation: above-ground and below-ground

Above-ground biomass per tree is calculated using one of two pathways. In a generalized pathway, the calculator applies a literature-based allometric form that depends on wood density, diameter, and estimated height, represented as $AGB = k \cdot (\rho \cdot D^2 \cdot H)^{\alpha}$ with constants selected according to the chosen generalized model. In a project-specific pathway, the calculator evaluates species-specific volume and/or biomass expressions supplied through the input workbook using available inputs such as DBH, height, wood density, and computed volume, and applies conservative smoothing if an expression produces non-physical early-year behavior.
Below-ground biomass is estimated using a root-shoot relationship computed as $BGB = r \cdot AGB$, where r is a root-shoot factor (0.27 used for current analysis). Total biomass per tree is the sum of above-ground and below-ground components, keeping the below-ground expansion explicitly tied to the above-ground estimate while remaining transparent about parameterization.

Converting biomass to carbon stock and CO2 equivalent

Total biomass is converted to carbon mass using a biomass-to-carbon fraction, expressed as $C = fC \cdot TB$, and carbon mass is converted to CO2-equivalent using $CO2e = (44/12) \cdot C$. These steps produce per-tree CO2-equivalent estimates as a function of tree age, which become the building blocks for cohort and project-level aggregation.

Scaling to project totals using cohort accounting

Project-level accounting is implemented through a cohort approach consistent with ARR stock-change logic. For each project year t, the calculator considers all cohorts planted in years 1 through t. Each cohort contributes according to its age, defined as the number of years since planting, and that contribution is multiplied by the surviving tree count derived from the survival schedule for the corresponding age. Totals are obtained by summing contributions across cohorts and species, yielding annual and cumulative project sequestration time series, and per-hectare metrics are computed by dividing totals by cumulative planted area up to year t.

Outputs, quality control, and limitations

The application produces time series outputs for annual and cumulative biomass, carbon, and CO2-equivalent, as well as tree counts that account for planting and survival dynamics. Quality control focuses on DBH unit consistency with selected allometric equations, plausibility and alignment of wood density and species identifiers across tables, validation of survival schedules for early years, and confirmation that environmental factor E reflects the intended project context from the Chave GlobAD source.

Conservative features include constraining and capping long-term maximum diameters, pooling growth curve fitting for under-measured species, smoothing non-physical biomass behavior from equation edge cases, and holding survival constant beyond provided years rather than assuming improving survival. While the calculator provides the planted biomass stock-change quantification engine, a full VM0047-aligned workflow also requires baseline and additionality demonstration, leakage assessment and deductions, non-permanence risk assessment and buffer contributions, uncertainty analysis and conservative deductions, and alignment of monitoring plans and evidence for validation and verification; the outputs should therefore be treated as traceable technical inputs rather than final issuance values.

E factor used for site 1: 0.6805
E factor used for site 2: 0.808