

Community Plantation as A Tool for Carbon Sequestration: A Study of Soil–Climate– Plant Interrelationships

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Abstract- This study examines the role of community plantations in enhancing carbon sequestration and promoting environmental sustainability, with a focus on Belkheda village in the Amravati district of Maharashtra. It highlights how environmental factors— such as soil properties, climatic conditions, and biodiversity—interact to influence the capacity of vegetation to absorb and store atmospheric carbon dioxide (CO₂). Increasing CO₂ levels due to human activities like deforestation, industrialization, and urbanization have intensified climate change, making carbon sequestration a critical mitigation strategy. The research evaluates carbon storage in plant biomass and soil, emphasizing the importance of healthy soils, adequate moisture, and suitable temperature for optimal plant growth and carbon capture. Community participation in plantation activities is identified as a key factor in improving ecological balance, restoring degraded lands, and increasing green cover. The study also considers biodiversity and local climatic conditions to assess ecosystem resilience and sustainability. Findings suggest that well-managed community plantations act as effective carbon sinks, contributing to reduced greenhouse gas concentrations while improving soil fertility, water retention, and air quality. Overall, the study underscores the significance of integrating environmental, social, and ecological approaches to achieve long-term climate change mitigation and sustainable rural development.

Keywords: Carbon Sequestration, Community Plantations, Sustainability.

I. INTRODUCTION

The environment refers to the sum of all external conditions and influences that affect the growth, development, and survival of living organisms. It includes both abiotic components such as soil, water, air, temperature, sunlight, and nutrients, and biotic components such as plants, animals, microorganisms,

and humans. These components interact continuously to maintain ecological balance and regulate key processes such as nutrient cycling, biodiversity conservation, and carbon sequestration. A stable and healthy environment is essential for sustaining life and ensuring the proper functioning of ecosystems (Odum & Barrett, 2005).

In recent decades, environmental sustainability has emerged as a major global concern. Rapid industrialization, urbanization, deforestation, and population growth have significantly contributed to environmental degradation, leading to biodiversity loss, soil erosion, and depletion of natural resources. One of the most serious consequences of these changes is the increase in greenhouse gas emissions, particularly carbon dioxide (CO₂), which is a major driver of climate change. Human activities such as fossil fuel combustion, industrial processes, and land-use changes have disrupted the natural carbon cycle, resulting in an accumulation of CO₂ in the atmosphere (IPCC, 2021; UNEP, 2020).

Carbon dioxide is a naturally occurring greenhouse gas that plays a vital role in maintaining the Earth's temperature by trapping heat in the atmosphere. However, excessive concentrations of CO₂ intensify the greenhouse effect, leading to global warming and climate instability. This has resulted in rising global temperatures, melting glaciers, sea-level rise, extreme weather events, and disruptions in agricultural productivity. These impacts not only threaten ecosystems but also pose serious risks to human health and livelihoods. Therefore, reducing atmospheric CO₂ levels has become a critical priority for achieving environmental sustainability (NASA, 2022; IPCC, 2021).

Carbon sequestration is considered one of the most effective strategies to mitigate climate change. It involves capturing and storing atmospheric CO₂ in natural or artificial reservoirs. Natural sequestration occurs through processes such as photosynthesis, where plants absorb CO₂ and store it in their biomass. Soil also acts as a major carbon sink by storing organic carbon derived from plant residues and microbial activity. These natural systems play a crucial role in regulating the global carbon cycle and reducing greenhouse gas concentrations (Lal, 2004; FAO, 2017).

Among various nature-based solutions, community plantation has gained importance as a sustainable approach to enhance carbon sequestration. It involves active participation of local communities in planting and managing trees in common areas such as village lands, roadsides, and degraded lands. Community plantations not only increase green cover but also improve soil fertility, conserve biodiversity, and support ecosystem restoration. Additionally, they provide socio-economic benefits by generating employment opportunities and promoting environmental awareness among local populations (Chazdon, 2008).

The effectiveness of carbon sequestration through plantation activities depends on environmental factors such as soil properties, climatic conditions, and plant species diversity. Soil characteristics like texture, moisture, organic carbon, and nutrient availability influence plant growth and carbon storage capacity. Similarly, climatic factors such as temperature, rainfall, humidity, and sunlight affect photosynthesis and biomass production. Understanding the interaction between these factors is essential for evaluating the success of plantation-based carbon mitigation strategies (Post & Kwon, 2000; Pan et al., 2011).

II. MATERIAL AND METHODOLOGY

Study Area: The present study was carried out in community plantation sites located in Wani (Belkheda) village, Chandur Bazar Taluka, Amravati District, Maharashtra, India. The study area lies between latitude 21.2339 °N and longitude

77.74°E. The region falls under tropical semi-arid climatic conditions characterized by hot summers and moderate monsoon rainfall. The present study was conducted in Wani Village, which is located near Amravati. The plantation area was established under community participation programs during the year 2014. The total plantation area covers approximately 4.15km (4153 hectares). The village is situated in the eastern part of Amravati district and is surrounded by agricultural land and scattered vegetation. The geographical location of the study area lies approximately between 20.93° N latitude and 77.75° E longitude.

The climate of the region is tropical with hot summers, moderate monsoon rainfall, and mild winters.

Agriculture and small-scale farming are the major occupations of the local population. The total population of the village is approximately 500 people, and community members actively participate in plantation activities and environmental conservation

programs. The average annual rainfall of the area ranges between 700–1000 mm, mainly received during the southwest monsoon (June–September). The temperature varies from a minimum of 12–15°C in winter to a maximum of 40–45°C in summer. The relative humidity ranges from 30% to 85% depending on the season.

III. STUDY OF CLIMATIC PARAMETERS

The climatic assessment was carried out to evaluate seasonal variations and their influence on carbon sequestration potential of community plantation. The climatic parameters showed clear seasonal variation. Maximum rainfall and relative humidity were observed during monsoon season, promoting higher biomass growth and carbon sequestration. Summer season exhibited high temperature and low moisture conditions, while winter showed moderate climatic.

Secondary climatic data were obtained from the nearest Meteorological Department/IMD station, while on-site temperature and humidity were measured using a digital thermometer. Rainfall data

were collected from local rain gauge records. The climatic data were analyzed season-wise to assess variations in temperature fluctuation, rainfall patterns, and humidity changes. Correlation analysis was conducted to examine the relationships between seasonal rainfall and biomass growth, temperature and soil organic carbon, and humidity and vegetation density. This analysis helped in understanding the influence of climatic variations on carbon sequestration potential. The results indicated that maximum biomass growth occurred during the monsoon season due to higher rainfall, while soil organic carbon showed a gradual increase after the monsoon period. In contrast, the summer season exhibited reduced moisture levels and lower microbial activity, highlighting the seasonal impact on carbon storage dynamics.

IV. SOIL SAMPLING PROCEDURE

Soil samples were collected from the Wani–Belkheda community plantation area to study soil properties and their role in carbon storage and plant growth. Different sampling locations were selected across the site to capture variations in soil conditions. Samples were taken from a depth of 0–30 cm, which represents the active root zone where most biological activity occurs.

Before sampling, surface litter like leaves and debris was removed. Soil was then collected using an auger and spade from multiple points and mixed to form a composite sample, ensuring a representative result. After collection, stones and roots were removed, and the samples were taken to the laboratory. There, they were air-dried in shade, gently crushed, sieved through a 2 mm mesh, and stored in labelled bags for further analysis.

V. SOIL TESTING PROCEDURE

The collected soil samples were analysed to determine key physical and chemical properties related to soil fertility and carbon sequestration. Soil pH was measured using a pH meter to identify whether the soil was acidic, neutral, or alkaline. Electrical conductivity (EC) was tested to assess soil salinity.

Soil organic carbon was estimated using the Walkley– Black method, which indicates the soil’s carbon storage capacity. Available nitrogen was measured using the alkaline potassium permanganate method, while phosphorus and potassium were analysed using standard laboratory methods like the Olsen method and flame photometry.

Physico-Chemical Parameters Analysed

Sr.no	Parameters	Method use	Instrument	Unit
1	Soil pH	Digital pH Meter Method	Soil: Water suspension (1:2.5 ratio)	-
2	Electrical Conductivity (EC)	Conductivity Meter Method	Soil: Water extract (1:2.5 ratio)	ds/m
3	Soil Organic Carbon (SOC)	Walkley and Black (1934) Wet Oxidation Method	Titration method	%
4	Bulk density	Core Method	Oven drying at 105°C	g/cm ³
5	Available nitrogen	Alkaline KMnO ₄	Method Distillation method	Kg/hc
6	Available phosphorus	Olsen’s Method	Spectrophotometer	Kg/hc
7	Available potassium	Neutral Ammonium Acetate Extraction	Flame photometer	Kg/hc

pH	—	< 6.5	6.5 – 7.5	> 7.5
Organic Carbon	%	< 0.5	0.5 – 0.75	
Nitrogen (N)	kg/ha	< 280	280 – 560	
Phosphorus (P)	kg/ha	< 10	10 – 25	
Potassium (K)	kg/ha	< 120	120 – 280	
Electrical Conductivity (EC)	dS/m	< 1.0	1.0 – 2.0	> 2.0

Soil Texture	—	Sandy	Loamy	
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Ministry of Agriculture, Government of India (MOAGOI, 2011). Methods Manual, Soil Testing in India. Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi.

Calculation of Carbon Sequestration the following steps are followed:

- Determine the Total (Green) Weight of the Tree
- Determine the Dry Weight of the Tree
- Determine the Weight of Carbon in the Tree
- Determine the Weight of Carbon Dioxide Sequestered in the Tree
- Determine the Weight of Carbon Dioxide Sequestered in the Tree per Year

1. Determine the Total Green Weight of the Tree
 Based on tree species in the Southeast United States, the algorithm to calculate the weight of tree is: $W =$ above ground weight of tree in pound
 $D =$ Diameter of the trunk in inches
 $H =$ Height of the tree in feet
 For trees with $D < 11$: $W = 0.25 D^2 H$
 For trees with $D \geq 11$: $W = 0.15 D^2 H$

Depending upon the species, the coefficient could change, and the variable D^2 and H could be raised to exponents just above or below 1. However, these two equations could be seen as an average equation for all tree species.
 The root system weighs about 20% as much as the above ground weight of the tree. Therefore, to determine the Total Green Weight of the Tree, multiply the above ground weight of the tree by 120%. Total Green Weight
 $=$ Above-ground Weight \times 120%

2. Determine the Dry Weight of the Tree
 This is based on an extension publication from the University of Nebraska. This publication has a table with average weight for one cord of wood for different temperate tree species. Taking all species in

the table into account, the average tree is 72.5% dry matter and 27.5% moisture.
 Therefore, to determine the Dry Weight of the Tree, multiply the weight of the tree by 72.5%.
 Dry Weight = Total Green Weight \times 72.5%

3. Determine the Weight of Carbon in the Tree
 The average carbon content is generally 50% of the tree's total volume. Therefore, to determine the Weight of Carbon in the Tree, multiply the dry weight of the tree by 50%.
 Carbon Content = Dry Weight \times 50%

4. Determine the Weight of Carbon Dioxide Sequestered in the Tree

Carbon dioxide is composed of one molecule of carbon and two molecules of oxygen.
 The atomic weight of Carbon = 12.001115
 The atomic weight of Oxygen = 15.9994
 The weight of Carbon Dioxide is:
 $C + 2O = 43.999915$

The ratio of Carbon Dioxide to Carbon is:
 $43.999915 / 12.001115 = 3.6663$

Therefore, to determine the weight of Carbon Dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.6663.

5. Determination of Annual Carbon Dioxide Sequestration

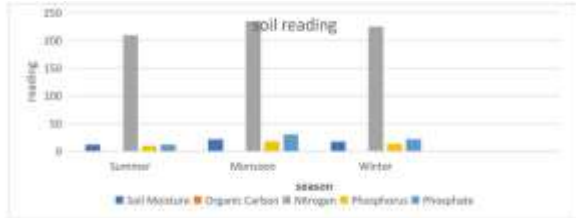
The annual carbon dioxide sequestration was estimated CO_2 Sequestered per Year = Total CO_2 Sequestered \div Age by dividing the total CO_2 stored in the tree by the age of of Tree the tree.

VI. RESULT

SOIL READINGS SEASON -WISE

Season	Soil pH	Soil Moisture (%)	Organic Carbon (%)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Phosphate (Kg/ha)

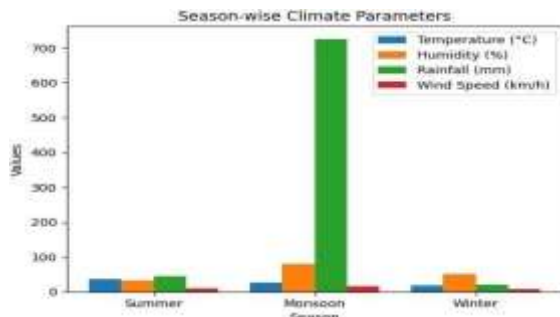
Summer	7.5	12	0.70	210	10	12
Monsoon	7.1	22	0.90	235	18	30
Winter	7.3	18	0.82	225	14	22



Seasonal Classification (After Plantation climatic data)

The study period was divided into three major seasons:

Season	Month	Temperature	Relative humidity %	Rainfall (mm)	Wind speed(km/he)
Summer	Mar-Jun	30-45	30-35	30-60	8-10
Monsoon	July-Oct	22-32 C	70-90	600-850	10-20



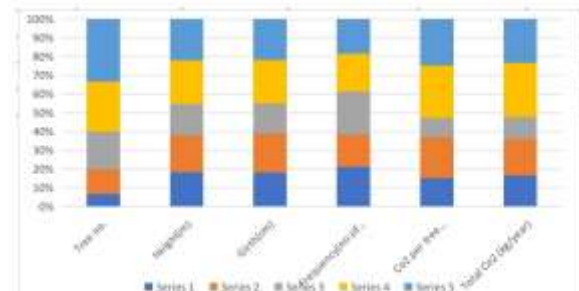
Estimation of Aboveground Biomass and Carbon

Annual Carbon Sequestration by Different Plant Species The carbon sequestration potential of different plant species present in the community plantation was estimated based on biomass calculation. It is generally assumed that 50% of the total biomass represents carbon content carbon Sequestration Result The community plantation

established in 2014 at Wani (Belkheda) has shown a significant potential for carbon sequestration. The trees present in the plantation area, such as Neem, Bamboo, Banyan (Vad), Ashok, Bor, Bel and Apta, contribute to the accumulation of biomass and storage of atmospheric carbon.

Based on the estimation of aboveground biomass, the plantation area has accumulated a considerable amount of carbon over the years. The biomass of trees acts as a major carbon sink by absorbing carbon dioxide (CO₂) from the atmosphere during photosynthesis and storing it in plant tissues such as stems, branches, leaves and roots.

The plantation has therefore contributed to long-term environmental sustainability, and such communitybased plantations can be useful in the future for carbon credit programs and climate change mitigation strategies... The annual carbon sequestration was calculated by dividing total carbon storage by the age of plantation



Calculation Based on Tree Height and Girth

Tree no.	Height(m)	Girth(cm)	ncy(no. of tree)	Co2 per tree (kg/year)	Total Co2 (kg/year)
1	15.78	11.811	37	39.805	1472.785
2	17.60	13.5	30	56.15	1684.5
3	14.10	10.2	40	26.52	1060.8
4	6.1	15.0	35	72.11	2523.85
5	5.8	14.1	32	64.32	2058.24

Component Bar Graph Based on Tree Height and Girth

Total CO₂ Sequestration = 8800.175 kg/year

The carbon sequestration potential of plantation trees was estimated based on tree height, girth, and frequency. The results show that a total of 8800.175 kg of CO₂ per year is sequestered by the plantation trees in the study area, highlighting the importance of plantation activities in reducing atmospheric carbon dioxide and improving environmental sustainability
Conclusion:

The study demonstrates that community-based plantation significantly enhances carbon sequestration through increased biomass accumulation and improved soil organic carbon content (Lal, 2004; Nair et al., 2010). The plantation area showed better soil quality compared to surrounding areas, indicating that afforestation improves soil structure and organic matter, which is critical for long-term ecosystem productivity (FAO, 2016).

Biodiversity assessment revealed moderate to high species diversity, suggesting that community plantations contribute to ecological stability and habitat improvement (Chazdon, 2008). Additionally, slight microclimatic regulation observed within the plantation area, such as temperature moderation and moisture retention, indicates the role of plantations in local climate mitigation (IPCC, 2019).

These findings confirm that participatory afforestation programs are effective for climate change mitigation, soil restoration, and biodiversity conservation. Community participation plays a key role in ensuring long-term plantation success and ecological sustainability, highlighting the importance of local involvement in sustainable land management (Nair et al., 2010). From an industrial perspective, such carbon sequestration potential can be linked to carbon credit mechanisms and corporate environmental responsibility initiatives. Industries can utilize plantation activities as part of their carbon offset strategies under frameworks promoted by the Ministry of Environment, Forest and Climate Change and

guidelines from the Forest Survey of India. This supports compliance with environmental regulations and contributes to sustainable industrial development. Forest Survey of India (FSI), India State of Forest

Report;
(MoEFCC) guidelines on carbon sequestration and afforestation programs.

Species-specific carbon sequestration can also be estimated using field measurements such as tree height and girth (DBH). In this study, carbon stock was calculated based on measured tree dimensions using standard allometric equations. Additionally, carbon sequestration can be assessed for individual species, as different species have varying biomass accumulation rates. This helps in identifying high carbon-sequestering species and improves the accuracy of carbon estimation (Brown, 1997; IPCC, 2006; Nair et al., 2010).

Overall, the research supports that community plantations are a viable and sustainable approach for enhancing carbon storage, improving soil health, and promoting biodiversity conservation at the regional level. Long-term monitoring and expansion of native species plantations are recommended to maximize ecological benefits and strengthen carbon sequestration capacity (Chazdon, 2008; FAO, 2016)

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