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Assessing Carbon Stocks and Ecosystem Functioning in Char (*Buchanania lanzan*) Forests of Central India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study assessment of plant community structure, carbon stock and CO_2 sequestration of char (*Buchanania lanzan*) dominant forest sites in Central India during 2020-22. The forest vegetation was analysed using 20 quadrats (each 10 x 10 m in size for tree layers, 5 x 5 m in size for sapling layers and 1 x 1 m size for seedling layers) within the representative one-hectare plot on each site. The biomass, carbon stock, and carbon dioxide sequestration from three district (Mahasamund, Gariaband, and Kabirdham) char dominated forest sites of dry deciduous forests in

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Central India were estimated using the non-destructive allometric equation approach. The results revealed that the density of tree, sapling and seedling were ranged from 430-605 stems ha^{-1}, 120-600 stems ha^{-1} and 28000-34500 stems ha^{-1}, respectively. The basal area of tree and sapling layers were varied from 18.15-29.68 m^2 ha^{-1} and 0.33-1.04 m^2 ha^{-1}, respectively. The diversity indices of tree layer viz; Shannon index, Simpson index, Evenness, species richness and beta diversity were ranged from 2.40-2.72, 0.17-0.22, 1.08-1.18, 2.26-3.11 and 5.0-6.0, respectively on different forest site in Central India. The total biomass, carbon stock and CO_2 sequestration potential of tree layers were varied from 105.72-216.96 Mg ha^{-1}, 50.22-103.06 Mg ha^{-1} and 184.29-378.22 Mg ha^{-1}, respectively on char dominant various forest sites in Central India. The correlation coefficients were statistically significant performed between basal area and biomass, carbon stock and CO_2 sequestration potential with R^2 values of 0.988 at $p<0.01$ levels. After doing this study, it can be concluded that estimating the biomass and carbon stock in Central India will be useful for managing forests sustainably.

Keywords: Structure; biomass; carbon stock; sequestration; allometric equation etc.

1. INTRODUCTION

“Protecting present carbon pools and expanding present carbon sinks are crucial for achieving sustainable forest management as well as mitigating and balancing the effects of climate change. To sustain carbon (C) storage in developing countries' tropical forests, the United Nations Framework Convention on Climate Change (UNFCCC) launched the Reducing Emissions from Deforestation and Forest Degradation (REDD+) project as an economic incentive” [1,2]. “The monitoring, reporting, and verification (MRV) techniques are necessary for the accurate quantification of carbon storage potential in order to faithfully implement the recommendations made by the IPCC (intergovernmental panel on climate change)” [1,2,3].

“Due to its 50% world carbon stock and 1/3 global primary productivity, tropical forests are widely acknowledged to play a crucial role in mitigating the effects of climate change by functioning as carbon sinks” [4,5,6]. “Estimating the carbon stock and biomass (both above and below ground) is a critical biophysical constraint for the sustainable management of these tropical forests, as it gives information about the growth, health, and productivity of the forest ecosystem” [7,8]. “Unfortunately, due to different techniques and site-specific (phytogeographic/ physiographic) allometric equations, the data about carbon stock and biomass for many tropical forests is ambiguous” [9,10].

“It has been noted that there are research gaps and that the regional estimations are also irregular” [11,12]. “Numerous investigations discovered regional uncertainties in the carbon sinks and stocks in tropical forest ecosystems. These uncertainties might be attributed to various factors such as forest type, anthropogenic disturbance intensity, topography variation, and microclimate” [13,14]. “For research pertaining to carbon stocks and sinks, field-based biomass estimates are vital since they offer substantial inputs for regional and global carbon and climate models that are deficient in data” [15,16]. “In addition, better allometric models based on field data and remote sensing methods are required to estimate the large-scale biomass and carbon stock of tropical forests” [10,17,18]. “Therefore, a crucial component of carrying out forest management, conservation, and climate change mitigation measures effectively is the application of rigorous methods for estimating biomass and carbon stocks” [19,20]. “The global carbon balance and local and national forest assessments can both benefit from the adoption of the most appropriate allometric equation” [21].

Because of the extensive forest tree fall in India, the destructive sampling method for estimating the country's carbon store and forest biomass is not always acceptable [22]. Because of this, the assessment of biomass and C stock is mostly dependent on allometric models, data from forest inventories' growing stock volume (GSV), and an appropriate conversion factor linked to biomass and C [23,24,25,26,27,28].

An important metric for determining the composition and health of ecosystems is aboveground biomass (AGB). Thus, estimating biomass is the primary foundation for estimating forest carbon stocks [1,3,29,30]. Nonetheless, a number of prior research revealed notable differences in AGB estimation in the ecosystems of Central India's tropical dry deciduous forests [18,28,31,32,33]. These differences result from the absence of reliable local and regional allometric models and techniques [3,10,19,28]. Thus, for accurate national ground-based MRV of carbon storage, using robust methodologies for carbon stock estimates is essential [34,35] and using REDD+ and other climate change mitigating techniques [2]. With this work, we hope to provide baseline data for future forest management and climate change mitigation initiatives by estimating the plant community structure, biomass, carbon stock, and CO_2 sequestration of the natural forests in the Central Indian region.

2. MATERIALS AND METHODS

2.1 Study Area

The present study was conducted in different localities, where the Chironji found to grown naturally viz. B.K. Bahra, Komakhan village from Mahsamund district, Joba village from Gariaband district and Neyur village from Kabirdham district falling in three districts of Central India during 2020-2022. The central region of Chhattisgarh, where the pick was made, has a typical tropical environment with warm and humid monsoons, reasonably hot summers, and moderately cold winters. The south west monsoon, which is focused in the months of June, July, and August, is responsible for the majority of the precipitation.

2.2 Methods of Data Collection, Data Computation and Analysis

The forest vegetation was analysed using 20 quadrats (each 10 x 10 m in size for tree layers, 5 x 5 m in size for sapling layers and 1 x 1 m size for seedling layers) within the representative one-hectare plot on each site. Girth at breast height (GBH) of trees was measured at 1.37 m on trunk of trees and saplings. Quantitative analysis was done on the vegetation data to determine the frequency, density, and abundance [36]. The sum of relative frequency, relative density, and relative dominance was used to determine an important value [37].

The following formula was used to compute the basal area of the tree and sapling, which is a major factor in the AGB/C calculation.

$$BA = (\pi D^2)/4$$

where, BA = Basal area (m^2), D = DBH (cm) and π = pi (3.142). By adding the BA of each tree in the plot, the total BA for each plot was calculated.

Species diversity indices for tree layers were determined, using basal cover values from Shannon-Wiener information function [38]. Concentration of dominance was measured by Simpson's index [39], species richness following Margalef [40], equitability following Pielou [41], and beta diversity following Whittaker [42].

Researchers have utilized Brown et al. [43] equation for estimating AGB to estimate biomass in tropical dry forests. This equation has been used by other researchers to determine how much carbon some developing countries can store [44,45,46,47].

$$AGB = 34.4703 – 8.0671(D) + 0.6589(D^2)$$

where, AGB = aboveground biomass per tree (kg), D = DBH (cm). Based on the root-to-shoot ratio relationship, Woldegerima et al. [46] state that BGB can be calculated by multiplying AGB by a factor of 0.26 [48], as used in the present research

$$BGB = AGB \times 0.26$$

The amount of carbon stock was determined through biomass assessment, using Tang et al. [49] formula: Total carbon stock = AGB + BGB. Since the amount of carbon in wood varies from 45 to 50% depending on the ecosystems, it was believed that the entire biomass of plants contains 47.5% carbon [50].

$$\text{Carbon (C)} = AGB + BGB \times 0.475$$

To calculate how much carbon the forest has sequestered, this carbon was transformed into carbon dioxide (CO_2) [45]. This correlation is given as: 1 t C=3.67 t CO_2 [45,51,52,53]. To calculate the amount of CO_2 sequestered by a forest, multiply the carbon stock value by 3.67, or the difference in atomic weight between carbon and CO_2 [54,55,56].

2.3 Statistical Analysis

Correlation coefficient between density, basal area, biomass, carbon stock and CO_2 sequestration of char dominant sites in Central India was analysed using IBM SPSS Statistics 20 software.

3. RESULTS

3.1 The Overall Composition of Tree, Sapling and Seedling Layer

Data on composition of tree, sapling and seedling layers of the char forest site in Central India is given in Tables 1-3. 15 species represented by 10 families were recorded in tree layers, 7 species represented by 7 families in sapling layers and 12 species represented by 10 families in seedling layers of the char forest sites in Central India. *Buchanania lanzan*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Madhuca longifolia* and *Shorea robusta* was found to be the dominant trees in the tree layer. The most abundant families of tree layer were Combretaceae with 4 species, and Anacardiaceae and Fabaceae both are represent two species.

3.2 Structure of Tree, Sapling and Seedling Layer on Mahasamund Forest Site

Tree layers: Results revealed that ten species representing six families in tree layer were recorded on Mahasamund forest site. The density and basal area of trees was 605 stems ha^{-1} and 18.15 m^2 ha^{-1}, respectively on this site. The frequency of species in the tree layer varied from 5% to 70%. The density of tree species varied from 5 to 160 stems ha^{-1}. The highest density was measured for *Buchanania lanzan* (160 stems ha^{-1}) followed by *Lagerstroemia parviflora* (140 stems ha^{-1}), *Anogeissus latifolia* (135 stems ha^{-1}) and *Terminalia tomentosa* (80 stems ha^{-1}), while the lowest density (5 stems ha^{-1}) was measured for *Diospyros melanoxylon*, *Pterocarpus marsupium*, *Terminalia bellirica* and *Terminalia chebula*. The basal area of species on this site ranged from 0.12 to 4.48 m^2 ha^{-1}. The highest basal area was measured for *Buchanania lanzan* (4.48 m^2 ha^{-1}) followed by *Anogeissus latifolia* (3.22 m^2 ha^{-1}), *Terminalia tomentosa* (3.0 m^2 ha^{-1}), *Lagerstroemia parviflora* (2.93 m^2 ha^{-1}) and *Madhuca longifolia* (2.65 m^2 ha^{-1}), while the lowest basal area was recorded for *Diospyros melanoxylon* (0.12 m^2 ha^{-1}). The IVI of tree species on this site for different species ranged from 3.31 to 76.60. Based on IVI *Buchanania lanzan* (76.60) indicated its dominance on this site, *Anogeissus latifolia* (63.72) and *Lagerstroemia parviflora* (53.84) were recognized as predominant, whereas *Terminalia tomentosa* and *Madhuca longifolia* as co-dominant and *Terminalia bellirica*, *Terminalia chebula* and *Diospyros melanoxylon* as suppressed plant communities on this site (Table 1).

Sapling layers: Results revealed that seven species representing seven families in sapling layer were recorded on Mahasamund forest site. The density and basal area of trees was 600 stems ha^{-1} and 1.04 m^2 ha^{-1}, respectively on this site. The density of sapling layer varied from 20 to 440 stems ha^{-1}. The highest density was measured for *Wrightia tintoria* (440 stems ha^{-1}), while the lowest density (20 stems ha^{-1}) was measured for *Madhuca longifolia*. The basal area of species on this site ranged from 0.05 to 0.63 m^2 ha^{-1}. The highest basal area was measured for *Wrightia tintoria* (0.63 m^2 ha^{-1}), while the lowest basal area was recorded for *Madhuca longifolia* (0.05 m^2 ha^{-1}). The IVI of sapling layers on this site for different species ranged from 16.09 to 192.06. Based on IVI *Wrightia tintoria* (192.06) indicated its dominance on this site (Table 2).

Seedling layers: Results revealed that seven species representing seven families in seedlings layer were recorded on Mahasamund forest site. The total density of seedling layers was measured 33500 stems ha^{-1} on this site. The density of seedling layer varied from 1000 to 13500 stems ha^{-1}. The highest density was measured for *Diospyros melanoxylon* (13500 stems ha^{-1}) followed by *Wrightia tentoria* (6000 stems ha^{-1}) and *Buchanania lanzan* and *Lagerstroemia parviflora* (4500 stems ha^{-1}), while the lowest density (1000 stems ha^{-1}) was measured for *Butea monosperma*. The IVI of seedling layers on this site for different species ranged from 17.36 to 91.39. Based on IVI *Diospyros melanoxylon* (91.39) indicated its dominance on this site (Table 3).

3.3 Structure of Tree, Sapling and Seedling Layer on Gariaband Forest Site

Tree layers: Results revealed that 11 species representing 9 families in tree layer were recorded on Gariaband forest site. The total density and basal area of trees was 430 stems ha^{-1} and 29.68 m^2 ha^{-1}, respectively on this site. The frequency of species in the tree layer varied from 5% to 70%. The density of tree species varied from 5 to 110 stems ha^{-1}. The highest density was measured for *Shorea robusta* (110 stems ha^{-1}) followed by *Madhuca longifolia* (80 stems ha^{-1}), *Buchanania lanzan* (75 stems ha^{-1}) and *Terminalia tomentosa* (60 stems ha^{-1}), while the lowest density (5 stems ha^{-1}) was measured for *Anogeissus latifolia, Lagerstroemia parviflora, Schleichera oleosa* and *Haldina cordifolia*. The basal area of species on this site ranged from 0.12 to 9.97 m^2 ha^{-1}. The highest basal area was measured for *Shorea robusta* (9.97 m^2 ha^{-1}) followed by *Terminalia tomentosa* (5.18 m^2 ha^{-1}), *Diospyros melanoxylon* (4.59 m^2 ha^{-1}), *Madhuca longifolia* (3.85 m^2 ha^{-1}) and *Pterocarpus marsupium* (3.35 m^2 ha^{-1}), while the lowest basal area was recorded 0.12 m^2 ha^{-1} for *Lagerstroemia parviflora* and *Haldina cordifolia*. The IVI of tree species on this site for different species ranged from 3.23 to 82.51. Based on IVI *Shorea robusta* (82.51) indicated its dominance on this site, *Madhuca longifolia* (48.23) and *Terminalia tomentosa* (44.74) were recognized as predominant, whereas *Diospyros melanoxylon* and *Buchanania lanzan* as co-dominant and *Anogeissus latifolia*, *Lagerstroemia parviflora* and *Haldina cordifolia* as suppressed plant communities on this site (Table 1).

Sapling layers: Results revealed that 2 species representing 2 families in sapling layer were recorded on Gariaband forest site. The total density and basal area of trees was 120 stems ha^{-1} and 0.33 m^2 ha^{-1}, respectively on this site. The density of sapling layer was recorded 60 stems ha^{-1} on *Casearia graveolens* and *Diospyros melanoxylon*. The basal area of species on this site ranged from 0.12 to 0.21 m^2 ha^{-1}. The IVI of sapling layers on this site for species ranged from 135.78 to 164.22 (Table 2).

Seedling layers: Results revealed that 6 species representing 6 families in seedlings layer were recorded on Gariaband forest site. The total density of seedling layers was measured 34500 stems ha^{-1} on this site. The density of seedling layer varied from 500 to 14000 stems ha^{-1}. The highest density was measured for *Shorea robusta* (14000 stems ha^{-1}) followed by *Casearia graveolens* (10000 stems ha^{-1}) and *Diospyros melanoxylon* (6500 stems ha^{-1}), while the lowest density (500 stems ha^{-1}) was measured for *Buchanania lanzan*. The IVI of seedling layers on this site for different species ranged from 13.0 to 100.45. Based on IVI *Shorea robusta* (100.45) indicated its dominance on this site (Table 3).

3.4 Structure of Tree, Sapling and Seedling Layer on Kabirdham Forest Site

Tree layers: Results revealed that 8 species representing 6 families in tree layer were recorded on Kabirdham forest site. The total density and basal area of trees was 525 stems ha^{-1} and 22.16 m^2 ha^{-1}, respectively on this site. The frequency of species in the tree layer varied from 5% to 85%. The density of tree species varied from 5 to 210 stems ha^{-1}. The highest density was measured for *Buchanania lanzan* (210 stems ha^{-1}) followed by *Madhuca longifolia* (150 stems ha^{-1}) and *Shorea robusta* (70 stems ha^{-1}), while the lowest density (5 stems ha^{-1}) was measured for *Semecarpus anacardium*. The basal area of species on this site ranged from 0.23 to 6.38 m^2 ha^{-1}. The highest basal area was measured for *Buchanania lanzan* (6.38 m^2 ha^{-1}) followed by *Madhuca longifolia* (6.27 m^2 ha^{-1}) and *Shorea robusta* (4.72 m^2 ha^{-1}), while the lowest basal area was recorded for *Semecarpus anacardium* (0.23 m^2 ha^{-1}). The IVI of tree species on this site for different species ranged from 3.99 to 102.79. Based on IVI *Buchanania lanzan* (102.79) indicated its dominance on this site, *Madhuca longifolia* (86.84) was recognized as predominant, whereas *Shorea robusta* as co-dominant and *Terminalia chebula* and *Semecarpus anacardium* as suppressed plant communities on this site (Table 1).

Sapling layers: Results revealed that 3 species representing 3 families in sapling layer were recorded on Kabirdham forest site. The density and basal area of trees was 240 stems ha^{-1} and 0.56 m^2 ha^{-1}, respectively on this site. The density of sapling layer varied from 40 to 120 stems ha^{-1}. The highest density was measured for *Shorea robusta* (120 stems ha^{-1}), while the lowest density (40 stems ha^{-1}) was measured for *Terminalia tomentosa*. The basal area of species on this site ranged from 0.05 to 0.31 m^2 ha^{-1}. The highest basal area was measured for *Shorea robusta* (0.31 m^2 ha^{-1}), while the lowest basal area was recorded for *Terminalia tomentosa* (0.05 m^2 ha^{-1}). The IVI of sapling layers on this site for different species ranged from 50.52 to 130.89. Based on IVI *Shorea robusta* (130.89) indicated its dominance on this site (Table 2).

Seedling layers: Results revealed that 8 species representing 6 families in seedlings layer were recorded on Kabirdham forest site. The total density of seedling layers was measured 28000 stems ha^{-1} on this site. The density of seedling layer varied from 500 to 12500 stems ha^{-1}. The highest density was measured for *Diospyros melanoxylon* (12500 stems ha^{-1}) followed by *Shorea robusta* (6500 stems ha^{-1}) and *Anogeissus latifolia* (3000 stems ha^{-1}), while the lowest density (500 stems ha^{-1}) was measured for *Terminalia tomentosa*. The IVI of seedling layers on this site for different species ranged from 12.14 to 100.22. Based on IVI *Diospyros melanoxylon* (100.22) indicated its dominance on this site (Table 3).

3.5 Diversity Indices of Tree and Sapling Layer of Char Dominant Sites in Central India

Tree layers: The Shannon index (H') value on different char dominant sites lies between 2.40 and 2.72. It was found highest on Mahasamund site (2.72) followed by Gariaband site (2.60) and lowest on Kabardham site (2.40). The concentration of dominance (Cd) varied from 0.17 to 0.22. It was found highest on Kabardham site (0.22) followed by Gariaband site (0.20) and lowest on Mahasamund site (0.17). The evenness index (e) ranged from 1.08 to 1.18, it was maximum on Mahasamund site (1.18) followed by Kabirdham site (1.16) and minimum on Gariaband site (1.08). The Margalef's index of species richness (d) varied from 2.26 to 3.11. It was recorded highest on Mahasamund site (3.11) followed by Gariaband site (2.95) and lowest value of species richness was on Kabirdham site (2.26). The beta diversity (Bd) ranged from 5.0 to 6.0, it was maximum on Kabirdham site (6.0) followed by Mahasamund site (5.45) and minimum was found on Gariaband site (5.0) (Table 4).

Sapling layers: The Shannon index (H') value on different char dominant sites lies between 0.94 and 1.50. It was found highest on Mahasamund site (1.50) followed by Kabardham site (1.31) and lowest on Gariaband site (0.94). The concentration of dominance (Cd) varied from 0.43 to 0.54. It was found highest on Gariaband site (0.54) followed by Kabardham site (0.44) and lowest on Mahasamund site (0.43). The evenness index (e) ranged from 1.08 to 1.36, it was maximum on Gariaband site (1.36) followed by Kabirdham site (1.19) and minimum on Mahasamund site (1.08). The beta diversity (Bd) ranged from 11.67 to 23.33, it was maximum on Gariaband site (23.33) followed by Kabardham site (17.50) and minimum was found on Mahasamund site (11.67) (Table 4).

3.6 Biomass, Carbon Content and CO_2 Sequestration of Tree and Sapling Layer

Tree layers: The result revealed that the biomass, carbon stock and CO_2 sequestration of tree layer was given on Table 5. The present study total biomass was ranged from 105.72±65.70 to 216.96±139.23 Mg ha^{-1}, whereas the above ground biomass was varied from 83.90±52.15 to 172.19±110.50 Mg ha^{-1} and belowground biomass was lies from 21.82±13.56 to 44.77±28.73 Mg ha^{-1}. The highest biomass was measured 216.96±139.23 Mg ha^{-1} on Gariaband and site followed by Kabirdham site (142.68±63.65 Mg ha^{-1}), while the lowest biomass was measured on Mahasamund site (105.72±65.70 Mg ha^{-1}). The total carbon stock of different sites was ranged from 50.22±31.21 to 103.06±66.14 Mg ha^{-1}, it the maximum carbon stock was measured on Gariaband site (103.06±66.14 Mg ha^{-1}) followed by Kabirdham site (67.77±30.23 Mg ha^{-1}), it's the minimum carbon stock was recorded on Mahasamund site (50.22±31.21 Mg ha^{-1}). Similarly, the carbon dioxide sequestration potential was ranged from 184.29±114.54 Mg ha^{-1} to 378.22±242.72 Mg ha^{-1}, the highest CO_2 sequestration was measured 378.22±242.72 Mg ha^{-1} on Gariaband site followed by Kabirdham site (248.72±110.96 Mg ha^{-1}), the lowest was measured on Mahasamund site (184.29±114.54 Mg ha^{-1}).

Sapling layers: The result revealed that the biomass, carbon stock and CO_2 sequestration of sapling layer was given on Table 5. The present study total biomass was ranged from 1.60 to 9.69 Mg ha^{-1}, whereas, the above ground biomass was varied from 1.27 to 7.69 Mg ha^{-1} and belowground biomass was lies from 0.33 to 2.0 Mg ha^{-1}. The highest biomass was measured 9.69 Mg ha^{-1} on Mahasamund site followed by Kabirdham site (3.63 Mg ha^{-1}), while the lowest biomass was measured on Gariaband site (1.60 Mg ha^{-1}). The total carbon stock of different sites was ranged from 0.76 to 4.60 Mg ha^{-1}, it the maximum carbon stock was measured on Mahasamund site (4.60 Mg ha^{-1}) followed by Kabirdham site (1.72 Mg ha^{-1}), it's the minimum carbon stock was recorded on Gariaband site (0.76 Mg ha^{-1}). Similarly, the carbon dioxide sequestration potential of sapling layers was ranged from 2.78 Mg ha^{-1} to 16.88 Mg ha^{-1}, the highest CO_2 sequestration was measured 16.88 Mg ha^{-1} on Mahasamund site followed by Kabirdham site (6.32 Mg ha^{-1}), the lowest was measured on Gariaband site (2.78 Mg ha^{-1}).

Table 1. Structure of tree layer of Char dominant forest sites in Central India

SN	Species	Botanical Name	Family	Sites											
				Mahasamund				Gariaband				Kabirdham			
				F (%)	D (stems ha^{-1})	BA (m^2 ha^{-1})	IVI	F (%)	D (stems ha^{-1})	BA (m^2 ha^{-1})	IVI	F (%)	D (stems ha^{-1})	BA (m^2 ha^{-1})	IVI
1	Char	*Buchanania lanzan*	Anacardiaceae	70	160	4.48	76.60	45	75	1.77	38.40	85	210	6.38	102.79
2	Dhawda	*Anogeissus latifolia*	Combretaceae	65	135	3.22	63.72	5	5	0.13	3.28	-	-	-	-
3	Senha	*Lagerstroemia parviflora*	Lythraceae	40	140	2.93	53.84	5	5	0.12	3.25	-	-	-	-
4	Palas	*Butea monosperma*	Fabaceae	10	10	0.10	5.83	-	-	-	-	-	-	-	-
5	Saja	*Terminalia tomentosa*	Combretaceae	50	80	3.00	47.96	40	60	5.18	44.74	20	40	1.73	23.41
6	Mahua	*Madhuca longifolia*	Sapotaceae	20	60	2.65	31.80	50	80	3.85	48.23	75	150	6.27	86.84
7	Tendu	*Diospyros melanoxylon*	Ebenaceae	5	5	0.12	3.31	40	45	4.59	39.27	15	25	0.66	13.75
8	Bijasal	*Pterocarpus marsupium*	Fabaceae	5	5	1.01	8.19	25	25	3.35	25.43	-	-	-	-
9	Baheda	*Terminalia Bellirica*	Combretaceae	5	5	0.38	4.75	-	-	-	-	-	-	-	-
10	Harra	*Terminalia chebula*	Combretaceae	5	5	0.25	4.01	-	-	-	-	10	10	0.32	7.36
11	Sal	*Shorea robusta*	Dipterocarpaceae	-	-	-	-	70	110	9.97	82.51	35	70	4.72	48.64
12	Bhelwa	*Semecarpus anacardium*	Anacardiaceae	-	-	-	-	10	15	0.20	7.51	5	5	0.23	3.99
13	Kusum	*Schleichera oleosa*	Sapindaceae	-	-	-	-	5	5	0.39	4.14	-	-	-	-
14	Haldu	*Haldina cordifolia*	Rubiaceae	-	-	-	-	5	5	0.12	3.23	-	-	-	-
15	Jamun	*Syzygium cumini*	Myrtaceae	-	-	-	-	-	-	-	-	5	15	1.85	13.22
Total				**275**	**605**	**18.15**	**300**	**300**	**430**	**29.68**	**300**	**250**	**525**	**22.16**	**300**

Table 2. Structure of sapling layer of Char dominant forest sites in Central India

S. No.	Species	Botanical Name	Family	Sites											
				Mahasamund				Gariaband				Kabirdham			
				F (%)	D (stems ha^{-1})	BA (m^2 ha^{-1})	IVI	F (%)	D (stems ha^{-1})	BA (m^2 ha^{-1})	IVI	F (%)	D (stems ha^{-1})	BA (m^2 ha^{-1})	IVI
1	Koria	*Wrightia tinctoria*	Apocynaceae	35	440	0.63	192.06	-	-	-	-	-	-	-	-
2	Saja	*Terminalia tomentosa*	Combretaceae	10	80	0.13	42.50	-	-	-	-	10	40	0.05	50.52
3	Mahua	*Madhuca longifolia*	Sapotaceae	5	20	0.05	16.09	-	-	-	-	-	-	-	-
4	Senha	*Lagerstroemia parviflora*	Lythraceae	10	60	0.24	49.35	-	-	-	-	-	-	-	-
5	Gilchi	*Casearia graveolens*	Salicaceae	-	-	-	-	15	60	0.12	135.78	-	-	-	-
6	Tendu	*Diospyros melanoxylon*	Ebenaceae	-	-	-	-	15	60	0.21	164.22	20	80	0.20	118.59
7	Sal	*Shorea robusta*	Dipterocarpaceae	-	-	-	-	-	-	-	-	10	120	0.31	130.89
Total				**60**	**600**	**1.04**	**300**	**30**	**120**	**0.33**	**300**	**40**	**240**	**0.56**	**300**

Table 3. Structure of seedling layer of Char dominant forest sites in Central India

S. No.	Species	Botanical Name	Family	Sites											
				Mahasamund				Gariaband				Kabirdham			
				F (%)	D (stems ha^{-1})	A	IVI	F (%)	D (stems ha^{-1})	A	IVI	F (%)	D (stems ha^{-1})	A	IVI
1	Char	*Buchanania lanzan*	Anacardiaceae	15	4500	30000	42.50	5	500	10000	13.00	10	2500	25000	32.44
2	Koriya	*Wrightia tinctoria*	Apocynaceae	15	6000	40000	51.66	-	-	-	-	-	-	-	-
3	Tendu	*Diospyros melanoxylon*	Ebenaceae	30	13500	45000	91.39	35	6500	18571.43	56.88	40	12500	31250	100.22
4	Dhawda	*Anogeissus latifolia*	Combretaceae	15	2000	13333.33	27.22	-	-	-	-	10	3000	30000	37.02
5	Senha	*Lagerstroemia parviflora*	Lythraceae	10	4500	45000	44.53	5	1000	20000	22.78	-	-	-	-
6	Palas	*Butea monosperma*	Fabaceae	5	1000	20000	17.36	-	-	-	-	10	1000	10000	18.69
7	Karra	*Cleistanthus collinus*	Phyllanthaceae	10	2000	20000	25.35	-	-	-	-	-	-	-	-
8	Sal	*Shorea robusta*	Dipterocarpaceae	-	-	-	-	65	14000	21538.46	100.45	20	6500	32500	60.44
9	Gilchi	*Casearia graveolens*	Salicaceae	-	-	-	-	30	10000	33333.33	76.09	-	-	-	-
10	Mahua	*Madhuca longifolia*	Sapotaceae	-	-	-	-	15	2500	16666.67	30.80	5	1000	20000	19.52
11	Saja	*Terminalia tomentosa*	Combretaceae	-	-	-	-	-	-	-	-	5	500	10000	12.14
12	Harra	*Terminalia chebula*	Combretaceae	-	-	-	-	-	-	-	-	5	1000	20000	19.52
Total				**100**	**33500**	**213333.33**	**300**	**155**	**34500**	**120109.89**	**300**	**105**	**28000**	**178750**	**300**

Table 4. Diversity indices of tree and sapling layer of Char dominant forest sites in Central India

	Sites		
Diversity Indices	**Mahasamund**	**Gariaband**	**Kabirdham**
Tree Layers			
Shannon-Wiener index (H')	2.72	2.60	2.40
Concentration of dominance (Cd)	0.17	0.20	0.22
Evenness (e)	1.18	1.08	1.16
Species richness (d)	3.11	2.95	2.26
Beta diversity (Bd)	5.45	5.00	6.00
Sapling Layers			
Shannon-Wiener index (H')	1.50	0.94	1.31
Concentration of dominance (Cd)	0.43	0.54	0.44
Evenness (e)	1.08	1.36	1.19
Beta diversity (Bd)	11.67	23.33	17.5

Table 5. Density, basal area, biomass, carbon content and CO_2 sequestration of tree and sapling layers of Char dominant forest sites in Central India

Sites	**Density (stems ha^{-1})**	**Basal area (m^2 ha^{-1})**	**Biomass (Mg ha^{-1})**			**Carbon stock (Mg ha^{-1})**	**CO_2 sequestration (Mg ha^{-1})**
			Above-ground	**Below-ground**	**Total**		
Tree layers							
Mahasamund	605 ±315.40	18.15 ±9.66	83.90 ±52.15	21.82 ±13.56	105.72 ±65.70	50.22 ±31.21	184.29 ±114.54
Gariaband	430 ±95.39	29.68 ±16.36	172.19 ±110.50	44.77 ±28.73	216.96 ±139.23	103.06 ±66.14	378.22 ±242.72
Kabirdham	525 ±99.37	22.16 ±7.63	113.24 ±50.52	29.44 ±13.13	142.68 ±63.65	67.77 ±30.23	248.72 ±110.96
Sapling Layers							
Mahasamund	600 ±663.32	1.04 ±1.13	7.69 ±8.82	2.00 ±2.29	9.69 ±11.12	4.60 ±5.28	16.88 ±19.38
Gariaband	120 ±183.30	0.33 ±0.55	1.27 ±1.94	0.33 ±0.50	1.60 ±2.44	0.76 ±1.16	2.78 ±4.26
Kabirdham	240 ±463.03	0.56 ±1.07	2.88 ±20.82	0.75 ±1.44	3.63 ±7.00	1.72 ±3.33	6.32 ±12.20

Table 6. Correlation between density, basal area, biomass, carbon content and CO_2 sequestration of Char dominant forest sites in Central India

	Density (stems ha^{-1})	BA (m^2 ha^{-1})	AGB (Mg ha^{-1})	BGB (Mg ha^{-1})	Total Biomass (Mg ha^{-1})	Carbon Stock (Mg ha^{-1})	CO_2 sequestration (Mg ha^{-1})
Density (stems ha^{-1})	1						
BA (m^2 ha^{-1})	0.212	1					
AGB (Mg ha^{-1})	0.073	0.988**	1				
BGB (Mg ha^{-1})	0.073	0.988**	1.000**	1			
Total Biomass (Mg ha^{-1})	0.073	0.988**	1.000**	1.000**	1		
Carbon Stock (Mg ha^{-1})	0.073	0.988**	1.000**	1.000**	1.000**	1	
CO_2 sequestration (Mg ha^{-1})	0.073	0.988**	1.000**	1.000**	1.000**	1.000**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Note: BA = Basal area, AGB = above ground biomass, BGB = Below ground biomass

3.7 Correlation between Density, Basal Area, Biomass, Carbon Content and CO_2 Sequestration

Correlation analysis was performed to study the significant relationship between density, basal area, biomass, carbon content and CO_2 sequestration of char dominant sites in Central India was given in Table 6. The highest statistically significant correlation was observed between basal area and biomass and carbon storage and CO_2 sequestration with R^2 values of 0.988 at 0.01 probability level. There was an insignificant correlation between density and biomass, carbon content and CO_2 sequestration with R^2 values 0.073. The correlation between density and basal area was performed statistically non-significant with R^2 values of 0.212.

4. DISCUSSION

4.1 Plant Community Structure

The structure of tropical forests is influenced by the density, basal area, and frequency distributions of the vegetation. According to the current study, the basal area and density of trees varied from 18.15 to 29.68 m^2 ha^{-1} and 430 to 605 stems ha^{-1}, respectively. Estimates from tropical forests in India were comparable to tree densities in the study area. In a tropical dry deciduous forest at Barnawapara Wildlife Sanctuary, the density of disturbed forests was found to be 190 stems ha^{-1}, while the density of undisturbed forests was 1090 stems ha^{-1} [57]. In the Deogarh district of Odisha, India, which is part of the Eastern Ghats, the mean stand density was 479 trees ha^{-1} with a basal area of 15.20 m^2 ha^{-1} [58]. Comparable findings were discovered in the dry tropical forest of Barnawapara Sanctuary, where the number of species recorded ranged from 9 to 26, the basal area varied from 8.13 to 28.87 m^2 ha^{-1}, and the density of various forest types varied from 324 to 733 trees ha^{-1} [59]. A study conducted in Chhattisgarh revealed that the tree density (individuals/ha) and basal area (m^2/ha) in a tropical Sal mixed forest ranged from 710 to 1010 and 33.5 to 46.8 [60]. In the tropical forest of the Nayagarh Forest Division of Odisha in the Eastern Ghats of India, the stand density varied between 355.33 and 740.53 stems ha^{-1}, whereas the basal area varied between 7.77 and 31.62 m^2 ha^{-1} [61]. In the tropical forest of the Similipal Biosphere Reserve in Orissa, India, tree stands with a density ranging from 527 to 665 stems ha^{-1} and an average basal area of 43.51 m^2 ha^{-1} were discovered [62]. Tree densities for various dry tropical forest communities in the Vindhyan region vary from 294-627 stems ha^{-1} [63,64]. The studied that density and basal area was ranged from 542.50-565 stems ha^{-1} and 26.07-27.57 m^2 ha^{-1}, respectively on two sites of buffer zone of AABR in Central India [65,66,67]. The studied that the density and basal area were ranged from 176 to 480 stems ha^{-1} and 6.07 to 16.0 m^2 ha^{-1}, respectively at Western Central India in Madhya Pradesh [68]. The studied that the density and basal area were ranged from 278 to 333 stems ha^{-1} and 16.18 to 19.38 m^2 ha^{-1}, respectively at dry tropical forest in Chhattisgarh, India [69].

The most varied, carbon-rich, and structurally complex ecosystems are tropical forests, which can undergo significant changes even at very small spatial scales [70]. It is essential to comprehend the geographical variation in forest physiognomy in order to establish conservation strategies that will enhance carbon-biodiversity and co-benefits, as well as to address how these forests could be managed to minimize global environmental change.

4.2 Diversity Analysis

The present result of different diversity indices was analysed in different char dominant sites in Central India, the Shannon index, Simpson index, Evenness, species richness and beta diversity were ranged from 2.40-2.72, 0.17-0.22, 1.08-1.18, 2.26-3.11 and 5.0-6.0, respectively. Similar results were observed by different scientist of dry tropical forest in India. Similar results were measured for both disturbed and undisturbed forest in the dry tropical forest of Barnawapara Sanctuary [57]. In natural forests in the Awi Zone in Northwest Ethiopia, the forest had an evenness of 0.89 and a Shannon species diversity index score of 3.84 [71]. The result was discovered in tropical dry forests in India's Eastern Ghats, Shannon's diversity index was 2.01 ± 0.22 and Simpson's index was 0.85 ± 0.03 [58]. Comparably, in the dry tropical forest environment of Chhattisgarh, species richness varied from 3.88 to 6.86, diversity from 1.36 to 2.98, concentration of dominance from 0.07 to 0.49, and beta diversity from 1.29 to 2.21 [59]. According to research, the Simpson index (0.085), Shannon diversity index (1.22) and Gibbon Wildlife Sanctuary were significant, but the Kholahat Reserve Forest did not show any statistical significance for any of these indices [72]. In similar results found the Shannon's diversity index was highest (2.46) in dry mixed forest, whereas Simpson's dominance index was maximum (0.85) in teak plantation of tropical forest at Katerniaghat Wildlife Sanctuary (KWLS), India [15]. The Dibru-Saikhowa biosphere reserve in Assam, North-East India, has both disturbed and undisturbed tropical forests. The biodiversity indices were significantly higher in the undisturbed forest stands; the Shannon-Wiener diversity index (H′) ranged from 1.97 to 3.57, the Simpson index (Cd) from 0.76 to 0.88, and the evenness index (e) from 0.65 to 0.97 in all the stands [73]. The studied that Shannon index, concentration of dominance, Evenness, species richness and beta diversity was ranged from 2.36-2.91, 0.21-0.37, 0.77-1.01, 5.13-6.13 and 3.33-4.56, respectively on two sites of buffer zone of AABR in Central India [65,66,67]. The studied that concentration of dominance, Shannon index, equitability, species richness and beta diversity ranged from 0.33–0.60, 1.43–2.31, 0.57–0.88, 3.95–4.39 and 2.94–4.17, respectively at dry tropical forest in Chhattisgarh, India [69].

4.3 Biomass

The present study biomass of char dominant sites in Central India was ranged from 105.72 to 216.96 Mg ha^{-1}. Similar results were recorded of different scientist in tropical forest. The result of tree layer biomass of disturbed and undisturbed forest in 111.7 t ha^{-1} and 356.87 t ha^{-1}, respectively [57]. Research indicates that the average above-ground biomass value in the tropical dry forests of India's Eastern Ghats was 98.87 ± 68.8 t ha^{-1} [58]. The Forest Ecosystem of Chhattisgarh, India, estimated the total biomass of tree layer in the site of planting at 245.22 t ha^{-1} and in the natural forest at 241.44 t ha^{-1} [74]. The above ground biomass was measured 135.30-146.42 t ha^{-1} of Gibbon Wildlife Sanctuary and Kholahat Reserve Forest in two tropical forests of Assam [72]. The total biomass calculated for tropical dry deciduous forests in Central India varied from 103.32 (in the Renukhund range) to 453.54 t ha^{-1} (in the Chitrange range) [75]. The above ground biomass was ranged from 290.82–455.99 t ha^{-1} in dry mixed, Sal mixed and Teak plantation at Katerniaghat Wildlife Sanctuary (KWLS) of Indian tropical deciduous forest [15]. In deciduous forests in the Western Ghats of Karnataka, India, the mean value of estimated above-ground biomass and RS-based above-ground biomass is 280 and 297.6 t ha^{-1}, respectively [76]. The total biomass of the Sal-dominant tropical deciduous forest in Chhattisgarh, India, varied between 182.27 and 375.84 t ha^{-1} in four different site qualities [60]. The biomass in the moist deciduous forests of the Doon Valley, Western Himalaya, India, varied from 338.40 to 438.17 t ha^{-1} [77]. The studied that the biomass was ranged from 55.91 to 108.84 Mg ha^{-1} at Western Central India in Madhya Pradesh [68]. The studied that stand biomass of tree layer vegetation ranged from 214.65–246.06 t ha^{-1} in which above ground tree component (AGTC) ranged from 149.66–171.25 t ha^{-1} and below ground component (BGTC) ranged from 64.99-74.83 t ha^{-1} at dry tropical forest in Chhattisgarh, India [69].

4.4 Carbon Stock and CO_2 Sequestration

The present study carbon stock and CO_2 sequestration of char dominant sites in Central India was ranged from 50.22 to 103.06 Mg ha^{-1} and 184.29 to 378.22 Mg ha^{-1}, respectively. The studied in different scientist of dry tropical forest are found similar results. The results of C storage of tree layer were measured of disturbed and undisturbed forest in 47.45 t ha^{-1} and 152.13 t ha^{-1}, respectively of tropical dry deciduous forest in Chhattisgarh, India [57]. The tree layer carbon storage was measured 105.74 t ha^{-1} and 106.02 t ha^{-1} in natural forest and Teak plantation in Sarguja forest division of Forest Ecosystem of Chhattisgarh, India [74]. The above ground carbon storage measured 67.64-73.21 t ha^{-1} in two tropical forests of Assam [72]. In tropical dry deciduous forests in Central India, the total tree carbon density result ranged from 48.97 to 214.97 t C ha^{-1} [75]. Above-ground carbon stock (t ha^{-1}) values in Indian tropical deciduous forest varied from 207.52–220.34, 215.58–228.87, and 125.94–141.18 in dry mixed, Sal mixed, and Teak plantations, respectively [15]. Total C in trees ranged from 79.86 to 163.63 t ha^{-1}. In the tropical Sal mixed deciduous forest ecosystem in Chhattisgarh, India, the amount of carbon in the above-ground and below-ground components of trees on different sites was 72.32–143.36 t ha^{-1} and 7.54–20.27 t ha^{-1}, respectively [60]. The results observed average C stock of woody vegetation 231.3 t ha^{-1} in tropical forests of Western Ghats, India [78]. The studied that total C storage of tree layer component ranged from 90.51–103.64 t ha^{-1} in which AGTC of C storage ranged from 67.29-76.91 t ha^{-1} and BGTC of C storage ranged from 23.22–26.74 t ha^{-1} at dry tropical forest in Chhattisgarh, India [69]. The result measured tree carbon storage in undisturbed forest and disturbed forest in 184–214.62 t C ha^{-1} and 124–137.53 t C ha^{-1}, respectively in Dibru-Saikhowa biosphere reserve in Assam North-East India [73]. The carbon stocks in the moist deciduous forests of the Doon Valley, Western Himalaya, India, ranged from 169.20 t ha^{-1} to 219.08 t ha^{-1} at the several study sites [77]. The study was conducted in bamboo plantation at Chhattisgarh plain zone, the results revealed that carbon stock and CO_2 sequestration were 30.01 Mg ha^{-1} and 110.13 Mg ha^{-1}, respectively [56]. The studied that the carbon stock and CO2 sequestration were ranged from 26.55 to 51.70 Mg ha^{-1} and 97.43 to 189.73 Mg ha^{-1}, respectively at Western Central India in Madhya Pradesh [68].

5. CONCLUSIONS

Global climate change problems are caused by an increase in the amount of greenhouse gases in the atmosphere. Research on the biomass of tropical forests worldwide and the assessment of their carbon stocks must be prioritized in order to lessen this issue. Due to the fact that it accounts for one-third of world primary production and 50% of global carbon stocks. The present study plant community structure, biomass, carbon stock and CO_2 sequestration in Central India. The outcome also shows that central India's tropical dry deciduous forest is a good reservoir of biomass, carbon stock, and plant diversity. Additionally, a positive correlation was seen between basal area and carbon stock. The importance of woody plants in tropical dry deciduous forests capacity for sequestering carbon is highlighted by the present study's useful data on forest biomass and carbon stocks of woody plant species. These are baseline data that scientists, conservation managers, and researchers may find useful in comprehending the function of tropical dry deciduous forest ecosystems in carbon stocking and sequestration capacity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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