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Quantification of Above Ground Biomass (AGB) and Carbon Stock, Help to Mitigate Climate Change in the Western Plateau Forest Division of Jharkhand

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Abstract

Forest volume inventories are a valuable source of data for estimating above-ground biomass (AGB) density and the carbon stored in the biomass of forests. Variation in tree biomass and carbon stocks (Cp) in tropical forests is vital at both regional and global scales to know their contribution to the global C cycle. In the present study, six forest divisions of the western plateau, part of agroclimatic sub-zone V- sub-humid to subtropical, Jharkhand, have been selected to assess the above-ground biomass and carbon stocks. A total of 90 quadrats (10 m X 10 m) were sampled in 90 grids of six forests division of Jharkhand for all trees (≥10 cm GBH) species using a stratified random sampling method. The size of the grid was 5 km x 5 km; each grid, one quadrat has laid down. A total of 15 quadrats were laid down in each forest division. Tree species diversity, stand basal area, and density is calculated through the standard method. AGB of all documented trees were estimated using non-destructive method, and AGB to carbon conversions for Cp was performed according to the guidelines established in the IPCC 2006. The total AGB and Cp were recorded 255.24 Mg ha^{-1} and 119.96 Mg C ha^{-1} in the studied forest, ranging from 13.68 Mg ha^{-1} and 6.43 Mg C ha^{-1} (Garhwa North Forest division) to 77.92 Mg ha^{-1} and 36.62 Mg C ha^{-1} (Medininagar forest division). A significant positive relationship has been observed between AGB and basal area indicates that basal area is a major contributor of AGB. However r^2 is very high for Lohardaga (r^2 =0.99, $p < 0.05$), while moderately r^2 has been observed in Medininagar ($r^2 = 0.48$, $p < 0.05$) due to medium and low girth size of trees.

Keywords

Above Ground Biomass, Basal Area, Carbon Stock, Agro-Climatic Zone

1. Introduction

Climate change mitigation focuses primarily on reducing greenhouse gas (GHG) emissions. There are an estimated 850 million hectares of degraded forests throughout the world that might be restored and rehabilitated to recover lost biodiversity and ecosystem services while also helping to mitigate and adapt to climate change [1]. Tropical deciduous forests have a diverse character, owing to increased species richness, varied species associations, uneven stem densities, and base cover, multistory canopy architecture, and various microclimatic conditions [2]. Tropical deciduous forests are regarded as ecosystems rich in species diversity and diverse forms of life [3], have unique plant communities, and are some of the most endangered ecosystems in the tropics [4].

The major carbon pool in a tropical forest ecosystem is made up of live biomass from trees, understory vegetation, and deadwood, which comprises standing deadwood and falling deadwood including fallen stems and branches, woody debris, and soil organic matter (SOM). The above-ground biomass of the tree is by far the greatest carbon pool among the aforementioned carbon pools [5]. Large-stature species with dense wood tend to store the most carbon [6], and trees of certain species may exhibit more desirable lifetime carbon capture-to-emissions ratios [7]. Maintaining tree canopy in perpetuity also sustains carbon storage within forests and accumulates carbon within soils [8]. Forests and trees are essential carbon sinks, absorb carbon dioxide from the atmosphere and store it as carbon. Carbon sequestration by woodlands has sparked a lot of attention as a mitigation strategy since it is seen as a very low-cost way to address climate change right now.

Forests of Jharkhand are dominated by *S. robusta* Gaertn. f. locally known as Sal. The western plateaus (WP) of Jharkhand is a discontinuous range of plateaus, and one of the forest divisions (Garhwa North) bordered by three states *i.e.* Bihar by Sone River, Chhattisgarh state on the south, and Sonebhadra district of Uttar Pradesh on the west of India. The western plateaus contribute significantly to both species richness and endemicity of the Indian region. Sal is a highly valuable timber species, but it also serves many subsistence needs for tribal populations in the area, such as minor timber (for house building, poles, farm equipment, and so on), fuelwood, fences, leaves for cups and plates, and compost [9]. Therefore, conservation and community-based management of these forests are highly essential for the economic development of the local tribal communities.

The biomass in dry tropical forests is not uniformly distributed across the forest but exhibits patchy distribution [10]. Tree diameter and height data from forest plots have been used to estimate carbon stocks by calculating AGB [11, 12]. Estimating the amount of forest biomass gives an idea of carbon sequestration potential in forest ecosystems [13]. The allometric equations are developed and applied to forest inventory data to assess forests' biomass and carbon stocks. Many investigators have developed generalized biomass prediction equations for diverse forest and tree species [14-16]. The allometric equations for biomass estimation are developed by establishing a relationship between the various physical parameters of the trees, such as the diameter at breast height, the height of the tree trunk, the total height of the tree, crown diameter, tree species, etc [17]. Development of allometric regression equations to estimate the above-ground biomass of individual trees for tropical forests as a function of diameter at breast height, total height, wood density, and Holdridge life zone [18]. According to [19], the quantity of biomass in a forest determines the potential amount of carbon. The carbon sequestration rate varies with the species composition, region, climate, topography and management practices, etc [20]. The tree biomass offers a range of advantages, including a secure environment, food, and wood to many societies worldwide [21-22]. Forests constitute an essential part of the world's carbon reserves [23] and greatly influence the lives of other organisms and human societies. In the past decades, forest biomass quantification has attracted renewed interest because forest standing biomass represents about 44% of the world's forest carbon pool [24], thereby having a pivotal role in climate change mitigation. Global climate change triggered by increasing levels of carbon dioxide (CO_2) and other greenhouse gases, and the role of terrestrial vegetation in capturing atmospheric carbon dioxide (CO_2) and storing the carbon in plant biomass and soil draw considerable attention in the recent past, especially after the Kyoto Protocol. To reduce greenhouse gas emissions and partly offset deforestation, the Kyoto protocol explicitly considered afforestation, reforestation, and regeneration of forests for carbon sequestration accounting [25]. The forest carbon stocks are widely estimated from the allometric equations for forest biomass. Generally, the carbon concentration of the different parts of a tree is assumed to be 50% of the biomass [17] or 45% [26]. The carbon stock of trees was estimated using an allometric equation, was estimated by the harvest method in managed *S. robusta* forests of the mid-hill regions of central Nepal [27].

The present study deals with the aboveground biomass and carbon stocks which is helpful to understanding the carbon sequestration potential in terms of AGB. Information from this quantitative inventory will provide a valuable reference forest assessment and improve our knowledge by the identification of ecologically sound species as well as species of particular concern, thus identifying conservation efforts for sustainability of forest biodiversity.

2. Methods

2.1 Study area

The plateau region of Jharkhand is characterized by three Agro-climatic sub-zones humid and sub-humid tropical monsoon in sub-zone IV, sub-humid to subtropical in sub-zone V, and humid to sub-tropical in sub-zone VI. The present study was carried out in Garhwa south, Garhwa North, Medininagar, Latehar, and Lohardaga forest division of western plateaus, which is part of Agro climate "sub humid to subtropical zone V" (Figure 1). This area is dominated by hilly ranges, valleys, and plateaus, which provide dense forest cover. The Jharkhand Forest is considered a tropical moist and dry deciduous forest dominated mainly by *S. robusta* (Dipterocarpaceae). I-C-2bc is the most common FAO soil type recorded in all studied forest divisions except Garhwa North, where Bc25-2c is common. I-Ne soil type recorded in Latehar forest division only.

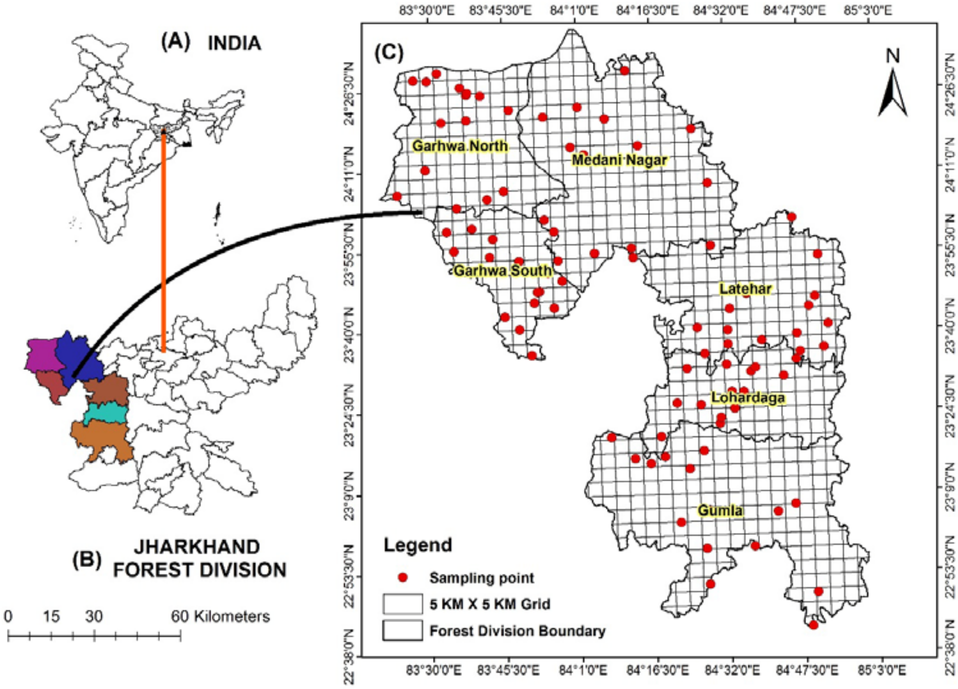

Figure 1. Map of studied sites (A-C) forest division of western plateaus in Jharkhand State.

2.2 Sampling design and data analysis

The location of the quadrat was decided based on the grid generation technique following [28], and the size of each grid was 5 km x 5 km. Girth at breast height (GBH) (1.37 m above ground) and height (H) of all individual trees (≥10 cm GBH) were measured using a measuring tape and range finder in each quadrat, respectively. A total of 90 quadrats each of 0.01 ha (10 m X 10 m) size have been sampled in 90 grids of six forests division of Jharkhand for all trees (≥10 cm GBH) species using a stratified random sampling method. Tree species diversity, stand basal area, density AGB, and carbon stock were calculated using the standard method. The non-destructive method of biomass estimation was used to determine the AGB of all documented trees, where the basal area, tree height, species-specific gravity, and volume equations were used as inputs. The GBH data collected from the field were converted into diameter (D) using the formula GBH/π. The volumetric equations and specific gravity of wood provided by the forest survey of India [29], have been used for further analysis of AGB. The general equation used for the volume estimation is

$$\boldsymbol{Biomass} = \boldsymbol{Volume} \times \boldsymbol{Wood\ density}$$

$$\boldsymbol{Volume} = (\boldsymbol{\pi d})\mathbf{2}\ \boldsymbol{h}$$

In the present study, species-specific volumetric equations were used as mentioned in Table 1.

The general equation proposed by the Ministry of Agriculture & Irrigation, Government of India (1977), was used to estimate the volume of the select species, for which species-specific volumetric equations are not available in the literature. AGB to carbon conversions was performed according to the guidelines established in the IPCC 2006 [31], and postulate conversion formula to estimate carbon from AGB:

$$\boldsymbol{Cp} = \boldsymbol{AGB} * \boldsymbol{CF}$$

Where Cp = carbon stock (Mg C ha^{-1}),
AGB = above-ground dry biomass (Mg ha^{-1}),
CF = carbon fraction (Mg C Mg^{-1} dry matter).
For tree vegetation, Carbon Fraction (CF) value fixed 0.47 Mg C Mg^{-1} [3].
Statistical analyses were performed with SPSS (*Version* 20) and maps were prepared by using ArcGIS *version* 10.3.

Table 1. Volume equations, and wood density (ρ) used for computation of ABG of different tree species recorded in western plateaus of Jharkhand

SL NO	Species name	[€]Wood density ρ (g cm^{-3})	[¥]Volumetric equation
1	*Acacia catechu* (L.F.) Willd.	0.88	V = 0.23781-2.09431D+7.78268D2
2	Acacia nilotica (L.) Delile	0.67	V=0.043849-0.55235*D+2.9523*D2+0.334508*D2*H
3	*Acacia auriculiformis* Benth.	0.5	V = 0.23781-2.09431D+7.78268D2
4	*Adina cordifolia (*Roxb.) Brandis	0.59	V=0.036+0.279D2H
5	*Ailanthus excelsa* Roxb.	0.52	V = 0.23781-2.09431D+7.78268D2
6	*Albizia stipulate* Boiv	0.52	√V=(-0.07109+2.99732*D-0.26953*√D)
7	*Albizia lebbeck* (L.) Benth.	0.57	V/D2H = −0.00858/D2H+0.0000316
8	*Anogeissus latifolia*	0.79	√V=(-0.0738+2.592167*D)
9	*Azadirachta indica* A. Juss.	0.52	V=(-03510+5.32981*D2)
10	*Bambusa vulgaris* Schrad. ex J.C.Wendl., nom. cons. Prop	0.68	V = 0.23781-2.09431D+7.78268D2
11	*Bauhinia variegata* L.	0.61	V=-0.0236+0.3078D+1.2361 D2
12	*Bombax ceiba* L.	0.33	V=(0.00978-0.21005*D+5.62160*D2)
13	*Boswellia serrata* Roxb. ex Colebr.	0.5	V=(0.03356-1.124*D+10.306*D2)
14	*Buchanania cochinchinensis* (Lour.) M.R.Almeida	0.46	V = 0.23781-2.09431D+7.78268D2
15	*Butea monosperma* (Lam.) Taub.	0.47	V=(0.0417-0.47789*D+3.50714*D2+9.76048*D3)
16	*Butea superba* Roxb.	0.5	V = 0.23781-2.09431D+7.78268D2
17	*Casearia tomentosa* Roxb.	0.7	V = 0.23781-2.09431D+7.78268D2
18	*Cassia fistula* L.	0.71	V=(0.05159-0.53331*D+3.46016*D2+10.1843*D3)
19	*Cassia siamea* Lamk	0.48	V = 0.23781-2.09431D+7.78268D2
20	*Celastrus paniculatus* Willd.	0.5	V = 0.23781-2.09431D+7.78268D2
21	*Dalbergia latifolia* Roxb.	0.75	V=0.04422+2.328465*D2+0.309150*D2*H
22	*Dalbergia sissoo* Linn.	0.67	V=0.04422+2.328465*D2+0.309150*D2*H
23	*Desmodium oojeinense* (Roxb.)H.Ohashi	0.7	V=0.037269/ D^2H 0.45979D
24	*Diospyros melanoxylon* Roxb.	0.68	V=(0.12401-2.00966*D+10.87747*D2)
25	*Ehretia laevis* Roxb.	0.63	V = 0.23781-2.09431D+7.78268D2
26	*Elaeodendron kamerunense* (Loes.) Villiers	0.62	V/D2=(0.0697/D2-1.4597/D+11.79933-2.35397*D)
27	*Eucalyptus globulus*	0.5	V=(0.02894-89284*D+8.72416*D2
28	*Ficus benghalensis* L.	0.65	V=(0.088074-1.449236*D+8.760534*D2)
29	*Gmelina arborea* Roxb. ex Sm.	0.45	V=(0.1156+0.21230*D+5.10448*D2)
30	*Holarrhena phubescence Wall ex G.Don*	0.64	V = 0.17994−2.78776D+14.44961D
31	*Holoptelea integrifolia* (Roxb.) Planch.	0.59	V = 0.23781-2.09431D+7.78268D2
32	*Lagerstroemia parviflora* Roxb.	0.65	V=(0.0568-1.19611*D+9.11319*D2)
33	*Lannea coromandelica* (Houtt.) Merr.	0.51	V=(0.57424-1.153088*D+8.542648*D2)
34	*Madhuca longifolia* (J.Koenig ex L.) J.F.Macbr.	0.73	V=(-0.00092-0.55547*D+7.3446*D2)
35	*Miliusa velutina* (A.DC.) Hook.f. & Thomson	0.5	V = 0.23781-2.09431D+7.78268D2
36	*Oroxylum indicum* (L.) Kurz	0.5	V = 0.23781-2.09431D+7.78268D2
37	*Phoenix dactylifera* L	0.5	V = 0.23781-2.09431D+7.78268D2
38	*Phyllanthus emblica* L.	0.62	V=(-0.406+3.540* D-3.231*D2)
39	*Pongamia pinnata* (L.)Pierre	0.61	V=0.013+0.271*(H)
40	*Pterocarpus marsupium* Roxb.	0.58	V=(0.58424-1.233468*D+9.433633*D2)
41	*Schleichera oleosa* (Lour.) Oken	0.84	V = 0.23781-2.09431D+7.78268D2
42	*Semecarpus anacardium* L. fil.	0.5	√V=1.67447 + 14.83747*D -9.43386*√D)
43	*Shorea robusta* Gaertn.	0.72	V=(0.08565-1.51685*D+10.24871*D2)
44	*Soymida febrifuga* (Roxb.) Juss.	0.53	V = 0.23781-2.09431D+7.78268D2
45	*Sterculia urens* Roxb.	0.53	V=0.001√D+0.0366D-0.128
46	*Swietenia mahagoni (*L.) Jacq.	0.64	VE = -2.4403 + 0.046383*DBH - 0.00006461*DBH2
47	*Syzygium cumini* (L.) Skeels	0.65	√V=(0.30706+5.12731*D-2.0987*√D)
48	*Tamarindus indica* L.	0.75	V=(0.088074-1.449236*D+8.760534*D2)
49	*Tectona grandis* L.f.	0.58	√V=(-0.405890+1.98158*D+0.987373*√D)
50	*Terminalia alata* Heyne ex Roth	0.69	V=(0.33695-1.23004*SQRT*D+11.86676* D2)
51	*Terminalia arjuna* (Roxb.) Wight & Arn.	0.68	V=0.1249+0.3707*(H)
52	*Terminalia chebula* Retz.	0.69	V=0.1249+0.3707*(H)
53	*Ziziphus jujuba* Mill.	0.6	V/D2=(0.0697/D2-1.4597/D+11.79933-2.35397*D)
V volume (m3), D= DBH (m), H height (m), SQRT= Square root, Wood density (g cm^{-3})			
[€]FSI Report, [¥]Forest Survey of India report [29-30] and Globallome Tree (http://www.globallometree.org/data/allometric-equations/)			

3. Results

3.1 Forest structure and composition

A total of 871 individual trees (>10 cm GBH) of 54 species belonging to 35 families were recorded in 90 quadrants. In each forest division, fifteen quadrats (10 m X 10 m) or 0.01 hectare were laid down. A quite high number of trees (181) belonging to 14 families were recorded in the Gumla forest division; however, minimum (99) individuals of trees were recorded in 15 quadrats in Latehar. Taxonomic diversity at the family level is relatively high in the studied *Sal* forests. Fabaceae is the most dominant family with 16 species, followed by Anacardiaceae (03 spp.), Annonaceae, Combretaceae, Mimosaceae, and Celastraceae with two and remaining of each family with 01 species each. The highest tree diversity in terms of Shannon-Weiner diversity index (H') (2.91) was recorded in Medininagar forest and the highest evenness index (E) (0.85) was recorded in Lohardaga. Evenness index is also known as species equitability ranged from 0.62 to 0.87, while Effective no of species (ENS) ranged from 5 to 18. The values of H', CD, E, Dmg, Dmn, and ENS do not follow a definite pattern in all studied forest divisions of Jharkhand. Details of community characteristic of the studied forests division showed in Table 2.

Table 2. Community characteristic of the studied sampling forest site within studied forest division

Community parameters	Garhwa North	Garhwa South	Gumla	Latehar	Lohardaga	Medininagar
Margalef in Biodiversity Richness Index (Dmg)	3.08	3.08	3.08	3.05	2.64	5.60
Menhinick's Richness index, (Dmn)	1.40	1.40	1.26	1.51	1.19	2.25
Pielou's evenness index (E)	0.75	0.75	0.69	0.72	0.85	0.62
Effective no of species (ENS)	8.00	8.00	7.10	7.03	18.17	5.10
Shannon-Weiner diversity index (H')	2.61	2.09	1.96	1.95	1.64	2.91
Simpson Index (CD)	0.10	0.21	0.26	0.23	0.35	0.07

3.2 Spatial pattern of above-ground biomass (AGB) and carbon stock (Cp)

The total AGB and Cp were recorded at 255.24 Mg ha^{-1} and 119.96 Mg C ha^{-1}. Highest AGB, as well as Cp, were recorded in the Medininagar forest division (77.92 (Mg ha^{-1} and 36.62 (Mg C ha^{-1}), however, the minimum was observed at Garhwa North forest division (13.68 Mg ha^{-1} and 6.43 Mg C ha^{-1}), respectively (Figure 2). *Shorea robusta* had the contributed highest AGB and Cp (8.28 Mg ha^{-1} and 3.89 Mg C ha^{-1}; 29.98 Mg ha^{-1}, 11.74 Mg C ha^{-1}; 19.57 Mg ha^{-1}, 9.20 Mg C ha^{-1}; 27.79 Mg ha^{-1}, 13.06 Mg C ha^{-1} in Garhwa south, Gumla, Latehar, and Lohardaga forest division except for Garhwa north and Medininagar where *Holoptelea integrifolia* (2.75 Mg ha^{-1}, 1.29 Mg C ha^{-1}) and *Holarrhena pubescence* (1.66 Mg ha^{-1}, 0.78 Mg C ha^{-1}) had highest AGB and Cp.

Out of 54 recorded tree species, *Shorea robusta* had the highest AGB, and Cp (81.80 Mg ha^{-1}, and 34.45 Mg C ha^{-1}) followed by its associate, *Madhuca longifolia* (22.19 Mg ha^{-1}, and 10.43 Mg C ha^{-1}), *Butea monosperma* (4.5 Mg ha^{-1}, and 2.12 Mg C ha^{-1}), *Lagerstroemia parviflora* (4.0 Mg ha^{-1}, and 1.9 Mg C ha^{-1}). The total basal area and density of trees in all studied *Sal* forests were 37.37 m2 ha^{-1} and 5853 ind. ha^{-1}, respectively. Species wise basal area of trees ranged from 0.002 to 16.15 m2 ha^{-1}, and density ranged from 0.02 to 2643 ind. ha^{-1}. *S. robusta* had a maximum basal cover (16.15 m2 ha^{-1}), as well as density (2643 individuals ha^{-1}).

3.3 Correlation between ABG with basal area

The correlation between ABG and BA was measured using Pearson's correlation coefficient at a 95% confidence interval (Figure 3). A significant positive linear correlation was found between for basal area with above-ground biomass with a high ($r2 = 0.99$, $p < 0.05$) recorded in Lohardaga forest division followed by Latehar ($r2 = 0.98$, $p < 0.05$) (Figure 3). The scatter plot **(**Figure 3 (B**)** & (F) shows variation, considering trees in smaller and medium girth sizes, so AGB and BA's co-relation is not strong in Garhwa south and Medininagar.

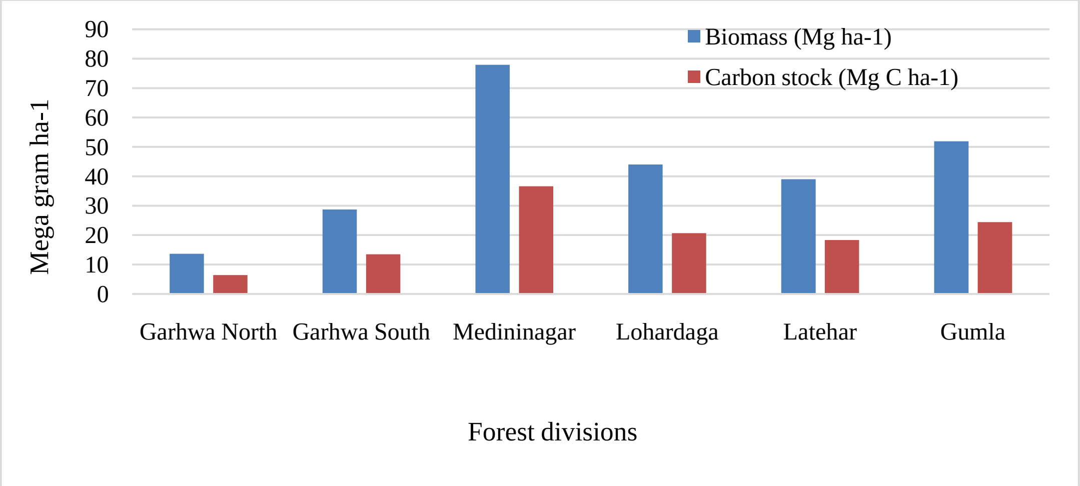

Figure 2. AGB and carbon stock (Cp) recorded sampling site of studied forests division.

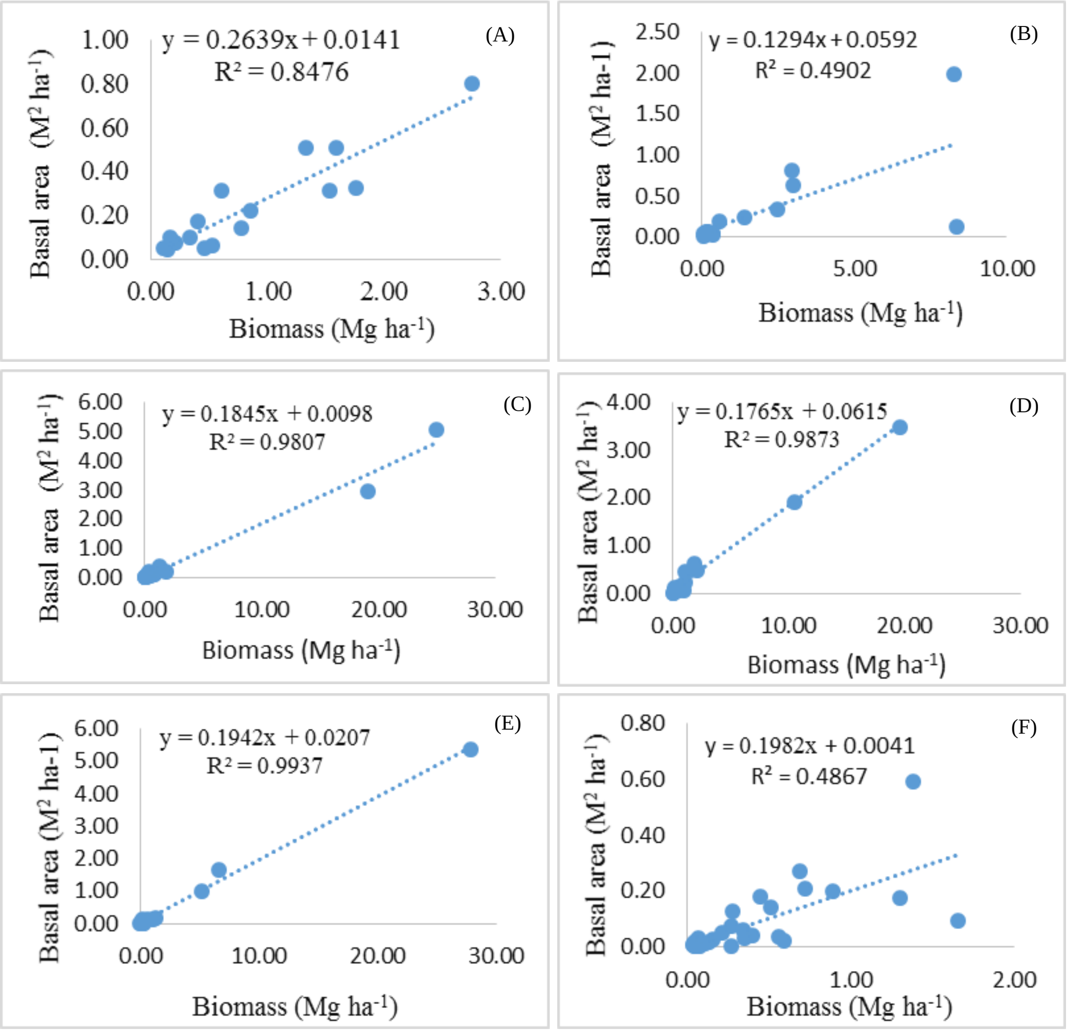

Figure 3. Co-relationship between aboveground biomass (Mg C ha^{-1}) with Basal area (M2 ha^{-1}) of trees in different forest division (A) Garhwa North (B) Garhwa South (C) Gumla (D) Latehar (E) Lohardaga and (F) Medininagar of Agro climatic sub zone (v) in Jharkhand.

4. Discussions

Jharkhand has been blessed with diverse vegetation diversity due to varying topography and physiographic and climatic conditions. The State comprises dry tropical deciduous and moist deciduous forest; *Sal* is the most dominant species along with its associates, mainly *Buchanania cochinchinensis*, *Butea monosperma*, *Lagerstroemia parviflora*, *Adina cordifolia*, etc. AGB varies with the division because carbon stock has directly related to the ABG, so it is also varied. The present report of Fabaceae as the most dominant family in deciduous *Sal* forests of Jharkhand is consistent with the other deciduous forests of the world, in which also Fabaceae is the most speciose family [31].

Shannon-Weiner diversity (H') in forests depicts various species present in a specific area. However, the evenness index depicts how close each species exists in an environment. H' for Indian forests has been reported to range from 0.83 to 4.10 [32-33]. In the present investigation, the value of H' for trees (2.21) lies within the range reported for tropical forests but was lower than the recorded value (3.59) for the tree of Eastern Himalayan *Sal* forest [34], (3.10) West Bengal moist *Sal* forest of India [35] (3.68) tropical forest of Balasore district, Odisha [36]. The concentration of dominance in the present study was (0.07-0.39) lower than the reported range of 0.64-1.34 in other forests. CD has been reported ranged from 0.03-0.9 for the tree of Northeastern Bangladesh [37]. One for the tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats [38], and (0.97 to 0.98) for the tropical deciduous forests of Northcentral Eastern Ghats [39].

Tree diversity in terms of Shannon-Weiner diversity index (H’) was ranged from 1.64 to 91, which falls within the range (0.62-3.96) reported by earlier workers for various tropical deciduous forests of India [40, 41]. The biodiversity of any ecosystem can be measured using distinctive tools *i.e.*, species richness, and species diversity [42]. ENS denotes the amount of diversity directly compared with the within-community, and among community components, provides more interpretable, and comparable assessments of biodiversity as compared to species richness, H’, and CD [43]. It is the true diversity of community used to assess species diversity based on H’, and responds to either known alteration in the assemblage or environmental variables [44]. On the other hand, CD ranged from 0.10 to 0.72 (mean 0.34 ± 0.01), which was within the reported range of CD (0.19 to 0.99) for forest vegetation [45]. Lower CD (0.07) in Medininagar forests indicate that dominance is shared by more than one species, and values of CD were lower in contrast with high species diversity (H’) (2.91) as species diversity behaves inversely to the index of dominance (CD) [46].

S. robusta being the most dominant tree species, adapts better in sub-tropical climate conditions and has the highest AGB (81.80 Mg ha^{-1}) and Cp (34.45 Mg C ha^{-1}). However, attention should be given to the conservation of other native tree species like *Bauhinia variegata* (0.01 Mg ha^{-1}, and 0.004 Mg C ha-1), *Albizia stipulate* (0.05 Mg ha^{-1}, and 0.02 Mg C ha^{-1}), *Sterculia urens* (0.12 Mg ha^{-1}, and 0.05 Mg C ha^{-1}), *Azadirachta indica* (0.06 Mg ha^{-1}, and 0.02 Mg C ha^{-1}), *Casearia tomentosa* (0.08 Mg ha^{-1}, and 0.03 Mg C ha^{-1}), *Cassia fistula* (0.08 Mg ha^{-1}, and 0.03 Mg C ha^{-1}), and *Ailanthus excelsa* (0.11 Mg ha^{-1}, and 0.05 Mg C ha^{-1}), with low AGB and Cp as these species, also have a lower density, as well as basal cover in the, studied *Sal* forests.

The carbon sequestration potential of forests depends on forest type, age of forest, age of trees, and its basal cover and density [47]. More diverse plant communities have a higher chance of including highly abundant species that dominate the community, as *S. robusta* dominated the whole AGB in *Sal* mixed tropical moist deciduous forest in the upper Gangetic plains adjoining Himalayan foothills in Uttar Pradesh, India [2]. Tree biomass in forests varies with forest type, species composition, stand age, size class of trees, site conditions, rainfall pattern, edaphic factors, and altitude [44, 48, 49].

The total AGB and Cp of all studied *Sal* forests sites were 255.24 Mg ha^{-1}, and 119.96 Mg C ha^{-1}, respectively, which is lower than the AGB of *Sal* plantation forest of Meghalaya, Northeast India (406 Mg ha^{-1}) [50] as well as *Sal* forests of the Himalayas (78 to 378 Mg ha^{-1}) [51]. The current record of AGB is within the reported range (150 to 698 Mg ha^{-1}) of diverse tropical forests of the world [47, 52] as well as compared with the reported range (28.1 to 330.87 Mg ha-1) of various tropical deciduous forests of India [53-56]

5. Conclusions

Forests are the largest carbon pool on earth. It acts as a significant source and sink of carbon in nature. Thus, it can form a chief component in the mitigation of global warming and adaptation to climate change. Applying allometric equations is the primary step for precisely estimating forest biomass and carbon stock. A positive and statistically significant correlation of a basal area with AGB indicates that the basal area is a significant contributor to AGB. Estimation of forest Cp enables us to assess the amount of carbon loss during deforestation or stored during forest regeneration. The present study will directly help understand the carbon sequestration potential in terms of AGB in climate change response to the ecosystem and assess the patterns of carbon sequestration in Indian forests under global climate change. Further research is needed to depict the long-term effects of tree harvesting to maintain their productivity and soil fertility status concerning the sustainability of *Sal*-dominated forests.

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