Baseline Report

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"Baseline Study for Estimating Carbon Stocks of Interventions done through ITC's Mission Sunehra Kal Programme"

Submitted to

ITC Ltd.

teri
The Energy and Resources Institute

...towards global sustainable development

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Abbreviations

ITC MSK	ITC Mission Sunehra Kal
SMC	Soil Moisture Conservation
SOC	Soil Organic Carbon
DBH	Diameter at Breast Height
SDG	Sustainable Development Goals
AGB	Above Ground Biomass
BGB	Below Ground Biomass
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
IPCC GPG	IPCC Good Practice Guidance
FAO	Food and Agricultural Organization
tCO_2	Tonne Carbon Equivalent
OM	Soil Organic Matter
CHNS	Carbon, Hydrogen, Sulphur and Nitrogen

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Executive Summary

ITC Mission Sunehra Kal (ITC MSK) project has been developed to assess the impact generated by the project's programmes. The objective is to assess the carbon sequestered as a result of ITC's interventions done through ITC's MSK in seven different states namely Andhra Pradesh, Maharasthra, Telangana, Karnataka, Tamil Nadu, Rajasthan and Madhya Pradesh. The major goal of the study is to establish a baseline and estimate the Carbon stocks for ITC MSK's intervention areas. ITC, with the help of various NGOs has been able to promote plantations in seven states, most of which are in seedling stage. In some states, grassland development has been done by sowing seeds and developing trenches to protect the grassland from cattle. ITC has also done soil moisture conservation works by constructing various structures (Farm Pond, Farm Bund, Check Dams and Percolation Tanks, etc) that aids in the enhancement of soil organic carbon.

This report has been developed by TERI to assess the baseline carbon stock of all the above-mentioned interventions done through ITC MSK project along with its carbon sequestration potential for 10, 20 and 30 years. TERI team visited interventions sites in all the seven states for field data collection.

To estimate the carbon stocks in 7 states, the states were clustered into different strata according to agro-climatic zones. For each stratum, stratified random sampling was carried out to estimate the number of sample plots to be laid on field in different strata in order to establish baseline carbon stock of existing biomass. In addition to assessing the baseline carbon stock, the carbon sequestration potential of the plantations has also been calculated in the form of carbon equivalent projections for 10, 20 and 30 years. This has been calculated for all the agro-climatic zones using area and productivity of the ecological zone. Measurement techniques of various parameters and analysis of the collected data has been done following the IPCC Good Practice Guidance 2006, Refinement of IPCC 2006 Good Practice Guideline 2019 and Working Plan Code 2014.

The total CO2 equivalent measured for the project is **2,17,656.34** that includes plantation and grasslands falling under different agro climatic zones. The carbon sequestration potential for plantations under ITC MSK has been estimated to be **70963.08 tCO2e** per annum, **709630.80 tCO2e** for 10 years, **14,19,261.60 tCO2e** for 20 years and **21,28,892 tCO2e** for 30 years respectively.

Biomass measured for existing mature plantations with DBH above 10 cm is **23779.77 tonnes** for 4063.24 Ha of plantation area. On comparing all the strata, it was found that the Central Plateau & Hills (Bundi, Jhalawar & Kota) zone has highest biomass sequestered i.e., **14357.08 tonnes**. The carbon sequestration potential of all the plantations done under ITC MSK project has been estimated as **70963.08 tCO2e** for total plantation area of 5954.80 Ha, out of which the Western Dry Region has the highest potential. The soil samples from plantation areas were also analysed for soil organic carbon (SOC) and has been compared with the soil organic carbon of soil sample from control region outside the project area. It has been observed that SOC in intervention area is more than the SOC in non-intervention area. Biomass calculated for grasslands is approximately **4590.61 tonnes**. In case of Soil Moisture Conservation (SMC) activities, the SOC from the SMC structure area was compared with the SOC of soil from a control area outside the project. A biodiversity assessment has also been carried out for each state, to calculate the floral diversity as a result of plantation activities done through this project.

Introduction

Context and Objectives of the Assessment

ITC Mission "Sunehra Kal" (MSK; 'Sunehra Kal' means "bright future"), was initiated with an intention to contribute to Sustainable Development Goals by enhancing soil quality, and biodiversity. The major goal of this report is to establish a baseline and estimate the Carbon stocks for ITC MSK's intervention areas.

ITC has done majorly three activities i.e., Plantation, Grassland development through seed sowing and Soil Moisture Conservation through construction of various water harvesting structures and farm bunds to protect soil erosion. TERI has developed this report which assesses the baseline carbon stock present in plantations, soil and grass as a result of three interventions done through ITC MSK in 7 states. The assessment has been done through appropriate methodologies developed by TERI suitable for the intervention sites depending upon their current ecological status.

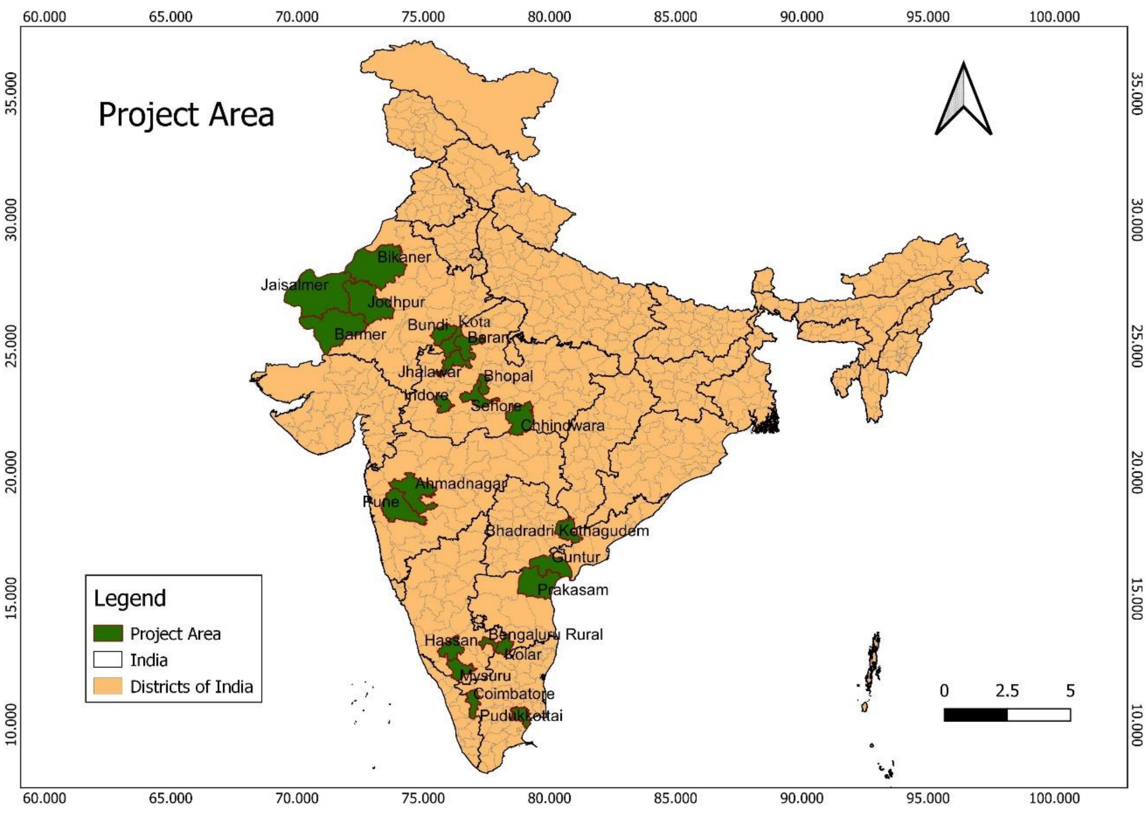


Figure 1: Districts covered under ITC Mission Sunehra Kal project

Scope of Work

1. Clustering of biodiversity conservation works (20-21 & 21-22), based on similar growth conditions or agro-climatic zones or any other technically recommended methodology as per referred standards.

2. Identification of sample plots through statistically appropriate sampling methodology and as guided by standards in each cluster.
3. Estimation of baseline conditions in each of identified sample plots covering above ground carbon stock in trees, shrubs, deadwood, litter, and below ground soil organic carbon.
4. In each cluster, post finalisation of sample plots, establishing baselines by estimating existing biomass (trees, shrubs and herbaceous vegetation) and soil organic carbon.
5. Extrapolation of baselines based on cluster wise area covered through programme during the year.
6. Developing and recommending methodology to be followed for periodical impact assessment in future to assess carbon sequestration due to ITC's biodiversity conservation work.

Approach

Stratification of the intervention areas has been done based on agro-climatic zones. The country has been broadly divided into fifteen agricultural regions based on agroclimatic features, particularly soil type, climate including temperature and rainfall and its variation and water resources availability as under[1]:

1. Western Himalayan division
2. Eastern Himalayan division
3. Lower Gangetic plain region
4. Middle Gangetic plain region
5. Upper Gangetic plain region
6. Trans-Gangetic plain region
7. Eastern plateau and hill region
8. Central plateau and hill region
9. Western plateau and hill region
10. Southern plateau and hill region
11. East coast plain and hill region
12. West coast plain and hill region
13. Gujarat plain and hill region
14. Western plain and hill region
15. Island region

[1] http://jalshakti-dowr.gov.in/agro-climatic-zones

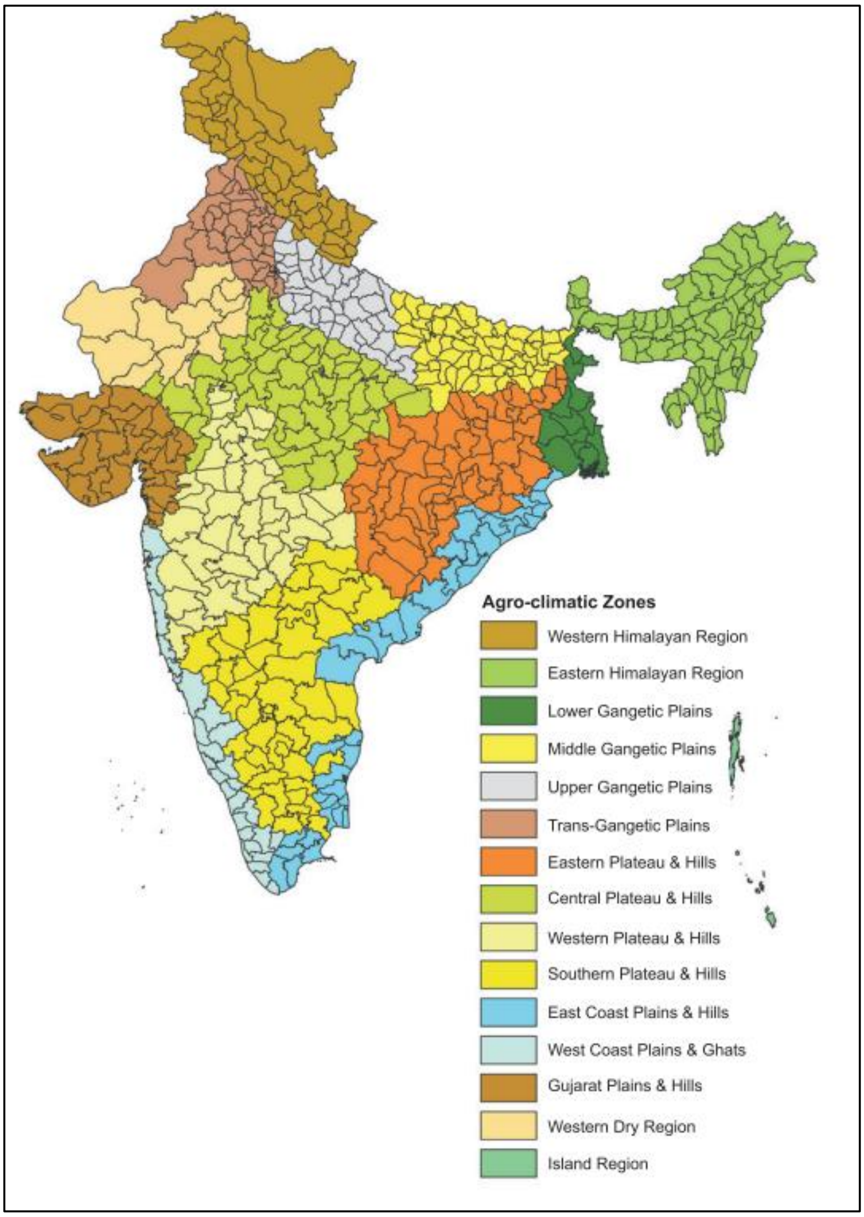


Figure 2: Division of Indian districts into Agro-climatic zone[2]

The seven states where interventions have been done fall under different agro-climatic zones which is mentioned in the table below.

Table 1: Agro-climatic zone wise division of seven states

States	Agro-climatic zones
Andhra Pradesh	Southern Plateau and Hills Region, East Coast Plains and Hills Region
Karnataka	Southern Plateau and Hills Region, West Coast Plains and Hills Region

[2] Source: http://www.nicra-icar.in/nicrarevised/images/publications/TDC/Impact%20of%20Climate%20Change%20on%20Indian%20Agriculture%20An%20Agro-Climatic%20Zone%20Level%20Estimation.pdf

States	Agro-climatic zones
Madhya Pradesh	Central Plateau and Hills Region, Eastern Plateau & Hills, Western Plateau & Hills
Maharashtra	Western Plateau and Hills Region, Eastern Plateau and Hills Region, West Coast Plains and Hills Region
Rajasthan	Central Plateau and Hills Regions, Trans-Gangetic Plains Region, Western Dry Region
Tamil Nadu	Southern Plateau and Hills Region, East Coast Plains and Hills Region, West Coast Plains & Hills
Telangana	Southern Plateau and Hills Region

The districts covered under this project have been clustered according to the agro-climatic zones they fall into. The table below elaborates the clustering of districts based on agro-climatic zones.

Table 2: District-wise division of agro-climatic zones

Agro-climatic Zone	District	State
Southern Plateau & Hills	Coimbatore	Tamil Nadu
	Pudukottai	Tamil Nadu
	Hassan	Karnataka
	Mysore	Karnataka
	Kolar	Karnataka
	Banglore Rural	Karnataka
	Bharadri Kothagudem	Telangana
East Coast Plains & Hills	Prakasam	Andhra Pradesh
	Palnadu	Andhra Pradesh
Central Plateau & Hills	Bhopal	Bhopal
	Chindwara	Bhopal
	Sehore	Bhopal
	Baran	Rajasthan
	Bundi	Rajasthan

Agro-climatic Zone	District	State
	Jhalawar	Rajasthan
	Kota	Rajasthan
Western Plateau & Hills	Indore	Bhopal
	Ahmednagar	Maharashtra
	Pune	Maharashtra
Trans Gangetic Plains	Bikaner	Rajasthan
Western Dry Region	Barmer	Rajasthan
	Jodhpur	Rajasthan
	Jaisalmer	Rajasthan

Description of Assessment Area

Climate and Soil

Andhra Pradesh

Andhra Pradesh is situated in tropical zone. The state has tropical monsoon type of climate, which is generally hot and humid. The climate is classified as tropical rainy climate represented by all regions of the state except the south-western portion where the climate is of steppe variation. In hot steppe areas, the mean daily temperature is 18° Celsius or less. Maximum temperature in the winter season ranges between 14° Celsius and 19° Celsius. In the tropical rainy areas, the mean daily temperature is above 20° Celsius with an annual rainfall of less than 150 cm.

There is a wide variation and uncertainty in the distribution of rainfall in the state. The annual rainfall in the coastal region between 70 and 150 cm, northern and central areas of the coastal region receive heavy rainfall from northeast monsoon. The average annual rainfall in the state is 940 mm.

Mainly six types of soils are found in Andhra Pradesh namely red, black, and alluvial, laterite, coastal sandy, and skeletal soils. Red soil is common throughout the Andhra Pradesh, the humus from the forest litter imparts an acidic content through decomposition. Black soils are also called black cotton soils. The black soils, rich in calcium and potash are found in western and north-western portions of the state. These are the second important soil group, which are fertile with retentive moisture but poor in nitrogen content. The black soils are of 3 types namely deep black, light black and mixed red and black soils. Alluvial soils are of two types, deltaic alluvial and coastal alluvial soils. The deltaic alluvial soils occur extensively in the deltas of Godavari and Krishna. The coastal alluvial soils are less fertile and stretch as a narrow belt along the coast for a short break in Vishakhapatnam district where the spurs of the Eastern Ghats meet the sea. Laterite soils occupy; large

Karnataka

Karnataka has the following four seasons in the year. The winter season from January to February, the summer season from March to May, the monsoon season from June to September and the post-monsoon season from October to December. The months of April and May are hot and very dry. Weather tends to be oppressive during June due to high humidity and temperature. In the next three months (July, August and September) relatively lower temperature are observed although the humidity continues to be high. Karnataka is divided into three meteorological zones:

Coastal Karnataka: This zone comprises the districts of Uttar Kannad, Udipi and Dakshin Kannad. It is a region of heavy rainfall and receives an average rainfall of 3638.5 mm per annum, far in excess of rest of state.

North Interior Karnataka: This zone comprises the districts of Belgaum, Bidar Bijapur, Bagalkot, Haveri, Gadag. Dharwad,Gulbarga, Koppal, Bellary and Raichur Districts. This is an arid zone and receives only 7115 mm of average rainfall per annum.

South Interior Karnataka: The rest of the districts of Karnataka fall into this one. This zone wives 10648 mm of average rainfall per annum. Bangalore rural, Kolar, Mysore and Hassan falls under this meteorological zone.

Eleven groups of soil orders are found in Karnataka viz Entisols, Inceptisols, Mollisols, Spodosols, Alfisols, Ultisols, Oxisols, Aridisols. Vertisols, Andisols and Histosols. Depending on the agricultural capability of the soil, the soil types are divided into six type's viz., Red, lateritic, black, Alluvio-colluvial, forest and coastal soils. The common types of soil groups found in Karnataka are:

- Red Soils: red gravelly loam soil, red loam soil, day soil, red clay soil
- Lateritic soils: rateritic gravelly soil, rateritic soil
- Black soils: deep black soil, medium deep black soil. shallow black soil
- Alluvio-Colluvial Soils: non-saline, saline and sodic
- Forest soils: brown forest soil
- Coastal soils: coastal laterite soil, coastal alluvial soil

Maharashtra

The soils of Maharashtra are residual, derived from the underlying basalts. In the semi-dry plateau, the regur (black-cotton soil) is clayey, rich in iron, but poor in nitrogen and organic matter; it is moisture-retentive. Where re-deposited along the river valleys, these soils are deeper and heavier. Farther away, with a better mixture of lime, the morand soils form the ideal Kharif zone.

The higher plateau areas have pather soils, which contain more gravel. In the Konkan and the Sahyadri Range, the same basalts give rise to the brick-red laterites productive under a forest-cover but readily stripped into a sterile varkas when the vegetation is removed. Overall, soils of Maharashtra are shallow.

The state enjoys a tropical monsoon climate. The average annual temperature ranges from 250ºC to 27.50ºC. The average annual rainfall ranges between 1600 and 2000 mm. The seasonal rains from the western sea-clouds are very heavy and the rainfall is over 4000 mm, on the Sahyadrian crests. The Konkan on the windward side is also endowed with heavy rainfall, declining northwards. East of the Sahyadri, the rainfall diminishes to a meagre 700 mm in the western plateau districts, with Sholapur-Ahmednagar lying in the heart of the dry zone. The rains increase slightly, later in the season, eastwards in the Marathwada and Vidarbha regions.

Tamil Nadu

Tamil Nadu with its varied climate has great variety of soil. Main soil types found in the State are Red Loamy soil, Lateritic soil, alluvial soil, Black soil, Sand Loamy soil and Arid Desert soil etc.

The Climate is tropical with little variation in temperatures during winter and summer. Summer season is between April and June and winter season between November and February. The temperature ranges from minimum of 2° Celsius in the hills to 45° Celsius in other areas. The southwest monsoon feeds the plateau and the retreating northeast monsoon brings rains to the east coast. The average rainfall ranges from 925mm to 1170mm.

Madhya Pradesh

Madhya Pradesh has distinctly diverse topography and hence a wide range of variation in the soil and vegetation. Region comprising of Gwalior, Bundelkhand and Baghelkhand in the Malwa region of the State is rich in black soil. The composition of soil and vegetation is different in the Narmada Valley. There are rich alluvial deposits in this part of the State.

Madhya Pradesh has a subtropical climate. Like most of north India, it has a hot dry summer (April-June) followed by monsoon rains (July-September) and acool and relatively dry winter. Based on the climate, the State can be clearly classified into four physical divsions, mainly the Northern Plains, the Hilly region of the Vindhyas, the Narmada Valley, and the Malwa Plateau. The Northern Plains experience extreme climatic conditions. The hilly Region of the Vindhyas enjoys moderate weather. The average rainfall is about 1370mm. It decreases from east to west. The south-eastern districts have the heaviest rainfall, some places receiving as much as 2150mm, while the western and north-western districts receives 1000mm or less rainfall.

Soil: The soil of Rajasthan alters with its wide-ranging topography of the state and the availability of water. The varied kind of soils available in Rajasthan are mostly sandy, saline, alkaline and chalky (calcareous). Clay, loamy black lava soil and nitrogenous soils are also found. The hilly tracts of the Aravallis are characterized by the black, lava soils that sustain the growth of cotton and sugarcane.

Rajasthan

The State of Rajasthan has varying climate like its varying topography. The rocky Aravallis, the western arid plains, the eastern fertile plains experience different climatic conditions. The weather or climate of the Rajasthan can be broadly classified into four distinct seasons. They are summer, monsoon, post-monsoon and winter

Summer, which is the hot season preceding the monsoon and extends from April to June; the monsoon that occurs in the month of June in the eastern region and mid- July in the western arid regions; the Post-monsoon that commences from mid-September and continues till November and the Winter that extends from December to March, January being the coldest month of the year. The average temperature in winter ranges from 80 to 280C and in summer the average temperature ranges from 250 to 460C. With the exception of Mount

Abu, Vagad region in South is the wettest region in Rajasthan, and the most heavily forested.

Aravalli Range does not intercept the moisture-giving southwest monsoon winds off the Arabian Sea, as it lies in a direction parallel to that of the coming monsoon winds, leaving the north western region in a rain shadow. On the average this region receives less than 400 mm of rains in a year.

Telangana

Telangana state, in general, experiences tropical climate and is geographically located in a semi-arid area and has predominantly hot and dry climate.

Conditions prior to project initiation and current scenario

The project aims to restore degraded vegetation through planting of native plant species on selected parcels of land within degraded vegetation. The lands selected for planting are privately owned and community held belonging predominantly to people from the local communities.

Prior to the project (2018), the area was barren. The ground was dry and hard, with no vegetation cover, and the soil was exposed, eroded, and lacking in organic matter and nutrients. The lack of plant cover had significant ecological, social, and economic impacts, with high risk of soil erosion, flooding, and limited economic opportunities for the local communities.

After the project (2022), the landscape was transformed. The once-barren land is now covered with a diverse range of trees and plants, creating a lush canopy cover that provides shade and shelter for the soil, preventing erosion and retaining moisture. The soil quality has improved, with increased organic matter and nutrients, and a greater ability to retain water.

Monitoring the temporal variation of Land Use Land Cover (LULC) Classes

Here, Land Use Land Cover (LULC) maps for 17 districts under 4 states (Table 3) have been prepared for the year 2018 (i.e., prior to the baseline year) and the year 2022 (i.e., Present scenario) using Random Tree Classifier algorithm in ArcGIS 10.8 platform to monitor the temporal variation of LULC classes.

Table 3: List of the districts for which LULC maps have been prepared

Sr. No.	Districts	State	Argo-Climatic Zone
1	Baran	Rajasthan	Central Plateau & Hills
2	Bundi		
3	Jhalawar		
4	Kota		
5	Bikaner		Trans Gangetic Plains
6	Jaisalmer		Western Dry Region
7	Barmer		
8	Jodhpur		
9	Hassan	Karnataka	Southern Plateau & Hills
10	Mysore		
11	Kolar		

Sr. No.	Districts	State	Argo-Climatic Zone
12	Bangalore Rural		
13	Bangalore Urban		
14	Ahmednagar	Maharashtra	Western Plateau & Hills
15	Pune		
16	Pudukottai	Tamil Nadu	Southern Plateau & Hills
17	Coimbatore		

Cloud free Sentinel-2 data, having spatial resolution of 10 meters, has been used to prepare the LULC map for the year 2018 and 2022. Sentinel-2 Data has been accessed from Copernicus Open Access Hub site[3].

Seven major LULC classes namely Waterbodies, Forest Green, Other Vegetation, Crop Land, Settlements, Barren Land and Grassland have been classified using Random Tree Classifier under the supervised classification scheme in ArcGIS 10.8 platform. LULC Classification scheme has been provided in Table 4.

Table 4: LULC Classification Scheme

LULC Classes	Description
Waterbodies	Areas with surface water, either impounded in the form of ponds, lakes, reservoirs or flowing as streams, rivers, etc. as well as rived bed, dried up paleochannels
Forest Green	Any significant clustering of tall (~15-m or higher) dense vegetation, typically with a closed or dense canopy
Other Vegetation	Areas of any type of vegetation with obvious intermixing of water throughout most of the year; seasonally flooded area that is a mix of grass/shrub/trees/bare ground
Cropland	Lands covered with temporary crops followed by harvest period, Crop fields and pastures
Settlements	Land covered by buildings and other man-made structures
Barren Land	Areas of rock or soil with very sparse to no vegetation for throughout the year; large areas of sand and deserts with no to little vegetation; exposed rock or soil, desert and sand dunes, dry salt flats/pans, dried lake beds, etc. area classified as Barren Land

3 (https://scihub.copernicus.eu/dhus/#/home)

LULC Classes	Description
Grassland	Open areas covered in homogenous grasses with little to no taller vegetation; wild cereals and grasses with no obvious human plotting (i.e., not a plotted field).

Plantation locations have been overlaid in the LULC maps for the year 2022 to delineate plantation zone as well as respective LULC classes. Also, from the LULC status of 2018 and 2022, it is also observed that the plantation activities have been carried out in the barren land and the open areas generally covered with wild cereals and grasses with no obvious anthropogenic intervention.

LULC classification of Rajasthan

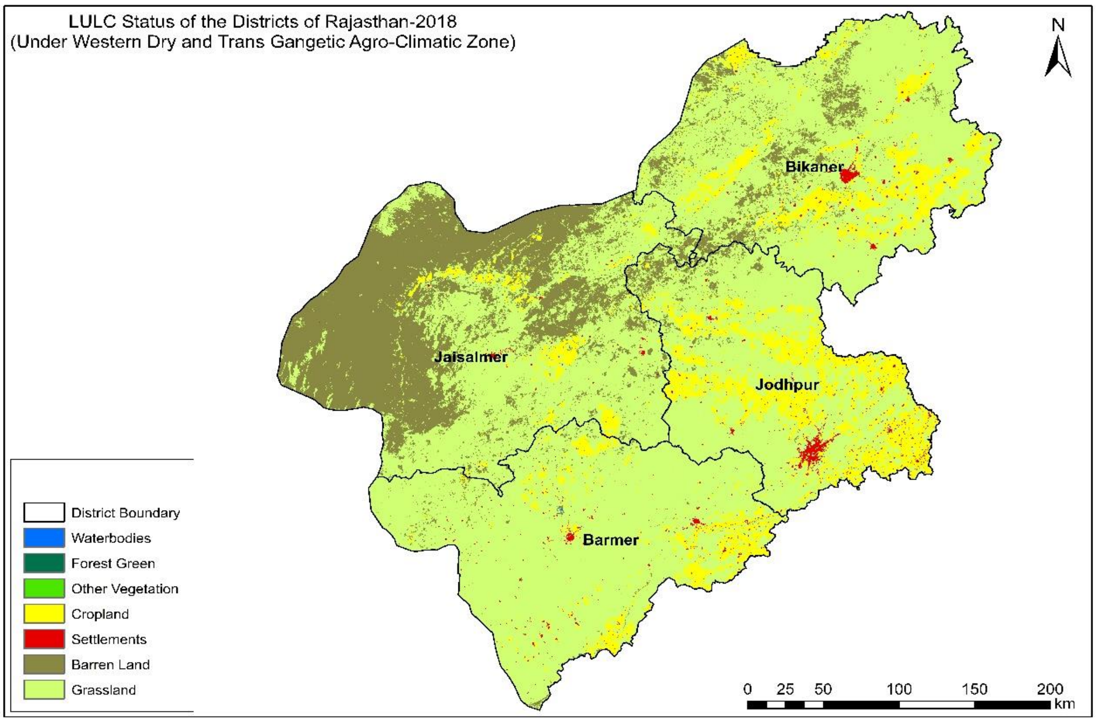


Figure 3: LULC Status of Western Dry and Trans Gangetic Agro-Climatic Zone in 2018

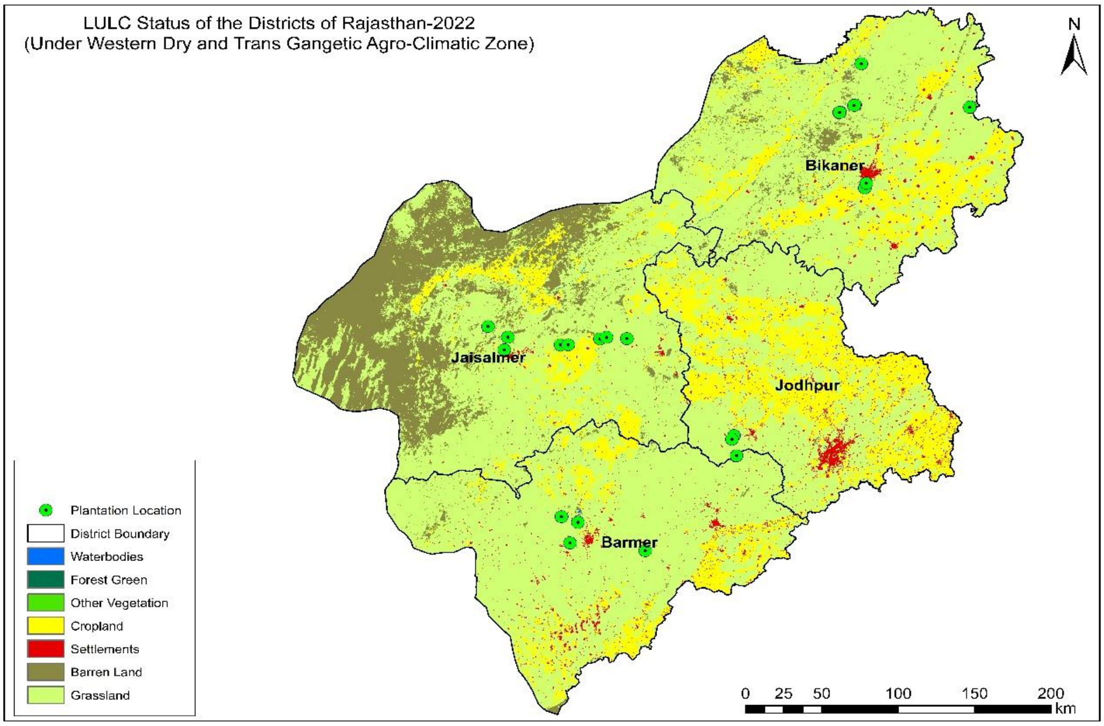


Figure 4: LULC Status of Western Dry and Trans Gangetic Agro-Climatic Zone in 2022

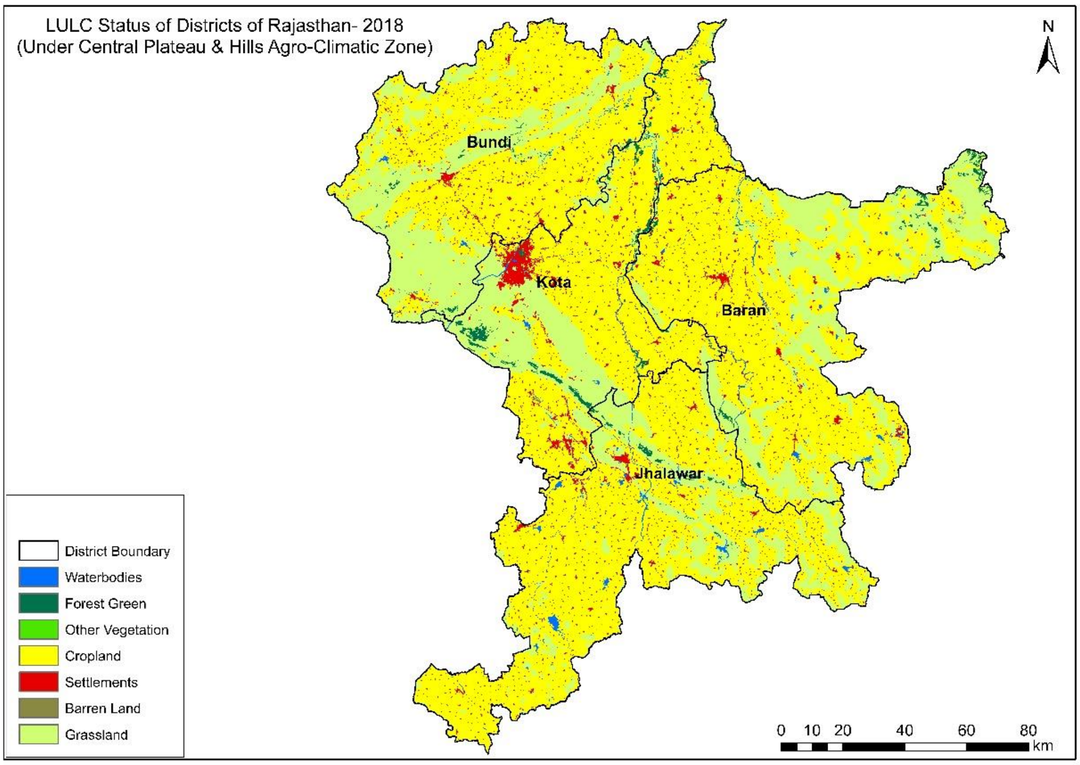


Figure 5: LULC Status of Central Plateau & Hills in 2018

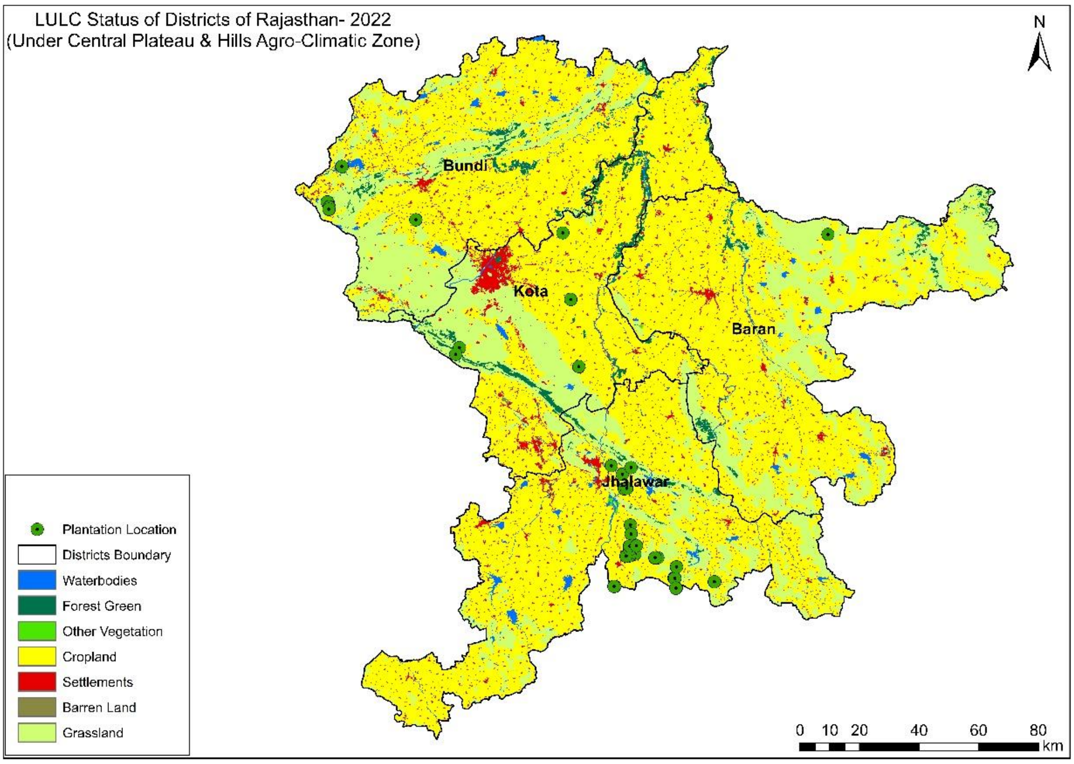


Figure 6: LULC Status of Central Plateau & Hills in 2022

LULC classification of Karnataka

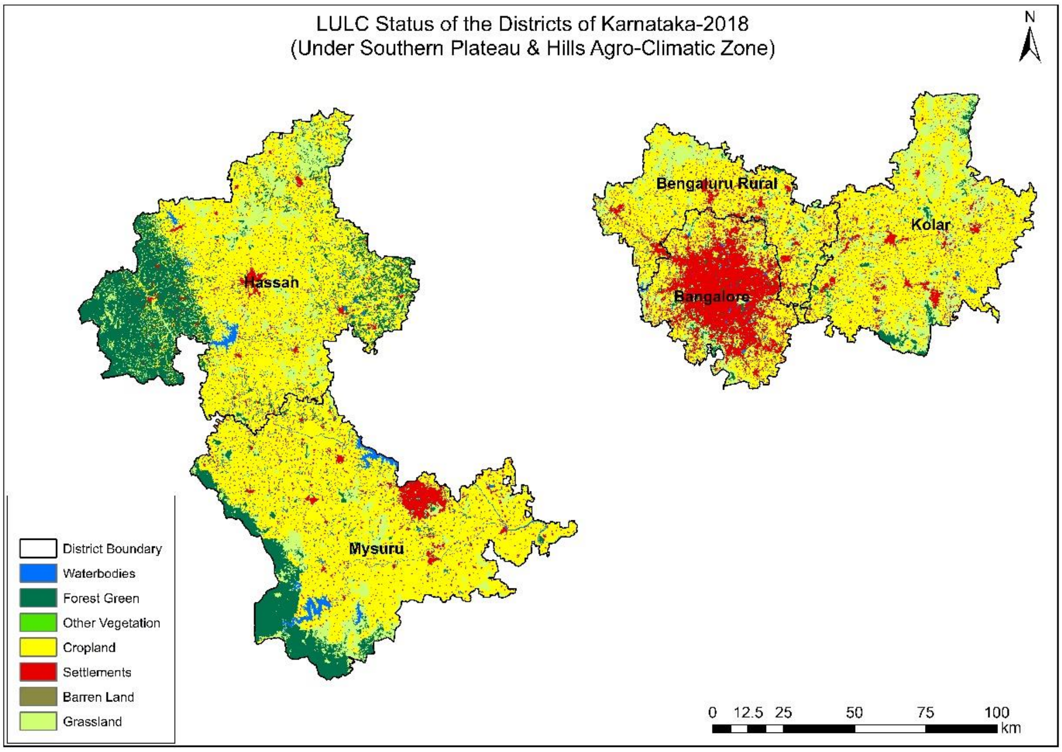


Figure 7: LULC Status of Southern Plateau & Hills in 2018

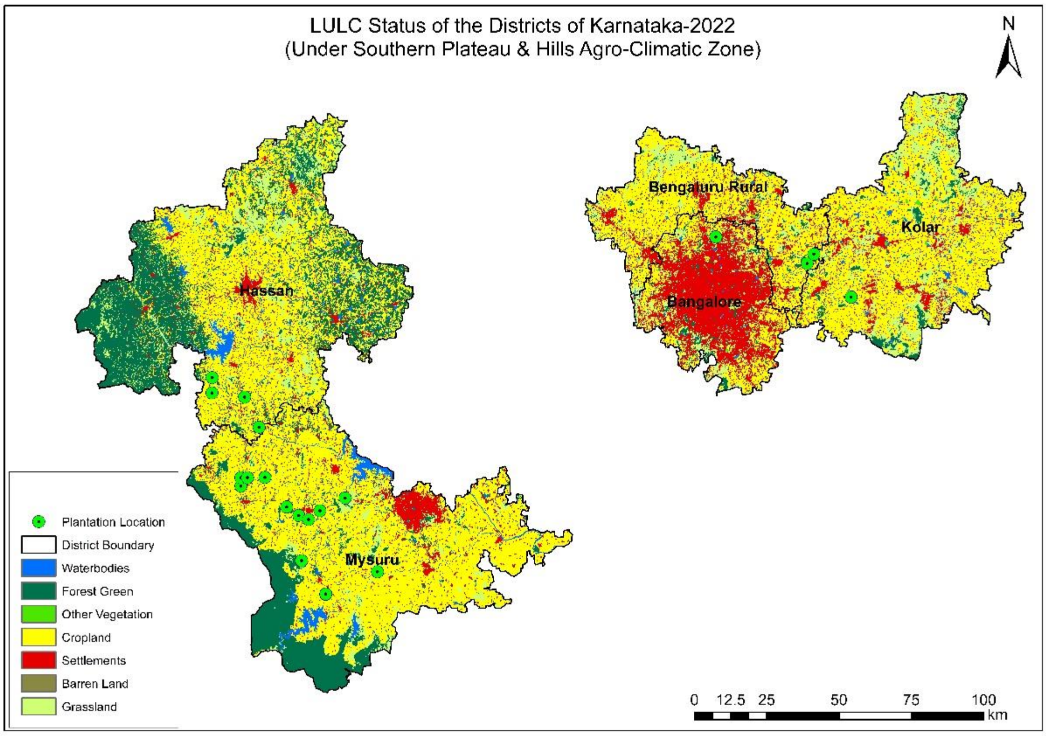


Figure 8: LULC Status of Southern Plateau & Hills in 2020

LULC classification of Maharashtra

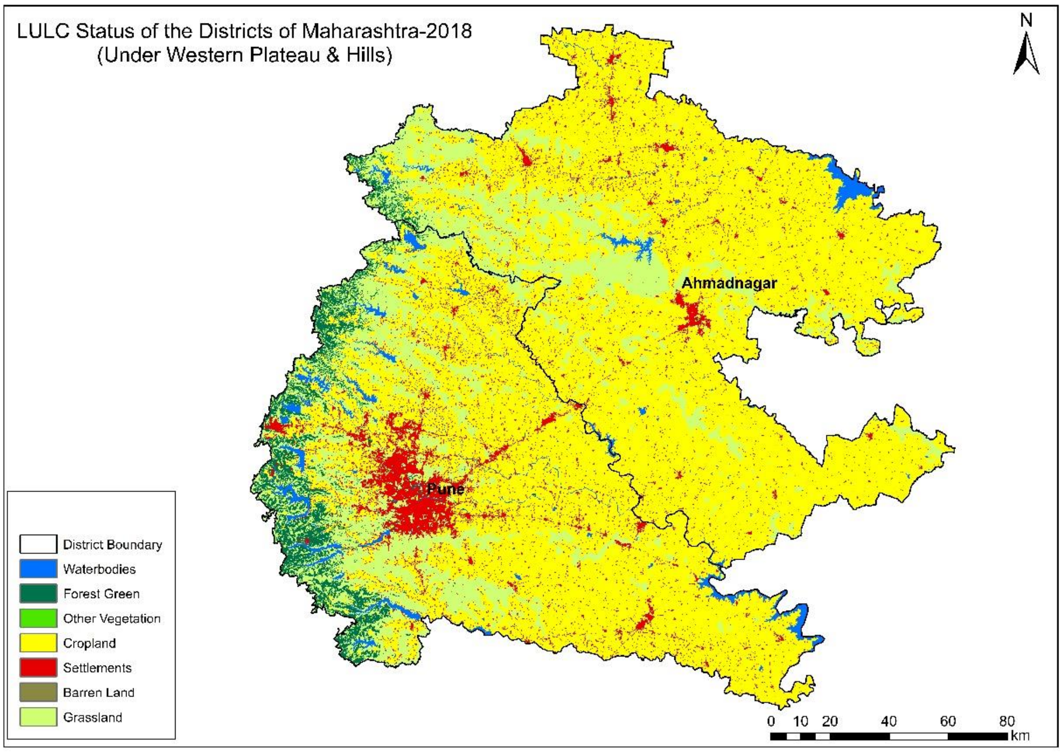


Figure 9: LULC Status of Western Plateau & Hills in 2018

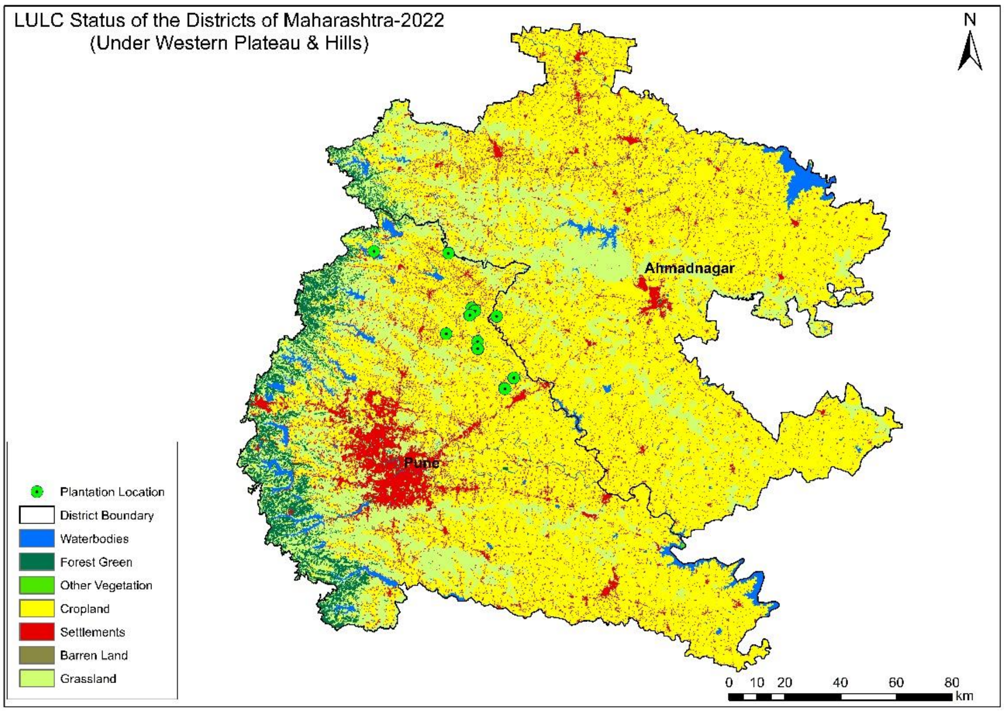


Figure 10: LULC Status of Western Plateau & Hills in 2020

LULC classification of Tamil Nadu

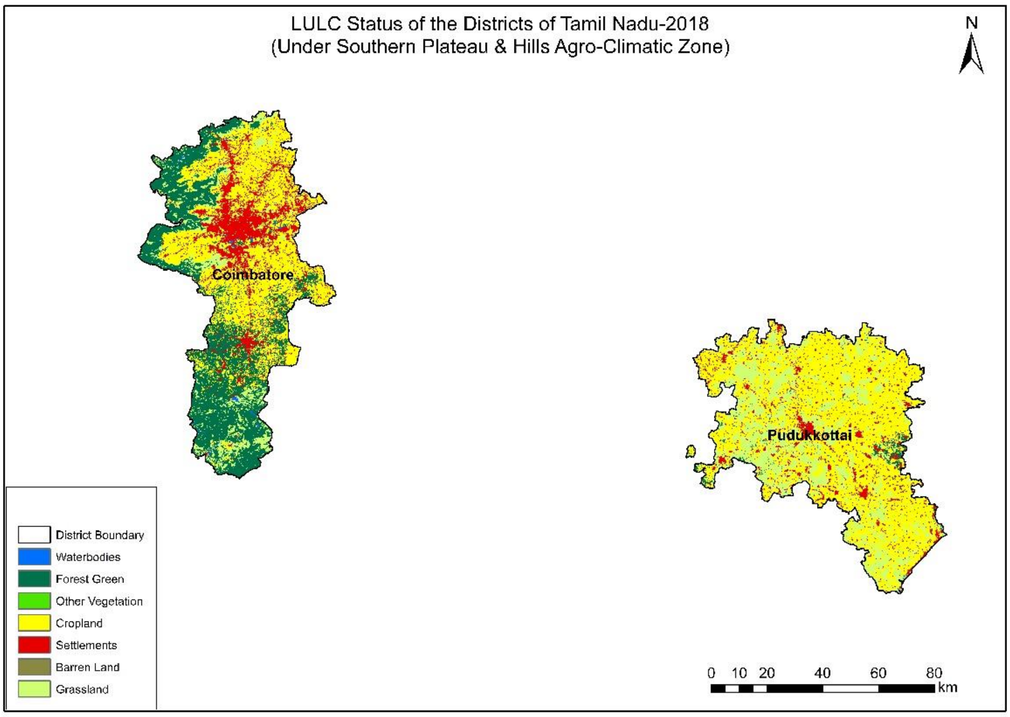


Figure 11: LULC Status of Southern Plateau & Hills in 2018

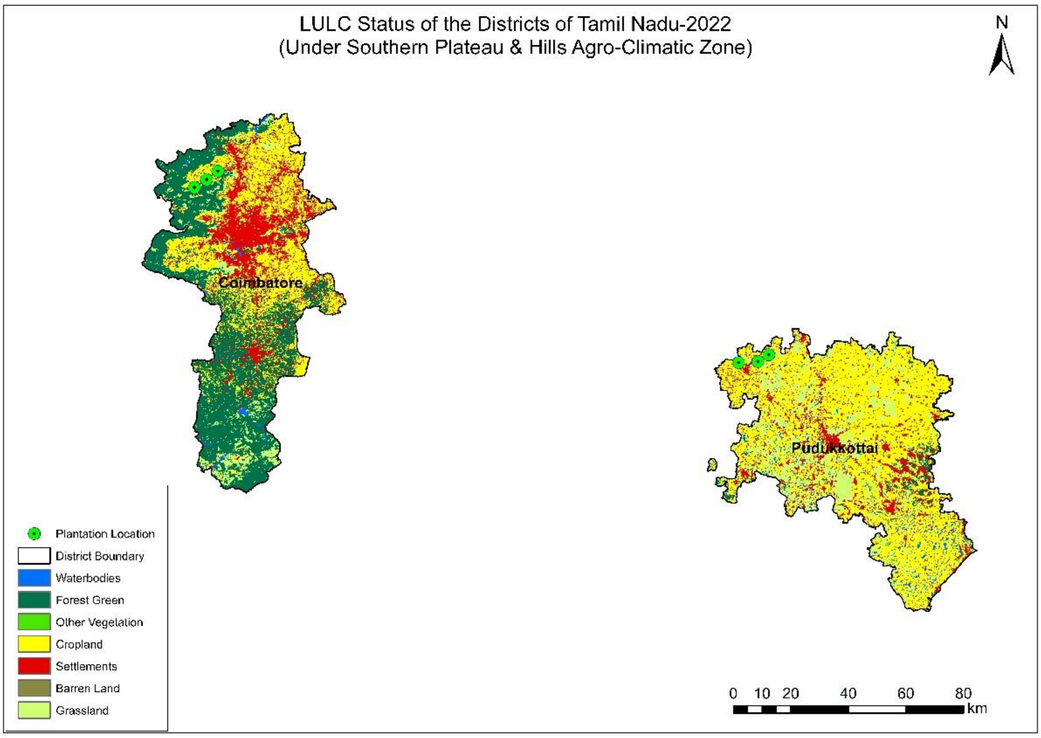


Figure 12: LULC Status of Southern Plateau & Hills in 2020

Assessment process and methods

Stratification and Estimation of Number of Sample Plots

For Plantation (with DBH > 10 cm) and Grasslands

For assessing the biomass of individuals with DBH above 10 cm and for plots with grass development activities, all the states were first stratified into various agro-climatic zones. Number of sample plots to be laid was calculated using Pearson formula.

$$n = \frac{N \times t_{VAL}^2 \times \left(\sum_i w_i \times s_i\right)^2}{N \times E^2 + t_{VAL}^2 \times \sum_i w_i \times s_i^2}$$

Where;

- **n** = Number of sample plots required for estimation within the project boundary; dimensionless
- **N** = Total number of possible sample plots within the project boundary (i.e. sampling space/population); dimensionless
- **E** = Desired level of precision
- **t_{val}**= Two-sided Student's t-value, at infinite degrees of freedom, for the required confidence level; dimensionless
- **w_i** = Relative weight of the area of stratum i (i.e. area of stratum i divided by project area); dimensionless
- **s** = Estimated standard deviation) in stratum i (when it is not available, instead 50% of estimated volume, biomass, etc. IPCC, Good Practice Guidelines, 2003); (or as per existing data or similar projects)
- **i** = Strata i within the project boundary

Number of sample plots to be laid to estimate plantation biomass in different strata are mentioned in the table below. Despite having calculated the possible number of sample plots, the actual number of sample plots laid on field was more to ensure high accuracy of data.

Table 5: Number of sample plots for existing mature plantations with DBH above 10 cm

Agro-climatic Zone	Districts	Area (Ha)	Sample Plots	Plots laid
Southern Plateau & Hills	Coimbatore	102.25	2	5
	Pudukottai	8.98*		5
	Hassan	123.48	2	4
	Mysore	139.27	2	12

Agro-climatic Zone	Districts	Area (Ha)	Sample Plots	Plots laid
	Kolar	8.09	0	0
	Banglore Rural	0.76*		4
	Bharadri Kothagudem	13.95*		4
East Coast Plains & Hills	Palnadu	77.31*		7
	Prakasam	398.73*		31
Central Plateau & Hills	Bhopal	4	0	2
	Chindwara	29.10	0	11
	Sehore	23.26	0	32
	Baran	58.70*		3
	Bundi	535.30	9	9
	Jhalawar	101.07	2	26
	Kota	810.52	13	13
Western Plateau & Hills	Ahmednagar	63.28	1	7
	Pune	38.55	1	10
	Indore	71.15*		28
Western Dry Region	Barmer	1723.48	28	28
	Jodhpur	495.95*		4
Trans Gangetic Plains	Bikaner	361.53	6	12
	Jaisalmer	765.99*		7
Total		**4063.24**	**67**	**264**

*Area not taken for sample plot calculation since the district did not have plantations having plants with DBG>10cm.

Project area is very scattered and distance is far between one plantation sites to another. To simplify calculations, plantation spacing was considered as 3m* 3m. However, in few locations, number of plants planted was not mentioned. Hence in the absence of plantation details, the area of plantation has been taken into account.

Number of sample plots to be laid to estimate grassland biomass in different strata are mentioned in the table below:

Table 6: Number of sample plots for grassland

Agro-climatic Zone	District	Area (Ha)	Sample Plots	Plots laid
East coast plains & Hills	Prakasam	398.73	3	15
	Palnadu	77.32	1	12
Central Plateau & Hills	Baran	58.70	0	2
	Bundi	535.30	4	5
	Jhalawar	159.92	1	23
	Kota	810.52	6	8
Western Plateau & Hills	Ahmednagar	63.28	0	1
	Pune	38.55	0	5
Trans Gangetic Plains	Bikaner	361.53	3	7
Western Plateau & Hills	Barmer	1723.482	14	16
	Jodhpur	495.95	4	5
	Jaisalmer	765.99	6	7
Total		**5489.325**	**43**	**106**

Table 7: Summarized matrix for sample plots of plantation and grassland

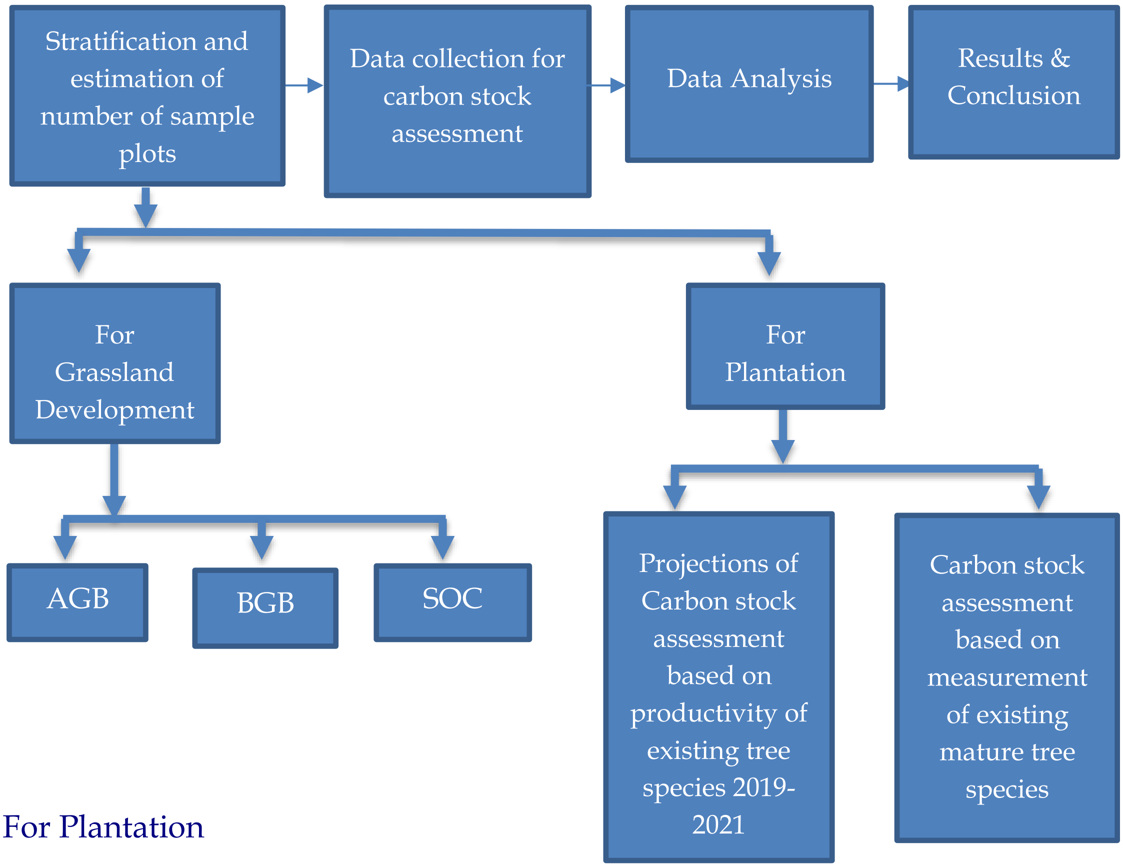
Agro-climatic Zone	District	State	Plantation		Grassland Development	Total
			Project (AGB+BGB+SOC)	Control	Project (AGB+BGB+SOC)	
Southern Plateau & Hills	Pudukottai	Tamil Nadu	5	2	0	7
	Coimbatore	Tamil Nadu	5	3	0	8
	Hassan	Karnataka	4	3	0	7
	Mysore	Karnataka	12	10	0	22
	Kolar	Karnataka	0	0	0	0
	Banglore Rural	Karnataka	4	1	0	5

Agro-climatic Zone	District	State	Plantation		Grassland Development	Total
			Project (AGB+BGB+SOC)	Control	Project (AGB+BGB+SOC)	
	Bharadri Kothagudem	Telangana	4	1	0	5
East Coast Plains & Hills	Palnadu	Andhara Pradesh	7	2	15	24
	Prakasham	Andhara Pradesh	31	3	12	46
Central Plateau & Hills	Bhopal	Madhya Pradesh	2	2	0	4
	Chindwara	Madhya Pradesh	11	2	0	13
	Sehore	Madhya Pradesh	32	2	0	34
	Baran	Rajasthan	3	1	2	6
	Bundi	Rajasthan	9	1	5	15
	Jhalawar	Rajasthan	26	15	23	64
	Kota	Rajasthan	13	4	8	25
Western Plateau & Hills	Indore	Madhya Pradesh	28	0	0	28
	Ahmednagar	Maharashtra	7	1	1	9
	Pune	Maharashtra	10	1	5	16
Trans Gangetic Plains	Bikaner	Rajasthan	12	3	7	22
Western Dry Region	Barmer	Rajasthan	28	4	16	48
	Jodhpur	Rajasthan	4	3	5	12
	Jaisalmer	Rajasthan	7	4	7	18
				Total		**438**

Laying out of Permanent sample plots

Stratified Random sampling was adopted to lay out the sample plots. One of the methods adopted for randomisation was the *rice grain method*. Grains of rice were spread randomly on the Topographic sheet of the plot and wherever the grains fell, that area was taken as the centre of the sample plot. The plots were square and of the size 31.62 m x 31.62 m. The point of grain was centre point taken for square sample plot. The post-stratification map was created with the help of GIS after the first monitoring to concentrate on the possible changes of the project boundary.

Data collection methodology for Carbon Stock Assessment



For Plantation

In a forest ecosystem, enormous carbon is stored which is classified in three pools as given by IPCC Good Practice Guidance 2006. Major eligible carbon pools from the forest areas are Above Ground Biomass (AGB), Below Ground Biomass (BGB) and Soil Organic Carbon (SOC). Dead wood (DW) and Litter (L) was not considered because they were not significantly present in the plots since the plantations were not more than two years old.

The steps involved in the process of assessing Carbon Stock are:

<u>Laying out of Sample plots</u>

The shape and size of the sample plots is a trade-off between accuracy, precision, time, and cost for measurement. In general, sample plots should be either permanent or temporary. Permanent sample plots are statistically more efficient in estimating changes in forest carbon stocks, but since, their locations are known they could be treated differently than the rest of the project area (Chauhan and Saxsena, 2012). Similarly, sample plots can either be one fixed size or 'nested,' means that they comprise smaller sub-units for various carbon pools. Nested plots are generally more practical and efficient in estimating forest biomass. Thus, in this study, geo referenced (permanent) nested sample plots can be laid out covering the clusters/states.

A plot of size 31.62m x 31.62m was first laid to measure the girth and height of the trees, then inside this bigger plot, soil samples was collected from the two different corners of the sample plot at 30 cm × 30 cm × 30 cm depths (IFSR, 2017).

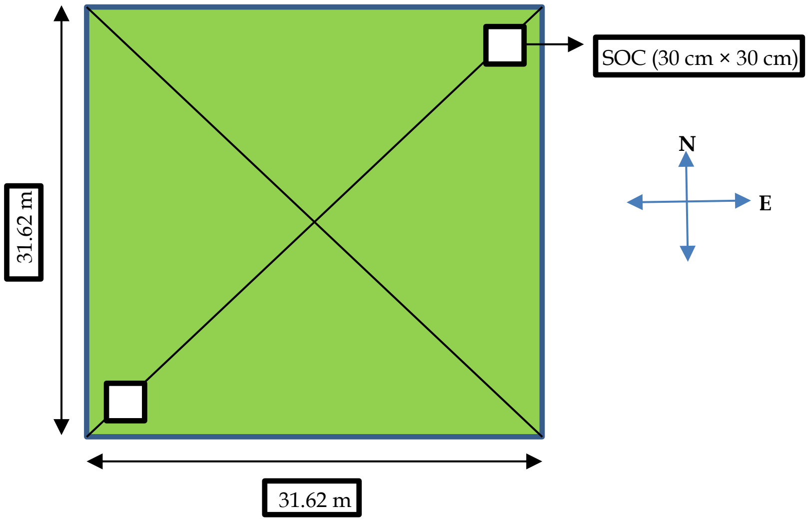


Figure 13: Permanent Sample Plot for plantation

<u>Measurement of tree</u>

Measurements were recorded for all individuals >10 cm DBH (Diameter at Breast Height) lying within the permanent nested sample plot, starting from the north direction. Tree species. Individuals which were having <=10 cm DBH were considered as saplings and they were measured and noted separately. Botanical as well as local names were recorded for all trees present within the sample plot. Diameter at Breast Height (DBH) is the basic measurement standard for trees, i.e. 1.37 m height of the tree.

Trees on border of sample plot were included if > 50% of basal area fell within the plot and excluded if < 50% of its basal area fell outside the plot. Trees overhanging into the plot were excluded, but trees with their trunks inside the sampling plot and branches outside were included. If a tree was forked below DBH, it was measured just below the fork point else when not possible to measure below the fork, it was assumed as two separate trees (Chaturvedi and Khanna, 1982). Similarly, height of tree was measured directly by height measuring instrument, known as Ravi altimeter. Further, the stem girth (in cm) were converted to a diameter (d, in cm) using the following formula: $d = Girth/\pi$, (π= 3.14).


Figure 14: Measurement of tree's girth

The measured height and girth of trees (>10 cm) will be used to calculate Above Ground Biomass (AGB) and Below Ground Biomass (BGB)

<u>Soil Organic Carbon</u>

Soil samples were collected from 1m × 1m subplots in the two different corners within the master plot of 0.1 Ha. Samples were collected from 0-30 cm depth. Samples of exactly 200gm were taken and transferred to pre-weighed sampling bags. Subsequently, samples were then transported to the laboratory for further analysis. The number of soil samples collected for plantation activity has been mentioned below.

Figure 15: Collection of Soil Sample

Soil Moisture Conservation Activities

In the Project area various soil moisture conservation activities has been done to reduce soil erosion and to increase the water infiltration capacity. The techniques that are used for the soil moisture conservation are as follows:

- Farm Pond
- Farm Bund
- Check Dams
- Percolation Tanks
- Bund Plantation

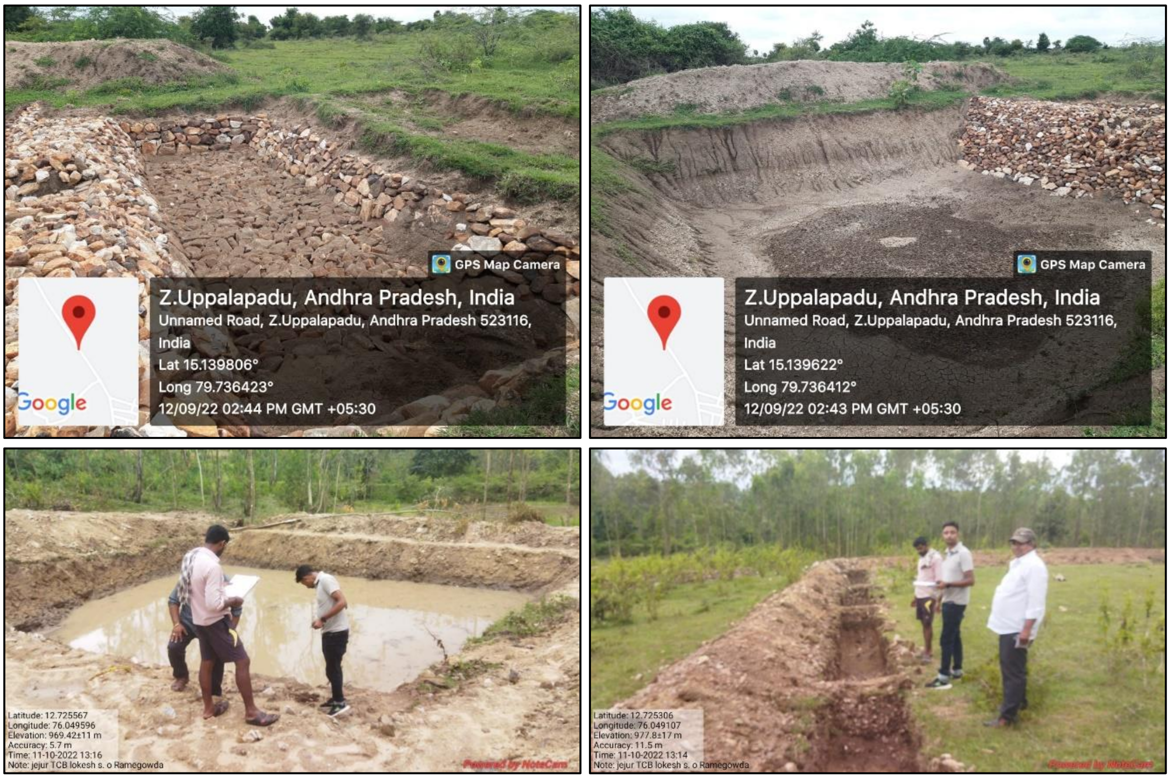


Figure 16: Soil Moisture Conservation structures

Soil Samples were collected at 0-30 cm depth from the site of intervention in the project area. A total of 200 gm. was collected from the site where the intervention was done and 200gm of control sample was collected outside the intervention area. Soil sample taken near SMC structure and soil sample taken from control area were compared for Soil Organic Carbon content and studied separately. These samples were then transferred to laboratories for further testing purpose.

Figure 17: Soil Moisture Conservation structure

Biomass assessment of Grassland

For areas where grassland development has been done, eligible carbon pools assessed were above ground biomass (AGB), below ground biomass (BGB) and soil organic carbon (SOC) as described in IPCC 2006. Sample plots of 5m x 5m square shape were laid down. Within the main plot, two quadrates 1m x 1m at two corners - north east and south west were laid for the estimation of grass biomass.

Above Ground Biomass (AGB)

Wooden sampling frame was placed to mark $1m^2$ squares within the main plot for above ground biomass harvesting. Samples of approximately 100 gm was collected from each plot and recorded on a working sheet. Fresh weight of 100 gm of sample was recorded and which was further sent to laboratory for analysis in order to calculate the total dry weight. (UNDP 2014)

Figure 18: Collection of grass sample

Below Ground Biomass (BGB)

BGB of will be estimated using default expansion factor, a simplified approach based upon below-ground biomass ratio i.e., 0.5 (IPCC 2006).

Soil Organic Carbon

For collecting data on soil carbon, two subplots 1m x 1m in size were laidout within the main plot of 5m × 5m. At the centre of these two subplots, a pit 30 cm x 30 cm x 30cm in size were dug and a composite sample of soil weighing around 200 gm were kept for organic carbon analysis. All samples were placed into zipped pouches which were labelled appropriately. Samples of soil will be further analysed from the standard soil laboratoriesand are used for calculation (IPCC 2006).

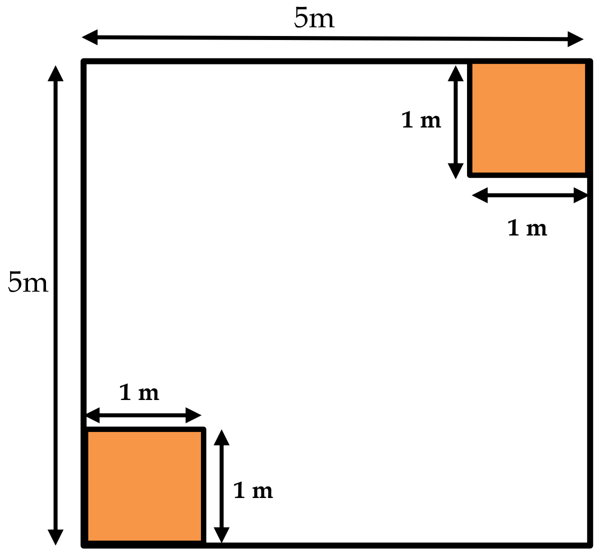


Figure 19: Permanent Sample Plot for grassland

Carbon stock analysis methodology

Plantation (with DBH > 10 cm)

Above Ground Biomass

For the assessment Above Ground Biomass, species specific allometric equations or biomass values from the biomass tables based on the allometric equations was applied for all individuals above 10 cm DBH. Volume equations were mainly referred from the FSI's publication published in 1996, which comprises of volume equations of major tree species of India, Nepal and Bhutan (FSI, 1996). Besides, research articles and forestry journals were also reviewed to get volume equations of tree species if not available in the FSI publication. General volume equations were also considered for tree species where allometric volume equations was be available, assuming cylindrical bole of tree (Chatuvedi and Khanna, 1982).

Once height and girth of tree species were measured, then data analysis were done through analytical techniques such as MS excel formulae, volume tables and chart analysis etc. Wood density of all tree species has been taken as 0.57 (Default value).

Above Ground Biomass (AGB) = Volume × Wood Density (WD) × Biomass Expansion Factor (BEF)

BEF value has been taken as 3.4 (IPCC Good Practice Guidance 2006)

All the volume equations of tree species along with the references observed in the project site is mentioned below. Volume equations used to calculate biomass has been attached in the annexure as in the **Volumetric Equations** of species.

Below Ground Biomass (BGB)

Below Ground Biomass was calculated using root to shoot ratio as approved by the UNFCCC. It has been used as standard method for estimating the root biomass. In simple, the BGB was calculated by multiplying the AGB with a default value, provided by the Intergovernmental Panel on Climate Change (IPCC, 2006). In case of Tropical Wet Evergreen strata, which includes two districts, Hassan and Mysore of Karnataka state, we have used the 0.325 root to shoot ratio value as mentioned in the Table 4.4 of the IPCC 2019 Refinement Report. However in case of districts that fall under Tropical Dry Deciduous strata, the standard value 0.27 was used because the root to shoot ratio value for plantation in Tropical Dry Forest of Asia is not mentioned in the IPCC 2019 Refinement Report.

For Tropical Dry Forest: BGB = AGB × 0.27 (IPCC Default value)

For Tropical Wet Evergreen (Hassan & Mysore) BGB = AGB × 0.325 (IPCC 2019 Refinement)

Where:

BGB = Below Ground Biomass and

AGB = Above Ground Biomass

Soil Organic Carbon (SOC)

The carbon stock density of soil organic carbon was calculated as (Pearson *et. al* 2007):

$$SOC = r_b \times d \times \%C$$

Where,

SOC = soil organic carbon stock per unit area (t/ha)

r_b = soil bulk density (g/cm^3) – Default value is 1.2

d = total depth at which sample is taken (cm)

%C = carbon concentration – Default value is 0.47 (IPCC 2006)

The plantation SOC has also been compared with control area SOC in order to showcase the variation between them as a result of interventions done through ITC MSK program.

To assess and compare organic carbon stock of soil samples from Soil Moisture Conservation activities and control areas, the same formula as mentioned above has been used.

For testing of soil samples collected from various states, samples were sent to the following laboratories and research institutes, namely, Tamilnadu Agriculture University (TNAU), Coimbatore, Indian Institute of Soil Science (IISS), Bhopal, Krishi Vigyan Kendra (ICAR), Narayangaon Pune and The Energy and Resource Institute Lab, New Delhi .The samples were tested using the two types of testing methodologies, namely, the Walkley-Black method and CHNS method. The soil reports of the respective states have been attached in Annexure.

Walkley-Black method: Walkley-Black method used for determining Soil Organic Matter (OM) utilizes a specified volume of acidic dichromate solution reacting with a determined amount of soil in order to oxidize the OM. The oxidation step is then followed by titration of the excess dichromate solution with ferrous sulphate which gives a volume of ferrous sulphate in mL. The OM is calculated using the difference between the total volumes of dichromate added and the volume titrated after reaction.

CHNS method: In CHNS elemental analysis, solid samples are combusted and the resulting oxides of carbon, hydrogen and sulphur along with nitrogen are analysed sequentially. It involves the complete and instantaneous oxidation of the sample by "flash combustion".

Potential of Plantations

To show the carbon sequestration potential of recent plantations with diameter at breast height less than 10 cm also, carbon equivalents were calculated as projections for 10 years as well as 30 years. Carbon sequestration potential is estimated using productivity of the ecosystem where the plantations have been done and the area covered by plants. The formula that has been used to calculate the same is mentioned below:

Area (Ha) **×** **Productivity** (Ton Ha^{-1} Yr^{-1}) **× 0.47** (Default Carbon Fraction as per IPCC GPG 2006) **× 3.67** (Ratio of the molecular weight of carbon dioxide to that of carbon)

According to FAO 2001, the world has been divided into global ecological zones based on types of forests, for which productivity has been given in IPCC GPG 2006. Districts were divided into ecological zones (as per IPCC 2006) having different productivity which was then used to calculate the carbon sequestration potential of plants with DBH below 10 cm. The productivities (from IPCC GPG 2006) taken for the same purpose has been mentioned below. Ecological zones here refers to the forest type in the region as mentioned in the IPCC GPG 2006.

Table 8: Productivity of ecological zones in project areas

State	District	Agroclimatic zone	Ecological Zone (FAO 2001)	Productivity (t.dm./Ha/yr)
Telangana	Kothagudem	Southern Plateau & Hills	**Tropical Dry Deciduous**	**7**
Andhra Pradesh	Palnadu	East Coast Plains & Hills	**Tropical Dry Deciduous**	**7**
	Prakasham	East Coast Plains & Hills	**Tropical Dry Deciduous**	**7**
Tamilnadu	Pudukottai	Southern Plateau & Hills	**Tropical Dry Deciduous**	**7**
	Coimbatore	Southern Plateau & Hills	**Tropical Dry Deciduous**	**7**

State	District	Agroclimatic zone	Ecological Zone (FAO 2001)	Productivity (t.dm./Ha/yr)
Rajasthan	Baran	Central Plateau & Hills	**Tropical Dry Deciduous**	**7**
	Barmer	Western Dry Region	**Tropical Dry Deciduous**	**7**
	Bikaner	Trans Gangetic Plains	**Tropical Dry Deciduous**	**7**
	Bundi	Central Plateau & Hills	**Tropical Dry Deciduous**	**7**
	Jaisalmer	Western Dry Region	**Tropical Dry Deciduous**	**7**
	Jhalawar	Central Plateau & Hills	**Tropical Dry Deciduous**	**7**
	Jodhpur	Western Dry Region	**Tropical Dry Deciduous**	**7**
	Kota	Central Plateau & Hills	**Tropical Dry Deciduous**	**7**
Maharashtra	Pune	Western Plateau & Hills	**Tropical Dry Deciduous**	**7**
	Ahmednagar	Western Plateau & Hills	**Tropical Dry Deciduous**	**7**
Madhya Pradesh	Chindwara	Central Plateau & Hills	**Tropical Dry Deciduous**	**7**
	Bhopal	Central Plateau & Hills	**Tropical Dry Deciduous**	**7**
	Indore	Western Plateau & Hills	**Tropical Dry Deciduous**	**7**
	Sehore	Central Plateau & Hills	**Tropical Dry Deciduous**	**7**
Karnataka	Hassan	Southern Plateau & Hills	**Tropical Wet Evergreen**	**5**
	Mysuru	Southern Plateau & Hills	**Tropical Wet Evergreen**	**5**

State	District	Agroclimatic zone	Ecological Zone (FAO 2001)	Productivity (t.dm./Ha/yr)
	Kolar	Southern Plateau & Hills	**Tropical Wet Evergreen**	**5**
	Bangalore Rural	Southern Plateau & Hills	**Tropical Wet Evergreen**	**5**

Grassland

Above Ground Biomass (AGB)

In order to estimate the total carbon stock, we will multiply the biomass by the carbon content of dry biomass. The default value is 0.47 tonne of C per tonne of biomass.

Total dry weight (kg/ m2) = Total fresh weight (kg) x Subsample dry weight (g) x Sample area (m2) / Subsample fresh weight (g)

Where; Total fresh weight = Grass Sample of either corners

Subsample Fresh weight= Subsample (100 g) have been collected from the Plot for Oven Dry

Subsample Dry weight= Oven Dry Weight

C_{AGB} =Total dry weight x 0.47

Below Ground Biomass (BGB)

For the estimation of below ground biomass, a simplified approach based upon below-ground biomass ratio will be used (IPCC 2006).

Below Ground Biomass = 0.5 * Above Ground Biomass

In order to estimate the total carbon stock, we could multiply the below ground biomass by the carbon content of dry biomass. The default value is 0.47 tonne of C per tonne of biomass(IPCC 2006)

C_{BGB} = Total below ground biomass x 0.47

Soil Organic Carbon (SOC)

The SOC is determined through samples collected from the default depth as prescribed by the FSI in 2017. For collecting data on soil carbon, two subplots 1m x 1m in size will be laidout within the main plot. At the centre of these two subplots, a pit 30 cm x 30 cm x 30cm insize will be dug and a composite sample of soil weighing around 200 gm will be kept for organic carbon analysis. All samples are placed into zipped pouches which will be labelled appropriately. Samples of soil will be further analysed from the standard soil laboratoriesand are used for calculation (IPCC 2006).

SOC is calculated from soil organic matter (SOM) by multiplying by the carbon content of SOM. The content of organic carbon in soil estimated in percentage terms needs to be converted to tonnes per hectare using bulk density, depth of the soil and area. (IPCC 2006)

Therefore, SOC (t/ha) = [soil mass in 0-30 cm layer SOC concentration (%)] / 100Total Carbon Stock Density

The carbon stock density will be calculated by summing the carbon stock densities of the individual carbon pools of that stratum using the below-mentioned formula. It should be noted that any individual carbon pool of the given formula can be ignored if it does not contribute significantly to the total carbon stock.

$$\Delta C = \Delta CAGB + \Delta CBGB + \Delta SOC$$

Where,

C = carbon stock density

C (AGB) = carbon in above-ground biomass

C (BGB) = carbon in below-ground biomass

SOC = soil organic carbon

The total carbon stock is then converted to tonnes of CO2 equivalent by multiplying it by 44/12, or 3.67 (Pearson et al. 2007).

Carbon stock assessment findings

Biomass, Carbon Stock, Carbon dioxide equivalent and SOC of Plantation

Biomass Assessment of Mature plantations

Biomass, SOC and total carbon sequestered by existing mature plantations having diameter at breast height above 10 cm has been calculated. Results show that maximum carbon has been sequestered by plantations done in the Central Plateau & Hills (covering Bundi, Jhalawar and Kota). This is because the area covered under this zone was the highest i.e., 47% of the total carbon sequestered by the plantation activity falls under the Central Plateau & Hills zone, as shown in **Table 09** is provided below. Total biomass sequestered by plantation activities is 57120.44 tonnes and the carbon dioxide equivalents are observed as 209632.04 tCO2e.

Table 9: Biomass and carbon dioxide equivalent calculation in different strata for existing mature plantations (total carbon stock in the program areas)

Agro-climatic zone	Biomass (AGB+BGB) (In tonnes)	Carbon Stock (AGB+BGB) (In tonnes)	Total SOC (In tonnes)	Total Carbon stock (In tonnes)	Total Carbon dioxide equivalent (tCO_2e)
Southern Plateau & Hills (Hassan & Mysore)	7324.51	3442.52	15714.97	19157.49	70308.01
Central Plateau & Hills (Bundi, Jhalawar & Kota)	14357.08	6747.83	20339.32	27087.15	99409.85
Western Plateau & Hills (Ahmednagar & Pune)	1171.93	550.81	2309.91	2860.71	10498.83
Western Dry Region (Barmer)	232.96	109.49	3523.28	3632.78	13332.31
Trans Gangetic Plains (Bikaner)	693.26	325.83	4056.46	4382.29	16083.02
Total	**23779.77**			**57120.44**	**209632.04**

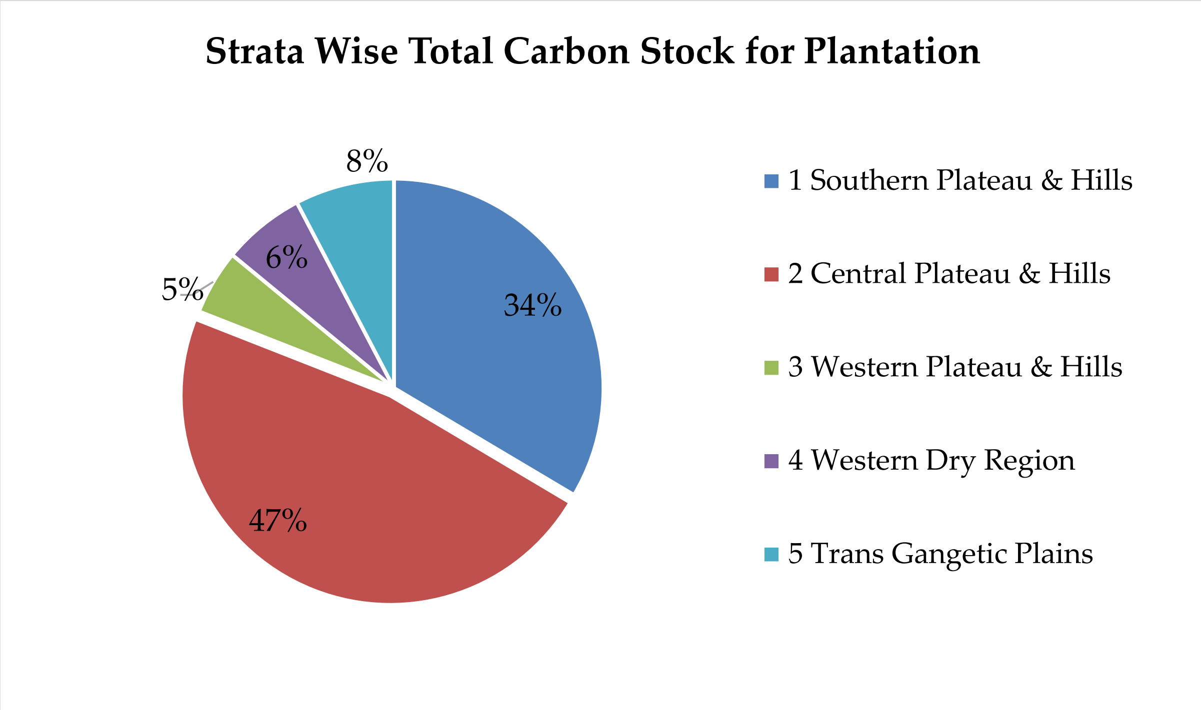


Figure 20: Percentage distribution of strata-wise Total Carbon Stock of plantations

Table 10: Biomass and carbon dioxide equivalent calculation of actual & extrapolation

Agro-climatic zone	Total actual area assessed (ha)	Actual Biomass (in tonnes)	Actual Mean Biomass/ha	Actual Mean Carbon stock plantation/ha	Actual Mean SOC/ha	Actual total carbon stock/ha	Actual carbon credit (tCO2e)	Total area	Extrapolated value of carbon credit (tCO2e)
Southern Plateau & Hills (Hassan & Mysore)	6	117.79	19.63	9.23	42.12	51.35	188.44	373.10	70308.11
Central Plateau & Hills (Bundi, Jhalawar & Kota)	25	238.76	9.55	4.49	13.53	18.02	66.13	1503.27	99409.12
Western Plateau & Hills (Ahmednagar & Pune)	2	23.01	11.51	5.41	22.68	28.09	103.08	101.84	10497.73
Western Dry Region (Barmer)	28	3.78	0.14	0.06	2.04	2.11	7.74	1723.48	13331.79
Trans Gangetic	6	11.51	1.92	0.90	11.22	12.12	44.49	361.53	16083.14

Agro-climatic zone	Total actual area assessed (ha)	Actual Biomass (in tonnes)	Actual Mean Biomass/ha	Actual Mean Carbon stock plantation/ha	Actual Mean SOC/ha	Actual total carbon stock/ha	Actual carbon credit (tCO2e)	Total area	Extrapolated value of carbon credit (tCO2e)
Plains (Bikaner)									
Total	67	394.86					**409.87**	**4063.22**	**209632.04**

The tCO2e has been calculated based on actual site visited which were further extrapolated with total area taken under various interventions.

Table 11: Comparison of tCO_2 with two different scenarios of project area.

S. No.	Agro climatic zone	Area (ha)					Actual tCO2e	Extrapolation	
	Southern Plateau & Hills (396 ha) & East Coast Plains & Hills (476.01 ha)	All diameter class with 3x3 M spacing	Diameter class > 10 cm with 3x3 M spacing	Mentioned by ITC	Sample plot area taken for calculation (Pearson correlation coefficient)	Sample plot area laid out		Scenario 1	Scenario 2 (using area mentioned by ITC)
1	Central Plateau & Hills	873	373	538.87	6	72	188.44	70,305	1,01,544
2	Western Plateau & Hills	1562	1503	3372.17	25	96	66.13	99,407	2,23,002
3	Trans Gangetic Plains	173	102	10149.39	2	45	103.08	10,497	10,46,199
4	Western Dry Region	1128	362	361.54	28	19	44.48	16,081	16,081
5	Southern Plateau & Hills (396 ha) & East Coast Plains & Hills (476.01 ha)	2219	1723	1723.48	6	32	7.74	13,340	13,340
	Total	**5954.67**	4063	**16145.45**	**67**	**264**		**2,09,632**	**14,00,166**

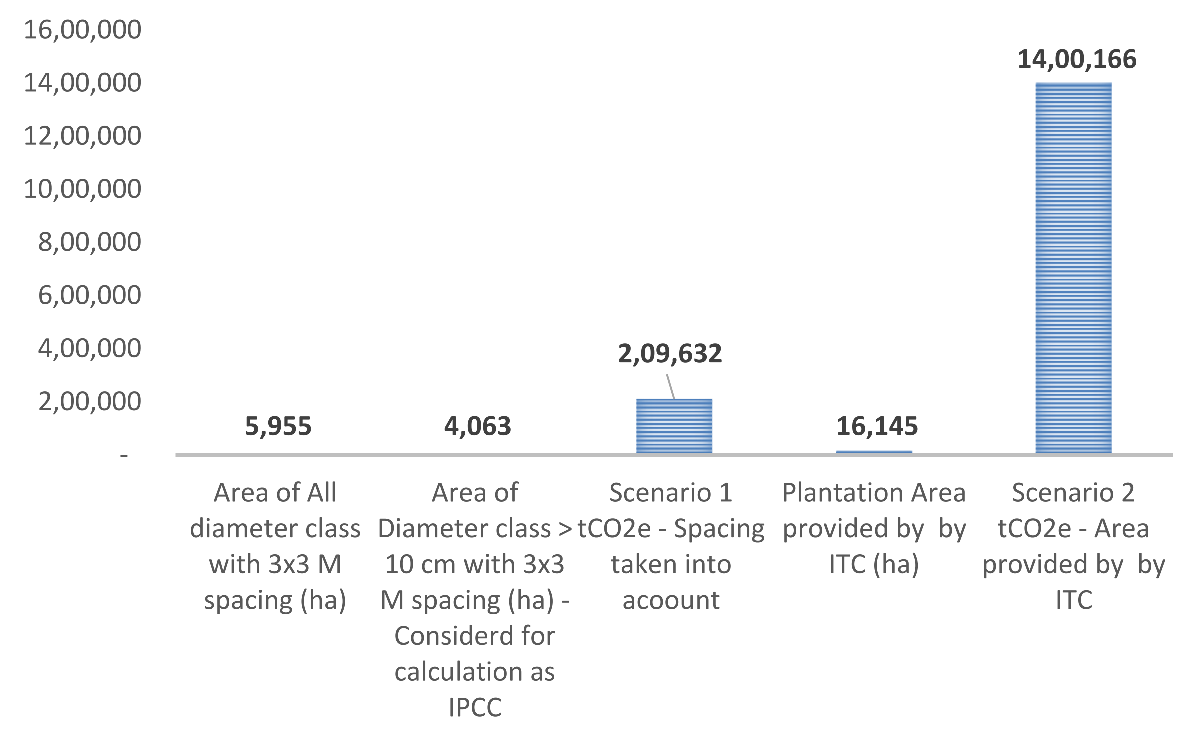


Figure 21: Comparison of tCO_2 with two different scenarios of project area.

Carbon Stock Sequestration Potential of plantations

Total carbon sequestration potential of plantations of three (2019,2020 and 2022) years done under ITC MSK project has been calculated based on the productivity of ecological zones and the area covered by the plantations under each agroclimatic zone. Results show that Western Dry Region has the maximum carbon sequestration potential i.e. 36046.92 tCO_2 per year because of the vast area covered by plantation activity under Western Dry Region.

Table 12: Carbon Sequestration Potential of existing tree species (annual change in carbon stock due to the program)

S. No.	Agro-climatic zone	District	State	Productivity (t.d.Ha/Yr)	Area (Ha)	Biomass (In tonnes)	Carbon (In tonnes)	CO2t/Ha/Year	Total Carbon dioxide Equivalent (tCO₂e)
1	**Southern Plateau & Hills**	Pudukottai	Tamil Nadu	7	8.98	62.90	29.56	108.49	3854.13
2		Coimbatore	Tamil Nadu	7	102.25	715.75	336.40	1234.60	
3		Hassan	Karnataka	5	123.48	617.41	290.18	1064.97	
4		Mysore	Karnataka	5	139.27	696.36	327.29	1201.14	
5		Kolar	Karnataka	5	8.09	40.49	19.03	69.83	

S. No.	Agro-climatic zone	District	State	Productivity (t.d.Ha/Yr)	Area (Ha)	Biomass (In tonnes)	Carbon (In tonnes)	CO2t/Ha/Year	Total Carbon dioxide Equivalent (tCO_2e)
6		Bangalore Rural	Karnataka	5	0.76	3.84	1.81	6.63	
7		Bharadri Kothagudem	Telangana	7	13.95	97.66	45.90	168.45	
8	**East Coast Plains & Hills**	Palnadu	Andhara Pradesh	7	77.31	541.22	254.38	933.56	5748.06
9		Prakasham	Andhara Pradesh	7	398.73	2791.18	1311.85	4814.50	
10	**Central Plateau & Hills**	Bhopal	Madhya Pradesh	7	4	28.00	13.16	48.30	18859.82
11		Chindwara	Madhya Pradesh	7	29.10	203.73	95.75	351.42	
12		Sehore	Madhya Pradesh	7	23.26	162.87	76.55	280.94	
13		Baran	Rajasthan	7	58.70	410.93	193.14	708.82	
14		Bundi	Rajasthan	7	535.30	3747.11	1761.14	6463.39	
15		Jhalawar	Rajasthan	7	101.07	707.54	332.54	1220.43	
16		Kota	Rajasthan	7	810.52	5673.68	2666.63	9786.54	
17	**Western Plateau & Hills**	Indore	Madhya Pradesh	7	71.15	498.05	234.08	859.09	2088.83
18		Ahmednagar	Maharashtra	7	63.28	443.02	208.22	764.16	
19		Pune	Maharashtra	7	38.55	269.92	126.86	465.58	
20	**Trans Gangetic Plains**	Bikaner	Rajasthan	7	361.53	2530.77	1189.46	4365.32	4365.32

S. No.	Agro-climatic zone	District	State	Productivity (t.d.Ha/Yr)	Area (Ha)	Biomass (In tonnes)	Carbon (In tonnes)	CO2t/Ha/Year	Total Carbon dioxide Equivalent (tCO_2e)
22	Western Dry Region	Barmer	Rajasthan	7	1723.48	12064.37	5670.26	20809.84	36046.92
23		Jodhpur	Rajasthan	7	495.95	3471.66	1631.68	5988.27	
		Jaisalmer	Rajasthan	7	765.99	5361.94	2520.11	9248.82	
Total									**70963.08**

The table below summarizes the present biomass of plantations and the carbon sequestration potential of theses plantations for the periods of 10, 20 and 30 years.

Table 13: Real Time biomass V/s projected carbon sequestration potential of existing plantations

Agro-climatic Zone	Real Times AGB and BGB based (DBH>10cm)	Projected Carbon stock AGB and BGB (Based on Total plantation area and Productivity)			
		10 Years	20 Years	30 Years	Per Year tCO_2e
Southern Plateau & Hills	70308.01	38541.30	77082.60	115623.90	3854.13
Central Plateau & Hills	99409.85	188598.20	377196.40	565794.60	18859.82
Western Plateau & Hills	10498.84	20888.30	41776.60	62664.90	2088.83
Trans Gangetic Plains	16083.03	136141.40	272282.80	408424.20	4365.32
Western Dry Region	13332.32	267981.00	535962.00	803943.00	36046.92
East Coast Plains & Hills	**	57480.60	114961.20	172441.80	5748.06
Total	**209632.05**	**709630.80**	**1419261.60**	**2128892.40**	**70963.08**

** DBH of existing plantation in this zone is < 10 cm hence it is not considered for biomass calculation as per IPCC GPG 2006.

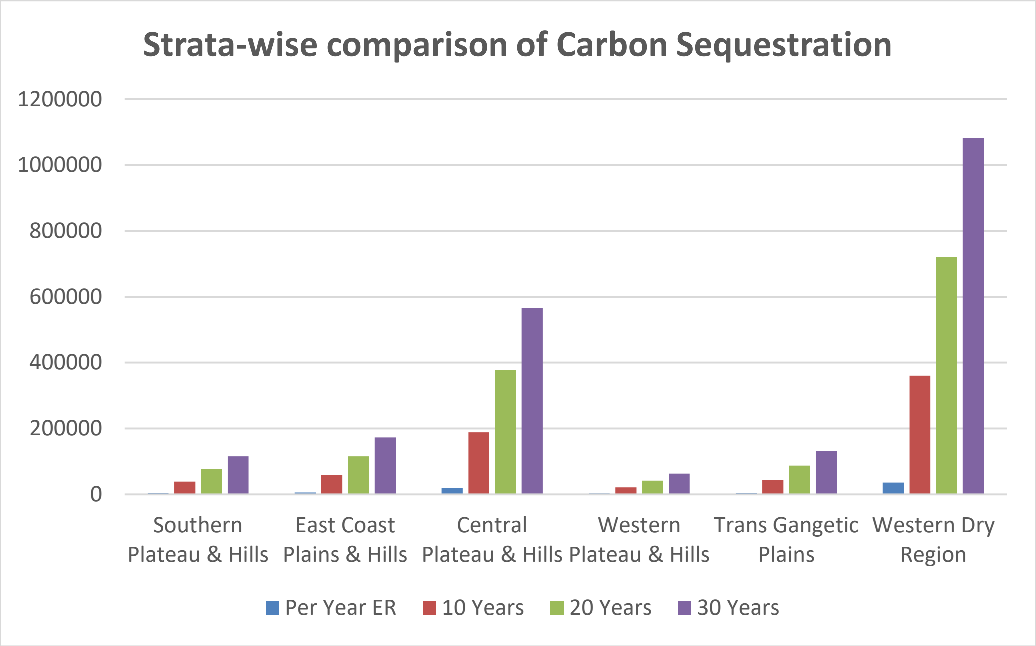


Figure 22: Strata-wise comparison of Carbon Sequestration Potential for 1, 10, 20 and 30 years

Biomass of Grasslands

Biomass of grasslands in all the strata has been assessed and the results have been provided in the table below. Results show that the Western Dry Region has maximum amount of carbon sequestered by grassland development activity.

Table 14: Summary of Grassland Biomass in all strata

Strata	Total Biomass (Per ha.)	No. of sample plot	Mean grass biomass/ha	Area (Ha.)	Total Biomass (In Tonnes)	Total Carbon Stock (Including SOC)	Total tCO2e
East Coast Plains & Hills	4.27	4	1.06	476.05	508.11	243.42	893.34
Central Plateau & Hills	10.36	12	0.86	1564.45	1350.61	646.05	2371.00
Trans Gangetic Plains	2.51	3	0.83	361.54	303.15	145.52	534.05
Western Dry Region	19.52	24	0.81	2985.43	2428.74	1151.47	4225.90
Total		43			4590.61	**2186.46**	**8024.30**

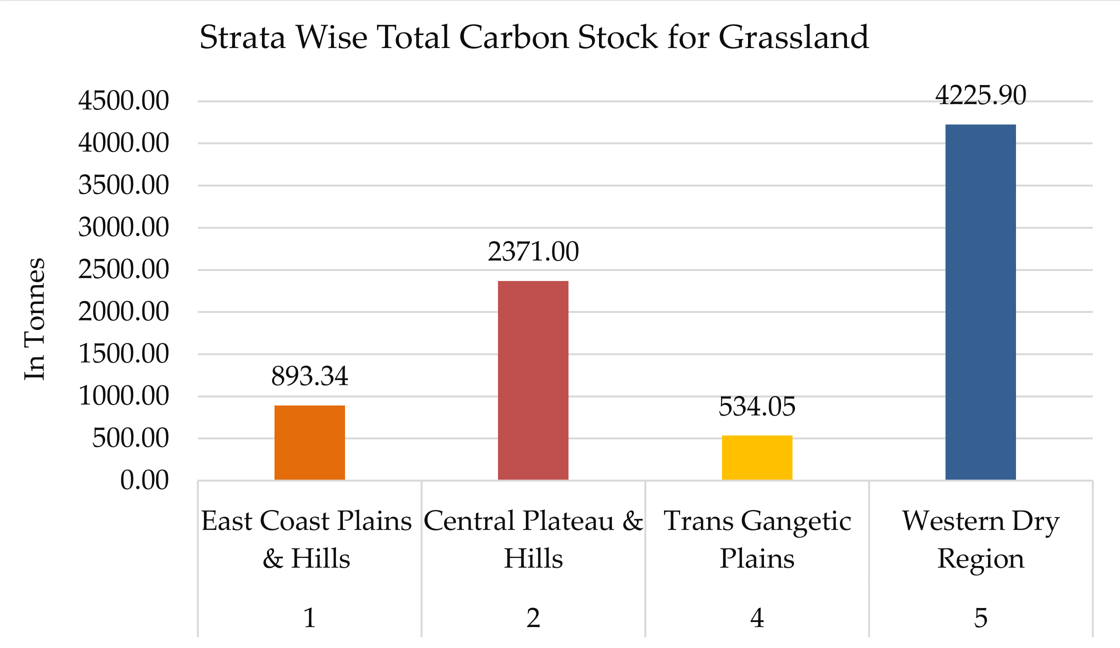


Figure 23: Strata-wise Carbon Stock for Grassland

Soil Moisture Conservation

Soil Organic Carbon of SMC activity has been compared with the Soil Organic Carbon of control areas. The results depict that the organic carbon content in soil samples taken from SMC activity area is more than that in the control areas. The SMC activities done under ITC MSK project have enhanced the SOC in project area by approximately 0.2% unit in all the agro climatic zones.

Table 15: Comparison of SOC in samples from SMC structures and control area

Agro-climatic Zone	District	State	Mean SOC-Value of SMC	Mean SOC Control
Southern Plateau & Hills	Pudukottai	Tamil Nadu	1.1	0.8
	Coimbatore	Tamil Nadu		
	Hassan	Karnataka		
	Mysore	Karnataka		
	Kolar	Karnataka		
	Banglore Rural	Karnataka		
	Bharadri Kothagudem	Telangana		
East Coast Plains & Hills	Palnadu	Andhra Pradesh	0.5	0.3
	Prakasham	Andhra Pradesh		

Agro-climatic Zone	District	State	Mean SOC-Value of SMC	Mean SOC Control
Central Plateau & Hills	Bhopal	Madhya Pradesh	0.8	0.6
	Chindwara	Madhya Pradesh		
	Sehore	Madhya Pradesh		
	Baran	Rajasthan		
	Bundi	Rajasthan		
	Jhalawar	Rajasthan		
	Kota	Rajasthan		
Western Plateau & Hills	Indore	Madhya Pradesh	0.9	0.7
	Ahmednagar	Maharashtra		
	Pune	Maharashtra		
Trans Gangetic Plains	Bikaner	Rajasthan	0.6	0.5
Western Dry Region	Jaisalmer	Rajasthan		
	Barmer	Rajasthan		
	Jodhpur	Rajasthan		

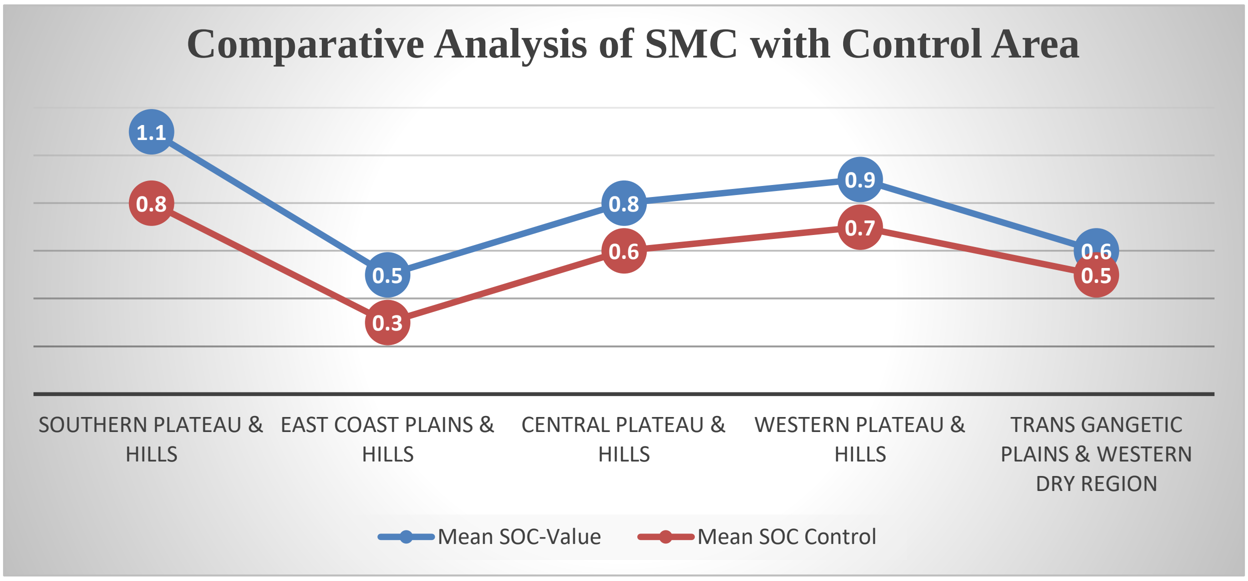


Figure 24: Comparative analysis of SMC with Control Area

A comparative analysis of Carbon Stock from SOCs of plantation, grassland and Soil Moisture Conservation activities has been provided in the table below.

Table 16: Summary of comparative analysis of Carbon Stock in project area and control area of SOCs of plantation, grassland and SMC.

S. No.	Strata	Carbon Stock of Plantation (SOC) In Tonnes		Carbon Stock of Grassland (SOC) In Tonnes		SMC-SOC	
		Project Area	Control Area	Project Area	Control Area	Project Area	Control Area
1	Southern Plateau & Hills	15714.97	8487.39	*	*	1.1	0.8
2	East Coast Plains & Hills	*	*	4.60	2.24	0.5	0.3
3	Central Plateau & Hills	20339.32	8521.91	11.26	9.8	0.8	0.6
4	Western Plateau & Hills	2309.91	2014.11	*	*	0.9	0.7
5	Trans Gangetic Plains	3523.28	3122.19	3.03	2.1	0.6	0.5
6	Western Dry Region	4056.46	1540.11	9.96	8.11	0.6	0.5
Total		45943.95	23685.71	30.65	22.58		

*Not applicable – as grassland development not done

Table 17: Summary of comparative analysis of Carbon Stock in project area and control area of SOCs of plantation, grassland

S. No.	Strata	Carbon Stock of Plantation& Grassland (SOC) In Tonnes	
		Project Area	**Control Area**
1	Southern Plateau & Hills	15714.97	8487.39
2	East Coast Plains & Hills	4.6	2.24
3	Central Plateau & Hills	20350.58	8531.71

S. No.	Strata	Carbon Stock of Plantation& Grassland (SOC) In Tonnes	
		Project Area	Control Area
4	Western Plateau & Hills	2309.91	2014.11
5	Trans Gangetic Plains	3526.31	3124.29
6	Western Dry Region	4066.42	1548.22
Total		**45972.79**	**23707.96**

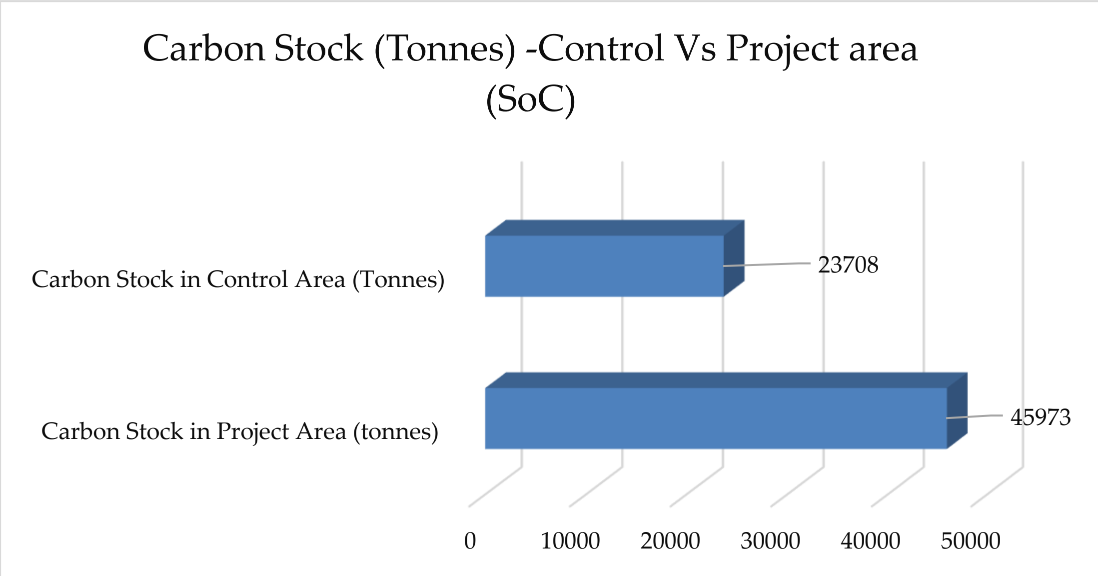


Figure 25 Soil Organic Carbon (SOC) Control verses Project area

A comparative analysis of Carbon Stock was done between the project V/s control (Reference) area of all the agro-climatic zones. The results clearly showed that the project area (45972.79) has comparatively more potential source of carbon stock than the reference region (23707.96). (Figure 25).

Biodiversity assessment

Species diversity, which is also referred as heterogeneity, is an expression of community structure. Also, it is one of the basic concepts of ecology that has been used to characterize communities and ecosystems and measured by species richness (the number of species present in a particular community) and species evenness (the relative abundance of the different species). The most commonly used diversity indices used in ecology are the Shannon and Simpson.

Simpson index is used to assess homogeneity of species in a given landscape whereas Shannon-Wiener index determines heterogeneity of species in the given landscape. Higher the homogeneity means lower the diversity whereas higher the heterogeneity means higher diversity of species. As, it also takes into account the abundance (the number of individuals per species) therefore, heterogeneity and homogeneity of the species is represented here. Alpha diversity is also calculated which refers to diversity on a local scale, describing the species diversity (richness) within a functional community.

Table 18: Results of Biodiversity Assessment

State	Alpha Mean	Shannon Diversity Index	Simpson Index
Karnataka	7	2.55	9.76
Maharashtra	11	3.12	15.13
Tamil Nadu	14	3.39	19.03
Telangana	18	3.57	22.33
Madhya Pradesh	20	3.7	24.8
Rajasthan	22	3.79	27.01
Andhra Pradesh	24	3.87	29.06

The Shannon diversity Index ranges from 0.1 to 5 and the result obtained from the study area shows high diversity as the value obtained ranges from 2.55 to 3.87. The values obtained for Simpson index are also high i.e., greater than 10 which means that the landscape is highly homogenous where a few species are represented by large number of individuals. Hence, even though the overall species diversity i.e. Shannon Diversity Index value is high, the composition of individuals is homogenous i.e. individuals of only a few species are dominating the landscape.

Conclusion

During the years 2019-20, 2020-2021, and 2021-2022, the ITC through its Mission Sunehra Kal project worked on natural resource management in seven states by conducting Plantation, Soil Moisture Conservation (SMC), and Grassland Development activities. Plantation activities cover an area of 4,063.24 Ha and grassland development activities covers an area of 5,489.32 Ha. Soil Moisture Conservation (SMC) activities have been carried out both in areas under plantations and grassland development.

The CO_2 sequestration potential of plantation activities for the intervention period 2019-2022 has been estimated as 70,963.08 tCO2 and the total potential for 30 years has been estimated as 21,28,892.38 tCO2.

The CO_2 sequestration for plantations with DBH above 10cm for the period of 2019-2022 across various Agro-climatic zones are estimated to be as follows- 70308.01 tCO_2e for the Southern Plateau & Hills, 99409.85 tCO_2e at the Central Plateau & Hills, 10498.83 tCO_2e for Western Plateau & Hills, 13332.31 tCO_2e for Western Dry Region and 16083.02 tCO_2e for the Trans Gangetic Plains. The Central Plateau and Hills region sequestered the highest amount of carbon (47%) and the Western Plateau & Hills sequestered the lowest amount of carbon (5%).

For Grasslands, the total tCO2e is recorded as follows 893.34 tCO2e for the East Coast Plain & Hills, 2371.00 tCO2e for the Central Plateau & Hills, 534.05 tCO2e for the Trans Gangetic Plains and 4225.90 tCO2e for the Western Dry Region. The Agro-climatic zone "Western Dry Region" recorded the highest percentage of carbon equivalent.

In case of Soil Moisture Conservation activities, the carbon content of the Project Area is consistently increasing as compared to the Control Area. The mean SMC-SOC value of Southern Plateau & Hills Project Area is 1.1 with respect to Control Area value 0.8, For East Coast Plains & Hills Project Area the mean SMC-SOC value is 0.5 and the Control value is 0.3 For Central Plateau & Hills Project area mean SMC-SOC value is 0.8 and Control value is 0.6, The Western Plateau & Hills Project Area mean SMC-SOC value is 0.9 and Control Area value is 0.7 and For the Trans Gangetic Plains & Western Dry Regions Project Area the mean SMC-SOC value is 0.6 with respect to Control Area value 0.5. The results deliver that the project area is rich in Soil Organic Content compared to Control Area due to the implementation of Soil Moisture Conservation Activities.

Recommendations/Key Highlights

Land Ownership

Since the plantation sites are owned by different entities, their consent will be required before developing a carbon finance project. Land ownership is a crucial part of developing any carbon finance project. As per field observation, ITC has done plantation activities in multiple titles of land such as Forest land, Community land, and farmland. In such a situation, land ownership issues will arrive at the time of claiming carbon credits. Therefore, it would be a necessary and integral part of becoming a project implementation partner or project proponent (in this case ITC), need to obtain permission from the Gram Panchayats/farmers/forest land where the project planting sites are located. The permission letter includes permission to undertake project activities, a carbon waiver, and support from the community for the implementation and maintenance of the project.

Institutional Mechanism

An institutional mechanism needs to be established for smooth functioning of the project and flow of funds to respective beneficiaries. An institutional body will be constituted at 3 levels such as District Level Committee', Regional Level Committee' and Corporate Level Committee. The '**District Level Committee**' shall be formed which will comprise of a **Chairman** (District Coordinators from ITC) and **Members** (Five Nominated Farmers from each district). The '**Regional Level Committee**' shall constitute clusters of districts. This committee will have a **Chairman** (Regional Coordinators from ITC), and Member Secretaries (ITC official) constituting of District Coordinators and 1 nominated farmer from each districts. Furthermore, a **Corporate Level Committee** shall be developed comprising of Chairman (ITC), Member Secretary (ITC) and Members (State/Regional Coordinators).

Project Boundaries

Project boundaries should be clearly demarcated by delineating with the help of GPS followed by delineating of plot parcels where intervention was done. The boundaries of plantation locations should be depicted in the form of KML file.

Maintenance of Data and Regular Monitoring

Regular monitoring by the field officials would ensure success of the plantation. Farmer wise plantation data should be recorded which include land area, plant species, number of plants against each species, year of plantation, tree spacing, height and girth of tree and source of irrigation.

Project Period

The rotation cycle of carbon finance project will be 20-30 year and carbon credits will be obtained every 5 year of monitoring cycle.

Demarcation of Permanent Sample plots

The permanent sample plot should be demarcated properly by using monitoring pillars/stone. These permanent monitoring plots will be convenient for the assessment of temporal change of biomass at the time of verification.

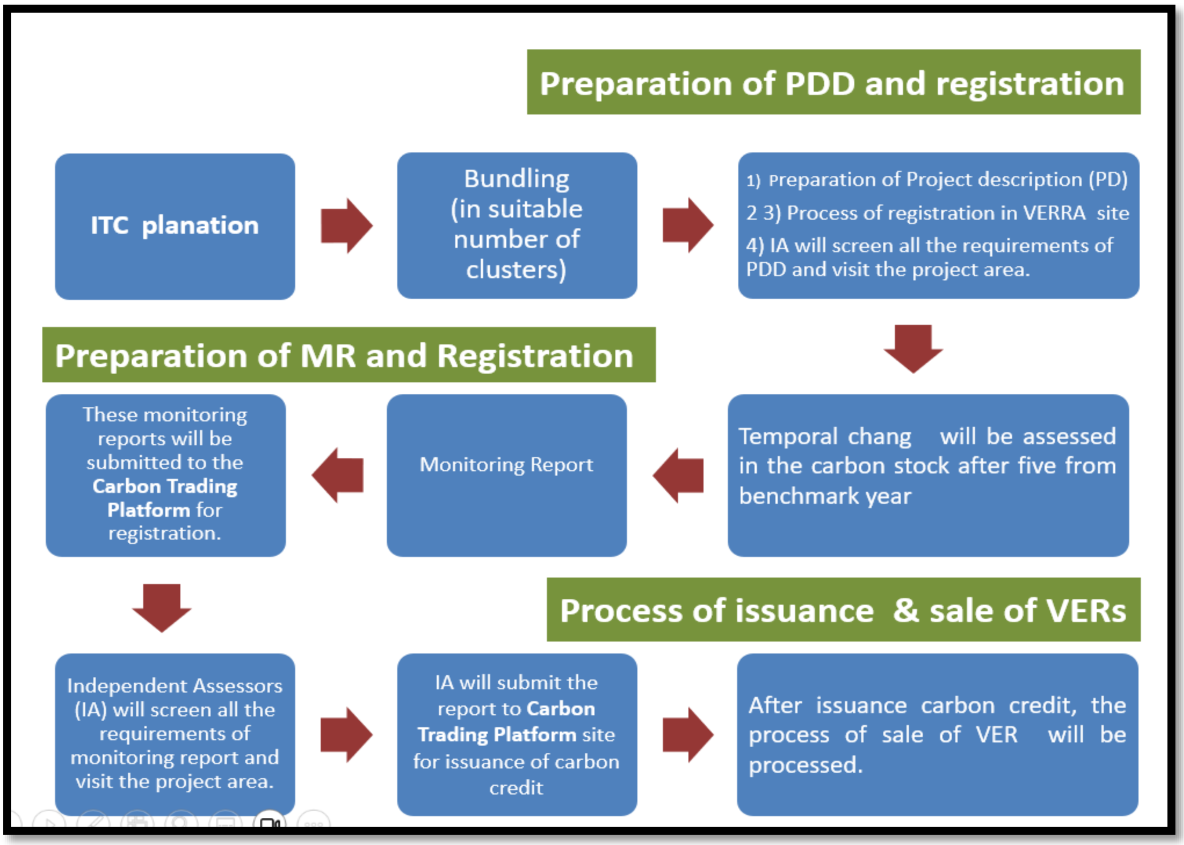
Training and capacity Building

Capacity building of ITC staffs should be done which will be advantageous for the re-assessment processes.

Carbon Trading Platform

- A carbon market platform and a suitable methodology will have to be identified to develop the carbon finance project. The available carbon trading platform is Gold Standard, VERRA and Plan vivo etc.

Process of developing Carbon Finance Project



Key Highlights

- Total 4063.24 ha of the area was covered under plantation activity in 7 states of the project whereas total area covered under grassland 5489.32 ha in 3 states.
- Around 70963.08 tCO_2 will be sequestering annually under plantation area from all 7 states covered under the project.
- On an average, around 11827.18 tCO_2 will be sequestering under plantation area annually from each state.
- The total 209632.05 tCO_2 has been recorded with reference to the project area that falls under Plantation activity, followed by the grassland is 8024.30 tCO_2.
- Around 1,650,935 saplings of 81 tree species belonging to 30 families were planted within the designated area under 7 states. Around 10 grass species belonging to 3 families were sown within the area under 3 states(*Stylo hemata*, *Aristida sp* (Lampadi), *Cyperus rotundus* (Nagar Motha), *Cynodon dactylon* (Doob), *Panicum maximum* (Ganthiyan), *Lasiurus scindicus* (Sewan), *Andropogon pumilus*, *Themala triandra*,

Cenchrus bifiourus (Bhurut), *Cenchrus ciliaris* (Dhaman) with following families Fabaceae, Poaceae, Cyperaceae).

- The project area has recorded a high value of soil organic carbon stock (45,974.60 tonnes) as compared to the reference region (23,708.29 tonnes).
- Most of the plantation has been done during the years 2020-21 & 2021-22.
- The project sites are much dispersed in manner and far apart.

Annexure I: Volumetric Equations

Volumetric Equations of species

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
KARNATAKA				
01	*Syzigium cumini*	(0.30706+5.12731*D-2.0987*D^1/2)^2	0.57	FSI 2019
02	*Tectona grandis*	(-0.2414+2.8458*D-5.5816*D^2+14.816*D^3)	0.57	FSI 1996
03	*Grevillea robusta*	(0.058+4.598*D^2)	0.57	FSI 1996
04	*Eucalyptus spp*	(0.02894-0.89284*D+8.72416*D^2)	0.57	FSI 1996
05	*Acacia auriculiformis*		0.57	FSI 1996
06	*Albizia lebbeck*		0.57	FSI 1996
07	*Annona squamosal*		0.57	FSI 1996
08	*Azadirachta indica*		0.57	FSI 1996
09	*Bombax cieba*		0.57	FSI 1996
10	*Butea monosperma*		0.57	FSI 1996
11	*Cassia siamea*		0.57	FSI 1996
12	*Dalbergia latifolia*		0.57	FSI 1996
13	*Dalbergia sissoo*		0.57	FSI 1996

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
14	*Delonix regia*	General Volume Equation 1 for among species (0.058+4.598*D^2)	0.57	FSI 1996
15	*Phyllanthus embelica*		0.57	FSI 1996
16	*Ficus benghalensis*		0.57	FSI 1996
17	*Ficus elastic*		0.57	FSI 1996
18	*Ficus religosa*		0.57	FSI 1996
19	*Gmelina arborea*		0.57	FSI 1996
20	*Grevillea robusta*		0.57	FSI 1996
21	*Holoptelea integrifolia*		0.57	FSI 1996
22	*Legerstroenua speciosa*		0.57	FSI 1996
23	*Madhuca indica*		0.57	FSI 1996
24	*Magnolia champaka*		0.57	FSI 1996
25	*Mangifera indica*		0.57	FSI 1996
26	*Melia dubia*		0.57	FSI 1996
27	*Neolamarkia cadamb*	General Volume Equation 1 for among species (0.058+4.598*D^2)	0.57	FSI 1996
28	*Pongamia pinnata*		0.57	FSI 1996

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
29	*Psidium guajava*		0.57	FSI 1996
30	*Swetienia mahogany*		0.57	FSI 1996
31	*Terminalia arjuna*		0.57	FSI 1996
32	*Terminalia bellerica*		0.57	FSI 1996
33	*Terminalia catappa*		0.57	FSI 1996
34	*Mutinga calabura*		0.57	FSI 1996
35	*Tamarindas indica*		0.57	FSI 1996
36	*Peltoforum*		0.57	FSI 1996
37	*Acacia auriculiformis(NR)*	General Volume Equation 2 for among species (-0.135764+2.756043*D)	0.57	FSI 1996
38	*Azadirachta indica(NR)*		0.57	FSI 1996
39	*Butea monosperma(NR)*		0.57	FSI 1996
40	*Dalbergia sissoo(NR)*		0.57	FSI 1996
41	*Ficus benghalensis(NR)*		0.57	FSI 1996
42	*Grevillea robusta(NR)*		0.57	FSI 1996
43	*Mutinga calabura(NR)*		0.57	FSI 1996

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
44	*Pongamia pinnata(NR)*		0.57	FSI 1996
		MAHARASHTRA		
45	*Tectona grandis*	(-0.10672+2.562418*D)^2	0.57	FSI 1996
46	*Acacia nilotica*	(-0.00142+2.61911*D-0.54703*D^1/2)	0.57	FSI 1996
47	*Butea monosperma*	(0.18573-2.85478*D+15.03576*D^2)	0.57	FSI 2019
48	*Phyllanthus embelica*	General Volume Equation for among species (0.081467-1.063661*D+6.452918*D^2)	0.57	FSI 1996
49	*Psidium guajava*		0.57	FSI 1996
50	*Terminalia arjuna*		0.57	FSI 1996
51	*Dalbergia sissoo*		0.57	FSI 1996
52	*Prunus indica*		0.57	FSI 1996
53	*Terminalia bellerica*		0.57	FSI 1996
54	*Ficus bengalensis*		0.57	FSI 1996
55	*Aegle mermelos*		0.57	FSI 1996
56	*Ziziphus jujube*		0.57	FSI 1996
57	*Cassia seamia*		0.57	FSI 1996
58	*Eucalyptus spp*		0.57	FSI 1996

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
59	*Delonix regia*	General Volume Equation for among species (0.081467-1.063661*D+6.452918*D^2)	0.57	FSI 1996
60	*Holoptelia integrifolia*		0.57	FSI 1996
61	*Tamarindas indica*		0.57	FSI 1996
62	*Syzygium cumini*		0.57	FSI 1996
63	*Pongamia pinnata*		0.57	FSI 1996
64	*Carrisa carondas*		0.57	FSI 1996
65	*Acacia cetachu*		0.57	FSI 1996
66	*Mangifera indica*		0.57	FSI 1996
67	*Swietenia mohagoni*		0.57	FSI 1996
68	*Azadirachta indica*		0.57	FSI 1996
69	*Peltoforum*		0.57	FSI 1996
70	*Annona squamosa*		0.57	FSI 1996
71	*Albizia lebbeck*		0.57	FSI 1996
72	*Leaucenea leucocephala*		0.57	FSI 1996
73	*Limonia acidissima*		0.57	FSI 1996
MADHYA PRADESH				

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
74	*Tectona grandis*	(0.04346-0.26352*SQRT(D)+8.79334*D^2)	0.57	FSI 1996
75	*Phyllanthus embelica*	(0.04935-1.026608*D+8.89721*D^2)	0.57	FSI 1996
76	*Dalbergia sissoo*	(0.04422+2.328465*D^2+0.30915*D^2*H)	0.57	FSI 1996 FRI 1999
77	*Butea monosperma*	(0.0417-0.47789*D+3.50714*D^2+9.76048*D^3)	0.57	FSI 2019
78	*Syzigium cumini*	(0.08481-1.81774*D+12.63047*D^2-6.6955*D^3)	0.57	FSI 1996 FRI 1999
79	*Acacia nilotica*	(0.043849+0.552735*D+2.952386*D+0.334508*D^2)	0.57	FSI 1996
80	*Annona squamosal*	General Volume Equation for among species (0.04935-1.026608*D+8.89721*D^2) General	0.57	FSI 2019
81	*Artocarpus heterophyllus*		0.57	FSI 2019
82	*Azadirachta indica*		0.57	FSI 2019
83	*Calatrophis procera*		0.57	FSI 2019
84	*Cascabela thevetia*		0.57	FSI 2019
85	*Citrus*		0.57	FSI 2019
86	*Delonix regia*		0.57	FSI 2019
87	*Eucalyptus spp*		0.57	FSI 2019

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
88	*Gliricidia spp*	General Volume Equation for among species (0.04935-1.026608*D+8.89721*D^2)	0.57	FSI 2019
89	*Hibiscus*		0.57	FSI 2019
90	*Leucenea leucocephala*		0.57	FSI 2019
91	*Madhuca latifolia*		0.57	FSI 2019
92	*Mangifera indica*		0.57	FSI 2019
93	*Neolamarkia cadamba*		0.57	FSI 2019
94	*Nerium oleander*		0.57	FSI 2019
95	*Prosophis cineraria*		0.57	FSI 2019
96	*Psidium guajava*		0.57	FSI 2019
97	*Pumica granatum*		0.57	FSI 2019
98	*Senna siamea*		0.57	FSI 2019
99	*Terminalia catappa*		0.57	FSI 2019
		TELANGANA		
100	*Albezia procera*		0.57	FSI 2021
101	*Azadirachta indica*		0.57	FSI 2021
102	*Dalbergia sissoo*		0.57	FSI 2021

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
103	*Holoptelia integrifolia*	General Volume Equation for among species (0.001+0.333*D^2*H)	0.57	FSI 2021
104	*Murayya koenigii*		0.57	FSI 2021
105	*Pongamia pinnata*		0.57	FSI 2021
106	*Syzygium cumini*		0.57	FSI 2021
107	*Terminalia arjuna*		0.57	FSI 2021
ANDHRA PRADESH				
108	*Senna ariculata*		0.57	FSI 2021
109	*Azadirachta indica*		0.57	FSI 2021
110	*Ocimum sanctum*		0.57	FSI 2021
111	*Acacia nilotica*		0.57	FSI 2021
112	*Haldina cordifolia*		0.57	FSI 2021
113	*Cassus quadrangularis*		0.57	FSI 2021
114	*Tamarindas indica*		0.57	FSI 2021
115	*Annona squamosal*		0.57	FSI 2021
116	*Delonix regia*		0.57	FSI 2021
117	*Terminalia arjuna*		0.57	FSI 2021

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
118	*Pongamia pinnata*	General Volume Equation for among species (0.088183-1.490948*D+8.984266*D^2)	0.57	FSI 2021
119	*Butea monosperma*		0.57	FSI 2021
120	*Gliricidia sepium*		0.57	FSI 2021
121	*Aegle marmelos*		0.57	FSI 2021
122	*Conocarpus lancifolicus*		0.57	FSI 2021
123	*Ficus religosa*		0.57	FSI 2021
124	*Lawsonia inermis*		0.57	FSI 2021
125	*Haloptelea integrefolia*		0.57	FSI 2021
126	*Calycopteris floribunda*		0.57	FSI 2021
		TAMILNADU		
127	*Tectona grandis*	(-0.40589+1.98158*D+0.987373*D^1/2)^2	0.57	FSI 1996
128	*Acacia nilotica*		0.57	FSI 1996
129	*Acacia Senegal*		0.57	FSI 1996
130	*Albizia lebbeck*		0.57	FSI 1996
131	*Annona squamosal*		0.57	FSI 1996
132	*Artocrpus heterophyllus*		0.57	FSI 1996

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
133	*Azadirachta indica*	General Volume Equation for among species (0.088183-1.490948*D+8.984266*D^2)	0.57	FSI 1996
134	*Calatrophis procera*		0.57	FSI 1996
135	*Carissa carandas*		0.57	FSI 1996
136	*Casurina equisitifolia*		0.57	FSI 1996
137	*Citrus*		0.57	FSI 1996
138	*Cocus nucifera*		0.57	FSI 1996
139	*Delonix regia*		0.57	FSI 1996
140	*Dryopteris erythrosors*		0.57	FSI 1996
141	*Phyllanthus embelica*		0.57	FSI 1996
142	*Ficus religosa*		0.57	FSI 1996
143	*Gmelina arborea*		0.57	FSI 1996
144	*Holoptelia integrifolia*		0.57	FSI 1996
145	*Leaucaena leucocephala*		0.57	FSI 1996
146	*Madhuca longifolia*		0.57	FSI 1996
147	*Mangifera indica*		0.57	FSI 1996

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
148	*Melia azedarach*		0.57	FSI 1996
149	*Narium oleander*		0.57	FSI 1996
150	*Peltoforum*		0.57	FSI 1996
151	*Polythia longifolia*		0.57	FSI 1996
152	*Pongamia pinnata*		0.57	FSI 1996
153	*Susbenia grandiflora*		0.57	FSI 1996
154	*Swetenia mahogony*		0.57	FSI 1996
155	*Syzygium cumini*		0.57	FSI 1996
156	*Terminalia catappa*		0.57	FSI 1996
157	*Pumica granatum*		0.57	FSI 1996
		RAJASTHAN		
158	*Acacia nilotica*	(-0.00142+2.61911*D-0.54703*D^1/2)^2	0.57	FSI 2021
159	*Acacia cetachu*	(0.26949-1.61804*D+8.79495*D^2+2.49489*D^3)	0.57	FSI 2021
160	*Tectona grandis*	(0.062108-0.927983*D+6.613031*D^2)	0.57	FSI 2019
161	*Butea monospema*	(-0.24276+2.95525*D)^2	0.57	FSI 2021
162	*Prosopis cineraria*		0.57	FSI 2021

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
163	*Pongamia Pinnata*	General Volume Equation for among species (0.081467-1.063661*D+6.452918*D^2) General	0.57	FSI 2021
164	*Dalbergia sissoo*		0.57	FSI 2021
165	*Acacia catechu*		0.57	FSI 2021
166	*Acacia Senegal*		0.57	FSI 2021
167	*Aegle marmelous*		0.57	FSI 2021
168	*Albizia lebbeck*		0.57	FSI 2021
169	*Anogeissus pendula*		0.57	FSI 2021
170	*Artocarpus heterophyllus*		0.57	FSI 2021
171	*Azadirachta indica*		0.57	FSI 2021
172	*Butea monosperma*		0.57	FSI 2021
173	*Carissa carandus*		0.57	FSI 2021
174	*Cassia fistula*		0.57	FSI 2021
175	*Citrus sinensis*		0.57	FSI 2021
176	*Combretum indicum*		0.57	FSI 2021
177	*Cordia dichotoma 2*		0.57	FSI 2021

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
178	*Delonix regia*	General Volume Equation for among species (0.081467-1.063661*D+6.452918*D^2)	0.57	FSI 2021
179	*Eucalyptus sp.*		0.57	FSI 2021
180	*Ficus benghalensis*		0.57	FSI 2021
181	*Ficus carica*		0.57	FSI 2021
182	*Holoptelia integrifolia*		0.57	FSI 2021
183	*Hyllanthus exelson*		0.57	FSI 2021
184	*Jatropha curcas*		0.57	FSI 2021
185	*Leucaena leucocephala*		0.57	FSI 2021
186	*Mangifera indica*		0.57	FSI 2021
187	*Madhuca longifolia*		0.57	FSI 2021
188	*Phyllanthus emblica 6*		0.57	FSI 2021
189	*Neolamarckia cadamba*		0.57	FSI 2021
190	*Pithecellobium dulce*		0.57	FSI 2021
191	*Citrus sinensis*		0.57	FSI 2021
192	*Combretum indicum*		0.57	FSI 2021

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
193	*Cordia dichotoma 2*	General Volume Equation for among species (0.081467-1.063661*D+6.452918*D2)	0.57	FSI 2021
194	*Delonix regia*		0.57	FSI 2021
195	*Eucalyptus spp*		0.57	FSI 2021
196	*Ficus benghalensis*		0.57	FSI 2021
197	*Ficus carica*		0.57	FSI 2021
198	*Holoptelia integrifolia*		0.57	FSI 2021
199	*Hyllanthus exelson*		0.57	FSI 2021
200	*Jatropha curcas*		0.57	FSI 2021
201	*Leucaena leucocephala*		0.57	FSI 2021
202	*Mangifera indica*		0.57	FSI 2021
203	*Madhuca longifolia*		0.57	FSI 2021
204	*Phyllanthus emblica*		0.57	FSI 2021
187	*Neolamarckia cadamba*		0.57	FSI 2021
188	*Pithecellobium dulce*		0.57	FSI 2021
189	*Prosopis juliflora*		0.57	FSI 2021

S.No	Species	Volumetric Equation	Wood Density (FAO)	Source
190	*Psidium guajava*		0.57	FSI 2021
191	*Pumica granatum*		0.57	FSI 2021
192	*Sapindus mukorosii*		0.57	FSI 2021
193	*Syzigium cumini*		0.57	FSI 2021
194	*Tamarindus indica*		0.57	FSI 2021
195	*Tecomella undulate*		0.57	FSI 2021
196	*Tectona grandis*		0.57	FSI 2021
197	*Terminalia arjuna*		0.57	FSI 2021
198	*Terminalia bellerica*		0.57	FSI 2021
199	*Vitex nigundo*		0.57	FSI 2021
200	*Ziziphus jujube*		0.57	FSI 2021

Annexure II: Field Pictures

Telangana



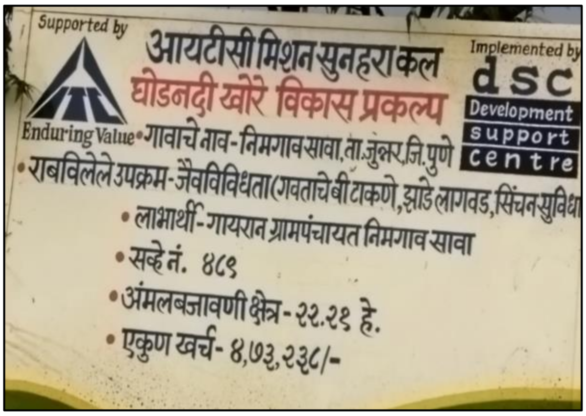

Andhra Pradesh




Tamil Nadu


ITC MISSION SUNEHRAKAL
ஒளிமயமான எதிர்காலம்
Project Cost ITC : 3,12,570
: 34,730
: 3,47,300
: 2021-2022

Maharashtra



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Madhya Pradesh

Rajasthan



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Karnataka

Additional Field Photographs






Preliminary Visit to Chindhwara, Madhya Pradesh

Preliminary Visit to Sehore, Madhya Pradesh


परियोजना से निर्मित परिसम्पत्तियों का विवरण
क्र. संकेत वाटरशेड विकास कार्य का नाम संख्या/मात्रा इकाई सहित लागत (राशि- रुपये में)
1. चैक डेम/स्टापडेम 1 8.56 लाख
2. खेत तालाब 23 62.48 लाख
3. नालागहरीकरण व चौड़ीकरण 1450 R.M. 9.49 लाख
4. गोबियन 3 0.98 लाख
5. मेढ़ बंधान 2605 R.M. 3.52 लाख
6. तालाब 2 14.09 लाख
खेत का पानी खेत में" गाँव का पानी गाँव में

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