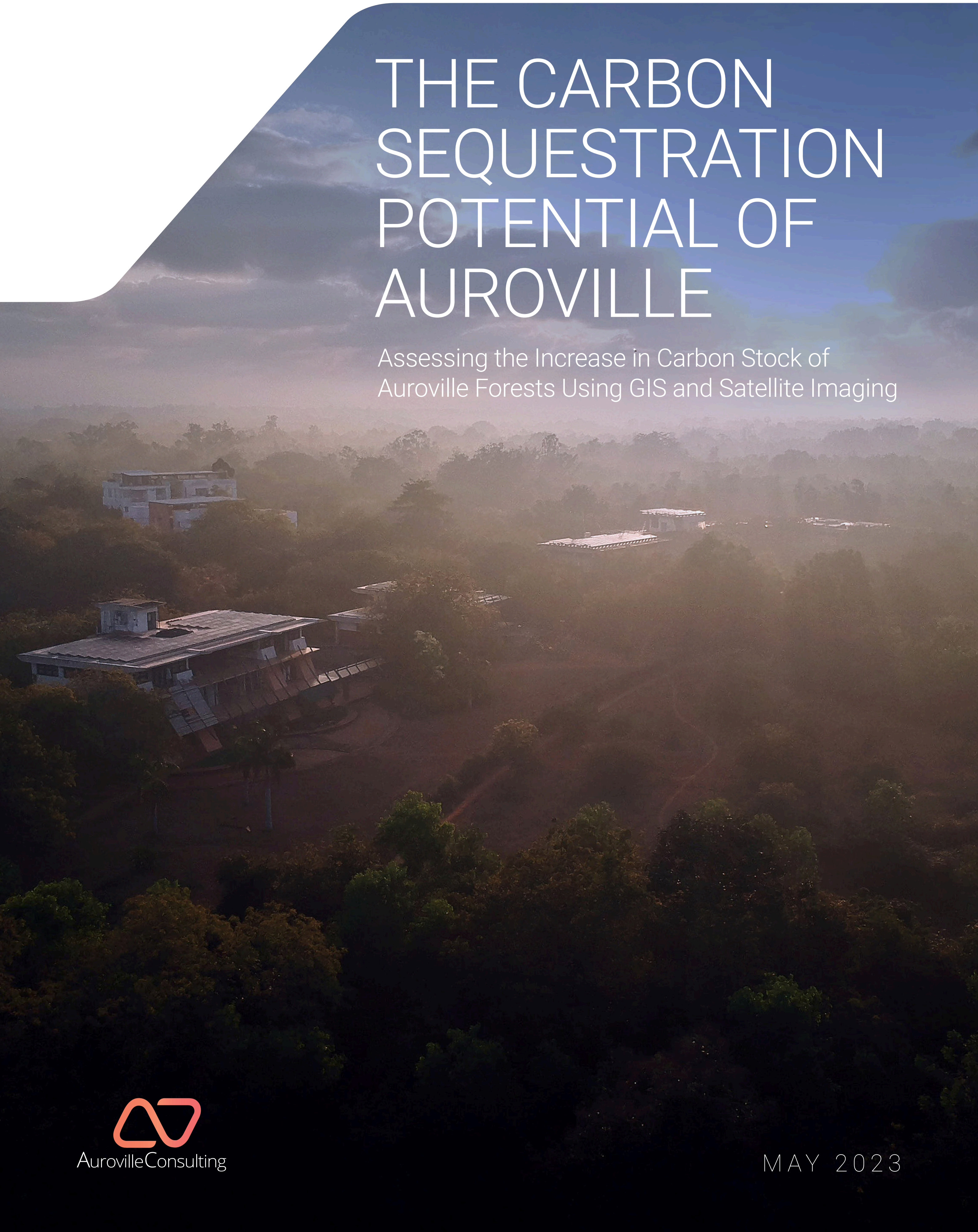
2017-2022

THE CARBON SEQUESTRATION POTENTIAL OF AUROVILLE

Assessing the Increase in Carbon Stock of Auroville Forests Using GIS and Satellite Imaging



AurovilleConsulting

MAY 2023

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Assessing the Increase in Carbon Stock of Auroville Forests using GIS and Satellite Imaging

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Acknowledgments

This report was possible through the help received from units and individuals in Auroville that believed in this project and took the time to put together the data.

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Executive Summary

The cumulative carbon stock for Auroville's land under tree cover of 920 hectares for the time period from February 2017 to February 2022 was estimated at 34,778 tCO2e. This equals an average carbon stock addition of 6,956 tCO2e per year.

The average carbon stock per hectare of forest land in Tamil Nadu was estimated at 87.26 tCO2e/year (MOEFCC 2017). The average carbon stock per hectare over five years for the Auroville forest was found to be 99.96 tCO2e/year which is 14.55% above the average.

Comparing the satellite images below of the Auroville area of 2017 (Figure 1) with the one from 2022 (Figure 2) a clear increase in green cover can be detected. This is highlighted by the darker green patches.

Table 1: Increase in carbon stock from 2017 to 2022

Year	Carbon stock (tCO2e)
February 2017	85,254.86
February 2022	1,20,033.2
Increase	**34,778.35**

Figure 1: February 2017 Satellite image of Auroville with the normalised FCD values overlayed.

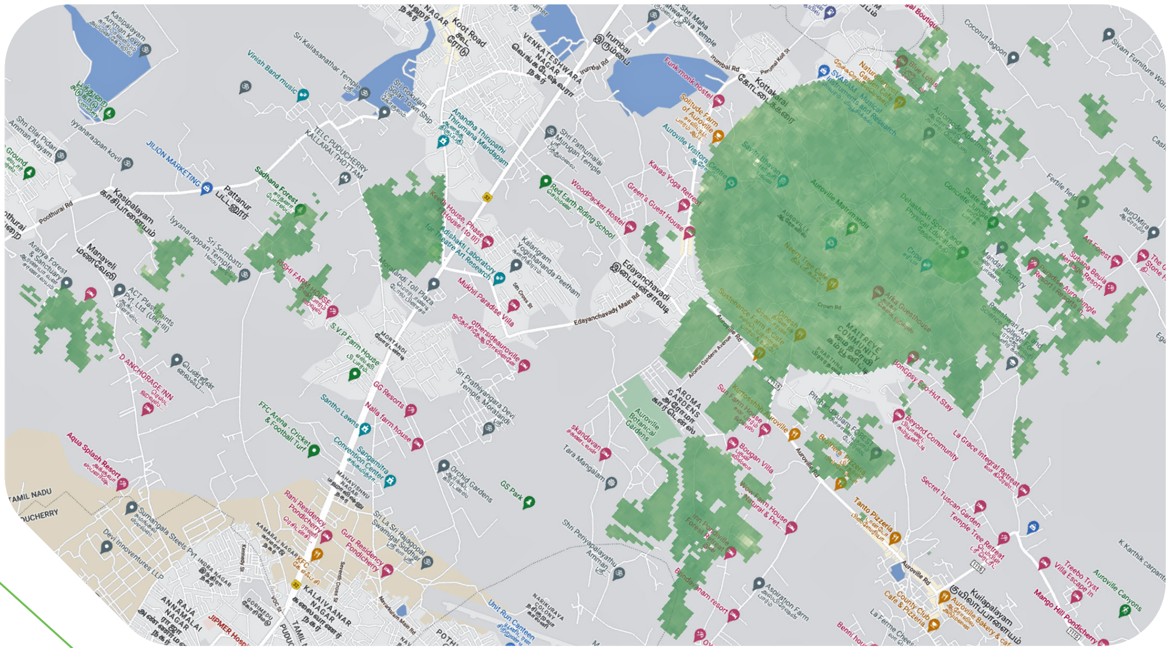
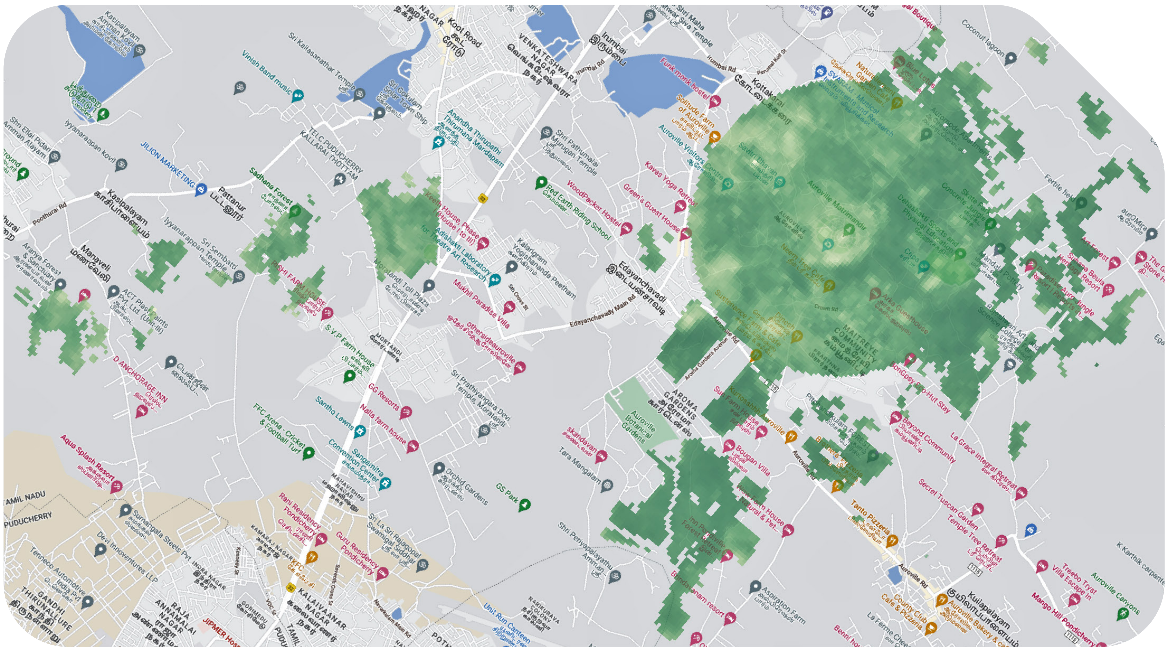


Figure 2: February 2022 Satellite image of Auroville with the normalised FCD values overlayed.

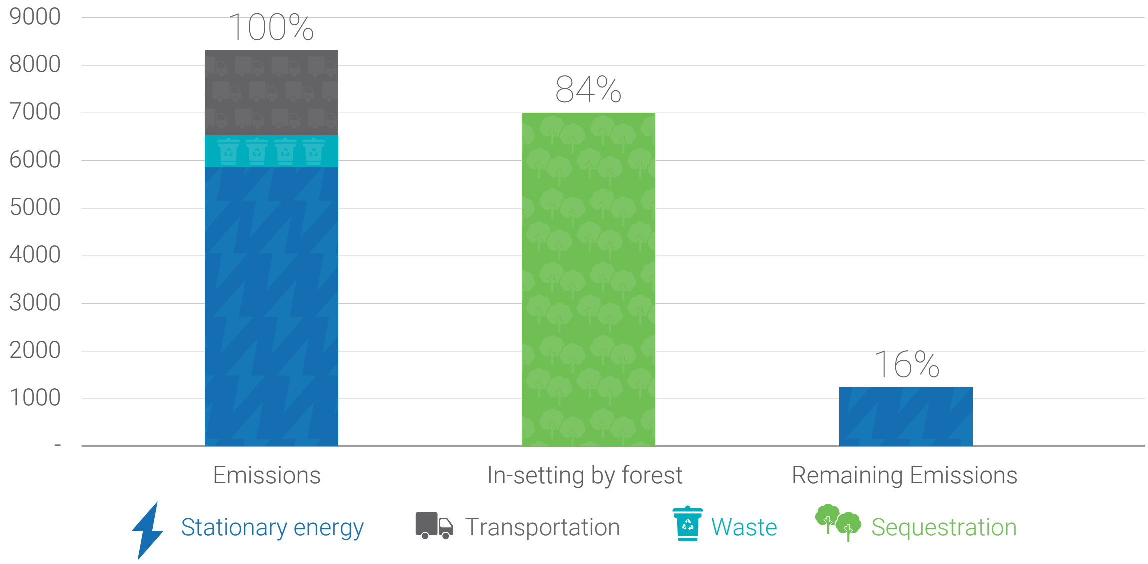


Source : LandsatTM 2022

Forest Canopy Density

Open Forest   Very Dense Forest

Figure 3: Emissions of the Auroville vs surplus emissions (FY2018-19)



As per the Auroville Greenhouse Gas Accounting Report (Auroville Consulting 2020) Auroville produced 8,298.54 tCO2e in FY 2018-2019, this excludes emissions from agriculture, forestry and other land use (AFLOU) and industrial production and product use (IPPU).

Auroville's green cover sequestered 84% of its total emission or 6,956 tCO2e per year. The surplus CO2e emitted for FY 2018-19 therefore is 1,343 tCO2e or 16%. To offset this carbon an additional 19.82 hectare of land would need to be converted from moderately dense forest to very dense forest. This could also be achieved by installing a 1.19 MW solar energy capacity or by transitioning all units to low or zero emission transport solutions.

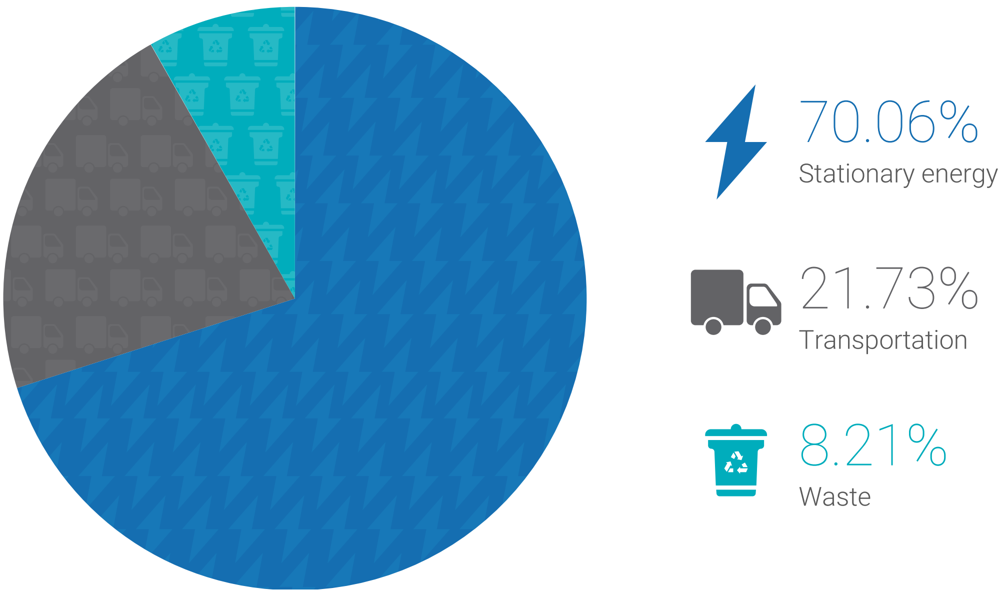
Consistent studies either on a yearly or bi-yearly basis can help improve accuracy of emissions tracking and sequestration numbers of the community and help set targets. This would lead to additional financing opportunities and access to voluntary mechanisms such as carbon financing to support existing forestry activities.

2

Introduction

With the earth's average temperatures increasing due to anthropogenic activity, the time to reflect on alternative trajectories of development is now. The first step in this journey is to take stock of our current carbon emissions and sequestration capabilities. In 2022 a GHG emission baseline for Auroville (Auroville Consulting 2022) was established. The inventory highted the overall emissions from the community, excluding land use and industrial production as 6,956 tCO_2e and a detailed analysis into the stationary energy, transportation and waste related emissions highlighted below.

Figure 4: Emissions of the Auroville community by sector in tCO_2e (FY2018-19)



This report now intends to assess the sequestration capabilities of Auroville land under tree cover for a five-year period from February 2017 to February 2022. The tree cover in Auroville is a prime contributor to the community's long-term vision of sustainable development. The overall tree cover includes the residential zones, industrial zones, parks, public spaces and the designated green belt area of Auroville developed and maintained by the Forest Group of Auroville.

3

Background

Auroville, a universal township in south India, has taken significant steps towards conscious and sustainable living since its inception over 55 years ago. These steps include research and implementation of climate responsive and green architecture, appropriate technologies in energy and mobility, waste and water management, organic farming and food production, and ecological restoration.

Considering the current global climate change emergency, the next step in Auroville's evolution was to take inventory of its emissions in order to improve its ability to take effective action and monitor progress.

While Auroville has established its GHG emission baseline in 2019, assessing its carbon sequestration potential will make another essential contribution for Auroville's aspiration toward climate neutrality. This activity was undertaken from the inception of the community and is an ongoing activity predominantly undertaken by the Auroville Forest Group.

The Auroville Forest Group manages approximately 1,380 acres of greenbelt and city land for Auroville, this land is divided into 44 stewardship areas of various sized plots. The forests are managed by 79 Aurovilian stewards and co-stewards, whose work is to protect and develop the forest area.

The protection against livestock grazing, land encroachment and firewood/timber extractors is an ongoing work that is partially supported by City Service, and a further team of permanent/semi-permanent/temporary/and seasonal forest workers who are employed by the different stewards and are funded by the income generated either by the sustainable forestry or by the stewards themselves.

4

Data & Assumptions

The sections below provide an overview of the data and assumptions that were utilized to estimate the forest canopy density (FCD) and carbon sequestration potential of Auroville.

Boundary Maps

Boundary maps were acquired from the Auroville Town Development Council (ATDC) and are subject to certain assumptions which are listed below:

(i) Data received is accurate up to the year 2020.

(ii) All land inside the master plan, although not under the financial control of Auroville, is assumed to be under the operational control of Auroville and hence considered as part of the study.

(iii) The source of remote sensing data for the FCD model is LANDSAT TM data and was acquired through Satellite images from the United States Geological Survey (USGS).

(iv) The maps are divided into pixels of 30m*30m on ground and all data is averaged within the boundary of each pixel.

Indices

The components for the model are advanced vegetation index, bare soil index, thermal index and shadow index which are used for calculating Forest Canopy Density (FCD). FCD is the basis for the planning and implementation of a forest rehabilitation program. The comparative sample set for the assessment was in the evergreen forests in the islands of Luzon (Philippines) and Sumatra (Indonesia); and for monsoon (subtropical deciduous) forest in Chiang -Mai (Thailand) and Terai (Nepal) (A. Rikimaru, s. Miyatake 1997).

5

Introduction to FCD

The FCD mapping and monitoring model utilizes forest canopy density as an essential parameter for characterization of forest conditions. FCD data indicates the degree of degradation, thereby the intensity of rehabilitation that may be required. The source remote sensing data for the FCD model is LANDSAT TM data. The FCD model comprises biophysical phenomenon modelling and analysis utilizing data derived from four indices: Advanced Vegetation Index (AVI), Bare Soil Index (BI), Shadow Index or Scaled Shadow Index (SI, SSI) and Thermal Index (TI). The canopy density is calculated in percentage for each pixel. The FCD model is a much more efficient alternative to the conventional methods of calculating carbon sequestration such as on-ground verification (A. Rikimaru, s. Miyatake 1997).

a. Characteristics of Forest Indices

FCD is one of the most useful parameters to consider in the planning and implementation of rehabilitation programs[1]. This assessment is the development of a biophysical analysis model for obtaining FCD using LANDSAT TM data image analysis. The components of the FCD model are four factors; vegetation, bare soil, thermal and shadow. FCD combines data from these four (4) indices.

- **Vegetation index (VI)** is a response to all vegetation items such as forest and grassland cover and is a combination of the Advanced vegetation index (AVI) and Normalised Difference Vegetation Index (NDVI).
- **Shadow Index (SI)** maps the isolated shadow patterns on the map and increases as the forest density increases.
- **Thermal Index (TI)** increases as the vegetation quantity increases. Black coloured soil areas tend to show a higher temperature.
- **Bare Soil Index (BI)** increases as the bare soil exposure increases.

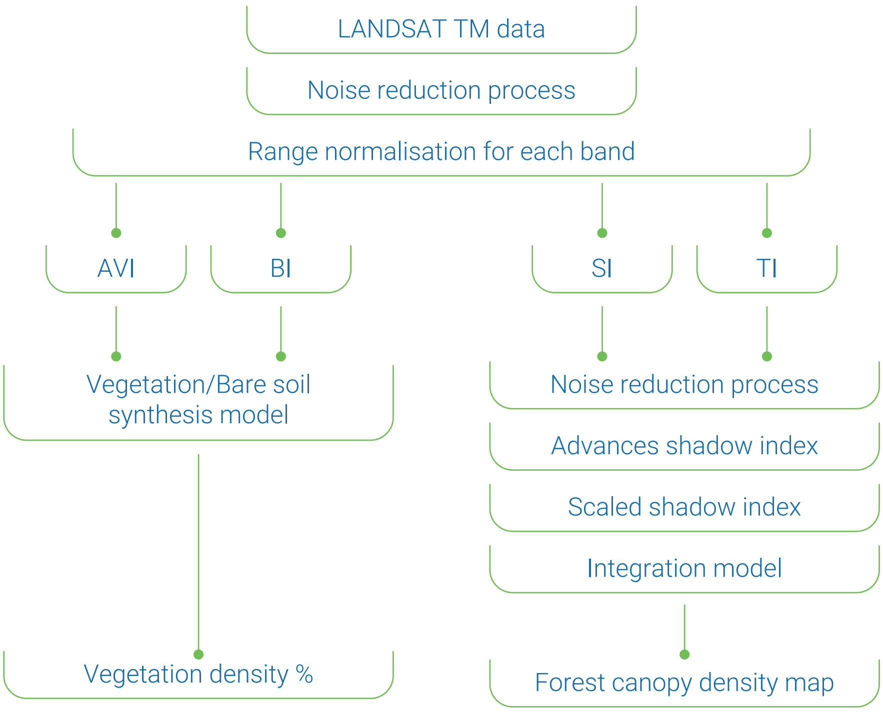
These index values are calculated for every pixel. Figure 4 illustrates the relationship between forest conditions and the four indices (VI, BI, SI and TI).

[1] A rehabilitation program aims to protect the forest from further degradation and promote natural regeneration

b. The Procedure of FCD Modelling

The flowchart of the procedure for the FCD mapping model is illustrated in Figure 5. Results post image processing are as shown in Figure 4.

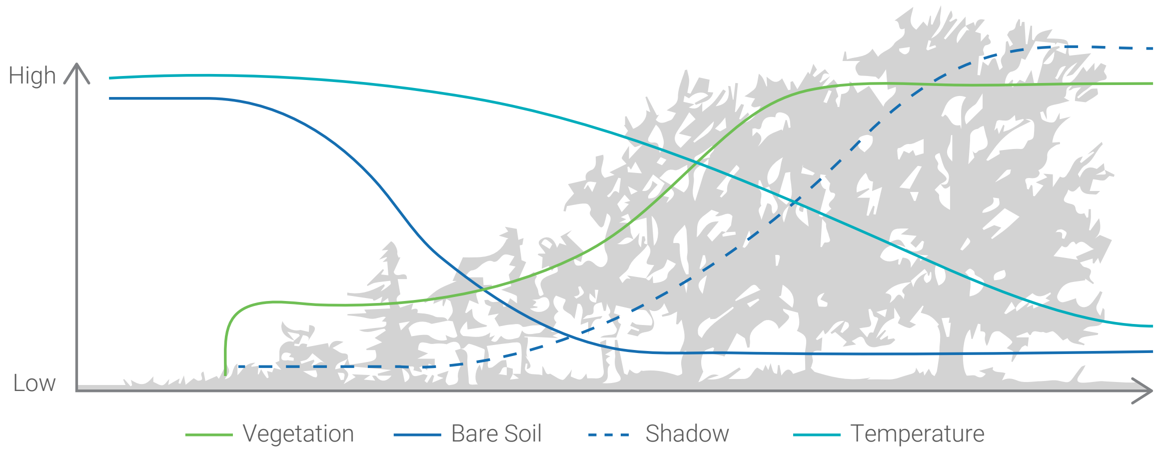
Figure 5: Flow chart of FCD Mapping Model



Source: Adapted from A. Rikimaru, s. Miyatake (1997)

The six steps to calculate FCD are mentioned below in Table 2. The process for the same corresponds to the flowchart as shown in Figure 5 (A. Rikimaru, s. Miyatake 1997).

Figure 6: The Characteristics of four indices for calculating forest canopy density (FCD)



Source: A. Rikimaru, s. Miyatake (1997)

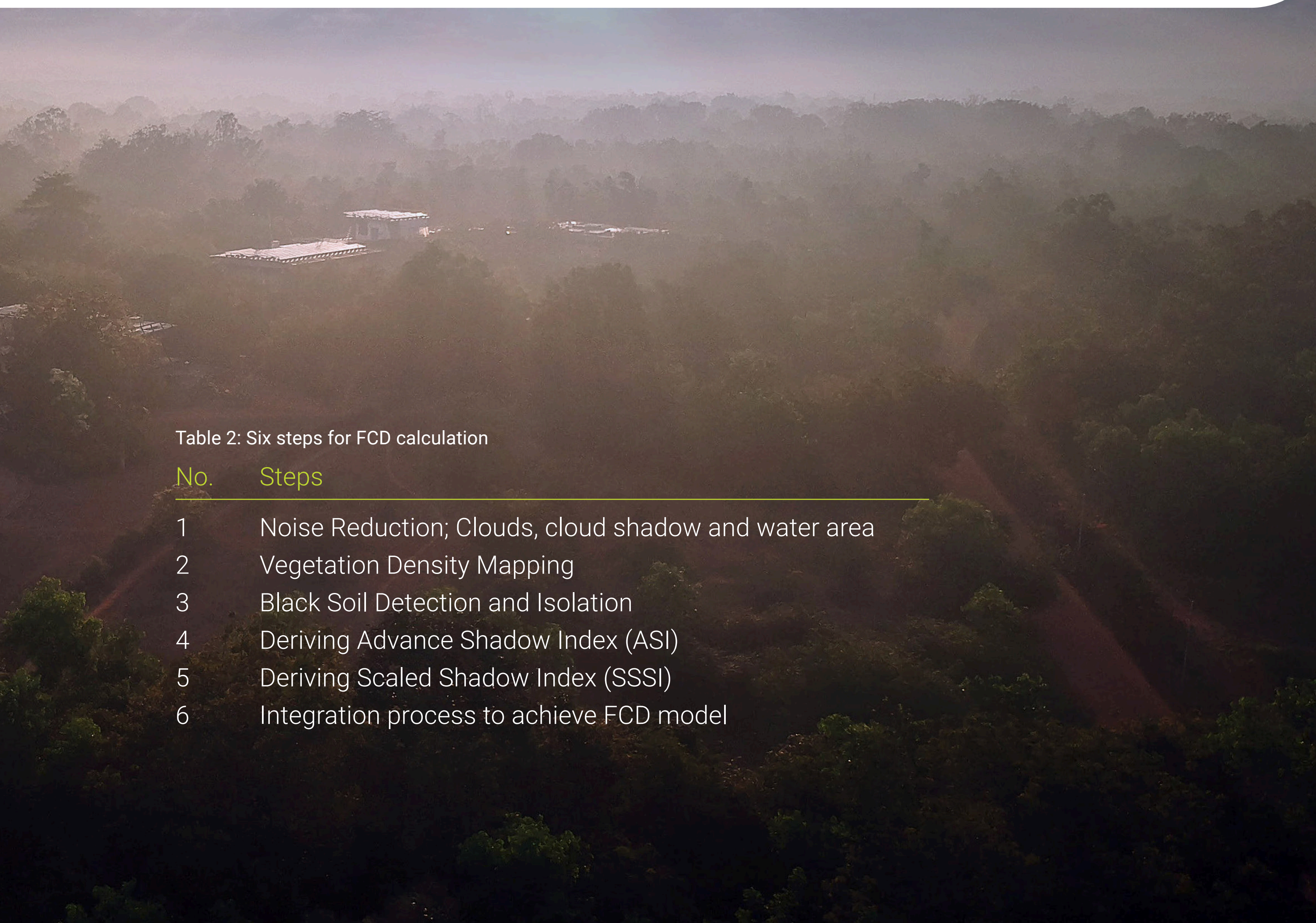


Table 2: Six steps for FCD calculation

No.	Steps
1	Noise Reduction; Clouds, cloud shadow and water area
2	Vegetation Density Mapping
3	Black Soil Detection and Isolation
4	Deriving Advance Shadow Index (ASI)
5	Deriving Scaled Shadow Index (SSSI)
6	Integration process to achieve FCD model

6

Calculating the carbon stock

The above mentioned FCD modelling is used to calculate the carbon stock per pixel in the satellite image received. Each pixel relates to a 30m by 30m (0.09 hectare) piece of land in the given region. The FCD values for each pixel are calculated and scaled for reference.

Scaling FCD values for reference

The initial data is received as raw data in the form of an FCD number per pixel. This number is further normalised for all data within the boundary. The data once normalised is overlayed on top of the boundary map of the region, and is highlighted in Figure 7 and Figure 8.

The data is further extracted by number of pixels by normalised brackets (0-10, 10-20…90-100) and is highlighted in table 3.

Table 3: Number of pixels falling into normalised categories for February 2017 and February 2022

Normalised bracket	Number of pixels 2017	Number of pixels 2022	**Change**
0-10	0	0	**0**
10-20	3	0	**-3**
20-30	5	21	**16**
30-40	24	154	**130**
40-50	222	499	**277**
50-60	3,509	1,295	**-2,214**
60-70	6,235	2,103	**-4,132**
70-80	234	3,043	**2,809**
80-90	0	2,644	**2,644**
90-100	0	404	**404**

Figure 1: February 2017 Satellite image of Auroville with the normalised FCD values overlayed.

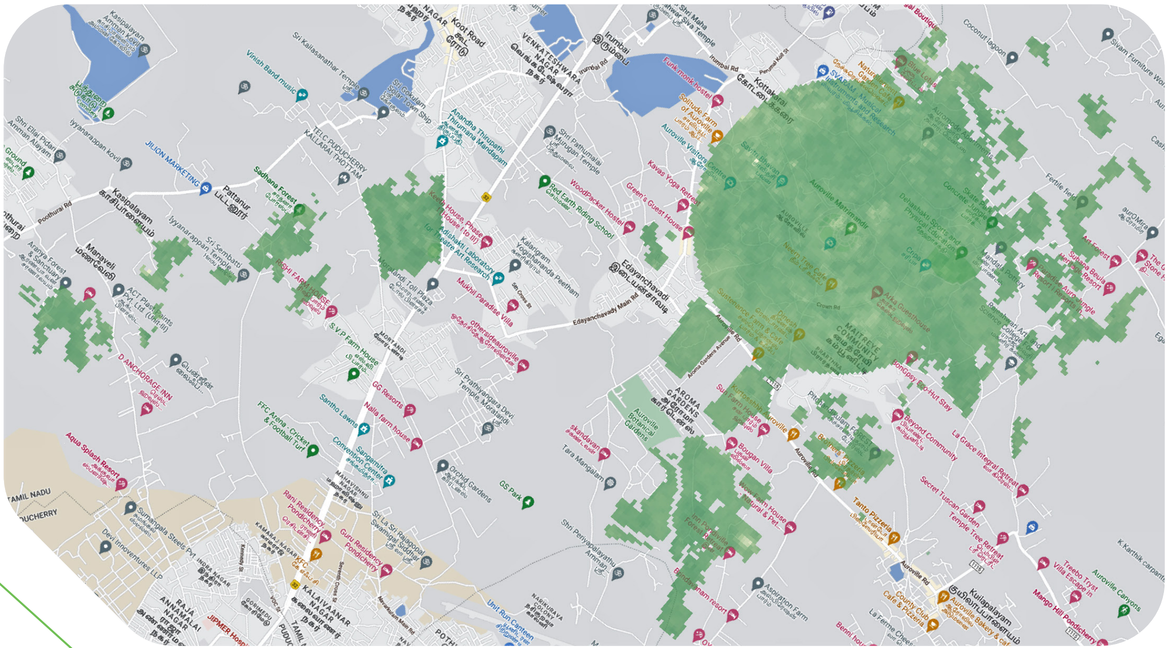
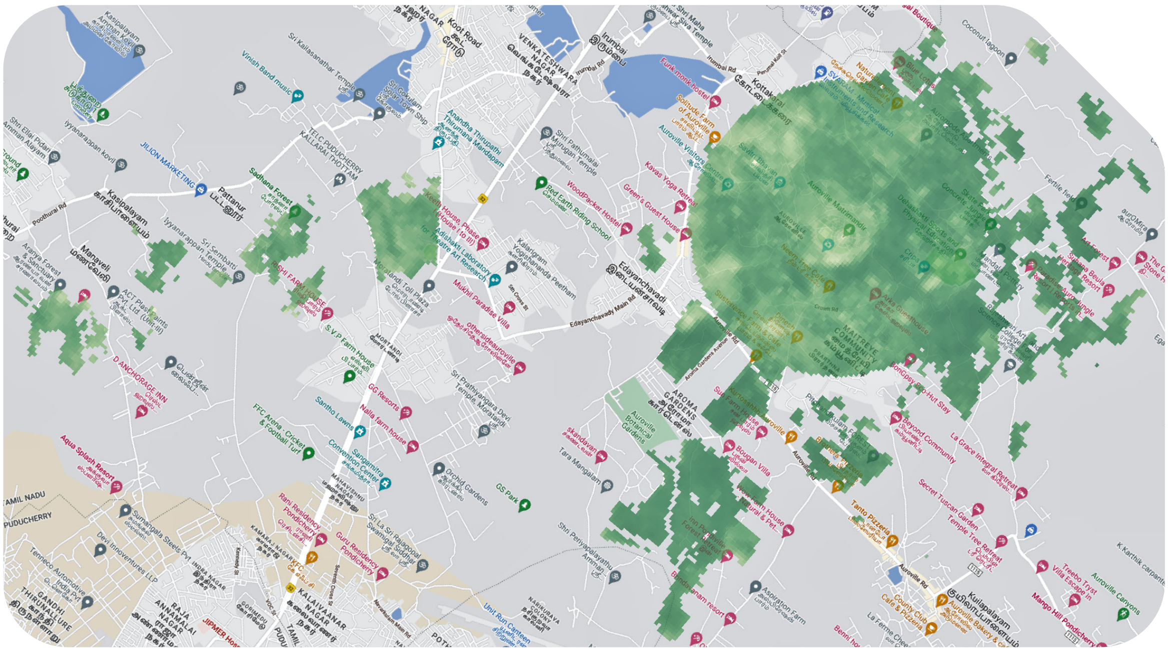


Figure 2: February 2022 Satellite image of Auroville with the normalised FCD values overlayed.



Source : LandsatTM 2022

Forest Canopy Density

Open Forest Very Dense Forest

Categorisation based on density

Categorisation refers to forming brackets of the normalised FCD values and assigning pre-determined density values to the categories. Table 4 shows the categories as per their normalized values.

Table 4: Density categorisation by normalised brackets

Normalised category	Colour	Forest type	Description
0-10		Scrub/Non forest	All forest lands with poor tree growth mainly of small or stunted trees having canopy density less than 10 percent
10-40		Open Forest (OF)	All lands with tree cover (Including mangrove cover) of canopy density between 10% and 40%
40-70		Moderately Dense Forest (MDF)	All lands with tree cover (Including mangrove cover) of canopy density between 40% and 70%
70-100		Very Dense Forest (VDF)	All Lands with tree cover (Including mangrove cover) of canopy density of 70% and above

Source: MoEFCC I 2017

Figure 9: February 2022 Satellite image of Auroville with the density by forest type overlayed.

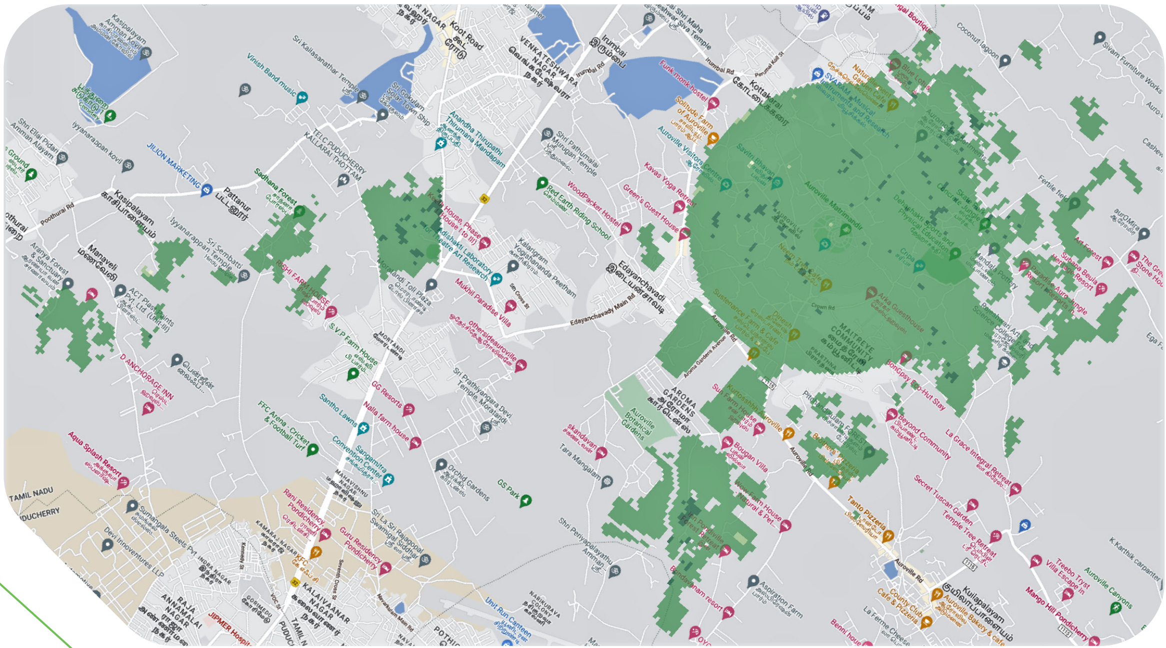
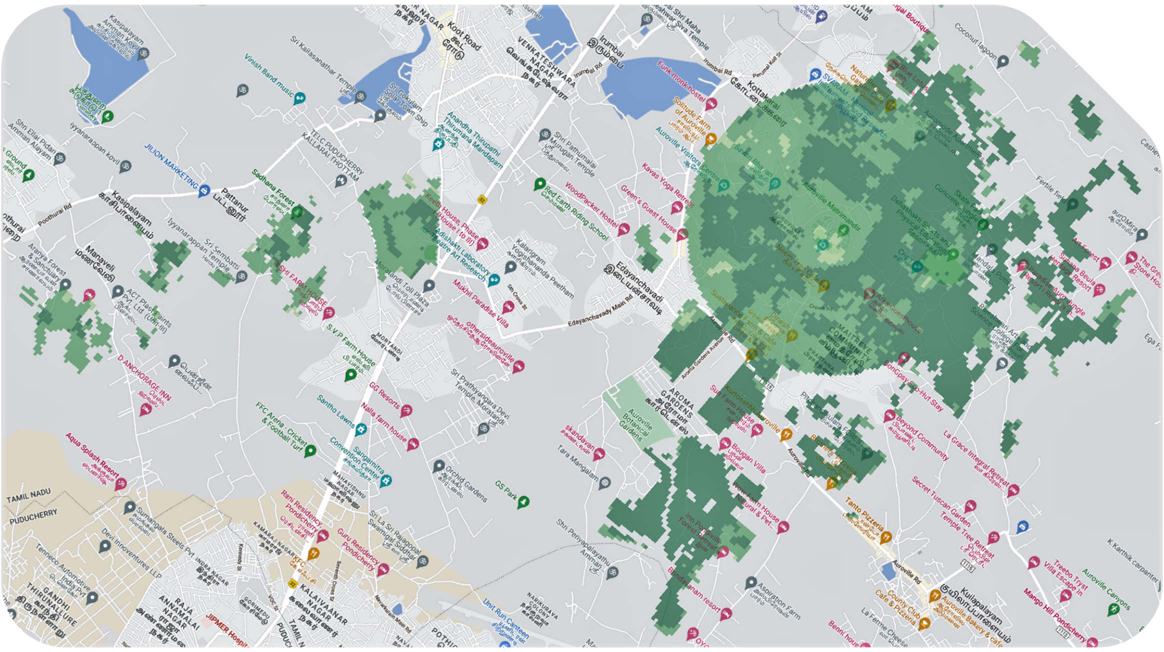


Figure 10: February 2022 Satellite image of Auroville with density by forest type overlayed.



Source : LandsatTM 2022

1 pixel = 30m * 30m (0.09 hectare)

Forest Canopy Density

0 10 40 70 100

Emission factor by forest type

An emission factor highlights the emissions per unit for a particular category, in this case the tonnes of carbon dioxide sequestered per hectare (tCO2e/ha). The forest considered in this specific case for the Auroville bioregion is the Tropical Dry Evergreen Forest (TDEF) with the related table attached below. The ISFR report categorizes forests across India by type and region. Calculating the average emission factor per hectare of forest, based on five categories mentioned below. The sum of these categories adds up to give the total carbon sequestered per hectare.

- Above ground biomass (AGB)
- Below ground biomass (BGB)
- Dead wood
- Litter
- Soil organic carbon (SOC)

Table 5: Category wise Emission Factor by forest type and density for Tropical Dry Evergreen Forests per hectare stock in tonnes.

Density	AGB	BGB	Dead wood	Litter	SOC	Total (tCO2e/ha)
VDF	48.58	48.58	1.21	0.99	89.01	**158.87**
		8			1	
MDF	33.33	13.09	0.37	1.91	42.42	**91.12**
		9			2	
OF	18.85	7.42	0.20	0.90	35.08	**62.46**
					2	

Source: MOEFCC 2017

The number of pixels are placed into the above mentioned brackets and multiplied by 0.09 (each pixel is a 30m*30m piece of land) to determine the amount of land in hectares for each category. This value is now multiplied by the respective emission factor to find the tonnes of carbon stock.

Calculating the carbon stock for each category

Table 6: Carbon Stock Calculation (February-2017)

Forest type	Normalised category	No. of pixels	Total area (ha)	Carbon stock (ha)	**Total Carbon stock (tonnes)**
Scrub	0-10	0	0	0	**0**
OF	10-40	32	2.88	62.46	**179.88**
MDF	40-70	9,966	896.94	91.12	**81,729.17**
VDF	70-100	234	21.06	158.87	**3,345.80**
Total					**85,254.86**

Table 7: Carbon Stock Calculation (February-2022)

Forest type	Normalised category	No. of pixels	Total area (ha)	Carbon stock (ha)	**Total Carbon stock (tonnes)**
Scrub	0-10	0	0	0	**0**
OF	10-40	175	15.75	62.46	**983.74**
MDF	40-70	3,897	350.73	91.12	**31,958.52**
VDF	70-100	6,091	548.19	158.87	**87,090.95**
Total					**1,20,033.20**

Table 8: Comparing change in area for each density category (2017 to 2022)

Density	Normalised category	Change in no. of pixels	**Change in total area**
Scrub	0-10	0	**0**
OF	10-40	143	**12.87**
MDF	40-70	-6069	**-546.21**
VDF	70-100	5857	**527.13**

7

Calculating increase in carbon stock

Based on the above calculations, the values shown in the table below indicate the carbon stock for February 2017, and February 2022.The difference of the two values gives us the increase in carbon stock over the period of five years amounting to a total increase (or sequestration) of 34,778 tCO2e as highlighted in table 8. The effective average carbon sequestered per year is 6,956 tCO2e.

Table 9: Increase in carbon stock from 2017 to 2022

Year	Carbon stock (tCO2e)
February 2017	85,254.86
February 2022	1,20,033.2
Increase	**34,778.35**

8

Conclusion

The average carbon stock per hectare of forest land in Tamil Nadu was estimated at 87.26 tCO2e/year (MOEFCC 2017). If we were to compare this to the average carbon stock per hectare for the 920 hectares of Auroville forest, we see that the Auroville forests held 90.39 tCO2e/year in 2017 and 109.53 tCO2e/year in 2022 which is 3.40% and 25.55% above average respectively. The average carbon stock per hectare over five years for the Auroville forest was found to be 99.96 tCO2e/year which is 14.55% above the average.

As per the Auroville Greenhouse Gas Accounting Report (Auroville Consulting 2020) Auroville produced 8,298.54 tCO2e in FY 2018-2019, this excludes emissions from agriculture, forestry and other land use (AFLOU) and industrial production and product use (IPPU). Auroville's green cover sequestered 84% of its total emission or 6,956 tCO2e per year.

The surplus CO2e emitted for FY 2018-19 therefore is 1,343 tCO2e or 16%. To offset this carbon an additional 19.82 hectare of land would need to be converted from moderately dense forest to very dense forest. This could also be achieved by installing a 1.19 MW solar energy capacity or by transitioning all units to low or zero emission transport solutions.

Table 10: Emissions balance for the Auroville community (2018-19)

Sector	tCO2e/year	%
Stationary energy	5,814	70%
Transportation	1,804	22%
Waste	681	8%
Total emissions	8,299	100%
In-setting by forest	6,956	84%
Remaining emissions	**1,343**	**16%**

Consistent studies either on a yearly or bi-yearly basis can help improve accuracy of emissions tracking and sequestration numbers of the community and help set targets. This would lead to additional financing opportunities and access to voluntary mechanisms such as carbon financing to support existing forestry activities.

9

References

1. Auroville Consulting. 2022. Auroville Greenhouse Gas Emissions inventory report (FY 2018-19). Available at: https://www.aurovilleconsulting.com/auroville-greenhouse-gas-accounting-report-fy-2018-2019/. (Accessed on: 03 January 2023)
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