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Biomass estimation in plantation forests of Papum Pare district of Arunachal Pradesh, India

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ABSTRACT

Above ground biomass of the woody species is often considered to be one of the largest carbon pools. Hence, present study was carried out with aims to analyze the terrestrial AGB and BGB carbon and species composition in the plantation forests of *Gmelina arborea* and *Tectona grandis* of Papum Pare district of Arunachal Pradesh. Non-destructive sampling approach was adopted in the study. Species specific volume equation was used to estimate the biomass accumulation. Stand density of *Tectona grandis* was 813 stems/ha whereas it was 390 stems/ha for *G. arborea*. The basal area of *T. grandis* and *G. arborea* was 69.40 m^2 ha^{-1} and 48.79 m^2 ha^{-1}, respectively. The above ground biomass was estimated 269.65 t/ha for former stand and 206.03 t ha^{-1} for later stands. Below ground biomass was recorded 78.19 t/ha in the teak and 59.74 t ha^{-1} in the *G.arborea* plantation. The total above ground biomass carbon was 902.65 t/ha, below ground biomass was 261.74 t/ha and the total soil organic carbon was 246.20 t/ha. The total carbon calculated for the plantation forests including the SOC was 886.6 t/ha. The results showed a positive correlation (R^2=0.99) between the basal area and tree biomass of both the woody species. The present findings showed that *T. grandis* and *G. arborea* has significant carbon storage potential.

Keywords: Biomass carbon, Plantation forests, Regression equation, Stand density, Volume equations

1. INTRODUCTION

Tropical forests are storehouse of global biodiversity hotspots while equivalently exposed to severe habitat loss mainly conversions for other land uses Lewis et al. [1]. Myers et al. [2] have reported that about half of the terrestrial species were present in tropical forests. The largest carbon (C) inflow into forests occurs by the photosynthetic activity of trees hence of vital importance to C sequestration [3]. Forest growth, development and species composition potentially affect the C sequestration [4]. Various researchers have reported that biomass carbon of a - land cover is largely governed by age, diameter, species, environmental factors and disturbances [5, 6]. Carbon storage in forest biomass is an essential attribute of stable forest ecosystem and a key link in the global carbon cycle. Forests serve as source as well as sinks of greenhouse gases through alterations in carbon stocks of in the distribution of biomass [7, 8]. According to IPCC [8] forest ecosystem reserves about 80% of the above ground and 40% of below ground terrestrial organic carbon. Biomass and carbon storing ability of forest ecosystem act significantly in global carbon cycle [9, 10, 11] and is found to add more carbon per unit area than other terrestrial ecosystems [12]. Forests also act as an efficacious dimension to mitigate elevated CO_2 concentrations by flourishing forested land area [13]. Patterns of forest carbon storage naturally imitate both the prevalence of forest land and the density of forest growth. UNFCCC and Kyoto Protocol recognized the importance of forest ecosystem in regulation of the global carbon cycle and introduced the carbon forestry activities in the developing nations as a means to mitigate climate change and endorse sustainable development goals. Soil as a natural resource, occupies a central portion of any ecosystem, and sustains all life forms on the planet. In any ecosystem the soil, climate and living organisms interact with each other in a complex way. Quality of soils is indeed of paramount importance for conservation of biodiversity. The quality of soil includes a built in component, resulted by the soil physical and chemical properties within the constraints entrenched by climatic conditions and vegetation. Soil properties and processes reveal the ability of soil to function effectively as a component of a healthy ecosystem.

Forest plantations have noteworthy influence on global carbon sink [14, 15]. It has an adverse impact on biodiversity and ecosystem services. It has become an essential concern to calculate the carbon storage in the plantation species in consideration with its contribution in carbon credit during climate change negotiations. Assessing C stocks by species is a significant trend and should be studied to a greater extent. Previous species-specific biomass studies based on plantation ecosystems showed relatively positive findings. Protracted species such as *T. grandis* and *G. arborea* has prolonged carbon locking period compared to short duration species [16]. Carbon storage prospective of woody species befits significant in this respect.

The present study was being carried out to get the precise estimate of biomass accumulation in *T. grandis* and *G. arborea* generally planted in the study area. *T. grandis* is considered the gallant among all the woods not merely because of its golden tone and magnificent texture, but even more because of its resilience, asset, attractiveness, work ability and superior seasoning capacity [17]. *G. arborea* is one of the important medicinal plants most widely propagated and cultivated species. It is fast growing avenue tree that grows throughout India. Biomass assessment is thus important for development planning's as well as for precise studies of ecosystem efficiency, carbon budgets [18, 19, 20].

2. MATERIALS AND METHODS

2.1. *Study area*

This study was carried out in the plantation forests of Papum Pare district of Arunachal Pradesh, India. The district occupies an area of approximately 3,875 sq km. Study area embraces varied climatic zones, higher rainfall due to its location. Rainfall varies from 100 cm in higher reaches to 575 cm in the foothill areas spread over 8-9 months except in the drier days in winter. Forests form one distinctive biophysical environmental identity. Forest cover in the study area was 3233 sq. km which accounts about 93% of its total geographical area and of the total forest cover about 78% area was under dense forests [21]. Materials for this study were collected from private plantations in the district. Six plantation forests of both *T. grandis* and *G. arborea* were selected from different sites of the district (Figure. 1). Ground truth data were used to get a precise estimate of carbon stock in the woody species of the study area. A non-destructive sampling methodology was adopted to fold the ground truth data which was in the regular shape of dimensions 31.6m×31.6m for woody species, 5m×5m for shrubs and 1m×1m for herbaceous species.

2.2. *Soil analysis and biomass estimation*

Soil samples were collected in replicates from each of the selected plots using soil corer and brought to the laboratory for further analysis. Soil pH was determined electronically by a digital pH meter in 1: 2.5 suspension of fresh soil and distilled water [22]. Soil organic carbon was determined by rapid titration method [23]. Soil organic matter was calculated by multiplying the organic carbon content by 1.724 assuming that soil organic matter contains 58% carbon [24]. Bulk density was determined using the core method as described by Anderson and Ingram [23].

Above ground biomass for each woody species was calculated by considering plant with girth (gbh) of more than 10 cm. Diameter at breast height (dbh) 1.37 m from the base of the individual tree was measured using measuring tape while, height was measured using clinometer. The data thus collected were used for volume estimations using species-specific equation depending on the physiographic zone of current study area for each species following Forest Survey of India [25]. Tree biomass was estimated by multiplying volume with specific gravity. The specific gravity of particular species was obtained from Indian woods (FRI). Stand density was determined for each species using number of trees per hectare, and basal area of the species was also calculated per unit area. Biomass obtained from sampled plot (0.1 ha each) were further extrapolated for the area (t/ha). Aboveground biomass (AGB) carbon was calculated by assuming that the carbon content is 55% of the total aboveground biomass [26] which is a representative of the average carbon content in tree biomass. Below ground biomass (BGB) was estimated by multiplying the factor 0.29 with corresponding AGB value. Above ground biomass for each shrubs and herbs species was calculated by laying quadrats of size 5m×5m and 1m×1m. Complete harvesting of shrubs and herbs was done for the species present in all quadrats. Fresh and dry weights for all the species harvested were measured for the biomass estimation. The values than were multiplied by the expansion factor to scale them for 1 hectare area.

3. RESULTS

3.1. Floristic and soil characteristics

In the *Tectona grandis* plantation forest, *T. grandis* showed the maximum density (813 stems ha^{-1}) followed by *Ficus hispida*, *Dillenia indica*, *Glochidion superbum*, *Cinnamomum tamala*, *Antidesma ghaesembilla*. In the *Gmelina arborea* plantation forest, *G. arborea* showed the maximum density (390 stems ha^{-1}) followed by *Bischofia javanica*, *Bauhinia variegata*, *Bombax ceiba*, *Ficus religiosa*, *Lagestromia speciosa*. It was observed that diameter (dbh) and height of *T. grandis* varied from 60 cm to 235 cm and 10 m to 35 m, respectively, however; for *G. arborea* it varied from 30cm to 260 cm and 7m to 27m, respectively. The dbh and height of the associated species in the former plantation forest varied from 9.54 cm to 38.19 cm and 8 m to 32 m. The dbh and height of the later plantation varied from 30 cm to 900 cm and 10 m to 48 m. Total basal area of plantation forests ranges from 40.22 m^2 ha^{-1} to100.3 m^2 ha^{-1} of which basal area of *T grandis* was 69.4 m^2/ha and for *G. arborea* it was 48.7 m^2/ha.

Soil was loamy sand in *T. grandis* plantation while it was loamy for soil of *G. arborea* plantation. The mean bulk density of former plantation ranges from 1.57-1.85 g/cc while it was recorded 1.79-1.80 g/cc in the later plantation site. The bulk density values were found to be increasing with increase in soil depth. Soil was acidic in nature and mean pH in Teak sites ranges from 4.81-5.64 whereas it was recorded 4.70-5.94 in the later plantation area. Soil organic carbon (SOC) ranges between 1.57 % and 1.64% in the *T. grandis* plantation with the total SOC estimate of 125.38 t/ha. However, it ranges from 1.42% to 1.61% in the *G. arborea* plantation with estimated total soil organic carbon of 120.825 t/ha. The SOM concentrations also followed the similar trend to that of SOC among the selected sites and soil depth (Table 1).

3.2 Standing biomass

For understanding the role of selected species in C storage apart from other utilities in global C cycle, precise estimate of biomass is required. Above (269.65 t ha^{-1}) and below ground biomass (78.19 t ha^{-1}) of *T. grandis* was estimated while it was estimated to be 206.03 t/ ha and 59.748 t/ ha, respectively for *G. arborea*. Total biomass was calculated by summing the above ground biomass and below ground biomass of the species. Total biomass of the *T. grandis* plantation site was estimated 347.84 t/ ha while for *G. arborea* plantation was 265.77 t/ha. Both the selected species showed significant positive correlation (R^2 =0.99) between total biomass and basal area. The specific gravity and volume equations used to calculate the biomass of woody species were presented in Table 2. AGB contribution by the associated trees like *Antidesma ghaesembilla* (1.57 t/ha), *Cinnamomum tamala* (0.35 t/ha), *Dillenia indica* (7.44 t/ha), *Ficus hispida* (1.88 t/ha), *Glochidion superbum* (1.36 t/ha) were also estimated in Teak plantation. *Bischofia javanica* (20.51 t/ha), *Bauhinia variegata* (0.82 t/ha), *Bombax ceiba* (0.80 t/ha), *Ficus religiosa* (0.38 t/ha), *Lagestromia speciosa* (1.77 t/ha) were the associated AGB contributing species of *Gmelina* plantation. The BGB was also estimated using conversion factor. The AGB and BGB of shrub species were 5.67 t/ha and 1.64 t/ha, respectively while it was 0.81 t/ha and 0.23 t/ha for the herbaceous species. Total shrub biomass was recorded 7.31 t/ha and was 1.04 t/ha for herbaceous species. The total understory biomass (shrubs+herbs) was 8.35 t/ha with total biomass carbon of 4.59 t/ha.

Total biomass of plantation forests was estimated to be 1164 t/ha, it was calculated as the sum of selected species, associated species including shrubs and herbs biomass and SOC. SOC contributed about 17% of the total carbon recorded from plantation forests. Biomass contribution by the selected species was 613.61 t/ha and 542.43 t/ha by the associated trees, 7.31 t/ha from shrubs and 1.04 t/ha from herbs. Per cent contribution of selected species of the total biomass was maximum (64 %) followed by associated species (19 %). Total calculated carbon of the plantation forest was 886.6 t/ha of which 72% was contributed by the biomass carbon and 28% by the soil organic carbon.

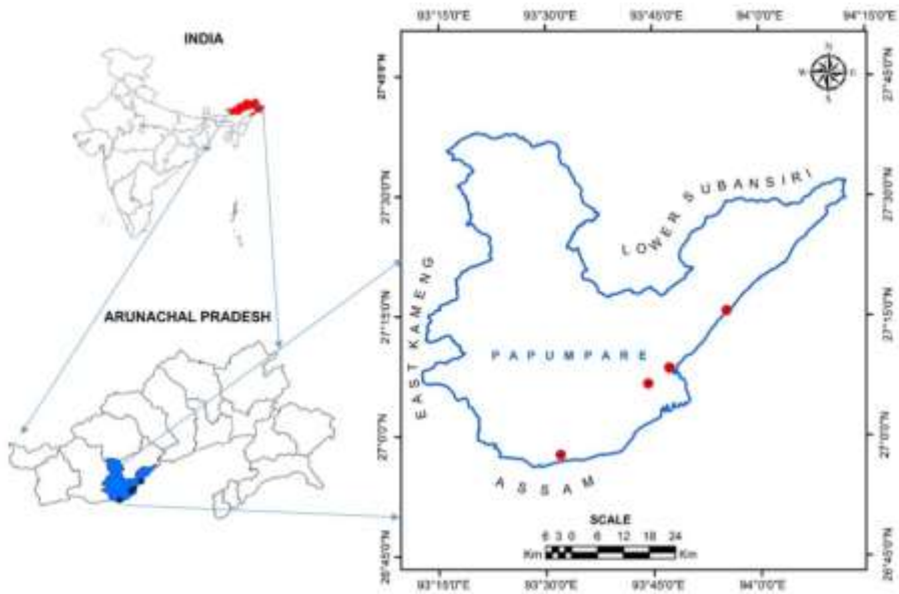

Figure 1. Location of study area.

Table 1. Soil characteristics measured at the *T. grandis* and *G. arborea* plantation forest

Parameters	***Tectona grandis***			***Gmelina arborea***		
Depth	**0-15 cm**	**15-30 cm**	**30-45cm**	**0-15 cm**	**15-30 cm**	**30-45cm**
pH	5.844±0.124	5.50±0.155	5.272±0.310	6.08±0.1401	5.668±0.077	4.728±0.038
	5.518±0.071	4.9±0.216	4.782±0.260	6.02±0.198	5.472±0.568	4.684±0.153
	5.584±0.066	4.874±0.228	4.692±0.142	5.74±0.196	5.14±0.139	4.69±1.003
Bulk density	1.88±0.010	1.648±0.006	1.82±0.007	1.81±0.010	1.83±0.008	1.79±0.124
	1.858±0.003	1.54±0.023	1.758±0.006	1.796±0.023	1.786±0.023	1.812±0.018
	1.828±0.003	1.536±0.005	1.70±0.016	1.774±0.046	1.764±0.030	1.808v0.007
SOC (%)	1.646±0.005	1.69±0.004	1.606±0.005	1.682±0.024	1.594±0.020	1.528±0.006
	1.708±0.005	1.638±0.005	1.578±0.003	1.592±0.005	1.416±0.007	1.38±0.012
	1.604±0.023	1.602±0.010	1.544±0.005	1.562±0.003	1.412±0.005	1.378±0.004
SOM (%)	2.837±0.008	2.913±0.007	2.768±0.008	2.899±0.041	2.748±0.035	2.634±0.011
	2.944±0.010	2.823±0.010	2.720±0.006	2.744±0.006	2.441±0.012	2.379±0.021
	2.765±0.023	1.602±0.010	1.544±0.005	2.692±0.006	2.434±0.010	2.375±0.008

Table 2. Allometric equations and specific gravity used for woody species in present study

Woody species	Volume equation	Specific gravity
Tectona grandis	SQRTV=-0.07109+2.99732*D-0.26953*SQRTD	0.55
Gmelina arborea	V=0.25058-3.55124*D+16.4172*D^2-8.32129*D^3	0.44
Antidesma ghaesembilla	V=0.15958-1.57976*D+8.25014*D^2-0.48518*D^3	0.48
Cinnamomum tamala	V=0.1097-0.88668*D+6.097*D^2-1.62672*D^3	0.44
Dilenia indica	V=0.15958-1.57976*D+8.25014*D^2-0.48518*D^3	0.53
Ficus hispida	SQRTV=0.03629+3.95389*D-0.84421*SQRTD	0.39
Glochidion superbum	V=0.15958-1.57976*D+8.25014*D^2-0.48518*D^3	0.48
Bauhinia variegata	SQRTV=-0.07109+2.99732*D-0.26953*SQRTD	0.67
Bischofia javanica	V=0.25771-2.33118*D+11.12071*D^2	0.50
Bombax ceiba	V=-0.10513+0.28329*D+6.11575*D^2	0.32
Ficus religiosa	SQRTV=0.03629+3.95389*D-0.84421*SQRTD	0.39
Lagestromia speciosa	V=0.1174-1.58941*D+9.76464*D^2	0.51

Table 3: Total biomass (t/ha) of *Tectona grandis* and *Gmelina arborea* plantation forest in Papum Pare district.

Carbon pool	Components				Total biomass	Total carbon
	Selected trees	Associated trees	Shrubs	Herbs		
AGB	475.68	420.49	5.67	0.81	902.65	496.45
BGB	137.93	121.94	1.64	0.23	261.74	143.95
SOC	246.20				246.20	246.20
Total	613.61	542.43	7.31	1.04	1410.59	886.6

4. DISCUSSION

The determined values of soil physico-chemical properties showed the textural class of the soil of the *T. grandis* and *G. arborea* were loamy to loamy sand. The bulk density of both the plantations was found to highest in the surface layer. Variation in soil bulk density along the depth could be associated with the existence of soil organic matter accumulation and low deforestation in the study site. The soil were found to be acidic in nature which could be attributed due to leaching of appreciable amounts of exchangeable bases from the soils due to high precipitation and decomposition of organic and inorganic acid. SOC percentage was found to be decreasing with increase in soil depth and higher organic carbon in the surface layer might be due to the rapid decomposition of litter in a favorable climatic circumstance. Jobaggy [27] reported that this trend of decrease in increase with depth might be also due to the increase ratio of slow cycling of SOC pools at depth. High organic matter accumulation in the present study might be due to the quality and quantity of biomass.

Basal area was usually assumed as indicators for predicting the C stock. Holland et al. [28] recommended a range of 9.18 m^2 ha^{-1} to 22.96 m^2 ha^{-1} as the proper basal area level per hectare. In the present study the basal area resulted a strong correlation with total biomass, it showed that the *G. arborea* plot with a basal area of 4.87 m^2 ha^{-1} while *T. grandis* plot with a basal area of 6.94 m^2 ha^{-1} was slightly lower than the values reported by Holland et al. [28] which might be due to the variations in dbh of the species and stem area occupied. Huy and Anh [29] reported that the higher absorption of C as biomass depends on the species, dbh and height but they did not consider the role of wood density and basal area in terms of their effect on carbon stock for the specific forest type. The stand density was found highest for *T. grandis* whereas it was quietly low in case of *G. arborea* .Stand density is used as an index of level of disturbances. Since, the present study was carried out in plantation forests hence the disturbance is negligible but the spacing in between the species might be the reason for higher stand density.

In the present study the biomass accumulation was found highest in *Tectona grandis* than *Gmelina arborea*. Jha [30] had reported that the *T. grandis* is neither nutrient demanding nor nutrient conserving species however, it produces considerably higher biomass at a very young age. Total above ground biomass recorded for *T .grandis* plantation was quite higher than the reported value (138 Mg ha^{-1}) from Tripura [31]. However, it was found lower than (378 Mg ha-1) from south western Nigeria [32]. Many researchers reported that per hectare biomass production of tropical forest plantations (*T. grandis* and *G.arborea*) increases with increase in precipitation [33, 34, 35]. Above ground biomass was recorded between 11.34 t/ha [36] and 76.95 t/ha [35] from tropical dry deciduous teak plantations which was very low in comparison to the present findings. The biomass (127 t ha^{-1}) value of *G.arborea* reported by Jose and Scarlet [37] from the plantation forests of Philippines and 11.8 t/ha by Lugo et al. [33] was found to be lower than the present findings. Naugraiya and Puri [38] had reported that biomass and carbon storage potential of *G.arborea* is relatively much better than many other indigenous species. Both the species in terms of biomass accumulation were proved as effective and hence enhance the carbon storage potential [39, 40, 41].

5. CONCLUSION

Plantations or naturally rejuvenated trees can safeguard against famines, flash floods or landslides assumed to be more widespread due to climate change. Species richness was slightly more in Teak as compared to *Gmelina* plantations. Stand density of *T. grandis* and *G. arborea* plantations were 813 stems ha^{-1} and 390 stems ha^{-1}, respectively with basal area of 69.4 m^2 ha^{-1} and 48.7 m^2 ha^{-1}. Soil was loamy to loamy sand and acidic in nature. Concentration of SOC and SOM was more in *Gmelina* plantation. Precise estimate of biomass is required for understanding the role of selected species in C storage hence present study was undertaken. Total biomass, AGB and BGB stocks were greater in Teak plantation. Both the species showed significant positive correlation between total biomass and basal area. Biomass and carbon contribution of the total by the associated species including herbs and shrubs were least (19%) however in both the plantation sites. Total carbon sequestered in the plantation forests including SOC was 886.6 t/ha. These findings will provide relevant data on biomass and carbon accumulation in the plantation forests of *Tectona grandis* and *Gmelina arborea* and will also serve as a scientific basis for sustainable practices to mitigate the atmospheric CO_2 concentrations apart from conservation and utilization of other ecosystem services.

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Conflicts of Interest

There are no conflicts of interest.

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