International Research Journal of Environment Sciences ISSN 2319–1414
Vol. **4(12),** 69-81, December **(2015)** *Int. Res. J. Environment Sci.*

Tree Diversity, Population Structure and Utilization in Traditionally Managed Sub-Tropical Wet Evergreen Forests of Meghalaya, North East India

Lynser M.B.[1]* and Tiwari B.K.[2]
[1]Department of Environmental Studies, Shillong College, Shillong, Meghalaya, 793003, INDIA
[2]Department of Environmental Studies, North-Eastern Hill University, Shillong, Meghalaya, 793022, INDIA

Available online at: www.isca.in, www.isca.me
Received 4th November 2015, revised 15th November 2015, accepted 20th December 2015

Abstract

Forest dependent communities of Meghalaya, India have evolved various traditional forest management systems for managing their forests. This study aims to understand the impact of different management systems on tree species diversity and population structure. Three traditionally managed subtropical wet evergreen forests in the state were studied following standard vegetation analysis methods. The study reveals that management systems have an effect on tree species diversity and population structure in that higher tree species diversity, density and basal cover were found in forest management systems involving higher degree of protection and low disturbance. The use percentage of economically important tree species was higher in forests with low protection and high disturbance. The findings highlight the important contribution of traditional forest management practices by the local people in maintaining a balance between conservation and sustainable utilization of forest resources.

Keywords: Species diversity, density, forest management practices, disturbances.

Introduction

Forests are vital to our survival and well-being. Trees in forest ecosystems are considered as an important component as they provide resources and ameliorate habitat of almost all other species found therein, thus supporting their survival. They are also a source of a variety of products required in the day to day activities of thousands of tribal communities living in the forest fringes. Growing human need of forest resources has led to a fast depletion of natural forest cover. Human activities like collection of timber, fuel wood and non-wood forest products and practices of grazing and trampling cause varying level of disturbance and alteration in the habitats of many forest species resulting in spatial and temporal variation in species richness, composition, productivity and regeneration status of trees[1-4]. Traditional forest management systems practiced by the local communities in many parts of the world has enabled forest protection and extraction of forest resources in a sustainable manner[5,6]. An understanding of the variability of these characteristics of the forests and their interactions in different traditional management systems can help evolve a management regime to enhance productivity, limit financial inputs, maintain species composition and conserve the plant diversity of community managed forests[2,7].

Forest dependent communities of northeast India have evolved elaborate institutions for management of their forests and have established mechanisms for their enforcement. These traditional forest management systems have been working fairly well until modern forest management system borrowed primarily from Europe was put in place initially by the colonial regime and later continued by the Government of India. In isolated pockets these age old community forest management systems are still functional and are contributing to conservation and sustainable utilization of forest resources. The tribal communities of Meghalaya, a hilly state in the Northeastern India, are among such communities who have retained their traditional forest management systems[5,8]. The state is endowed with rich forest resources with more than 77 percent of its total geographical area under forest cover[9]. More than 80 percent out of 3 million people live in the rural areas and are dependent on forests for their livelihood, creating a tremendous pressure on the forest resources. A unique pattern of forests ownership exists, where 90 percent of the forests are owned by the communities[10]. These community forests are managed in a way to provide benefit to the community as a whole. They are of several types and are subject to different extraction and protection regimes; which vary from totally set aside with no extraction to those which are subjected to day to day extraction of forest produce. The present investigation was undertaken with the objective of understanding the relationship between the degree of protection, disturbance level of forests under different management systems in Meghalaya, India and the resultant variation in tree species diversity and population structure. It also aims to analyze the contribution from these forests in terms of plant resources used by the people.

Material and Methods

Study area: The study was conducted in the sub-tropical wet evergreen forests of Saw Symper, located in the central plateau of Meghalaya (1400 m to 1760 m above MSL) between 91° 30' - 91° 40' N latitude and 25° 25' - 25° 15' E longitude, 14 km from Mawsynram the world's heaviest rainfall area. The area has a monsoonic climate and about 75% of the total annual rainfall is received between June and September. Average maximum and minimum temperature during summer months (July-August) was 23°C and 18°C respectively and during the winter (December-January) it often comes down as low as 1°C. Owing to the topography and the persistent rains, most of the top soils in the area have been washed away, making a large part of arable lands unsuitable for agriculture. The area is inhabited by the people belonging to Khasi tribe who practice shifting cultivation on hill slopes, though on a limited scale. The landscape is mainly dominated by grasslands dotted with patches of wet evergreen forests. These forests have been free from human interference over several centuries particularly due to low density of human population in the area; hence the need for any kind of management systems for their forests did not arise. However, during past five to six decades as population increased so do activities like timber and fuel wood extraction, cattle grazing and shifting cultivation. During this time, the local communities started setting aside patches of forest and devise various management practices for forest protection and resource extraction.

Three traditionally community managed forests called by different local names, located within the same physiographic zone and altitudinal range (1600-1740 masl) and of about same age and history were selected for the study (figure-1 and table-1).

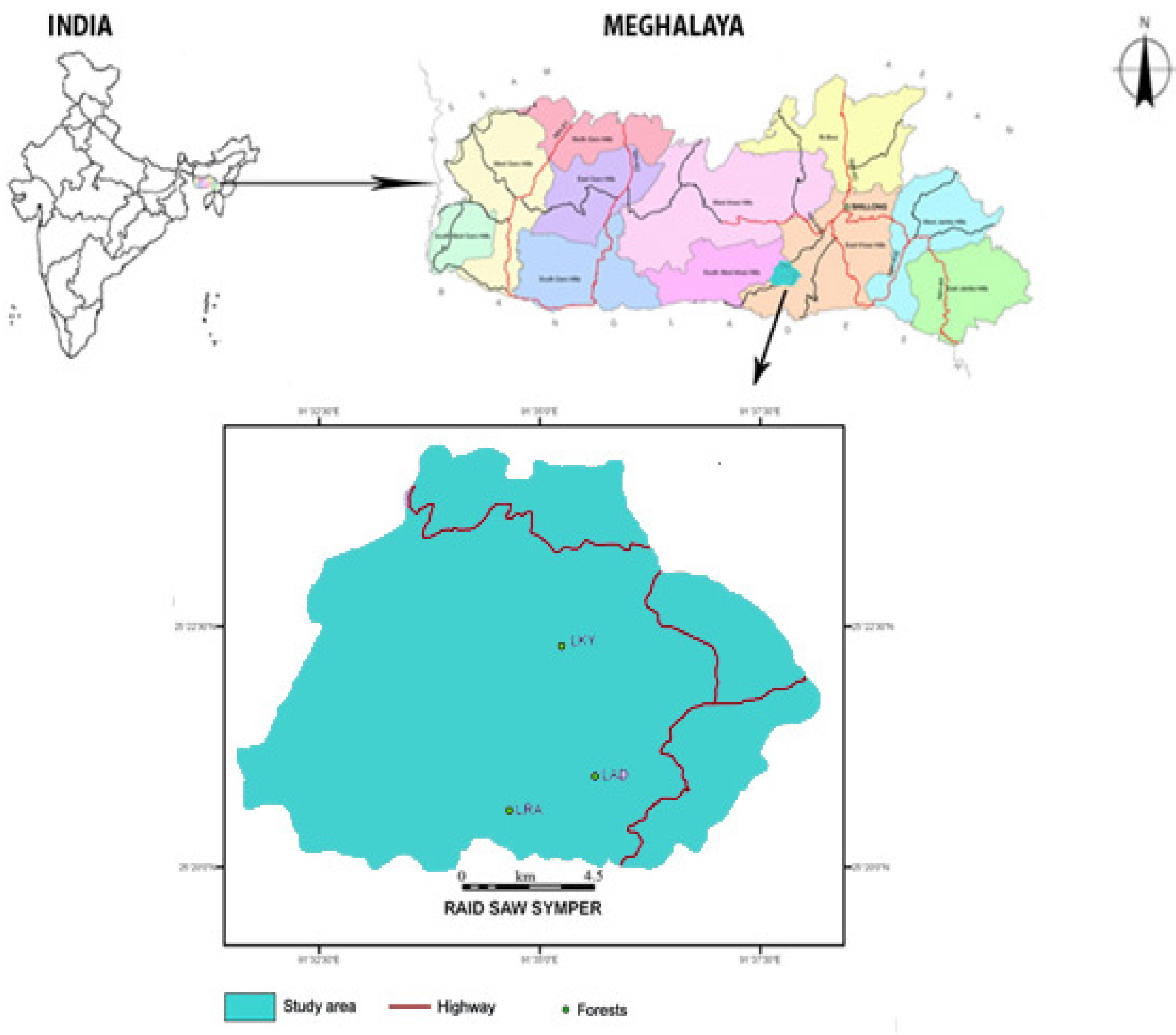

Figure-1
Location map of the study area

Table-1
Characteristic features of three traditionally managed forests selected for the study

Forests	***Law Kyntang* (LKY)**	***Law Adong* (LAD)**	***Law Raid* (LRA)**
Common name	Sacred Forest	Village Protected Forest	Group of Village Forest
Area (ha)	30	60	150
Altitude (m)	1631-1736	1621-1728	1616-1705
Topography	Steep slope (60-70%)	Steep slope (60-70%)	Steep slope (60-70%)
Management institution	Village Council	Village Council	Group of Village Council
Level of accessibility	Low	Moderate	High
Products Extracted	Extraction of few NTFPs only	Full extraction of NTFPs, Regulated extraction of Firewood and Timber	Full extraction of NTFPs, Firewood and Timber

Assessing disturbance level: In order to rank the level of disturbance of these forests, the type of management systems (intensity of activities permitted) and the percentage of cut stems were considered[11, 12]. Disturbance level was assessed by assigning a score of 0 to 10 for various activities permitted with zero value signifying least disturbance, 5 for moderate disturbance and 10 for high disturbance. Forests close to human settlements are subjected to human activities such as collection of forest products and grazing. The percentage of cut stumps in each forest was also calculated and assigned similar scores. Scores for various factors were summed to obtain a total disturbance score for each forest (table-2). Intensity of disturbances varies in an order LKY<LAD<LRA.

Table-2
Disturbance score of three forests

Forests	**LKY**	**LAD**	**LRA**
Timber extraction	0	5	5
Firewood extraction	0	5	10
NTFPs extraction	5	10	10
Charcoal making	0	0	10
Livestock grazing	5	5	10
Shifting cultivation	0	0	5
Forest fire	0	0	5
Distance from Settlements	0	5	0
*Cut stems	0 (0)	5 (2)	10 (45)
Total Score	10	35	65

*Figures in parenthesis give the percentage of cut stems

Vegetation sampling: The floristic composition and phytosociology of the tree community of the three forests were studied using quadrat method[13]. In each forest 35 quadrats of 10m x10m were randomly laid for tree sampling. All the tree species (>30 cm cbh (circumference at breast height i.e., 1.37 m above the ground) occurring within the quadrats were measured. If a tree trunk was buttressed at breast height, the girth was measured just above the buttress, and if a tree was branched at or below breast height, it was counted as two (or more) trees and each measured just above the branch point[14]. For multi-stem trees bole girths were measured separately and treated as individual tree[11]. Saplings and seedlings were not considered for the study.

Plant identification: Specimens of all species were collected and herbarium was prepared. Identification was done following flora references like Forest Flora of Meghalaya[15] and Flora of Assam[16]. The identifications were confirmed by consulting the herbaria at Botanical Survey of India, North-Eastern Circle, Shillong. The nomenclature of the species follows the regional flora.

Utilization of tree species: Data on utilization of tree species found in the study area were collected following ethno-botanical methods as described by Jain[17].

Data analysis: Important community parameters such as frequency, density, abundance, basal area and important value index (IVI) of all tree species were computed following Misra (1968)[13]. To determine species richness, diversity and evenness indices in the five forests, Margalef's index (DMg), the Shannon's diversity index (H'), Simpson's dominance index (D), Pielou's evenness index were calculated[18]. Circumferences at breast height (cbh) of trees in a forest were divided into various size classes and size structure of tree species in each forest was determined. The successional status of tree species was classed in early, mid and late succession following Shukla and Ramakrishnan[19].

Results and Discussion

Floristic diversity and species richness: A total number of 70 tree species (1 unidentified) belonging to 50 genera and 31 families were recorded from the three forests with Lauraceae and Fagaceae as the dominant families. The families, genera and species of the three forests are given in table 3. Tree species richness was found to be comparatively higher in traditionally managed forests with less disturbances and higher degree of protection (LKY and LAD) than in highly disturbed and unprotected forests (LRA). Forest LKY was found to have highest tree species with 52 species belonging to 41 genera and 28 families, LAD with 48 species representing 36 genera under 25 families and lowest for LRA with 30 species from 26 genera under 21 families.

The floristic richness recorded in the present study is higher than 45 species reported by Tripathi and Khongjee[20] and Tripathi and Tripathi[21] in subtropical humid forest and subtropical evergreen forest of Meghalaya. Despite the study site being located in a very high rainfall area with rugged terrain, where most of the top soil have been washed away, the high diversity status may be attributed to the different management practices which regulate human activities in these forests. Plant diversity of an area is related to a variety of factors such as topography, climate, soil and natural/human disturbance. As all the three studied forests are located within a distance of 10 km and an elevation between 1621 and 1736 m, the soil, climate and topography largely remain the same. But the difference in type of management and human interference between each studied forest has considerable influence on species richness as there is a decreased from 52 species in the protected and undisturbed forest LKY to 31 species in the unprotected and highly disturbed forest LRA which clearly demonstrates the reduction in tree species diversity in human impacted forests. Anthropogenic factors such as mining, timber extraction and livestock grazing resulted in a sharp decline in forest vegetation attributes[2,11,22,23].

Stand density and basal cover: Tree density was recorded to be highest in LAD (1671 individuals ha^{-1}), followed by LKY (1669 individuals ha^{-1}) and lowest in LRA (540 individuals ha^{-1}) (table-4). Tree species like *Quercus* sp., *Castanopsis purpurella* and *Helicia neligarica* contribute maximum density in LKY, while *Lithocarpus fenestratus* and *Quercus glauca* shows maximum density in LAD. In LRA, trees like *Helicia nilagirica* and *Schefflera hypoleuca* have maximum density.

The basal area of tree species in the three forests varied greatly. It decreased with increase in disturbances. The maximum basal area was recorded in LKY (77.57 m^2 ha^{-1}), followed by LAD (62.72 m^2 ha^{-1}) and least in LRA (12.36 m^2 ha^{-1}) (table-4). Maximum basal area in LKY was exhibited by tree species *Betula alnoides.* In LAD and LRA, maximum basal area was contributed by tree species like *Schima khasiana* and *Myrica esculenta* respectively.

It was noted in the present study that tree species richness, density and basal area decreased with increase in disturbance. These findings are in conformity with those of Chittibabu and Parthasarathy, Bhuyan et al. and Tripathi and Khongjee[2,20,24], which also showed reduced species richness, density, and basal area, as well as altered species composition in disturbed plots, as compared to the undisturbed plots. Murali et al.[7] found that unrestricted and open accessibility to forests can result in enhanced utilization of the forest resources and this may eventually lead to a decrease in species richness. Further, forests with open accessibility such as LRA experiencing firewood and timber extraction and to some extent shifting cultivation harbour low species richness (table-4). Higher density and basal area of tree species in LAD and LKY forests than in LRA forest was primarily due to restricted extraction of timber and firewood from these forests. A steep decline in tree density in LRA is because of greater human disturbances as most of the young and mature trees in this forest are harvested for firewood and charcoal making.

Frequency and Dominance distribution pattern: In all the forests, majority of tree species (77–87%) showed low frequency (<20%) and none of the individual having >80% frequency (Figure 2 and Annexure 1). In forest LRA, tree species in frequency class C, D and E are absent. Frequency class A was dominant; therefore, the forest may be termed as highly heterogeneous and patchy in terms of species distribution. *Quercus* sp., *Castanopsis purpurella* and *Helicia neligarica* were among the most frequently found species in forest LKY, while *Schima wallichii*, *Lithocarpus fenestratus* and *Aralia aramata* are more frequently found in forest LAD. In LRA, trees like *Helicia nilagirica, Schefflera hypoleuca* and *Aralia aramata* have highest frequency.

Based on importance value (IVI), it was found that tree species share almost equal IVI in all the three forest (Annexure 1). In LKY *Quercus* sp. was the dominant species with highest IVI (55.9) followed by species like *Castanopsis purpurella* (33.4), *Schima wallichii* (28.7), *Helicia nilagirica* (22.6) etc. *Lithocarpus fenestratus* was the dominant tree species in LAD forest with highest IVI (40.6) while, *Helicia nilagirica* is the most dominant tree species in LRA forest (IVI=37.4). The dominance-diversity curve shows that in all the three forests relatively few species had a high IVI value (figure-3).

There was a variation in the dominant and co-dominant species even though all the three forests were located under similar agro-climatic conditions. This variation in species diversity and composition may be attributed to the differences in microenvironment which is the outcome of human activities that takes place in the forests[25]. The dominance–distribution curve showed a log-normal distribution which represents equitability and stability of the community that signifies abundance of species having intermediate dominance values in the community[18]. It also indicates maturity and complexity of natural community.

Table-3
Families, genera and species of trees recorded in the three forests

Family	LKY		LAD		LRA	
	Gen	Sp	Gen	Sp	Gen	Sp
Aceraceae	1	1	1	1	-	-
Anacardiaceae	1	1	1	1	1	1
Aquifoliaceae	1	2	-	-	-	-
Araliaceae	3	3	4	5	2	2
Betulaceae	1	1	-	-	-	-
Caprifoliaceae	-	-	1	1	-	-
Celastraceae	1	1	1	1	-	-
Clusiaceae	1	1	1	1	1	1
Elaeocarpaceae	1	1	1	2	1	1
Eurphobiaceae	1	1	2	2	2	2
Fagaceae	3	6	3	6	2	2
Hamamelidaceae	1	1	1	1	1	1
Juglandaceae	1	1	-	-	-	-
Lauraceae	5	7	5	7	3	4
Leeaceae	1	1	1	1	1	1
Magnoliaceae	2	2	1	1	-	-
Moraceae	1	2	1	3	1	3
Myricaceae	1	2	1	2	1	2
Myrtaceae	1	2	1	1	1	1
Olacaceae	1	1	1	1	1	1
Palmae	-	-	-	-	1	1
Pittosporaceae	-	-	1	1	-	-
Proteaceae	1	1	1	1	1	1
Rosaceae	3	3	1	1	1	1
Rubiaceae	2	2	-	-	1	1
Sapotaceae	1	1	1	1	1	1
Symplocaceae	1	3	1	2	1	1
Theaceae	2	2	2	3	1	1
Thymelaeaceae	1	1	1	1	1	1
Vaccinaceae	1	1	1	1	-	-
Verbenaceae	1	1	-	-	-	-
Total*	28,41,52		25,36,48		21,26,30	

*Number of families, genera and species

Table-4
Density, basal area and species richness, diversity, dominance and evenness indices of tree species of three forests

Attributes	LKY	LAD	LRA
Density (individuals ha^{-1})	1669	1671	540
Basal area (m^2 ha^{-1})	77.57	62.72	12.36
Margalef's richness index	8.18	7.38	5.72
Shannon diversity index	3.01	3.03	3.00
Simpson's dominance index	0.09	0.08	0.07
Pielou eveness index	0.76	0.78	0.87

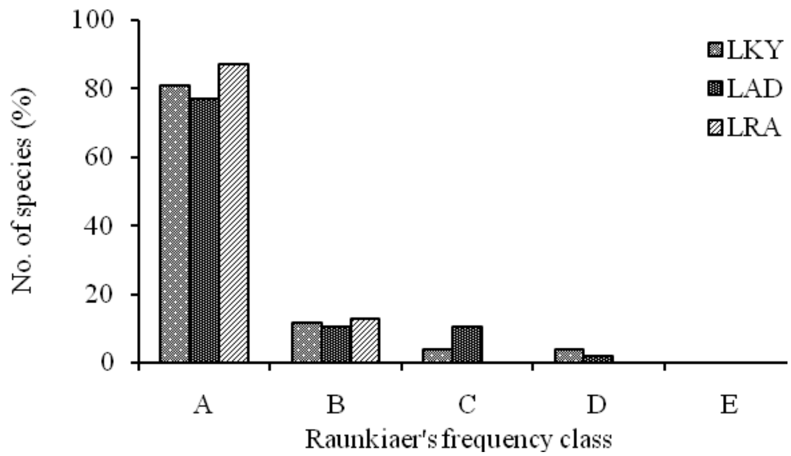

Figure-2
Frequency distribution of tree species in the three forests

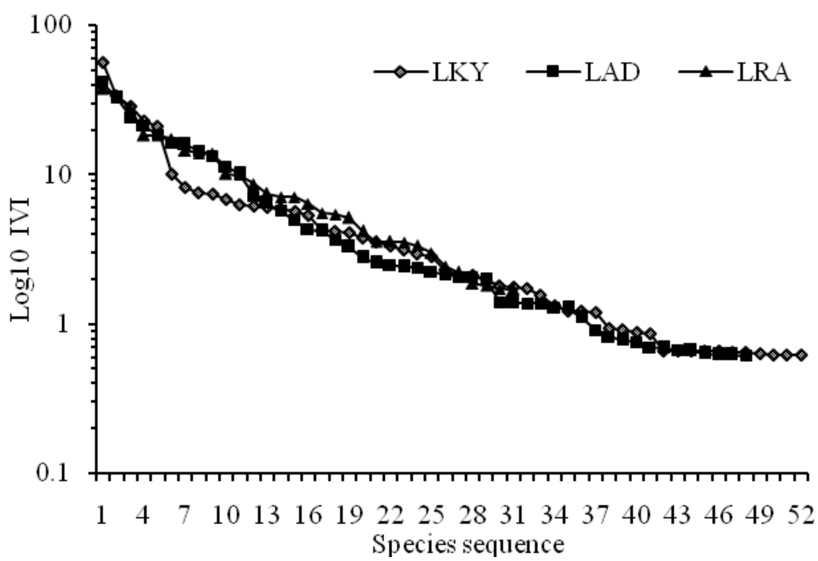

Figure-3
Dominance-diversity curves for tree species in the three forests

Species richness, diversity, dominance and evenness indices: Margalef's species richness index for trees was found to fluctuate from one forest to the other. It was highest in LKY (8.18), followed by LAD (7.38) and least for LRA (5.72). On the other hand, the Shannon species diversity index was found to vary slightly between the different forests. Forest LAD recorded slightly higher diversity index of 3.03, followed by LKY with 3.01 and LRA with 3.00 (table-4). The main factor responsible for lower diversity index in disturbed and unprotected forest (LRA) than protected and less disturbed forests (LKY and LAD) may be attributed to disturbance impact by human activities [20]. Simpson dominance index follows the same trend as species richness index. It was maximum in LKY (0.09), followed by LAD (0.08) and least for LRA (0.07). Pielou evenness index for tree species was maximum in LRA (0.87).

Density girth distribution, species richness and basal area: Irrespective of protection and disturbance level, tree density and species richness in various girth classes followed the same trend. Tree density and species richness consistently decreased with increase in girth size resulting in a reverse J-shaped curve (Figure 4). In LAD and LRA, majority of the stems (73 and 80%) belonged to lower girth class (30 – 60 cm gbh). The stand density contribution by 30–60 cm class ranged from 54.5% (LKY) to 80.4% (LRA), while from girth class 120 – 150 cm onwards, stand density contribution was very low and ranged from 0.5% (LRA) to 2.9% (LKY) (table-5). Similarly, species richness in all the three forests was highest in the lowermost girth class (30-60cm). The distribution of basal area for LAD and LRA decreased with increase in girth size, whereas in forests LKY it was found that the basal area increases upto the girth class 60-90 cm beyond which it decreased with increase in girth size (Figure 4). In LKY, the girth class 180 – 210 cm shows minimum basal area (1.2 m^2 ha^{-1}), while the girth class 60-90 cm contributed the maximum basal area (30.5 m^2 ha^{-1}) (table-5). In LAD forest, the minimum basal area (3.4 m^2 ha^{-1}) is recorded in girth class 180 – 210 cm and highest (24.9 m^2 ha^{-1}) in girth class 30-60 cm. From LRA forest, minimum basal area (0 m^2 ha^{-1}) was recorded in girth class 150-180 cm as tree were absent in this girth class, while maximum (9.0 m^2 ha^{-1}) in girth class 30-60 cm.

In all the three forests, species richness and density was highest in the lowermost girth class. Tree density decreases with increasing girth class resulting in a reverse J shaped curve at all sites revealing that adult individuals were few[2,26]. Abundance of young individuals in lower girth class is less in forest LKY due to denser canopy which inhibits growth of young seedlings. Forest LAD and forest LRA showed higher percentage of young individuals as they experience disturbances due to clear felling for timber, firewood and charcoal making.

Proportion of Early and Late Successional Tree species: The percentage of early successional tree species increases with increase in level of disturbance. It was highest in most disturbed and least protected forest LRA. LRA recorded 27% of early successional tree species while LAD and LKY recorded only 17%. In terms of late successional tree species LKY recorded the highest with 52% (figure-5). Higher proportion of early successional species in disturbed forests (LRA) may be attributed to better recruitment of such species in open spaces as has been emphasized by a number of workers[27,28]. Seedlings have a limited tolerance range of light, temperature and humidity[29] and in disturbed forests, fragmentation occurs which often alters these factors leading to reduced abundance of shade-tolerant understory seedlings as a result of limited seedling recruitment and increased mortality of established seedlings[30].

Table-5
Results of girth class analysis of trees in the three forests of sub-tropical evergreen forest in Saw Symper

CBH class (cm)	Density (trees ha^{-1})			Species richness			Basal area (m^2 ha^{-1})		
	LKY	LAD	LRA	LKY	LAD	LRA	LKY	LAD	LRA
30 - 60	909 (54.5)	1220 (73.0)	434 (80.4)	47	44	30	20.3	24.9	9.0
60 - 90	483 (28.9)	300 (17.9)	66 (12.2)	27	26	14	30.5	18.8	3.8
90 - 120	189 (11.3)	83 (5.0)	29 (5.3)	11	11	9	23.3	10.0	3.6
120 - 150	49 (2.9)	40 (2.4)	3 (0.5)	10	6	1	9.7	8.7	0.5
150 - 180	29 (1.7)	11 (0.7)	0 (0)	6	3	0	8.5	3.8	0.0
180 - 210	3 (0.2)	9 (0.5)	6 (1.1)	1	2	2	1.2	3.4	2.7
> 210	9 (0.5)	9 (0.5)	3 (0.5)	2	3	1	5.0	5.6	1.9

*Figures in parenthesis represents percentage

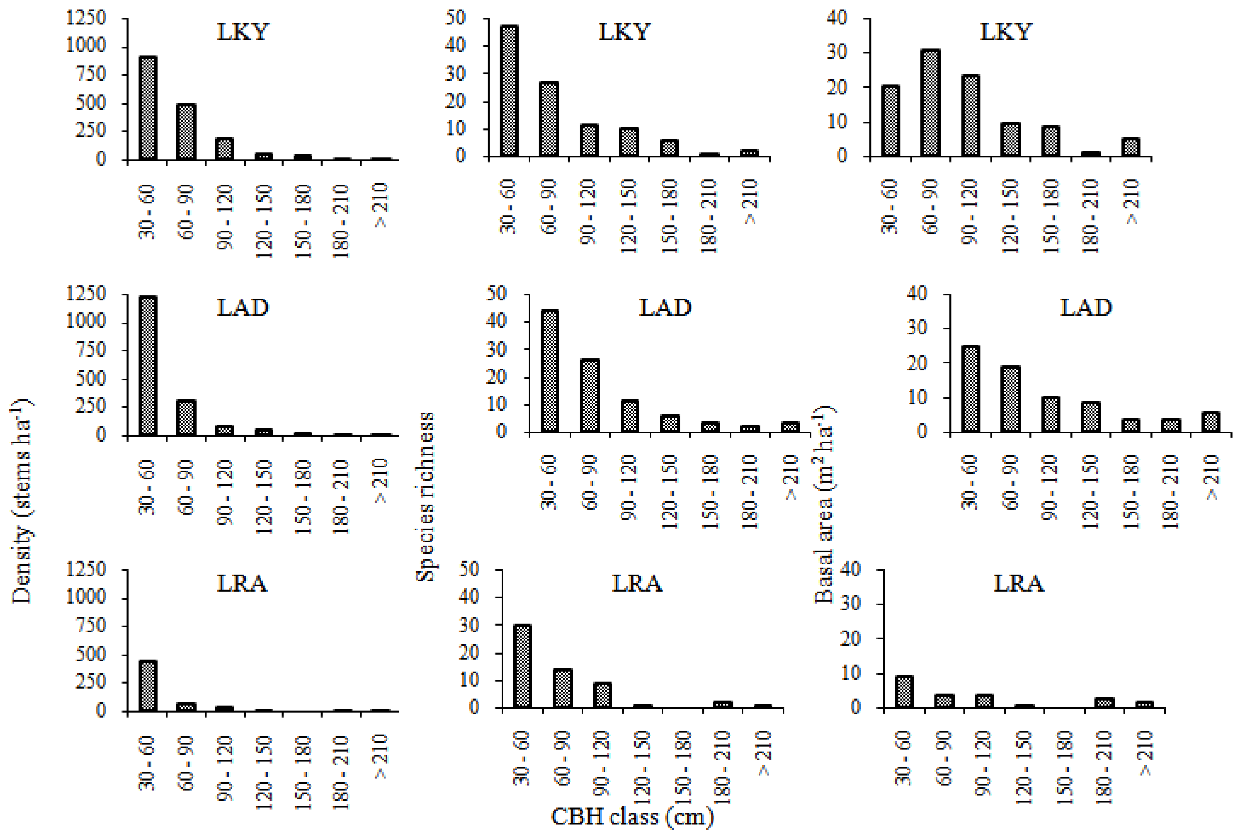

Figure-4
Density, species richness and basal area of tree species in different girth classes (cm) in the three forests

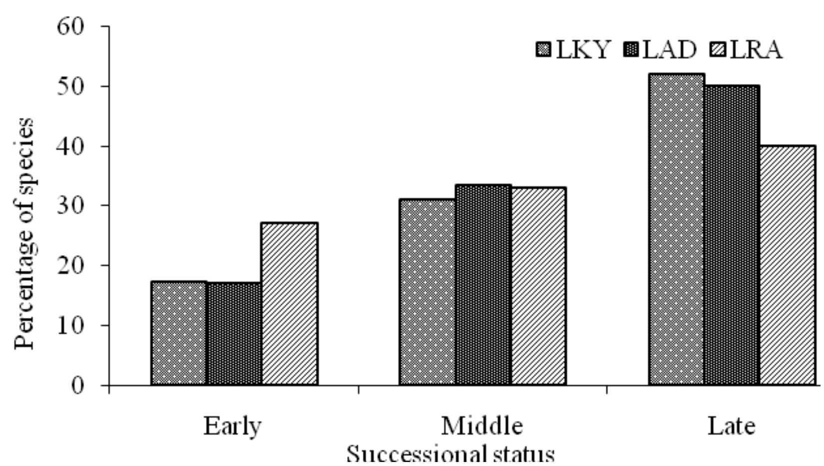

Figure-5
Percentage of early, mid and late successional tree species in the three forests

Tree species utilized by people: A total of 32 out of 70 tree species encountered during phytosociological survey are utilized by people of the study area for different purposes. The percentage of tree species utilized by people was highest in forest LRA (51.6%), followed by LKY (48.1%) and least is in LAD (45.8 %) (table-6). Different plant parts such as fruits, leaves, stem, branches, flowers and bark are utilized by people for fuelwood, food, medicine, construction, etc. Majority of the tree species collected by the people are used as fuelwood (40%), followed by food (17%) and for making tools and implements

(10%). For firewood purpose any kind of tree species is used, however, those which are abundant and easily available like *Myrica* spp., *Quercus* spp., *Lithocarpus* spp., *Castanopsis* spp., *Garcinia* spp., *Lindera* spp. *Elaeocarpus* spp. and *Schima wallichii* are mostly collected by the people. Hard wood tree species *viz*., *Quercus* sp., *Lithocarpus fenestratus, Lithocarpus dealbatus, Lithocarpus elagans, Symplocos laurina, Myrica nagi* and *Schima wallichii* are generally preferred for charcoal making. Fruits of *Myrica esculenta, Myrica nagi, Castanopsis purpurella* and *Pyrus pashia* are commonly collected by the people. Bark of *Eurya accuminata* and *Persea parviflora* is used as a dye and leaves of *Schefflera hypoleuca* is used as fodder for livestock. Straight bole hard wood tree species like *Exbucklandia populnea, Glochidion thomsonii, Wendlandia wallichii* and *Castanopsis armata* are used as poles for support in construction. Further, tree species with straight bole *viz*., *Quercus glauca, Helicia nelagirica, Castanopsis armata* and *Castanopsis purpurella* are used for making tools and implements like handle for coal digger which is very popular in the study area. Although a good number of plant species which can be utilized by people were also found in forest LKY and LAD, but since the collection of forest products from these forests is restricted hence they are not of so much benefit to the people.

Table-6
Availability of plant species utilized by people in different forests

Forests	LKY	LAD	LRA
Number of tree species encountered during phytosociological survey	52	48	31
Number of tree species utilized by people	25	22	16
Percentage of tree species utilized by people	48.1	45.8	51.6

Table-7
Distribution of tree species in different use categories

Uses Categories	No. of tree species	Percentage
Construction (poles)	3	7
Dye	2	5
Firewood	22	52
Fodder	1	2
Food	7	17
Medicinal	2	5
Ornamental	1	2
Tools and Implements	4	10

Conclusion

Tree species composition and community structure of forests of the study area is a function of type of activities permitted and level of disturbances. Less disturbed traditionally managed forests restricted for extraction of timber, firewood and shifting cultivation have higher species richness and diversity than disturbed and open access forests. Tree species richness, density and basal cover were low in forests open for extraction of timber, firewood and shifting cultivation. The study brings to fore that conservation of regional biodiversity faces major challenges since it competes with basic demands of local communities. But to a large extent the traditional forest management systems practiced by people of the area are helping in conservation of biodiversity in other wise fragile forest ecosystems of this area. Thus, the findings of the study reconfirms the importance of traditional forest management practices in meeting the daily needs of the people, in conserving biodiversity as well as maintaining health of forests in the area.

Acknowledgements

The authors are thankful to the University Grant Commission, New Delhi for providing financial assistance.

References

1. Cadotte M.W., Franck R., Reza L. and Lovett-Doust J., Tree and shrub diversity and abundance in fragmented littoral forest of southeastern Madagascar, *Biodivers. Conserv.,* **11**, 1417–1436 **(2002)**
2. Bhuyan P., Khan M.L. and Tripathi R.S., Tree diversity and population structure in undisturbed and human-impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India, *Biodivers. Conserv.,* **12**, 1753 – 1773 **(2003)**
3. Thapa N., Upadhaya K., Bhaishya R. and Barik S. K., Effect of Plantation on Plant Diversity and Soil Status of Tropical Forest Ecosystems in Meghalaya, Northeast India, *Int. J. Ecol.Environ. Sci.,* **37** (**1**), 61-73 **(2011)**
4. Kyayesimira J. and Lejju J. B., Vegetation Regeneration in Formerly degraded Hilly areas of Rwampara, South Western Uganda, *Int. Res. J. Environment Sci.* **4(8),** 1-7 **(2015)**
5. Tiwari B. K., Tynsong H. and Lynser M. B., Forest Management Practices of the Tribal People of Meghalaya, North-east India, *J. Trop. For. Sci.,* **22**(**3**), 329-342 **(2010)**
6. Mo X., Zhu H., Zhang Y., Slik J.W.F. and Liu, J., Traditional forest management has limited impact on plant diversity and composition in a tropical seasonal rainforest in SW China, *Biol. Conserv.,* **144**, 1832–1840 **(2011)**

Annexure-1

Tree species density, frequency and IVI of plants recorded in three forests of Raid Saw Symper, Meghalaya

Plant Species	Family	SS status	LKY			LAD			LRA		
			Den	Fre	IVI	Den	Fre	IVI	Den	Fre	IVI
Acer laevigatum Wall.	Aceraceae	LS	3	2.9	0.7	3	2.9	0.8	-	-	-
Aralia aramata (G.Don) Seem.	Araliaceae	MS	23	22.9	5.9	94	54.3	16.5	31	25.7	18.2
Betula alnoides Buch-Ham	Betulaceae	LS	20	17.1	10.0	-	-	-	-	-	-
Bleischmedia assamica Meissn.	Lauraceae	LS	11	8.6	2.3	49	31.4	10.1	9	8.6	5.6
Camellia caduca CBC	Theaceae	MS	-	-	-	6	5.7	1.3	-	-	-
Castanopsis armata Spach	Fagaceae	LS	6	2.9	2.0	-	-	-	-	-	-
Castanopsis purpurella (Miq.) Balak	Fagaceae	LS	217	57.1	33.4	69	25.7	14.5	29	11.4	13.9
Cinamomum bejolghota (Buch.-Ham.) Sw	Lauraceae	LS	-	-	-	3	2.9	0.8	-	-	-
Cleidion spiciflorum (Burm.) Merr	Eurphobiaceae	LS	-	-	-	40	22.9	7.2	14	11.4	8.7
Clerodendrum sp.	Verbenaceae	MS	6	2.9	0.9	-	-	-	-	-	-
Daphne involucrata Wall.	Thymelaeaceae	ES	6	5.7	1.3	14	8.6	2.4	3	2.9	1.7
Dendropanax japonicum Seem.	Araliaceae	ES	-	-	-	11	5.7	2.1	-	-	-
Elaeocarpus lancifolius Roxb.	Elaeocarpaceae	MS	20	17.1	6.1	9	8.6	2.6	-	-	-
Elaeocarpus sp.	Elaeocarpaceae	MS	-	-	-	26	11.4	3.7	6	5.7	3.5
Engelhertia spicata Leschen.ex Bl.	Juglandaceae	LS	34	20.0	6.8	-	-	-	-	-	-
Eurya accuminata DC.	Theaceae	ES	3	2.9	0.7	-	-	-	-	-	-
Exbucklandia populnea Griff	Hamamelidaceae	ES	134	37.1	21.0	103	42.9	18.6	6	5.7	3.6
Ficus nerifolia J. E. Sm	Moraceae	MS	23	14.3	4.3	20	14.3	4.3	26	20.0	14.5
Ficus nervosa Heyne ex Roth.	Moraceae	MS	-	-	-	9	8.6	2.2	6	5.7	4.2
Ficus sp	Moraceae	MS	51	22.9	8.2	34	20.0	6.4	11	11.4	7.4
Garcinia penduculata G. Don	Clusiaceae	LS	-	-	-	17	11.4	3.3	34	20.0	18.2
Garcinia sp.	Clusiaceae	LS	3	2.9	0.6	-	-	-	-	-	-
Glocidion thomsonii Hk. f.	Eurphobiaceae	LS	20	17.1	4.2	23	17.1	4.2	11	8.6	6.4

Plant Species	Family	SS status	LKY			LAD			LRA		
			Den	Fre	IVI	Den	Fre	IVI	Den	Fre	IVI
Helicia nilagirica Bedd.	Proteaceae	LS	146	62.9	22.6	100	48.6	15.9	77	40.0	37.4
Ilex embeloides Hk.f.	Aquifoliaceae	MS	3	2.9	0.7	-	-	-	-	-	-
Ilex venulosa Hk.f.	Aquifoliaceae	MS	3	2.9	0.7	-	-	-	-	-	-
Illichium griffithii Hk.f and Thoms.	Magnoliaceae	ES	-	-	-	3	2.9	0.8	-	-	-
Leea indica (Burm. F.) Merr	Leeaceae	ES	6	5.7	1.2	6	5.7	1.3	9	8.6	5.1
Lindera caudata Benth.	Lauraceae	LS	6	5.7	1.2	14	5.7	2.2	-	-	-
Lindera latifolia Hk.f	Lauraceae	LS	-	-	-	-	-	-	3	2.9	1.8
Lindera nacusua (D.Don) Merr.	Lauraceae	LS	17	11.4	3.1	3	2.9	0.7	3	2.9	1.9
Lithocarpus dealbatus (Hk.f.et Th.ex Miq.) Rehder	Fagaceae	LS	9	5.7	1.6	-	-	-	-	-	-
Lithocarpus elagans (Bl.) Hatus ex Soepadmo	Fagaceae	LS	9	5.7	2.1	3	2.9	1.1	-	-	-
Lithocarpus fenestratus (Roxb.) Rehder	Fagaceae	LS	46	22.9	7.3	337	57.1	40.6	23	17.1	13.8
Lithocarpus sp.	Fagaceae	LS	-	-	-	3	2.9	0.7	-	-	-
Litsea sp.	Lauraceae	LS	11	5.7	2.1	-	-	-	-	-	-
Macropanax dispermus (Bl.) O. Ktze	Araliaceae	MS	6	5.7	1.8	3	2.9	0.7	-	-	-
Macropanax sp.	Araliaceae	MS	-	-	-	3	2.9	0.7	-	-	-
Manglietia insignis (Wall.) Bl.	Magnoliaceae	LS	3	2.9	0.6	-	-	-	-	-	-
Michelia doltsopa DC.	Magnoliaceae	LS	11	8.6	3.3	-	-	-	-	-	-
Microtropis discolor (Wall.) Arn	Celastraceae	MS	3	2.9	1.7	3	2.9	0.6	-	-	-
Myrica esculenta Buch.-Ham	Myricaceae	MS	9	5.7	3.0	126	45.7	24.1	3	2.9	2.4
Myrica nagi Hk. F	Myricaceae	MS	17	14.3	3.5	14	8.6	2.5	3	2.9	2.2
Neolitsea cassia (Linn.) Kosterm.	Lauraceae	LS	3	2.9	0.6	6	5.7	1.4	-	-	-
Persea duthiei (King ex Hk.f.) Kosterm.	Lauraceae	LS	3	2.9	0.6	6	5.7	1.4	-	-	-
Persea parviflora (Meissn.) Haridasan et R.R. Rao	Lauraceae	LS	23	11.4	3.7	9	8.6	2.0	20	8.6	10.1
Photinia cuspidata (Bertol) Balak	Rosaceae	ES	3	2.9	0.7	9	2.9	1.4	20	5.7	10.0

Plant Species	Family	SS status	LKY			LAD			LRA		
			Den	Fre	IVI	Den	Fre	IVI	Den	Fre	IVI
Pittosporum napaulense (DC.) Rehder and Wilson	Pittosporaceae	LS	-	-	-	3	2.9	0.6	-	-	-
Prunus cerasoides D. Don.	Rosaceae	MS	6	2.9	0.9	-	-	-	-	-	-
Prunus triflora Roxb.	Rosaceae	MS	-	-	-	-	-	-	-	-	-
Psychotria symplocifolia Kurz.	Rubiaceae	LS	3	2.9	0.6	-	-	-	-	-	-
Pyrus pashia D. Don.	Rosaceae	MS	17	8.6	2.8	-	-	-	-	-	-
Quercus glauca Thunb.	Fagaceae	LS	-	-	-	137	31.4	21.3	-	-	-
Quercus sp.	Fagaceae	LS	349	77.1	55.8	57	17.1	11.4	-	-	-
Rhus javanica Linn.	Anacardiaceae	ES	3	2.9	0.6	6	2.9	0.9	6	5.7	3.4
Sarcosperma griffithii Cl.	Sapotaceae	MS	11	5.7	1.8	6	5.7	1.4	3	2.9	1.7
Schefflera hypoleuca (Kurz.) Harms	Araliaceae	MS	6	2.9	0.9	9	5.7	2.4	54	28.6	27.9
Schima khasiana Dyer.	Theaceae	LS	-	-	-	9	5.7	5.7	-	-	-
Schima wallichii DC.	Theaceae	ES	143	48.6	28.7	123	68.6	33.4	9	8.6	7.1
Schoepfia fragans Wall.	Olacaceae	MS	29	25.7	6.0	29	17.1	5.0	9	8.6	5.4
Symplocos glomerata King ex Cl.	Symplocaceae	LS	23	20.0	5.3	-	-	-	-	-	-
Symplocos javanica (Bl.) Kurz.	Symplocaceae	LS	6	2.9	0.9	-	-	-	-	-	-
Symplocos laurina (Retz.) Wall	Symplocaceae	LS	46	17.1	6.3	14	11.4	2.8	11	11.4	7.1
Symplocos lucida (Thumb.) S and Z.	Symplocaceae	LS	-	-	-	3	2.9	0.6	-	-	-
Syzygium sp.	Myrtaceae	ES	29	8.6	4.1	-	-	-	-	-	-
Syzygium tetragonum Kurz	Myrtaceae	LS	49	22.9	7.5	86	34.3	13.3	34	17.1	17.4
Trachycarpus sp.	Palmae	ES	-	-	-	-	-	-	6	5.7	3.5
Vaccinium sprengelii G. Don	Vaccinaceae	LS	6	5.7	1.2	14	5.7	2.1	-	-	-
Viburnum sp	Caprifoliaceae	MS	-	-	-	3	2.9	0.6	-	-	-
Wendlandia wallichii W. and A.	Rubiaceae	ES	29	20.0	5.7	-	-	-	6	2.9	3.0
Unidentified sp 1		-	-	-	-	-	-	-	57	22.9	32.9

Successional (SS) status of species: LS = Late successional, MS = Mid successional, ES = Early successional

7. Murali K. S., Shankar U., Ganeshaih K. N., Umashaanker R. and Bawa K. S., Extraction of non timber forest products in the forest of BilgiriRangan Hill, India, 2. Impact of NTFP extraction on regeneration; population structure and species composition, *Econ. Bot.*, **50**, 252–269 **(1996)**

8. Lynser M. B., Forest Products of Raid Saw Symper, Meghalaya and their contribution to the Livelihood of the people. Ph.D. dissertation, North-Eastern Hill University, Shillong, **(2013)**

9. FSI., The State of Forest Report, Forest Survey of India, Ministry of Environment and Forests, New Delhi, **(2011)**

10. Poffenberger M., Communities and Forest Management, IUCN Working Group on Community Involvement in Forest Management, Cambridge, UK, **(1996)**

11. Muthuramkumar S., Ayyappan N., Parthasarathy N., Mudappa D., Raman T. R. S., Selwyn M. A. and Pragasan L. A., Plant Community Structure in Tropical Rain Forest Fragments of the Western Ghats, India, *Biotropica,* **38(2)**, 143–160 **(2006)**

12. Mishra B. P., Tripathi R. S., Tripathi O. P. and Pandey, H. N., Effect of disturbance on the regeneration of four dominant and economically important woody species in a broad-leaved subtropical humid forest of Meghalaya, northeast India, *Curr. Sci.,* **84**, 1449–1453 **(2003)**

13. Misra R., Ecology Work Book, Oxford and IBH, New Delhi, **(1968)**

14. Kumar A., Marcot B. G. and Saxena A., Tree species diversity and distribution patterns in tropical forests of Garo Hills, *Curr. Sci.,* **91(10)**, 1370-1381 **(2006)**

15. Haridasan K. and Rao R.R., Forest Flora of Meghalaya, **Vols I and II,** Bishen Singh Mahendrapal Singh, DehraDun, **(1985–1987)**

16. Kanjilal U. N., Kanjilal P. C., Das A., De R. N. and Bor N. L., Flora of Assam*,* **Vols I-V**, Omsons Publication, New Delhi, **(1934-1940)**

17. Jain S. K., Methods and Approaches in Ethnobotany, Society of Ethnobotanist, Lucknow, **(1989)**

18. Magurran A., Ecological Diversity and its Measurement, Princeton University Press, New Jersey, **(1988)**

19. Shukla R. P. and Ramakrishnan P. S., Architecture and growth strategies of tropical trees in relation to successional status, *J. Ecol.,* **74**, 33–46 **(1986)**

20. Tripathi O. P. and Khongjee R., Effect of forest fragment size on tree diversity and population structure of humid subtropical forest of Meghalaya, *Biodivers. Sci.,* **18(2)**, 208–214 **(2010)**

21. Tripathi O. P. and Tripathi R. S., Community composition, structure and management of subtropical vegetation of forests in Meghalaya State, Northeast India, *Int. J. Biodivers. Sci. Ecosyst. Serv. Manage.,* **6(3-4)**, 157-163 **(2011)**

22. Rao P., Barik S. K., Pandey H. N. and Tripathi R. S., Community composition and tree population structure in a subtropical broad leaved forest along a disturbance gradient, *Vegetatio,* **88**, 151-162 **(1990)**

23. Shaheen H., Qureshi R. A. and Shinwari Z. K., Structural Diversity, Vegetation Dynamics and Anthropogenic Impact on Lesser Himalayan Subtropical Forests of Bagh District, Kashmir, *Pakistan J. Bot.,* **43(4)**, 1861-1866 **(2011)**

24. Chittibabu C. V. and Parthasarathy N., Attenuated tree species diversity in human-impacted tropical evergreen forest sites at Kolli hills, Eastern Ghats, India, *Biodivers. Conserv.,* **9**, 1493–1519 **(2000)**

25. Cao M., Zhang J.H., Feng Z., Deng J. and Deng X., Tree species composition of a seasonal rain forest in Xishuangbanna, South West China, *Trop. Ecol.* **37(2)**, 183–192, **(1996).**

26. Kadavul K. and Parthasarathy N., Structure and composition of woody species in tropical semi-evergreen forest of Kalrayan hills, Eastern Ghats, India, *Trop. Ecol.***, 40(2),** 247-260 **(1999)**

27. Davies S. J., Tree mortality and growth in sympatric *Macaranga* species in Borneo, *Ecology,* **82**, 920-932 **(2001)**

28. Lichstein J. W., Grau H. R. and Roxana A., Recruitment limitation in secondary forests dominated by an exotic tree, *J. Veg.Sci.,* **15**, 712-728 **(2004)**

29. Gehlhausen S. M., Schwartz M. W. and Augspurger C. K., Vegetation and microclimatic edge effects in two mixed-mesophytic forest fragments, *Plant Ecol.,* **147**, 21–35 **(2000)**

30. Bruna E. M., Effects of forest fragmentation on *Heliconia cuminate* seedling recruitment in central Amazonia, *Oecologia,* **132**, 235-243 **(2002)**