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Aboveground Woody Biomass, Carbon Stocks Potential in Selected Tropical Forest Patches of Tripura, Northeast India

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Abstract

To estimate woody plant biomass stocks in different patches of forest ecosystems, total 20, 500 × 10 m (0.5 ha) sized line transects were laid in a protected area of Tripura, Northeast India. Overall, 9160 individuals were measured at ≥10 cm diameter at breast height (dbh) in 10 ha sampled area. Estimation of biomass suggested that highest coefficient for allometric relationships between density and biomass in 10 dbh classes was observed in bamboo brakes ($R^2 = 0.90$) than lowest for semi evergreen patch ($R^2 = 0.48$). The stock of carbon (C) was differ significantly along the forest patches ($F = 7.01$, $df = 3.19$; $p < 0.01$). Most of biomass stock (69.38%) was accumulated in lower dbh class (<30 cm) and only 23% of biomass was estimated at higher dbh classes (> 70 cm). Range of biomass stock (37.85 - 85.58 Mg ha^{-1}) was low, compared to other tropical forest ecosystems in India, which implies that the proper management is required to monitor regional ecosystem C pool.

Keywords

Woody Biomass, Potential Carbon Storage, Tropical Forest Patches, Tripura

1. Introduction

World wide tropical forests are accounts about 40% of the total carbon (C) storage as terrestrial biomass [1] and, thus playing a fundamental role in the global C cycle [2]. Spatial distribution of tropical forest biomass is influenced by a range of climatic, edaphic and anthropogenic factors [2]. Out of total C stored in ecosystem *ca.*90% loses are due to loss of living biomass, an indicator of ecosystem services [1] [3]. In fact, C emissions from deforestation and forest degradation are one of the most important challenges for global climate change and mitigation of greenhouse gasses [4]. Quantification of biomass, C and its distributions, even in local forest ecosystems comprises the significant parts of global C budget; and, thus important component of the basis for predicting future climate change [4]. To better understand the climate change and its impacts, information on fragmented forest patch, their biomass and C storage is still needed at regional and local scales [4] [5]. Given the high rate of deforestation in tropical forest and the limited extent of old growth tropical forests [4] [6] [7], determination of above-ground biomass (AGB) and C stocks in the remaining forest patches are the important concerns and priorities for most of the ecologist.

According to Ramachandra & Shwetamala (2012) [8], forest biomass contributing 74% of total C in India; and annually, 7.35% of total C emissions get stored in either forest biomass or in soil. During 1995-2005, C stocks in forest vegetation have increased from 6245 - 6662 mt, registering an annual increment of 38 mt of C or 138 mt of equivalent CO_2; which recorded that forests have neutralized about 11.25% of total CO_2 equivalent greenhouse gas emission [9]. In Northeast India, numerous experiments have quantified forest biomass structure and C stock in different forest ecosystems [10]-[13]. However, it is widely recognized that Northeast India represents several virgin, natural, semi-natural and modified ecosystems due to greater variation in physiographic, climatic, edaphic and anthropogenic factors [14]. Tripura is the second smallest state of Northeast India, the estimation of biomass and C stock for Tripura was investigated [15] [16]. In 2010, Forest survey of India (FSI) has completed estimation of forest carbon stock and change between two time period viz1994 and 2004 as part of Second National Communication [17]. Forest fragmentation followed by high anthropogenic pressure typically affected the forest characteristics and thereby reduced Caccumulation rate [18] [19]. Since the time of earlier studies, land degradation and habitat modification have resulted serious loss of biomass stocked in this region. Tree composition and structure are the important predictive variable when estimating AGB [20]. Since forest structure and biomass are known to vary along different environmental gradients, including forest types and communities [20]; and, even along the successional gradients [21]. We hypothesized that, stand density should decrease from early to late successional stages; biomass and C storage should increase from early to late stages. We also hypothesized that understanding tree age class variables are also crucial to know the differences in biomass and C stock across a successional gradient. Despite these results, C stock has yet to be studied or quantified form wide landscape levels and to be incorporated in global C estimation, especially across relatively less studied tropical moist deciduous forest ecosystem. Hence, there was a need to estimate biomass and C storage for better understanding of local forest ecosystem dynamics. Thus, overall objective of this study was set to 1) quantify first structure of woody species along different tropical moist forest patches, to 2) estimate biomass and Cstocks in different forest patches and to 3) observe how above-ground biomass and density vary from semi evergreen forest to moist deciduous vegetation patches along different age classes.

2. Material and Methods

2.1. Study Area

We conducted our field studies in Tripura, which is the second smallest state of North-east India with total 10,491 km^2 geographical area. This sanctuary covers total 194.704 km^2 geographical area located between 23˚05'N - 23˚25'N, and 91˚20'E - 91˚35'E (**Figure 1**), which was notified in November 1988, with total 27 revenue Mouza of Belonia, Udaipur and Sonamura Civil sub-division of South Tripura District. As per the Champion and Seth (1968) [22] classification system forest types of the sanctuary mainly consists of: 1) Cachar Tropical Semi Evergreen Forest 2) East Himayan lower Bhabhar

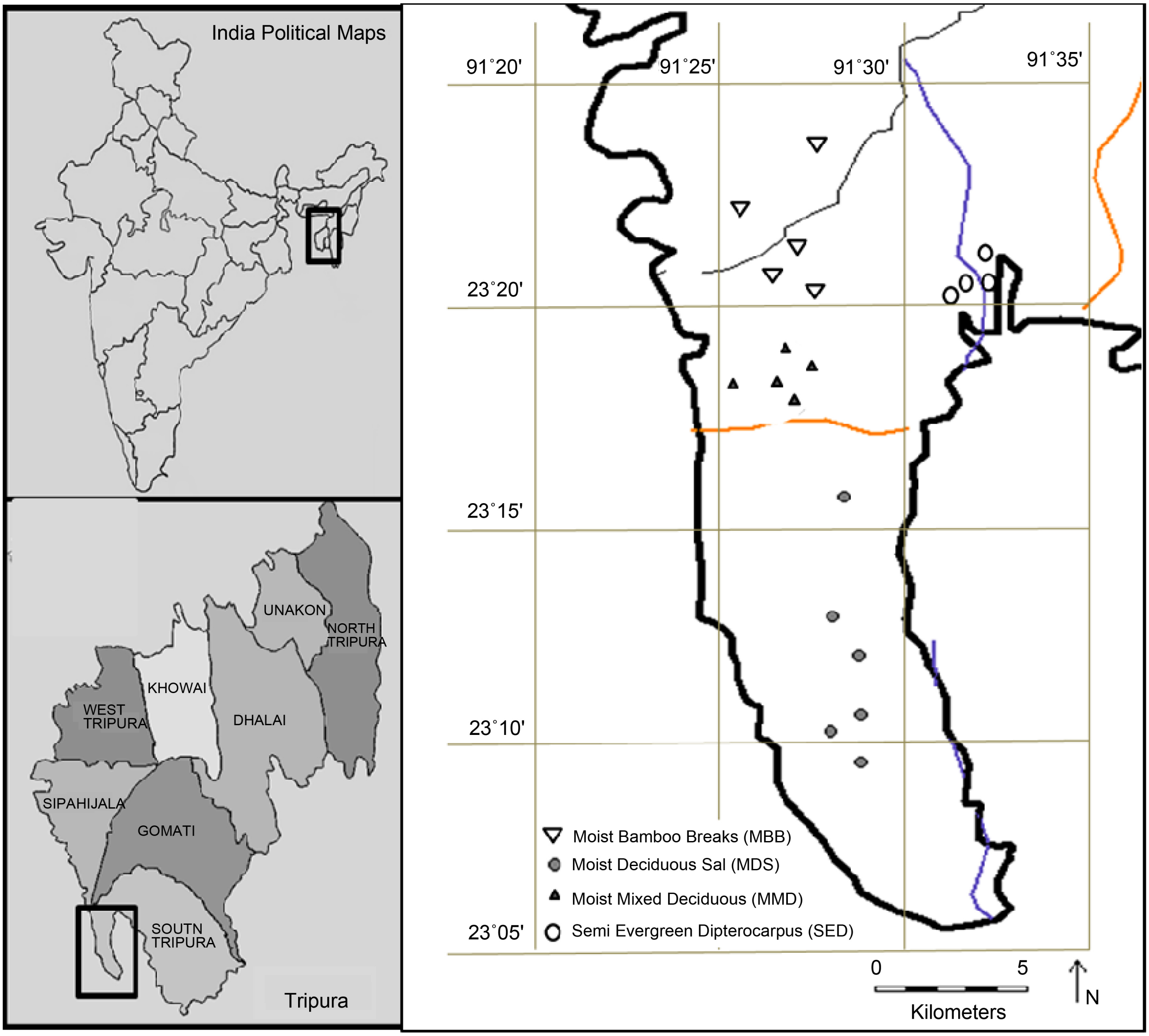


Figure 1. Location of the study area and sampling points in TWS.

Moist Deciduous Sal Forest, 3) Moist Mixed Deciduous Forest, 4) Moist Bamboo Brakes and 5) Savanah Wood Land [23]. The elevation of the study sites ranges between 17 m to 83 m above mean sea level. The climate of this area is generally moist and humid. The minimum and maximum temperatures in summer are 21˚C and 38˚C. In winter it ranges between 4˚C and 33˚C. Humidity is generally high throughout the year. In the summer season the relative humidity differs between 50% - 74% whereas in the rainy season it is over 85%. The mean wind speed is 7.1 km/hr, with maximum of 13.1 km/h in May and minimum of 3 km/h in December. The mean annual rainfall varies between 192 - 285 cm and increased from Southwest to Northeast. The soil type of the study area is mainly red loam and sandy loam soils.

2.2. Field Data Collection

Vegetation inventories data were collected during 2010 to 2011 by 20 line transects. Line transects were placed randomly in different forest patches in Trishna Wildlife Sanctuary. The successional gradients were identified visually following the characteristics drawn by Champion and Seth (1968) [22]. Out of 20 transects, 5 transects represents Moist Bamboo Brakes (MBB) dominated by *Bambusa tulda*, 6 transects from Moist Deciduous Sal (MDS) patch dominated by *Shorea robusta*, 5 transects represents Moist Mixed Deciduous (MMD) patch dominated by *Schima wallichii* and 4 transects from Semi Evergreen Dipterocarpus (SED) patches dominated by *Dipterocarpus turbinatus.* All woody individuals at ≥10 cm girth at breast height (gbh), at 1.3 m height were measured in 10 m wide and 500 m length transects. Thus, each line transect represented an area of 0.5 ha (10 × 500 m) and encompassed 5 (10 × 100 m) contiguous sub-plots. Specimens were identified with the help of The Flora of Tripura State [24]. The reference herbarium was deposited in herbarium of Botany Department; Tripura University. Information about individual species, their status including their herbarium voucher number recorded from the study site is available in a separate publication [23].

2.3. Data Analysis

Field data were quantitatively analysed on per hectare basis for density and basal area [25]. For estimation of woody Above Ground Biomass (AGB), regression model was used proposed by Brown *et al.* (1989) [26] due to relatively similar climatic condition of the study area (rainfall 150 - 400 cm range per year): AGB per woody species in kg (Y) = 42.69 − 12.800 (dbh) + 1.242 (dbh^2) was and presented into S I unit (AGB Mg ha^{-1}). Where, DBH ranges between 5 - 148 cm, number of sampled tree was 170 and regression coefficient (R^2) = 0.84 [26]. Moist deciduous forest frequently dominated several bamboo species. Since, present study area was found to be dominate by *Bambusa tulda;* we used separate equation for biomass estimation of bamboo species [27], W = a dbh^b. Where, W= weight of bamboo culm in kg, dbh = diameter at breast height, allometric values for a = 0.141 and b = 2.48 with regression coefficient (R^2) = 0.973 [27]. The estimation of Cstocks (C Mg ha^{-1}) was calculated as 50% of the total biomass; since, C content in plant tissue is approximately half of the dry weight of aboveground live biomass [4] [6]. The significance of differences in forest structural variables among the patches was statistically tested using one–way analysis of variance (ANOVA) and Tukey's test.

To compare the size-class distributions of biomass storage in each forest patches, we plotted AGB and C Mg ha^{-1} along ten gbh classes (>10, 10.1 - 20, 20.1 - 30, 30.1 - 40, 40.1 - 50, 50.1 - 60, 60.1 - 70, 70.1 - 80, 80.1 - 90 and >90 cm). The relationship between AGB Mg ha^{-1} (y) and density ha^{-1} (x) along teng bh classes in four different forest patches were examined and compared by linear curve fitting. The statistical analysis was performed by PAST version 1.89 [28].

3. Results and Discussion

3.1. Woody Vegetation Structure

Stem density was recorded highest for MBB (1088.4 ± 96.15 ha^{-1}) and lowest in case of SED (701 ± 45.79 ha^{-1}). However, density of stems was found varied significantly (F = 4.20, df = 3.19; p = 0.02) within the forest patches. Basal area at the study sites ranged between 8.91 ± 1.39 m^2 ha^{-1} (MMD)to 33.69 ± 8.76 m^2 ha^{-1} (SED), followed by 9.17 ± 1.24 m^2 ha^{-1} in MBB and 9.05 ± 1.60 m^2 ha^{-1} in MDS. Basal area also significantly varied (F = 10.04, df = 3.19; p < 0.001) among the patches. Mean stem dbh was significantly high in SED (50.56 ± 2.77 cm) than other patches (F = 25.88, df = 3.19; p < 0.001). Even, mean canopy height (m) was also recorded high in SED (9.28 ± 0.97 m) and found significantly differed among the forest patches (F = 12.71, df = 3.19; p < 0.001) (Table 1).

Highest stem density in MBB might be due to high abundance of *Bambusa tulda* (density ha^{-1}); which is locally adaptive and ecologically dominated species, facilitated

Table 1. Woody species structural variables (Mean ± SE) along forest patches in TWS. Variations are analyzed by ANOVA (degree of freedom 3, 19).

Forest ecosystems	Moist Bamboo Breaks (MBB)	Moist Deciduous Sal (MDS)	Moist Mixed Deciduous (MMD)	Semi Evergreen Dipterocarpus (SED)	ANOVA	
					F-value	*p*-value
Structural variables						
Density (ha^{-1})	1088.4 ± 96.15	957.60 ± 83.64	853.2 ± 75.93	701 ± 45.79	4.20	0.02
Basal area (m^2 ha^{-1})	9.17 ± 1.24	9.05 ± 1.60	8.91 ± 1.39	33.69 ± 8.76	10.04	0.0006
Avg. stem diameter (cm)	26.36 ± 1.09	29.81 ± 1.84	29.66 ± 2.51	50.56 ± 2.77	25.88	0.0002
Avg. canopy height (m)	8.91 ± 0.91	4.73 ± 0.25	5.79 ± 0.38	9.28 ± 0.97	12.72	0.0001
Above Ground Biomass (Mg ha^{-1})	41.84 ± 2.94	42.26 ± 5.91	37.85 ± 4.02	85.59 ± 17.76	7.01	0.003
Above Ground Carbon (Mg ha^{-1})	20.92 ± 1.47	20.38 ± 2.52	18.93 ± 2.01	42.80 ± 8.88	7.01	0.003

with high regeneration abilities and greater growth rate [29]. Even, high growth trait of bamboo can fix atmospheric C faster than similar dbh sized of a tree. In fact, *Bambusa tulda* have the potentiality to shift the present forest under bamboo controlled retrogression stage. Usually, there is a high density of stems with low dbh in early and intermediate stages (e.g. MMD and MBB patches), and as dbh increases with successional trend, stem density decreases in late stage (SED patch). Negi *et al.* (2003) [30] observed that the tree types have maximum C stored in the order conifers > deciduous > evergreen > bamboos. Instead of low stem density in SED patch (701 ± 45.79 ha^{-1}), basal area was significantly high (33.69 ± 8.76 m^2 ha^{-1}) due to presence of voluminous *Dipterocarpus turbinatus* as the representative of late successional stage. Nevertheless, forest structure changed along the successional gradient according to the general pattern of secondary succession with a gradual increase in height and basal area as described for tropical forests. In addition, *Shorea robusta* and *Dipterocarpus turbinatus* locally possess good natural regeneration trait and fast growing ability [31]. Therefore, these species came out as significant C sequester in this region and long term monitoring of C dynamics in those forests are possible through timescale observation on these two key dominated species. We also predicted that, significant differences in species composition and dominant trends may influence the biomass and C stock in each forest patch through control over water availability, litter and debris deposition, composition and quantity of root exudates and the distribution of C in the soil profile.

3.2. Status of Biomass and C Stocks along the Forest Patches

The value of AGB in the whole study area, ranged between 20.86 Mg ha^{-1} (MDS) to 126.37 Mg ha^{-1} (SED). However, mean AGB was significantly greater ($F = 7.01$, df = 3.19; $p < 0.01$) in SED (85.59 ± 17.76 Mg ha^{-1}) than recorded minimum value (37.85 ± 4.02 Mg ha^{-1}) in case of MMD. Highest contributor of AGC stock was SED patch (35.13 ± 8.88 Mg ha^{-1}) followed by MBB (22.08 ± 2.60 Mg ha^{-1}), MDS (19.11 ± 2.39 Mg ha^{-1}) and MMD (18.92 ± 2.01 Mg ha^{-1}), which also found significantly varied among the different patches ($F = 7.01$, df = 3.19; $p < 0.01$) (Table 2). In MBB patch, *Bambusa tulda* contributed about 35.5% (14.46 Mg ha^{-1}) of total biomass. Other dominant tree shared less than 10% of total biomass *i.e.* *Schima wallichii* (9.21% or 3.86 Mg ha^{-1}); *Terminalia bellirica* (6.55% or 2.72 Mg ha^{-1}); *Microcos peniculata* (4% or 1.68 Mg ha^{-1}) and *Lannea coromandellica* (2.62% or 1.10 Mg ha^{-1}). In MDS patch, *Shorea robusta* was the highest contributor and shared about 56.33% (23.81 Mg ha^{-1}) of total biomass followed by *Dipterocarpus turbunatus* 6.09% (2.58 Mg ha^{-1}), *Schima wallichii* 3.33% (1.41% Mg ha^{-1}), *Terminalia bellirica* 3.13% (1.33 Mg ha^{-1}) and *Microcos peniculata* 2.14% (0.91 Mg ha^{-1}). Among the present studied forest patches, most common dominant species was *Schima wallichii* and it contributed about 8.1% (16.63 Mg ha^{-1}) of the total biomass of the study area. Overall, the highest contributor was *Dipterocarpus turbinatus,* it shared about 22.34% (46.38 Mg ha^{-1}) of total biomass (Table 2). In the present estimation of total biomass, 70% was stocked at <30 cm dbh class; which indicated sufficient amount of young stems or maximum number of trees could not attained full maturity in those

Table 2. Above ground biomass and carbon contribution by top five dominant species along forest patches in TWS.

Species	Above Ground Biomass/Above Ground Carbon (Mg ha^{-1})			
	MBB	MDS	MMD	SED
Aporosa octandra	-	-	1.45/0.72	-
Bambusa tulda	14.46/7.23	-	-	-
Careya arborea	-	-	1.29/0.65	-
Castanopsis indica	-	-	-	2.06/1.03
Dipterocarpus turbinatus	-	2.58/1.29	-	43.80/21.90
Ficus religiosa	-	-	-	2.09/1.04
Holarrhena pubescens	-	-	1.10/0.55	-
Lannea coromandelica	1.10/0.55	-	-	-
Microcos paniculata	1.68/0.84	0.91/0.45	-	2.55/1.27
Schima wallichii	3.86/1.93	1.41/0.71	1.88/0.94	9.49/4.74
Shorea robusta	-	23.81/11.90	-	-
Terminalia bellirica	2.72/1.36	1.33/0.66	2.24/1.12	-
Sum of 5 most dominant	23.81/11.90	30.03/15.01	7.96/3.98	59.98/29.99
Rest other species	17.67/8.83	12.23/6.12	29.89/14.95	25.61/12.80
Total	**41.48/20.74**	**42.26/21.13**	**37.85/18.93**	**85.59/42.80**

forest patches, possibly these forest patches were recovering from significant historic disturbances. Being as early and intermediated stages MMD and MBB patches (37.85 and 41.84 Mg ha^{-1}) recover much biomass compared to MDS patch (42.26 ± 5.91 Mg ha^{-1}). This may due to the changes in forest composition and structure during succession, occurred at very different rates; and biomass generally recovers more rapidly than species richness [8] [11] [12]. About 40% tree species contributed >70% of total biomass in dry deciduous forest [26] [27]. In the present moist deciduous forest patches, five most dominant species contributed 57.41% of biomass in MBB, 70.06% in MDS, 21.02% in MMD and 70.08% in SED. Out of 5 most dominated species in all forest patches, the top dominant species contributed 34.85% biomass (*Bambusa tulda*) in MBB, *Shorea robusta* had 56.34% biomass in MDS, *Terminalia bellirica* had 5.92% in MMD and *Dipterocarpus turbinatus* contributed 51.18% biomass in SED (Table 2). Both SED and MSD forests were came out as more mature or late successional phase than other patches and might preserve much more C and also responsible for greater C management. Further, AGB recorded in the present study ranged from 20.86 Mg ha^{-1} to 126.37 Mg ha^{-1} also fall within the range of the earlier study from the area [15]-[17], which was found less than AGB value of Central Himalaya (171.9 - 380.3 Mg ha^{-1}) [32], Western Ghats (468 - 607.7 Mg ha^{-1}) [33] and in Eastern Ghats (15.61 - 597.13 Mg ha^{-1}) [34]. Present AGB value was found close to other reported value of biomass in north-east India viz. Meghalaya, Assam and Manipur [10]-[12].

Estimation of live tree biomass is very crucial for an ecosystem, especially to understand overall ecosystem health and services including the hydrological cycle, soil erosion, nutrient cycling and dynamics of terrestrial C [3] [5] [6]. Although, our biomass and C stock means were statistically different, which suggested there was considerable variation in stand structure across the forest patches. The biomass contrast of five top most dominant trees was consistent with diversity and structural complexity. For instance, basal area, density of voluminous trees and diameter were found greater in late successional forest patch (SED) than the patches at early stages, and thereby represented higher quantity of biomass and C stocks (**Table 1**). Results also suggest that key dominant trees make a proportionately greater contribution to total biomass as stands undergo late-successional development [4] [5] [20] [21]. Our rationale was that local ecological factors (patch size, isolation, species composition, soils, productivity, and disturbance regimes) were accounted for variability in biomass C stock levels in those forest patches. And, succession has the potential influences to biomass development and C cycling in those forest patches.

3.3. Distribution of Biomass and C Storage along the Age Classes

Mean maximum AGC stock was recorded from 42.80 Mg ha^{-1} (SED) to18.93 Mg ha^{-1} (MMD). The value is quite comparable with other previous estimates of biomass in different forest areas of Tripura. In India, the estimated Forest phytomass carbon density pool for the recent period are mostly in the range of 50 - 68 Mg ha^{-1}. Tripura was having phytomass C density between 0 - 25 Mg ha^{-1} in 1988 [15] [16]. The cumulative net "C" flux from Indian Forests during 1888-1996, due to land use change (deforestation, afforestation and phytomass degradation) was estimated at 4.54 PgC. Using Biomass expansion factor total estimated biomass of Tripura was about 40 Mt. In Tripura average biomass density ranged from 66.7 to 83.6 Mg ha^{-1} for open forest and dense forest respectively [16] [17]. While, stocks of C was substantially declined in larger dbh classes; except in case of SED patch, most stock of AGC was restricted in smaller dbh classes (<30 cm) (**Figure 2**). Comparison of allometric relationships between total AGB and density distribution in different dbh classes in four tropical moist deciduous forest patches implied that there were significant differences among the AGB distribution (**Figure 3**). Overall, 69.38% (35.73 Mg ha^{-1}) of total biomass was concentrated in <30 cm dbh class and 23% at >70 cm dbh class (12.08 Mg ha^{-1}). The intermediated dbh classes between >30 to <70 cm contributed only 7% of biomass (3.69 Mg ha^{-1}). However in MBB, 90% (37.55 Mg ha^{-1}) of biomass was represented by <40 cm girth class, which indicated that the higher proportion of AGB was contributed by lower dbh classes, particularly in the form of dominated bamboo culms. Biomass distribution in 10 dbh classes was significantly varied ($F = 74.13$, $df = 1.9$; $p < 0.001$), which showed relatively highest coefficient for allometric relationships between density and AGB in different dbh classes (equation: $Y = 0.56X - 0.23$, $R^2 = 0.90$; **Figure 3** MBB). In MDS patch, about 90% (36.62 Mg ha^{-1}) of AGB was concentrated in <20 cm dbh class and 8% (3.35 Mg ha^{-1}) between <30 to <60 cm dbh class; but only 1.45% (0.59 Mg ha^{-1}) of ABG represented by higher dbh class (>90 cm). Analysis showed that the allometric equation of total AGB and density distribution highly correlated ($Y = 0.56X - 0.20$, $R^2 = 0.81$;

Figure 3 MDS). AGB distribution was significantly higher ($F = 34.59$, $df = 1.9$; $p < 0.001$) among the lower dbh classes which indicated that forest is either immature or recovering its maturity from historic disturbances. About 75% (28.28 Mg ha^{-1}) of AGB was contributed by <20 cm dbh and about 90% of biomass (33.22 Mg ha^{-1}) by <30 cm dbh class in MMD patch. In addition, analysis showed low correlation for the allometric equation ($Y = 0.49X - 0.08$, $R^2 = 0.76$; Figure 3 MMD) of total AGB in MMD and AGB distribution was significantly less in the higher dbh classes ($F = 25.25$, $df = 1.9$; $p < 0.001$). Whether in case of SED patch, only 51% (44.33 Mg ha^{-1}) of AGB was shared by <60 cm dbh class and 39% (33.55 Mg ha^{-1}) contributed by due to >90 cm dbh; whereas total AGB as a function of density distribution in dbh classes showed low correlation ($Y = 0.35X - 0.31$, $R^2 = 0.48$; Figure 3 SED), significantly high biomass storage among the larger dbh classes ($F = 7.41$, $df = 1.9$; $p < 0.05$). Among the tree species, *Dipterocarpus turbinatus* (43.80 Mg ha^{-1}) accounted highest AGB in SED patch followed by *Shorea robusta* (23.81 Mg ha^{-1}) for MDS patch, *Bambusa tulda* (14.46 Mg ha^{-1}) for MBB patch and *Terminalia bellirica* (2.24 Mg ha^{-1}) for MMD patch (Table 2).

Likewise, Day *et al.* (2014) also reported high variability in biomass distribution, but in general more diverse forest tends to be accumulating more biomass [35]. In spite of having highest species richness, MMD had lowest value of biomass (37.85 ± 4.02); even, there was also relatively low coefficient ($R^2 = 0.76$; $p < 0.01$) for allometric relationships between density distribution and AGB (Figure 3 MMD). Similarly tree density was

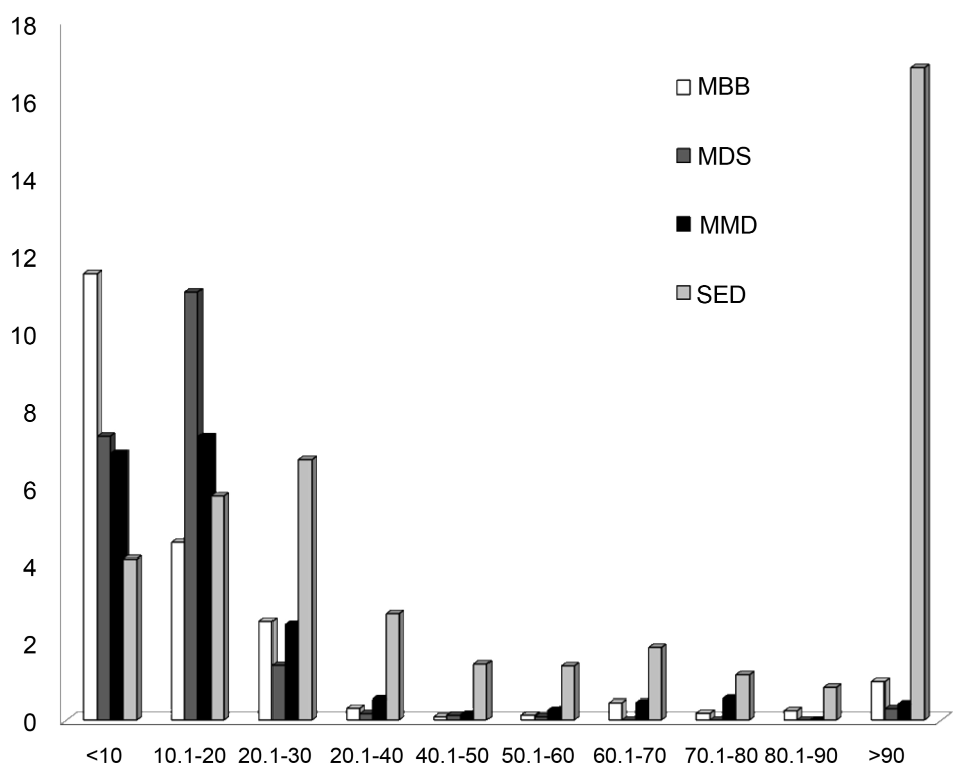
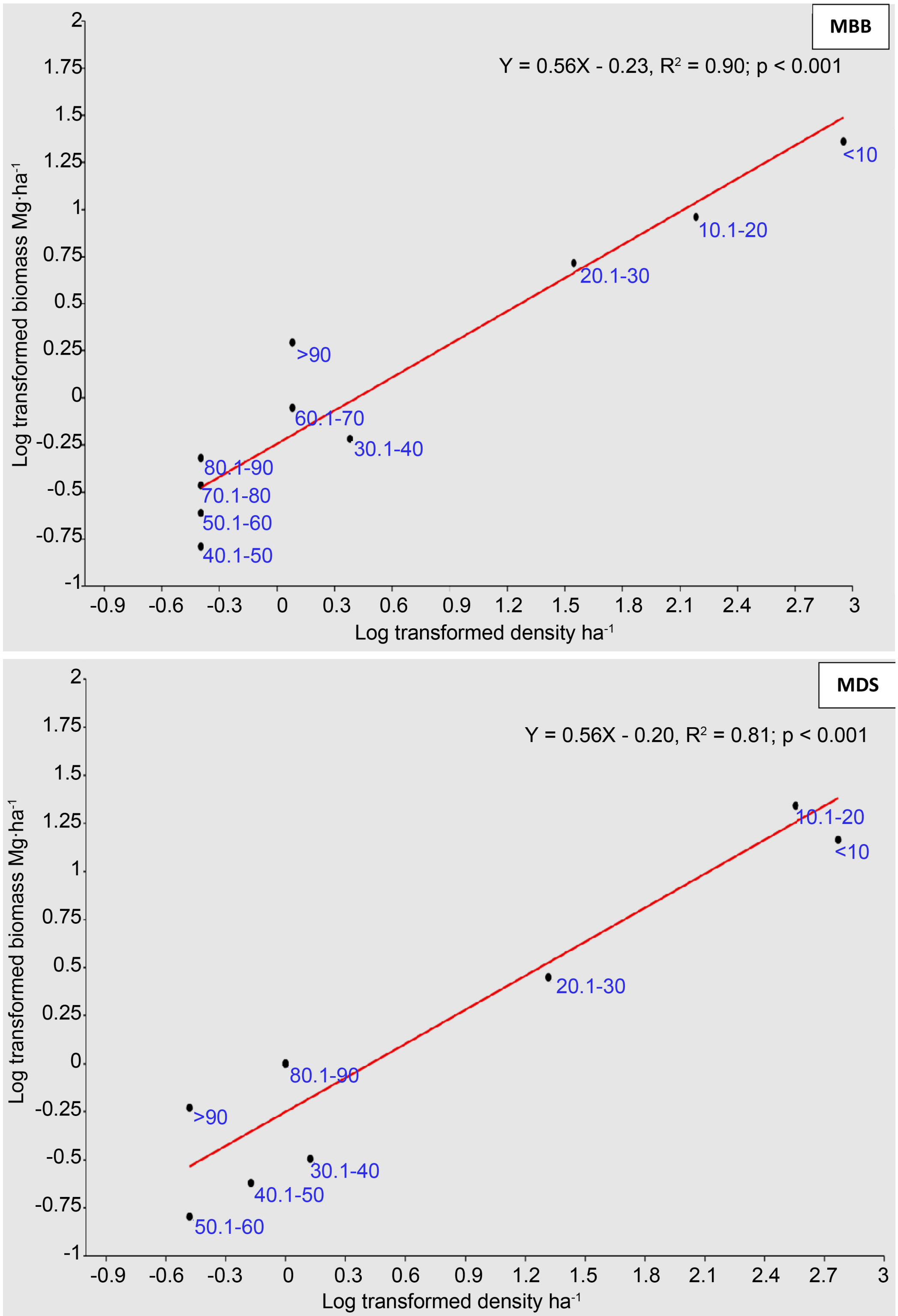


Figure 2. Distribution of Above Ground Carbon Mg ha^{-1} along different diameter classes in four major forest types in TWS.

highest for MBB (1088.4 ± 96.15), but it had lower value of biomass (41.84 ± 2.94) showed relatively highest coefficient value ($R^2 = 0.90$; $p < 0.001$) for allometric relationships between density distribution and AGB (Figure 3 MBB). Inverse to that, SED



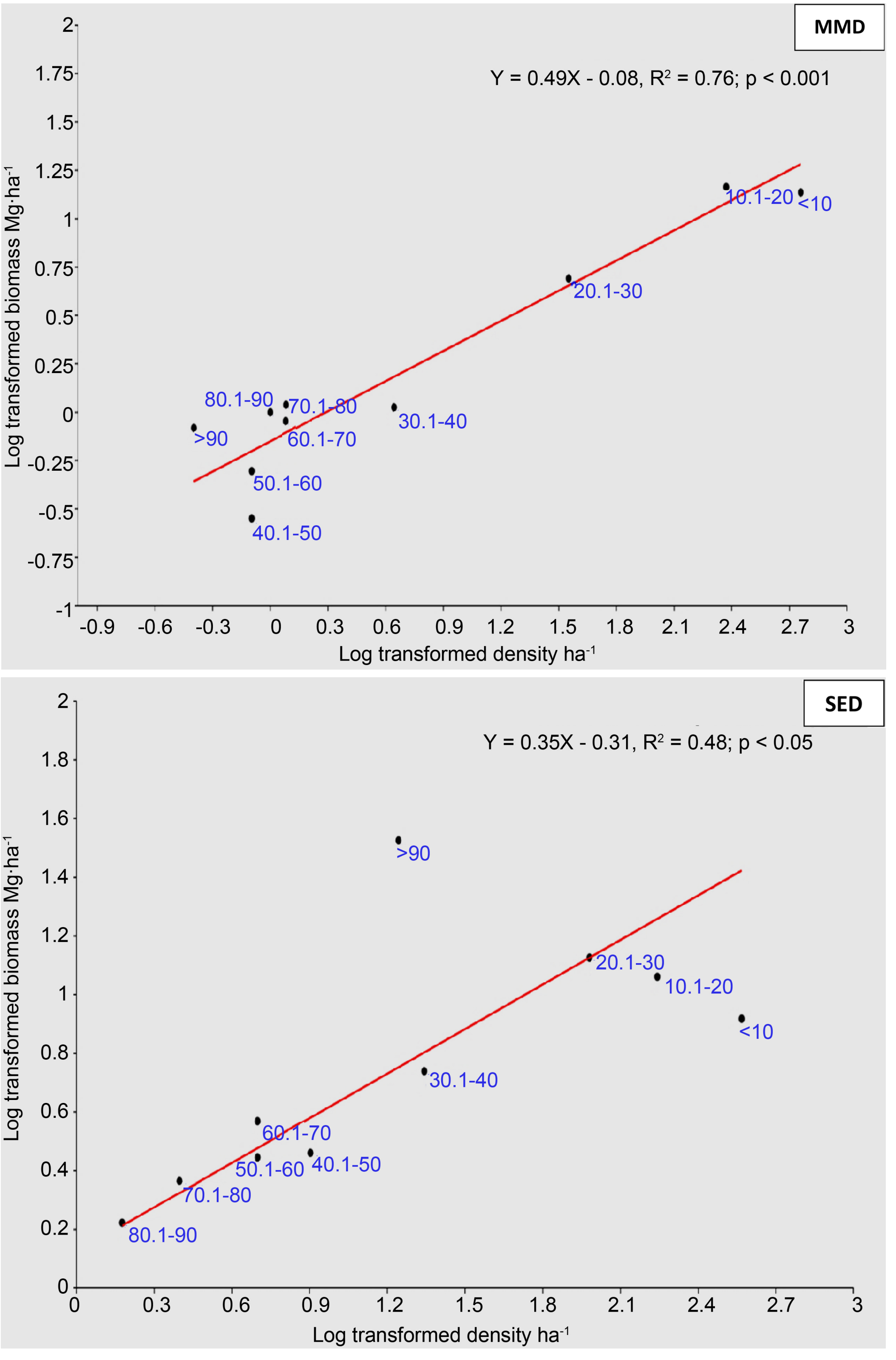


Figure 3. Relationship between log transformed AGB and density ha^{-1} in different dbh classes along major forest patches (MBB, MDS, MMD and SED) in Trishna Wildlife Sanctuary of Tripura, Northeast India.

had highest amount of biomass stock (85.59 ± 17.76) but was relatively lowest correlation coefficient ($R^2 = 0.48$; $p < 0.05$) for equation relationships (**Figure 3** SED); which may due to low density and irregular distribution of trees along the dbh classes. This may further be able to explain by the fact that differences in tree composition and dominance of the species along the patches, and more importantly this may related to the forest successional age [10] [20] [21]. On the basis of biomass stocked in all dbh classes, SED patch found different from rest other three types; where trees in higher dbh class >90 cm stocked maximum biomass (40%) and might represented that this forest community has comparatively reached to its maximum potential in terms of sequestration of CO_2. Surprisingly, *Bambusa tulda* in MBB patch contributed about 35% of biomass, this shows that bamboo patch could capture considerable amount of CO_2 within very early stage. C pool in the above ground biomass of village bamboo in Assam increased from 21.69 Mg ha^{-1} to 76.55 Mg ha^{-1} within three years [14]. The recovery of biodiversity and biomass in tropical moist deciduous forest patches provides hope that they are helping to sequester considerable amount of atmospheric C. It is predicted that present trends will change over time when the early stages will grow into more mature layers and subsequently increase total biomass and C stock in those patches in course of secondary succession. In addition, sapling or regenerating woody stems density was high in MMD and MBB patches; which suggested that these forest patches can provide important ecosystem services as C sequestration. Since the regenerating stage of most woody species can sequester considerable amount of CO_2 by reducing it into biomass [18]. Our result also supporting the potentiality of fragmented village bamboo patches for quick C sequestration; and, this is due to bamboo rapid growth rate, easy multiplication ability and high biomass production. In fact, C assimilation in bamboo plantation is 16% - 20% more compared to other planted tree species *i.e. Dalbergia sissoo* (11.11%), *Terminalia arjuna* (12.07%) and natural forest of *Shorea robusta* (3.34%) [14].

4. Conclusion

In this present study, depending on heterogeneity in forest patches the amount of biomass and C stock determined and found differed significantly. Species specific biomass structure and its distribution along different dbh classes are very important to know C dynamics and its sequestration processes. Besides AGB, it would be more crucial if C accumulation rates in below ground biomass, dead material, and soil along the landscapes specifically could be estimated. Even, studies also required to understand the key processes of biomass and C accumulation through time scale investigation in those forest patches. There are wide variations in terms of biomass distribution and C storage in the patch area, which suggested that present forest patches have huge potentiality as C sequestration and stocked it in the form of biomass. Climate change mitigations by restoring CO_2 through different local forest patches have great advantages like conservation of other species and other ecological services. Hence, it is possible that small forest patches or fragmented forest landscapes may claim enough incentive by demanding fund against management of local landscapes for restoration of CO_2 and conservation of biodiversity. Present quantitative structural attributes of small forest patches will be vital in future to understand C dynamics in small forest patches including the role of dominant community, niche attributes, successional trend, effects of edge and on-going disturbances on the distribution and population of threatened species.

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