Plant species diversity andtree population structure in disturbed and undisturbed stands of wet tropical forestsin Dehang-Debang Biosphere Reserve of Arunachal Pradesh, India

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Abstract
Plant species richness, density, diversity index, species similarity, rarity and population structure including their distribution pattern of tree species were investigated in undisturbed, moderately disturbed and highly disturbed stands of tropical wet evergreen forests in Siang part under Dehang-Debang Biosphere Reserve in Arunachal Pradesh. It was studied through quadrat method and all important community parameters were worked out using standard procedures. A total of 63 tree species, belonging to 55 genera and 42 families were recorded from the three forest stands at different level of disturbances. The species richness index of tree and herb species was high atundisturbed stand which was compararively less in disturbed forest stand while for shrub it was highest at highly distubed forest stand. The species diversity indicesof herb and tree were high in comparisons with the shrubs at undisturbed stand. It was found that most of the species exhibits clump or contagious distributionirresspective of study stands. The stem density for trees, shrubs and herbs was high in undistturbed stand in comparison with the others. The concentration of dominance for tree and herbwas high as compared to others at moderatelydisturbed standbut for shrubs it was high at undisturbed stand. The highest basal area for trees was 57.89m^2 at highly disturbed and lowest at undisturbed (42.59m^2) as compare to average basal area of 48.58m^2 for the study stands. Undisturbed stand has highest tree species richness and tree density (individual ha^{-1}) with *Persea gamblei* as the dominant tree species.Where as *Meliosma wallichii*dominates in moderately disturbedand *Terminlia myriocarpa* in highly disturbed stands respectively. In the whole study forest stands*Meliosma wallichii* was a dominant where as other former two was codominant species. Thisdata may help inplaning for conservation and management of the plant biodiversity.

Key word:Plant Species diversity, population structure , disturbed forests, management.

INTRODUCTION

Phytogeographycally wet tropical forests are rich in biological diversity (Bhuyan et al. 2003; Chandrasekharan 1960). These forests face a serious threat, both natural as well as anthropogenic. The current stress on forest communities for large-scale collection of fuelwood and minor forest products, as well as the practices of grazing and flattening may alter the habitats of many species. As a result there is a lot of spatial and temporial variation in species richness, composition and productivity. Thus, the need to set priorities for conservation of tree diversity have become inveritable. Indentification of conserved area ideally requires exhaustive knowledge of species and ecosystem diversity and distribution (Bhuyan et al. 2003; Menon et al.2001). Northeastern India is one of the 25 mega-biodiversity hotspot of the world (Myers et al.2000) harbouring rich vegetation, both in number as well as species density and diversity (Rao and Murti 1990). The shifting cultivation is one of the potent factors changing the forest cover in the region (Ramakrishnan et al.1981; Arunachalam et al.2002). It is believed that if the present trends are continued and effective conservation measures are not implemented, most of the remnant native vegetation in the tropics will be destroyed or replaced by successional communities (Beniwal and Haridasan 1992; Procter et al. 1998; Menon et al. 2001). An understanding of forest process is also fundamental to the management of natural and disturbed vegetation (Congdon and Herbohn 1993). The Dehang –Debang Biosphere Reserve of Arunachal Pradesh is one of the relatively unexplored area harbouring rich plant diversity. The forests in

the lower reaches of the area, near villages are highly disturbed. Vegetation analysis of these nondisturbed and differentialy degraded forests would help in understanding the disturbance effects on the composition and dynamics of forest community. Most plant biodiversity studies have been focused on the species-rich tropical moist forests protected area where as in Dehang-Debang Biosphere Reserve (DDBR) forests are exceptionally limited. Henceforth the present study was under taken to study plant species diversity,community structure and tree population structure under different degree of disturbances.

MATERIAL AND METHOD

Study area

The study was carried out during 2001-2003 in the wet evergreen forests of Upper Siang part of Dehang-Debang Biosphere Reserve, Arunachal Pradesh (26^0 to $29^028^{'}$N latitude and $91^025^{'}$ to 97^024' E longitude) .The studies were confined in three different sitesamong these two stands were selected within the Mouling National Park. One is anundisturbed stand as UD at Karko and the other one is a moderately disturbed stand as MD at Ramsing. The third stand is located outside the Mouling National Park but within the buffer zone of Dehang-Debang Biosphere Reserve as highly disturbed stand as HD at Kopu. The magnitude of disturbances was quantifiedthrough biotic and abiotic disturbance held during the study period as information received from the old age local people and estimating by calculatingthe cut stump area of the tree species. It may be inferred from the compartment history that the site HD is more disturbed followed by MD and UD respectively. However, at site HD, frequency of major disturbances e.g. cutting of big logs was at the high rate as compared to other sites. The forests at site UD, MD lies between the slopes while site HD is in plain valley with very gentle slopes. As perthe geology, medium to high-grade metamorphic rocks as granetiferous graphite schist, staurolite-garnet-graphitic schist, cale-silacate rocks, staurolite-garnet-biotiteschists, biotite gneisses occur in and around Jengging. The metavolcanics exposed at Tuting succeed the Siang Group with a gametiforus zone of about 10-15 cm in thickness. The soils are mainly of warm Per-humid eastern Himalayan ecosystem and a very little portion under warm Per-humid Siwalik hill ecosystem in the region. The total annual precipitation is about 2949mm. About 27.26% of rainfall is received during March to May (Summer), 60.88% during June to September (monsoon), 6.53% during October and November (post monsoon) and finally 5.32% during December to February (winter). Precipitation of the study area is characterized by high rainfall (600 cm). The abrupt rise of the Himalayan mountain chain in the regions causes topographic variations and complicates the climate of the region leading to the meso and microclimate formation (Ghosh, 2005).

Methods

Three forest stands was taken from differentialy human impacted forests each with 0.5ha area for plant diversity study.Structural analysis of plant community was carried out on the basis of species richness and similarity index. Total number of species recorded in the forest stands was taken as species richness. Similarity between the stands was studied by computing Sorensen's index of similarity (Sorensen, 1948). A total 20 quadrates of 10m X10m size were randomly laid in the selected study sites to study the phyto-sociological parameters of tree, shrubs and herb species. The diameter at breast height (dbh at 1.37 m above ground level) of each tree was measured and recorded in each quadrate. Trees having 10cm diameter (dbh) or above were considered for this study. For the study of shrubs and herbs, 30 quadrates each of 5m X 5m and 1mX1m size were laid out respectively. Frequency, density, basal cover, abundance and importance value index (IVI) of the species were calculated according to Misra (1968) and Muller-Dombois and Ellengberg (1974). The IVI for tree species calculated by summing up the relative values of frequency, density and basal area while, the IVI for shrubs and herbs were obtained by summing the relative values of frequency and density. The abundance to frequency ratio (A/F) for different tree species was determined basedon Whitford (1948) for obtaining their distribution patterns in the community. This ratio indicates regular (<0.025) random (0.025-0.05) and contagious (>0.05).Shannon and Wiener (1963) index of diversity

(H^-) was used in estimating species diversity using proportional number of species. Betadiversity were estimated following Whittaker (1975) as beta diversity (βω)=(S/α)-1; Where 'S' is the total number of species recorded in the two sites considering each species only once and 'α' is the mean species richness of the two sites. Simpson index of dominance (D) was considered in calculating species dominance (Simpson 1949).Dominance calculated on the basis of importance value index (IVI) of different species in different forest stands. Tree species represented by one or two in the sampling area were considered rare in the study sites. The population structure of tree species in different dbh classes (age group) was also studied. Finally population behavior of dominant tree species was studied on the basis of age structure of adult population. All individuals of a given species having ≥10cm dbh were grouped in 9 dbh classes like 10-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90 and >90cm and density and basal cover of each dbh class was determined.

RESULT AND DISCUSSIONS

Plant families diversity of the study stands

A total of 151 plant species representing 128 genera belonging to 93 families were recorded from the three study stands. Out of these, 63 were tree species of ≥ 10 cm dbh class belonging to 55 genera and 42 families. Where as 27 species of shrubs were belonging to 24 genera and 19 families and 61 species of herbswere representing 49 genera and 40 families. The accounts of these families, genera and species of the study stands are given in table 1,2 &3.

Out of the 42 tree families prevailing in the study areas, 22 families (51.16 %) were represented by single species. The six most specious families were Lauraceae,Fagaceae, Fabaceae, Moraceae, Rubiaceae and Elaeocarpaceae. Among them four families such as Lauraceae (415 stem ha^{-1}), Fabaceae (155 stem ha^{-1}), Fagaceae (95 stem ha^{-1}), and Rubiaceae (60 stem ha^{-1}) was abundant contributing to 34.86 % of the total density. Euphorbiaceae, Fabaceae, Fagaceae, Hamamelidaceae, Lauraceae, Moraceae, Rubiaceae, Sauraraceae, Utricaceae and Verbenaceae occurred in all study sites. Aceraceae, Betulaceae, Bignoniaceae, Boraginaceae, Burseraceae, Capparaceae, Juglandaceae, Lythraceae, Magnoliaceae, Malvaceae, Meliaceae, Myrsinaceae, Myrtaceae, Podocarpaceae, Primulaceae, Rosaceae, Rutaceae, Salicaeae, Saxifragaceae, Theaceae and Ulmaceaewere the twenty one families (48.84%) that had only single site existence.

As regard to the total number of families in 1 ha forest inventories across the tropics (except for a few Brazilian Amazon sites) recorded 16 to 58 families (Gentry, 1988; Campbell et al., 1992), in many sites the number of plant families mostly varied from 30 to 36 (Pascal and Pelissier, 1996; Parthasarathy and Karthikeyan, 1997; Bhuyan et al., 2003). In the present study the number of tree families in each 0.5 ha study area ranged from 20 to 27 in tropical wet evergreen forests and that is more or less similar with the earlier studies.

The shrub families like Melastomaceae, Urticaceae and Verbenaceae occurred in all study sites, whereas Actinidiaceae, Buddlejaceae, Caprifoliaceae, Eleocarpiaceae, Ericaceae, Moraceae, Orchidaceae and Symplocaceae had only single site existence.

The herb species recorded in the three sites belonging to families like Asteraceae, Balsaminaceae, Begoniaceae, Caryophyllaceae, Dioscoreaceae, Dryopteridaceae, Piperaceae and Polygonaceae and Utricaceae were found in all sites, but Acanthaceae, Amaranthaceae, Apiaceae, Chenopodiaceae, Convolvulaceae, Cucurbitaceae, Euphorbiaceae, Fabaceae, Gesneriaceae, Hypericaceae, Loranthaceae, Lycopodiaceae, Melastomataceae, Myrsinaceae, Ophioglossaceae, Poaceae, Pyrolaceae, Rafflesiaceae, Smilaceae and Violaceae had single site existence.

Table1. Family-wise contribution of tree plants to genera, species and density in study forest stands

	UD(Karko)			MD(Ramsing)			HD(Kopu)		
Family	**Gen**	**Sp**	**D**	**Gen**	**Sp**	**D**	**Gen**	**Sp**	**D**
Aceraceae	-	-	-	1	1	10	-	-	-
Anacardiaceae	1	1	45	1	1	25	-	-	-
Anonaceae	-	-	-	1	1	25	-	-	-
Araliaceae	-	-	-	1	1	10	1	1	5
Arecaceae	1	1	10	2	2	15	-	-	-

Betulaceae	-	-	-	-	-	-	1	1	20
Bignoniaceae	2	2	15	-	-	-	-	-	-
Boraginaceae	-	-	-	1	1	20	-	-	-
Burseraceae	-	-	-	-	-	-	1	1	5
Capparaceae	1	1	5	-	-	-	-	-	-
Caprifoliaceae	1	1	10	-	-	-	1	1	15
Combretaceae	-	-	-	1	1	15	2	3	115
Elaeocarpaceae	2	3	30	1	2	20	-	-	-
Euphorbiaceae	1	1	5	2	2	15	1	1	15
Fabaceae	3	4	55	1	2	20	2	2	50
Fagaceae	1	3	55	2	4	35	1	1	5
Hamamelidaceae	1	1	10	1	1	55	1	1	40
Juglandaceae	-	-	-	1	1	5	-	-	-
Lauraceae	4	5	345	4	4	65	1	1	5
Lythraceae	1	1	30	-	-	-	-	-	-
Magnoliaceae	1	1	15	-	-	-	-	-	-
Malvaceae	-	-	-	-	-	-	1	1	15
Meliaceae	-	-	-	1	1	5	-	-	-
Meliosomaceae	1	3	45	1	1	215	-	-	-
Moraceae	2	2	40	3	3	75	2	3	105
Myrsinaceae	1	1	10	-	-	-	-	-	-
Myrtaceae	1	1	20	-	-	-	-	-	-
Podocarpaceae	-	-	-	1	1	5	-	-	-
Primulaceae	1	1	5	-	-	-	-	-	-
Rosaceae	-	-	-	-	-	-	1	1	5
Rubiaceae	2	2	30	3	3	25	1	1	5
Rutaceae	-	-	-	-	-	-	1	1	5
Salicaeae	1	1	10	-	-	-	-	-	-
Saururaceae	1	1	35	1	1	10	1	1	5
Saxifragaceae	1	1	5	-	-	-	-	-	-
Simaroubaceae	1	1	5	1	1	10	-	-	-
Sonneratiaceae	1	1	20	1	1	10	-	-	-
Sterculaceae	-	-	-	1	1	15	1	1	5
Theaceae	-	-	-	-	-	-	1	1	5
Ulmaceae	1	1	10	-	-	-	-	-	-
Urticaceae	1	1	35	1	1	10	1	1	20
Verbenaceae	2	2	10	1	1	5	1	1	5
Total 42	**37**	**44**	**910**	**35**	**39**	**720**	**23**	**25**	**450**

Table 2. Family-wise contribution of herb plants to genera and species in study forest stands

Family	UD(Karko)		MD(Ramsing)		HD(Kopu)	
	Gen	Sp	Gen	Sp	Gen	Sp
Acanthaceae	-	-	-	-	1	1
Amaranthaceae	-	-	-	-	1	2
Apiaceae	-	-	1	1	-	-
Araceae	1	1	1	1	-	-
Areaceae	-	-	1	1	1	1
Asteraceae	3	3	1	1	3	4
Balsaminaceae	1	1	1	1	1	1
Begoniaceae	1	1	1	3	1	1
Caryophyllaceae	1	1	1	1	1	1
Chenopodiaceae	-	-	-	-	1	2
Convolvulaceae	-	-	-	-	1	1
Cucurbitaceae	-	-	-	-	1	1

Dennstaedtiaceae	-	-	1	1	-	-
Dioscorea	1	1	1	1	1	1
Dryopteridaceae	1	1	1	1	1	1
Euphorbiaceae	-	-	-	-	1	1
Fabaceae	-	-	-	-	3	4
Gesneriaceae	-	-	1	1	-	-
Hypericaceae	1	1	-	-	-	-
Lamiaceae	1	1	2	2	-	-
Loranthaceae	-	-	-	-	1	1
Lycopodiaceae	1	1	-	-	-	-
Melastomataceae	-	-	-	-	1	1
Myrsinaceae	-	-	-	-	1	2
Ophioglossaceae	1	1	-	-	-	-
Orchidaceae	1	1	-	-	1	1
Oxalidaceae	1	1	1	1	-	-
Piperaceae	1	1	1	1	1	1
Poaceae	-	-	1	1	-	-
Polygonaceae	1	1	1	1	1	1
Pyrolaceae	1	1	-	-	-	-
Rafflesiaceae	1	1	-	-	-	-
Rosaceae	1	1	-	-	1	1
Rubiaceae	1	1	2	3	-	-
Selaginellaceae	1	1	1	1	-	-
Smilaceae	-	-	1	1	-	-
Trilliaceae	1	1	-	-	1	1
Urticaceae	4	5	2	3	1	1
Violaceae	-	-	1	1	-	-
Zingiberaceae	3	4	2	2	-	-
Total 43	**30**	**32**	**26**	**30**	**27**	**32**

(*Gen=genus, *Sp= Species)

Table 3. Family-wise contribution of shrub plants to genera and species in study forest stands

Family	UD(Karko)		MD(Ramsing)		HD(Kopu)	
	Gen	Sp	Gen	Sp	Gen	Sp
Actinidiaceae	-	-	-	-	1	1
Arecaceae	-	-	1	1	1	1
Buddlejaceae	1	1	-	-	-	-
Caprifoliaceae	1	1	-	-	-	-
Eleocarpiaceae	1	1	-	-	-	-
Ericaceae	-	-	1	1	-	-
Euphorbiaceae	1	1	-	-	2	2
Flacourtiaceae	-	-	-	-	1	1
Lauraceae	1	1	1	1	-	-
Melastomaceae	2	2	1	1	2	2
Moraceae	-	-	1	2	-	-
Myrtaceae	-	-	1	1	1	2
Orchidaceae	-	-	-	-	1	1
Rosaceae	-	-	1	1	2	3
Rubiaceae	-	-	1	1	2	2
Rutaceae	1	1	1	1	-	-
Symplocaceae	-	-	1	1	-	-
Urticaceae	1	1	2	2	1	1
Verbenaceae	1	1	1	1	1	1
Total 19	**10**	**10**	**13**	**14**	**15**	**17**

(*Gen=genus, *Sp= Species)

Species richness

Stand-wise species richness for trees in Karko, Ramsing, and Kopu were 44, 39, and 25 respectively with a range of difference of 5-19 species between the sites and it ranged from 25-44.Whereas the shrub richness recorded as 10, 14 and 17 at Karko, Ramsing, and Kopu respectively with a comparatively narrow range difference of 3 to 7 species

between the sites irrespective of forest types. The herb richness in the study stand was 33, 30 and 32 at Karko, Ramsing, and Kopu respectively.

The tree species richness in tropical evergreen forest of Kalakad National Park of Western Ghats (having six 1-ha plots) was reported to be 64-85 (Parthasarathy et al.1992). The tropical wet evergreen forest of Uppangala in Karnataka (3.12 ha plots) recorded 91 (Pascal and Pelissier, 1996), the tropical evergreen forest in Courtallum of Western Ghats contained 57 (Parthasarathy and Karthikeyan 1997) and the tropical wet evergreen forest (0.9 ha plot) in Arunachal Pradesh had 16-54 inventories of tree species (Bhuyan et al., 2003). Tropical lowland forest (four 1-ha plots) in Kurupukari of Central Guyana recorded 50-71 (Johnston and Gillman, 1995), and the tropical rain forest in Reunion Island of France had 43 tree species (Strasberg, 1996). The species richness of the present study sites was moderate and fell well within the range of 16 species ha^{-1} in Arunachal Pradesh of India to 43 species ha^{-1} in tropical rain forest of Reunion Island, France(Parthasarathy and Karthikeyan,1997).

Species diversity

The species diversity index has been presented in the table 4. The species diversity index for trees ranged from 2.62 to 3.20. However, the values varied from 2.21 to 2.76 for shrubs and from 3.14 to 3.32 for herbs among the three study sites.The diversity index was generally higher for tropical forests (5.06 and 5.40 for young and old stand respectively) as reported by Knight (1975); but in Indian tropical forests, it ranged from 0.83 to 4.1 (Singh et al., 1984; Parthasarathy et al., 1992; Visalakshi, 1995). The species diversity index obtained under the present study was well within the reported range for the tropical forests of Indian subcontinent.

Stands Density

Total number of 2080 stems of trees was enumerated from three stands under study (table 4). Stem density was highest at Karko (910 stem ha^{-1}), lowest at Kopu (450 stem ha^{-1}) and intermediate at Ramsing (720 stem ha^{-1}). The mean stand density for the study area was 693.33 stems ha^{-1}. The forest stand density varied from 450 to 910 stems ha^{-1} in the study area. This was comparable to that of the tropical wet evergreen forest in Kalakad National Park (574-915 stem ha^{-1}), Western Ghats (Parthasarathy et al., 1992), and to the stand density (550 to 1800 trees ha^{-1}) in several other tropical forests (Visalakshi, 1995; Pande, 1999).

The mean of stand density of all study sites was 693.33 stems ha^{-1} which was slightly higher than the tropical wet evergreen forest in Uppangala sites (610 and 635 stems ha^{-1}) in Karnataka (Loffeier, 1988; Pascal and Pelissier, 1996) in India. Further it was noted that the mean stand density in wet evergreen forests in the study area was 693.33 stems ha^{-1}. In comparison to the tropical forests in the world, stand density of the present study sites was lower (28%) than tropical rain forest in Reunion Island in France (Strasberg, 1996) but was almost similar to the other studies (Davis and Richards, 1934; Boom, 1986; Pascal and Pelissier, 1996).

The shrub and herb densities recorded under study are presented in the table 4. The highest shrub density was recorded in Karko (125 plants $100m^{-2}$), Kopu stand (123 plants $100m^{-2}$) and Ramsing (100 plants $100m^{-2}$) under the tropical wet evergreen forests. Pande et al. (2000) studying in old plantation reported the shrub density of 18-70 plants 100 m^{-2}. More heterogeneity in natural forests than those of the plantations might be the probable cause for higher density values occurred in the present study. Herbs covered the entire ground surface of the forest stands. The tropical wet evergreen forest stands recorded the low herb density (175-180 plants $10m^{-2}$). The perusal of the data showed that the highest number of tree species was noticed in Karko, followed by Ramsing, and Kopu. While for shrubs species, the order of importance was Karko>Kopu>Ramsing. Highest values for herb species was recorded for site Ramsing, followed by Kopu, and Karko.

Table 4. Species richness (S.R.) and species diversity index (H^-) for tree, shrub and herb layers

Sites	Tree			Shrub			Herb		
	D	S.R.	H^-	D	S.R.	H^-	D	S.R.	H^-
UD(Karko)	910	44	3.20	125	10	2.21	175	180	176
MD(Ramsing)	125	39	3.00	100	14	2.48	180	30	3.14
HD(Kopu)	175	25	2.65	123	17	2.76	176	32	3.30

The Species similarity

The similarity indices between sites for trees, shrubs and herbs have been presented in the table 5. The perusal of the data indicated that similarity of tree, shrubs and herbs were high among the Karko and Ramsingh stands. The similarity indices between the sites within similar type of forests were greater in comparison to those of sites under different forest types.

Table Table 5. Similarity index among different forest stands of Upper Siang forests

		MD(Ramsing)			HD(Kopu)		
		T	S	H	T	S	H
UD(Karko)	T	0.34	-	-	0.09	-	-
	S	-	0.17	-	-	0.15	-
	H	-	-	0.22	-	-	0.18
MD(Ramsing)	T	-	-	-	0.13	-	-
	S	-	-	-	-	0.06	-
	H	-	-	-	-		0.06

(H, herb; S, shrub; T, tree)

Beta-diversity(β- diversity) was calculated to ascertain the degree of species turn over among the various stands for tree, shrub and herb species (table 6). The maximum turnover of tree species was recorded between the sites of Karko and Kopu (0.91) followed by Ramsing and Kopu (0.88) and the lowest value of β- diversity(0.56) of tree species was recorded between the sites of Karko and Ramsing. The range for turnover of species for shrub layer was 0.83 (between Karko and Ramsing) to 0.95 (between Ramsing and Kopu), while the values for herbs were varied from 0.78 (between Karko and Ramsing) to 0.94 (between Ramsing and Kopu) .

Table 6. β -diversity among different sites of forest stands in DDBR

		Ramsing(MD)			Kopu(HD)		
		T	S	H	T	S	H
Karko (UD)	**T**	0.66			0.91		
	S	-	0.83	-	-	0.85	-
	H	-	-	0.78	-	-	0.82
Ramsing(HD)	**T**	-	-	-	0.88	-	-
	S	-	-	-	-	0.95	-
	H	-	-	-	-		0.94

(H, herb; S, shrub; T, tree)

Basal area

The total basal area of trees in the study sites was 145.74 m^2. The site wise total basal area was as high as 57.89m^2 at Kapu, 45.26 m^2 at Ramsing and 42.59 m^2 at Karko (Table 7). The average basal cover in the forest sites was 48.58 m^2 ha^{-1}. The mean stand basal area of all the study sites was found to be 48.58m^2 ha^{-1}. All these figures were comparable to the total basal cover in several tropical forests, which ranged from 10.73 to 107m^2 ha^{-1} (Visalakshi, 1995; Pande, 1999). But the total basal area of the study sites was greater than those of many forest stands in Varzea tropical forest (25.5-27.0 m^2 ha^{-1}) at Rio Xingu, Brazil (Campbell et al., 1986; Campbell et al., 1992). The mean of total basal area of 52.55m^2 ha^{-1} for all sites was higher than that of the tropical evergreen forests (42.6 m^2 ha^{-1}) of Courtallum (Parthasarathy and Karthikeyan, 1997) and of the Uppangala forest stand (39.7 m^2 ha^{-1}) in Coorg (Pascal and Pelissier 1996); but lower than that of Kalakad forest (73.95 m^2 ha^{-1}) in Western Ghats (Parthasarathy et al. 1992). In the present study, the total basal cover values were well within the reported range for tropical forests.

Table 7. Basal cover (m^2 ha^{-1}) of tree species (≥10 cm dbh) in different forest stands

	Forest stands		
Plant type	UD(Karko)	MD(Ramsing)	HD(Kopu)
Tree species	42.59	45.26	57.89

Concentration of dominance

The values of concentration of dominance (cd)) for tree layer were of the order of 0.110 at Ramsing, 0.094 at Kopu, 0.084 at Karko (table 8). But the highest concentration of dominance for the shrub layer was recorded at Karko (0.12) and was followed by those of Ramsing (0.094), and Kopu (0.065). Herb layer had the highest concentration of dominance at Ramsing (0.07) that was followed by Kopu (0.04) and Karko (0.04).The values of concentration of dominance (cd) for tropical forests, the average value was 0.06 as reported by Knight (1975). The range of concentration of dominance for the Indian tropical forests was from 0.21 to 0.92 (Bisht, 1989; Parthasarathy et al., 1992; Visalakshi, 1995; Pande, 1999). Thus, the values for concentration of dominance in the present study fall within the reported range for tropical forests.

Table 8. Concentration of dominance of plant species at study sites

Site	UD(Karko)	MD(Ramsing)	HD(Kopu)
Trees	0.084	0.110	0.094
Shrubs	0.119	0.094	0.065
Herbs	0.041	0.072	0.042

Distribution pattern

The abundance/frequency ratio ranged from 0.05 to 0.40 at Karko, 0.06 to 0.60 at Ramsing, 0.04 to 0.20 at Kopu. The distribution pattern of different tree species was contagious clump at all the sites except *Bauhinia variegata*, *Castanopsis indica* and *Perseagamblei* at Karko; *Terminalia myriocarpa* at Kopu, which showed random distribution pattern and absence of regular distribution. This contagious distribution is more characteristic pattern in nature (Odum, 1971). The random distribution, which was indicative of uniform environment, was noticed in some natural forests under temperate zone (Saxena and Singh, 1982; Singhal et al., 1986) and in plantation ecosystems of Doon-valley (Pande et al., 2000).

The abundance/frequency ratio of different shrub and herb species also varied considerably at different study sites. The entire shrub and herb species showed clumped distribution. The abundance/frequency ratio of shrub ranged from 0.22 to 0.64 at Karko, 0.20 to 1.00 at Ramsing, 0.09 to 0.58 at Kopu. Where as for herb species it was ranged from 0.11 to 0.90 at Karko, 0.09 to 0.75 at Ramsing, 0.08 to 0.43 at Kopu.

Species dominance and rarity

Dominance calculated as the importance value index (IVI) of different species varied greatly in different stands. The different species was dominated in different forest stands. The IVIvaluesof trees for different site have been given in the table 9. The perusal of the data showed that the dominant tree species at different study sites were *Meliosoma wallichi* at Ramsing, *Terminlia myriocarpa* at Kopu and *Persea gamblei* at Karko. Aomong the other species like *Altingia excelsa* and *Ficus elmeri* also found dominating in wet evergreen forests.

Tree species represented by one or two in the sampling area were considered rare in any study site. Out of the 88 tree species, 51 species (40.91%) were rare of which 36 species were represented by only one. This study corroborates the findings of Parthasarathy and Karthikeyan (1997) who noticed about 47% rare tree species in tropical evergreen forest under Courtallum reserve forest in Western Ghats of India. This finding is also comparable to the species rarity of the tropical forests in New Guinea (50%), Barro Colorado Island of Panama (40%) and in Malaysia (30%) as reported by Poore (1968) Paijman (1970) and Pascal and Pelissier (1996).

Table 9. Importance value index (IVI) of some important tree species at DDBR forest stands

Tree species	Karko	Ramsing	Kopu
Meliosma wallichii Planch	3.58	85.93	-
Terminlia myriocarpa Van Heurck & Muell.-Arg.	-	7.87	82.65
Persea gamblei (King ex Hk. F.) Koster	65.13	-	-
Ficus elmeri Govt.	-	12.13	39.10
Altingia excelsa Noronha	6.84	30.78	28.48
Albizia stipulate (Roxb.) Boiv.	-	7.55	25.44
Cinnamomum obtusifolium Ness	19.15	8.90	-
Mangifera sylvatica Roxb.	14.26	9.94	-
Ficus hispida Linn.	-	-	13.76
Baccaurea sapida Muell.	-	-	12.29
Morus laevigata Wall.	6.29	12.06	-
Betula alnoides Buch.-Ham.ex D.Don	-	-	11.56

Size (DBH) class wise tree density, basal area and species richness in study forest stands

The forest stand structure based on the dbh frequency was of expanding type with greater number of trees in lower size classes (10-20cm dbh at Ramsing and 21-30cm dbh class at Karko and Kopu). The tree density reduced gradually gradually as dbh size increased (table 10.) However, there were somee exceptional cases where increase in tree diversity were recorded at high dbh classes like 51-60 and 61-70cm dbh at Kopu in comparison to their respective lower classes. Species richness, stand density and diversity indices consistently decreased with increasing size classes of tree species from 10cm to >90cm dbh class (table 10). The lower two dbh classes (10-20 and 21-30cm) accounted for 72.84% (35.10% and 37.74% respectively)

species richness and stand density and the lowest value of stand density was recorded at 81-90 of 0.72% and >90cm dbh class of 0.24%.

Table 10.The population structure at stand level (dbh class wise species richness, density and diversity)

Sites	UD(Karko)			MD (Ramsing)			HD (Kopu)		
dbh class (cm)	D	S R	H^-	D	S R	H^-	D	S R	H^-
10-20	340	31	3.01	290	25	2.63	100	14	2.48
21-30	430	33	3.03	220	17	2.40	135	13	2.39
31-40	125	10	1.96	150	13	2.39	100	9	2.02
41-50	10	1	0.00	25	3	0.95	15	1	0.00
51-60	-	-	-	10	1	0.00	20	3	0.69
61-70	5	1	0.00	15	2	0.64	45	3	0.97
71-80	-	-	-	5	1	0.00	20	2	0.56
81-90	-	-	-	5	1	0.00	10	1	0.00
>90	-	-	-	-	-	-	5	1	0.00

*D=Density (plants ha^{-1}), S. R. = Species richness and H^-= Diversity index.

But the basal area distribution over all the sites showed a different pattern (table 11). The 21-30 and 31-40cm dbh classes contributed nearly half of the total basal area (48.87%) having 26.43% and 22.45% for respective classes);whereas, the lowest (10-20cm) and the heighest (>90cm)dbh classes contributed only 10.25% and 2.62% basal area respectively. The contribution in basal area cover of other size classes was within the wide range of 6.70 to 22.18m^2 at different study stands. The trend of decreasing species diversity and density with increasing tree size class was similar to that observed by Paijman (1970) in New Guinea, Jeffre and Veillon (1990) in New Caledonia and Newbery et al. (1992) in Malaysia.

Table 11. Basal cover (m^2ha^{-1}) of tree species in different dbh classes at DDBR

	dbh classes in cm								
Sites	**10-20**	**21-30**	**31-40**	**41-50**	**51-60**	**61-70**	**71-80**	**81-90**	**>90**
UD(Karko)	7.23	21.15	10.67	2.02	-	1.52	-	-	-
MD(Ramsing)	5.87	10.88	12.41	3.85	2.47	4.91	1.96	2.90	-
HD(Kopu)	1.83	6.48	9.63	2.17	4.23	15.75	8.42	5.55	3.82
Total	**14.93**	**38.51**	**32.71**	**8.04**	**6.7**	**22.18**	**10.38**	**8.45**	**3.82**

The population structure of selected dominant tree species

The IVI of some important species have been presented in the table 9.The perusal of the data indicated that the stands wise dominant tree species as *Meliosoma wallichii*at Ramsingrecorded 85.93 as its IVI value. Similarly the dominant species like *Terminalia myriocarpa* at Kopu, *Persea gambleia*t Karko recorded the IVI values of 82.65, and 65.13respectively. In whole study area, *Meliosoma wallichii* was the dominant and other two were codominant species like *Terminalia myriocarpa* and *Persea gamblei*. The population density of the tree species also varied greatly in the different study stands. The dominant species in the whole study area were identified as *Meliosoma wallichii* (215 stems ha^{-1}) and the other two were as codominant like *Terminlia myriocarpa*, (85 stems ha^{-1}), and *Perseagamblei* (230 stems ha^{-1}).

The basal area contribution by the above mention dominant tree species also varied greatly. The basal area of *Terminlia myriocarpa* was 26.66m^2 ha^{-1} and those of *Meliosoma wallichii*and *Perseagamblei* were18.36, and 11.01m^2 ha^{-1} respectively. The dominant species accounted for nearly 26(25.48) % of the total stand density and 38.45 % of total basal area. Hill summit was found to be favourable microhabitats for these species (*Terminlia myriocarpa*, *Meliosoma wallichii* and *Perseagamblei*). *Terminalia myriocarpa* and *Perseagamblei* were the two predominant species exhibited clear expanding population structure at Kopu and Karko respectively (Fig.1).*Meliosoma wallichii* was also the predominant species exhibited clear expanding population at Ramsing although their frequency was lower than the former two species. The greater number of trees at 30 to 60cm dbh class for *Meliosoma wallichii* and *Perseagamblei* indicated that the stands would continue to be dominated by these species.

The number of individual of *Meliosoma wallichii*is less in higher dbh class than lower dbh class that indicates that the forest stand of Ramsing may be dominated by this species in future also. Where as the number of *Terminalia myriocarpa*wasabsent at 10-20cm dbh that indicated the forest stand may be lack of tree in far future if there was no seedling or sapling of the tree in that forest stand. The number of *Persea gamblei* at lower dbh classes like 20-30,

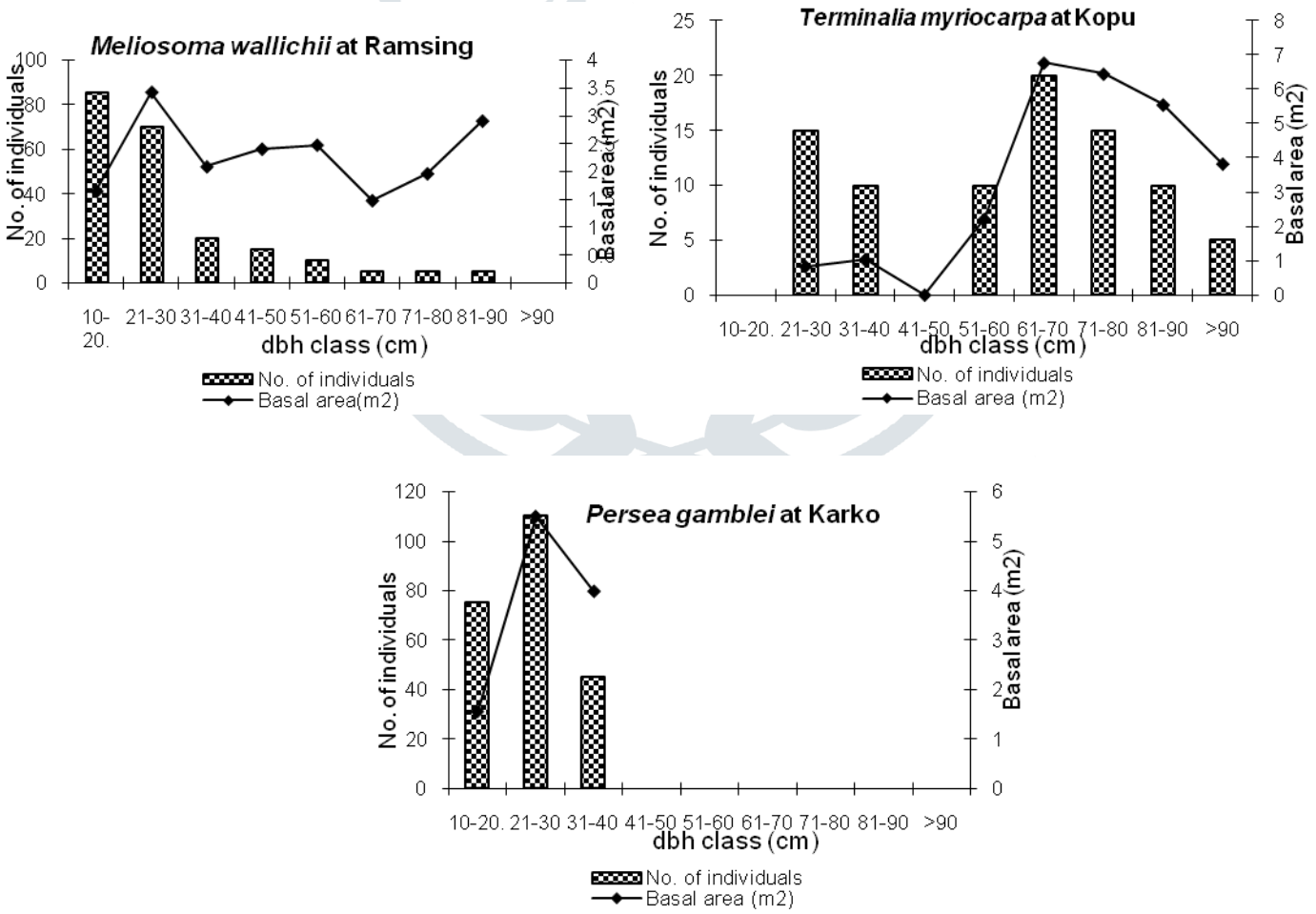
followed by 30-40 and 10-20 was higher as compared to higher dbh classes where the individual was absent that also indicates the forest stand may be lack of the species in near future and may be dominated in far future by the species.

The trend in basal area distributions differed in which *Meliosoma wallichii* showed a gradual increase in basal area with increasing tree size class leading to the highest value at >90cm dbh class. *Terminalia myriocarpa* also showed a gradual increase in basal area with increasing tree size up to the 61-70cm dbh class. All these dominant species like *Terminlia myriocarpa* at Kopu (HD) and *Perseagamblei* at Karko (UD), exhibited random dispersion; whereas, *Meliosoma wallichii* exhibited clumped dispersion at Ramsing(Table 12).Chowudhury (1997) also noticed the dominance of these species in Siang area. The clump dispersion obtained for some species is in conformity with the findings of Ashton (1969), Hubbell (1979) and Forman and Hahn (1980).

Table 12. Population structure and dispersion of dominant tree species in DDBR

Species	Density	Sampling units	Basal area (m^2)	IVI	Dispersion pattern
Meliosoma wallichii	215	11	18.36	85.93	0.06(C)
Terminlia myriocarpa	85	9	26.66	82.65	0.04(R)
Perseagamblei	230	14	11.01	65.13	0.05(R)

Fig. 1. Comperative population structure of the dominant species as *Meliosoma wallachii* and other two codominant species as *Terminalia myriocarpa* and *Persea gamblei*in the study area.



CONCLUSIONS

The present study suggests that the variation in species diversity, community structure and population behaviour of the plant species in wet evergreen forests in the study stands is mainly regulated by the variableanthropogenic pressure. The study also gives an understanding of the species diversity, pattern of population of the tree species in wet tropical forestsunder Dehang –Debang Biosphere Reserve. As a considerable area of Siang of Arunachal Pradesh had been under shifting cultivation and plantation crops, conservation of remaining natural forests is critical for maintaining the biodiversity of Upper Siang districtare of Dehang-Debang Biosphere Reserve in Arunachal Pradesh. This quantitative inventory of plant diversity will definitely provide a base-line data for conservation planning.

ACKNOWLEDGEMENTS

I am thankful to MoEF, GOI, New Delhi for financial support and Department of Environment and theForest, Government of Arunachal Pradesh for site permission. I express my heart felt regards and gratitude to my teachers Dr. Uma Melkania, North EasternRegional Institute of Science and Technology (NERIST), Nirjuli (Itanagar), Arunachal Pradesh and G. B.Pant University of Agriculture and Technology, Pantnagar, Uttaranchal and Dr. D. C. Ghosh, Visva-Bharati,Sriniketan, West Bengal for their proper guidance and supervisions .I am also thankful to the Director, NERIST, Nirjuli, ArunachalPradesh for providing infrastructure facilities.

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