Aboveground Tree Carbon Stocks Along a Disturbance Gradient in Wet Tropical Forests of South Assam, India

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Abstract

Human activities have been severely affecting forest structure and functions in humid tropics across the globe. In present study, we estimated aboveground biomass and carbon stocks along a disturbance gradient in wet tropical forests of southern Assam, India, using non-destructive sampling method. A total of 26 forest stands were surveyed and based on a disturbance index grouped into 4 categories, viz. undisturbed (UD), mildly disturbed (MLD), moderately disturbed (MD) and highly disturbed (HD) forests. Mean aboveground carbon (AGC) stocks and basal area decreased with increased disturbance index. Though phytosociological parameters such as species richness, Shannon-Wiener diversity index, tree density, basal area and AGC stocks showed a significant negative correlation with disturbance index, tree density (693 ± 11.6 trees ha^{-1}) and Shannon-Wiener diversity index (1.98 ± 0.07) were highest in mildly disturbed forests. Aboveground carbon stocks were positively correlated with basal area ($p < 0.01$) and diversity indices ($p < 0.01$) across disturbance regimes. Tree species such as *Cynometra polyandra, Mesua ferrea, Palaquium polyanthum, Mesua floribunda, Artocarpus chama* and *Stereospermum personatum* together contributed 41.3 ± 6.2 % and 42.4 ± 6.7% of the total AGC stocks in undisturbed and mildly disturbed forests, respectively, while *Artocarpu schama, Holarrhena pubescens, Mitragyna rotundifolia, Sapium baccatum, Schima wallichii* and

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Toona ciliata contributed 47.2 ± 3.5% in moderately and 55.4 ± 4.0% in highly disturbed forests.

Keywords
Tropical forests · C stock · Disturbance index · Basal area · Diversity

6.1 Introduction

Forests play a significant role in offsetting anthropogenic CO_2 emissions and hence in climate change mitigation and adaptation (Brown et al. 1996: IPCC 2013; Brienen et al. 2015). With the widespread concern about human activities increasing level of atmospheric CO_2, there is a need to assess the potential of native forests in carbon sequestration and storage (C) (Johnson and Kern 2002; Sharma et al. 2010; Borah and Garkoti 2011; Gandhi and Sundarapandian 2017). Forest biomass determines the potential amount of C that can be added to the atmosphere or sequestered in terrestrial ecosystems when they are managed for meeting emission targets (Brown et al. 1999; Brienen et al. 2015). Estimation of the existing C stocks in different forest ecosystems at national and local levels would help in appropriate decision-making on C management and country's intended nationally determined contributions under the United Nations Framework Convention on Climate Change (UNFCC) towards atmospheric carbon reduction targets as part of its international obligations in this regard (FCCC 2014; Sahu et al. 2016). In addition, forest C stock is also a useful measure for comparing structural and functional attributes of forest ecosystems across a wide range of environmental conditions (Brown 2002; Gandhi and Sundarapandian 2017).

Tropical forests are considered as the most diverse terrestrial ecosystems and largest pool of aboveground C stock covering only about 6% of the earth surface (Beer et al. 2010; Pan et al. 2013; Brienen et al. 2015). Agricultural expansion, urbanization and industrialization have been responsible for deforestation and forest degradation in the tropics (LaFrankie et al. 2006; Brienen et al. 2015) and changes in forest structure, which in turn influence ecosystem functions (Collins and Pickett 1987; Pawar et al. 2014; Sicard and Dalstein-Richier 2015). In view of the growing threats to tropical forests, it is important to understand how natural forests and their phytosociological attributes are affected by the progressive degradation due to anthropogenic activities and functional relationship between such attributes and C storage for developing suitable management plans (Chapin et al. 2000; Tilman 1988; Srivastava and Vellend 2005; Kirby and Potvin 2007).

Being part of Indo-Burma biodiversity hotspots, tropical forests of southern Assam are rich from a biodiversity standpoint (Borah and Garkoti 2011). Though such forests occupying inaccessible areas are still rich in biodiversity, those closer to the human settlements have been facing high level of pressure mainly through extraction of timber, fuel wood, grazing and overexploitation of non-timber forest products (NTFPs) by the local people (Borah 2012; Borah et al. 2014). Such anthropogenic activities have not only accelerated biodiversity loss in the forests of the study area but also impacted other ecological functions such as productivity, carbon stocks and regeneration (Borah 2012; Borah et al. 2014; Athokpam et al. 2014; Borogayary et al. 2018). In this paper we estimate the aboveground C stocks of the tree species in some wet tropical forests of southern Assam along a disturbance gradient and establish its relationships with various phytosociological attributes.

6.2 Materials and Methods

6.2.1 Study Site

The present study was conducted in the three districts, viz. Cachar, Hailakandi and Karimganj, of southern Assam (24°08′–25°05′N, 92°15′–93°15′E) collectively known as Barak Valley (Fig. 6.1). The valley is characterized by hot and humid climate and covering 6920 km² geographical area of which 55% is covered by forests (FSI 2017). According to Champion and Seth (1968), vegetation of the southern Assam is dominated by Cachar tropical evergreen forests and Cachar tropical semi-evergreen forests with *Cynometra polyandra*, *Mesua ferrea*, *Stereospermum personatum*, *Artocarpus chama*, *Palaquium polyanthum*, *Mesua floribunda*, *Dysoxylum binectariferum*, *Trewia nudiflora* and *Pterygota alata* being the most dominant tree species (Borah et al. 2014).

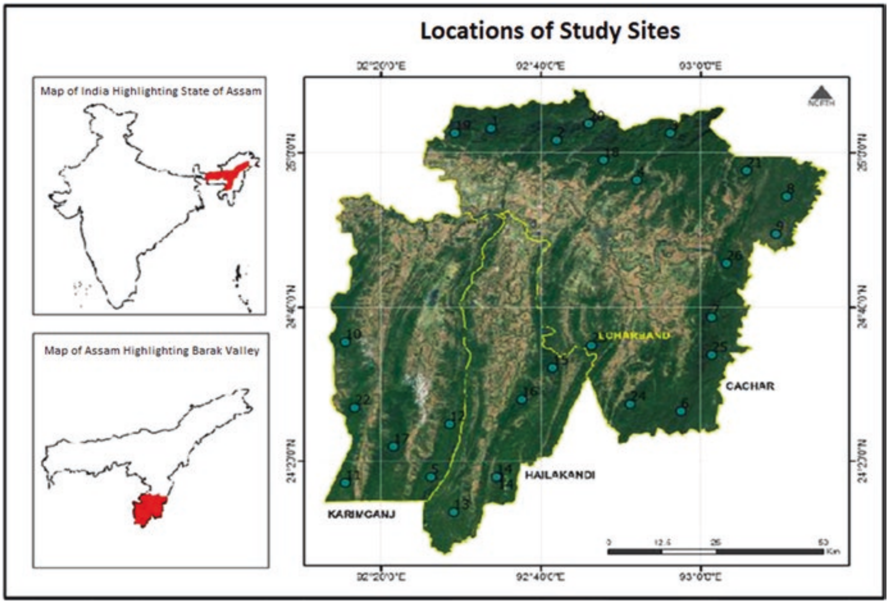

Fig. 6.1 Maps of the present study area

6.2.2 Vegetation Sampling

Based on visual reconnaissance, total 26 forest sites having different levels of disturbance (reflected by number of cut stumps, human trails and canopy cover) were selected (Fig. 6.1). The vegetation of each forest site was analysed using belt transect of 500 m × 10 m following Ganesh et al. (1996) and Borah and Garkoti (2011). Each transect was again subdivided into 50 quadrats of 10 m × 10 m size along its length. In each quadrat, all the woody plants (excluding lianas) with >10 cm circumference at breast height (CBH) were considered as tree and recorded with their CBH (Singh and Dadhwal 2009, Borah et al. 2014). The cut stumps and lopped trees in each quadrat were also counted, and their girths were measured at 10 cm from the ground for estimating the disturbance index. Plant specimens were brought to the laboratory and identified with the help of 'Flora of Assam' (Kanjilal 1934–1940), 'Assam's Flora' (Chowdhury et al. 2005) and the herbarium of the regional centre of Botanical Survey of India located at Shillong, Meghalaya.

6.2.3 Disturbance Index

A disturbance index for each forest site was calculated following Kanzaki and Kyoji (1968), Rao et al. (1990) and Borah (2012). The disturbance index (DI) was calculated as the basal area of cut trees measured at the ground level expressed as a fraction of total basal area of all trees

$$\text{DI}\left(\%\right)=\frac{\text{Basal area of cut stumps}\times 100}{\text{Total basal area}\left(\text{cut stumps basal area}+\text{Standing tree basal area}\right)}$$

Based on the disturbance index, the forest sites were classified into (1) undisturbed forest (disturbance index 0%), (2) mildly disturbed forest (disturbance index up to 20%), (3) moderately disturbed forest (disturbance index 20–40%) and (4) highly disturbed forest (disturbance index above 40%) following Bhuyan et al. (2003). Of the 26 forest sites, 5 sites were recorded as undisturbed forests, 6 forest sites were mildly disturbed, 7 sites were moderately disturbed and 8 sites were highly disturbed. Generally undisturbed and mildly disturbed forests were approximately >6 kms, and moderately and highly disturbed forests were <6 km away from the human habitation. Thus, proximity to human habitation determined the level of disturbance in the forests of the study area.

6.2.4 Phytosociological Attributes

The phytosociological data were quantitatively analysed for frequency, density, basal area, relative density, relative frequency and relative dominance (Curtis and McIntosh 1950). Distribution of tree density and basal area in different DBH classes was estimated by following Mueller-Dombois and Ellenberg (1974). Trees were categorized into ten DBH classes starting with <10 cm and ending with >90 cm class, and tree density and basal area in each DBH class were estimated.

Diversity index was calculated following Shannon and Wiener (1963) as follows:

$$H = -\sum_{S}^{i=1} P_i In P_i$$

where p_i is the proportion of individuals of *i*th species and total number of individuals of all species.

The concentration of dominance was calculated following Simpson (1949) as follows:

$$\mathrm{CD} = \sum P_i^2$$

where p_i is the proportion of individuals of *i*th species and total number of individuals of all species.

6.2.5 Aboveground Biomass (AGB) and Aboveground Carbon (AGC)

Because of high species richness (132 tree species) in the studied forests, species-specific regression models were not used. Though there are several regression equations (Brown et al. 1989: Chambers et al. 2001; Chave et al. 2001; Brown and Iverson 1992) for estimating aboveground biomass (AGB), we used the following equation developed by Brown (1997) for simplicity, less prediction error and higher R^2 value. The regression model is

$$Y = 21.297 - 6.953(D) + 0.740(D^2) \quad \text{with } R^2 \text{ value } 0.87.$$

where Y is the aboveground biomass (AGB) and D is diameter of the tree.

We assumed vegetation carbon equal to 50% of biomass for all the tree components. The estimates are based on assumption of common carbon content per biomass unit as in many other similar studies (Brown and Lugo 1982; Montagnini and Porras 1998; Borah et al. 2013).

6.2.6 Statistical Analysis

ANOVA was performed to compare the average tree density, basal area, diversity index, AGB and AGC among the forest categories with the help of SPSS 16.0. Pearson correlation coefficient was calculated to determine the functional relationships among the phytosociological attributes of the forests.

6.3 Results and Discussion

6.3.1 Forest Structure

A total of 132 tree species was recorded in 26 forest stands. The highest number of species (92) was recorded in mildly disturbed forests and the lowest (47) in highly disturbed forests (Table 6.1). The Shannon diversity index of undisturbed forests ranged from 1.72 to 2.14, while it was recorded 1.78 to 2.19, 1.29 to 1.71 and 1.11 to 1.35, respectively, in mildly, moderately and highly disturbed forests. The average Shannon diversity index was highest (1.98) in mildly disturbed forests followed by undisturbed (1.94), moderately (1.51) and highly disturbed (1.23) forests (Table 6.1). The average tree density was highest in mildly disturbed forests (693 ± 12 trees ha^{-1}) followed by undisturbed (676 ± 10 trees ha^{-1}), moderately (675 ± 17 trees ha^{-1}) and highly disturbed (328 ± 6 trees ha^{-1}) forests. The average basal area was highest (42.9 ± 1.6 m^2 ha^{-1}) in undisturbed forests followed by mildly disturbed forests (39.6 ± 1.8 m^2 ha^{-1}), moderately disturbed forests (20.8 ± 1.0 m^2 ha^{-1}) and highly disturbed forests (14.4 ± 0.9 m^2 ha^{-1}). The Simpson dominance index was highest (0.075) in highly disturbed forests and lowest (0.047) in mildly disturbed forests (Table 6.1). All the phytosociological attributes (species number, tree density, diversity and basal area) were significantly different in different forest categories (Table 6.1). The forest structural analysis reveals that the species richness (47–92 species), Shannon index (1.11–2.19), tree density (328–693 trees ha^{-1}) and tree basal area (14.37–42.91 m^2 ha^{-1}) recorded in different forest categories are comparable with earlier studies (Table 6.2) in tropical forests of north-east India by Nath et al. (2005), Deb and Sundriyal (2008), Deb et al. (2009), Borah and Garkoti (2011), Thapa et al. (2011), Borah et al. (2013, 2014) and Nandy and Das (2013).

The highest species richness, diversity and density of tree species in the mildly disturbed forests were due to the favourable conditions (such as less competition for available resources, more sunlight penetration to the forest floor through canopy gaps, etc.) for the growth and regeneration of tree species (Boarh and Garkoti 2011). Pressures such as relentless extraction of fuel wood, tree felling, and non-timber forest products including bamboo collection were found responsible for lower species richness, density, diversity and basal area in moderately and highly disturbed forests (Boarh and Garkoti 2011; Borah et al. 2014).

6.3.2 Distribution of Density and Basal Area in Different DBH Classes

Density and basal area distribution in different DBH (diameter at breast height) classes can be used as indicators of changes in population structure and species composition (Newbery and Gartlan 1996). The distribution of tree density and basal area in different DBH classes of undisturbed and mildly disturbed forests revealed a reversed J-shaped and J-shaped curve, respectively. In undisturbed and mildly disturbed forests, tree density decreased, and basal area increased with increasing

Table 6.1 Phytosociological attributes of different wet tropical forests along disturbance gradient of southern Assam

	Forest categories				ANOVA	
Phytosociological attributes	Undisturbed	Mildly disturbed	Moderately disturbed	Highly disturbed	F-value	Significance
Number of species	78	92	68	47	72.3	$P < 0.001$
Number of genera	65	73	45	38	12.45	$P < 0.05$
Tree density (tree ha^{-1})	676.2 ± 10.1	693.3 ± 11.6	417.17 ± 17.2	328.6 ± 5.79	245.32	$P < 0.001$
Basal area (m^2 ha^{-2})	42.9 ± 1.6	39.6 ± 1.8	20.8 ± 1.0	14.4 ± 0.9	101.7	$P < 0.001$
Shannon diversity index (H)	1.94 ± 0.03	1.98 ± 0.07	1.51 ± 0.04	1.23 ± 0.02	64.69	$P < 0.001$
Simpson index (Cd)	0.051 ± 0.002	0.047 ± 0.001	0.052 ± 0.002	0.075 ± 0.001	57.25	$P < 0.05$
AGB (Mg ha^{-1})	361.6± 9.0	358.9 ± 9.0	240.9 ± 7.9	212.4 ± 6.9	115.81	$P < 0.001$
AGC-stock (Mg ha^{-1})	180.8 ± 4.5	179.4 ± 4.48	120.5 ± 3.9	106.2 ± 3.5	115.81	$P < 0.001$

Table 6.2 Comparison of the phytosociological attributes with other tropical forests of north-east India

Author	Location	Species number	Shannon index	Density (trees ha^{-1})	Basal area (m^2 ha^{-1})
Nath et al. (2005)	Namdapha, Arunachal Pradesh	18–50	0.96–1.45	340–610	7.8–98.5
Deb et al. (2009)	Arunachal Pradesh	130	–	245–418	18.3–49.7
Deb and Sundriyal (2008)	Arunachal Pradesh	20–73	1.71–3.85	245–418	–
Borah and Garkoti (2011)	Barak Valley, Assam	49–91	1.46–1.77	396–1110	9.4–42.1
Thapa et al. (2011)	Meghalaya, India	31–94	1.81–3.77	524–1110	38.3–93.7
Borah et al. (2013)	Barak Valley, Assam	22–62	1.02–1.62	295–965	5.37–37.09
Nandy and Das (2013)	Barak Valley	32–42	3.0–3.36	522–865	41.6–74.05
Borah et al. (2014)	Cachar District, Assam	22–62	1.02–1.62	295–965	5.37–37.09
Present study	Southern Assam	47–92	1.39–1.69	328–693	14.4–42.9

DBH classes (Fig. 6.2). In both undisturbed and mildly disturbed forests, tree density was high in <10 cm DBH class, whereas tree total basal area was high in >90 cm DBH class. High tree density in lower DBH classes indicates continuous regeneration of the forest ecosystems and higher total basal area in higher DBH classes in the forests represent relatively undisturbed and old growth forests. Similar trends of density and basal area distribution were also observed for different tropical forests of north-east India by Khamyong et al. (2004), Nath et al. (2005), Deb et al. (2009), Borah and Garkoti (2011) and Borogayary et al. (2018). In moderately disturbed and highly disturbed forests, both tree density and basal area showed fluctuating distribution curves. In moderately disturbed forests, the density of younger trees (DBH <10 cm) was recorded highest, whereas trees in DBH class between 40 and 50 cm contributed more to total basal area. Lower basal area in higher DBH classes indicates the selective extraction of larger trees from these forests. In highly disturbed forests, tree density in DBH class 20–30 cm was higher, whereas trees in 80–90 cm DBH class contributed highest to total basal area. Lower density of younger trees indicates the low regeneration in the highly disturbed forests.

6.3.3 Aboveground Biomass (AGB) and Aboveground Carbon Stocks (AGC)

The mean aboveground biomass (AGB) (361.6 ± 9.0 Mg ha^{-1}) and aboveground carbon (AGC) (180.8 ± 4.5 Mg ha^{-1}) were estimated highest for undisturbed forests

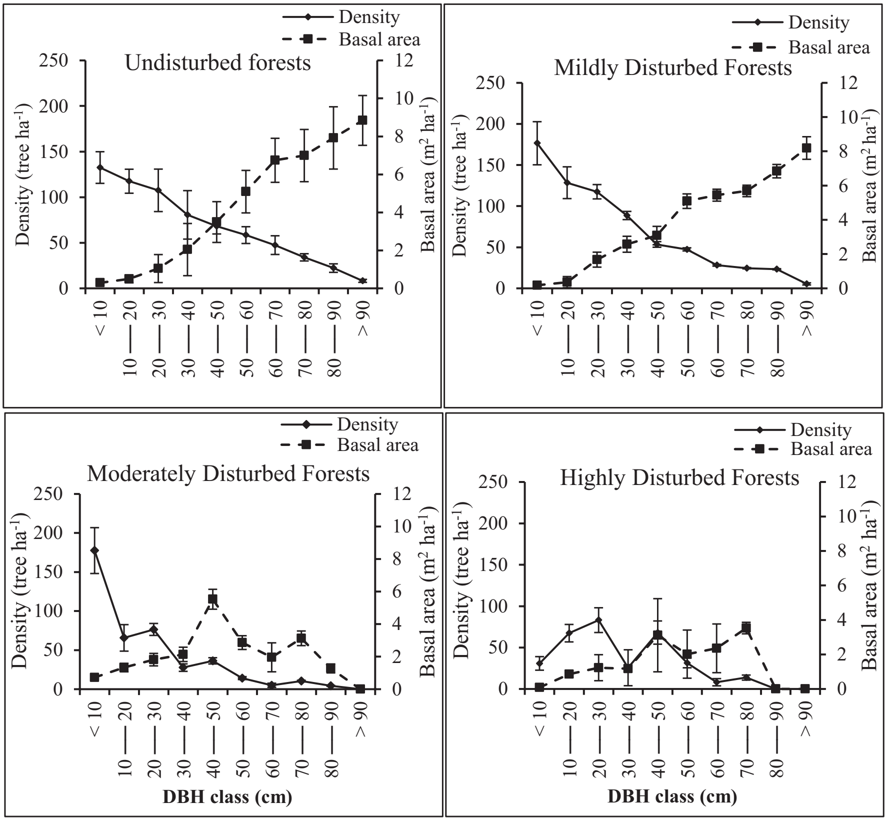

Fig. 6.2 Distribution of tree density and basal area in different DBH classes in undisturbed and differently disturbed forests. The error bars indicate the standard error of mean of tree density in each DBH class

followed by mildly disturbed forests, moderately disturbed forests and highly disturbed forests. The AGB and AGC varied significantly ($P < 0.001$) in different forest categories (Table 6.1). The AGB in undisturbed (361.6 Mg ha^{-1}) and mildly disturbed forests (358.0 Mg ha^{-1}) were within the range 236.0–425.7 Mg ha^{-1}) reported for tropical forests of India (Chaturvedi et al. 2011, Gogoi et al. 2017). Similarly, AGB of moderately (240.5 Mg ha^{-1}) and highly disturbed forests (212.4 Mg ha^{-1}) in the present study was comparable with disturbed tropical forests of Mizoram (116.8–278.5 Mg ha^{-1}) as reported by Singh and Sahoo (2018).

The lower AGB and AGC recorded in the disturbed forests may be mainly due to the lower tree basal area and tree density, especially in higher size classes. Local people living in the proximity of the forests constantly extract forest resources for meeting their subsistence needs of fuel wood, construction materials, timber and NTFPs from these forests, which resulted in a decline in tree basal area as well as lower AGB and AGC in disturbed forests.

Of the total 78 species recorded in the undisturbed forests, the top 5 contributors to aboveground carbon (AGC) were *Cynometra polyandra* (11.5%), *Palaquium polyanthum* (8.8%), *Artocarpus chama* (7.8%), *Mesua ferrea* (7.4%) and *Mesua floribunda* (5.5%) which cumulatively contributed 41.3 ± 6.2% of the total AGC (Fig. 6.3). In mildly disturbed forests, these were *C. polyandra* (12.9%), *M. ferrea* (9.6%), *S. personatum* (7.3%), *P. polyanthus* (6.5%) and *A. chama* (6.5%) and together contributed 42.4 ± 6.7% of the total AGC. In moderately disturbed forests, *A. chama* (15.8%) was the top contributor of AGC followed by *Tetrameles nudiflora*, *Schima wallichii*, *Toona ciliata* and *Bombax ceiba* (Fig. 6.2). These five species contributed 47.2 ± 3.5% of the total AGC in moderately disturbed forests. *S. wallichii*, *H. pubescens*, *S. baccatum*, *Mitragyna rotundifolia* and *T. ciliata* were five major contributors to AGC and aggregately contributed 55.2 ± 4.0% of the total AGC in highly disturbed forests (Fig. 6.3). In highly disturbed forests, *S. wallichii* alone contributed 26.2% of the total AGC implying that species contributed higher

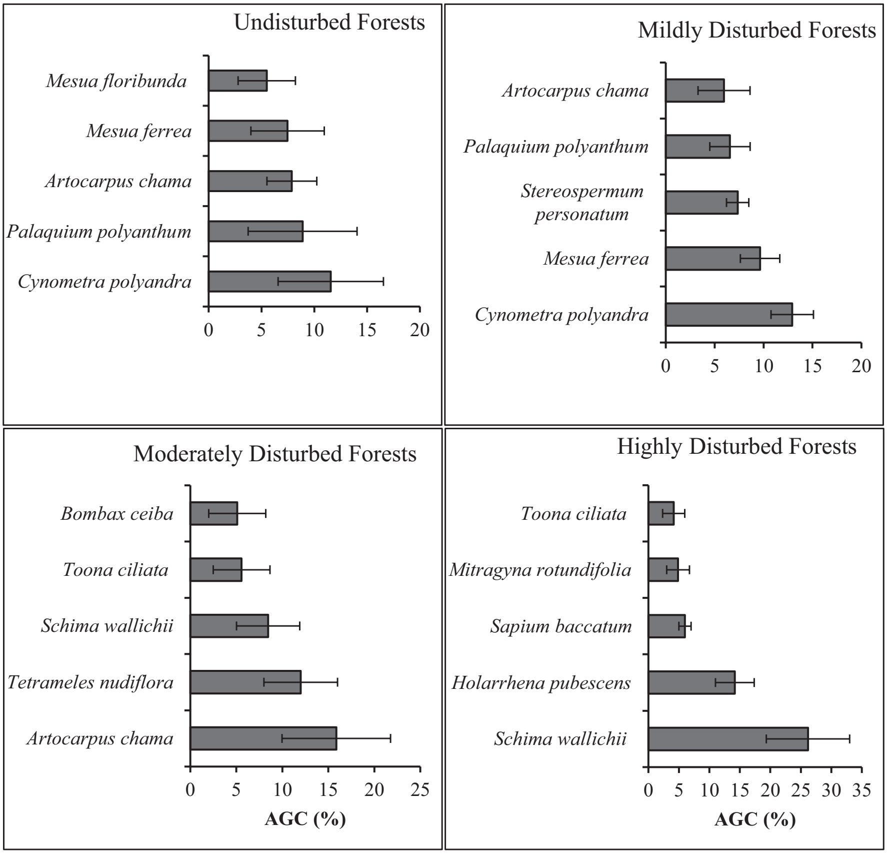

Fig. 6.3 Top five contributors to aboveground carbon (AGC) in undisturbed and differently disturbed forests. The error bars indicate the standard error of mean of AGCs in each species

Table 6.3 Correlation between AGC of dominant tree species with disturbance index

Species name	R^2	Significance
Artocarpus chama	0.09	ns
Bombax ceiba	0.1	ns
Cynometra polyandra	0.58	$P < 0.01$
Holarrhena pubescens	0.43	$P < 0.01$
Mesua ferrea	0.47	$P < 0.01$
Mesua floribunda	0.32	$P < 0.01$
Mitragyna rotundifolia	0.47	$P < 0.01$
Palaquium polyanthum	0.25	$P < 0.01$
Schima wallichii	0.71	$P < 0.01$
Stereospermum personatum	0.68	$P < 0.01$
Tetrameles nudiflora	0.06	ns
Toona ciliata	0.4	P < 0.01

in degraded forests were less preferred for local extraction. Removal or conservation of the top AGC contributor species greatly influenced total AGC across differently disturbed forests. Therefore, identification and conservation of such tree species are important for sustainable carbon management viewpoint in tropical forests (Kirby and Potvin 2007; Borah et al. 2013) (Table 6.3).

It was observed that the relative contribution to AGB and AGC by *C. polyandra*, *M. ferrea*, *M. floribunda*, *P. polyanthum* and *S. personatum* in the forest sites decreased along the disturbance gradient (Fig. 6.4). These species (*C. polyandra*, *M. ferrea*, *M. floribunda*, *P. polyanthum* and *S. personatum*) were dominant species in undisturbed and mildly disturbed forests (Borah 2012). However, these being the most preferred timber species in the study area, local people frequently extracted them from the forests resulting in a decrease in their presence in the disturbed forests and corresponding contribution in forest AGC. Statistical analysis revealed a significant ($p < 0.1$) negative correlation between disturbance and AGC of *C. polyandra*, *M. ferrea*, *M. floribunda*, *P. polyanthum* and *S. personatum* (Table 6.3). However, species such as *H. pubescens*, *S. wallichii*, *M. rotundifolia* and *T. ciliata* showed significantly ($p < 0.0$) increasing trend of AGC with the increasing levels of disturbance (Fig. 6.3; Table 6.3). Relatively higher AGC of these species in moderately and highly disturbed forests may be due to favourable conditions created by selective extraction of preferred species providing ample space for growth and regeneration and more light penetration through canopy gaps (Sahoo and Lalfakawma 2010; Asase et al. 2012). However, *Bombax ceiba* and *Trewia nudiflora* contributed higher to AGC in mildly and moderately disturbed forests (Fig. 6.4). Distribution of AGC in different DBH classes in undisturbed and mildly disturbed forests showed reversed J shaped curves while in moderately and highly disturbed forests it showed fluctuating curves (Fig. 6.5). Reversed J shaped curves in relatively undisturbed forests were due to higher total basal area in the higher DBH classes in these forests and fluctuating curves in moderately and highly disturbed forests may be due to excessive removal of certain DBH class trees from these forests.

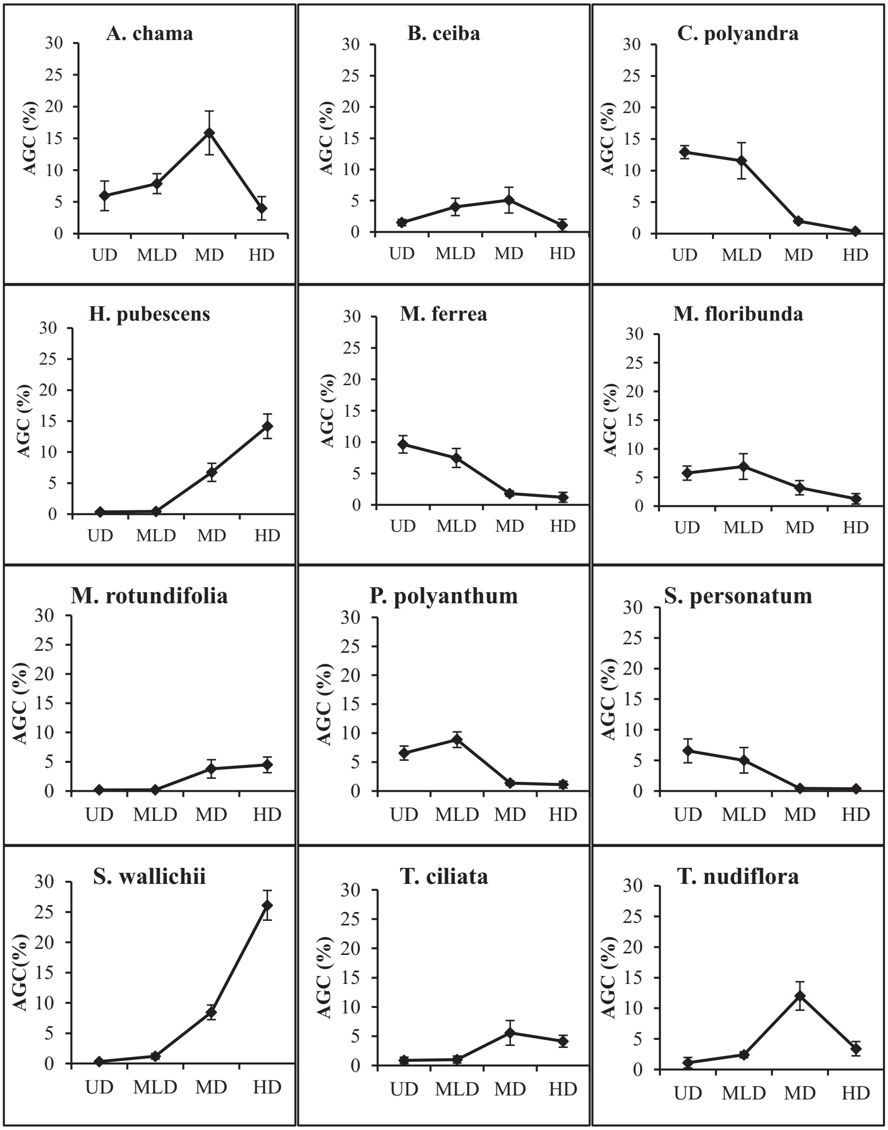

Fig. 6.4 Distribution of aboveground carbon (AGC) of dominant tree species in undisturbed and differently disturbed forests, viz. mildly disturbed (MLD), moderately disturbed (MD) and highly disturbed forests. The error bars indicate the standard error of mean of AGCs in each forest category

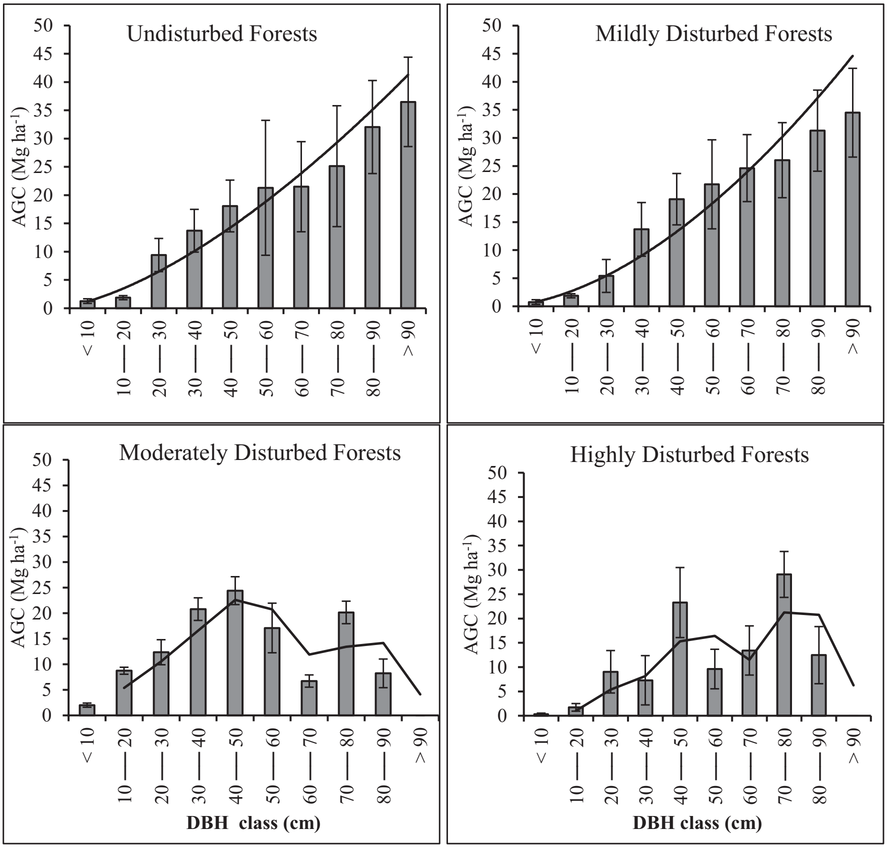

Fig. 6.5 Distribution of aboveground carbon (AGC) in different DBH classes in different forest categories of south Assam. The error bars indicate the standard error of mean of AGCs in each DBH class

6.3.4 Relationship of AGC with Phytosociological Attributes and Disturbance Index

AGC was positively correlated ($P < 0.001$) with basal area ($R^2 = 0.885$), total number of species ($R^2 = 0.696$) and Shannon diversity index ($R^2 = 0.867$) (Fig. 6.6) which is similar to earlier findings of various workers for tropical forests (Terakunpisut et al. 2007; Kumar et al. 2011; Borah et al. 2013; Con et al. 2013; Thokchom and Yadava 2013; Van de Perre et al. 2018). Contrary to the present findings, studies by Enquist and Niklas (2001) and Kirby and Potvin (2007) found no correlation between AGC and diversity indices. Frivold and Frank (2002) mentioned that there may be positive or negative relationship depending on the diversity index used and relative dominance of species in mixed forests. No significant relationship was found between AGC and tree density (Fig. 6.6). The phytosociological attributes such as species richness, diversity, tree density, basal

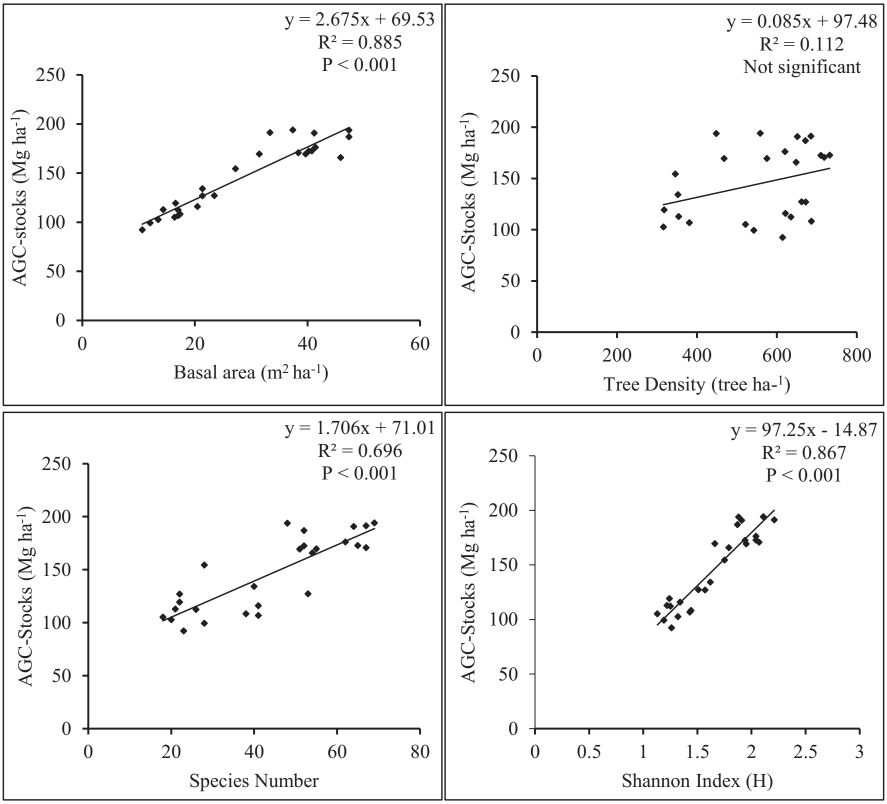

Fig. 6.6 Relationship of aboveground carbon (AGC) with basal area, tree density, species number and diversity index

Table 6.4 Relationship of disturbance index with different phytosociological attributes and aboveground carbon in tropical forests of south Assam

Attributes	*r*	*P*
Species number	−0.98	$P < 0.01$
Tree density	−0.81	$P < 0.05$
Tree basal area	−0.98	$P < 0.01$
Shannon index	−0.97	$P < 0.01$
AGC stocks	−0.96	$P < 0.01$

area and AGC in the present study showed significant negative correlation with disturbance index (Table 6.4). A similar relationship was also reported for different tropical forests by Bhuyan et al. (2003), Marín-Spiotta et al. (2007), Asase et al. (2012), Borah et al. (2013), Gogoi et al. (2017), and Van de Perre et al. (2018).

6.4 Conclusions

The aboveground tree carbon stocks were significantly lower in the disturbed forest stands than in undisturbed stands due to frequent removal of large trees from the formers. Locally preferred species, viz. *C. polyandra*, *M. ferrea*, *M. floribunda*, *P. polyanthum*, *A. chama* and *S. personatum*, contributed higher to the total AGC in undisturbed and mildly disturbed forests, whereas less preferred species, viz. *S. wallichii*, *H. pubescens*, *S. baccatum*, *M. rotundifolia* and *T. ciliata*, contributed higher in moderately and highly disturbed forests. Contribution of older trees with higher girths was higher to the total AGC stocks than the younger trees in lower girth classes irrespective of disturbance level. The phytosociological attributes, viz. tree diversity, species richness and basal area, revealed significant positive correlations with AGC stocks across disturbance gradient.

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