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Carbon sequestration potential of agroforestry systems in the Central Western Ghats: A study of Mundgod and Haliyal Taluks

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ABSTRACT

Agroforestry systems in the Central Western Ghats play a critical role in sustainable land management and climate change mitigation by integrating trees, crops, and livestock. This study evaluates the carbon sequestration potential of agroforestry systems in Mundgod and Haliyal taluks of Uttara Kannada district, Karnataka, focusing on above-ground and below-ground carbon pools. A total of 70 sampling plots were assessed to measure growth parameters such as tree height, diameter at breast height (DBH), and biomass, using standard allometric equations. Results revealed that species like *Casuarina equisetifolia*, *Tectona grandis*, and *Santalum album* exhibited the highest carbon sequestration capacities due to their fast growth and high wood density. *Casuarina equisetifolia* recorded the highest potential in Mundgod (577.95 tCO_2/ha), while *Tectona grandis* led in Haliyal (528.04 tCO_2/ha). Lower sequestration was observed in slower-growing species like *Azadirachta indica*. The study highlights significant variability in species performance and underscores the importance of selecting high-biomass, fast-growing species for maximizing carbon storage. These findings reinforce the role of agroforestry as a climate-resilient, sustainable land-use strategy that contributes to biodiversity conservation, rural livelihoods, and national climate goals, in alignment with India's (National Agroforestry Policy, 2014).

KEYWORDS

Carbon Sequestration Potential, Agroforestry Systems, Climate Change Mitigation

HOW TO CITE THIS ARTICLE

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Agroforestry systems are increasingly recognized for their vital role in sustainable land management and climate change mitigation, with a particular focus on their potential for carbon sequestration. These systems integrate trees, crops, and livestock within a single land unit, enhancing ecological interactions and promoting the capture and storage of atmospheric carbon dioxide (CO_2) in both biomass and soil organic matter (Nair, 1993). Studies have demonstrated that agroforestry systems can sequester significant amounts of carbon, with global estimates ranging from 0.29 to 15.21 Mg C ha^{-1} yr^{-1}, depending on factors such as climate, system design, and management practices (Nair *et al.,* 2010). This positions agroforestry as a key strategy for mitigating greenhouse gas emissions while providing additional ecological and economic benefits. The Central Western Ghats recognized as a global biodiversity hotspot, present unique opportunities to explore the carbon sequestration potential of agroforestry systems. In Mundgod and Haliyal taluks of Uttara Kannada district, diverse agroforestry practices are employed, yet their contribution to carbon storage has not been adequately quantified. Given the region's rapid land-use changes and growing environmental pressures, assessing the carbon sequestration capacity of these systems is critical. Such an understanding can help optimize agroforestry designs for maximum carbon capture, align with national initiatives like India's (National Agroforestry Policy, 2014), and contribute to global climate goals. This study aims to evaluate the carbon sequestration potential of agroforestry systems in Mundgod and Haliyal taluks, focusing on both above-ground and below-ground carbon pools. By identifying system-specific contributions to carbon storage and sustainability, the research seeks to highlight agroforestry's transformative role in combating climate change while supporting local livelihoods and conserving the unique ecological heritage of the Central Western Ghats.

Materials and Methods

Study Area

This study was conducted in the taluks of Mundgod and Haliyal, located in Uttara Kannada district of Karnataka, India, within the Central Western Ghats. Mundgod taluk, situated at approximately 14.97°N latitude and 75.03°E longitude, has a predominantly tropical climate and an agricultural landscape. Haliyal taluk, positioned at 15.33°N latitude and 74.75°E longitude, features diverse agroforestry systems interspersed with forest patches and agricultural land. The ecological diversity and widespread agroforestry practices in these taluks make them suitable for studying carbon sequestration potential.

Data Collection

The study involved the establishment of 70 sampling plots across the two taluks, each measuring 20 m × 20 m. Of these, 40 plots were selected in Mundgod and 30 in Haliyal. Growth parameters of trees within these plots were recorded to assess the productivity and carbon sequestration potential of agroforestry systems. Tree Height (m): Measured using a Ravi Altimeter (Bower and Zar, 1998; Singh *et al*., 2019). Diameter at Breast Height (DBH, m): Recorded using calipers and a measuring tape.

$$\text{Volume } (m^3) = \text{B.A.}(m^2) * \text{H}(m)$$

Where, B.A = Basal area and H=height

Basal area = $\pi d^2/4$, Where d = diameter at breast height.

Biomass Estimation

Biomass was estimated to evaluate carbon stock potential

Above-Ground Biomass (AGB)

Represents the total living and dead plant organic matter above the ground. AGB was derived from the standing volume of trees using standard allometric equations.

$$\text{AGB} = \text{Volume } (m^3) \times \text{Wood Density } (g/cm^3) \times 1000$$

(Converting wood density to tonnes/m³ by multiplying by 1000)

Below-Ground Biomass (BGB)

Estimated by applying a root-to-shoot ratio of 0.26 to the AGB, as per (Cairns *et al.,* 1997; Ravindranath and Ostwald, 2008).

$$\text{BGB} = \text{AGB} \times 0.26$$

Carbon Stock Calculation

Carbon stock in both AGB and BGB was estimated by assuming a carbon content factor of 50% of the biomass (Singh and Singh, 1991). Where, CBS is the amount of C or C stock, expressed as tonnes per hectare (t /ha), and 3.67 is the ratio of CO_2 to C, which is used to measure the amount of C sequestered (Nguyen, 2012).

$$\text{Carbon Stock (t/ha)} = \text{Total Biomass (AGB+BGB)} \times 0.5$$

Data Analysis

The collected data on growth attributes (tree height, DBH, and volume) and biomass were statistically analyzed to assess variability in productivity and carbon sequestration potential across different agroforestry systems. Averages of the recorded data were calculated to facilitate comparative analysis among systems.

$$CO_2 \text{ sequestration} = 3.67 \times \text{Carbon}$$

The findings highlight the ecological contributions of agroforestry systems in the study region, offering valuable insights into their role in climate mitigation, sustainable land management, and enhanced ecosystem services.

Results and Discussion

In Mundgod Taluk, the highest biomass and carbon sequestration potential were observed in *Casuarina equisetifolia*, with a total biomass of 314.96 t/ha and carbon stock of 157.48 t/ha, resulting in a carbon sequestration potential of 577.95 tCO_2/ha (table 1). This performance is attributed to its high wood density (0.919 g/cm^3) and fast growth. *Santalum album* and *Pterocarpus santalinus* also showed significant carbon sequestration potentials of 333.63 tCO_2/ha and 317.81 tCO_2/ha, respectively, supported by their dense wood and favorable growth attributes. Species like *Melia dubia* (carbon sequestration: 196.07 tCO_2/ha) and *Tectona grandis* (294.80 tCO_2/ha) further demonstrated strong performance, aligning with findings from (Sharma *et al*., 2021), who reported biomass values of 73.71 t/ha and carbon storage of 31.62 t/ha in *Tectona grandis* plantations in Chhattisgarh. Likewise, (Subramanian *et al*., 2021) reported *Casuarina equisetifolia* biomass at 38.1 Mg/ha in Tamil Nadu, indicating its strong sequestration potential.

In contrast, lower carbon sequestration values were recorded in species such as *Anacardium occidentale* (89.22 tCO_2/ha) and *Mangifera indica* (137.85 tCO_2/ha), possibly due to lower biomass accumulation. These trends emphasize the role of species selection and growth traits in enhancing carbon storage. They are consistent with broader studies that highlight agroforestry systems as effective carbon sinks in tropical landscapes. In Haliyal Taluk, *Tectona grandis* emerged as the most effective species for biomass accumulation and carbon sequestration, with a total biomass of 287.76 t/ha and carbon stock of 143.88 t/ha, translating to a carbon sequestration potential of 528.04 tCO_2/ha (table 2).

This aligns with studies such as (Sharma *et al.,* 2021), which highlighted *Tectona grandis* plantations in Chhattisgarh storing 31.62 tC/ha. *Santalum album* (329.11 tCO_2/ha) and *Swietenia mahagoni* (246.65 tCO_2/ha) also demonstrated strong sequestration potentials, attributed to their dense wood and efficient growth characteristics. Fast growing species like *Casuarina equisetifolia* (296.39 tCO_2/ha) and *Leucaena leucocephala* (293.55 tCO_2/ha) showed high biomass productivity, consistent with findings from (Subramanian *et al.*, 2021 and Vijayalakshmi *et al.*, 2020), who reported their success in improving carbon stocks and soil quality in tropical agroforestry systems. *Ailanthus excelsa* and *Calliandra calothyrsus* followed closely, contributing 285.39 and 234.51 tCO_2/ha, respectively, further affirming the role of nitrogen-fixing and multipurpose species in climate-smart agroforestry. In contrast, *Azadirachta indica* recorded the lowest carbon stock (27.72 t/ha) and sequestration potential (101.72 tCO_2/ha), likely due to its smaller size and slower growth. These results underline the importance of selecting high biomass-accumulating species to enhance the carbon sink capacity of agroforestry systems in the Central Western Ghats.

Conclusion

The study in the agroforestry systems of Mundgod and Haliyal taluks in the Central Western Ghats highlights significant variability in tree species' carbon sequestration potential, with species like *Casuarina equisetifolia*, *Tectona grandis*, and *Santalum album* showing high biomass and carbon storage capacities. Fast-growing, high wood-density species proved most effective, with *Casuarina equisetifolia* recording 577.95 tCO_2/ha in Mundgod and *Tectona grandis* 528.04 tCO_2/ha in Haliyal. These findings underscore the importance of selecting suitable species based on site conditions to optimize carbon sequestration while maintaining ecological balance. Agroforestry in these regions thus serves as a climate-resilient land-use strategy that supports biodiversity, farmer livelihoods, and national climate goals, aligning with India's (National Agroforestry Policy, 2014).

Table 1. Growth Attributes, Biomass, and Carbon Sequestration Potential of Tree Species in Agroforestry Systems of Mundgod Taluk

Tree Species	No. of Trees/ha	Avg. DBH (m)	Avg. Height (m)	Avg. Volume (m^3)	Wood Density (g/cm^3)	AGB (t/ha)	BGB (t/ha)	Total Biomass (t/ha)	Carbon Stock(t/ha)	Carbon Sequestration Potential
Anacardium occidentale	75.00	0.19	3.13	0.085	0.454	38.59	10.03	48.62	24.31	89.22
Artocarpus heterophyllus	100.00	0.22	3.65	0.152	0.536	81.47	21.18	102.65	51.33	188.37
Casuarina equisetifolia	287.50	0.25	4.74	0.272	0.919	249.97	64.99	314.96	157.48	577.95
Grevillea robusta	250.00	0.30	4.13	0.264	0.536	141.50	36.79	178.30	89.15	327.17
Melia dubia	50.00	0.25	4.09	0.212	0.400	84.80	22.05	106.85	53.42	196.07
Pterocarpus santalinus	75.00	0.27	3.10	0.185	0.743	137.46	35.74	173.19	86.60	317.81
Satalum album	255.00	0.23	3.38	0.154	0.937	144.30	37.52	181.82	90.91	333.63
Swietenia macrophylla	316.76	0.25	4.27	0.245	0.533	130.59	33.95	164.54	82.27	301.93
Tectona grandis	195.24	0.25	4.25	0.208	0.613	127.50	33.15	160.66	80.33	294.80
Mangifera indica	100.00	0.22	2.75	0.114	0.523	59.62	15.50	75.12	37.56	137.85
Hevea brasiliensis	277.00	0.28	3.22	0.208	0.533	111.04	28.87	139.91	69.96	256.74
SEm ±	-	0.006	0.041	0.002	-	1.068	0.278	1.345	0.673	2.468
C.D (0.05)	-	0.019	0.121	0.005	-	3.149	0.819	3.968	1.984	7.281

Table 2. Growth Attributes, Biomass, and Carbon Sequestration Potential of Tree Species in Agroforestry Systems of Haliyal Taluk

Tree Species	No. of Trees/ha	Avg. DBH (m)	Avg. Height (m)	Avg. Volume (m^3)	Wood Density (g/cm^3)	AGB (t/ha)	BGB (t/ha)	Total Biomass (t/ha)	Carbon Stock(t/ha)	Carbon Sequestration Potential
Santalum album	154.17	0.24	3.33	0.152	0.937	142.340	37.008	179.349	89.67	329.11
Tectona grandis	195.31	0.30	5.25	0.373	0.613	228.381	59.379	287.760	143.88	528.04
Swietenia mahagoni	75.00	0.25	4.00	0.200	0.533	106.677	27.736	134.414	67.21	246.65
Melia dubia	200.00	0.26	4.00	0.208	0.4	83.268	21.650	104.917	52.46	192.52
Azadirachta indica	200.00	0.18	2.25	0.059	0.74	43.993	11.438	55.431	27.72	101.72
Casuarina equisetifolia	300.00	0.22	3.56	0.139	0.919	128.190	33.330	161.520	80.76	296.39
Leucaena leucocephala	500.00	0.25	4.02	0.198	0.64	126.964	33.011	159.975	79.99	293.55
Ailanthus excelsa	507.76	0.21	4.10	0.146	0.846	123.433	32.092	155.525	77.76	285.39
Calliandra calothyrsus	500	0.23	3.01	0.127	0.8	101.426	26.371	127.796	63.90	234.51
SEm ±	-	0.005	0.081	0.008	-	6.466	1.681	8.147	4.073	14.949
C.D (0.05)	-	0.015	0.244	0.024	-	19.384	5.039	24.424	12.216	44.817

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