Geo-tagging of Plantation and Assisting in Estimating the Carbon sequestration Potential

Final Report

CRISIL FOUNDATION

September 2024

Strictly Private and Confidential

Contents

List of Tables

List of Figures

Abbreviation

AGB	Above-Ground Biomass
BGB	Below-Ground Biomass
CAMPA	Compensatory Afforestation Fund Management and Planning Authority
CSR	Corporate Social Responsibility
DBH	Diameter at Breast Height
GIS	Geographic Information System
GPS	Global Positioning System
IIFM	Indian Institute of Forest Management
IPLCs	Indigenous Peoples and local communities
NDVI	Normalized difference vegetation index
UNDP	United Nations Development Programme
IFAD	International Fund for Agricultural Development
FAO	Food and Agriculture Organization
IUCN	International Union for Conservation of Nature
ICLEI	International Council for Local Environmental Initiatives
KML	Keyhole Markup Language
IPCC	Intergovernmental Panel on Climate Change
QGIS	Quantum Geographic Information System
AGWC	Above Ground Wood Carbon
BGWC	Below Ground Wood Carbon
NIR	Near-Infrared
NGO	Non-governmental organization
GAP	Good Agricultural Practices
FAO	Food and Agriculture Organization

Executive Summary

The CRISIL Foundation, with the assistance of PricewaterhouseCoopers India (PwC India), undertook an assignment to geo-tag plantation sites, survey plant species, and estimate the carbon sequestration potential of their plantation initiatives during FY19-23. This initiative represents the first instance of a geo-tagged plantation by the CRISIL, creating a valuable reference for future activities.

The project aims to enhance the effectiveness and sustainability of CRISIL Foundation’s plantation efforts. This involves thoroughly reviewing the geotagging process to ensure precise location mapping of all plantation sites using advanced geospatial technology. Furthermore, the project aims to assess the impact of plantation efforts on carbon sequestration, utilizing geospatial technologies and scientific methods. Through these efforts, the project seeks to provide actionable insights and recommendations to improve the overall impact and efficiency of the foundation’s environmental initiatives.

The methodology employed in this assessment was structured around five key pillars: desk research, data collection, stakeholder consultations, data analysis, and impact analysis. Desk research provided a foundational understanding by utilizing sources such as the Indian State of Forest Report and various guidelines from international organizations. Data collection involved primary and secondary sources, with GPS and TreeMapper applications ensuring precise geospatial data for 15% of the observed plantations. The primary sources were complemented by geospatial tools like the Restor web application and Google Earth for temporal analysis and carbon sequestration estimation. Data was gathered by the field teams, consisting of four PwC members, including two senior forestry experts. Furthermore, stakeholder consultations were conducted in phases, engaging local communities, Non-Governmental Organizations (NGOs), and CRISIL to integrate diverse insights and address site-specific challenges. Data analysis, field survey results, and advanced tools were used to assess plantation health, survival rates, and carbon sequestration potential. Finally, the report integrated an impact analysis that examined the plantations’ contributions to sustainable forest management, biodiversity conservation, and alignment with the Sustainable Development Goals (SDGs). The comprehensive approach ensures that the project not only evaluates the current state of the plantations but also provides actionable insights and recommendations to improve the overall impact and efficiency of the foundation’s environmental initiatives.

Geo-tagging was conducted for 11 plantation sites across West Bengal, Tamil Nadu, Haryana, and Maharashtra using the TreeMapper application and GPS. The data, uploaded to QGIS and Google Earth, provided precise geographic coordinates for 15% of the observed plantations, revealing variations in plant distribution. For example, some sites, such as Kakdwip and Rajarhat in West Bengal and the Badshahpur site in Haryana, displayed uniform spacing, while others showed clusters or scattered patterns. The variation highlighted higher soil fertility or water availability areas, suggesting differential management practices were needed. Additionally, temporal change detection using Google Earth imagery showed incremental improvements in vegetation density over time across plantation sites in West Bengal, Tamil Nadu, and Maharashtra. Miyawaki plantations in Tamil Nadu and Maharashtra, as well as conventional urban plantations in West Bengal and Haryana, exhibited rapid canopy development. Conversely, other sites showed gradual improvements with minor variations influenced by natural growth cycles and environmental factors. The geo-tagged data and temporal change detection results serve as a baseline for understanding growth and change over time, which is essential for addressing future challenges and improving plantation strategies.

The survey found significant variations in tree growth across different sites and species. Survival rates varied due to site-specific stressors; the survey revealed substantial variations in tree survival rates across other sites and species.

State	Site	Plantation Type	Survival Rate (%)
West Bengal	*Taranagar*	Mangrove	58.4
	Mandirtala	Mangrove	21
	Bajpukur	Mangrove	43.2
	Rajarhat Newtown	Conventional	85
Haryana	*Gurugram*	Conventional	91
Tamil Nadu	*Perambur*	Miyawaki	19.4
	Perambur	Miyawaki	21.8
Maharashtra	*Bhyander*	Miyawaki	40
	Bhatsai	Conventional	9.4
	Ghatkopar	Mangrove	25.5
	Rayate	Conventional	11.1

Community involvement was a crucial differentiator in the growth of these plantation sites. Positive results were observed where community involvement was present, such as at the Rajarhat and Badshahpur sites. The collaboration between the Project facilitating agency (NGO) and the community fostered initial protection which developed a sense of ownership, leading to continuous monitoring and gap identification. Effective management practices were also crucial for successful growth. Sites that were well-managed during the initial year focused on protection, replacement, and understanding site-specific needs, demonstrated good growth due to these practices.

Normalized Difference Vegetation Index (NDVI) values indicated differences in vegetation health, with Perambur (TN) and Bhyander (MH) showing higher values, reflecting healthier vegetation due to the Miyawaki plantation method. However, there is a significant gap between current and potential carbon sequestration levels in all the sites except Rajarhat (WB) and Badshahpur (Haryana), highlighting the need for improved management practices. These findings are crucial for understanding the impact of plantation activities, which contribute to multiple SDGs such as food security, health, water security, climate action, and biodiversity conservation. Additionally, these efforts create jobs, enhance urban resilience, and support sustainable economic growth, further aligning with the SDGs 1, 3, 6, 11, 13, and 15.

Challenges encountered during the survey included site inaccessibility, and high tides in mangrove plantations like Canning and Kakdwip, as well as technical difficulties in dense plantations. Morning surveys, carefully planned tide schedules, and high-accuracy GPS machines were utilized, and site areas were prioritized to avoid physical injury. These strategies were essential in overcoming obstacles and ensuring the accuracy and safety of data collection efforts. The combination of NDVI analysis, SDG alignment, and strategic management of survey challenges highlighted the importance of continuous monitoring and adaptive management to enhance the health and sustainability of plantation sites.

An action plan has been developed with short-term and mid to long-term recommendations:

Short-Term	Mid to Long-Term
➢ Establish a robust verification and monitoring system. ➢ Update documentation monthly with photos and maintain records at partner NGOs. ➢ Enhance visibility through signboards with donor and plantation details. ➢ Record and submit KML files or GPS locations before starting activities.	➢ Conduct thorough feasibility assessments to avoid unsuitable areas. ➢ Develop SOPs based on best practices in Forestry for Plantation Initiatives. ➢ Implement comprehensive soil quality assessments covering physical, chemical, and biological parameters.

Short-Term	Mid to Long-Term
➢ Plan with local bodies to make sites more accessible.	➢ Optimize KML files for precise geospatial representation of plantation boundaries. ➢ Utilize the survey data as a baseline to keep track of plantation growth and management.

Overall, CRISIL's geotagged plantation is a strategic initiative to ensure the effectiveness and sustainability of the Foundation's plantation efforts. By implementing these recommendations, the Foundation can significantly enhance the effectiveness of its plantation initiatives, improve biodiversity, and optimize carbon sequestration potential. These efforts will contribute to environmental sustainability and the well-being of local communities. The project marks a significant step forward in leveraging geospatial technology and scientific methods to achieve sustainable development goals and create a positive environmental impact. The initiative is, therefore, integral to Crisil's commitment to environmental stewardship and corporate social responsibility.

1. Introduction

1.1. Background

Tree plantation initiatives have gained significant momentum in India, driven by the urgent need to address environmental degradation and climate change. Trees play a pivotal role in maintaining ecological balance, providing myriad benefits to ecosystems, including carbon sequestration, soil stabilization, and habitat provision for diverse species. Recognizing these benefits, numerous tree plantation projects have been launched across the country, aiming to enhance green cover and promote sustainable development.[1,2,3]

Trees are fundamental to the health and stability of ecosystems. Like several ecosystems, trees also act as carbon sinks, absorbing carbon dioxide from the atmosphere and mitigating the effects of climate change.[4] Trees enhance soil fertility and prevent erosion by stabilizing the soil with their root systems.[5] Additionally, they regulate water cycles, improve air quality by filtering pollutants, and provide habitats for countless wildlife species, thereby supporting biodiversity.[6]

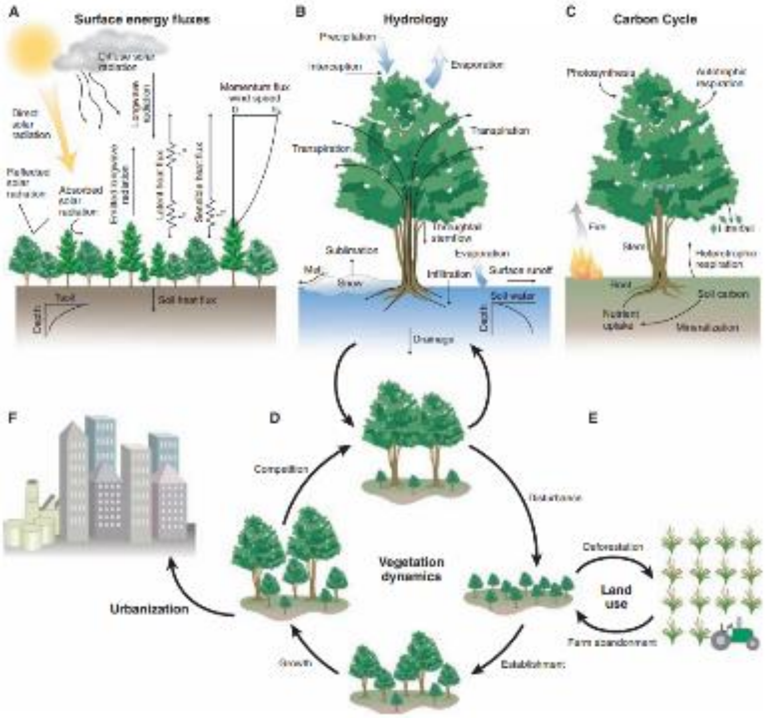

Figure 1. Schematic representation of the main biophysical and biogeochemical processes in terrestrial ecosystems (*Source: Bonan et al., 2008*)[7]

[1] Sundarapandian, S. M., Swamy, P. S., & Kumar, M. S. (2022). Evaluation of tree plantations in Tamil Nadu, India: Implications for conservation and management. Journal of Forestry Research, 33(3), 859-872.
[2] Aggarwal, A., Paul, V., & Das, D. (2021). Tree planting for restoring degraded lands in India: Reimagining reforestation. Land Use Policy, 109, 105618.
[3] Food and Agriculture Organization of the United Nations (FAO). (2018). The State of the World's Forests 2018: Forest Pathways to Sustainable Development. FAO.
[4] Chaturvedi, R. K., Ranjith Gopalakrishnan, R., Jayaraman, M., Bala, G., & Ravindranath, N. H. (2019). Impact of climate change on Indian forests: A dynamic vegetation modeling approach. Mitigation and Adaptation Strategies for Global Change, 16(2), 119-142.
[5] Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. Science, 304(5677), 1623-1627.
[6] Singh, S., Singh, J. S., & Lal, R. (2021). Biodiversity conservation for sustainable development in India: A review. Journal of Environmental Management, 281, 111902.
[7] Bonan, G.B. Forests and Climate Change: Forcings, Feedbacks, and the Climate Benefits of Forests. Science 2008, 320, 1444–1449.

In India, where rapid urbanization and deforestation have led to significant environmental challenges, tree plantation has been widely used for restoring degraded landscapes and promoting ecological resilience. Planting trees helps to counteract the adverse effects of deforestation, such as loss of biodiversity, soil erosion, and climate change.[8] Moreover, tree plantations can enhance the livelihoods of local communities by providing resources such as fruits, nuts, and timber, and by creating job opportunities in tree planting and maintenance.[9]

Effective monitoring and impact assessment are crucial components of successful tree plantation initiatives**.** These processes ensure that plantation projects achieve their intended ecological and social outcomes. Monitoring involves tracking the growth, health, and survival rates of planted trees, which helps identify challenges and implement corrective measures.[10] Impact assessment evaluates the broader ecological, economic, and social benefits of tree plantations, providing data that can guide future projects and policy decisions.[11]

Geo-tagging technology enhances the monitoring and documentation of tree plantation projects by marking the precise geographical locations of each plantation site on digital maps. This enables better tracking of tree growth and health over time, facilitates the identification of patterns and trends, and improves accountability and transparency in reporting.[12] The use of geospatial technology also supports the assessment of carbon sequestration potential, as it allows for accurate mapping and analysis of carbon stocks in different plantation areas.[13]

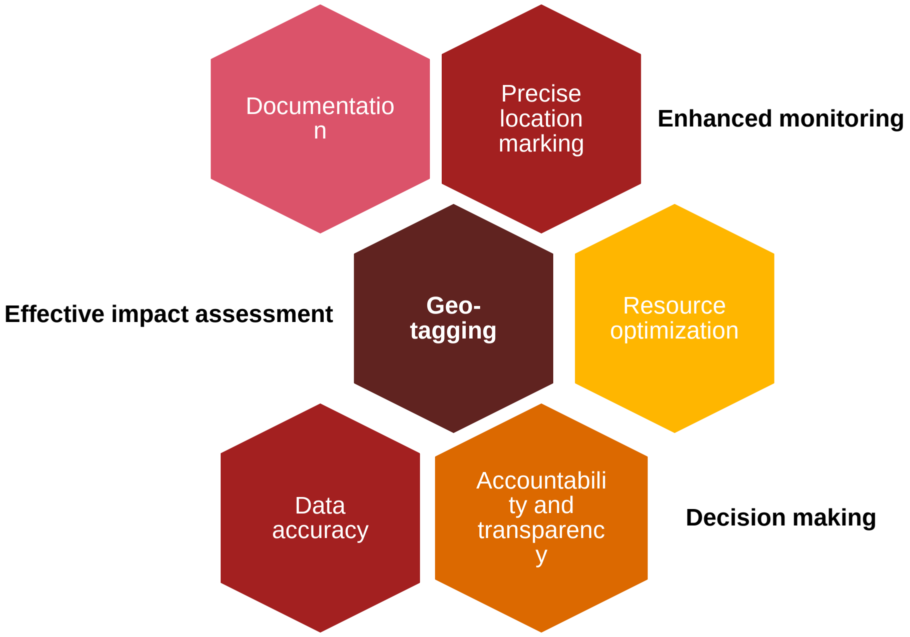

Figure 2. Benefits of geo-tagging in tree plantation

In this context, CRISIL Foundation, the Corporate Social Responsibility (CSR) arm of CRISIL, commissioned PwC India to conduct a geo-tagging and plantation survey to evaluate plantations conducted during 2019-2023. By engaging PwC India, the Foundation aims to enhance its social and environmental impact initiatives.

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[8] Kumar, B. M., & Nair, P. K. R. (2011). Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges. Springer.
[9] Das, N., & Das, D. K. (2019). Socio-economic impact of community forestry program in India: A case study. Forest Policy and Economics, 21, 98-104.
[10] FAO. (2015). Guidelines for monitoring and evaluation of tree plantation projects. Food and Agriculture Organization of the United Nations.
[11] Pandey, D. N., & Shukla, P. R. (2019). Trees for Global Benefits: A Programme to Address Climate Change and Support Livelihoods. UNEP.
[12] Kumar, M., Singh, R., & Pandey, A. (2020). *Application of geo-tagging technology in forest management: A case study from India*. Journal of Environmental Management, 275, 111224.
[13] Chhabra, A., Palria, S., & Dadhwal, V. K. (2002). Growing stock-based forest biomass estimate for India. Biomass and Bioenergy, 22(3), 187-194.

This project involves geo-tagging plantation sites and conducting comprehensive plant species surveys to monitor and assess the plantations' environmental benefits effectively.

1.2. Project objectives and scope of work

The main objective was to conduct a geo-tagging and plantation survey to evaluate the plantations from 2019 to 2023.

The scope of work for the assignment covers the following activities:

Geo-tagging of plantation:

- Initiate the process of geotagging for all plantations carried out by CRISIL Foundation during FY19-23.
- Utilize geospatial technology to mark the precise locations of each plantation site on digital maps for better monitoring and documentation.

Survey of plant species:

- Assist in determining the minimum sample size from the total plantations done during FY19-23.
- The sample selection will be based on a statistically sound method to achieve representative results.
- Conduct a comprehensive survey of the plant species in each plantation area to assess biodiversity and environmental impact.
- Record relevant data about the health and growth status of the planted trees.

Assist in estimating the carbon sequestration potential:

- Develop a mechanism to know the impact of the plantation efforts.
- carbon sequestration potential mapping using scientific methods.

The outcomes of this assignment are:

Geo-tagging of plantations	• Enhanced monitoring and documentation of plantation sites. • A comprehensive digital map for real-time monitoring and future reference.
Survey of plant species	• Detailed records of plant species, biodiversity levels, and environmental impact. • An extensive database of plant health and growth metrics.
Estimating carbon sequestration potential	• A detailed section on the carbon sequestration potential of the plantations.

2. Detailed Approach and Methodology

2.1. Approach and Methodology

The overall approach for conducting a geo-tagging and plantation assessment was based on five key pillars:

Desk research → Data collection → Data analysis → Stakeholder consultations → Analysis of impacts

The work included desk research, data collection through field inspections, conducting stakeholder consultations, analysis of the data collected, and analysis of impacts.

Desk research

Desk research was undertaken to gain a broad understanding of the subject. The focus was on geographical coordinates, the performance of plantations, and carbon sequestration.

A list of sources considered for the desk research are:

Reports/Manuals/Guidelines

- *State of Forest Report, Forest Survey of India (2021)*
- *National Evaluation Manual for Compensatory Afforestation Fund Management and Planning Authority (CAMPA), IIFM (2016)*
- *Handbook on Planning, Monitoring and Evaluating for Development Results, UNDP (2009)*
- *Evaluation Manual: Methodology and Processes, IFAD (2015)*
- *The Center for International Forestry Research (CIFOR)*
- *FAO guidelines on vegetation fire management, emphasizing prevention, preparedness, and suppression (2013)*
- *Study by Maurya on Soil Monitoring Quality Indicators (2020)*
- *IUCN: List for Classification of Species (2021)*
- *ICLEI South Asia: Guidelines for Miyawaki Forest (2020)*
- *Botanical Survey of India: Mangrove Identification (2019)*

Research articles

- *Talosig, E. E., Adriatico, C., & Yap, F. R. P. (2019). Profiling and Geo-Tagging of Rubber Tree Plantation through Geographic Information System. Open Access Library Journal, 6(7), 1-14.*
- *Arya, A., Negi, S. S., Kathota, J. C., Patel, A. N., Kalubarme, M. H., & Garg, J. K. (2017). Carbon Sequestration Analysis of dominant tree species using Geo-informatics Technology in Gujarat State (INDIA). International Journal of Environment and Geoinformatics, 4(2), 79-93.*
- *Pandey, S., Kumari, N., Dash, S. K., & Al Nawajish, S. (2022). Challenges and Monitoring Methods of Forest Management Through Geospatial Application: A Review. Advances in Remote Sensing for Forest Monitoring, 289-328.*
- *Wibowo, A., Salleh, K. O., Frans, F. T. R. S., & Semedi, J. M. (2016, November). Spatial temporal land use change detection using Google Earth data. In IOP Conference Series: Earth and Environmental Science (Vol. 47, No. 1, p. 012031). IOP Publishing.*

Data collection

The required data and information were collected from various primary and secondary sources. A list of sources is provided in Tables 1 and 2. The data-gathering process was designed based on extensive desk research and our expertise. GPS coordinates for the plantations were recorded and are available in the report. Our team has sufficient expertise in designing primary ecological surveys. Enumerators with strong local knowledge and appropriate educational levels were engaged in data collection and were adequately trained to ensure accuracy and reliability.

The data collection process involved primary data sources, where direct measurements and observations were made, and secondary data sources provided supplementary information from existing databases and research. Below is a detailed representation of this study's primary and secondary data sources**.**

Primary data

Table 1: Primary data source

Data source	Methods/Tools	Data collected	Uses
GPS	High-accuracy GPS machines	Geotagged locations of sample plantations	Ensures precise geospatial data for individual trees and plantation clusters
TreeMapper application	TreeMapper app	Real-time geotagging data	Streamlines data recording and synchronization
Field survey	Manual survey, measurement tools	Tree height, DBH, canopy cover, soil type, moisture content	Comprehensive metrics for assessing plantation growth and health

Secondary data

Table 2: Secondary data sources

Data source	Method/Tools	Data collected	Uses
Restor web application[14]	Remote sensing tools, NDVI analysis	Vegetation health, density, carbon sequestration potential	Provides remote sensing data to complement field survey findings
Google Earth[15]	Temporal change detection	Historical imagery, plantation growth over time.	Allows for the analysis of changes in plantation area and health over different time periods
Notable research[16]	Peer-reviewed articles, reports	Insights into plantation growth factors, carbon capture efficiency	Supplements of primary data with scientifically validated information
Forest Survey of India - State-wise carbon database[17]	Biomass and Carbon Database	State-wise Above-ground and below-ground biomass and carbon sequestration data	Regional carbon data to enhance the accuracy of sequestration potential estimates

[14] https://restor.eco/?lat=26&lng=14.23&zoom=3
[15] https://www.google.com/intl/en_in/earth/about/versions/
[16] https://fsi.nic.in/isfr-2021/chapter-9.pdf
[17] https://fsi.nic.in/isfr-2021/chapter-9.pdf

Photo 1. Evaluation team

Data analysis

Data analysis for the geotagging of plantations and assessment of carbon sequestration potential was conducted using both primary and secondary data sources.

Primary data analysis

1. **Field survey using GPS and TreeMapper application**:
    - **Polygon creation and KML file development**: Using high-accuracy GPS machines and the TreeMapper application, polygons were created, and KML files were developed for geotagged plantations. Each geotag included photographs of the trees and details of their height and girth.
    - **Survival rate**: At each plantation site, 0.1-hectare plots (33m x 33m) were surveyed to determine the survival rate of the plantations. This provided critical insights into the health and viability of plantation efforts.

The geospatial data collected allowed for accurate mapping of plantation areas, and the survival rate data provided insights into the quality of the plantation and helped to understand the gaps in the plantation.

Secondary data analysis

1. **Restor web application**:
    - **KML utilization**: The KML files developed from the TreeMapper application were integrated into the Restor web application.
    - **Carbon sequestration potential**: Restor helped estimate the current and potential carbon sequestration for all the sites.
    - **NDVI analysis**: The application provided NDVI data, which helped assess vegetation health and density within the polygons.
    - **Distribution pattern**: Analysis showed that 15% of the geotagged plantations exhibited a distinct distribution pattern, aiding in understanding plantation spread and density.
2. **Temporal change detection using Google Earth Pro**:

- **Canopy cover and growth analysis**: The KML files from primary data sources were used in Google Earth Pro to detect temporal change. This allowed for the assessment of canopy cover and growth patterns over time.
- **Overall area analysis**: Historical imagery and temporal analysis provided a comprehensive view of changes in plantation areas and health, contributing to an overall understanding of plantation effectiveness and growth dynamics.

Stakeholder consultation

During the stakeholder consultations, the following steps were undertaken to integrate stakeholder knowledge and comprehend their requirements:

Field survey and initial discussions

In the initial phase, field surveys were conducted, involving discussions on the qualitative parameters of the plantation sites with NGO representatives and communities. In Mumbai, these included the Forest Department (Ghatkopar site) and the Municipal body (Miyawaki site). The discussions focused on the health and growth of plantations, identifying immediate issues, and understanding existing management practices.

Opportunities and challenges

The second phase involved detailed discussions with CRISIL on the opportunities and challenges identified at each site. Their suggestions were evaluated and incorporated in the report. This phase aimed to align with understanding CRISIL's approach, ensuring the reports addressed current conditions and future improvement recommendations.

Stakeholders Visit

In the third phase, a CRISIL and NGO representatives team visited the field to understand the impact and identify further opportunities. Detailed observations were made, focusing on successes and areas for improvement.

Photo 2. Client visits to the plantation site

Analysis of impacts

Impacts of plantations were studied concerning their contribution to sustainable management of forest resources, rejuvenation of degraded forests, addressing issues of biodiversity conservation, and influence of biotic and abiotic factors, focusing on Sustainable Development Goal 15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss), Sustainable Development Goal 13 (Take urgent action to combat climate change and its impacts) and also Sustainable Development Goal 1 (End poverty in all its forms everywhere) concerning contribution in employment generation, livelihood support and resource augmentation.

Extensive analysis was undertaken to prepare the deliverables based on the inputs obtained through desk research and stakeholder consultation.

2.2. Plantation sites

Table 3 provides information on various plantation sites, including the state, type of plantation, specific location, the number of trees planted, the year of plantation, and additional detail on the type of plantation.

Table 3: Crisil- plantation sites

State	Type of plantation	Location	No trees planted	Plantation year	Particulars
Tamil Nadu	Miyawaki	Perambur, Chennai	3000	2019	single mass plantations
Tamil Nadu	Miyawaki	Perambur, Chennai	1000	2020	single mass plantations
Delhi	Conventional	Yamuna area	10000	2020	single mass plantations
Delhi	Conventional	Mayur Vihar	10000	2022	single mass plantations
Haryana	Conventional	Badshahpur	500	2019	single mass plantations
West Bengal	Conventional	Rajarhat Newtown	300	2019	single mass plantations
West Bengal	Mangroves	Patharpratima	6000	2020	single mass plantations
West Bengal	Mangroves	Canning	10000	2021	single mass plantations
West Bengal	Mangroves	Sagar	18000	2022	single mass plantations
West Bengal	Mangroves	Kakdwip	54000	2023	single mass plantations
Maharashtra	Mangroves	Ghatkopar	10000	2021	single mass plantations
Maharashtra	Conventional	Bhatsai	10000	2021	single mass plantations
Maharashtra	Conventional	Rayate	10200	2022	single mass plantations
Maharashtra	Miyawaki	Mira- Bhyander	6500	2022	single mass plantations
Total		**149500**			

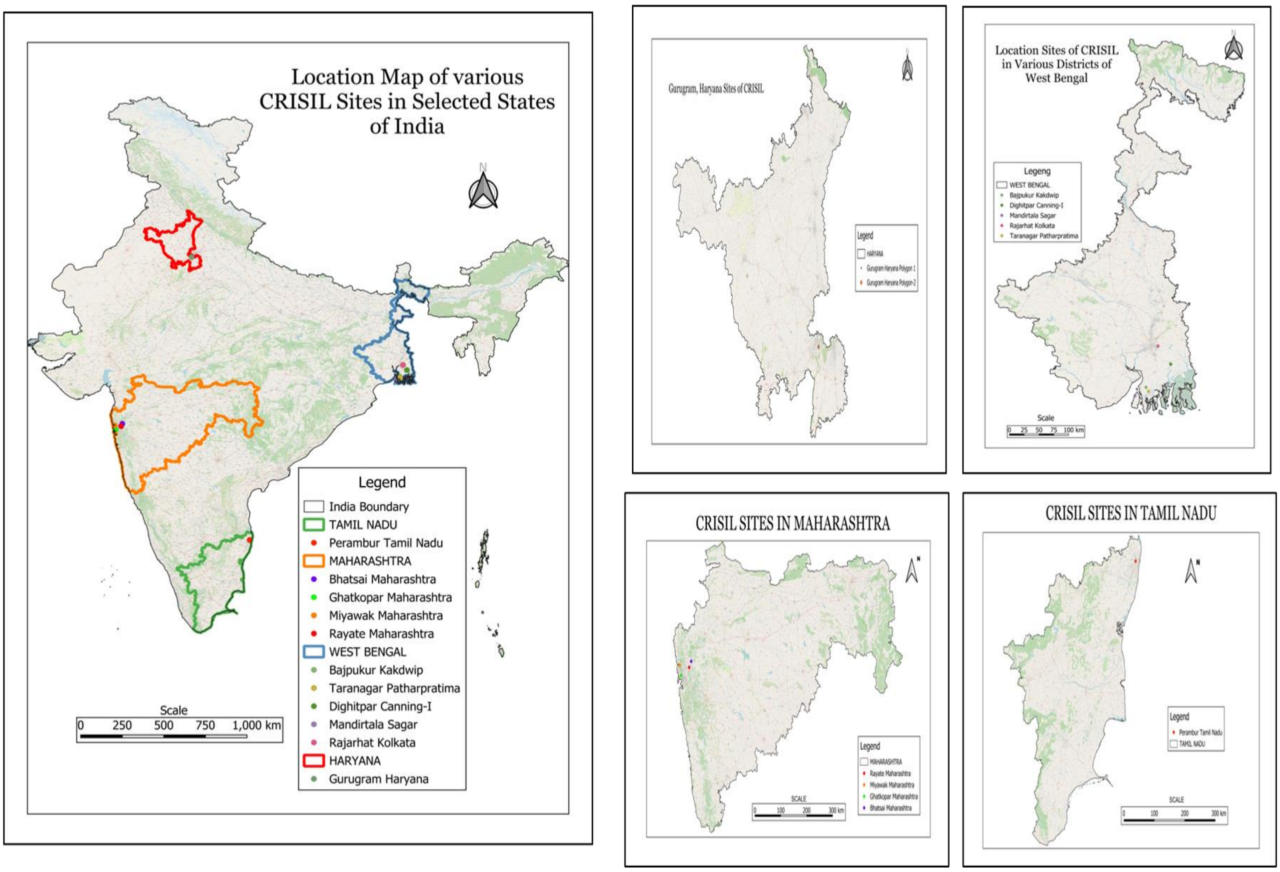


Figure 3. Location map

The data reflects a variety of plantation strategies employed across multiple cities, each tailored to address specific ecological and urban needs. The Miyawaki method was adopted for rapid urban greening in Chennai and Mumbai. In contrast, Delhi and Gurgaon focused on conventional large-scale plantations to enhance their urban green cover. West Bengal's substantial investment in mangrove plantations underscores its commitment to coastal ecosystem restoration. These diverse approaches to reforestation highlight the unique ecology of each region.

Plantation periods:

Older plantations	Established in 2019 and 2020 (e.g., Perambur, Chennai; Yamuna area, Delhi; Badshahpur, Gurgaon; Newtown, Kolkata).
Newer plantations	Established in 2021 and 2022 (e.g., Mayur Vihar, Delhi; Canning, Kolkata; Sagar, Kolkata; Kakdwip, Kolkata; Rayate, Mumbai; Mira-Bhyander, Mumbai).

This data is crucial as it provides a foundational understanding of geo-tagging plantation sites and analysing their carbon sequestration potential. The information is a base for understanding the plantation's growth and /or making informed decisions.

Sampling

A systematic random sampling was used to geo-tag the sample plants. Enumerators identified a starting point within the study grid and selected subsequent geotagging locations at regular intervals, such as every 10th tree, ensuring systematic distribution. The sample size was 15% of the observed count for geotagging, as identified before the commencement of this assignment. This subset was used for detailed geospatial analysis and ecological assessment, providing a comprehensive overview of the plantation area.

Table 4: Crisil- observed plantation.

State	Plantation type	Location	Total no of trees	Observed	Sample (15% of Observed[18])	Remarks
Tamil Nadu	Miyawaki	Perambur, Chennai	3000	560	80	Completed
Tamil Nadu	Miyawaki	Perambur, Chennai	1000	180	30	Completed
Delhi	Conventional	Yamuna area	10000	-		Reported loss
Delhi	Conventional	Mayur Vihar	10000	-		Reported loss[19]
Haryana	Conventional	Badshahpur	500	500	75	Completed
West Bengal	Conventional	Rajarhat Newtown	300	240	35	Completed
West Bengal	Mangroves	Patharpratima	6000	3000-3500	310	Some sections of the planted area were not accessible[20]
West Bengal	Mangroves	Canning	10000	-	-	The site was not accessible.
West Bengal	Mangroves	Sagar	18000	3500	310	Completed
West Bengal	Mangroves	Kakdwip	54000	18000-22000	1010	The sample size is limited due to sinking up to 3 feet in the planted area, and the duration of high tides during the day further restricts access.
Maharashtra	Mangroves	Ghatkopar	10000	2000-2500	310	Completed
Maharashtra	Conventional	Bhatsai	10000	1400-1500	220	Completed
Maharashtra	Conventional	Rayate	10200	150-160	22	Completed
Maharashtra	Miyawaki	Mira-Bhyander	6500	2000-2500	300	Completed

Table 4 provides a detailed overview of various plantation sites across different states, including Tamil Nadu, Delhi, Haryana, West Bengal, and Maharashtra. It outlines the type of plantation, specific location, the number of trees planted, the number of trees during the site visit, and a sample size representing 15% of the observed trees. The data encompasses diverse plantation methods such as Miyawaki, conventional, and mangrove plantations and highlights the extensive efforts carried out by the CRISIL Foundation.

[18] Sample size: The 15% sample was chosen to provide adequate geo-tagged points, ensuring comprehensive coverage and detailed analysis. This percentage is based on the total number of plants observed during the site visit.
[19] The plantation visit was cancelled due to a reported loss by the NGO/ client.
[20] Site inaccessibility: Some patches of the planted area were inaccessible due to sinking and high tidal duration.

3. Results

3.1. Geo-tagging

Geo-tagging of plantations involved capturing geographical coordinates to create a comprehensive digital record. Each tree's latitude and longitude were recorded using the Tree Mapper application.[21]. The collected data was uploaded to QGIS and Google Earth software to produce maps. This process ensured a detailed and accurate layout of each plantation site, with centralized and organized data readily accessible for analysis and reporting. The *yellow line* in the polygon delineates the plantation area, while the *white dots* represent the geo-tagged plants, including coordinate details and plantation photographs. All sites yield similar outputs, as illustrated in **Figure 4**.

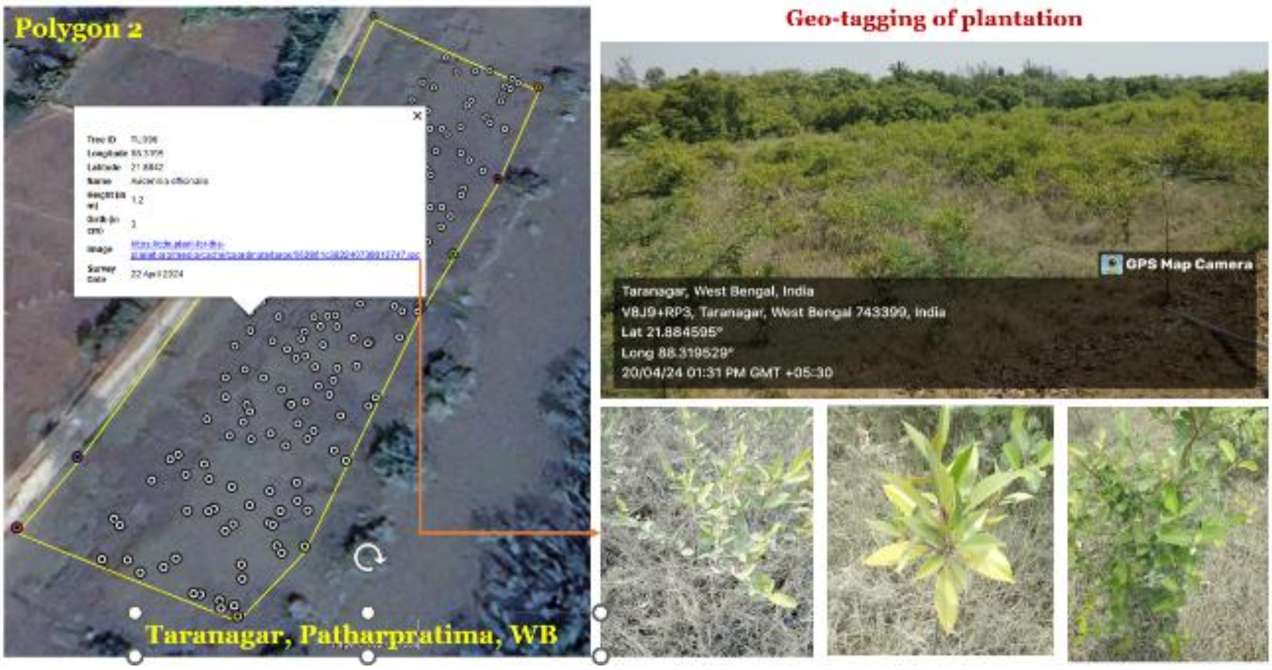


Figure 4. Geo-tagging of plantation (*Site: Taranagar, Patharpratima, West Bengal*)

3.1.1 West Bengal:

The state encompasses four plantation sites. A detailed analysis of all the sites is provided below.

Taranagar, Patharpratima

Taranagar plantation site, located in the Patharpratima block of South 24 Parganas, West Bengal, lies within the Sundarbans delta. This area is characterized by its extensive mangrove forests, accessible via local roads and waterways. Its proximity to the Bay of Bengal influences the regional climate and ecosystem, making it an ideal site for plantation projects focused on ecological restoration.

[21] The monitoring tool developed by UNEP and Plant for the Planet for forest restoration programs (https://www.plant-for-the-planet.org/treemapper/)

Polygon 1

Polygon 2

Polygon 3

Site – Taranagar, Patharpratima, West Bengal

Figure 5. Geo-tagged plantation site - Taranagar

The plantation area is delineated within three polygons, measured in hectares as follows**:** Polygon-1 covers 0.25 hectares, Polygon-2 spans 0.47 hectares, and Polygon-3 extends across 0.51 hectares. In total, the plantation areas encompass 1.23 hectares. A total of 310 plants were geo-tagged along with their growth parameters. Additionally, 33m by 33m plots were measured to gain insights into the survival percentage within the planted area.

The geo-tagged images indicate individual plant locations within the polygon. By analyzing the spatial distribution, it can be said that:

- **Uniform distribution:** The plants are evenly spaced in Polygon 2, suggesting a well-planned planting strategy.
- **Clustered areas:** There are clusters in certain parts of the polygon 1 and 3, indicating areas of higher soil fertility or water availability.

For instance, the southern section of Polygon 3 shows a higher plant density, while the south section shows a lower density. This variation may require differential management practices.

Mandirtala, Sagar Island

Mandirtala is part of Sagar Island, situated in the South 24 Parganas district of West Bengal. Sagar Island is the largest island in the Sundarbans delta. The unique geographical positioning of Mandirtala makes it a crucial habitat for mangrove forests, which thrive in brackish intertidal zones.

Polygon 1	**Polygon 2**
Site - Mandirtala, Sagar, West Bengal	

Figure 6. Geo-tagged plantation site - Mandirtala

The plantation area in Mandirtala is delineated within two main polygons: Polygon-1 covers 0.5738 hectares, and Polygon-2 spans 1.1032 hectares; in total, the plantation areas encompass approximately 1.677 hectares. 310 plants were geo-tagged along with their growth parameters. Additionally, 33m by 33m plots were measured to gain insights into the survival percentage within the planted area.

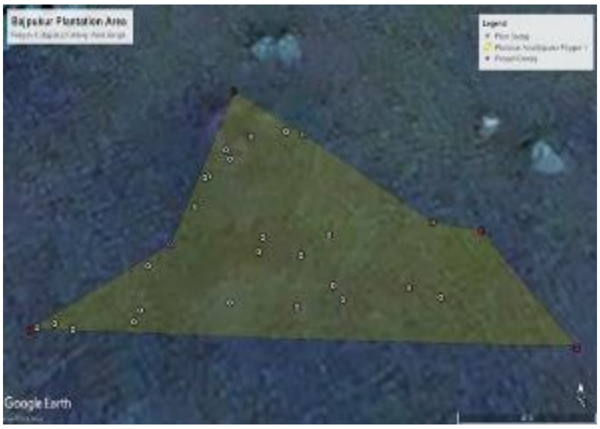
The geo-tagged images indicate individual plant locations within the polygon. By analyzing the spatial distribution, it can be said that:

- **Uniform distribution:** The plants are evenly spaced in Polygon 2, suggesting a well-planned planting strategy, while Polygon 1 shows scattered plantation or unevenly spread plantation.
- **Clustered areas:** There are clusters in certain parts of the polygon 2, indicating areas of higher soil fertility or water availability.

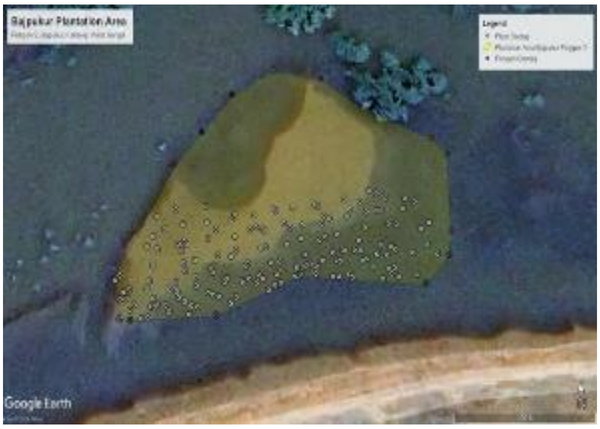
For instance, the eastern section of both polygons shows a higher plant density, while the western section shows an exceptionally low density. This variation may require differential management practices.

Bajpukur, Kakdwip

Located in Bajpukur, a small region within Kakdwip in the South 24 Parganas district of West Bengal, it is an important mangrove plantation site. This area, positioned within the Sundarbans delta, is crucial for the ecological and environmental stability of the region.



Polygon 1



Polygon 2

Polygon 3

Polygon 4

Polygon 5

Polygon 6

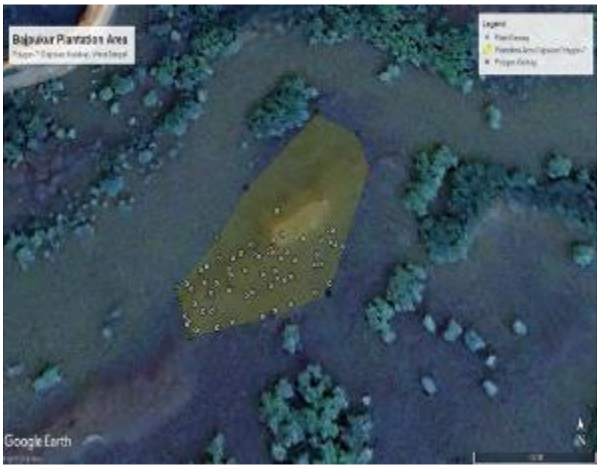
	
Polygon 7	**Polygon 8**
Site – Bajpukur, Kakdwip, West Bengal	

Figure 7. Geo-tagged plantation site - Bajpukur

The plantation area in Bajpukur, Kakdwip, is delineated within eight polygons. The areas are as follows: Polygon-1 covers 0.0593 hectares, Polygon-2 spans 0.3260 hectares, Polygon-3 extends across 0.6886 hectares, Polygon-4 encompasses 0.2571 hectares, Polygon-5 covers 0.2185 hectares, Polygon-6 spans 1.0438 hectares, Polygon-7 extends across 0.1914 hectares, and Polygon-8 covers 0.1234 hectares. In total, these plantation areas encompass approximately 2.91 hectares. 1010 plants were geo-tagged along with their growth parameters. Additionally, 33m by 33m plots were measured to gain insights into the survival percentage within the planted area.

The geo-tagged images indicate individual plant locations within the polygon. By analyzing the spatial distribution, it can be said that:

- **Uniform distribution:** The plants are evenly spaced in Polygons 2,3 and 6, suggesting a well-planned planting strategy, while Polygons 1, 4,5, 7 and 8 show scattered or unevenly spread plantations.
- **Clustered areas:** There are clusters in certain parts of polygons 2,3 and 6, indicating areas of higher soil fertility or water availability.

For instance, the western section of polygon 3 shows a higher plant density, while the eastern section shows an exceptionally low density. This variation may require differential management practices.

Rajarhat, Kolkata

Rajarhat is a rapidly developing area located in the northeastern part of Kolkata, West Bengal. This urban plantation site is maintained by the local municipality and plays a vital role in enhancing the city's green cover. Rajarhat's strategic location within the urban landscape makes promoting biodiversity and improving air quality essential. The plantation efforts here focus on creating a sustainable urban environment, contributing to the overall ecological balance, and providing a green oasis amidst the bustling cityscape.

Polygon 1
Site – Rajarhat, Kolkata

Figure 8. Geo-tagged plantation site – Rajarhat, Kolkata

The plantation area in Rajarhat is delineated in one polygon: Polygon-1 covers 0.09 hectares. 40 plants were geo-tagged along with their growth parameters. Additionally, entire plots were measured to gain insights into the survival percentage.

The geo-tagged images indicate individual plant locations within the polygon. By analyzing the spatial distribution, it can be said that:

- **Uniform distribution:** The plants are evenly spaced in the polygons, indicating a well-planned planting strategy. The high plantation density in the polygons is evident from the geotagged plantation samples, which are distributed across the polygon.

3.1.2 Tamil Nadu:

There are two plantation sites in Tamil Nadu. The analysis of each site is detailed below:

Perambur, Chennai

The Miyawaki plantation site is near the ICF factory in Perambur, in northern Chennai. Surrounded by industrial areas, this site was transformed using the Miyawaki urban forestry technique to create a green space amidst the industrial landscape.

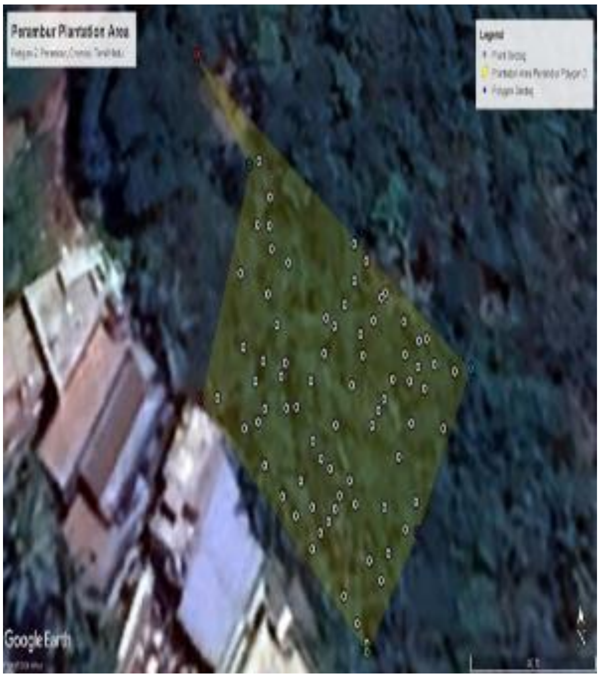
	
Polygon 1	**Polygon 2**
Site - ICF, Chennai, Tamil Nadu	

Figure 9. Geo-tagged plantation site – ICF, Chennai

The plantation area is delineated within two polygons. These plantation areas encompass approximately 0.063 hectares divided into 2 patches. 110 plants were geo-tagged along with their growth parameters. Additionally, 33m by 33m plots were measured to gain insights into the survival percentage within the planted area.

The geo-tagged images indicate individual plant locations within the polygon. By analyzing the spatial distribution, it can be said that:

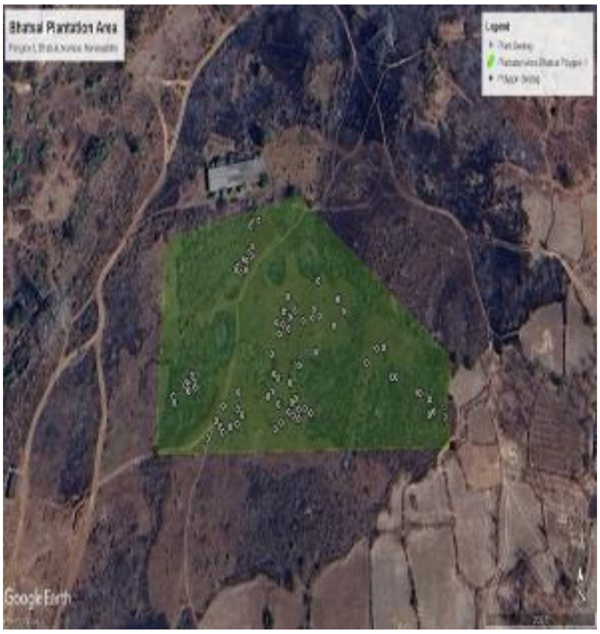
- **Uniform distribution:** The plants are evenly spaced in both polygons, suggesting a well-planned planting strategy, but it can be said that the plantation density is low in both polygons as the geotagged plantation samples are at a distance across the polygons.

3.1.3 Maharashtra:

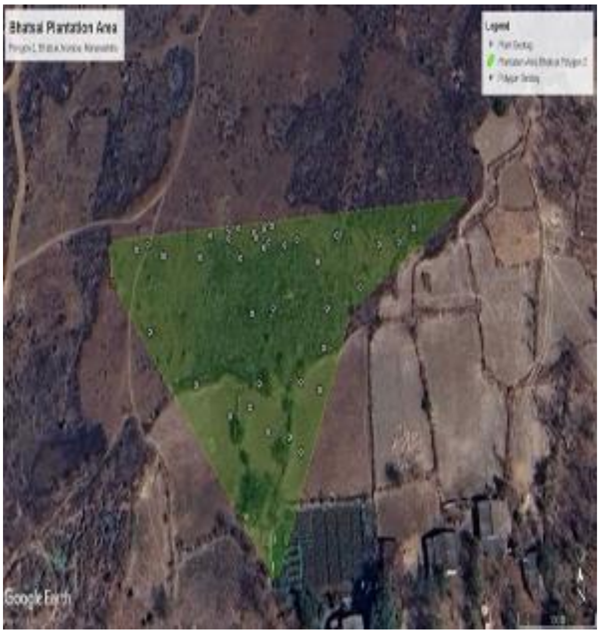
There are four plantation sites in the state. The analysis of each site is detailed below:

Bhatsai, Mumbai

Bhatsai plantation site is in the Thane district of Maharashtra, the western part of the state. These conventional plantation techniques serve as vital tools for reforestation and soil conservation, enhancing the local environment and contributing to the ecological sustainability of the area.



Polygon 1



Polygon 2

Polygon 3

Site - Bhatsai, Mumbai, Maharashtra

Figure 10. Geo-tagged plantation site –Bhatsai

The plantation area in Bhatsai, Thane, is delineated within three polygons. The areas are as follows: Polygon-1 covers 1.4657 hectares, Polygon-2 spans 0.6441 hectares, and Polygon-3 extends across 0.8848 hectares. In total, these plantation areas encompass approximately 2.99 hectares. 220 plants were geo-tagged along with their growth parameters. Additionally, 33m by 33m plots were measured to gain insights into the survival percentage within the planted area.

The geo-tagged images indicate individual plant locations within the polygon. By analyzing the spatial distribution, it can be said that:

- **Uniform distribution:** The plants are evenly spaced in Polygon 3, suggesting a well-planned planting strategy, while Polygons 1 and 2 show scattered or unevenly spread plantations.
- **Clustered areas:** There are clusters in certain parts of polygons 1 and 2, indicating areas of higher soil fertility or water availability.

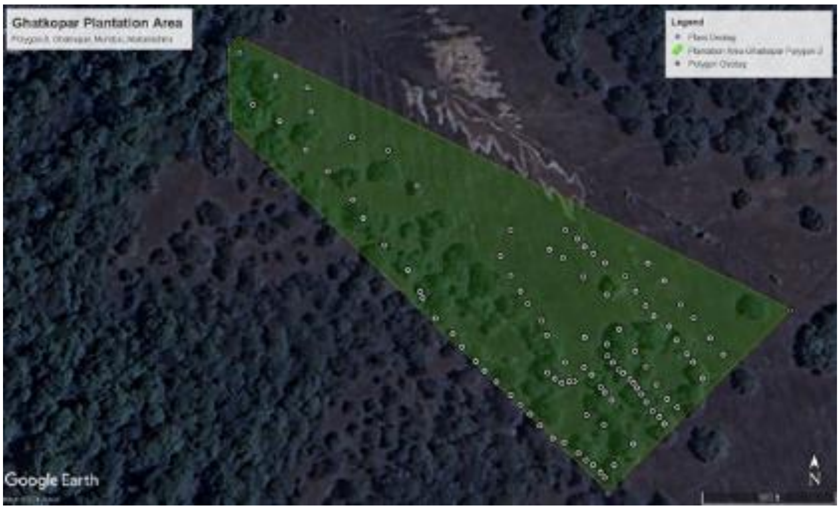
For instance, the northern section of both polygons shows a higher plant density, while the southern section shows an exceptionally low density. This variation may require differential management practices.

Ghatkopar, Mumbai

The mangrove site is in Ghatkopar, in the eastern suburbs of Mumbai. This strategic location is ideal for the mangrove plantation project, which aims to restore and protect the coastal ecosystem and is maintained by the Forest Department, Maharashtra. By leveraging the natural tidal flows of the local stream, the project seeks to enhance coastal resilience, prevent erosion, and support biodiversity in the region.

Polygon 1

Polygon 2



Polygon 3

Site - Ghatkopar, Mumbai, Maharashtra

Figure 11. Geo-tagged plantation site – Ghatkopar

The plantation area in Ghatkopar is delineated within three polygons. The areas are as follows: Polygon-1 covers 0.2309 hectares, Polygon-2 spans 1.4906 hectares, and Polygon-3 extends across 0.5458 hectares. In total, these plantation areas encompass approximately 2.3 hectares. 310 plants were geo-tagged along with their growth parameters. Additionally, 33m by 33m plots were measured to gain insights into the survival percentage within the planted area.

The geo-tagged images indicate individual plant locations within the polygon. By analyzing the spatial distribution, it can be said that:

- **Uniform distribution:** The plants are evenly spaced in Polygon 2, suggesting a well-planned planting strategy, while Polygons 1 and 3 show scattered or unevenly spread plantations.
- **Clustered areas:** There are clusters in certain parts of the polygon 1 and 3, indicating areas of higher soil fertility or water availability.

For instance, the Northern section of polygon 3 shows a higher plant density, while the southern section shows an exceptionally low density. This variation may require differential management practices.

Miyawaki, Mumbai

The Miyawaki plantation site is in Mira Bhyander, in the northern suburbs of Mumbai, Maharashtra. Positioned strategically along the western coastline, this site was transformed using the Miyawaki urban forestry technique to create a green space amidst residential and commercial developments.

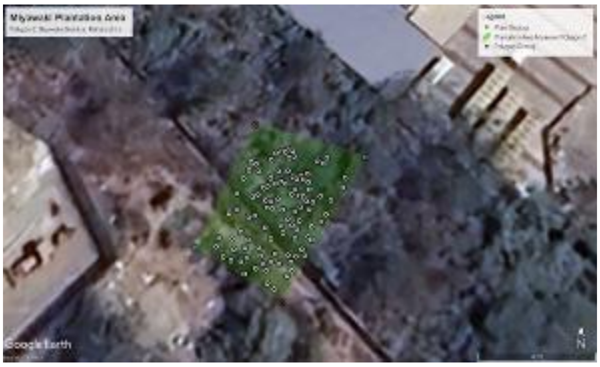
	
Polygon 1	**Polygon 2**
	
Polygon 3	**Polygon 4**
Site - Bhyander, Mumbai, Maharashtra	

Figure 12. Geo-tagged plantation site –Bhyander

The plantation area in Mira Bhyander is delineated within four polygons. The areas are as follows: Polygon-1 covers 0.0330 hectares, Polygon-2 spans 0.0210 hectares, Polygon-3 extends across 0.0427 hectares, and Polygon-4 encompasses 0.0358 hectares. In total, these plantation areas encompass approximately 0.13

hectares. 300 plants were geo-tagged along with their growth parameters. Additionally, 33m by 33m plots were measured to gain insights into the survival percentage within the planted area.

The geo-tagged images indicate individual plant locations within the polygon. By analyzing the spatial distribution, it can be said that:

- **Uniform Distribution:** The plants are evenly spaced in both polygons, suggesting a well-planned planting strategy, but it can be said that the plantation density is low in both polygons as the geotagged plantation samples are at a distance across the polygons.

Rayate, Mumbai

The plantation site is in Rayate, a village in the Thane district of Maharashtra. Positioned northeast of Thane city, the conventional plantation techniques serve as vital tools for reforestation and soil conservation, enhancing the local environment and contributing to the ecological sustainability of the area.

Polygon 1

Site - Rayate, Thane, Maharashtra

Figure 13. Geo-tagged plantation site –Rayate.

The plantation area in Rayate, Thane is delineated within a single polygon. The area is as follows: Polygon-1 covers 0.5528 hectares**.** 300 plants were geo-tagged along with their growth parameters. Additionally, 33m by 33m plots were measured to gain insights into the survival percentage within the planted area.
The geo-tagged images indicate individual plant locations within the polygon. By analyzing the spatial distribution, it can be said:

- **Uniform Distribution:** The plants are not evenly spaced in Polygon, suggesting scattered plantations, unevenly spread plantations or low survival in the area.
- **Clustered Areas:** There are clusters in certain parts of the polygon, indicating areas of higher soil fertility or water availability.

3.1.4 Haryana:

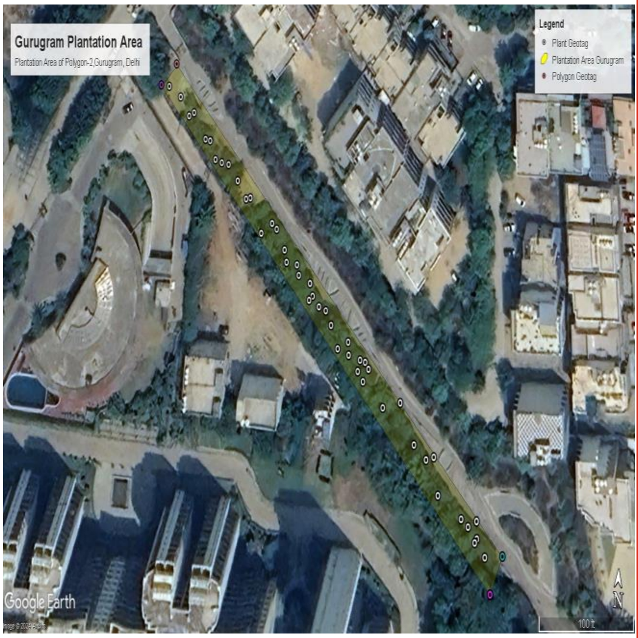
There is one plantation site in Haryana. The analysis is detailed below:

Badshahpur, Gurugram

The conventional plantation site is in Badshahpur, in the southern part of Gurugram. Surrounded by high-density residential areas, this site was transformed using conventional urban forestry techniques to create a green oasis amidst the urban landscape.

<table>
<tr><td>

</td><td>



</td></tr>
<tr><td>Polygon 1</td><td>Polygon 2</td></tr>
<tr><td colspan="2">Site - Badshahpur, Gurgaon</td></tr>
</table>

Figure 14. Geo-tagged plantation site – Badshahpur, Gurgaon

The plantation area is delineated within two polygons. These plantation areas encompass approximately 0.3 hectares divided into 2 patches. 75 plants were geo-tagged along with their growth parameters. Additionally, entire plots were measured to gain insights into the survival percentage.

The geo-tagged images indicate individual plant locations within the polygon. By analyzing the spatial distribution, it can be said that:

- **Uniform distribution:** The plants are evenly spaced in both polygons, indicating a well-planned planting strategy. The high plantation density in both polygons is evident from the geotagged plantation samples distributed across the polygons.

3.2. Temporal change detection

Temporal change detection was carried out using Google Earth imageries[22]. The process involves comparing the baseline kml location (usually from the initial plantation year) with the present kml location. Yellow lines were used to delineate polygons representing the plantation areas. These polygons were analyzed using the best available historical and current satellite images from Google Earth Engine. By visually inspecting these time-lapse images, cylindrical or 3D impressions indicative of tree canopies were identified, providing qualitative growth measures. The quantitative analysis involved estimating canopy cover to assess vegetation health and density.

The comparison between the base year and the most recent year images highlights changes in growth and density within the plantation polygons. The integrated approach of GIS, remote sensing, and image analysis effectively monitors and evaluates changes in plantation areas over time, offering valuable insights into the success of the plantation efforts.

3.2.1 West Bengal:

The state comprises four plantation sites. A temporal change analysis of each site is provided below.

Taranagar, Patharpratima

The Taranagar site in Patharpratima, West Bengal, underwent mangrove plantation activities in 2020. The images illustrate temporal changes at the plantation site, with a yellow circle highlighting the growth and emerging canopy cover.

Plantation year (2020)	Present situation (2023)
	

Polygon-1

[22] https://earthengine.google.com/timelapse/

Plantation year (2020)	Present situation (2023)
	
Polygon-2	
	
Polygon-3	

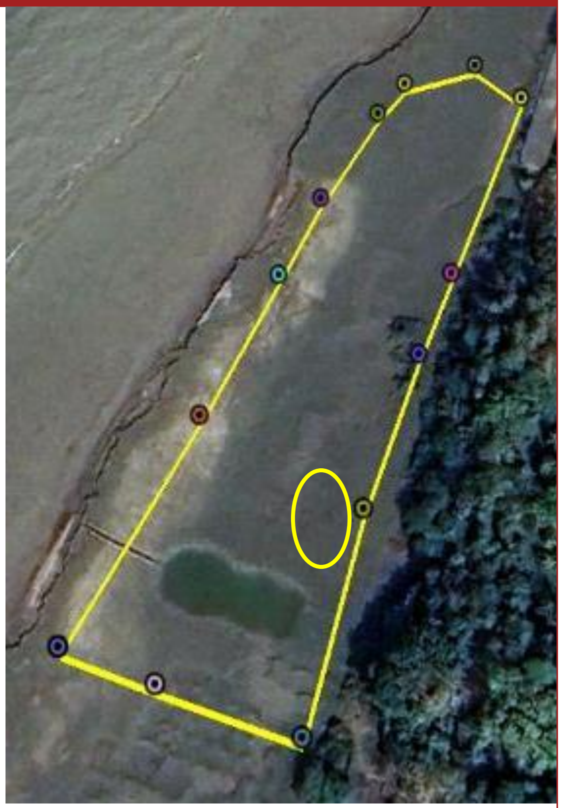
Figure 15. Temporal changes- Taranagar

- **Plantation year (2020):**
    - The initial imagery from 2020 shows the preliminary stages of the plantation. The canopy cover is sparse, with young saplings beginning to establish themselves.
    - Much of the ground cover is still visible, indicating the forest is in its infancy.

- **Present situation (2023):**
  - The imagery from 2023 shows positive changes in the canopy cover, although the variations are minor.
  - There are subtle differences in vegetation density, with some patches appearing slightly denser and others sparser.
  - These minor changes could be attributed to natural growth cycles. Areas showing no changes might be experiencing selective logging activities or early signs of environmental stress, such as mild pest infestations or water scarcity.
  - The overall canopy cover has improved since 2020, indicating some level of growth and development.

Mandirtala, Sagar Island

The Mandirtala site in Sagar, West Bengal, underwent mangrove plantation activities in 2022. The images illustrate temporal changes at the plantation site, with yellow markers highlighting changes in growth and emerging canopy cover.

Plantation year (2022)	Present situation (2023)
	

Polygon-1

Plantation year (2022)	Present situation (2023)
	
Polygon-2	

Figure 16. Temporal changes- Mandirtala

- **Plantation year (2022):**
  - The initial imagery from 2022 shows the preliminary stages of the mangrove plantation. The canopy cover is sparse, with young saplings beginning to establish themselves.
  - The ground cover is visible, indicating that the plantation is in its infancy.
- **Present situation (2023):**
  - The imagery from 2023 shows positive changes in the canopy cover, with minor variations in vegetation density.
  - The canopy varies from slight to deep green, indicating subtle vegetation density and health differences.
  - There are patches where the foliage appears slightly denser or sparser, showing early signs of natural growth cycles.

Bajpukur, Kakdwip

The Bajpukur site in Kakdwip, West Bengal, underwent initial mangrove plantation activities in 2023. The images illustrate temporal changes at the plantation site, with yellow markers highlighting changes in growth and emerging canopy cover.

Plantation year (2023)	Present situation (2024)
	
Polygon-1	
	
Polygon-2	
	
Polygon-3	

Plantation year (2023)	Present situation (2024)
	

Polygon-4

Polygon-5

Polygon-6

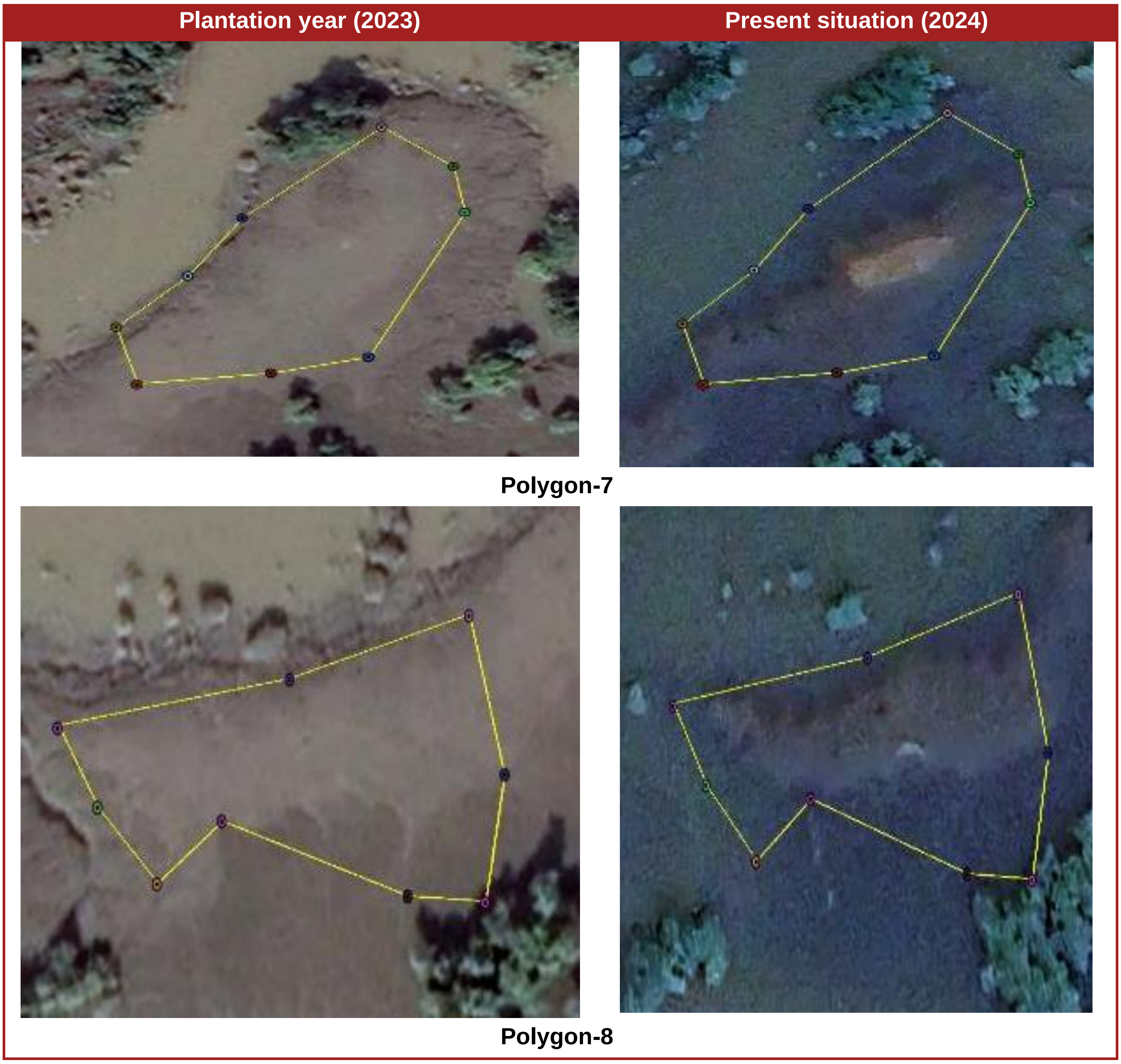


Figure 17. Temporal changes- Bajpukur

- **Plantation year (2023):**
    - The imagery from 2023 captures the preliminary stages of the plantation, showing a sparse canopy covered with young saplings just beginning to establish themselves.
    - The ground cover is minimal, reflecting the nascent stage of the plantation.
- **Present situation (2024):**
    - The imagery from 2024 shows positive changes in the canopy cover, with minor variations in vegetation density.
    - The canopy varies from slight to deep green, indicating subtle vegetation density and health differences.
    - There are patches where the foliage appears slightly denser or sparser, showing early signs of natural growth cycles.
    - The visible changes correspond to a layer of vegetation consistent with a one-year-old mangrove plantation, with varying growth rates across different areas.

Rajarhat, Kolkata

The Rajarhat site in Kolkata, West Bengal, underwent conventional plantation activities in 2019. The images illustrate temporal changes at the plantation site, with yellow markers highlighting changes in growth and emerging canopy cover.

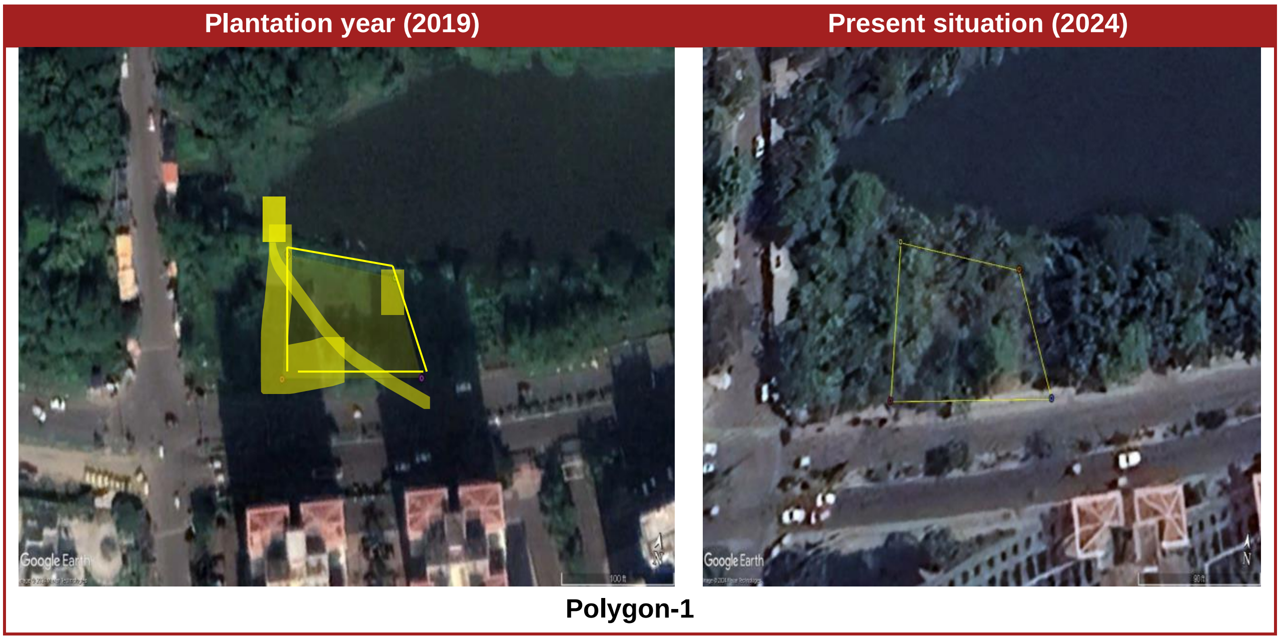


Figure 18. Temporal Changes- Rajarhat, Kolkata

- **Plantation year (2019):**
  - The initial imagery from 2019 shows the preliminary stages of the plantation. The canopy cover is sparse, with young saplings beginning to establish themselves.
  - The ground cover is visible, indicating that the plantation is in its infancy.

- **Present situation (2024):**
  - The imagery from 2024 demonstrates significant positive changes in the canopy cover.
  - There is a marked increase in vegetation density, with a healthy and robust canopy covering the area.
  - Areas sparse or degraded in 2019 are now lush and green, highlighting successful afforestation efforts.
  - The existing trees exhibit vigorous growth and a well-established canopy, and the diversity of the canopy structure indicates that multiple species have thrived, contributing to a heterogeneous and resilient ecosystem.

3.2.2 Tamil Nadu:

There are two plantation sites in the state. The temporal changes of each site are detailed below:

Perambur, Chennai

The Perambur site in Chennai underwent Miyawaki plantation activities in 2019 and 2020. The Miyawaki method, known for its dense and rapid forestation using native species, was employed to rejuvenate the area, enhance biodiversity, and create a sustainable urban forest. The images illustrate temporal changes at the plantation site, with yellow markers highlighting changes in growth and emerging canopy cover.

Plantation year (2020)	Present situation (2024)
	
Polygon-1	
	
Polygon-2	

Figure 19. Temporal changes- Perambur

- **Plantation year (2020):**
  - The initial imagery from 2020 shows the preliminary stages of the Miyawaki plantation. The canopy cover is sparse, with young saplings beginning to establish themselves.
  - The vegetation density is low, and the planted saplings are identifiable, indicating the initial stages of growth.
  - Much of the ground cover is visible, potentially due to initial planting density or species selection.
- **Present situation (2024):**
  - The imagery from 2024 demonstrates significant positive changes in the canopy cover.

- There is a marked increase in vegetation density, with a healthy and robust canopy covering the area.
- Areas sparse or degraded in 2020 are now lush and green, highlighting successful afforestation efforts.
- Although the number of trees remains lower than in typical Miyawaki plantations, the existing trees exhibit vigorous growth and a well-established canopy.
- The diversity of the canopy structure indicates that multiple species have thrived, contributing to a heterogeneous and resilient ecosystem.

3.2.3 Maharashtra:

There are four plantation sites in the state. The temporal changes of each site are detailed below:

Bhatsai, Mumbai

The Bhatsai site in Mumbai, Maharashtra, underwent block plantation activities in 2022. The images illustrate temporal changes at the plantation site, with yellow markers highlighting changes in growth and emerging canopy cover.

Plantation year (2022)	Present situation (2024)
	
Polygon-1	

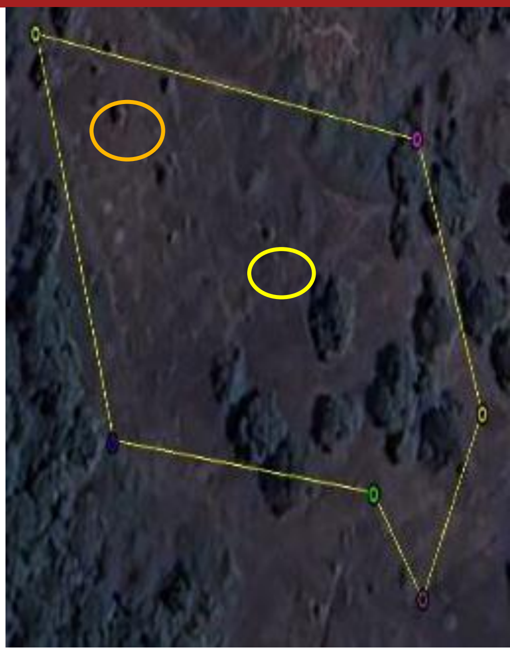
Figure 20. Temporal changes- Bhatsai

- **Plantation year (2022):**
  - The initial imagery from 2022 shows the preliminary stages of the plantation. The canopy cover is sparse, with young saplings beginning to establish themselves.
  - Much of the ground cover is still visible, indicating the forest is in its infancy.
- **Present situation (2024):**
  - The imagery from 2024 shows positive changes in the canopy cover, although the variations are minor.

- There are subtle differences in vegetation density, with some patches appearing slightly denser and others sparser.
- These minor changes could be attributed to natural growth cycles, selective logging activities, or early signs of environmental stress, such as mild pest infestations or water scarcity.
- The overall canopy cover has improved since 2020, indicating some level of growth and development.

Ghatkopar, Mumbai

The Ghatkopar site in Mumbai, Maharashtra, underwent initial mangrove plantation activities in 2021. The images illustrate temporal changes at the plantation site, with yellow markers highlighting changes in growth and emerging canopy cover.

Plantation year (2021)	**Present situation (2024)**
	
Polygon-1	
	
Polygon-2	

Plantation year (2021)	Present situation (2024)

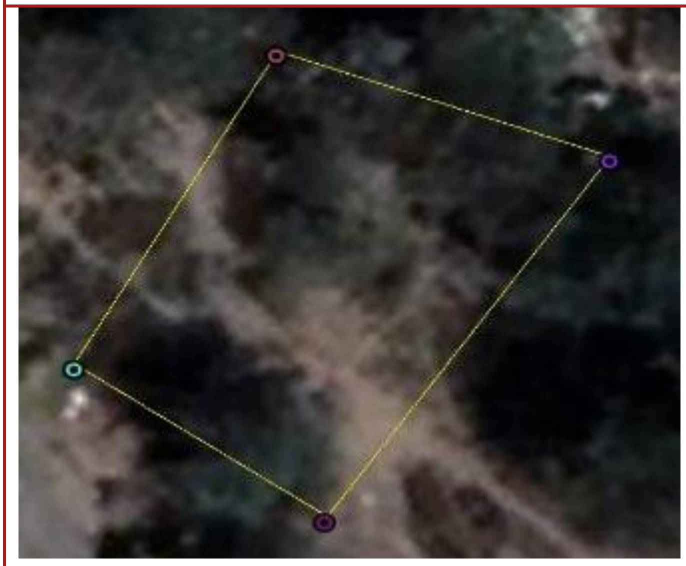
Polygon-3

Figure 21. Temporal changes- Ghatkopar

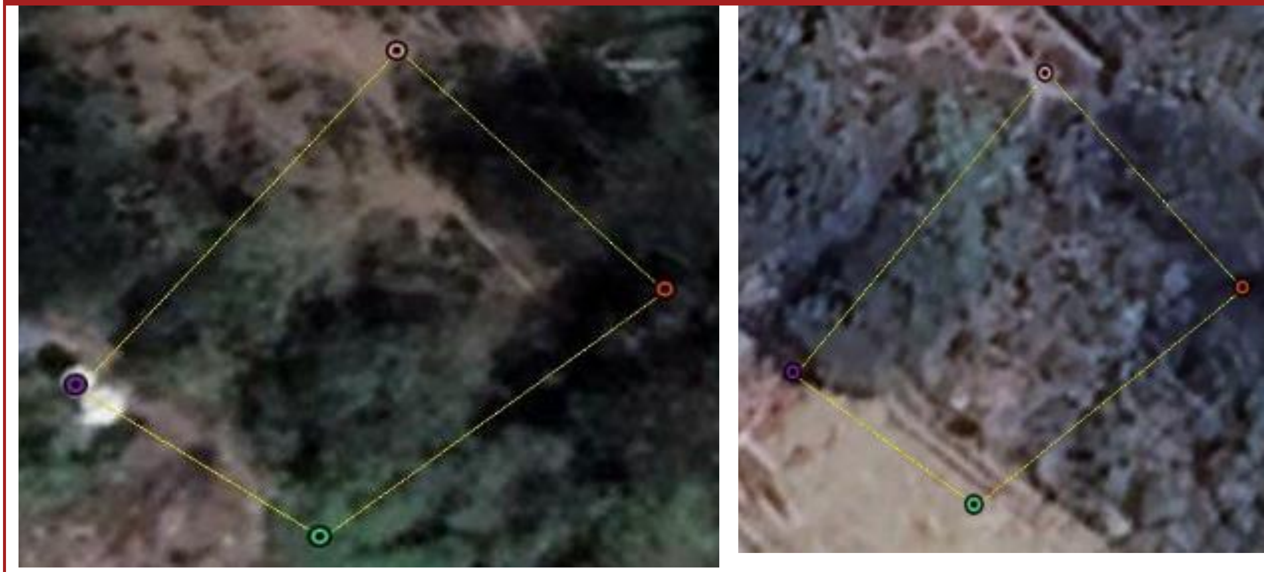
- **Plantation year (2022):**
  - The initial imagery from 2021 shows the preliminary stages of the mangrove plantation. The canopy cover is sparse, with young saplings beginning to establish themselves.
  - A large group of tree canopy covers indicate earlier plantation on the site.
  - The ground cover is visible, indicating that the plantation is in its infancy.
  - The planted saplings are identifiable, suggesting organized planting efforts.
- **Present situation (2023):**
  - The imagery from 2024 shows positive changes in the canopy cover, with minor variations in vegetation density.
  - The canopy varies from slight to deep green, indicating subtle vegetation density and health differences.
  - There are patches where the foliage appears slightly denser or sparser, showing early signs of natural growth cycles, selective logging, or environmental stress factors such as mild pest infestations or water scarcity.
  - The changes are visible as a layer of plantation typical for a two-year-old mangrove plantation, with some areas showing more vigorous growth than others.

Bhyander, Mumbai

The Bhyander site underwent a Miyawaki plantation activity in 2022. The Miyawaki method is renowned for its ability to create dense, native forests using a high-density planting technique that accelerates forest growth, improving biodiversity and ecological balance. The images illustrate temporal changes at the plantation site, with yellow markers highlighting changes in growth and emerging canopy cover.

Plantation year (2022)	Present situation (2024)
	
Polygon-1	
	
Polygon-2	
	
Polygon-3	

Plantation year (2022)	Present situation (2024)



Polygon-4

Figure 22. Temporal changes- Bhyander

- **Plantation year (2022):**
  - Initial imagery from 2022 shows the preliminary stages of the Miyawaki plantation. Some tree's canopy covers indicate earlier plantation on the site.
  - The canopy cover is sparse, with young saplings and minimal foliage density, typical of newly established plantations.
  - Ground cover appears exposed, with visible patches of planted saplings.
- **Present situation (2024):**
  - The entire area now exhibits a robust and dense canopy cover, characteristic of a well-established young forest.
  - The previously sparse and exposed areas are now lush with thick foliage, demonstrating the rapid growth and success of the Miyawaki method.
  - The canopy density and coverage indicate healthy and vigorous plant growth, with various native species contributing to a diverse ecosystem.
  - Although the number of trees remains lower than in typical Miyawaki plantations, the existing trees exhibit vigorous growth and a well-established canopy.

Rayate, Mumbai

The Rayate site in Mumbai, Maharashtra, underwent block plantation activities in 2021. The images illustrate temporal changes at the plantation site, with yellow markers highlighting changes in growth and emerging canopy cover.

Plantation year (2021)	Present situation (2024)
	
Polygon-1	

Figure 23. Temporal changes- Rayate

- **Plantation year (2021):**
  - The initial imagery from 2021 shows the preliminary stages of the plantation. The canopy cover is sparse, with young saplings beginning to establish themselves. Some tree's canopy covers indicate earlier plantation on the site.
  - Much of the ground cover is still visible, indicating the forest is in its infancy.
- **Present situation (2024):**
  - The imagery from 2024 shows positive changes in the canopy cover, although the variations are minor.
  - There are subtle differences in vegetation density, with some patches appearing slightly denser and others sparser.
  - These minor changes could be attributed to natural growth cycles, selective logging activities, or early signs of environmental stress, such as mild pest infestations or water scarcity.
  - The overall canopy cover has improved since 2020, indicating some level of growth and development.

3.2.4 **Haryana**:

There are two plantation sites in the state. The temporal changes of each site are detailed below:

Badshahpur, Gurugram

The Badshahpur site in Gurugram underwent conventional plantation activities in 2019. The conventional method was employed to rejuvenate the area, enhancing biodiversity, and creating a sustainable urban forest. The images illustrate temporal changes at the plantation site, with yellow markers highlighting changes in growth and emerging canopy cover.

Plantation year (2019) | **Present situation (2024)**

Polygon-1

Polygon-2

Figure 24. Temporal changes- Badshahpur

- **Plantation year (2020):**
  - The initial imagery from 2019 shows the preliminary stages of the conventional plantation. The canopy cover is sparse, with young saplings beginning to establish themselves.
  - Much of the ground cover is visible, potentially due to initial planting density or species selection.
- **Present situation (2024):**
  - The imagery from 2024 demonstrates significant positive changes in the canopy cover.
  - There is a marked increase in vegetation density, with a healthy and robust canopy covering the area.
  - Areas sparse or degraded in 2019 are now lush and green, highlighting successful afforestation efforts.
  - The diversity of the canopy structure indicates that multiple species have thrived, contributing to a heterogeneous and resilient ecosystem.

3.3. Plantation survey

Several aspects of the plantation were collected, such as tree species, health, and other relevant information. 15% of the observed plantation numbers were randomly selected from each site for this purpose. The data will serve as a baseline to measure these species' future growth and health. By comparing future data against this baseline, conservationists can assess the effectiveness of afforestation and reforestation efforts.

Photo 3. Plantation survey (*Site: Mira- Bhyander*)

3.3.1 West Bengal:

The information below provides an analysis of the plantation sites in West Bengal, including the average height (in meters) and girth (in centimetres) of each species, along with their conservation status.

Taranagar, Patharpratima

Table 5: Species-wise height and girth - Taranagar

Species	Average height (in m)	Average girth (in cm)	Conservation status
Avicennia marina	1.41	6.43	Least Concern
Avicennia officinalis	1.39	6.62	Least Concern
Bruguiera cylindrica	0.90	3.67	Least Concern
Bruguiera gymnorhiza	1.19	4.95	Least Concern
Ceriops sp	0.85	2.72	Least Concern

Among the species listed, *Avicennia marina* and *Avicennia officinalis* have the highest average heights (1.41 m and 1.39 m, respectively) and girths (6.43 cm and 6.62 cm, respectively). These species seem to show better growth compared to others. *Ceriops sp* appears to be the shortest, with an average height of 0.85 m and the smallest girth of 2.72 cm. This might be due to species-specific growth patterns or environmental conditions.

Mandirtala, Sagar Island

Table 6: Species-wise height and girth- Sagar Island

Species	Average height (in m)	Average girth (in cm)	Conservation status
Bruguiera cylindrica	0.22	1.65	Least Concern
Bruguiera gymnorhiza	0.24	1.70	Least Concern
Ceriops sp	0.10	1.00	Least Concern
Heritiera fomes	0.77	1.50	Endangered
Rhizophora mucronata	0.66	4.03	Least Concern

Heritiera fomes have the highest average height (0.77 m). Despite being endangered, it shows good growth compared to other species in this dataset. *Rhizophora mucronata* has the second-highest average height (0.66 m) and the most considerable average girth (4.03 cm). This indicates robust growth conditions for this species. *Ceriops sp* is the shortest species, with an average height of 0.10 m and the smallest girth of 1.00 cm. This could be due to species-specific growth patterns or less favorable conditions. *Bruguiera cylindrica* and *Bruguiera gymnorhiza* have similar growth metrics with heights of 0.22 m and 0.24 m and girths of 1.65 cm and 1.70 cm, respectively, indicating consistent growth patterns.

Bajpukur, Kakdwip

Table 7: Species-wise height and girth- Kakdwip

Species	Average height (in m)	Average girth (in cm)	Conservation status
Avicennia marina	0.2	1.5	Least Concern
Bruguiera cylindrica	0.2	1.5	Least Concern
Bruguiera gymnorhiza	0.3	2.0	Least Concern
Ceriops tagal	0.2	1.5	Least Concern
Rhizophora mucronata	0.2	1.5	Least Concern

Bruguiera gymnorhiza has the highest average height (0.3 m) and girth (2.0 cm) among the species in Kakdwip. This indicates better growth conditions or inherent growth characteristics for this species. Avicennia marina, Bruguiera cylindrica, Ceriops tagal, and Rhizophora mucronata all have similar average heights (0.2 m) and girths (around 1.5 cm). This suggests consistent growth conditions across these species.

Rajarhat, Kolkata

Table 8: Species-wise height and girth Rajarhat

Species	Average of Height (in m)	Average of Girth (in cm)	Conservation Status
Alstonia scholaris	3.02	7.30	Least Concern
Azadirachta indica	3.15	5.50	Least Concern
Cassia fistula	4.50	6.50	Least Concern
Lagerstroemia speciosa	5.59	12.79	Not Evaluated
Mimusops elengi	3.38	5.63	Least Concern
Nyctanthes arbor-tristis	4.85	8.00	Least Concern
Putranjiva roxburghii	1.00	2.50	Not Evaluated
Saraca asoca	1.30	2.50	Vulnerable

Species	Average of Height (in m)	Average of Girth (in cm)	Conservation Status
Spathodea campanulata	6.75	16.50	Least Concern
Syzygium cumini	2.00	4.50	Least Concern
Tectona grandis	8.60	14.70	Not Evaluated
Terminalia arjuna	7.00	16.00	Not Evaluated

Spathodea campanulata has the highest average height (6.75 m) and the largest girth (16.50 cm), indicating robust growth. Tectona grandis follows with a significant height of 8.60 m and a substantial girth (14.70 cm), showing excellent growth conditions. *Terminalia arjuna* also displays robust growth with a height of 7.00 m and a girth of 16.00 cm. *Lagerstroemia speciosa* has a considerable height of 5.59 m and a notable girth (12.79 cm), reflecting healthy growth patterns. *Nyctanthes arbor-tristis and Cassia fistula* exhibit moderate growth, with heights of 4.85 m and 4.50 m respectively, and girths of 8.00 cm and 6.50 cm, indicating consistent but varied growth. *Mimusops elengi and Azadirachta indica* show moderate growth with heights of 3.38 m and 3.15 m, respectively, and girths of 5.63 cm and 5.50 cm. *Alstonia scholaris* has an average height of 3.02 m and a girth of 7.30 cm, suggesting steady growth under suitable conditions*. Syzygium cumini* shows moderate growth with a height of 2.00 m and a girth of 4.50 cm, due to species-specific growth patterns or environmental factors. *Saraca asoca and Putranjiva roxburghii* display the smallest average heights of 1.30 m and 1.00 m, respectively, and both have a girth of 2.50 cm, indicating limited growth, due to specific environmental conditions.

3.3.2 Tamil Nadu:

The following information provides an analysis of the plantation sites in Tamil Nadu, including the average height (in meters) and girth (in centimetres) of each species, along with their conservation status and growth quality:

Perambur, Chennai

Table 9: Species-wise height and girth – Perambur

Species	Average height (in m)	Average girth (in cm)	Conservation status
Butea monosperma	1.54	7.00	Least Concern
Caryota mitis	4.00	35.00	Least Concern
Ceiba pentandra	6.56	56.20	Least Concern
Dalbergia sissoo	5.55	29.45	Least Concern
Millettia pinnata	2.09	9.15	Least Concern
Neolamarckia cadamba	9.00	50.00	Data not available
Phyllanthus acidus	3.50	12.00	Data not available
Pithecellobium dulce	4.25	20.83	Least Concern
Swietenia mahagoni	2.76	9.50	Near Threatened
Terminalia arjuna	3.05	11.23	Data not available
Terminalia catappa	4.00	15.00	Least Concern

Neolamarckia cadamba shows the highest average height (9.00 m) and a significant girth (50.00 cm), indicating robust growth. *Ceiba pentandra* follows with a height of 6.56 m and the most considerable girth (56.20 cm), showing excellent growth conditions. *Dalbergia sissoo* also indicates robust growth with a height of 5.55 m and a girth of 29.45 cm. *Caryota mitis, Pithecellobium dulce, and Terminalia catappa* have heights around 4.00 m, with varying girths, indicating consistent but varied growth. *Phyllanthus acidus, Terminalia arjuna, Swietenia mahagoni, and Millettia pinnata* show moderate growth with heights between 2.09 m and

3.50 m. *Butea monosperma* shows the most diminutive average height (1.54 m) and girth (7.00 cm) due to species-specific growth patterns or environmental factors.

3.3.3 Maharashtra:

The following information provides an analysis of the plantation sites in Tamil Nadu, including the average height (in meters) and girth (in centimetres) of each species, along with their conservation status and growth quality:

Bhatsai, Thane

Table 10: Species-wise height and girth- Bhatsai

Species	Average height (in m)	Average girth (in cm)	Conservation status
Azadirachta indica	0.15	1.25	Least Concern
Dalbergia sissoo	0.18	1.20	Least Concern
Mangifera indica	0.10	2.00	Least Concern
Millettia pinnata	0.17	1.39	Least Concern
Phyllanthus emblica	0.36	2.26	Least Concern
Syzygium cumini	0.20	1.70	Least Concern
Tectona grandis	0.14	1.68	Endangered

Phyllanthus emblica shows the highest average height (0.36 m) and the most considerable girth (2.26 cm), indicating robust growth among the species listed. *Syzygium cumini* follows with an average height (0.20 m) and a girth of 1.70 cm. Dalbergia sissoo also shows moderate growth with a height of 0.18 m and a girth of 1.20 cm. *Millettia pinnata* has a height of 0.17 m and a girth of 1.39 cm. Azadirachta indica and Tectona grandis have similar growth metrics with heights of 0.15 m and 0.14 m and girths of 1.25 cm and 1.68 cm, respectively. *Mangifera indica* shows the most diminutive average height (0.10 m) but has a greater girth (2.00 cm). It suggests that it may not grow as tall initially but develops a thicker trunk.

Ghatkopar, Mumbai

Table 11: Species-wise height and girth- Ghatkopar

Species	Average height (in m)	Average girth (in cm)	Conservation status
Avicennia marina	0.72	2.91	Least Concern
Ceriops tagal	0.41	2.38	Least Concern
Rhizophora apiculata	0.44	4.06	Least Concern
Rhizophora stylosa	0.58	3.06	Least Concern

Avicennia marina shows the highest average height (0.72 m) and a girth of 2.91 cm, indicating robust growth among the species listed. *Rhizophora stylosa* follows with an average height (0.58 m) and a girth of 3.06 cm, showing consistent growth. *Rhizophora apiculata* has a height of 0.44 m but the most considerable girth (4.06 cm) among the species, suggesting a thicker trunk development. *Ceriops tagal* has the most diminutive average height (0.41 m) and girth (2.38 cm), indicating slower growth than other species.

Bhyander, Mumbai

Table 12: Species-wise height and girth- Bhyander

Species	Average height (in m)	Average girth (in cm)	Conservation status
Aegle marmelos	2.06	5.80	Near Threatened
Albizia odoratissima	4.83	17.17	Least Concern
Azadirachta indica	3.34	8.44	Least Concern
Bauhinia racemosa	1.59	3.65	Least Concern
Bombax ceiba	4.00	12.61	Least Concern
Butea monosperma	1.40	5.00	Least Concern
Caesalpinia pulcherrima	6.00	16.00	Least Concern
Ceiba pentandra	2.10	17.00	Least Concern
Cordia dichotoma	3.89	14.00	Least Concern
Dalbergia latifolia	1.10	4.00	Vulnerable
Erythrina suberosa	2.00	6.00	Data not available
Ficus benghalensis	2.17	6.00	Least Concern
Ficus carica	3.00	5.00	Least Concern
Ficus racemose	4.25	27.50	Data not available
Ficus religiosa	2.73	5.58	Least Concern
Hibiscus rosa-sinensis	3.06	6.65	Data not available
Jasminum brachyscyphum	1.00	1.50	Least Concern
Justicia adhatodoides	2.35	5.52	Least Concern
Lawsonia inermis	2.27	1.50	Least Concern
Limonia acidissima	0.30	2.00	Data not available
Mangifera indica	1.47	4.43	Least Concern
Mimusops elengi	1.70	4.00	Least Concern
Morus alba	3.80	6.00	Least Concern
Murraya paniculata	1.15	2.50	Data not available
Nyctanthes arbor-tristis	3.17	6.00	Least Concern
Polyalthia longifolia	1.13	2.78	Least Concern
Senna siamea	1.81	3.57	Least Concern
Syzygium cacuminis	1.56	3.77	Data not available
Syzygium cumini	1.10	1.50	Least Concern
Tabernaemontana divaricate	1.25	2.50	Data not available
Tamarindus indica	1.65	3.40	Least Concern
Terminalia arjuna	1.05	4.00	Data not available
Terminalia catappa	2.00	4.75	Least Concern
Thespesia populnea	2.80	7.50	Least Concern
Vitex negundo	2.00	6.40	Least Concern

Caesalpinia pulcherrima shows the highest average height (6.00 m) and a significant girth (16.00 cm), indicating robust growth. *Albizia odoratissima* also shows robust growth with a height of 4.83 m and a girth of 17.17 cm. Ficus racemose has the most considerable girth (27.50 cm) and a substantial height (4.25 m), showing excellent growth conditions. *Cordia dichotoma, Bombax ceiba, Nyctanthes arbor-tristis, and Azadirachta indica* show moderate growth with heights between 3.34 m and 4.00 m. *Dalbergia latifolia, Syzygium cumini, and Jasminum brachyscyphum* show smaller growth metrics, with heights around

1.10 m and girths around 1.50 cm. *Limonia acidissima* shows the most diminutive average height (0.30 m) and girth (2.00 cm) due to species-specific growth patterns or environmental factors.

Rayate, Mumbai

Table 13: Species-wise height and girth- Rayate

Species	Average Height (in m)	Average Girth (in cm)	Conservation Status
Dalbergia sissoo	1.40	3.80	Least Concern
Millettia pinnata	1.35	3.75	Least Concern
Phyllanthus emblica	0.90	4.40	Least Concern

Dalbergia sissoo shows the highest average height (1.40 m) and a girth of 3.80 cm, indicating robust growth. *Millettia pinnata* follows closely with a height of 1.35 m and a girth of 3.75 cm, showing consistent growth. *Phyllanthus emblica* has the most diminutive average height (0.90 m) but the most considerable girth (4.40 cm) among the three species. This suggests that it may not grow as tall but develops a thicker girth.

3.3.4 Haryana

Gurugram, Haryana

Table 14: Species-wise height and girth- Gurugram

Species	Average Height (in m)	Average Girth (in cm)	Conservation Status
Barleria popovii	1.30	6.13	Endangered
Butea monosperma	4.13	25.83	Not Evaluated
Clerodendrum phlomidis	2.50	13.00	Least Concern
Diospyros cordata	3.88	19.50	Data Deficient
Flueggea leucopyrus	2.03	8.67	Least Concern
Grewia flavescens	3.30	10.60	Least Concern
Helicteres isora	5.90	16.50	Not Evaluated
Hiptage benghalensis	4.00	16.00	Least Concern
Madhuca longifolia	1.90	9.00	Least Concern
Phyllanthus reticulatus	2.77	10.67	Not Evaluated
Salvadora persica	4.48	21.25	Least Concern
Tecomella undulata	4.85	18.00	Least Concern
Wrightia arborea	5.04	16.00	Least Concern

Helicteres isora shows the highest average height (5.90 m) and a significant girth (16.50 cm), indicating robust growth. *Wrightia arborea* follows with a height of 5.04 m and a substantial girth (16.00 cm), showing excellent growth conditions*. Tecomella undulata* also displays robust growth with a height of 4.85 m and a girth of 18.00 cm. Salvadora persica has a considerable height of 4.48 m and a notable girth (21.25 cm), reflecting healthy growth patterns. *Butea monosperma and Hiptage benghalensis* exhibit moderate growth, with heights of 4.13 m and 4.00 m respectively, and girths of 25.83 cm and 16.00 cm, indicating consistent but varied growth. *Diospyros cordata and Grewia flavescens* show moderate growth with heights of 3.88 m and 3.30 m respectively, and girths of 19.50 cm and 10.60 cm. *Phyllanthus reticulatus and Clerodendrum phlomidis* have heights of 2.77 m and 2.50 m respectively, with girths of 10.67 cm and 13.00 cm, suggesting steady growth under suitable conditions. *Barleria popovii* shows the most diminutive average height (1.30 m) and a girth (6.13 cm), due to species-specific growth patterns or environmental factors.

3.4. Survival rate

For each site, the evaluation was done on a representative plot of 33 m X 33 m (0.1 ha) size as a sample plot for our study. The number of plantations within this plot was counted, and data analysis was conducted based on the primary data collected from each site.

The survival rate is calculated site-wise using the following formula.

$$Survival\ rate = \frac{number\ of\ surving\ plants\ occuring\ in\ sample\ plot}{number\ of\ trees\ planted\ in\ sample\ plot}\ x\ 100$$

The table below represents the survival rate of each site:

Table 15: Survival rate calculation

State	Site	Plantation Type	Plantation Year	Survival Rate (%)	Category
West Bengal	Taranagar	Mangrove	2021	58.4	Moderate
West Bengal	Mandirtala	Mangrove	2022	21.0	Low
West Bengal	Bajpukur	Mangrove	2023	43.2	Moderate
West Bengal	Canning	Mangrove	2021	NA	NA[23]
West Bengal	Rajarhat	Conventional	2019	85	Very High
Haryana	Gurugram	Conventional	2019	91	Very High
Tamil Nadu	Perambur	Miyawaki	2020	19.4	Very Low
Tamil Nadu	Perambur	Miyawaki	2019	21.8	Low
Maharashtra	Bhyander	Miyawaki	2022	40.0	Moderate
Maharashtra	Bhatsai	Conventional	2022	9.4	Very Low
Maharashtra	Ghatkopar	Mangrove	2021	25.5	Low
Maharashtra	Rayate	Conventional	2021	11.1	Very Low

Category	Survival Rate (%)	Colour Code
Very Low	< 20	
Low	20 - 40	
Moderate	40 - 60	
High	60-80	
Very High	> 80	
NA	Data not available	

West Bengal (Mangrove plantations)

1. **Taranagar (2021):** The high survival rate in Taranagar can be attributed to effective community management, the absence of logging, and favorable slope conditions.

[23] The site was inaccessible.

2. **Mandirtala (2022):** The low survival rate in Mandirtala is primarily due to high erosion and flooding, which disturb the planted saplings. These environmental stressors significantly impact the establishment and growth of the mangroves.

3. **Bajpukur (2023):** The moderate survival rate in Bajpukur indicates resilience despite high tides and unsecured fencing that led to saplings being washed away and grazing are significant factors.

4. **Rajarhat (2019):** The exceptionally high survival rate at the Rajarhat site can be attributed to several key factors. Firstly, the strategic selection of the site and plant species ensured optimal growth conditions. Secondly, regular maintenance practices were diligently followed during the initial three years, addressing any emerging issues promptly. Lastly, active community involvement was crucial in developing a sense of ownership and ensuring consistent care.

   However, after the initial three-year management period, the municipal authorities have not taken ownership, and community engagement has declined. This has led to some instances of grazing and encouraging free rider behaviour. Despite these challenges, the initial maintenance efforts have resulted in a very high survival rate, demonstrating the importance of early and sustained management practices.

Tamil Nadu (Miyawaki plantations)

1. **Perambur (2020 and 2019):** The exceptionally low survival rate in Perambur can be attributed to multiple stressors, including grazing, water scarcity, human disturbance, and cutting. These factors collectively hinder the establishment and growth of the plantations.

Maharashtra (Various plantation types)

1. **Bhyander (2022):** The moderate survival rate in Bhyander suggests some resilience despite challenges posed by hard soil, water scarcity during summer, and dust pollution from nearby construction activities. These factors stress the saplings, impacting their growth and survival.

2. **Bhatsai (2022) and Rayate (2021):** The extremely low survival rate in Bhatsai is due to multiple severe stressors, including vehicle movement, hard soil, lack of water, absence of protection, fire, and grazing. These conditions create an inhospitable environment for the saplings, drastically reducing their survival chances.

3. **Ghatkopar (2021):** The low survival rate in Ghatkopar can be attributed to issues such as water logging in certain spots, weed management challenges, and pest management problems. The presence of grass and other vegetation covering the saplings contributes to vegetative competition, further hindering the establishment and growth of the mangroves.

Haryana

1. **Badshahpur (2019):** The exceptionally high survival rate at the Badshahpur site can be attributed to several key factors. Firstly, the strategic selection of the site and plant species has ensured optimal growth conditions. Secondly, regular maintenance practices have been diligently followed, addressing any emerging issues promptly, and active community involvement has played a crucial role in developing a sense of ownership and ensuring consistent care. This urban site, characterized by its well-managed environment, is a model for successful plantation initiatives in similar settings.

3.5. Qualitative parameter

Table 16: Qualitative parameters- Site-wise

Sate	Parameters Site	Grazing	Fire	Erosion	Pest Management	Water Source	Wildlife Interaction	Community Engagement	Plantation Journal	Treatment Register	Display Board	Accessibility
Tamil	Perambur (2019)	2	2	3	3	2	2	1	1	1	1	3
Nadu	Perambur (2020)	2	2	3	3	2	2	1	1	1	1	3
Bengal	Patharpratima	2	3	3	3	3	2	3	1	1	3	3
	Canning	3	3	3	3	3	3	3	1	1	1	1
	Sagar	3	3	1	3	3	2	3	1	1	2	3
	Kakdwip	3	3	2	3	3	3	3	1	1	3	2
	Rajarhat	2	3	3	3	3	3	2	1	1	1	3
Haryana	Gurugram	3	3	3	3	3	3	3	1	1	2	3
MH	Ghatkopar, Mumbai	3	3	3	2	2	2	2	1	1	1	2
	Kalyan	1	1	2	2	1	2	1	1	1	1	3
	Shahpur	1	1	2	2	1	2	1	1	1	1	3
	Bhayandar East, Mumbai	3	2	3	2	2	2	2	1	1	3	3
Score: 3 = Good, 2= Moderate/ Average, 1= Poor												

A systematic approach was employed to evaluate the quality of each plantation site, involving calculating average scores for various parameters. The steps are outlined as follows:

1. **Calculation of average score:**
   - The scores for each parameter (Grazing, Fire, Erosion, Pest Management, Water Source, Wildlife Interaction, Community Engagement, Plantation Journal, Treatment Register, Display Board, and Accessibility) were summed for each site.
   - The total score was then divided by the number of parameters (11) to obtain the average score.
2. **Grading categories:**
   - Sites were categorized based on their average scores:

Good	**2.5 to 3.0**	
Moderate	**1.5 to 2.4**	
Poor	**Below 1.5**	

Table 17: Qualitative grading

State	Site	Average Score	Grade
Tamil Nadu	Mannurpet	1.91	Moderate
West Bengal	Patharpratima	2.45	Moderate
West Bengal	Canning	2.27	Moderate
West Bengal	Sagar	2.27	Moderate
West Bengal	Kakdwip	2.45	Moderate

State	Site	Average Score	Grade
West Bengal	Rajarhat	2.27	Moderate
Haryana	Gurugram	2.54	Good
Maharashtra	Ghatkopar, Mumbai	2	Moderate
Maharashtra	Kalyan	1.45	Poor
Maharashtra	Shahpur	1.45	Poor
Maharashtra	Bhayandar East, Mumbai	2.18	Moderate

Based on the provided data, the average scores and grades across various sites in Tamil Nadu, West Bengal, Haryana, and Maharashtra highlight a diverse range of plantation performance. In Tamil Nadu, Mannurpet has an average score of 1.91, placing it in the moderate category. West Bengal sites, including Patharpratima, Canning, Sagar, Rajarhat and Kakdwip, all have similar average scores ranging from 2.27 to 2.45, also categorized as moderate. This indicates relative consistency in plantation conditions and management practices within the state. In Maharashtra, the performance is more varied. Ghatkopar, Mumbai, and Bhayandar East, Mumbai, scored 2 and 2.18, respectively, achieving a moderate grade. However, Kalyan and Shahpur have lower average scores of 1.45, categorizing them as low, suggesting these sites face more significant challenges impacting their plantation success. The **Badshahpur site** in Haryana stands out as the best-maintained site among all the evaluated locations, achieving a value of 2.54, which falls into the 'good' category. This site exemplifies effective plantation practices that should be replicated in other areas. Overall, while most sites fall into the moderate category under qualitative parameters, there are notable outliers in Maharashtra that require attention to improve their plantation health and sustainability**.**

3.6. Carbon sequestration potential:

Carbon sequestration potential was estimated and mapped based on primary and secondary data.

Current and potential total biomass carbon:

Each site's total biomass carbon sequestration was calculated using allometric equations developed explicitly for tropical trees and mangroves. Field data, including tree height and girth, were collected, and utilized in these calculations.

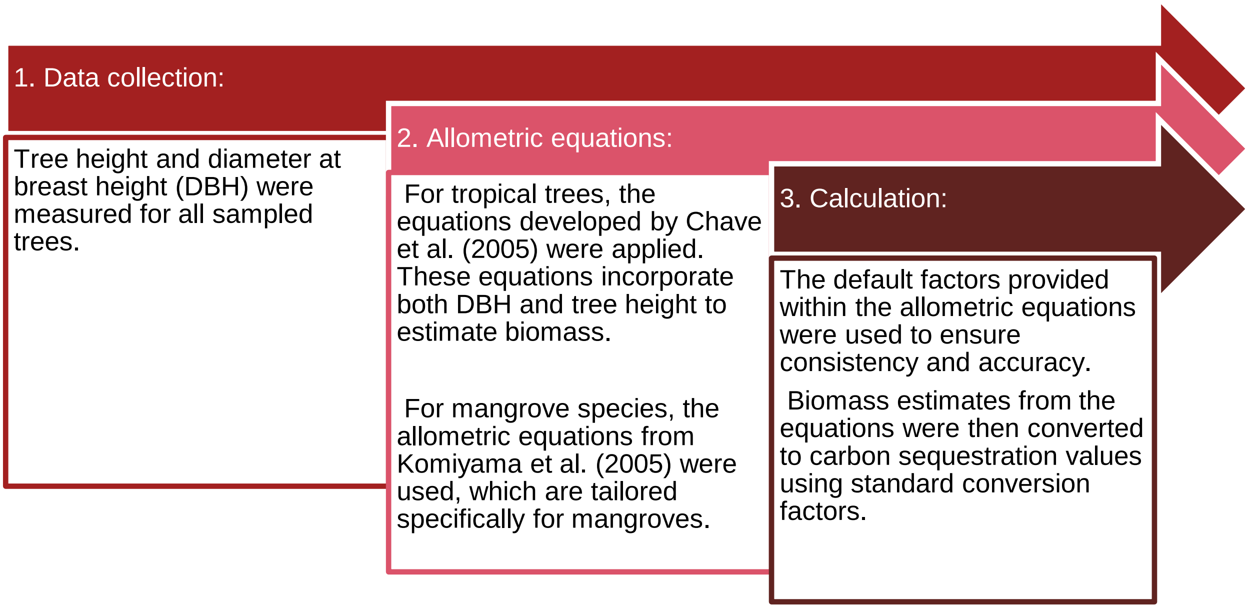


Figure 25. Key steps for carbon sequestration potential

Current and potential organic carbon in soil:

Carbon sequestration was estimated using the Restor application (https://restor.eco/). This provides an estimate of how much organic carbon currently exists in the soil of the plantation site and how much could exist if the soil is restored.

Carbon sequestration using the Restor application.

Key Parameters

- **Current organic carbon in soil:** This dataset estimates current carbon storage in the top two metres of soil at any given location on the terrestrial land surface. Estimates are derived from a combination of direct observations and environmental and anthropogenic covariates, with a machine learning approach then adopted to infer patterns of storage globally.

- **Potential organic carbon in soil:** This dataset estimates potential carbon storage in the top two metres of soil at any given location on the terrestrial land surface. Estimates are derived from a combination of direct current observations and historical environmental and anthropogenic covariates, with a machine learning approach then adopted to infer patterns of potential storage globally.

- **Above-ground biomass (AGB)** includes all the living vegetation above the soil surface, such as stems, branches, leaves, and reproductive structures. It plays a crucial role in carbon sequestration, directly absorbing atmospheric CO_2 through photosynthesis. Accurate estimation of AGB is essential for understanding the carbon storage potential of forests and mangroves.

- **Below-ground biomass (BGB),** on the other hand, consists of all the living root systems that exist below the soil surface. Although less visible, BGB is equally important for carbon sequestration. Roots contribute to soil health, prevent erosion, and store carbon for extended periods due to slower decomposition rates than above-ground parts. AGB and BGB provide a comprehensive picture of a site's total biomass and capacity to sequester carbon.

3.6.1 West Bengal:

Table 18: Carbon sequestration potential- West Bengal

State	Site Name	Year of Plantation	Total Biomass (AGB+BGB)[24] CO2e		Soil Carbon	
			Current[25] (in tonnes)	Potential[26] (in tonnes)	Current (in tonnes)	Potential (in tonnes)
WB	Sagar	2022	0.37	1.68	255.59	300.71
WB	Patharpratima	2021	3.84	6.59	137.24	175.65
WB	Kakdwip	2023	0.22	0.49	463.23	567.45
WB	Rajarhat	2019	0.5	0.65	15.45	18.62
Total			**4.93**	**9.41**	**871.51**	**1062.43**

1. **Total Biomass CO2e:**

- **Current Biomass CO2e**: The combined current total biomass CO2e for all three sites is 4.93 tonnes. This value is based on the observed plantations in the field and represents their immediate contribution to carbon sequestration, reflecting the current capacity of the existing trees to sequester.

- **Potential Biomass CO2e**: The combined potential total biomass CO2e for all sites is projected to be 8.76 tonnes. This potential value is based on the number of trees planted and indicates the expected biomass if survival rates were optimal. However, due to observed lower survival rates, the current biomass CO2e is 4.93 tonnes, half of the potential value. This discrepancy highlights the impact of tree survival on the effectiveness of carbon sequestration efforts.

The total biomass carbon sequestration data for the plantation sites in West Bengal demonstrates a promising but currently under-realized contribution to carbon mitigation efforts. The current total biomass CO2e of 4.43 tonnes, based on observed plantations, falls short of the potential 9.41 tonnes due to lower survival rates. This highlights the critical need for strategies to improve tree survival to leverage these afforestation projects' carbon sequestration potential fully.

2. **Soil Carbon:** This is the carbon stored in the soil. The potential for soil carbon sequestration is slightly higher than the current levels at all sites. This suggests some scope for enhancing carbon sequestration in the soil through practices like organic matter addition or improved land management. However, the small gap between the current and potential levels indicates that the soil has reached near its maximum carbon storage capacity.

Regarding the relation between the numbers, the data suggests that the potential for carbon sequestration is untapped at these sites, especially in woody biomass. The significant gaps between the current and potential levels of AGWC and BGWC indicate that these sites can store much more carbon than they currently do. This highlights the importance of implementing strategies to enhance tree growth and health, such as better forest management practices. However, it is essential to note that realizing this potential would require

[24] Total Biomass is equal to the sum of Above ground biomass and Below ground Biomass (AGB+BGB)
[25] Current: Based on the observed plantation.
[26] Potential: Based on the actual planted

overcoming various challenges, such as improving soil quality and ensuring adequate water availability. It would also require monitoring key progress indicators, such as the year-on-year increase in woody carbon and improvements in soil quality.

3.6.2 Tamil Nadu:

Table 19: Carbon sequestration potential- Tamil Nadu

State	Site Name	Year of Plantation	Total Biomass (AGB+BGB)[27] CO2e		Soil Carbon CO2e	
			Current (in tonnes)	Current (in tonnes)	Current (in tonnes)	Potential (in tonnes)
Tamil Nadu	ICF Factory	2019 and 2020	7.13	31.7	14.4	14.5

1. **Total Biomass CO2e:**

- Current Biomass CO2e: The combined current total biomass CO2e for both sites are 7.13 tonnes. This value is based on the observed plantations in the field and represents their immediate contribution to carbon sequestration, reflecting the current capacity of the existing trees.

- Potential Biomass CO2e: The combined potential total biomass CO2e for all sites is projected to be 23.7 tonnes. This potential value is based on the number of trees planted and indicates the expected biomass if survival rates were optimal. However, due to observed lower survival rates, the current biomass CO2e is 7.13 tonnes, approximately one-third of the potential value. This discrepancy highlights the impact of tree survival on the effectiveness of carbon sequestration efforts.

The total biomass carbon sequestration data for the plantation sites in West Tamil Nadu demonstrates a promising but currently under-realized contribution to carbon mitigation efforts. The current total biomass CO2e of 7.13 tonnes, based on observed plantations, falls short of the potential 23.7 tonnes due to lower survival rates. This highlights the critical need for strategies to improve tree survival to fully leverage the carbon sequestration potential of these afforestation projects.

2. **Soil Carbon:** The potential for soil carbon sequestration is close to the current levels at both sites. This suggests that there is limited scope for enhancing carbon sequestration in the soil through practices such as organic matter addition or improved land management. However, the small gap between the current and potential levels indicates that the soil has reached near its maximum carbon storage capacity.

Regarding the relation between the numbers, the data suggests significant potential for increasing carbon sequestration in above-ground and below-ground woody biomass at both sites. However, soil carbon sequestration is at its maximum potential already.

[27] Total Biomass is equal to the sum of Above ground biomass and Below ground Biomass (AGB+BGB)

3.6.3 Maharashtra:

Table 20: Carbon sequestration potential- Maharashtra

State	Site Name	Year of Plantation	Total Biomass (AGB+BGB)[28] CO_2e		Soil Carbon	
			Current (in tonnes)	Potential (in tonnes)	Current (in tonnes)	Potential (in tonnes)
Maharashtra	Ghatkopar-Mangrove	2021	0.69	2.9	829.54	829.54
Maharashtra	Bhyandar-Miyawaki	2022	1.6	3.77	61.11	63.74
Maharashtra	Bhatsai	2021	-	0.04	304	359
Maharashtra	Rayate	2022	0.03	1.53	69.56	88.19
Total			**2.32**	**8.24**		

1. **Total Biomass CO_2e:**

    - **Current Biomass CO_2e**: The combined current total biomass CO_2e for all three sites is 2.32 tonnes. This value is based on the observed plantations in the field and represents their immediate contribution to carbon sequestration, reflecting the current capacity of the existing trees to sequester.

    - **Potential Biomass CO_2e**: The combined potential total biomass CO_2e for all sites is projected to be 8.24 tonnes. This potential value is based on the number of trees planted and indicates the expected biomass if survival rates were optimal. However, due to decreased survival rates, the current biomass CO_2e is 2.32 tonnes, approximately one-fourth of the potential value. This discrepancy highlights the impact of tree survival on the effectiveness of carbon sequestration efforts.

The total biomass carbon sequestration data for the plantation sites in Maharashtra demonstrates a promising but currently under-realized contribution to carbon mitigation efforts. The current total biomass CO_2e of 2.32 tonnes, based on observed plantations, falls short of the potential 8.24 tonnes due to lower survival rates. This highlights the critical need for strategies to improve tree survival to fully leverage the carbon sequestration potential of these afforestation projects.

2. **Soil Carbon:** The potential for soil carbon sequestration is close to the current levels at all sites. This suggests relative scope for enhancing carbon sequestration in the soil through practices such as organic matter addition or improved land management. However, the small gap between the current and potential levels indicates that the soil has reached near its maximum carbon storage capacity.

[28] Total Biomass is equal to the sum of Above ground biomass and Below ground Biomass (AGB+BGB)

3.6.4 Haryana:

Table 21: Carbon sequestration potential-Haryana

State	Site Name	Year of Plantation	Total Biomass (AGB+BGB)[29] CO2e		Soil Carbon CO2e	
			Current (in tonnes)	Current (in tonnes)	Current (in tonnes)	Potential (in tonnes)
Haryana	Badshahpur	2019	2.75	3.05	22.74	23.72

1. Total Biomass CO2e:

- Current Biomass CO2e: The current total biomass CO2e for both sites are 2.75 tonnes. This value is based on the observed plantations in the field and represents their immediate contribution to carbon sequestration, reflecting the current capacity of the existing trees.

- Potential Biomass CO2e: The combined potential total biomass CO2e for all sites is projected to be 3.05 tonnes. This potential value is based on the number of trees planted and indicates the expected biomass if survival rates were optimal. However, due to the higher survival rate, the difference is negligible, providing similar values for the current vs potential, equal to the potential value. This highlights the impact of tree survival on the effectiveness of carbon sequestration efforts.

2. Soil Carbon: The potential for soil carbon sequestration is close to the current levels at both sites. This suggests that there is limited scope for enhancing carbon sequestration in the soil through practices such as organic matter addition or improved land management. However, the small gap between the current and potential levels indicates that the soil has reached near its maximum carbon storage capacity.

Regarding the relation between the numbers, the data suggests significant potential for increasing carbon sequestration in above-ground and below-ground woody biomass at both sites. However, soil carbon sequestration is at its maximum potential already.

3.7. Normalized difference vegetation index (NDVI)

NDVI values were estimated using the Restor application. Measuring and monitoring NDVI[30] A method used to evaluate the health status of vegetation. The NDVI is the difference between near-infrared (NIR) and visible red reflectance values normalized over reflectance. Healthy vegetation absorbs red light and reflects more NIR light, resulting in higher NDVI values. NDVI has various applications, including geo-tagging and plantation assessment, plant health and canopy growth monitoring, and ecological studies. Correlating NDVI with plantation sites can provide insights for resource allocation and intervention.

NDVI= (NIR - RED) / (NIR + RED)

where, RED = The red portion of the electromagnetic spectrum (0.6-0.7 μm)
NIR = The near-infrared portion of the electromagnetic spectrum (0.75-1.5 μm).

[29] Total Biomass is equal to the sum of Above ground biomass and Below ground Biomass (AGB+BGB)
[30] https://www.landscapetoolbox.org/remote-sensing-methods/normalized-difference-vegetation-index-ndvi/

Typically, NDVI values range from -1.0 to 1.0. Negative values are associated with clouds and water, while positive values close to zero indicate bare soil. Higher positive NDVI values, ranging from 0.1 to 0.5, indicate sparse vegetation, while values of 0.6 and above correspond to dense green foliage[31].

3.7.1 West Bengal

Table 22: NDVI - plantation site in West Bengal

State	Site Name	NDVI
West Bengal	Sagar	0.09
West Bengal	Patharpratima	0.24
West Bengal	Kakdwip	0.25
West Bengal	Rajarhat[32]	

1. **Sagar (NDVI: 0.09):** The NDVI value is low, indicating sparse or less healthy vegetation. Since the plantation was done in 2022, the vegetation might still be in its preliminary stages of growth, which can explain the lower NDVI. Young plants typically have lower NDVI values until they mature and establish a denser canopy.
2. **Patharpratima (NDVI:0.24):** The NDVI value is moderate, suggesting healthier and denser vegetation than Sagar. As the plantation was done in 2021, the plants have had more time to grow and establish themselves, leading to a higher NDVI value. This indicates that the vegetation is in a more advanced growth stage than the Sagar site. Typically, young, and healthy plantations would have higher NDVI values closer to 0.3-0.6 depending on their growth conditions and species.[33].

3. **Kakdwip (NDVI: 0.25):** The NDVI value is also moderate, similar to Patharpratima. Despite being planted in 2023, the NDVI value is high. This could indicate that the site has favorable conditions for rapid vegetation growth, such as suitable soil, adequate water availability, and favorable climate conditions. Typically, young, and healthy plantations would have higher NDVI values closer to 0.3-0.6, depending on their growth conditions and species.

3.7.2 Tamil Nadu

Table 23: NDVI - plantation site in Tamil Nadu

State	Site Name	NDVI
Tamil Nadu	ICF Factory (2019)	0.51
Tamil Nadu	ICF Factory (2020)	0.48

1. **Perambur (NDVI: 0.5):** The NDVI value for Perambur, Chennai is 0.50. As the Perambur site is a Miyawaki plantation, the method promotes high plant density and species diversity, contributing to higher NDVI values as the forest matures. An NDVI of 0.50 indicates moderate to good vegetation health and canopy density. While it is not as high as values seen in mature, dense forests (which can be above 0.7), it

[31] ipad.fas.usda.gov
[32] Rajarhat: the limited size of the plot restricts the restor application of NDVI analysis.
[33] https://www.jstor.org/stable/4298797

suggests that the plantation is progressing well. At five years old, Miyawaki Forest is still in an early stage of development.

- For young, developing forests, NDVI values can range from 0.3 to 0.6. An NDVI of 0.50 is within this expected range, indicating that the forest is on a good trajectory.

3.7.3 Maharashtra

Table 24: NDVI - plantation site in Maharashtra

State	Site Name	NDVI
Maharashtra	Ghatkopar- Mangrove	0.55
Maharashtra	Bhyander- Miyawaki	0.57
Maharashtra	Bhatsai	0.20
Maharashtra	Rayate	0.15

1. **Ghatkopar (NDVI: 0.55):** An NDVI value of 0.5 indicates moderate to high vegetation health and density. This means that there is significant vegetation cover in the area. The high NDVI value is influenced by pre-existing trees with large canopy covers. These established trees contribute to the overall vegetation health and density within the polygon area.

2. **Bhayandar (NDVI: 0.57):** The NDVI value for Bhyander, Mumbai is 0.57. As the Bhyander site is a Miyawaki plantation, the method promotes high plant density and species diversity, contributing to higher NDVI values as the forest matures. An NDVI of 0.50 indicates moderate to good vegetation health and canopy density. While it is not as high as values seen in mature, dense forests (which can be above 0.7), it suggests that the plantation is progressing well. At 2-3 years old, Miyawaki forest is still in an early stage of development. For young, developing forests, NDVI values can range from 0.3 to 0.6. An NDVI of 0.50 is within this expected range, indicating that the forest is on a good trajectory.

3. **Bhatsai (NDVI: 0.20)**: The NDVI value is low, indicating sparse or less healthy vegetation. Since the plantation was done in 2022, the vegetation might still be in the initial stages of growth, or the site might have less favorable conditions compared to other sites.

4. **Rayate (NDVI: 0.15):** The NDVI value is low, indicating sparse or less healthy vegetation. Despite being planted in the same year as Ghatkopar, the lower NDVI suggests that the vegetation at Rayate has not been established as well. This could be due to less favorable environmental conditions, soil quality, or other site-specific factors.

3.7.4 Haryana

Table 25: NDVI - plantation site in Haryana

State	Site Name	NDVI
Haryana	Badshahpur [34](2019)	

[34] The limited size of the plot restricts the application of NDVI analysis.

4. Impact in terms of SDG Indicators

The foundation's plantation activity has played a pivotal role in creating a sustainable and healthier environment. Protecting forests and the environment is essential for improving the quality of life. While there is no specific Sustainable Development Goal (SDG) titled "Forests," numerous SDGs address aspects related to forests and the environment. Specifically, SDG 1 (No Poverty), SDG 3 (Good Health and Well-being), SDG 6 (Clean Water and Sanitation), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land all intersect with the forestry sector in various ways. The foundation's efforts have significantly contributed to these goals by improving food and nutrition security, enhancing health, ensuring water security, promoting responsible consumption, taking climate action, and conserving biodiversity.

The nature of forest dependence and sustainable forest management is integral to achieving these SDGs and enhancing the overall well-being of communities. The foundation's commitment to these activities underscores the critical role of plantation in defining living conditions for humanity and fostering a sustainable

Figure 26. SDG indicators

This table outlines the intersection of plantation activities with various SDGs, highlighting the impact and coverage in the states of West Bengal, Maharashtra, and Tamil Nadu.

Table 26: SDGs indicators and coverage

SDG	Indicators	Coverage under Foundation plantation
SDG 1: No Poverty	Ending poverty in all its forms everywhere	West Bengal (Mangrove and Miyawaki): Community engagement in mangrove management provides livelihoods and reduces poverty.
		Maharashtra (All types): Employment opportunities in plantation activities help alleviate poverty among local communities.
		Tamil Nadu and Haryana: Job creation through the implementation and maintenance of Miyawaki forests.

SDG	Indicators	Coverage under Foundation plantation
SDG 3: Good Health and Well-being	Ensuring healthy lives and promoting well-being for all at all ages	West Bengal (Mangrove and Miyawaki): Improved air quality and reduced heat islands contribute to better health.
		Maharashtra (All types): Enhanced green cover improves air quality, reducing respiratory issues.
		Tamil Nadu and Haryana: Increased urban green space promotes physical and mental well-being.
SDG 6: Clean Water and Sanitation	Ensuring availability and sustainable management of water and sanitation for all	West Bengal (Mangrove): Mangroves help filtrate and maintain water quality.
		Maharashtra (Mangrove and Conventional): Improves water retention and groundwater recharge.
		Tamil Nadu (Miyawaki): Enhanced soil moisture retention improves water availability.
SDG 11: Sustainable Cities and Communities	Making cities and human settlements inclusive, safe, resilient, and sustainable	West Bengal (Mangrove and Miyawaki): Enhanced green spaces contribute to urban sustainability and resilience.
		Maharashtra (All types): Plantation activities increase urban green cover, enhancing livability and resilience to climate change.
		Tamil Nadu (Miyawaki) and Haryana: Increased urban green cover contributes to sustainable urban development.
SDG 13: Climate Action	Taking urgent action to combat climate change and its impacts	West Bengal (Mangrove and Miyawaki): Carbon sequestration and protection against storm surges.
		Maharashtra (All types): Contributes to carbon sequestration and mitigates the urban heat island effect.
		Tamil Nadu (Miyawaki): Enhanced carbon capture through dense forestation.
SDG 15: Life on Land	Protecting, restoring, and promoting sustainable use of terrestrial ecosystems	West Bengal (Mangrove and Miyawaki): Restoration of mangrove ecosystems and urban biodiversity.
		Maharashtra (All types): Biodiversity conservation and restoration of degraded lands.
		Tamil Nadu (Miyawaki): Enhances urban biodiversity and restores native flora.

5. Key observations and recommendations

Several key observations were made **during** the project, highlighting successes and improvement areas. The following recommendations are based on these observations and are aimed at enhancing future plantation initiatives:

5.1 West Bengal

Key Aspects	Observations	Sites	Recommendations
Discrepancy in numbers of plant and species	Opportunities for improving data accuracy were identified, as there were differences between the recorded and observed data on the number of plantations and species at most sites.	Applicable to all sites of West Bengal	Establish an enhanced verification and monitoring system for regular checks. Guidelines on monitoring and verification can assist in developing such systems.
Documentation	The availability of plantation journals during field visits can be enhanced for better verification.	Applicable to all sites of West Bengal	Ensure the visiting register is updated monthly with photos and plantation records are kept at the partner NGOs with the required signatures.
Plantation area	Some sites presented opportunities for improving the accuracy of recorded plantation areas.	Sagar	Accurate recording and submission of KML files or GPS locations before activities commence. The KML files help accurately define plantation areas, and analyzing the area's property using various tools is convenient.
Visibility	Most sites can improve the visitor experience and information accessibility by adding signage.	Sagar, Canning	Installation of signboards with donor and plantation details enhances credibility and visibility.
Site selection	Most sites were suitably chosen for plantation, with a few exceptions.	Sagar	Conduct a feasibility assessment before the plantation to avoid unsuitable/vulnerable areas.
GPS/ KML file	KML files or GPS points can be optimized to map the plantation activity and improve boundary demarcation accurately.	Sagar, Rajarhat	Develop a KML file before the intervention to ensure an accurate geospatial representation of the plantation boundaries.

Key Aspects	Observations	Sites	Recommendations
Quality of plantation	While some sites fell short of expected standards in survival rate and plantation growth, they provide valuable insights for future improvements.	Applicable to all sites of West Bengal	Adhere to the quality standards for plantation as per the Good Agricultural Practices (India GAP) and other relevant standards.
Species selection	Documenting the rationale behind species selection can help align plantation activities with intended outcomes and minimize discrepancies.	Applicable to all sites of West Bengal	Develop documentation, which should include the rationale for species choice, considering ecological compatibility and growth requirements.
Soil quality	The opportunity exists to enhance the pre-plantation evaluation of soil quality to ensure optimal site selection.	Applicable to all sites of West Bengal	Implement a soil quality assessment that includes physical, chemical, and biological parameters.

5.2 Maharashtra:

Key Aspects	Observations	Sites	Recommendations
Discrepancy in numbers	Opportunities for improving data accuracy were identified, as there were differences between recorded and observed data on plantations and species.	All sites in Maharashtra	Establish an enhanced verification and monitoring system. Provide guidelines for regular checks and verification procedures.
Documentation	Enhance the availability of plantation journals during field visits for better verification.	All sites in Maharashtra	Ensure the visit register is updated monthly with photos and maintain plantation records at partner NGOs with required signatures.
Plantation area accuracy	Some sites need improved accuracy in recorded plantation areas.	All sites in Maharashtra	Record and submit accurate KML files or GPS locations before activities commence. Analyze property boundaries using appropriate tools.
Maintenance	Several sites require better weed and grass management and accessibility.	Ghatkopar	Allocate an adequate budget for upkeep and maintenance to promote healthy growth.

Key Aspects	Observations	Sites	Recommendations
Visibility	Most sites can enhance the visitor experience through signage.	Ghatkopar, Bhatsai, Rayate	Install signboards with donor and plantation details for improved credibility and visibility.
Protection	Sites with signs of human activity need protection measures.	Bhatsai, Rayate	Safeguard saplings from grazing animals, pests, and human interference. Designate specific pathways or roads for vehicle access.
Fire management	Instances of large patch fires highlight the need for adequate fire management strategies.	Bhatsai, Rayate	Implement comprehensive fire management strategies based on guidelines (e.g., FAO recommendations).
Site selection	Most sites were suitable, but feasibility assessments are crucial.	Bhatsai, Rayate	Conduct feasibility assessments before planting the plantation to avoid unsuitable or vulnerable areas.
Soil quality assessment	Enhance pre-plantation evaluation of soil quality for optimal site selection.	All sites in Maharashtra	Implement soil quality assessments covering physical, chemical, and biological parameters.
GPS/KML file optimization	Optimize KML files or GPS points for accurate mapping and boundary demarcation.	Ghatkopar, Rayate, Bhatsai	Develop KML files before interventions to ensure precise geospatial representation of plantation boundaries.
Quality of plantation	Some sites fell short of expected standards and adhered to quality guidelines.	Rayate, Bhatsai	Follow Good Agricultural Practices (India GAP) and relevant standards for plantation quality.
Species selection rationale	Document the rationale behind species choice to align with intended outcomes.	All sites in Maharashtra	Develop documentation considering ecological compatibility and growth requirements.
Spacing and pattern	Uniform planning and execution across sites are essential.	Bhatsai, Rayate	Organize saplings in structured rows and columns for consistent spacing.

5.3 Tamil Nadu:

Key Aspects	Observations	Sites	Recommendations
Discrepancy in numbers	Opportunities for improving data accuracy were identified, as there were differences between recorded and observed data on plantations and species.	All sites	Establish an enhanced verification and monitoring system for regular checks. Provide guidelines for monitoring and verification procedures.
Documentation	Enhance the availability of plantation journals during field visits for better verification.	All sites	Ensure the visit register is updated monthly with photos and maintain plantation records at partner NGOs with required signatures.
Plantation area accuracy	Some sites need improved accuracy in recorded plantation areas.	All sites	Record and submit accurate KML files or GPS locations before activities commence. Analyze property boundaries using appropriate tools.
Visibility	Most sites can enhance the visitor experience through signage.	All Sites	Install signboards with donor and plantation details for improved credibility and visibility.
Protection	Sites with signs of human activity need protection measures.	All Sites	Safeguard saplings from grazing animals, pests, and human interference. Designate specific pathways or roads for vehicle access.
Soil quality assessment	Enhance pre-plantation evaluation of soil quality for optimal site selection.	All sites	Implement soil quality assessments covering physical, chemical, and biological parameters.
GPS/KML file optimization	Optimize KML files or GPS points for accurate mapping and boundary demarcation.	All Sites	Develop a KML file before the intervention to ensure a precise geospatial representation of plantation boundaries.
Quality of plantation	Some sites fell short of expected standards and adhered to quality guidelines.	All sites	Follow Good Agricultural Practices (India GAP) and relevant standards for plantation quality.

Key Aspects	**Observations**	**Sites**	**Recommendations**
Species selection rationale	Document the rationale behind species choice to align with intended outcomes.	All sites	Develop documentation considering ecological compatibility and growth requirements.

5.4 Haryana:

Key Aspects	**Observations**	**Sites**	**Recommendations**
Documentation	The availability of plantation journals during field visits can be enhanced for better verification.	Badshahpur	Ensure the visiting register is updated monthly with photos and plantation records are kept at the partner NGOs with the required signatures.
Visibility	Sites can improve visitor experience and information accessibility through adding signage. **Note:** Signage is available at the site, but its visibility is limited due to its small size. The information is included in the footnote of the information board.	Badshahpur.	To enhance the visibility of the signage at the site, it is recommended that its size be increased, making it more noticeable and easier to read.
GPS/ KML file	KML files or GPS points can be optimized to map the plantation activity and improve boundary demarcation accurately.	Badshahpur	Develop a KML file before the intervention to ensure an accurate geospatial representation of the plantation boundaries.

6. Conclusion

During the fiscal years 2019 to 2023, the CRISIL Foundation undertook a detailed geo-tagging process for its plantation projects, yielding several crucial insights. This initiative utilized advanced geospatial technologies, including the TreeMapper application, GPS devices, Google Earth Pro, and QGIS software, to precisely mark plantation sites on digital maps. The analysis revealed significant variations in survival rates across different sites and plantation types, with extremely low to moderate categories.

A robust, statistically sound method was employed to determine the minimum sample size for geo-tagging, adopting a row vs. column approach. This methodology effectively identified 15% of the plantation sites for geo-tagging activities. However, challenges such as site inaccessibility, high sink areas, and high tide periods during working hours occasionally resulted in lower sample sizes than anticipated.

The comprehensive tree survey, which measured the girth and height of 15% of the observed plantations, established a baseline for studying plant growth and assessing overall tree health and survival. This assessment mechanism provided valuable insights into survival counts, tree health, soil erosion, slope identification, and the effectiveness of distinct species in the area. Additionally, qualitative parameters such as grazing, fire, erosion, pest management, water sources, wildlife interaction, and community engagement were evaluated to understand the broader impact.

The carbon sequestration potential of the plantations was calculated using allometric methods, estimating existing biomass above and below ground, as well as potential biomass under optimal survival conditions. Despite the valuable data generated, certain methodological limitations were noted. Soil carbon estimates relied on secondary data, and total biomass calculations were based on default factors, using averaged height and girth measurements for each site.

The geo-tagging review and plant species survey faced several challenges, including site accessibility, resource allocation, and the need for permissions. Nonetheless, the process identified opportunities to enhance data accuracy, documentation, and the recording of plantation areas. Recommendations for future projects include:

- Introducing plantation journals.
- Improving site visibility through better signage.
- Optimizing GPS/KML files.
- Implementing stricter quality control measures for plantations.
- Documenting the rationale behind species selection.
- Conducting pre-plantation soil quality evaluations.

The overall impact of the CRISIL Foundation's plantation efforts from FY19-23 was moderate, with notable outliers at some sites. For future plantation initiatives, the focus should be on developing and adhering to standardized operating procedures (SOPs) for plantation management and survival. Additionally, annual monitoring of plantations is recommended to ensure continuous improvement and sustainability.

In conclusion, the CRISIL Foundation's plantation project provided significant insights into the effectiveness of various methodologies and offered a comprehensive impact assessment. The initiative highlighted several challenges but also identified key opportunities for improvement. By implementing the provided recommendations, future plantation projects can achieve greater accuracy, sustainability, and overall success.

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8. Annexure:

Location of the plantation area

YBD

Bhatsai

Taranagar

Dighirpar

Mandirtala

Bajpukur

Plantation journal (species name and number of species planted)

Yudhisthir Bridge, Yamuna area, Northeast Delhi

Common/ (*Botanical Name)*	**No saplings planted***
Arjuna *(Terminilia arjuna)*	3750
Seesham *(Dalbergia sisso)*	4375
Bargad *(Ficus benghalensis)*	310
Pilkhan *(Ficus virens)*	625
Belpathhar *(Aegle marmelos)*	625
Lasoda *(Cordia myxa)*	315
Total Species Planted	**10,000**

Smriti Van, Mayur Vihar Phase III, East Delhi

Common/ (*Botanical Name)*	**No saplings planted**
Pilkan *(Ficus virens)*	1500
Sheesham *(Dalbergia sissoo)*	500
Papdi *(Terminalia catappa)*	3000
Arjun *(Terminalia Arjuna)*	1000
Mauleseery *(Mimusops elengi)*	2500
Neem *(Azadirachta indica)*	500
Jamun *(Syzygium cumini)*	700
Benjamina *(Ficus benjamina)*	300
Species Planted	**10,000**
**Additional Species planted at the plantation site	
Kachnar *(Bauhinia variegate)*	500
Kadam *(Neolamarckia cadamba)*	100
Peepal *(Ficus religiosa)*	50
Bargad *(Ficus benghalensis)*	100
Ashok *(Saraca asoca)*	100
Papdi *(Terminalia catappa)*	500
Total Additional species	**1350**
Total Species Planted	**11,350**

Rayate, Kalyan, Thane, Maharashtra

Common/ (*Botanical Name)*	**No of saplings**
Earleaf Acacia *(Acacia auriculiformis)*	1000
Karanj *(Milletiia pinnata)*	1,500
Sheesam *(Dalbergia sissoo)*	2000
Teak *(Tectona Grandis)*	3500
Lemon *(Citrus Limon)*	1500
Guava *(Psidium guajava)*	200
Mango *(Mangifera Indica)*	300
Total Species Planted	**10,000**

Bhatsai, Shahpur, Thane, Maharashtra

Botanical Name	**No fo Saplings**
Teak *(Tectona grandis)*	4000
Karanj *(Pongamia pinnata)*	2000
Seesham *(Dalbergia sissoo)*	2100
Mango *(Mangifera indica)*	500
Amla *(Phyllanthus emblica)*	1100
Jamun *(Syzygium cumini)*	150
Sarifa *(Annona squamosa)*	150
Neem *(Azadirachta indica)*	200
Total Species Planted	**10,200**

Mira-Bhyandar, Mumbai, Maharashtra

S.no	Botanical Name	Number of Saplings
1	*Bauhinia racemosa*	119
2	*Justicia adhatoda*	119
3	*Ficus carica*	119
4	*Terminalia arjuna*	119
5	*Polyalthia longifolia*	119
6	*Phyllanthus emblica*	119
7	*Holoptelea integrifolia*	119
8	*Terminalia catappa*	119
9	*Terminalia bellirica*	119
10	*Mimusops elengi*	119
11	*Bambusa vulgaris*	100
12	*Aegle marmelos*	119
13	*Cordia dichotoma*	119
14	*Gardenia resinifera*	119
15	*Artocarpus heterophyllus*	119
16	*Sesbania grandiflora*	119
17	*Tamarindus indica*	119
18	*Syzygium cumini*	119
19	*Hibiscus rosa-sinensis*	119
20	*Neolamarckia cadamba*	119
21	*Bergera koenigii*	119
22	*Murraya paniculata*	119
23	*Bauhinia variegata*	119
24	*Nerium oleander*	119
25	*Senna siamea*	119
26	*Bombax ceiba*	119
27	*Senegalia ferruginea*	119
28	*Limonia acidissima*	119
29	*Madhuca longifolia var. latifolia*	119

S.no	Botanical Name	Number of Saplings
30	*Mangifera indica*	119
31	*Lawsonia inermis*	100
32	*Jasminum sambac*	119
33	*Morus sps.*	119
34	*Azadirachta indica*	119
35	*Citrus x limon*	119
36	*Vitex negundo*	119
37	*Butea monosperma*	119
38	*Erythrina suberosa*	119
39	*Thespesia populnea*	119
40	*Nyctanthes arbor-tristis*	119
41	*Ficus religiosa*	119
42	*Ficus tsjakela*	119
43	*Adenanthera pavonina*	119
44	*Caesalpinia pulcherrima*	119
45	*Dalbergia latifolia*	119
46	*Albizia odoratissima*	119
47	*Saraca asoca*	119
48	*Magnolia champaca*	119
49	*Tabernaemontana divaricata*	119
50	*Lagerstroemia speciosa*	119
51	*Pauldopia ghorta*	119
52	*Oroxylum indicum*	119
53	*Ficus racemosa*	119
54	*Ficus benghalensis*	119
55	*Prosopis cineraria*	119

Badshahpur Corridor 2019

No	Botanical name	No. Of Saplings
1	*Adhatoda vasaca*	88
2	*Wrightia arborea*	30
3	*Clerodendrum phlomides*	35
4	*Barleria prionites*	40
5	*Diospyros cordifolia*	35
6	*Butea monosperma*	23
7	*Grewia flavescens*	40
8	*Salvadora persica*	16
9	*Flueggea leucopyros*	60
10	*Phyllanthus reticulata*	90
11	*Hiptage benghalense*	5
12	*Madhuca longifolia var latifolia*	2
13	*Helicteris isora*	16
14	*Plumbago zeylanica*	15
15	*Tecomella undulata*	5

Perambur Chennai, 2019

S. No	Name	No. of saplings planted
1	*Artocarpus integrifolia - Jackfruit*	20
2	*Parijatha*	20
3	*Bauhinia purposes - butterfly tree*	28
4	*Terminlia bellerica -p tropical almond*	28
5	*Albezia lebbec - silk tree, women's tongue tree*	28
6	*Syzygium operculatum - Jamun family*	28
7	*Citrus medica - grapefruit*	20
8	*Michellia champaca - champak tree*	20
9	*Feronia elephantum - wood apple*	20
10	*Azadirechta indica - neem*	20
11	*Pungamia pinata - pongamia*	20
12	*Zizyphus jujuba - indian plum*	25
13	*Ficus infectoria - white fig*	20
14	*Cassia siamea - kasod tree*	10
15	*Ficus amplisima - Indian bat tree*	15
16	*Nanthiyavattai - crepe jasmine*	15
17	*Terminalia cetapa - indian almond*	25
18	*Syzygium cumini- Malabar plum*	10
19	*Holoptelea integrifolia - jungle cork*	15
20	*Millingtonia hortensis - indian cork tree*	20
21	*Ceiba petandra - kapok tree*	15
22	*Wrightia tinctoria - pala indigo plant*	10
23	*Lawsonia inermis - henna*	15
24	*Ficus religiosa - peepal*	20
25	*Gmelina arborea - gamhar*	15
26	*Ficus mysorensis - brown wolly fig*	15
27	*Termanalia Arjuna - Star fruit*	32
28	*Butea monosperma - flame of the forest*	32
29	*Moringa olefeira - Drumstick*	33
30	*Vitex negundo - Chinese chaste tree*	32
31	*Tectona Grandis - Teak*	25
32	*Ficus hispidia- Fig*	25
33	*Phyllanthus embelica - Amla*	25
34	*Punica granatum - pomegranate*	25
35	*Maduca india - Mahua*	32
36	*Bassia latifora-*	22
37	*Adhathoda zeylanica - Malabar Nut*	26
38	*Nerium Oleander*	20
39	*Murraya Koenigi*	15
40	*Thespesea Populena*	10
41	*Calotropis procea*	15
42	*Custard Apple*	15
43	*Bamboo*	10
44	*Red sandal*	20

S. No	Name	No. of saplings planted
45	*Citrus lemon*	10
46	*Indian Cherry*	12
47	*Indian Cherry*	14
48	*Papaya*	18
49	*Guava*	20
50	*Lemon*	22
	TOTAL	**1007**

Perambur Chennai, 2020

S.NO	Name	No. of saplings planted
1	*Termanalia Arjuna - Star fruit*	72
2	*Butea monosperma - flame of the forest*	75
3	*Moringa olefeira - Drumstick*	70
4	*Vitex negundo - Chinese chaste tree*	72
5	*Tectona Grandis - Teak*	56
6	*Ficus hispidia- Fig*	58
7	*Phyllanthus embelica - Amla*	55
8	*Punica granatum - pomegranate*	60
9	*Maduca india - Mahua*	70
10	*Bassia latifora-*	28
11	*Adhathoda zeylanica - Malabar Nut*	72
12	*Artocarpus integrifolia - Jackfruit*	72
13	*Parijatha*	55
14	*Bauhinia purposes - butterfly tree*	75
15	*Terminlia bellerica -p tropical almond*	75
16	*Albezia lebbec - silk tree, women's tongue tree*	75
17	*Syzygium operculatum - Jamun family*	70
18	*Citrus medica - grapefruit*	58
19	*Michellia champaca - champak tree*	60
20	*Feronia elephantum - wood apple*	58
21	*Azadirechta indica - neem*	56
22	*Pungamia pinata - pongamia*	54
23	*Zizyphus jujuba - indian plum*	59
24	*Ficus infectoria - white fig*	72
25	*Cassia siamea - kasod tree*	56
26	*Ficus amplisima - Indian bat tree*	58
27	*Nanthiyavattai - crepe jasmine*	60
28	*Terminalia cetapa - indian almond*	70
29	*Syzygium cumini- Malabar plum*	30
30	*Holoptelea integrifolia - jungle cork*	70
31	*Millingtonia hortensis - indian cork tree*	70
32	*Ceiba petandra - kapok tree*	70
33	*Wrightia tinctoria - pala indigo plant*	30
34	*Lawsonia inermis - henna*	70
35	*Ficus religiosa - peepal*	55

S.NO	Name	No. of saplings planted
36	*Gmelina arborea - gamhar*	70
37	*Ficus mysorensis - brown wolly fig*	55
38	*Nerium Oleander*	70
39	*Murraya Koenigi*	70
40	*Thespesea Populena*	58
41	*Calotropis procea*	72
42	*Custard Apple*	74
43	*Bamboo*	28
44	*Red sandal*	58
45	*Citrus lemon*	35
46	*Indian Cherry*	38
47	*Indian Cherry*	32
48	*Papaya*	34
49	*Guava*	70
50	*Lemon*	70
	TOTAL	**3000**

Kakdwip, WB, 2023

S.No	Scientific Name	No of Samplings
1	*Avicennia marina*	1000
2	*Avicennia officinalis*	1000
3	*Bruguiera cylindrica*	33300
4	*Bruguiera gymnorhiza*	17270
5	*Rhizophora mucronata*	250
6	*Ceriops tagal*	1210

Sagar, WB, 2022

S.No	Scientific Name	No of Sampling
1	*Heritiera fomes*	30
2	*Xylocarpus granatum*	30
3	*Xylocarpus mekongensis*	120
4	*Rhizophora mucronata*	2700
5	*Bruguiera cylindrica*	3300
6	*Bruguiera gymnorhiza*	7820
7	*Ceriops sp*	4000

Taranagar-Patharpratima, WB, 2021

S. No	Scientific Name	No of Saplings
1	*Ceriops sp*	1460
2	*Avicennia marina*	1000
3	*Avicennia officinalis*	1000
4	*Rhizophora*	40
5	*Bruguiera gymnorhiza*	1500
6	*Bruguiera cylindrica*	1000

Field photos

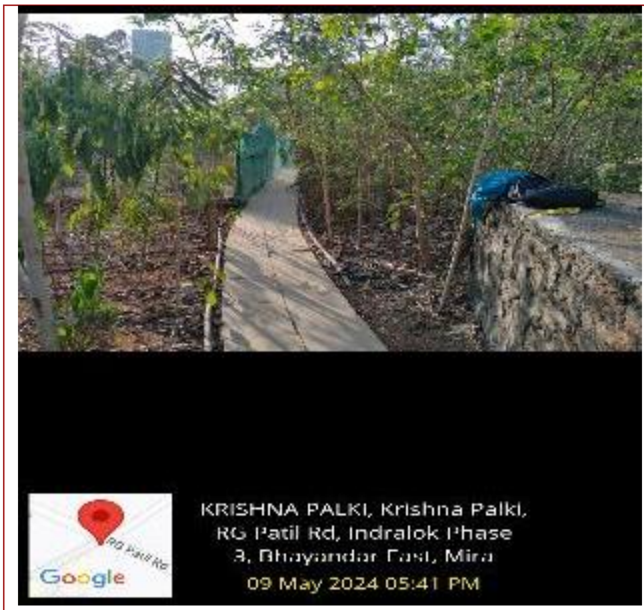
Tamil Nadu

Site: Perambur, Chennai




Maharashtra

Site: Mira-Bhyandar, Mumbai



Site: Ghatkopar, Mumbai

Site: Bhatsai, Thane

Site: Rayate, Thane

West Bengal

Sites – Taranagaar, Bajpukur

Haryana

Sites: Badshahpur, Gurugram