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Research Paper

Tree diversity and carbon stocks of hmuifang forest, Mizoram

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Abstract

The diversity of trees and carbon stock of Hmuifang forest were studied. The highest Density, Frequency and Important value Index were found in *Dipterocarpus retusus* with 153.33, 86.67 and 42.33 respectively, followed by *Helicia excelsa with 136.67, 73.33 and 22.10 respectively*. *Lithocarpus xylocarpus* has the highest abundance (2.40) followed by *Helicia excelsa (1.86)*. The study of diversity indices shows that there is greater diversity, the community has a higher evenness and there are fewer disturbances in the forest. Biomass of trees was calculated by using allometric equations. Below ground Biomass was estimated by the Root-Shoot ratio relationship. The highest biomass was stored in *Quercus floribunda* (244.61 t/ha) followed by *Dipterocarpus retusus* (175.04 t/ha). Soil samples were collected from four depths layer (0-10 cm), (10-20 cm), (20-30 cm) and (30-40 cm). Soil Organic Carbon was determined by using Walkley-Black wet oxidation method. The Total Carbon Stock of Hmuifang Forest was found to be 468.26 t/ha and total CO_2 sequestered is 1718.51. The results of this study help understand the status of this forest and its importance in Carbon sequestration.

Keywords: *Dipterocarpus retusus*, *Quercus floribunda*, Allometric Equations, Soil Organic Carbon, Carbon Stock.

Introduction

Forest and woodlands cover more than 3.95 billion hectares of the Earth's land mass[1] and the tropical forests accounted for around 50% of the total forest having the most diverse plant communities of the earth. Most of the tropical forests come under the energy-hungry developing nations that need huge energy for its developmental works. This leads to the reduction of the forest cover in tropical regions and causes the alteration of climate. The burning of fossil fuel has released Carbon into the atmosphere as CO_2 gas and the amount of CO_2 gas in the atmosphere has increased from 280 parts per million (ppm) in 1750 up to 406 ppm in early 2017[2]. CO_2 gas is a major green house gas and it is responsible for the global warming. Forest has a huge potential of Carbon sequestration. During the photosynthesis, CO_2 gas is absorbed by the plants and stored them into the plant parts as biomass. It is estimated that 50% of the biomass as carbon content for all tree species[3]. The major carbon pool in an ecosystem includes, Above Ground Biomass, Below Ground Biomass, Dead Wood, Litter and Soil Organic Matter [4,1]. Soil Organic Matter is the main contributor to the forest carbon pools[4] and it is accounted for 86 % of the total carbon sequestered[5]. The Asia Pacific Biodiversity Hotspot covers a large area and the Indo-Burma hotspot is one of its units which encompass more than 2 million km2 of Tropical Asia. Mizoram falls under the Indo-Burma hotspot and it has the highest forest cover among the states of India i.e. 88.93%[6]. The present study aims to assess the diversity of trees of Hmuifang forest. The other important objectives are to estimate the tree biomass and carbon stock of Hmuifang forest.

Materials and Methods

Study site

The study area is situated in the southern part of Aizawl and it is also a famous tourist spot. It is about 50 km away from the state capital Aizawl with an average elevation of 1619 amsl. The survey area lies between the coordinates 23°27´22´´ N - 23°27´31´´ N latitudes and 92°45´19´´ E - 92°45´24´´ E longitudes. The mountain area is still covered with virgin forests. The texture class of the soil falls under the loamy sand. The vegetations of the study area fall under Tropical semi-evergreen forests7. And under the Koppen Climate Classification, the study area comes under the Humid subtropical climate (Cwa). The average annual rainfall is about 267.13 mm8. The temperature ranges from 20°C - 29°C during summer and winter temperature ranges from 7°C - 21°C.

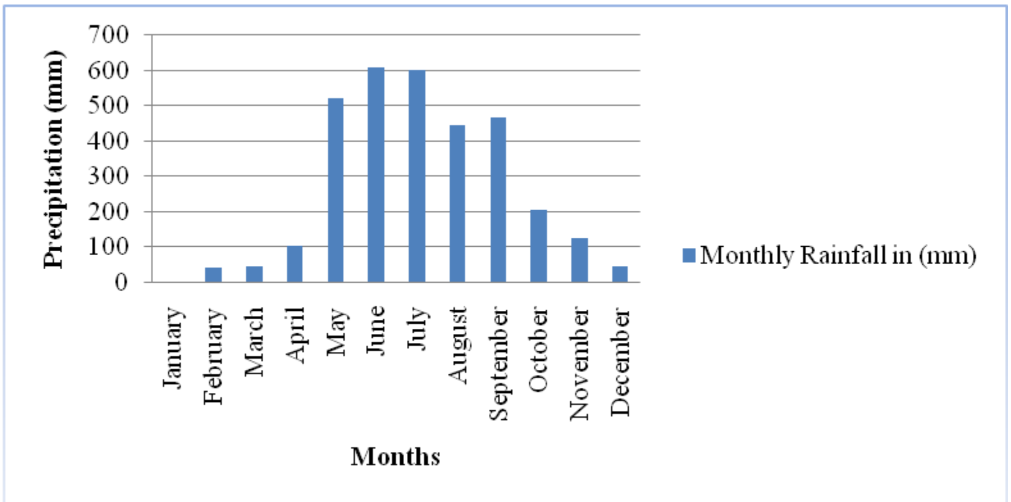

Figure 1: Monthly rainfall data for the year 2016 (in mm) from the station around the study area

Field Sampling for Vegetational and Biomass Analysis

Stratified random sampling was used for collecting data, quadrats of 10m x 10m were laid inside the Hmuifang forest, height of trees was measured by using clinometers and single pole methods. Diameter at Breast Height (DBH) of the trees in each quadrant was measured at approximately 1.37 meter by using diameter tape.

The girth classes of trees are categorized in 6 different groups[9]. The girth class A is considered as Saplings with Girth at Breast Height of 10-31 cm, Girth class B as Bole with 32-66 cm, Girth class C with 67-101 cm (Post bole), Girth class D with 102-136 cm (Mature trees), Girth class E with 137-171 cm (Mature trees) and Girth class F with >171 cm (Over mature trees.)

The forest litter was sampled directly by simple harvesting techniques in small subplots. Square frames, usually encompassing an area of about 0.25m x 0.25m were used. All litters within the frame were collected and all samples from the subplots are pooled and weighed. Well-mixed subsamples were collected and placed in marked bags. The subsamples were oven dried and dry weights were estimated.

Phytosociological/Analytical parameters

Quantitative analysis such as density, frequency and abundance and their relative values were determined as per Muller-Dombios and Ellenberg and Mishra[10,11]. The species diversity was determined by using Shannon-wieners diversity index and Simpson's index of diversity was calculated by using Important Value Index (IVI) of species[12]. Evenness index and Margalef's index of richness were also calculated.

Soil Sampling

The method suggested by IPCC[13] was used to collect the soil samples. The soil samples were taken from the centre of selected quadrats by driving a core sampler at four different depth classes up to 40 cm depth. Soil cores were sectioned into 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm.

Bulk Density Measurement
The bulk density of the soil was determined based on the method suggested by IPCC[13]. The Soil inside the cylinder was collected, oven-dried and weighed to find the bulk density. The soil was sieved (2 mm sieve) to find out the fragment (stone and gravel) content.

$$BD\ sample = \frac{ODW - RF}{CV}$$

Where, BD sample means bulk density of the < 2mm fraction, in grams per cubic centimetre ( ), ODW is oven-dry mass total sample in gram, CV is core volume in , and RF is a mass of coarse fragments (> 2 mm) in gram.

Estimation of Soil Organic Carbon (SOC)

The amount of SOC that was stored in the soil was quantified by using the equation given by Broos and Baldock14, i.e.

$$SOC\ (t/ha) = Depth(cm) \times BulkDensity(g/cm^3) \times Organic\ Carbon\ Content(\%)$$

Walkley and Black wet oxidation method were used to determine the organic carbon content (%) of the soil[15].

Biomass Estimation of the Tree
Above Ground Biomass
For the estimation of aboveground biomass, the model developed by Chave et al.[16] has been used. The equation used for estimation of biomass was:

$$M = 0.0509 \times (\rho D^2 H)$$

Where, M is the above-ground biomass (kg), H is the height of the trees (meter), D is the diameter at breast height in cm, and ρ is the wood density (gm/cm^3). The specific gravity of trees was taken from Zanne et al., [17] Global wood density database.

Below Ground Biomass
Root biomass was calculated by using the equation given by Cairns et al.[18].

$$Y = Exp[-1.0587 + 0.8836\ x\ LN(AGB)]$$

Where, LN = natural logarithm, AGB = above-ground biomass (dry tonnes/hectare).

Estimation of carbon content in litter
The Carbon Content of litter was derived from Ash content of the plant materials by Dry-Ashing method[19]. The oven dried and ground materials were taken in a silica crucible and burned to ash at 550°C for 3 hours in a muffle furnace.

$$Carbon\ content\ (\%) = 100 - (Ash\ content + 53.28)$$

Estimation of C-Stock of the standing Trees
The carbon storage in trees was calculated by multiplying the total biomass with constant factor 0.55 [20].

Results and Discussion
The present study reported 50 species of trees which belong to 43 genera and 22 families in the study area. Lauraceae was the most dominated family (9) followed by Euphorbiaceae (6), Rubiaceae and Fagaceae (4) and Myrtaceae (3).

Table 1: Density, Frequency (%), Abundance and Important Value Index of Tree species in the Hmuifang Forest

Sl. No.	Name of the species	Family	Density (Individual/ha)	Frequency (%)	Abundance	Important Value Index (IVI)
1	*Dipterocarpus retusus* Blume	Dipterocarpaceae	153.33	86.67	1.77	42.88
2	*Quercus floribunda* Lindl. ex A.Camus	Fagaceae	36.67	33.33	1.1	30.39
3	*Helicia excelsa* (Roxb.) Blume	Proteaceae	136.67	73.33	1.86	22.1
4	*Lithocarpus xylocarpus* (Kurz) Markgr.	Fagaceae	120	50	2.4	22
5	*Symplocos racemosa* Roxb.	Symplocaceae	80	56.67	1.41	17.18
6	*Drypetes indica* (Mull.-Arg) Pax & K. Hoffm.	Euphorbiaceae	80	63.33	1.26	16.5
7	*Elaeocarpus rugosus* Roxb. ex G. Don	Elaeocarpaceae	53.33	50	1.07	12.66
8	*Styrax polysperma* C.B. Clarke	Styraceae	46.67	33.33	1.4	11.66
9	*Olea dioica* Roxb.	Oleaceae	60	53.33	1.13	11.57
10	*Machilus gamblei* King ex Hook.f.	Lauraceae	40	40	1	10.1
11	*Calophyllum polyanthum* Wall. ex Planch. & Triana	Clusiaceae	40	36.67	1.09	9.52
12	*Wedlendia grandis* (Hook. f.) Cowan	Rubiaceae	36.67	30	1.22	8.12
13	*Tarennoidea walichii* (Hook.f.) Triveng. & Sastre	Rubiaceae	40	30	1.33	7.26
14	*Rapanea capitellata* (Wall.) Mez	Myrsinaceae	26.67	26.67	1	6.49
15	*Litsea lancifolia* (Roxb. ex Nees) Benth. & Hook.f.ex Villar	Lauraceae	33.33	26.67	1.25	6.1
16	*Alseodaphne petiolaris* Hook. f.	Lauraceae	23.33	20	1.17	4.86

17	*Benkara fasciculata* (Roxb.) Ridsdale	Rubiaceae	26.67	23.33	1.14	4.78
18	*Eriobotrya bengalensis* (Roxb.) Hook. f.	Rosaceae	30	20	1.5	4.66
19	*Listea semicarpifolia* (Wall. ex Nees) Hook. f.	Lauraceae	20	20	1	4.57
20	*Castanopsis echinocarpa* Miq.	Fagaceae	26.67	16.67	1.6	4.47
21	*Beilschmiedia gammieana* King ex Hook.f.	Lauraceae	16.67	13.33	1.25	3.82
22	*Sapium eugeniaefolium* Buch.-Ham.	Euphorbiaceae	13.33	13.33	1	3.69
23	*Ficus obtusifolia* Roxb.	Moraceae	13.33	13.33	1	3.64
24	*Quercus glauca* Thunb.	Fagaceae	13.33	13.33	1	3.38
25	*Prunus nepalensis* Ser.	Rosaceae	13.33	6.67	2	2.54
26	*Syzygium claviflorum (*Roxb.) Wall. ex A.M. Cowan & Cowan	Myrtaceae	6.67	6.67	1	1.77
27	*Celtis timorensis* Span.	Ulmaceae	10	6.67	1.5	1.6
28	*Helicia robusta* (Roxb.) R. Br. ex Blume	Proteaceae	6.67	6.67	1	1.6
29	*Magnolia hodgsonii* (Hook.f. & Thoms) Keng	Magnoliaceae	6.67	6.67	1	1.58
30	*Ixora nigricans* R.Br. ex Wight & Arn.	Rubiaceae	6.67	6.67	1	1.49
31	*Syzygium praecox* (Roxb.) Rathakr. & N.C. Nair	Myrtaceae	6.67	6.67	1	1.31
32	*Vitex penduncularis* Wall. ex Schauer	Verbenaceae	6.67	6.67	1	1.31
33	*Croton lissophyllus* Radcl.-Sm. & Govaerts ex Esser	Euphorbiaceae	6.67	6.67	1	1.29
34	*Macaranga peltata* (Roxb.) Mull. Arg.	Euphorbiaceae	6.67	3.33	2	1.09
35	*Fraxinus floribunda* Wall.	Oleaceae	3.33	3.33	1	1.06
36	*Syzygium cumini* (L.) Skeels	Myrtaceae	3.33	3.33	1	1.01

37	*Glochidion sphaerogynum* (Mull.Arg.) Kurz	Euphorbiaceae	6.67	3.33	2	0.97
38	*Myrica esculenta* Buch.-Ham. ex D. Don	Myricaceae	3.33	3.33	1	0.85
39	*Ostodes paniculata* Blume	Euphorbiaceae	3.33	3.33	1	0.85
40	*Cinnamomum glaucescens* (Nees) Hand.-Mazz.	Lauraceae	3.33	3.33	1	0.75
41	*Lindera nacusua* (D. Don) Merr. var. nacusua	Lauraceae	3.33	3.33	1	0.7
42	*Eurya japonica* Thunb.	Theaceae	3.33	3.33	1	0.69
43	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	3.33	3.33	1	0.69
44	*Nostolachma khasiana* (Korth.) Deb & Lahiri	Rubiaceae	3.33	3.33	1	0.68
45	*Vitex canescens* Kurz	Verbenaceae	3.33	3.33	1	0.65
46	*Aphananthe cuspidata* (Blume) Planch.	Ulmaceae	3.33	3.33	1	0.64
47	*Garcinia cowa* Roxb. ex Choisy	Clusiaceae	3.33	3.33	1	0.64
48	*Mangifera sylvatica* Roxb.	Anacardiaceae	3.33	3.33	1	0.63
49	*Eurya acuminata* DC.	Theaceae	3.33	3.33	1	0.62
50	*Carallia integerrima* DC.	Rhizophoraceae	3.33	3.33	1	0.61

Community analysis of trees

Out of 50 trees species reported, *Dipterocarpus retusus* was found to have the highest density with 153.33 individuals/ha followed by *Helicia excelsa* (136.67 individuals/ha), *Lithocarpus xylocarpus* (120.00 individuals/ha), *Symplocos recemosa* and *Dryptes indica* (80.00 individuals/ha), *Elaeocarpus rugosus* (53.33 individuals/ha). The total tree stem density was 1300 individuals/ha which was much higher than the range of 276-905 stems/ha reported by Murali et al. 21, Sundarapandian and Swamy 22, for the tropical forests. *Dipterocarpus retusus* has the highest frequency with 86.67, followed by *Helicia excelsa* (73.33), *Dryptes indica* (63.33), *Symplocos recemosa* (56.67), *Lithocarpus xylocarpus* and *Elaeocarpus rugosus* (50.00). However, the most abundant species was Lithocarpus xylocarpus (2.40) followed by *Helicia excelsa* (1.86), *Dipterocarpus retusus* (1.77), *Symplocos recemosa* (1.41), *Dryptes indica* (1.26). Important Value Index (IVI) was found highest in the *Dipterocarpus retusus* (42.88) and followed by *Quercus floribunda* (30.39), *Helicia excelsa* (22.10), *Lithocarpus xylocarpus* (22.00), *Symplocos recemosa* (17.18). The minimum Diversity, Frequency, Abundance and Important value index were found in *Aphananthe cuspidata*, *Carallia integenima*, *Eurya acuminata*, *E. japonica*, *Gracinia cowa*, *Mangifera sylvatica, Litsea monopetala*. The Density, Frequency, Abundance and Important Value Index of tree species were shown in table 1 and the tree species sequence curve is shown in figure 2.

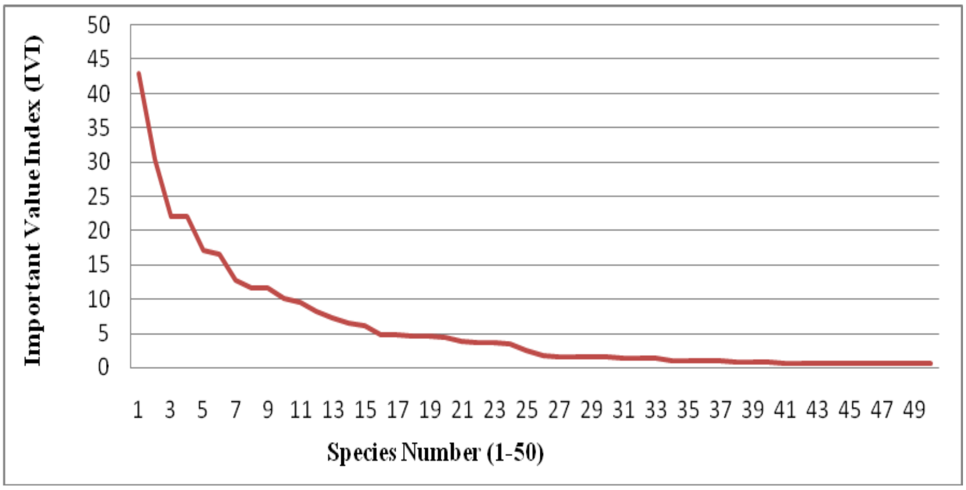

Figure 2: Tree species sequence curve

Shannon-Wiener's diversity index of tree species was found to be 3.22 which fall within the range of 0.83-4.0 reported by Singh et al. [23] for tropical forests. The Simpson index of diversity in the study area was found to be 0.94 which is the same value reported for tropical forests by Knight[24]. Evenness index was found to be 0.82 which falls within the range of 0.64-1.34 for tropical forests [25,26] and species richness of the site was found to be 8.21 which fall within the range 4.58-14.28 for the tropical forest reported by Lalchhuanawma and Lalramnghinglova [27]. The higher value of Simpson Index of Diversity (1-D) represents that there is a greater diversity of trees in the study area. The higher value of Evenness Index (J) shows that the community has a higher evenness and there is less degree of disturbance. The diversity indices of tree species are shown in Table 2.

Table 2: Phyto-sociological indices of trees in Hmuifang forest

Parameters	
Total Number of Tree Species	50
Tree Density (Individuals ha^{-1})	1300
Shannon Wiener's Diversity Index (H')	3.22
Simpson Index of Diversity (1-D)	0.94
Evenness Index (J)	0.82
Margalef's Species Richness (Dmg)	8.21

Above ground biomass (AGB)

Among the tree species found in the study area, Quercus floribunda shows the highest Above Ground Biomass (AGB) i.e. 206.15 t/ha and followed by *Dipterocarpus retusus* with 146.58 t/ha and *Lithocarpus xylocarpus* with 48.58 t/ha. In all the tree species found in the study area stem contributed the most amount of AGB and leaf contributed the smallest amount of AGB. A total of 634.64 t/ha aboveground biomass was recorded from the Hmuifang forest which was little higher than the AGB value of 607.7 t/ha of Western Ghats of India by Rai28 and Swamy29, respectively. The observed value of AGB in the present study is higher than the value reported by Baishya et al.30 i.e. 324 t/ha and Ramachandran et al.31 i.e. 307 t/ha for the tropical evergreen forests of the eastern coast of Tamil Nadu, India. Rabha et al.32 also reported a lower amount of biomass in Dipterocarpus forests of South Assam, northeast India i.e. 284.53 t/ha as compared to the present study.

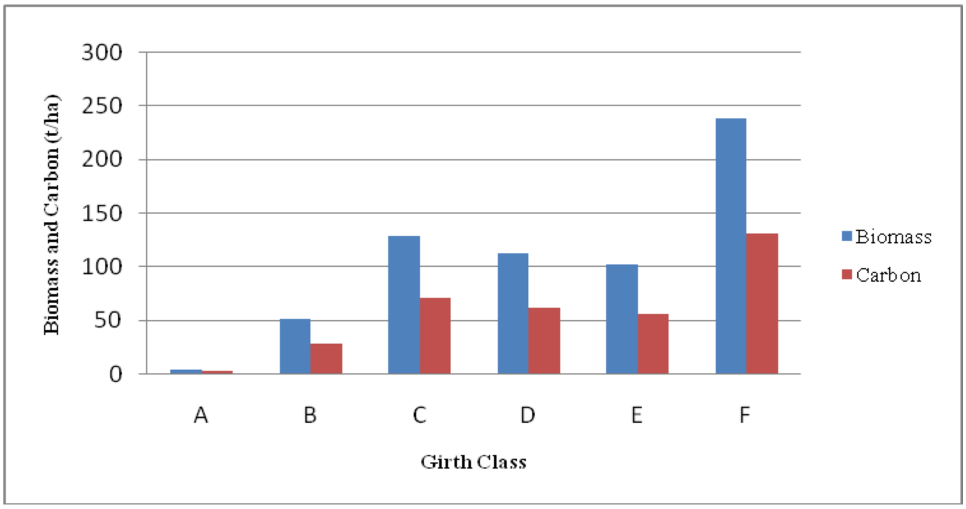

Figure 3: Girth Class Distribution of Biomass and Carbon (t/ha)

The Girth Class distribution of AGB is shown in figure 3. Among the tree species reported in the present study, the girth class F contributed maximum AGB (238.96 t/ha) but this class present a lesser number of individuals. The presence of higher AGB in this girth class is due to the presence of larger diameter mature trees. However, Pradhan et al.[33] reported that the girth class D store maximum biomass in the natural forest of Western Odisha. The girth class A has lesser number of individuals and contributes lesser AGB (3.30 t/ha) as compared to other girth classes.

Below Ground Biomass and Litter Biomass

It was observed that the below-ground biomass was found to be 139.40 t/ha which is higher than the reported value of 51.68 t/ha by Pradhan et al. 33. The litter biomass was found to be 1.79 t/ha.

Bulk Density and Soil Organic Carbon

The bulk density varies with the depth of the soil. It was found that as the depth increases the bulk density of the soil gradually increases, however, Rabha et al. [32] reported that the bulk density showed no significant difference between the soil depths. The mean Bulk Density value of the forest floor is 1.00 gm/cm^3 while the minimum is 0.65 gm/cm^3 at the topmost soil layer (0-10 cm) and the maximum is 1.35 gm/cm^3 at the depth of (30-40) cm. The Bulk density is gradually increasing with respect to soil depth and the difference in the bulk density implies that the organic matter present in 0-10 cm was more as compared to remaining depth classes of soil. The SOC content differs according to the depth. The total SOC of the forest soil is 41.85 tC/ha. The topsoil 0-10 cm contributes maximum SOC i.e., 18.28 tC/ha and 30-40 cm soil contributes the least amount of SOC i.e. 6.09 tC/ha. Rabha et al.[32] found that the soil organic carbon decreased with increasing soil depth. Our study also follows the same trend. The relation between the Soil Bulk Density and Soil Organic Carbon is shown in figure 4.

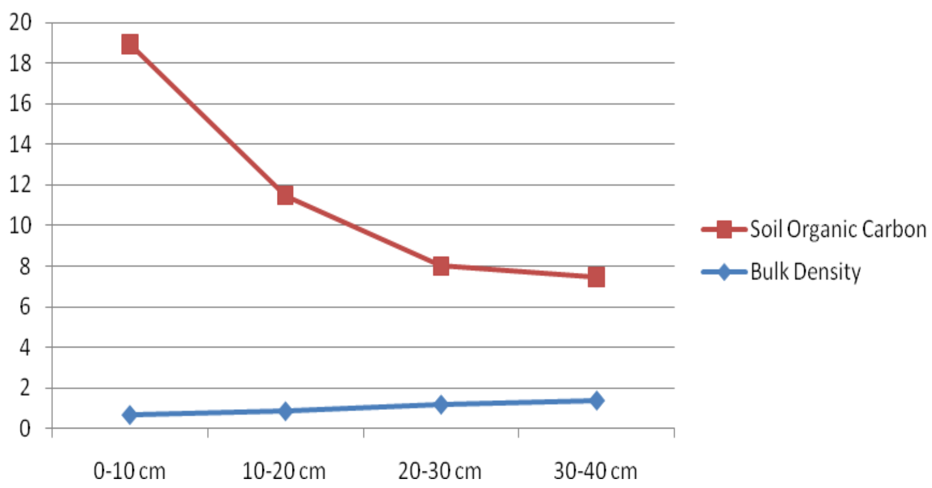

Figure 4: Relation between Bulk density and Soil organic carbon

Total Biomass and Carbon Stock in Hmuifang forest

It was found that the total biomass of 775.88 t/ha is stored by the trees of Hmuifang forest which was higher than the reported range 129-533 t/ha by Sharma et al.[34] in Garhwal Himalaya. The observed value in this study is also higher than the value reported i.e. 550 t/ha by Iverson et al.[35] in Peninsular Malaysia. Out of the total biomass, the above-ground biomass contributes 634.64 t/ha and the below-ground biomass contributes 139.40 t/ha. The litter biomass contributes the least among the pools with only 1.77 t/ha.

Table 3: Total Carbon Stock of Hmuifang forest

Carbon Pool	Carbon Distribution	Biomass t/ha	Carbon Stock t/ha
Above Ground Biomass (AGB)	Above Ground Tree Biomass (AGTB)	634.64	349.05
	Litter Biomass (LB)	1.79	0.69
	Total	**636.44**	**348.72**
Below Ground Carbon	Below Ground Biomass (BGB)	139.40	76.67
	Soil Organic Carbon (SOC)	-	41.85
	Total	**139.40**	**-**
Total Carbon Stock of Hmuifang Forest			**468.26**
CO_2 Sequestered by the Trees (CO_2e)			**1718.51**

The Total Carbon stock of the Hmuifang forest was found to be 468.26 tC/ha (Table: 3) which was very much higher than the range reported by Sharma et al.[34] i.e. 59-245 tC/ha Garhwal Himalaya. Xiao et al. [36] in Xishuangbanna, SW China also reported a lower tree carbon stock ranged from 163 to 258 t C/ha in the tropical forest of Asia as compared to the value found in the present study. Similar to the biomass distribution, the above ground contributes the majority of carbon stock i.e. 348.04 tC/ha which is higher than reported value of 142.26 t/ha by Rabha et al. [32] in Dipterocarpus forests of South Assam, northeast India. Below ground contributes 76.67 tC/ha which is lesser than AGB carbon stock. In Secondary Forest of Congo Ekoungoulou et al. [37] reported the carbon stock value higher in above ground biomass with 135.97 tC/ha as compared to below ground biomass with 31.95 tC/ha. The SOC stock in the present study is slightly lower than the range of 50-140 tC/ha reported by Powers and Schlesinger[38]. Devagiri et al. estimated the SOC stock as 75% of the total carbon stock but the present study represent lesser percentage of Carbon this is because in this study the soil samples are taken only up to 40 cm depth and it is recommended to study up to the depth of 1meter and the study should be conducted in another season also in order to estimate the precise Soil Organic Carbon stock of this forest[39]. From this study, it is found that the Hmuifang forest sequestered a total amount of 1718.51 t CO_2.

Conclusion

The Hmuifang forest has higher stem density and the stem portion of the trees contributes the highest amount of the Above Ground Biomass and Carbon, and Litter Biomass contributes the least. The SOC is found the maximum in the upper layer of soil and decreases as the depth decreases and the Bulk density increases as the depth increased. The biomass and carbon stock of the Hmuifang forest are significantly higher. The results of this research proved that Hmuifang forest has great potential of carbon storage in the biomass.

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