Assessment of woody species diversity and composition along a disturbance gradient in Behali Reserve Forest of Biswanath district, Assam, India

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Abstract. The present study was carried out in Behali Reserve Forest, a semi-evergreen forest of Assam, India to record and analyze the woody species diversity and community characteristics using random sampling. Altogether, 35 quadrats (20 m × 20 m) were randomly established and studied from August 2018 to April 2019 spreading across nine study sites. A total of 128 (118 identified and 10 unidentified) woody species from 83 genera and 43 families were found in the sampled area of 1.4 ha. Lauraceae with 19 species was the richest family by species followed by Euphorbiaceae and Phyllanthaceae (eight species each). Altogether, 787 individuals were recorded from the sampled plots and the stand density ranged between 250 individuals × ha^{-1} to 725 individuals × ha^{-1} with mean stand density of 543 individuals × ha^{-1}. Species-wise density analysis revealed that *Magnolia hodgsonii* (96.43 individuals × ha^{-1}) has the maximum tree density. Plot wise analysis showed that Dikal (58.32 m^2 × ha^{-1}) recorded the maximum basal area as well as the equitability index of 0.95. In Serelia, we recorded the highest Simpson index (0.92), Shannon H index (2.76), Brillouin index (2.11), Menhinick (3.49), Margalef (5.29) and Fisher alpha index (26.59). In Radhasu, we recorded maximum evenness (0.90), dominance (0.58) and Berger-Parker index (0.65). The maximal values of Chao index (38.53) was recorded in Hatimara. Our study also revealed that diversity was maximal for the community under medium level of disturbance in the reserve, while communities under the lowest and highest disturbance pressure had minimal diversity. The Behali Reserve Forest exhibited a great species richness (118 species), mean basal area (44.42 m^2 × ha^{-1}) and stand density (in total, 788 individuals per study area of 1.4 ha) compared to the other forests of the northeastern region of India.

Keywords: basal area, Eastern Himalaya, population structure, semi-evergreen forest, species richness.

1. Introduction

Forests are the backbone to the existence of the most number of faunal species present in the world (Chifundera, 2019; Palei et al., 2019). They can provide each and every necessity in a sustainable manner (Schuldt & Scherer-Lorenzen, 2014). The rapid extent of exploitation in its cover due to colonization, urbanization and agriculture has affected the ecological balance, threatening survival of plants and animals (Elliott & Swank, 1994; Hernandez, 2018; Mohd-Azlan et al. 2018). Hence, conserving the present biodiversity has become a great challenge as well as a global concern, which needs basic studies to be addressed first (Brockerhoff et al., 2008).

Plant diversity assessments have proven to be an essential tool for the quantitative studies of regional scale biogeographical patterns (Gordon & Newton, 2006). Tropical deciduous forests as well as evergreen forests are one of the most varied among the tropical forest types and are also the least studied. Though they play an important role in plant conservation but are the most used and threatened, especially in India (Thakur & Khare, 2006). They are one of the largest carbon sinks and also have a higher standing biomass (Naidu et al., 2018).

Assam is well known for its rich biodiversity, in floral context, as the centre of botanical explorations in the British period, but has negligible literature considering the diversity of this vast province. Works of Hooker & Thomson (1855), Kanjilal (1934–1940), Kachroo (1953), Kar & Panigrahi (1963), Rao & Verma (1970–1976), Borthakur (1976), Hajra & Jain (1978), were worth mentioning and have been the literature base for many studies conducted in the following years.

With the extensive rate of deforestation, the remaining forest cover is present only in the protected areas (National Parks, Wildlife Sanctuaries and Reserve Forests) of the state covering about 26 832 km^2 of the total geographic area (Loushambam et al., 2017). Understanding the structure of the present forest is critical to unearth diverse ecological processes like energy flow, nutrient status, food reserve for the dependent fauna, oxygen composition (Elouard et al., 1997). Moreover, it will also eventually make an understanding of the native elements of the forests and the present population structure, its association with the other species and their survival. Hence it will serve as a tool for evaluation of the threat level and thus planning a working plan for effective conservation (Saikia et al., 2017).

In context to phytosociological and diversity studies of Assam, numerous works have been conducted recently (Borah & Garkoti, 2011; Dutta & Devi, 2013a,b; Sarkar & Devi, 2014; Sarma & Borah, 2014; Borah et al., 2016, 2018; Deka & Sarma, 2016; Saikia & Khan, 2016; Bora & Bhattacharyya, 2017; Borogayary et al., 2017; Barua et al., 2018). But not in the northern back of Brahmaputra, i.e. in the foothill regions of Arunachal Pradesh and Assam.

The present paper aimed to study the community structure across a disturbance gradient in Behali Reserve Forest (BRF), a fragmented patch of 140 km^2 semi-evergreen forests in the foothills of eastern Himalaya.

2. Study area

The survey was conducted in the only remaining patch of natural forest in the entire Biswanath district of Assam namely, Behali Reserve Forest, on the foothills of Eastern Himalayas. It is located between 26° 52′ 20.08″ N and 26° 57′ 33.17″ N and 93° 11′ 30.58″ E and 93° 23′ 21.09″ E. The total geographical area is 140.16 km^2 and the elevation of the area ranges between 90 m a.s.l. and 110 m a.s.l. (Fig. 1).

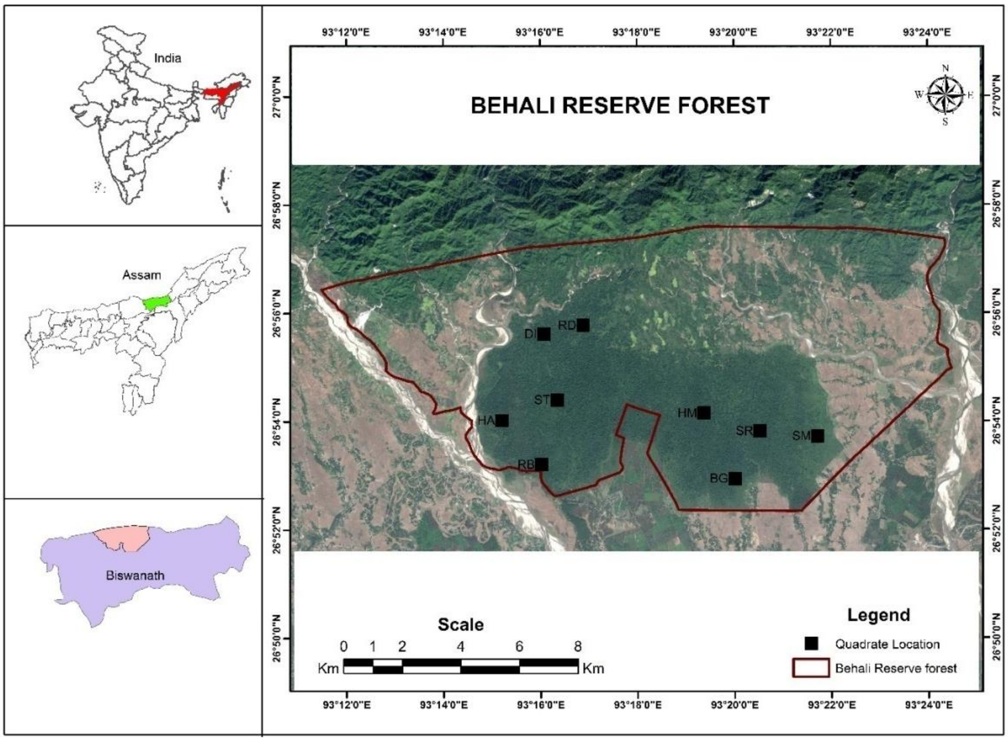

Figure 1. Location of Behali Reserve Forest, Assam, India

The temperature is very mild (13–37°C) and the mean annual rainfall is 1800 mm (Sarma et al., 2009; Upadhaya, 2016–2017). The area is surrounded by Papum Reserve Forest in the North, Tea gardens and human habitations in the South, Buroi River in the East, and West by Singlijan Reserve Forest (Sarma et al., 2009). The forest type is identified as semi-evergreen forest (Champion & Seth, 1968). Numerous annual and perennial streams, wetlands, swamps, mixed grasslands are also present within the reserve that provides shelter to different forms of life. The forest is now known to host several newly discovered and rediscovered taxa (Borah et al., 2019 a,b; 2020 a,b). Agriculture is present in almost all sides of the reserve and degradation has severely hampered its boundaries. Shifting cultivation is seen in the North boundaries, whereas settled agriculture is predominant in the south and east.

3. Material and Methods

3.1. Sampling plots and ground survey

The sampling plots were established covering almost all the nooks and corners of the forest from August 2018 to April 2019. The woody vegetation was sampled by laying thirty-five (20 m × 20 m) quadrats and all the individuals with breast height diameter (GBH > 30 cm), were tagged, measured and collected giving a specific collection number that was used throughout the field study. The collected samples were later processed following the methods of Jain & Rao (1977). It was then identified using relevant literatures and consulting the regional herbaria (ASSAM) and submitted in HAU (Herbarium of Rajiv Gandhi University, Arunachal Pradesh).

3.2. Data Analysis

Community characteristics such as frequency, density, abundance, species richness, dominance distribution, dispersion pattern, species diversity, and dominance index were calculated as per Margalef (1958), Menhinick (1964), Berger and Parker (1970), Chao (1984) Magurran (1988). Importance Value Index (IVI) for each species was also computed and it was expressed as the sum of relative density, relative dominance, and relative frequency of species in and among plots (Curtis, 1959). Furthermore, the diversity of different sites was compared using a k-dominance plot, in which percentage cumulative importance value index is plotted against log species rank for each disturbance category (Platt et al., 1984). Population structure of tree species (> 30 cm) gbh was characterized as the size distribution using gbh classes. All individual trees were grouped into five girth classes i.e. 30–60 cm, 61–90 cm, 91–120 cm, 121–150 cm, and > 150 cm.

The updated nomenclature of plant species was followed using the database Plants of the World online of Royal Botanical Garden Kew (http://powo.science.kew.org/).

4. Results

Our approach was to study the tree species diversity and determine the community characteristics of BRF along a disturbance gradient. It is important to mention here that we were not sampling the total species diversity because of the large coverage of the reserve area. The study was based 1.4 ha from randomly sampled nine plots namely, Bongaon (BG), Dikal (DI), Hatidipu (HA), Hatimara (HM), Radhasu (RD), Rangagorha (RB), Serelia (SR), Sialmari (SM) and Siklibandha Tiniali (ST).

4.1. Floristic diversity

The forest of BRF was found to be very rich and diverse in floristic composition. The floristic diversity analysis in selected nine study stands indicated instance of a total 118 woody species belonging to 83 genera representing 43 families. List of taxonomic diversity in terms of family and their occurrence in nine study stands are provided in Appendix.

The families showing the most diversity in terms of the number of species were Lauraceae (19 species), Euphorbiaceae and Phyllanthaceae (8 species each), Annonaceae, Malvaceae, Meliaceae and Moraceae (6 species each), Elaeocarpaceae and Lamiaceae (4 species each), Burseraceae, Fabaceae, Fagaceae, Magnoliaceae, Myrtaceae (3 species each), Actinidiaceae, Boraginaceae, Combretaceae, Rutaceae, Simaroubaceae, Urticaceae (2 species each) and the rest twenty-four families with one species each. Genera wise, *Litsea* was the most dominant with 8 species followed by *Ficus* with 6 species, *Castanopsis*, *Elaeocarpus*, *Magnolia*, *Mallotus*, *Phoebe* and *Syzygium* with three species each, 9 genera with two species each while the genus to species ratio for the rest 68 was 1:1.

4.2. Species richness

The census of individuals having GBH $\geq$ 30 cm in the 1.4 ha random sampled plots spreading in nine study stands (plots) recorded a total of 788 woody individuals belonging to 118 identified and 10 unidentified plant species which represented 83 genera and 43 families. Among the study stands, the stand SR showed maximum number of species with 47 species belonging to 36 genera and 23 families followed by the stand HM representing 46 species belonging to 35 genera and 20 families, HA representing 44 species under 39 genera and 24 families. The RD stand recorded least number of species with 10 species belonging to 10 genera and 8 families (Appendix). Species richness varied from 3 to 36 number of species per quadrat with an average of 22 species per quadrat. The densities of the 128 species enumerated in the 1.4 ha plot showed a wide variation, ranging from 1 individual each for fifty-five species to 135 individuals for *Magnolia hodgsonii*.

Based on their density in the sampled plots, species were grouped into following five categories:

(a) Dominant species (species with ≥ 100 individuals): *Magnolia hodgsonii* accounting for 17 % of the stand density (135 individuals) represented this group.

(b) Common species (species with 25 to 99 individuals): Five species, *Bauhinia variegata*, *Mesua ferrea*, *Elaeocarpus rugosus*, *Elaeocarpus varunua* and *Gynocardia odorata* (Fig. 2e) accounting for 25 % of the stand density representing this group and collectively they had 201 stems/ individuals.

(c) Rare species (species with 3 to 24 individuals): Forty-seven species with 355 individuals (45 % of the stand density) formed this group. Examples are *Phoebe attenuata*, *Syzygium oblatum*, *Aglaia edulis*, *Picrasma javanica* (Fig. 2f).

(e) Very rare species (species with < 3 individuals): Twenty species with 2 individuals each and fifty-five species with 1 individual each contributed to this group (e.g. *Terminalia citrina*, *Magnolia griffithii*, *Litsea assamica*, *Horsfieldia kingii* (Fig. 5b)).

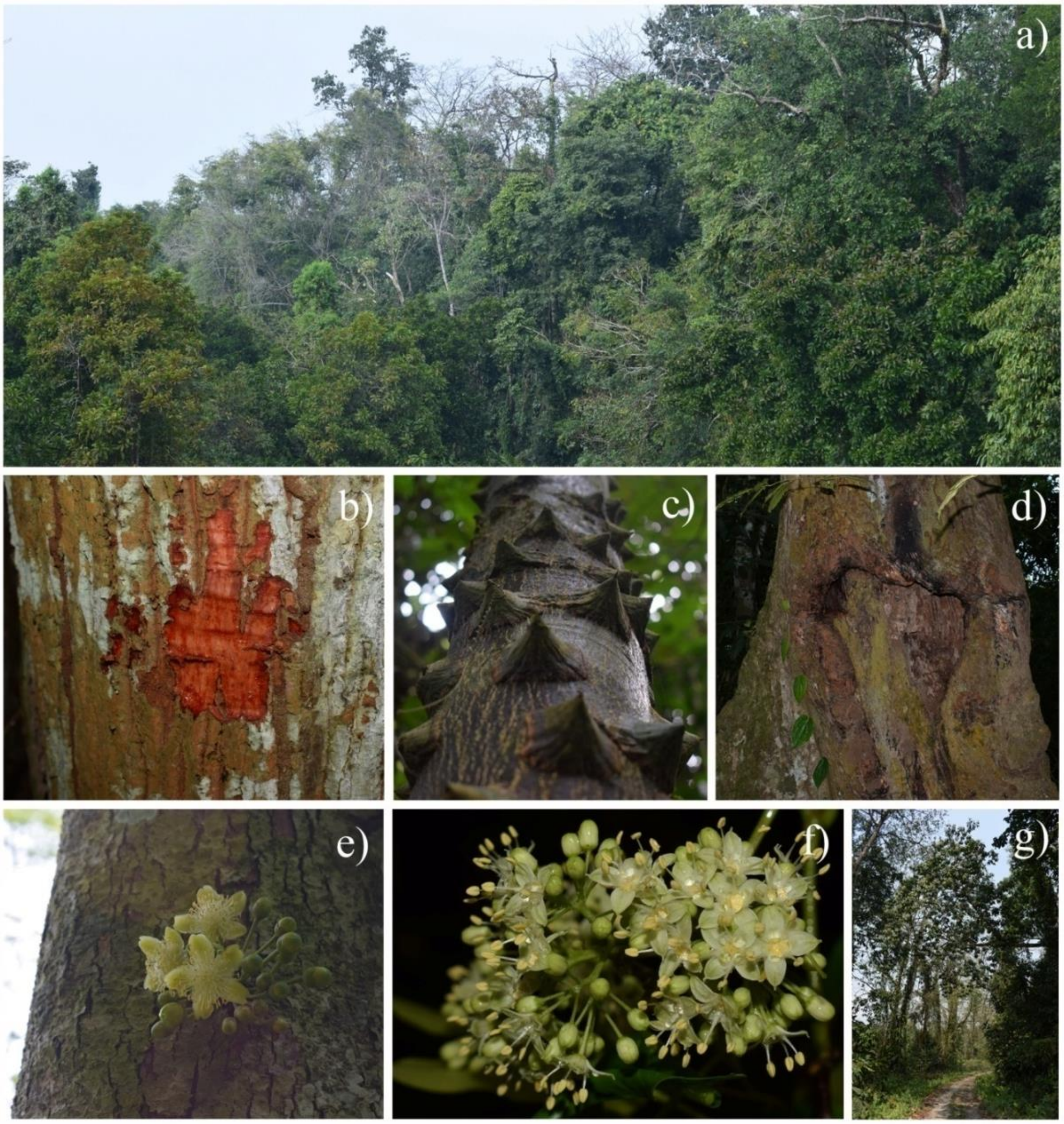

Figure 2. a) Landscape of Behali Reserve Forest, b) *Horsfieldia kingii*, c) *Zanthoxylum rhetsa*, d) *Canarium resiniferum*, e) *Gynocardia odorata*, f) *Picrasma javanica*, g) *Elaeocarpus varunua*.

Quadrat-wise species richness was highest in HM1 (36 species) and lowest in RD2 (3 species). The diversity did not vary much from plot to plot on the whole sampled study area. A low Shannon diversity index was obtained in RD (H'= 2.09) with 10 species whereas, the highest value was obtained in SR (H'= 3.45) with 47 species. The Evenness index ranged from 0.42 for HA to 0.81 for RD, and Margalef index (Margalef, 1958) had highest in plot SR (9.67) and lowest in RD (3.00). The maximal values of Chao index (Chao, 1984) was recorded in Hatimara i.e. 38.53.

Figure 3 shows the k-dominance of species rank plot. The bottom curve (medium disturbance category) represented the highest diversity, while the other two curves (low and high disturbance categories) represented the similarly lowest diversity.

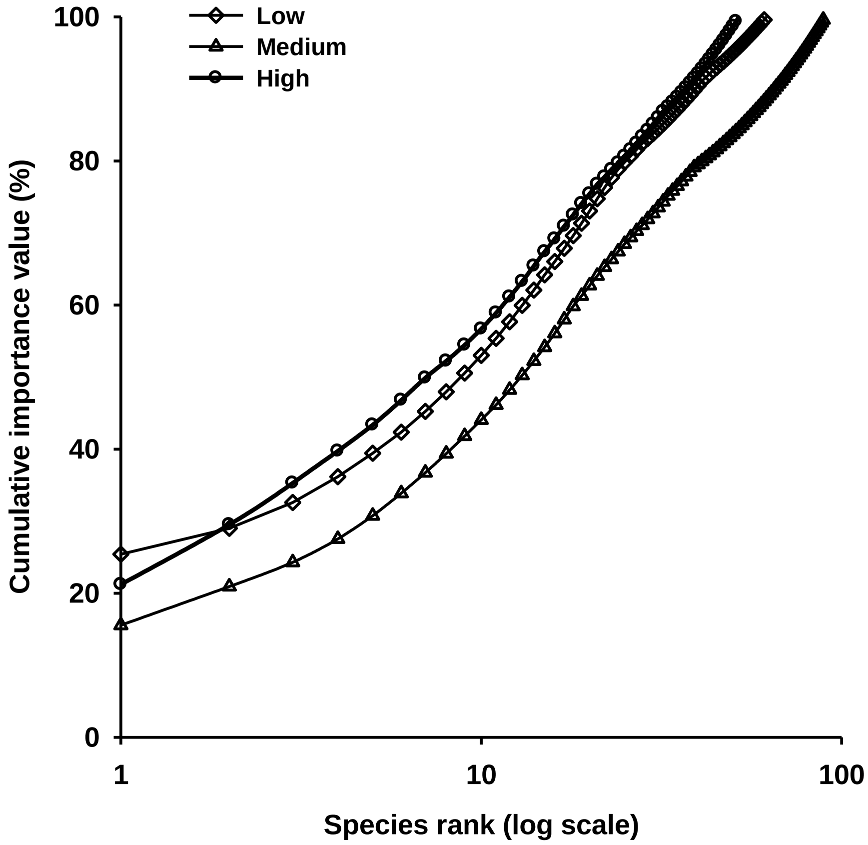

Figure 3. The k-dominance plot in which percentage Cumulative Importance Value is plotted against log of species rank for each disturbance category

The Menhinick species richness index analysis showed that the SR stand recorded maximum species richness index of 3.49 followed by DI (3.10), HM (2.81), HA(2.73). The stand RD recorded least species richness index of 1.38.

4.3. Stand density and Basal area

For the different stand studied, the highest stand density was observed in SR (725 individuals $\times$ ha^{-1}), whereas the lowest stand density in RD (250 individuals $\times$ ha^{-1}) (Table 1). The mean stand density was 543 individuals $\times$ ha^{-1}. Among the observed species, the species wise density analysis revealed that *Magnolia hodgsonii* (96.43 individuals $\times$ ha^{-1}) had the maximum tree density followed by *Bauhinia variegata* (43.57 individuals × ha^{-1}), *Mesua ferrea* (30.71 individuals × ha^{-1}), *Elaeocarpus rugosus* (27.86 individuals × ha^{-1}), and *Elaeocarpus varunua* (21.43 individuals × ha^{-1}) (Appendix). The basal area varied from 26.39 m^2 × ha^{-1} to 58.32 m^2 × ha^{-1} with mean basal area of 44.42 m^2 × ha^{-1}. The quadrat wise analysis showed that the basal area differs among the quadrats and DI3 recorded the maximum (79.41 m^2 × ha^{-1}) basal area and RD2 recorded the least (8.21 m^2 × ha^{-1}) basal area. Among the species, *Ficus* sp. observed maximum (22.48 m^2 × ha^{-1}) basal area followed by *Bombax ceiba* (17.68 m^2 × ha^{-1}), *Ficus drupacea* (13.27 m^2 × ha^{-1}), *Balakata baccata* (12.81 m^2 × ha^{-1}) and *Bischofia javanica* (11.2 m^2 × ha^{-1}). Girth class density distribution indicated that the girth class (< 90 cm GBH) contributed 62% of total number of stems in nine stands; however, it contributed only 31% of basal area (Fig. 4). In all the stands, trees having girth (< 90 cm GBH) were comparatively larger in number than girth (> 90 cm, GBH) however, later girth class has contributed maximum basal area than the former girth class.

Table 1. Community characteristics of different plots in Behali Reserve Forest

Variable	**BG**	**DI**	**HA**	**HM**	**RB**	**RD**	**SM**	**SR**	**ST**
Number of individual	58	123	142	127	69	20	43	116	89
Number of species	22	38	44	46	34	10	21	47	32
Number of genera	20	34	39	35	30	10	18	36	27
Number of families	18	24	24	20	24	8	14	23	18
Density	290	615	710	635	575	250	538	725	556
Basal area	26.39	58.32	53.47	49.80	53.50	30.63	42.81	45.42	39.45
Dominance_D	0.22	0.09	0.17	0.13	0.14	0.58	0.17	0.08	0.17
Simpson_1-D	0.78	0.91	0.83	0.87	0.86	0.42	0.83	0.92	0.83
Shannon_H	1.78	2.56	2.26	2.37	2.29	0.99	2.13	2.76	2.11
Evenness_e^H/	0.84	0.86	0.69	0.78	0.78	0.90	0.73	0.85	0.75

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Brillouin	1.26	1.93	1.76	1.82	1.75	0.74	1.61	2.11	1.61
Menhinick	2.16	3.10	2.73	2.81	2.70	1.38	2.48	3.49	2.40
Margalef	2.59	4.47	4.05	4.10	3.81	1.41	3.42	5.28	3.31
Equitability_J	0.90	0.95	0.85	0.90	0.90	0.90	0.87	0.94	0.87
Fisher alpha	11.46	26.18	14.17	14.55	12.90	4.14	10.07	26.59	10.87
Berger-Parker	0.34	0.16	0.31	0.25	0.27	0.65	0.35	0.16	0.33
Chao-1	15.15	32.47	38.53	23.91	32.17	12.50	18.79	35.37	24.38

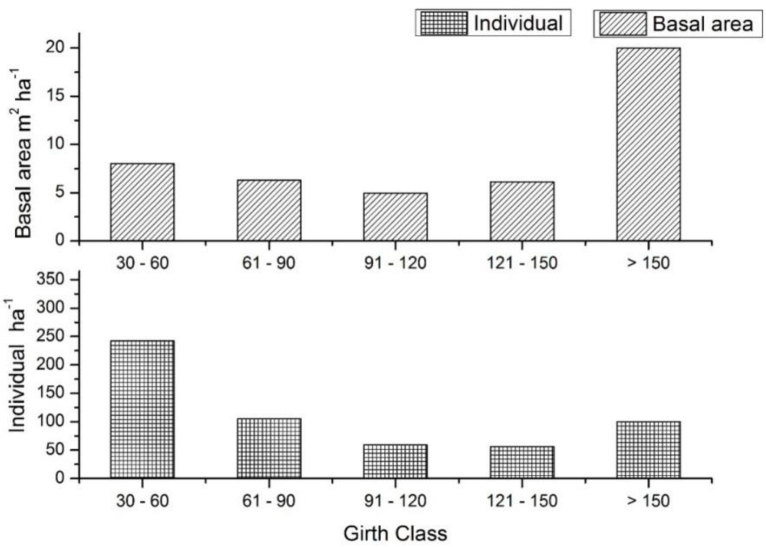

Figure 4. Girth class contribution of individual and their basal area cover

The girth class distribution revealed that the girth class (30–60 cm) having maximum density was 43% followed by class (61–90 cm) (18.6%) and class (> 150 cm) (10.5%). It was also revealed that more 70% of tree individual contributed in first three girth classes (30–60 cm, 61–90 cm, 91–120 cm) than the last two girth class contributed, 7% of basal area of the studied area. The girth class (> 150 cm) contributed to the maximum basal area (44.03 $m^2 \times ha^{-1}$) followed by girth class (30–60 cm) (17.33%) and class (61–90 cm) (13.85%). Tree species richness as well as density decreased with increasing girth class in all the study plots. The girth class distribution revealed that majority of the individuals (43%) represented the 30–60 cm girth class, followed by 61–90 cm (18%), 91–120 cm (10%) and so forth the individuals count of > 150 cm represented 2.1%. The individuals of > 150 cm girth were very discrete within the taken range of 30 cm difference; hence, a single class was made. The individual location's girth class analysis revealed that the all the locations follows the same pattern (Fig. 5). It was also observed that density of the plant species was maximum in girth class 30–60 cm followed by 61–90 cm, 91–120 cm and hence the pattern increased accordingly, however the girth class wise basal area of the different location followed completely different pattern. Both the density and basal area in different girth class exhibits reversed J-shaped pattern in each location.

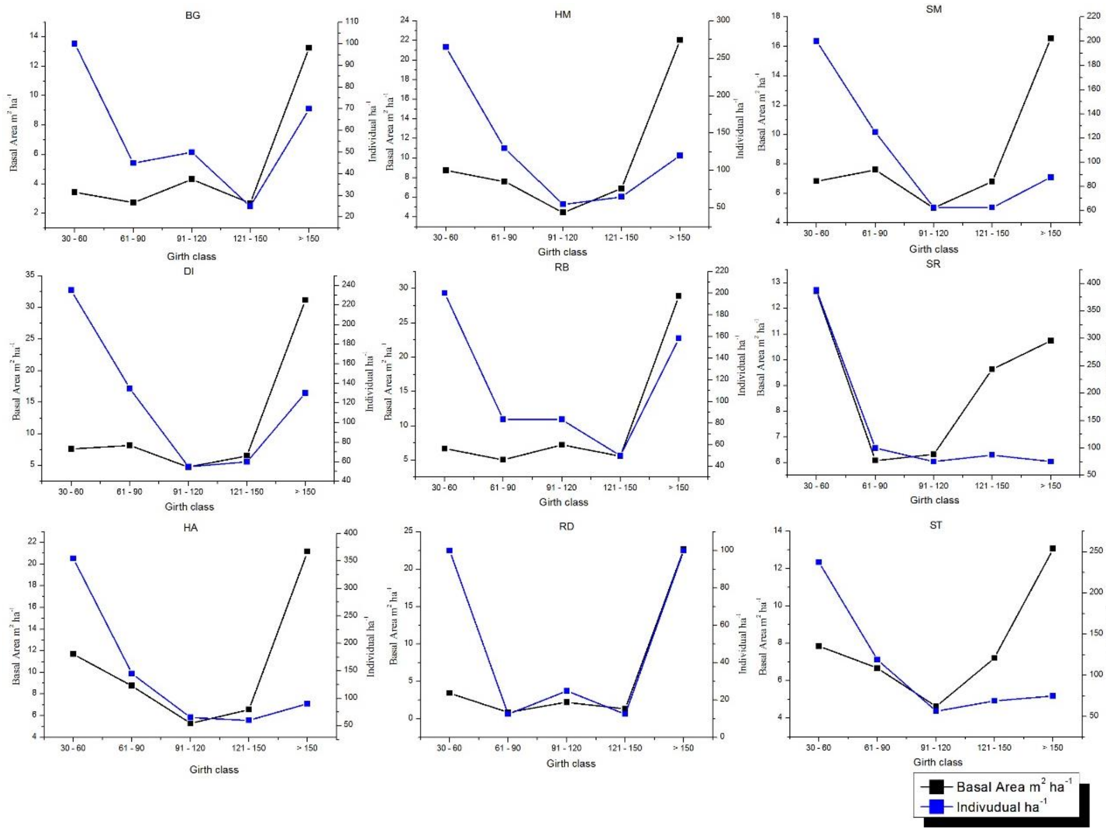

Figure 5. Contribution of woody species stands density and basal area based on girth class distribution in Behali Reserve Forest

4.4. IVI and tree dominance

The IVI was highest in *Magnolia hodgsonii* (26.83 and lowest in 55 species (with 0.94 each). The density of different species varied widely in the nine study pots. Based on their density in 1.4 individuals × ha^{-1} area, the dominant plants with density of > 10 individuals × ha^{-1}

comprising 56% of the total individuals were *Magnolia hodgsonii*, *Bauhinia variegata*, *Mesua ferrea*, *Elaeocarpus rugosus*, *Elaeocarpus varunua* (Fig. 2g), *Gynocardia odorata*, *Dalrympelea pomifera*, *Dysoxylum gotadhora*, *Miliusa dioeca*, *Oreocnide integrifolia*, *Dillenia indica* and *Monoon simiarum.*

Among the studied stands, *Magnolia hodgsonii* had maximum dominance (26.83) followed by *Bauhinia variegata* (13.39), *Mesua ferrea* (10.28) and *Elaeocarpus rugosus* (10.05). The different stand-wise dominance analysis showed that in stand BG, maximum dominance was maintained by the species *Mesua ferrea* (39.98). The species *Magnolia hodgsonii* (22.13, 31.22, 43.08, 71.79, and 23.98) had the highest dominance in stand DI, HM, RB, SM, and SR respectively. *Bauhinia variegata* (40.40, 60, 34.21) had the highest dominance in stand HA, RD and ST respectively. In the present study, it was observed that all the trees are having more or less similar pattern in all the nine different study stands.

4.5. Diversity and dominance indices

The Shannon Weiner diversity index analysis of selected stands showed that the diversity index was higher in stand SR (2.76) followed by DI (2.56), HM (2.37), RB (2.29), HA (2.26), SM (2.13), ST (2.11), BG (1.78) and RD (0.99). From the above it can be interpreted that the tree diversity were high in stand SR, DI, HM, RB, and HA. The stand RD (0.99) has found to be least diverse in tree species. Simpson dominance index recorded higher in stand SR (0.92) followed by DI (0.91), HM (0.87) and RB (0.86). The least Simpson dominance Index occurred in stand RD (0.42).

4.6. Sorenson's similarity indices

The Sorenson's similarity indices analysis indicated that the similarity index was highest (22.6%) in between stand HM and SR Least similarity index (7.4%), however, was found in between ST and BG stand (Table 2).

Table 2. Sorenson's similarity index of woody species in selected different stand

	DI	**HA**	**HM**	**RB**	**RD**	**SM**	**SR**	**ST**
BG	13.8	19.7	14.7	12.5	12.5	16.3	20.3	7.4
DI	–	21.8	22.5	19.5	15.1	21.9	22.2	21.3

HA	–	–	15.6	17.9	11.1	16.9	22.0	19.7
HM	–	–	–	16.3	8.9	19.4	22.6	14.1
RB	–	–	–	–	9.1	20.0	19.8	16.7
RD	–	–	–	–	–	16.1	8.8	14.3
SM	–	–	–	–	–	–	19.1	13.2
SR	–	–	–	–	–	–	–	17.7

5. Discussion

In terms of diversity, tropical evergreen and semi-evergreen forests comprise higher diversity compared to the tropical dry forests (Murphy & Lugo, 1986). The study conducted in BRF also shows similarity in species diversity and composition with the others conducted in similar vegetation types in different parts of the country (Jayakumar & Nair, 2013). The woody species richness (135) recorded here is much higher than 89 species reported by Dutta & Devi (2013b) from Doboka reserve forest Nagaon, Assam. Ali et al. (2015) reported 74 species from Sepahijala wildlife sanctuary, West Tripura. Das et al. (2017) reported 98 species from tropical semi-evergreen forest of Anjaw, Arunachal Pradesh. The species richness reported in present study, however, was lower than the value reported from higher elevation areas of Eastern Himalayan forest that is comprised of tropical to sub-tropical forest with species richness (482) by Saikia et al. (2017), also from Golaghat and Jorhat districts of Assam with 154 species by Saikia & Khan (2016). Barua et al. (2018) also reported higher species richness (261) from moist semi-evergreen forest of Nambor wildlife sanctuary and Bornewria forest of Karbi Anglong, Assam. The cause of high species richness in BRF is due to its geographic location within the foothills of the Himalayas, which is known for its rich biodiversity.

The dominant families reported in the present study corroborates the results of Mishra et al. (2005) conducted in sub-tropical humid forests of Meghalaya, Tynsong & Tiwari (2011) in natural forests and arecanut agroforests of south Meghalaya, Borah et al. (2016) in tropical moist evergreen and tropical moist semi evergreen of Barak valley in Assam, and Deb & Sundriyal (2007) in tropical wet evergreen forests of Namdapha National Park.

The tree density (543 individuals × ha^{-1}) observed in the present study was lower as compared to the tree densities reported by various authors across the region. Of them, Sarkar & Devi (2014) reported 750 individuals × ha^{-1} from Hollongapar Gibbon wild life sanctuary of Assam; Majumdar & Dutta (2015) recorded 566–964 individuals × ha^{-1} in tropical semi-evergreen forest of North east India; Mishra et al. (2018) reported 34 to 610 individuals × ha^{-1} in tropical forest cover of Balasore district of Odisha. It is quite higher than reported by Hossain et al. (1997) (369 individuals × ha^{-1}) in Bamu Reserved Forest of Cox's Bazar forest division, Bangladesh, and Nath et al. (1998) (381 individuals × ha^{-1}) in Sitapahar forest reserve of Chittagong hill tracts (south) forest division, Bangladesh. The mean basal area (44.42 m^2 × ha^{-1}) recorded is comparable to data of Majumdar & Dutta (2015) (19.22–53.82 m^2 × ha^{-1}) and Sarkar & Devi (2014) (58 m^2 × ha^{-1}). Finally, it is higher than it was reported by Sahoo et al. (2017) (7.77 m^2 × ha^{-1} to 31.62 m^2 × ha^{-1}) in tropical deciduous forest of Eastern Ghats and Mishra et al. (2018) (28.45 m^2 × ha^{-1}) for tropical forest of Balasore district of Odisha.

Some studies (e.g. Bhat et al., 2000) showed that, in contrary to our results, the decreasing trend of α-diversity and its components along the perturbation intensity reflects enhanced utilization pressure. On the basis of our study, we may assume the decline in exploitation load in the study area. Increasing disturbance can also lead to decreased resource availability (Brokaw, 1985). The k-dominance measures intrinsic diversity (Lambshead et al., 1983). Platt et al. (1984) noted that diversity can only be clearly estimated when the k-dominance curves from the communities to be compared do not overlap. The most diverse community is indicated by the lowest curve represented at the plot. Thus in our study, diversity was maximal for the community under medium level of disturbance, while communities under the lowest and highest disturbance pressure had minimal diversity. These results are a bit in contrast to Sagar & Singh (2005) demonstrated expectedly that the least disturbed sites have maximal diversity.

The Shannon Weiner index (0.99 to 2.76) recorded in present study is lower than the value reported by Sarkar & Devi (2014), Majumdar & Dutta (2015). However, it was higher than value reported by Khali & Bhatt (2014) for Garhwal forest. The Shannon diversity index generally ranged between 0.83 and 4.10 (Singh et al., 1984; Parthasarathy et al., 1992) for Indian forests and the present study value is within this range. The Simpson index (0.42 to 0.92) recorded in present study also was within the range as it was reported (0.03 to 0.93) for tropical forest of India (Deb & Sundriyal, 2011; Kushwaha & Nandy, 2012). The evenness index (0.79) was comparable to Nath et al. (2005) (0.78) and Sarkar & Devi (2014) (0.82), while the higher evenness index value indicated continuity in species distribution and rich distribution of species across different forest stands. In the present study, it was found that mainly *Magnolia hodgsonii* recorded highest IVI and was most dominant species, followed by *Bauhinia variegata, Mesua ferrea* and *Elaeocarpus rugosus,* indicated by total IVI (25%) dominance across the forest stands.

The girth class distribution frequency recorded in the present study well exhibited reverse J-shaped curve (Fig. 5). It was similar to those reported from different forests of northeast India (Mishra et al., 2005; Tynsong & Tiwari, 2011) and Eastern Ghats (Sahoo et al., 2017).

The studied forest has a multilayered canopy with the large sized canopy occupied by *Syzygium oblatum*, *Stereospermum chelonoides, Pterospermum acerifolium, Pterospermum lanceifolium, Monoon simiarum* and others. The medium sized canopy was represented by *Dillenia indica*, *Mesua ferrea*, *Magnolia hodgsonii*, *Drypetes assamica*, *Sloanea sterculiacea* var. *assamica*, *Castanopsis armata,* while the lower-sized canopy by *Saurauia napaulensis, Litsea chartacea*, *Baccaurea ramiflora*, *Croton persimilis* an others. These three layered canopy systems were also evident in the studies of Upadhaya et al. (2003) from two sub-tropical humid forests of Jaintia hills district of Meghalaya and Tynsong & Tiwari (2011) from South Meghalaya.

6. Conclusions

The 1.4-ha area studied in semi-evergreen forest of BRF exhibited high species richness (118 species), mean basal area (44.42 $m^2 \times ha^{-1}$) and forest stand density (788 stems) as compared to other forests of the northeastern region. The forest comes under the protected areas of Assam. But it is still not sufficient to protect the biodiversity presented in this area. Illegal tree felling for timber as well as firewood and encroachment for agriculture and settlements is a serious threat and has been the cause of much devastation in the last few decades. More subsequent studies on regeneration, overall diversity could help initiate restoration works in the peripheral zones of the Behali Reserve Forest. Furthermore, educating the local people on the sustainable use of resources would lower the pressure on the forest which in turn will decrease the damage caused to this fragile ecosystem due to the various human disturbances. The present study in the BRF is a preliminary one, and more subsequent studies are necessary for monitoring the status and proposing various strategies useful in forest management and conservation.

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Appendix. Abundance, density (DHA), frequency (FRQ), basal area (BA) and Importance Value Index (IVI) of the studied vegetation in Behali Reserve Forest (India)

Species	**Family**	**Abundance (number of individuals)**	**DHA**	**FRQ**	**BA**	**IVI**
Actinodaphne obovata (Nees) Blume	Lauraceae	5	3.57	14.29	0.21	2.33
Aesculus assamica Griff.	Sapindaceae	1	0.71	2.86	0.05	0.94
Aglaia edulis (Roxb.) Wall.	Meliaceae	4	2.86	11.43	0.20	1.98
Ailanthus integrifolia Lam.	Simaroubaceae	3	2.14	5.71	0.09	1.71
Alseodaphne khasyana (Meisn.) Kosterm.	Lauraceae	1	0.71	2.86	0.04	0.94
Alseodaphnopsis andersonii (King ex Hook.f.) H.W.Li & J.Li	Lauraceae	1	0.71	2.86	0.11	0.94
Alstonia scholaris (L.) R.Br.	Apocynaceae	3	2.14	8.57	0.30	1.63
Antidesma montanum Blume	Phyllanthaceae	6	4.29	14.29	0.22	2.57
Aphanamixis polystachya (Wall.) R.Parker	Meliaceae	6	4.29	8.57	0.94	2.60
Aporosa wallichii Hook.f.	Phyllanthaceae	1	0.71	2.86	0.03	0.94
Archidendron clypearia (Jack) I.C.Nielsen	Fabaceae	2	1.43	5.71	0.19	1.28
Baccaurea ramiflora Lour.	Phyllanthaceae	7	5.00	17.14	0.25	2.90
Balakata baccata (Roxb.) Esser	Euphorbiaceae	2	1.43	2.86	0.51	1.65
Baliospermum calycinum Müll. Arg.	Euphorbiaceae	1	0.71	2.86	0.03	0.94
Bauhinia variegata L.	Fabaceae	61	43.57	34.29	4.99	13.39
Beilschmiedia assamica Meisn.	Lauraceae	10	7.14	25.71	0.57	3.91
Beilschmiedia brandisii Hook.f.	Lauraceae	7	5.00	20.00	0.57	3.02
Bischofia javanica Blume	Phyllanthaceae	9	6.43	5.71	0.90	4.24
Bombax ceiba L.	Malvaceae	5	3.57	2.86	0.71	3.80
Breynia androgyna (L.) Chakrab. & N.P.Balakr.	Phyllanthaceae	1	0.71	2.86	0.02	0.94
Bridelia sp.	Phyllanthaceae	2	1.43	5.71	0.06	1.28
Callicarpa arborea Roxb.	Lamiaceae	3	2.14	8.57	0.33	1.63
Canarium bengalense Roxb.	Burseraceae	3	2.14	8.57	0.14	1.63
Canarium resiniferum Bruce ex King	Burseraceae	13	9.29	20.00	0.88	4.29
Carallia brachiata (Lour.) Merr.	Rhizophoraceae	1	0.71	2.86	0.07	0.94
Casearia vareca Roxb.	Salicaceae	2	1.43	5.71	0.08	1.28
Castanopsis armata (Roxb.) Spach	Fagaceae	4	2.86	8.57	0.30	1.96

Castanopsis indica (Roxb. ex Lindl.) A.DC.	Fagaceae	1	0.71	2.86	0.12	0.94
Castanopsis lanceifolia (Oerst.) Hickel &A.Camus	Fagaceae	11	7.86	25.71	0.94	4.10
Chisocheton cumingianus subsp. *balansae* (C.DC.) Mabb.	Meliaceae	13	9.29	17.14	0.75	4.25
Cinnamomum bejolghota (Buch.-Ham.) Sweet	Lauraceae	4	2.86	11.43	0.19	1.98
Claoxylon longipetiolatum Kurz	Euphorbiaceae	1	0.71	2.86	0.02	0.94
Cordia dichotoma G.Forst.	Boraginaceae	1	0.71	2.86	0.07	0.94
Crateva religiosa G.Forst	Capparaceae	1	0.71	2.86	0.04	0.94
Croton persimilis Müll.Arg	Euphorbiaceae	1	0.71	2.86	0.03	0.94
Cryptocarya amygdalina Nees	Lauraceae	2	1.43	5.71	0.07	1.28
Dalbergia rimosa Roxb.	Fabaceae	1	0.71	2.86	0.09	0.94
Dalrympelea pomifera Roxb.	Staphyleaceae	23	16.43	48.57	1.69	7.47
Dendrocnide sinuata (Blume) Chew	Urticaceae	3	2.14	5.71	0.09	1.71
Dillenia indica L.	Dilleniaceae	16	11.43	28.57	2.47	5.18
Drypetes assamica (Hook.f.) Pax & K.Hoffm.	Putranjivaceae	2	1.43	5.71	0.18	1.28
Duabanga grandiflora (Roxb. ex DC.) Walp.	Lythraceae	1	0.71	2.86	0.33	0.94
Dysoxylum excelsum Blume	Meliaceae	5	3.57	11.43	0.57	2.25
Dysoxylum gotadhora (Buch.-Ham.) Mabb.	Meliaceae	20	14.29	31.43	1.34	6.04
Ehretia wallichiana Hook.f. & Thomson ex C.B.Clarke	Boraginaceae	2	1.43	5.71	0.05	1.28
Elaeocarpus angustifolius Blume	Elaeocarpaceae	1	0.71	2.86	0.03	0.94
Elaeocarpus rugosus Roxb. ex G.Don	Elaeocarpaceae	39	27.86	48.57	2.87	10.05
Elaeocarpus varunua Buch.-Ham. ex Mast.	Elaeocarpaceae	30	21.43	42.86	1.17	8.30
Ficus drupacea Thunb.	Moraceae	5	3.57	11.43	2.12	2.25
Ficus nervosa B.Heyne ex Roth	Moraceae	1	0.71	2.86	0.20	0.94
Ficus oligodon Miq.	Moraceae	1	0.71	2.86	0.03	0.94
Ficus sp. 1	Moraceae	1	0.71	2.86	0.26	0.94
Ficus sp. 2	Moraceae	1	0.71	2.86	0.90	0.94
Friesodielsia fornicata (Roxb.) D.Das	Annonaceae	1	0.71	2.86	0.10	0.94
Garcinia xanthochymus Hook.f. ex T.Anderson	Clusiaceae	1	0.71	2.86	0.04	0.94
Glochidion zeylanicum var. arborescens (Blume) Chakrab. &M.Gangop.	Phyllanthaceae	1	0.71	2.86	0.08	0.94
Glochidion zeylanicum var. *tomentosum* (Dalzell)	Phyllanthaceae	1	0.71	2.86	0.06	0.94

Trimen						
Gynocardia odorata R.Br.	Achariaceae	28	20.00	51.43	3.02	8.44
Horsfieldia kingii (Hook.f.) Warb.	Myristicaceae	1	0.71	2.86	0.04	0.94
Huberantha jenkinsii (Hook.f. & Thomson) Chaowasku	Annonaceae	1	0.71	2.86	0.02	0.94
Kydia calycina Roxb.	Malvaceae	1	0.71	2.86	0.17	0.94
Leea macrophylla Roxb. ex Hornem.	Vitaceae	4	2.86	8.57	0.24	1.96
Lindera reticulata (Blume) Benth. &Hook.f. ex Fern.-Vill.	Lauraceae	2	1.43	5.71	0.07	1.28
Litsea albescens (Hook.f.) D.G.Long	Lauraceae	1	0.71	2.86	0.03	0.94
Litsea assamica Hook.f.	Lauraceae	1	0.71	2.86	0.07	0.94
Litsea chartacea Hook.f.	Lauraceae	3	2.14	8.57	0.08	1.63
Litsea glutinosa (Lour.) C.B.Rob.	Lauraceae	1	0.71	2.86	0.31	0.94
Litsea hookeri (Meisn.) D.G.Long	Lauraceae	3	2.14	5.71	0.14	1.71
Litsea khasyana Meisn.	Lauraceae	2	1.43	5.71	0.09	1.28
Litsea laeta (Nees) Trimen	Lauraceae	1	0.71	2.86	0.03	0.94
Litsea monopetala (Roxb.) Pers.	Lauraceae	2	1.43	5.71	0.28	1.28
Macaranga denticulata (Blume) Müll.Arg.	Euphorbiaceae	5	3.57	14.29	0.26	2.33
Macropanax dispermus (Blume) Kuntze	Araliaceae	1	0.71	2.86	0.03	0.94
Magnolia griffithii Hook.f. & Thomson	Magnoliaceae	1	0.71	2.86	0.14	0.94
Magnolia hodgsonii (Hook.f. & Thomson) H.Keng	Magnoliaceae	135	96.43	94.29	10.43	26.83
Magnolia kingii (Dandy) Figlar	Magnoliaceae	2	1.43	5.71	0.06	1.28
Mallotus nudiflorus (L.) Kulju &Welzen	Euphorbiaceae	3	2.14	2.86	0.29	2.37
Mallotus philippensis (Lam.) Müll.Arg.	Euphorbiaceae	3	2.14	5.71	0.15	1.71
Mallotus roxburghianus Müll.Arg.	Euphorbiaceae	2	1.43	2.86	0.06	1.65
Mesua ferrea L.	Calophyllaceae	43	30.71	37.14	4.34	10.28
Microcos paniculata L.	Malvaceae	1	0.71	2.86	0.07	0.94
Miliusa dioeca (Roxb.) Chaowasku& Kessler	Annonaceae	18	12.86	31.43	0.62	5.68
Mitrephora tomentosa Hook.f. & Thomson	Annonaceae	2	1.43	5.71	0.06	1.28
Monoon simiarum (Buch.-Ham. ex Hook.f. & Thomson) B.Xue & R.M.K.Saunders	Annonaceae	15	10.71	28.57	0.72	5.00
Morus macroura Miq.	Moraceae	6	4.29	11.43	0.37	2.53

Oreocnide integrifolia (Gaudich.) Miq.	Urticaceae	17	12.14	34.29	0.81	5.64
Phoebe attenuata (Nees) Nees	Lauraceae	3	2.14	5.71	0.22	1.71
Phoebe bootanica (Meisn.) M.Gangop.	Lauraceae	1	0.71	2.86	0.08	0.94
Phoebe lanceolata (Nees) Nees	Lauraceae	1	0.71	2.86	0.08	0.94
Picrasma javanica Blume	Simaroubaceae	13	9.29	31.43	0.79	4.77
Protium serratum (Wall. ex Colebr.) Engl.	Burseraceae	2	1.43	2.86	0.26	1.65
Pterospermum acerifolium (L.) Willd.	Malvaceae	12	8.57	22.86	1.88	4.17
Pterospermum lanceifolium Roxb. ex DC.	Malvaceae	4	2.86	11.43	0.63	1.98
Pyrenaria khasiana var. lakhimpurense N. Odyuo & D.K. Roy	Theaceae	6	4.29	14.29	0.18	2.57
Saurauia armata Kurz.	Actinidiaceae	3	2.14	5.71	0.21	1.71
Saurauia napaulensis DC.	Actinidiaceae	9	6.43	11.43	0.35	3.35
Sloanea sterculiacea var. assamica (Benth.) Coode	Elaeocarpaceae	14	10.00	37.14	0.84	5.28
Sterculia lanceolata var. coccinea (Jack) Phengklai	Malvaceae	2	1.43	5.71	0.05	1.28
Sterculia villosa Roxb. ex Sm.	Malvaceae	5	3.57	8.57	0.64	2.28
Stereospermum chelonoides (L.f.) DC.	Bignoniaceae	10	7.14	22.86	1.72	3.77
Styrax hookeri C.B.Clarke	Styracaceae	2	1.43	5.71	0.16	1.28
Symplocos sp.	Symplocaceae	1	0.71	2.86	0.11	0.94
Syzygium balsameum (Wight) Wall. ex Walp.	Myrtaceae	1	0.71	2.86	0.06	0.94
Syzygium fruticosum DC.	Myrtaceae	4	2.86	11.43	0.20	1.98
Syzygium oblatum (Roxb.) Wall. ex A.M.Cowan & Cowan	Myrtaceae	4	2.86	11.43	0.21	1.98
Toona hexandra (Wall.) M.Roem.	Meliaceae	1	0.71	2.86	0.05	0.94
Unknown 10		1	0.71	2.86	0.12	0.94
Unknown 11		1	0.71	2.86	0.05	0.94
Unknown 12		2	1.43	2.86	0.06	1.65
Unknown 13		1	0.71	2.86	0.02	0.94
Unknown 14		1	0.71	2.86	0.04	0.94
Unknown 15		1	0.71	2.86	0.05	0.94
Unknown 16		1	0.71	2.86	0.03	0.94
Unknown 17		4	2.86	5.71	0.13	2.13
Unknown 18		1	0.71	2.86	0.04	0.94

Unknown 2		1	0.71	2.86	0.03	0.94
Unknown 3		1	0.71	2.86	0.19	0.94
Unknown 4		1	0.71	2.86	0.04	0.94
Unknown 5		1	0.71	2.86	0.16	0.94
Unknown 6		1	0.71	2.86	0.02	0.94
Unknown 7		1	0.71	2.86	0.06	0.94
Unknown 8		1	0.71	2.86	0.05	0.94
Unknown 20		1	0.71	2.86	0.07	0.94
Vitex glabrata R.Br.	Lamiaceae	3	2.14	8.57	0.42	1.63
Vitex pinnata L.	Lamiaceae	2	1.43	5.71	0.23	1.28
Vitex quinata (Lour.) F.N.Williams	Lamiaceae	2	1.43	5.71	0.12	1.28
Wrightia arborea (Dennst.) Mabb	Apocynaceae	1	0.71	2.86	0.03	0.94
Zanthoxylum rhetsa (Roxb.) DC.	Rutaceae	1	0.71	2.86	0.06	0.94
Total		**788**	**562.86**	**1294.29**	**63.47**	**300.00**