Article

Cachar tropical semi-evergreen forest type of Northeast India: status of species diversity, distribution and population structure

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Received 27 April 2015; Accepted 15 June 2015; Published online 1 September 2015

Abstract
Conservation of threatened species in most cases is difficult because of incomplete knowledge about their actual distribution, population and habitat ecology. Quantitative vegetation inventory was applied to analyse phytosociological structure of Cachar tropical semi–evergreen forest type in Northeast India, which is consider as a rare forest sub–type. Total 9, 500 × 10m (0.5 ha) sized line transects were laid in Tripura. Overall 3,391individuals of woody species were measured in 4.5 ha analysis, which represented total 167 species. Out of 167 species, 138 species were tree, 14 were shrubs, 10 woody climbers, 3 bamboos and 2 palm species. Again, taxonomically out of 167 species only 6 species was monocot; deciduous and evergreen ratio was 98: 69. Further, out of 167 species 95 species showed aggregated distribution than 72 random distributions. Stem density was ranged 566–964 ha^{-1}, basal area 19.22–52.82 $m^2 ha^{-1}$; but most species listed with very low Important Value Index (IVI), where 51 species identified as very rare (<2 individuals). Overall density was declined linearly (r^2_{adj} =0.62; p>0.05) from predominant to very rare population group (r^2_{adj} is adjusted correlation co-efficient). Stem density–girth relation was significantly quadratic and showed highest coefficient value for sapling (r^2_{adj} =0.99; p<0.05) than adult density (r^2_{adj}=0.96; p<0.001); however, stem density was declined across the height classes (r^2_{adj} =0.56; p<0.05). Present findings demonstrate the high conservation value of this habitat, as umbrella species (*Dipterocarpus turbinatus*) was red listed as critically endangered by International Union for Conservation of Nature and Natural Resources (IUCN) with 13 globally threatened plants. Present analysis offers easy scope for effective habitat management and strategies for species conservation and restoration through ecological niche modeling tool.

Keywords semi–evergreen forest; diversity and structure; population inventory; keystone and singleton taxa; species conservation.

Proceedings of the International Academy of Ecology and Environmental Sciences
ISSN 2220-8860
URL: http://www.iaees.org/publications/journals/piaees/online-version.asp
RSS: http://www.iaees.org/publications/journals/piaees/rss.xml
E-mail: piaees@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

North–eastern region of India has wide range of ecological habitats varying from grassland to dense forests, disturbed secondary *Jhum* fallows to almost virgin natural forests (Rao, 1994). These diverse landscapes has vital role from biodiversity and conservation point of view due to its great floristic richness and endemism (Chatterjjee, 1939). Champion and Seth (1968) have classified Indian forests into 16 types, 46 sub–types and 221 ecologically stable formations in different geographic zones of the country; out of which 16 major forest types, 13 sub types and 54 ecologically stable formations are situated in North–east India (IIRS, 2002).

The semi–evergreen forest is the type where the upper canopy tree is defoliated for some of the year especially during dry season or drought periods and the lower canopy tree retains its foliage (Walter, 1976; Dittus, 1977). Tropical semi–evergreen forest type is one of the most important forest types with respect to both floral and faunal richness (Farnsworth, 1993; Khan et al., 1997). Likewise Andaman, Western and Eastern Ghats in India, this forest type is also distributed in the North–eastern states with 15363.42 km^2 geographical areas i.e. 5.86 % of total land cover in this region (ISFR, 2011) and sustaining the rich endemic biodiversity, many ecological functions and interactions since time immemorial. Instead of legal protection, large tracts of tropical Semi–evergreen forest have been modified, reduced and destroyed for multiple requirements (Islam et al., 2001)

More specifically, the Cachar tropical Semi–evergreen forest type (2B/2S2/C2) was considered as an ecologically stable formation of tropical Semi–evergreen forest (Champion and Seth, 1968). The structural features are not so dense and canopy mostly dominated by *Dipterocarpus turbinatus*, *Artocarpus chaplasha*, *D. tuberculatus* and *Melanorrhoea usitata* etc.; which almost closed on hills tops and ridges on sandy loam and laterite soils where annual rainfall somewhat over 2,500 mm. It was also predicted that much of the area would have tropical evergreen as the climatic climax, but the semi– evergreen stage holds this position and locally appears on more exposed aspects; traversed by *Jhuming* and bamboo brakes scattered with both evergreen and deciduous trees (Champion and Seth, 1968).

Structure and diversity of evergreen and semi–evergreen forests especially for south–east Asian lowland Dipterocarp forests were well studied (Newbery et al., 1992; Newbery et al., 1999). Kadavul and Parthasarathy (1999a; 1999b) investigated the structure and dynamics of semi–evergreen forests Shervarayan hills and Kalayan hills in Eastern Ghats of India. However, undisturbed and disturbed tropical semi–evergreen forests of Mizorum were also investigated (Lalfakawma et al., 2009). Devi and Yadava (2002) analysed the vegetation structure of tropical semi–evergreen forest dominated by *D. tuberculatus*in Manipur. Although, earlier studies were different in terms of local topography and climate; even in terms of local edaphic and anthropogenic factors. In fact, variation in dominant composition, diversity, structure, species abundance and rarity are strongly determines by those factors with respect to local environment. In addition, semi–evergreen forests of Northeast India have received very little attention; and, hence composition and structural pattern of this forest type was underexplored and still inadequately understood. Whereas, structural attributes of forests, size distribution and spatial arrangement of individual trees are largely accepted both for theoretical and practical applications to understand and manage forest ecosystems (Laurance and Bierregaard, 1997). Habitat loss and illegal logging are considered as the main factors for reduction of population of *Dipterocarpus* trees in the forest areas and, hence many species are globally threatened (Ashton, 1998). Large number of trees was exploited historically especially for laying railway sleeper from northeast India. High timber value of these key dominant trees resulted over –exploitation of these species even from the protected reserve forests and changes in the land use system also causes severe depletion of remaining forest tracts. Present approach was also significant as the umbrella tree species of semi-evergreen habitat (*Dipterocarpus* spp.) have been red listed by IUCN, 2013. In addition, fruitful conservation and species restoration programme also requires data on habitat status, distribution and structural information (Margules and Pressey, 2000). Consequently, it was felt necessary to setup immediate priorities for gathering baseline data for this stable habitat, the remaining diversity and population by floristic inventorization for future conservation implications and habitat management. Both vertical and horizontal structures were investigated to better understand the present ecological status of this lowland semi–evergreen forest. Thus, the present study was designed to assessment of diversity, species distributional pattern, both horizontal and vertical structure and present population status within fragmented Cachar tropical semi–evergreen forests in Tripura, Northeast India. Hence, objectives were set (1) to inventory the woody floral diversity in Cachar tropical semi–evergreen habitat types, (2) to observe species ecological distribution and population grouping patterns, (3) to determine the quantitative habitat structural characteristics including species population status, and (4) application of IUCN red list (2013) for identification of globally threatened species, if any.

2 Materials and methods

2.1 Study area

Champion and Seth (1968) described the distribution of the Cachar tropical Semi–evergreen forest mostly on the lower slopes of the Cachar hils of Assam, Cittagong hills of Bangladesh and adjoining (Tripura), in the Surma valley, Lusai hills of Mizorum and Manipur. The present study was conducted in Tripura, the third smallest state of India located in the Biogeographic zone of 9B of Northeast region between 22^{o}56' and 24^{o}32' N latitudes and between 91^{o}10' and 92^{o}21' E longitudes with an area geographical of 10,497.69 km^2. This area enjoys tropical monsoon climate and there are mainly three season *viz.* winter, summer and the rainy season. Altitude was recorded <65 a.m.s.l. and annual rainfalls in Tripura are mostly derived from the south–west monsoon and mean annual rainfall is about 2,250 to 2,500 mm. The temperature ranges between 10 and 36° C. There are 19 tribal communities comprising 29 per cent of the state's population. The state has four major primary forest types and three secondary forest formations as per Champion and Seth (1968) classification system (see for details Majumdar et al., 2012). The dataset on tree diversity used in this paper is based on the line transects inventories carried out in 9 semi–evergreen forest sites distributed mostly in Southern parts of the state (Fig. 1); where the forests are considerably similar in terms of dominant canopy formation by *Dipterocarpus turbinatus*. Monitoring of forest areas and their protection in Tripura are administered through territorial forest divisions (FDs), this type of Dipterocarpus dominated forests mostly found in Trishna and some parts in Bagafa, and Gumti forest divisions. Earlier this forest type was scattered throughout the state, but since 1970s, forests of Tripura has experienced severe anthropogenic pressure, especially after immigration of large population from Bangladesh. Large area of natural forests were converted for human habitation and settlements, and now these forests are mostly restricted as small patches into some protected area and reserve forests. The size of the patches varies from >2–<100 ha. The distance between the independent study sites ranged from 5–20 km. Forest areas and its natural resources were encroached upon and heavily exploited, and presently only few area of the remaining forests kept relatively undisturbed in Trishna wildlife sanctuary. The remaining forests and forest resources are under pressure through continuous extraction of timber, fuel wood, bamboo and collection of other Non-Timber Forest Products (NTFPs)by forest dependent people living in and around the forest reserve.

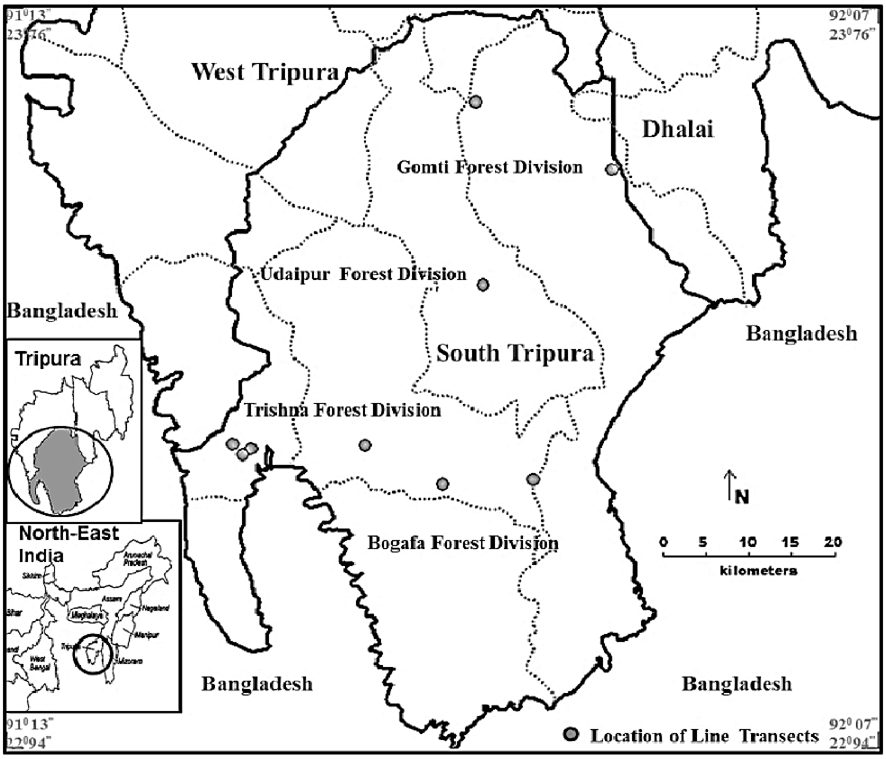

Fig. 1 Geographical location of study area and the sampling plots (line transects) in Cachar tropical semi-evergreen forest of Tripura, Northeast India.

2.2 Field data collection

The preliminary survey was conducted for identification of Cachar tropical semi–evergreen forest using Forest Department reports and maps, interviewing with forestry personnel for locating existing *Dipterocarpus turbinatus* habitat in Tripura. Earlier, this type of forest was distributed in both Northern and Southern parts of the state; but, now have been restricted only in some protected forest patches in South district due to sever biotic influences (Deb 1981). Sampling locations were randomly established where this forest types were observed. Thus, we identified total 4 Forest Divisions (FD) in South district (Udaipur FD, Bagafa FD, Gumti FD and Trishna FD) which represents Cachar tropical semi–evergreen forest. We laid one plot in Garjee Reserve Forest (RF) under Udaipur FD, one plot in Tekkatulsi RF and one plot in Muhuripur RF under Bagafa FD, one plot each in South and North Barmura–Deotamura RF of Gumti FD, one plot in West Kalazhari RF in Gumti FD, one plot in Trishna RF and two plots in Kasari RF under Trishna FD. We used line transects of 10 m × 500 m size (each plot 0.5 ha) to record present floristic inventory in Cachar tropical semi–evergreen forests during 2011–2012. We recorded geographical location and altitude (m) of all identified forests by GPS (Germin e–trex vista) at starting (100m), middle (250m) and ending point (500m) of our 9 line transects. Starting points of all transects were laid in the forest at 10 to 100 m distance from edge, roadside or footpath. All transects were placed in such way that these survey could cover maximum habitat heterogeneity distributed in the existing Reserve Forests (RFs) of this study area. Thus, overall 9 line transects of 0.5 ha size (total 4.5

ha) sampling area were established in 4 FDs and 8 RFs of South Tripura. Therefore, we sampled 0.03% of total geographical area of south Tripura and 0.08% of total recorded forest area of the district. Hence, present sampling intensity was calculated greater than required standard minimum sampling intensity 0.01% (Sukumar et al., 1992). All individual stem ≥10 cm girth (gbh) was measured in centimetre at 1.3 m height and tree height at nearest meters. Shrubs and climbers that attained at ≥10 cm girth category were also measured with in each sampling plot. For individual tree with buttresses or other stem irregularities at breast height, gbh was measured above the buttresses. Specimens were deposited in the herbarium in Botany Department of Tripura University and identified with the help of The Flora of Tripura State (Deb, 1981 and 1983); Flora of Assam (Kanjilal et al., 1934 –1940) and Indian Trees (Brandis.,1906).

2.3 Data analysis

Field oriented data were analysed for quantitative vegetation structural parameters viz. relative frequency, relative density, relative basal area and Importance Value Index (IVI) following Mueller–Dombois and Ellenberg (1974). For quantitative diversity indices, we calculated species diversity index by Shannon and Wiener (1963). The habitat dominance index was calculated following Simpson (1949) and species evenness index was computed following Pielou (1966). Species distribution was analysed by Chi–squared tests, which was used to examine the patchiness of species populations in semi–evergreen forests to observe whether the woody species are distributed randomly through the samples or aggregated or uniformly distributed in the studied area communities (Lambshead and Hodda ,1994; Rice and Lambshead, 1994). Tree density and species richness were also calculated into different population groups viz. Predominant (>50 individuals), Dominant (25 to <50 individuals), Common (10 to <25 individuals), Rare (2 to <10 individuals) and Very Rare (<2 individuals) (Kadavul and Parthasarathy, 1999a). For all population groups, curve estimation was performed to examine the density (y) and richness (x) relationships for this forest type. Height and girth of the trees were analysed for each transects to obtain the mean canopy height (m) and mean forest girth classes. Structure of the vegetation was analysed bythe relationship of population distribution between ean canopy height and girth classes, expressed by regression analysis to observe the forest growth pattern, i.e. both horizontal and vertical distribution of stem. Population of trees ≤30cm gbh were considered as sapling and arranged into four regenerated stages or gbh categories from ≥10–30cm at 5cm interval (Sukumar et al., 1992; Sundriyal and Sharma, 1996). Individuals having girth >30 cm (gbh) were considered as mature or adult trees and also classified into ten girth classes at 30 cm interval. To estimate the density–girth relationships for better understanding of population structure (Sapkota et al., 2009), regression curve was performed between log transformed density ha^{-1} with mid value of sapling girth classes (12.5, 17.5, 22.5, 27.5), mid value of adult girth classes (45, 75, 105, 135, 165, 195, 225, 255, 285, 315), and mid value of height classes (2, 4.5, 7.5, 10.5, 13.5, 16.5, 19.5, 22.5, 25.5, 28.5). All graphs and statistical analysis was performed using Origin software (Pro 7.0).

3 Results

3.1 Species composition and diversity

A total of 3,391 individuals belonging to 167 species (52.67 ±8.86; range 30–65) of 116 genera (44.78 ±7.81; range 33–55) and 54 families (30.56±5.81; range 21–37) were documented at ≥10 cm girth from 4.5 ha sampled area of Cachar Tropical Semi–evergreen forests in Tripura. Shannon's diversity index ranges between 2.90– 3.53 (3.18 ±0.22) and Simpson's dominance index range 0.05–0.17 (0.10±0.04) within the studied plots.

While, overall Pielou's evenness index ranged between 0.72–0.88 (0.81±0.15) along the forests and Menhinick's species richness index ranged between 1.82–3.61 (2.76±0.60). Tree community of this semi–evergreen forest patches were found to predominate by *D. turbinatus*. Major community association was recorded as *D. turbinatus – A. chama, D. turbinatus – Castanopsis indica,* and *D. turbinatus – S. walichii.* Even in more exposed locations *D. turbinatus – B. ceiba, D. turbinatus – M. paniculata, D. turbinatus – S. robusta* was also observed (Table 1). Taxonomically, monocot and dicot ratio was 6:161; besides 165 species Angiosperms, 1 Gymnosperm species (*Gnetum*) and 1 Pteridophyte (Tree fern) were also recorded under this study. Monocot species belongs to families like Poaceae (Bamboo), Arecaceae (Palm), Pandanaceae and Agavaceae. While out of 167 woody species, 138 species were tree, 14 species were shrubs, 10 species woody climbers, 3 bamboo and 2 palm species were recorded. Again out of 167 species, 98 species were deciduous and 69 species were evergreen (Table 2). Canopy layers of this forest formation were distinctly formed and the upper storey typically dominated by *D. turbinatus* with sparse distribution of *A. chama, C. indica, S. wallichii, B. ceiba, Eugenia spp., S. cumini* etc. While, *S. cerasoides, A. procera, T. bellirica, L. coromandelica, L. parviflora, C. arborea, D. pentagyna L. glutinosa* and *M. rotundifolia* typically formed the middle canopy layer. The lower canopy was dominated by several locally adaptable small tree species viz. *H. antidysenterica, B. malabarica, M. paniculata, Macaranga spp.,* and *M. philippensis, Ziziphus funiculosa, Ziziphus rugosa*. Several woody shrubs and climber viz. *Dalbergia thomsonii, Dalbergia volubilis, Combretum* spp., *Acacia* spp., *and Ardesia* spp. were dominated over the ground flora. Rattans and bamboos were randomly formed frequent bushes especially in the forest gaps. The composition of ground flora was mostly belongs to species of Zingiberaceae, Areceae, Poaceae, Bigoniaceae, Rubiacee, Amaryllidaceae. Root parasite (*Aginetia indica*) and different macro–fungus species were also observed under canopy of *D. turbinatus*.

Table 1 Species diversity, dominance and stand structure of Cachar tropical semi– evergreen forest type of Tripura in Northeast India.

Plots	No. of Species	No. of Genus	No. of Family	Shannon's Index	Simpson's Index	Pielou's Index	Density ha^{-1}	Basal Area m^2ha^{-1}	IVI of *D. turbinatus*
P1	53	48	33	3.51	0.05	0.88	812	19.22	91.14
P2	51	41	26	3.22	0.08	0.82	566	39.84	122.3
P3	40	33	21	3.03	0.09	0.82	964	50.88	131.1
P4	53	48	35	3.22	0.08	0.81	680	47.47	127.41
P5	57	49	32	3.15	0.12	0.78	880	50.71	133.68
P6	39	34	23	3.08	0.08	0.84	764	33.99	121.31
P7	65	53	36	3.53	0.07	0.85	648	20.67	96.8
P8	63	55	37	2.97	0.17	0.72	634	44.16	150.8
P9	53	42	32	2.90	0.15	0.73	834	52.82	153.84
Mean± Sd	52.67± 8.86	44.78± 7.81	30.56± 5.81	3.18± 0.22	0.10± 0.04	0.81± 0.05	753.56± 130.53	39.97± 12.81	125.38± 21.15

Table 2 Population distribution, habit and phonological groups of Cachar tropical semi–evergreen forest type of Tripura in Northeast India.

Structural attributes	No. of Individuals	No. of Species	Density ha^{-1}	Basal Area m^2ha^{-1}
Population Groups				
Predominant (Individuals >50)	1824	9	405.33	29.17
Dominant (Individuals 25-50)	565	15	125.56	4.43
Common (Individuals 10-25)	594	36	132.00	3.56
Rare (Individuals 2-10)	338	56	75.11	1.78
Very Rare (Individuals <2)	70	51	15.56	0.36
Total	3391	167	753.56	39.31
Habit Groups				
Bamboo	41	3	9.11	0.02
Tree	3229	138	717.56	39.15
Woody Lianas	68	12	15.11	0.10
Woody Shrubs	53	14	11.78	0.05
Total	3391	167	753.56	39.31
Phenological Groups				
Deciduous	1457	91	323.78	10.89
Evergreen	1934	76	429.78	28.42
Total	3391	167	753.56	39.31

3.2 Species distribution pattern, forest structure and population status

Out of 167 species recorded within 4.5 ha sampled area, 95 species were recorded as aggregated distribution and 72 species were found randomly distributed; but no species was recorded as regular distribution (Fig. 2; Appendix 1). When the mean height class of all 167 species were relate with the mean girth class for better representation of the horizontal and vertical structure of the forest (Fig. 3). Distribution of maximum number of species was significantly (r^2_{adj} =0.48; p<0.001) observed in understories (<10 m mean canopy height and <50 cm girth) and showed quadratic relation (equation: $Y = –0.0004X^2 + 0.155X + 2.615$). Species diversity at middle canopy stories (<10 m mean canopy height) was higher than upper canopy stories (<25 m mean canopy height), with very few species distributed at the over stories; species diversity was significantly decreased ($F_{1, 166}$ =75.37; p<0.0001) from understories to upper canopy stories (Fig. 3). Further, analysis of population grouping suggested that predominant group represented 9 species and contributed density of 405.3 $ha^{–1}$, 15 species were in dominant group with density of 125.6 $ha^{–1}$, 36 species were in common group (132 $ha^{–1}$), 56 species were rare with 75.1 $ha^{–1}$ density and 51 species were recorded as very rare with density of 15.6 $ha^{–1}$. Stem density was declined linearly (r^2_{adj} =0.62; p=0.11, equation: Y = –5.61X + 338.19) from predominant to very rare population group, but was not significantly observed ($F_{1, 8}$ =4.85; p>0.05, Fig. 4). Out of the 167 species, 14 globally threatened species were recognized from IUCN red list and analysed for their basic ecological status (Appendix 1). However, Out of 14 red listed species one species listed as Data Deficient (DD), 9 species as Lower Risk/least concern (LC), 2 species as Vulnerable (VU) category and 2 species listed as Critically Endangered (CR) by IUCN (2013).

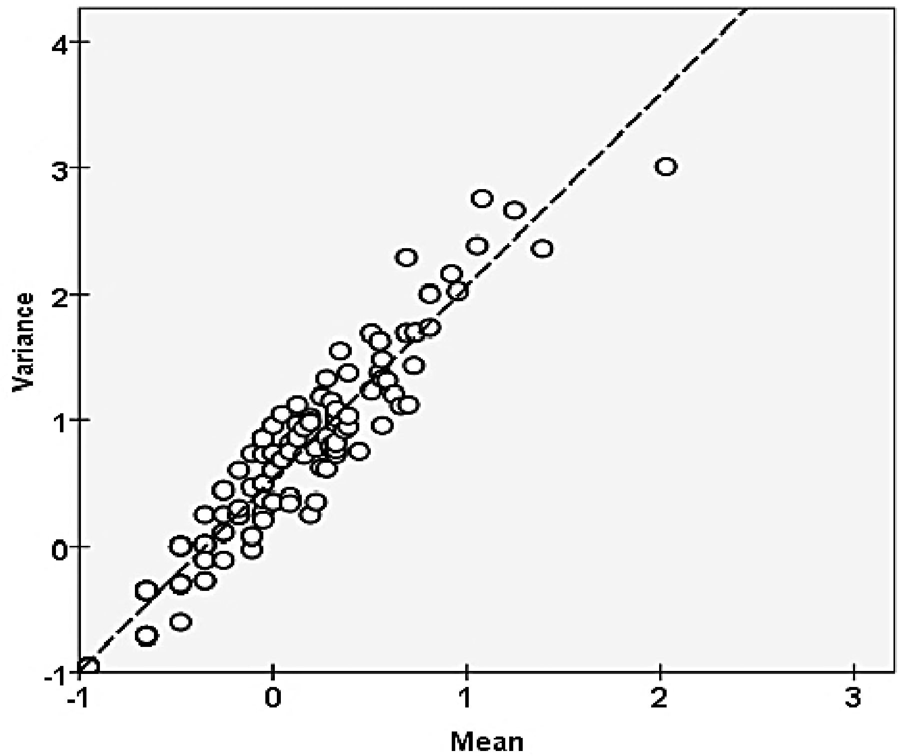

Fig. 2 Species distribution pattern (variance to mean ratio) in Cachar tropical semi-evergreen forest of Tripura.

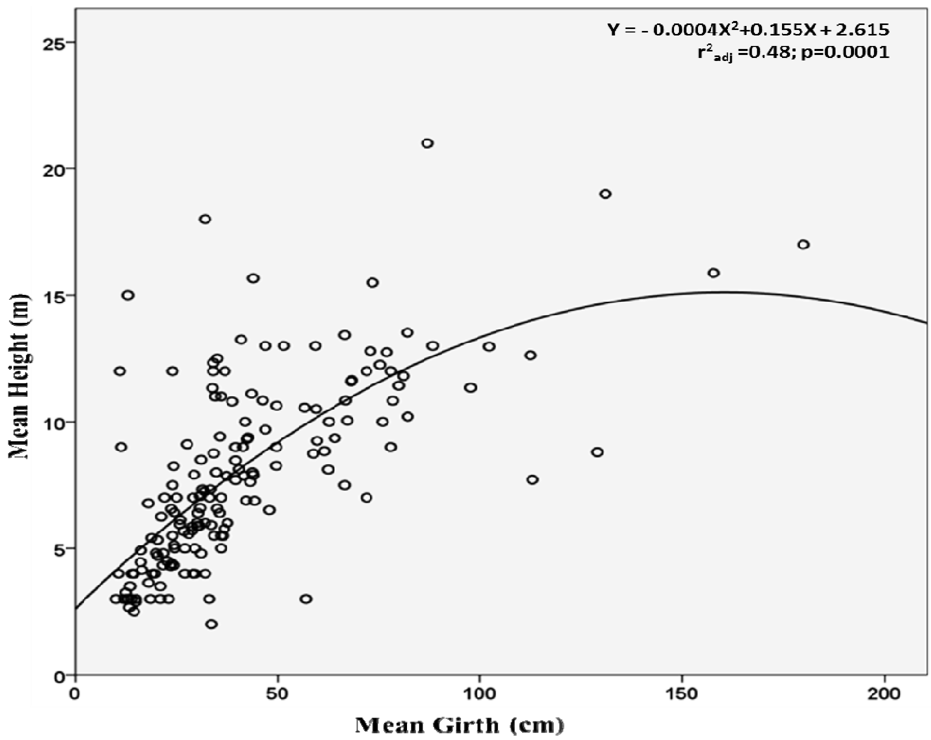

Fig. 3 Relationship between mean girth and height classes showing the distribution of 167 species in different canopy layers in Cachar tropical semi-evergreen forest of Tripura.

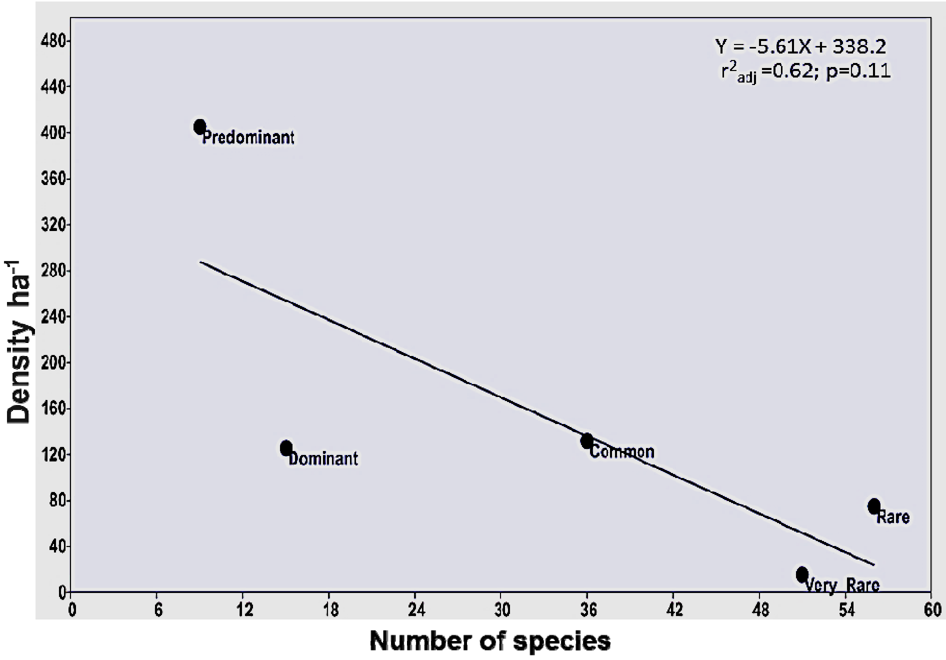

Fig. 4 Distribution of 167 species in different population group (Predominant, dominant, common, rare and very rare) in Cachar tropical semi-evergreen forest.

Total 3,392 individuals were measured with mean density of 753.56 ha^{-1} (range 566–964 ha^{-1}). Mean basal cover area was 39.97 m^{2}ha^{-1} and ranged between 19.22–52.82 m^{2}ha^{-1} among the studied plots. *D. turbinatus* alone contributed 28.37% density (213.78 ha^{-1}), 50.29% basal area (20.10 m^{2}ha^{-1}) and 80.56 % IVI in the present Cachar Tropical Semi–evergreen forest type of Tripura. Top ten dominant tree composition were *D. turbinatus, A.chama, S. wallichii, M. paniculata, S. cerasoides, T. bellirica, D. pentagyna, A. acuminata, L. coromandelica* and *S. cumini*; which encompassed 54.40 % (density 410 ha^{-1}) of total density and 75.60% of total basal area (30.22 m^{2}ha^{-1}). When overall density and basal area was grouped in different girth classes to obtain the distribution of stems along different age classes, maximum density was observed between the sapling (<30 cm) and juvenile group (<60 cm). Whereas, overall distribution of stems in different age groups was more or less reveres ‘J’ shaped, suggested that the individuals predominate at the lowest sizes class (Fig. 5). Overall distribution of basal area along the girth classes showed that maximum mature trees were distributed within 90–150 cm girth and very few trees were exhibited at relatively higher girth classes. Basal area (8.26 m^{2}ha^{-1}) was increased at highest girth class (>300 cm), but number of voluminous tree population was very less (7.78 ha^{-1}) compared to other age classes (Fig. 5).

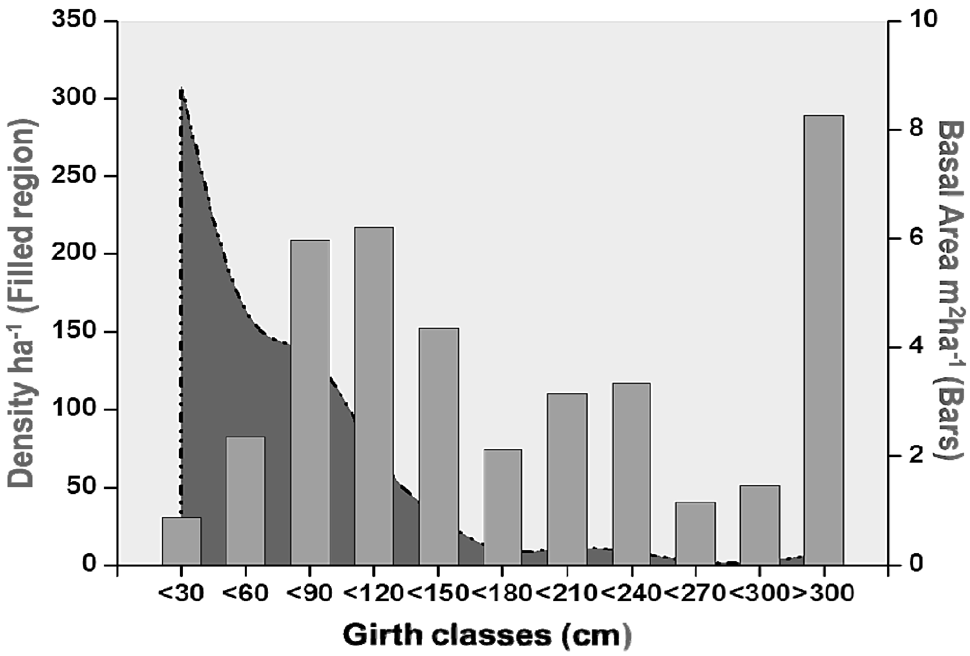

Fig. 5 Stem density and basal area distribution along the girth classes in Cachar tropical semi-evergreen forest.

Sapling density along <30 cm girth classes showed "L" model of distribution, indicating steady dynamic populations distribution (r^2_{adj} =0.99; $p<0.05$); fits better to a polygonal equation: $Y = 0.56X^2 – 27.19X + 363$ (Fig. 6a). Inverse relationship was found between the stand density and the girth class of adult stages (r^2_{adj} =0.96; $p<0.001$; equation $Y = 0.004X^2 – 2.12X + 253.41$) (Fig. 6b). For this forest type, stem density was mostly linearly declined with height classes (r^2_{adj} =0.56; $p<0.05$; equation $Y = –0.05X^2 – 4.04X + 149.81$) (Fig. 6c).

4 Discussion

4.1 Composition and dominant association of Cachar tropical semi evergreen forest

Tropical Semi–evergreen forests are typically distributed in the area where the annual precipitation ranges between 200 to 250cm (Champion and Seth, 1968) and the present study area falls within the similar range of annual rainfall, mostly due to south–west monsoon. The semi–evergreen forest of Tripura found to dominate by *D. turbinatus*, which also similarly observed as most dominant in Cachar tropical semi–evergreen forest types (2B/2S2/C2) proposed by Champion and Seth (1968). However, few top canopy trees (*Cynometra* spp., *Adina*spp., *Xylia* spp., *Chukrasia* spp., *Tetrameles* spp. etc.) were absent might due to its restricted distribution in fragmented habitats and historically exposure to sever biotic pressures (Deb, 1981). Typically, *D. turbinatus* was found to dominate over other evergreen and deciduous trees in this forest type and forms several types of co–dominant associations with *A. chama*, *S. wallichii*, *Castanopsis* spp., *Syzygium* spp.;even with *S. robusta* and several disturbance tolerance small tree species in more exposed areas depending on local edaphic and anthropogenic factors. Similar predominant trend by *Dipterocarpus spp.* in the overstorey was also reported from other tropical rain forests, in Southeast Asia (Whitmore and Brown, 1996; Tyree et al., 1998; Maltamo et al., 2000; Lee et al., 2002; King et al., 2005; Davies et al., 2005; Gunatilleke et al., 2006). *Dipterocarpus* spp. are considered as keystone tree in tropical rainforest, evergreen and semi-evergreen forests; but, many of them have been listed as critically endangered by IUCN (2013).

Many Indian tropical evergreen and semi–evergreen forests dominated by several evergreen tree species (Table 3), but all *Dipterocarpus* spp. have been red listed instead of their ecological dominance (high IVI value) over other trees. This is possibly due to their extensive historical logging for railway sleeper and bridge construction, high timber value, shrinking of natural habitats for human residences and agricultural land expansions. However, *D. turbinatus*is typically abundant with *D. tubercularis* and *D. alatus* in the upper canopy of the forests on moist soil areas of Southern part in Myanmar (Davis, 1964). It was predicted that the flora of seasonal evergreen Dipterocarp forests of Indo–Myanmar are largely endemic to both the region; and forest formation spreads further over West direction than Chittagong, Manipur, and Easternmost of Assam; but, relatively have few species are common in this forest to the seasonal evergreen forests in Peninsular India (Ashton, 1990). Whereas, several trees like *Haldina cordifolia, Calophyllum tomentosum, Hopea parviflora, Spondias mangifera, Tetramales nudiflora, Terminalia paniculata* etc. of Western Ghats typically forms the dominant composition in semi–evergreen forests (Padaki and Parthasarathy, 2000; Muthuramkumar and Parthasarathy, 2000); but, those are not common to the present study area. Tree species like *Chionanthus paniculata, Syzygium cumini, Canthium dicoccum* and *Ligustrum perrottetii* are commonly dominated in the semi–evergreen forests of Eastern Ghats (Kadavul and Parthasarathy, 1999a). But the semi–evergreen forest of Andaman, which commonly occurs in the valleys on well drained alluvial soil usually dominated by several Dipterocarpus spp. (Rajkumar and Parthasarathy, 2008), whereas *D. turbinatus*isthe second dominant tree after *Myristica andamanica* in Andaman evergreen forest (Padalia et al., 2004). However, semi–evergreen forests of Manipur typically dominated by *D. tuberculatus* (Devi and Yadava, 2006) instead of *D. turbinatus* in case of Tripura and Assam. Rare association of *D. turbinatus* with *S. robusta* in this region might develop due to climate change effects, as Sal forest are shifting from North–western to relatively moisture North–eastern region (Chitale and Behera, 2012). However, *D. turbinatus* insome sites typically associates with some local oligarchic small trees and bamboo species etc. which might result due to the aggressive trend oligarchy of some small trees in degraded habitats.

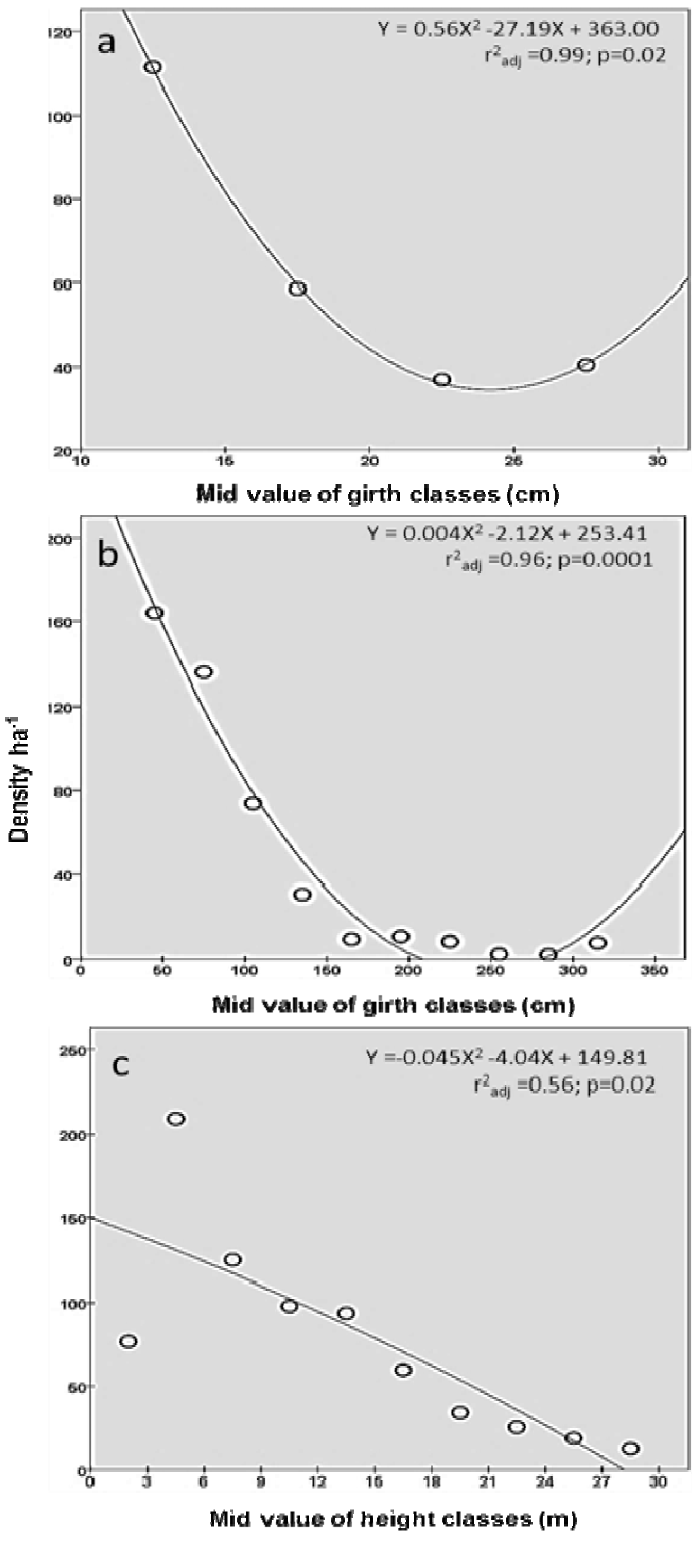

Fig. 6 Density-mid value girth of sapling (a) and adult (b), density - mid value of height (c) classes relationship in Cachar tropical semi-evergreen forest.

Table 3 Comparative major edaphic factors, species diversity and population structure under various tropical evergreen and semi-evergreen forests in India and neighbouring country.

Sl. No.	Altitude (m)	Annual Rainfall (mm)	Forest Type	Sample Area (ha)	Girth Size (cm)	Species	Density ha^{-1}	Basal Area m^2ha^{-1}	Dominated by	Source
1	18-63	2250 - 2500	Cachar tropical semi–evergreen	4.5	≥10	167	566-964	19.22-52.82	*Dipterocarpus turbinatus*	Present Study
2	722	2773	Tropical semi-evergreen	1.2	>1	67	–	–	*Castanopsis tribuloides*	Lalfakawma et al. 2009
3	990-2035	2500	Subtropical wet semi-evergreen	0.4	≥15	132-192	852-2103	7.1-26.9	*Rhododendron arboreum*	Mishra et al. 2004
4	300-360	1245	Tropical semi - evergreen	5	>1	123	685-820	18.9-19.58	*Dipterocarpus tuberculatus*	Devi and Yadava 2006
5	200	2500	Tropical wet - evergreen	0.9	>1	16-54	338-5452	18.60-104.6	*Dipterocarpus macrocarpus*	Bhuyan et al. 2003
6	460-600	1335	Tropical semi-evergreen	4	≥30	80	640-986	21.62-44.26	*Syzygium cumini*	Kadavul and Parthasarathy 1999a
7	200	5100	Tropical wet - evergreen	3.12	≥30	91	635	39.1	*Vateria indica*	Pascal and Pelissier 1996
8	–	3200	Giant evergreen	2	≥30	105	579 - 732	45.25-47.51	*Dipterocarpus incanus*	Rajkumar and Parthasarathy 2008
9	210	3000-3500	Andaman semi-evergreen	2	≥30	43-83	543-935	44.7-55.3	*Tetrameles nudiflora*	Rasingam and Parthasarathy 2009
10	–	3048	Andaman evergreen	4.52	≥30	264	1137	44.28	*Dipterocarpus turbinatus*	Padalia et al. 2004
11	–	3048	Andaman semi-evergreen	4	≥17	231	1027	33.76	*Myristica andamanica*	Padalia et al. 2004
12	–	700–1200	Tropical semi-evergreen	2	≥ 10	66	384.05	48.05	*Dipterocarpus turbinatus*	Biswas and Misbahuzzaman, 2008
13	30-900	2450-3810	Tropical semi-evergreen	0.1	>5	63	399	35.5	*Tetrameles nudiflora*	Dewan 2009

4.2 Tree species diversity and habitat structure

Total number of 167 woody species recorded in the present study was greater than 123 species (Devi and Yadava, 2006) and 85 species (Chowdhury et al., 2000) from tropical semi–evergreen forests of Indo–Myanmar region. Also found to be higher than the 89 species reported by Kadavul and Parthasarathy (1999a) from Eastern Ghats and 91 species from tropical wet evergreen forest of Western Ghats (Pascal and Pelissier, 1996). Overall 167 species (range 39–65) was also greater than Hossain et al. (1997), Nath et al. (1998) and Biswas and Misbahuzzaman (2010); where 85, 85 and 66 species respectively were reported from *D. turbinatus* dominated semi–evergreen forests of Chittagong Hill Tracts of Bangladesh. High species richness in this forest types may due to lower altitudinal areas (mean 41.95m amsl) and geographical confluence of Indo–Myanmar biogeographic zone (Eastern Himalayan range). Because, increasing species richness at lower elevation is expectable both in case of whole floras and smaller spatial scales (Korner, 1992). However, 167 species was also very less than 244 species in Malaysia (Manokaran and Kochummen, 1987), 214 species in Sarawak (Proctor et al. 1983) and 198 species in Tropical forest of Asia (Nicholson 1965). Mean Shannon diversity index obtained for the present study (3.18) was within the general limit of 1.5–3.5 reported by Kent and Coker (1992) and Parthasarathy (2001). Diversity is quite high because of several rare species in this forest formation. Stand density ranges between 566–964 ha^{-1}, which was closed to Semi–evergreen forest of Northeast (685–820 tree ha^{-1}; Devi and Yadava, 2006) and Eastern Ghats (640–986 ha^{-1}; Kadavul and Parthasarathy, 1999a). Mean density value also quite higher than Hossain et al. (1997), 369 stem ha^{-1}; Nath et al. (1998), 381 stem ha^{-1} and Biswas and Misbahuzzaman (2010) 384.05 stem ha^{-1} in Bangladesh. The mean basal area of the present forest type was 39.97 m^2ha^{-1}, which was ranged between 19.22–52.82 m^2ha^{-1} and found slightly greater than the pantropical average of 32 m^2ha^{-1} (Dawkins 1959) and semi–evergreen forest in Kalrayan hills (33.7 m^2ha^{-1}) and Shervarayan hills (34.9 m^2ha^{-1}) of Eastern Ghats (Kadavul and Parthasarathy, 1999a). While, mean basal area of this community was greater than 18.9–19.58 m^{-2} ha^{-1} (Devi and Yadava, 2006), closed to 48.05 m^2ha^{-1} (Nath et al., 1998) and 52.05 m^2ha^{-1} (Biswas and Misbahuzzaman, 2010) in the adjacent region (Table 3).

4.3 Species distribution patterns

Maximum number of trees was in aggregated distribution pattern in this forest type, from plain to undulated land forms. Habitat undulation and degree of slope can also lead to higher patchy distributions (Hubbell and Foster, 1983). Winged seeds of *A. scholaris, B. ceiba, D. turbinatus, H. antidysenterica, P. acerifolium, S. wallichii, S. robusta*etc. randomly disperse by wind. Aggregated pattern occurs due to random dispersal of seeds over a heterogeneous environment or due to both seeded and non–seeded regeneration capacities of some trees (Feller, 1943). For instance, *M. paniculata, M. rotundifolia, S. robusta, H. antidysenterica* etc. have high coppicing ability. Seed shape, size, presence of any special appendages and agents also determine species distribution. However, clumping or aggregated distribution patterns of trees may occur due to relatively larger size and weight of fruits (e.g. *A. chama, C. arborea*) which may not disperse over long distance. Without any strong agents, some seeds may not distribute randomly and less frugivore diversity may also results aggregated distribution. Especially, distribution and diversity of *Ficus* spp. or other wild fruit yielding trees intensely reliant on the frugivore diversity in this forest (Majumdar et al., 2012). Present study reflected that most dominant trees or several shrub species appears to have greater ecological amplitude with respect to this forest formation, which might increase this patchy condition and also commonly observed in various other tropical forests (Ashton, 1969; Whitmore and Burnham, 1975; Hubbell, 2001; Forman and Hahn, 1980; Parthasarathy and Karthikeyan, 1997). Species which observed as random distributional pattern were mostly with small individuals and rare may due to less dispersal and regeneration capacity in this association or any edaphic restriction and competition by co–dominant species for resources. In general, findings of the study was confirms the hypothesis that clumping or aggregated distribution pattern of tree is the typical characteristic of natural forests in tropical to temperate climates of the world (Armesto and Pickett, 1985).

4.4 Tree girth–height attributes and population structure

The shape of overall density– girth distribution of tree species stated inverted J–curve, with increasing girth density of trees was decreased; which is a good indication of natural forest (Nath et al., 2005). Since, historic disturbances can be predicted by the multimodal basal area distributions (Maltamo et al., 2000); and the productivity of the forest was decrease across adult girth classes as basal area was decreased which indicated the historic logging activities and enormous demand for fuel wood by local inhabitants of Tripura. However, 7.78 ha^{-1} density (1.03%) of trees in the highest girth class (>300 cm) due to old voluminous *D. turbinatus* (max. 540 cm girth), *A. chama* (max. 347 cm girth), *B. ceiba* (max. 572 cm girth) and *E. spicata* (max. 433 cm girth) etc. were persisted under strict protection especially within the Sanctuary boundary and, therefore these also representing high basal cover area (8.26 m^2ha^{-1}). However, only 3.00% individual trees were in the highest girth class (>80 cm); *D. turbinatus* had the highest relative density (9.38%) and relative basal cover area (23.30%) recorded from similar forest type in neighbouring country of Bangladesh (Biswas and Misbahuzzaman, 2010). *D. tuberculatus* exhibited very low in sapling and adult population than higher proportion of seedlings, and relatively adult trees (>40–50 cm GBH) were absent in semi–evergreen forest of Manipur (Devi and Yadava, 2006). Though, *D. turbinatus* represented 28.37 % relative density, 50.54 % relative basal cover area and 80.08 % IVI (out of 300) in present study area. These suggested the potentiality and dynamic nature of lowland *D. turbinatus* dominated semi–evergreen forest of Tripura.

The greatest rates of height growth for a given girth at breast height increment were found among the understory and midstorey species. Analysis of sapling (<30cm girth) and adult (>30cm) girth classes distribution was also reverse J–shaped pattern. About 40.48% of trees were in advance sapling stages (<30cm girth), which included many adult small sized tree species of understory. Significant inverse relation was detected among the pole sized girth classes (≥ 10 –<30 cm), which indicated that the saplings population was significantly ($F_{2,3}$ =1053.05; p=0.02) established in this forest type (Fig. 6a). Population of adult trees was declined ($F_{2,9}$ =107.13; p=0.001) across higher girth classes and also showed significant inverse relation (Fig. 6b); tree density in old aged class category (>200–300 cm girth) might reduce due to historic illegal removal of mature *D. turbinatus* trees. Low mature population in the larger girth classes was also similarly observed in other tropical forests (Muthuramkumar et al., 2006). This indicated that present tropical semi–evergreen forest understorey was dominated by shade tolerant species and their regeneration in moist forest floor and in relatively shortage of light was fair which rather influenced by spreading canopy of *D. turbinatus*. However, *S. robusta* and other local oligarchic small tree species has also non–seeded regeneration capabilities (Pandey and Shukla, 2001; Majumdar et al., 2012) compared to *D. turbinatus, A.chama, B. ceiba* etc. Regeneration and distribution of *D. turbinatus* strongly depends on its seed traits, which also has short distance dispersal aptitude, only ≤40 m from mother tree (Biswas and Misbahuzzaman 2010) compared to >100 m distance dispersedability of Sal seed by wind (Jackson, 1994). However, in moist deciduous forests which dominated by *S. robusta*, *S. wallichii* etc. forced many species towards rarity and interferes with the proper seedling establishment and growth of other species by bringing autogenic as well as allogenic changes in the community level (Pandey and Shukla, 1999; Sapkota et al., 2009). About 67.56% trees were in shaded understory (<15m height) and only 32.44 % trees were exceeded 15 m height. The overstory typically dominated by *D. turbinatus, A. chama, T. bellirica, A. acuminata, S. comuni* and *S. robusta,* recorded as mean maximum height holding trees. Regression analyses also revealed that the density of trees was mostly linearly declined ($F_{2,9}$ =6.65; p=0.02) across the height classes (Fig. 6c). Tree height increases with the light requirements of the species (King 1996), pioneer or light demanding species has the advantages to grow rapidly and efficiently in height in forest gaps to attain a position in the canopy before the gap closes (Gelder et al., 2006). But in case of semi–evergreen formations where the canopy are typically parabolic shape (e.g. *Dipterocarpus* spp., *Ficus* spp., *Castanopsis* spp. etc.), only shade–tolerant species may better adopted than other light demanding species. But, *Aporusa spp.*, *Ficus spp.*, *Glochidion spp.*, *H. antidysenterica*, *Macaranga spp.*, *Mallotus spp.*, *M. paniculata*, *M. rotundifolia*, *S. cerasoides* and *Z. rugosa* small oligarchic tree species were frequently adopted both in sunny gaps and in the shaded understories.However, present study revealed that several species has already been red listed (IUCN 2013); where *Mangifera indica* listed as Data Deficient (DD); *Aglaia edulis, Aglaia spectabilis, Alstonia scholaris, Aphanamixis polystachya, Bhesa robusta, Butea parviflora, Gnetum montanum, Mangifera sylvatica* and *Shorea robusta* listed as Lower Risk / Least Concern (LC); species like *Canthium dicoccum* and *Saraca asoca* were in Vulnerable (VU) category and surprisingly the keystone species (*Dipterocarpus turbinatus* and *Dipterocarpus gracilis*) of this habitat were also in Critically Endangered (CR) category (Appendix 1).

5 Conclusion

Quantitative floristic analysis of present lowland Dipterocarp dominated semi–evergreen forests in Tripura of Northeast India over 4.5 ha sampling areas are very crucial for many ecological applications. Sine, analyses of any forest flora are very useful for identifying spatial patterns in plant diversity and population dynamics (Slik et al., 2002). Quantitative floristic inventories have been used in recent years to characterization of habitat ecosystem and species restoration programme. Present habitat are being threatened by uncontrolled historical degradations and conversion to other forms of land uses, for aggressive rubber plantation expansions, illegal logging for timber and fuelwood, bamboo and NTFPs collection etc. causing serious threats for preferred habitat loss for thesered listed species in the area.

Specifically, as semi–evergreen forest represents unique habitat for those threatened and singleton species it seeks immediate attention for sustainable biodiversity conservation without any changes of their preferred habitat. The umbrella trees (*Dipterocarpus* spp.) of Cachar tropical semi-evergreen forest has already red listed as critically endangered, special observation and monitoring of this tree population are necessary for overall ecosystem species conservation and management (Roberge and Angelstam,2004). Present quantitative species compositional and structural attributes of this forest formation will be vital in future to understand community dynamics, niche patterns, successional trend, spatial distribution of threatened species and effects of forest fragmentation, edge and on-going disturbances etc. However, the application of Ecological Niche Model (ENM) will be proven as useful tool to identify additional distributional extension and population, including forest patches or areas having potential for this restricted forest habitat and red listed species. Even species association-ship, niche specification and requirements of each threatened species possible to sort out from present efforts through habitat modeling and promote species restoration programme. Since, ENM tool is used to predict the new occurrence of habitat, species as well as to select the target suitable habitats areas for future exploration, reintroduction and restoration (Adhikari et al., 2012). The selected forest habitat of the present study is both economically and ecologically important. Locally, occurrence of 14 globally threatened species with presently recorded 56 rare and 51 singleton species would be taken on priority basis for fruitful species conservation initiation and restoration programme.

Acknowledgements

We are grateful to Department of Biotechnology (DBT), Govt. of India for financial assistance received through DBT Network Project (BT/PR7928/NDB/52/9/2006). We are grateful to Prof. Uma Shankar, Departmentof Botany, North-Eastern Hill University, Shillong for his valuable suggestions.We wish to thank Sri Samir Kumar Debnath and Sri Monthosh Roy for their consistent supports during field survey. We are also thankful to Dr. A K Gupta, IFS, Principal Conservator of Forest (PCCF), Tripura Forest Department, Govt. of Tripura for cooperation. Appreciations also extended to Prof. S. Sinha, Dean, Faculty of Science, Tripura University for facilities and encouragements. Thanks to anonymous referees, for helping to improve the original version of the manuscript.

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Appendix 1 Quantitative status of woody species diversity and population structure in Cachar tropical semi–evergreen forest type of Tripura in Northeast India.

Species* name	Family name	Habit form	Type	Distribution pattern	Density ha^{-1}	Basal Area** m^2 ha^{-1}	IVI %
Acacia coccenia	Mimosaceae	WL	D	R	0.22	0.00	0.25
Acacia pinnata	Mimosaceae	WL	D	A	1.78	0.01	0.69
Acronychia pedunculata	Rutaceae	T	E	A	1.33	0.06	0.74
Actinodaphne angustifolia	Lauraceae	T	E	R	0.67	0.00	0.52
Actinodaphne obovata	Lauraceae	T	E	R	0.22	0.01	0.27
Aglaia edulis	Meliaceae	T	D	R	0.44	0.02	0.31
Aglaia spectabilis	Meliaceae	T	D	A	4.22	0.11	2.11
Albizia chinensis	Mimosaceae	T	D	A	2.00	0.07	1.29
Albizia procera	Mimosaceae	T	D	A	7.11	0.70	3.76
Alstonia scholaris	Apocynaceae	T	D	A	4.00	0.06	1.74
Ampelocissus barbata	Vitaceae	WL	D	R	1.56	0.02	1.31
Anogeissus acuminata	Combretaceae	T	D	A	12.89	0.57	4.20
Anthocephalus chinensis	Rubiaceae	T	D	A	0.67	0.04	0.41
Antidesma acidum	Euphorbiaceae	WS	E	A	1.33	0.00	0.82
Aphanamixis polystachya	Meliaceae	T	D	A	1.33	0.01	0.82
Aporusadioica	Euphorbiaceae	T	D	A	6.44	0.07	1.65
Aporusaobloga	Euphorbiaceae	T	D	A	2.67	0.04	0.87
Archidendron clypearia	Mimosaceae	T	D	R	0.22	0.00	0.25
Ardisia floribunda	Myrsinaceae	WS	E	R	0.44	0.00	0.27
Artocarpus chama	Moraceae	T	E	A	22.67	3.30	13.19
Artocarpus heterophyllus	Moraceae	T	E	R	0.89	0.05	0.88
Artocarpus lakoocha	Moraceae	T	D	R	3.11	0.12	1.97
Bambusa tulda	Poaceae	B	E	A	4.89	0.02	1.11
Bauhinia malabarica	Caesalpiniaceae	T	D	R	0.44	0.00	0.28
Bhesa robusta	Celustraceae	T	D	A	2.00	0.03	0.99
Bischofia javanica	Euphorbiaceae	T	E	R	0.22	0.00	0.24
Bombax ceiba	Bombacaceae	T	D	R	1.78	0.73	2.91
Bridelia assamica	Euphorbiaceae	T	D	R	0.22	0.00	0.25
Bridelia pubescens	Euphorbiaceae	WS	D	A	0.89	0.00	0.54
Bridelia retusa	Euphorbiaceae	T	D	R	3.78	0.01	1.80
Butea parviflora	Papilionaceae	WL	D	R	0.44	0.00	0.27
Caesalpinia bonduc	Caesalpiniaceae	WL	D	R	0.67	0.00	0.52
Callicarpa arborea	Lamiaceae	T	D	A	4.22	0.09	1.84
Canthium dicoccum	Rubiaceae	WS	E	R	0.22	0.00	0.24
Canthium glabrum	Rubiaceae	T	E	A	2.00	0.01	0.70
Carallia brachiata	Rhizophoraceae	T	E	R	1.78	0.02	1.12
Careya arborea	Lecythidaceae	T	D	A	10.67	0.21	3.21
Caryota mitis	Arecaceae	T	E	R	0.22	0.00	0.24
Caryota urens	Arecaceae	WS	E	A	1.33	0.01	0.40
Cassia fistula	Caesalpiniaceae	T	D	A	4.22	0.09	1.64
Castanopsis armata	Fagaceae	T	E	A	4.00	0.08	1.36

Castanopsis indica	Fagaceae	T	E	A	3.78	0.24	1.74
Castanopsis tribuloides	Fagaceae	T	E	A	2.00	0.11	0.95
Chaetocarpus castanicarpus	Euphorbiaceae	T	D	A	7.33	0.13	2.15
Cinnamomum obtusifolium	Lauraceae	T	E	R	0.67	0.00	0.52
Combretum punctatum	Combretaceae	WL	E	A	2.44	0.01	0.77
Combretum roxburghii	Combretaceae	WL	E	A	2.89	0.01	1.03
Combretum spp.	Combretaceae	WL	E	R	0.22	0.00	0.24
Cordia grandis	Erethiaceae	T	D	A	2.00	0.04	0.79
Croton oblongifolius	Euphorbiaceae	T	D	A	2.44	0.01	0.98
Crypteronia glabra	Lythraceae	T	D	A	3.11	0.23	1.82
Cyathia gigantea	Cyatheaceae	T	E	A	0.89	0.00	0.55
Dalbergia thomsonii	Papilionaceae	WL	D	A	1.78	0.01	0.47
Dalbergia volubilis	Papilionaceae	WL	D	A	2.00	0.02	0.94
Derris robusta	Papilionaceae	T	D	A	2.67	0.13	1.11
Desmos longiflorus	Annonaceae	WS	E	R	0.44	0.00	0.27
Dillenia pentagyna	Dilleniaceae	T	D	A	9.11	0.72	4.91
Dillenia scabrella	Dilleniaceae	T	D	R	0.44	0.00	0.48
Diospyros spp.	Ebenaceae	T	E	R	0.44	0.01	0.28
Dipterocarpus gracilis	Dipterocarpaceae	T	E	A	0.22	0.00	0.25
Dipterocarpus turbinatus	Dipterocarpaceae	T	E	R	213.78	20.10	80.81
Dysoxylum bineetariferum	Meliaceae	T	D	R	0.22	0.00	0.24
Elaeocarpus obtusus	Elaeocarpaceae	T	E	R	0.44	0.00	0.28
Elaeocarpus prunifolia	Elaeocarpaceae	T	E	R	0.22	0.00	0.24
Elaeocarpus robusta	Elaeocarpaceae	T	E	A	0.22	0.00	0.24
Elaeocarpus spp.	Elaeocarpaceae	T	E	A	0.67	0.00	0.31
Emblica officinalis	Euphorbiaceae	T	D	A	7.33	0.10	2.27
Engelhardia spicata	Juglandaceae	T	E	A	4.89	0.45	3.04
Erioglossum rubiginosum	Sapindaceae	T	E	R	3.56	0.04	1.21
Erythrina arborescens	Papilionaceae	T	D	A	0.44	0.00	0.49
Eugenia macrocarpa	Myrtaceae	T	E	A	4.44	0.54	2.36
Eugenia praecox	Myrtaceae	T	E	R	1.33	0.01	0.63
Eurya acuminata	Theaceae	T	E	A	1.56	0.02	1.10
Ficus auriculata	Moraceae	T	E	A	1.56	0.02	0.67
Ficus curtipes	Moraceae	T	E	R	0.67	0.08	0.50
Ficus drupacea	Moraceae	T	E	R	0.22	0.00	0.25
Ficus hirta	Moraceae	T	D	A	0.22	0.00	0.24
Ficus hispida	Moraceae	T	E	R	10.00	0.14	3.57
Ficus nervosa	Moraceae	T	D	A	0.44	0.01	0.51
Ficus racemosa	Moraceae	T	E	R	1.11	0.02	0.63
Ficus religiosa	Moraceae	T	E	R	0.22	0.03	0.31
Ficus rumphii	Moraceae	T	E	R	0.22	0.00	0.25
Ficus semicordata	Moraceae	T	E	R	0.44	0.00	0.28
Ficus spp.	Moraceae	T	E	R	0.22	0.01	0.27
Ficus spp.	Moraceae	T	E	A	0.44	0.00	0.28
Firmiana colorata	Sterculiaceae	T	D	A	0.67	0.00	0.30
Garcinia cowa	Guttiferae	T	E	R	7.33	0.08	2.85

Garcinia lanceaefolia	Guttiferae	T	E	A	0.44	0.01	0.31
Gardenia resinifera	Rubiaceae	T	E	A	4.67	0.15	2.06
Garuga pinnata	Burseraceae	T	D	A	4.22	0.10	1.86
Glochidion assamicum	Euphorbiaceae	T	D	A	4.22	0.03	1.26
Glochidion lanceolarium	Euphorbiaceae	T	D	A	2.67	0.04	1.08
Glochidion multiloculare	Euphorbiaceae	T	D	A	7.11	0.03	1.87
Glochidion sphaerogymum	Euphorbiaceae	T	D	A	0.89	0.01	0.55
Glochidion zeylanicum	Euphorbiaceae	T	D	R	0.89	0.01	0.36
Glycosmis mauritiana	Rutaceae	WS	E	A	0.44	0.00	0.27
Gnetum montanum	Gnetaceae	WL	E	A	0.89	0.01	0.58
Holarrhena antidysenterica	Apocynaceae	T	D	A	12.89	0.13	3.50
Horsfieldia amygdalina	Myristicaceae	T	E	A	1.11	0.02	0.61
Hymenodictyon escelsum	Rubiaceae	T	D	A	1.78	0.02	0.71
Lagerstroemia parviflora	Lythraceae	T	D	A	2.22	0.01	0.75
Lagerstroemia speciosa	Lythraceae	T	D	A	3.11	0.15	1.21
Lannea coromandelica	Anacardiaceae	T	D	R	8.44	0.46	3.96
Leea aequata	Leeaceae	WS	E	R	0.22	0.00	0.24
Lithocarpus spicata	Fagaceae	T	E	R	0.22	0.00	0.24
Litsea cubeba	Lauraceae	T	E	A	0.22	0.00	0.24
Litsea glutinosa	Lauraceae	T	E	A	4.89	0.05	2.03
Litsea monopetala	Lauraceae	T	E	A	4.22	0.03	1.68
Macaranga denticulata	Euphorbiaceae	T	D	A	3.56	0.13	1.85
Macaranga peltada	Euphorbiaceae	T	D	A	1.78	0.01	0.47
Macropanax undulatus	Araliaceae	T	E	R	1.78	0.02	0.50
Maesa indica	Myrsinaceae	T	D	A	0.22	0.00	0.24
Maesa ramentacea	Myrsinaceae	T	D	A	4.00	0.03	1.44
Mallotus philippensis	Euphorbiaceae	T	D	R	4.22	0.08	1.80
Mangifera indica	Anacardiaceae	T	E	R	0.44	0.07	0.44
Mangifera sylvatica	Anacardiaceae	T	E	A	0.44	0.02	0.54
Markhamia stipulata	Bignoniaceae	T	D	A	3.78	0.04	1.66
Melocanna baccifera	Poaceae	B	E	R	2.00	0.00	0.48
Mesua ferrea	Guttiferae	T	E	R	0.22	0.00	0.25
Meyna spinosa	Rubiaceae	T	D	R	0.67	0.01	0.52
Michelia champaca	Magnoliaceae	T	E	A	0.22	0.01	0.27
Microcos paniculata	Tiliaceae	T	E	R	49.11	0.52	9.73
Micromellum intergifolium	Rutaceae	T	D	A	1.11	0.01	0.79
Mitragyna rotundifolia	Rubiaceae	T	D	R	9.78	0.11	2.84
Olax accuminata	Olacaceae	WS	D	A	2.44	0.01	1.18
Oreocnide integrifolia	Urticaceae	T	E	R	0.67	0.00	0.31
Oroxylum indicum	Bignoniaceae	T	D	A	0.44	0.01	0.51
Oxytenanthera nigrociliata	Poaceae	B	E	R	2.22	0.00	0.51
Pandanus spp.	Pandanaceae	WS	E	A	0.22	0.00	0.24
Persea villosa	Lauraceae	T	E	A	1.11	0.05	0.49
Ptereospermum acerifolium	Sterculiaceae	T	D	R	2.22	0.06	0.87
Pterospermum semisaggitum	Sterculiaceae	T	D	R	3.33	0.08	1.92

Randia racemosa	Rubiaceae	WS	D	A	0.22	0.00	0.24
Sapium baccatum	Euphorbiaceae	T	E	A	3.11	0.16	1.45
Saraca asoca	Caesalpiniaceae	T	E	A	1.78	0.03	0.75
Sarcochlamys pulcherrima	Urticaceae	WS	D	R	1.56	0.00	0.43
Schefflera venulosa	Araliaceae	WL	D	A	0.22	0.00	0.24
Schima wallichii	Theaceae	T	D	A	35.33	1.80	10.69
Shorea assamica	Dipterocarpaceae	T	D	R	0.22	0.01	0.26
Shorea robusta	Dipterocarpaceae	T	D	R	24.00	1.65	8.18
Sterculia indica	Sterculiaceae	T	D	A	0.22	0.00	0.25
Sterculia villosa	Sterculiaceae	T	D	A	0.89	0.00	0.55
Stereospermum personatum	Bignoniaceae	T	E	R	6.44	0.40	2.91
Streblus aspera	Moraceae	T	E	R	3.33	0.03	1.36
Suregada multiflora	Euphorbiaceae	T	D	A	5.56	0.05	2.33
Symplocos ferruginea	Symplocaceae	T	E	A	0.67	0.01	0.74
Symplocos racemosa	Symplocaceae	WS	E	A	1.11	0.01	0.39
Syzygium cerasoides	Myrtaceae	T	E	R	16.67	0.77	5.82
Syzygium cumini	Myrtaceae	T	E	R	10.89	0.54	3.87
Syzygium fruticosum	Myrtaceae	T	E	A	0.22	0.00	0.25
Syzygium spp.	Myrtaceae	T	D	A	2.89	0.09	1.46
Tamarindus indica	Caesalpiniaceae	T	D	A	0.22	0.06	0.38
Tectona grandis	Lamiaceae	T	D	R	9.78	0.59	3.20
Terminalia bellirica	Combretaceae	T	D	R	18.00	0.33	4.92
Terminalia chebula	Combretaceae	T	D	R	0.22	0.00	0.25
Tonna ciliata	Meliaceae	T	D	R	2.44	0.07	1.33
Trema orientalis	Ulmaceae	T	D	R	0.89	0.00	0.55
Trevesia palmata	Araliaceae	T	D	A	2.00	0.00	0.49
Trewia nudiflora	Euphorbiaceae	T	D	R	0.44	0.02	0.31
Vitex altissima	Lamiaceae	T	D	A	1.78	0.02	0.91
Vitex peduncularis	Lamiaceae	T	D	A	7.78	0.17	3.14
Vitex pubascens	Lamiaceae	T	D	R	1.56	0.02	1.10
Walsura robusta	Meliaceae	T	D	R	0.22	0.01	0.26
Xantolis assamica	Sapotaceae	T	D	A	0.67	0.01	0.32
Zanthoxylum limonella	Rutaceae	T	D	R	0.44	0.00	0.49
Ziziphus funiculosa	Rhamnaceae	WS	D	R	0.89	0.01	0.78
Ziziphus rugosa	Rhamnaceae	T	D	A	1.11	0.01	0.61

* Basal Area 0.00 are <0.01