Plant Diversity and Fragmentation of Major Forest Types of Meghalaya, North-east India

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ABSTRACT

The four major forest types viz., tropical moist deciduous, subtropical evergreen, subtropical semi-evergreen and subtropical pine forests, which together cover about 42% of the total geographical area of the state of Meghalaya in north-east India, were studied to find out their fragmentation pattern and plant diversity status. The tropical moist deciduous forests are found below 1000 m a.s.l., subtropical evergreen and subtropical semi-evergreen forests occur between 1000 and 2000 m and subtropical pine forest are distributed between 800 and 2000 m altitudes. These forests occur in strongly seasonal climate on highly leached acidic soils and are poor in TKN and available P and are fairly rich in organic matter content.

Altogether, 59, 82, 102 and 26 tree species (≥15 cm cbh) were recorded from 0.4 ha areas of the tropical moist deciduous, subtropical evergreen and subtropical semi-evergreen and subtropical pine forests, respectively. The subtropical semi-evergreen forests were most species-rich with 206 species and pine forests were most species-poor with 54 species in 0.4 ha area. The species content of the subtropical evergreen and tropical moist deciduous forests was more than the pine forest, but less than the subtropical semi-evergreen forest. Both current and past land use practices particularly slash and burn agriculture, have led to fragmentation of all major forest types of the state into patches of varied sizes. About 60 to 95% of the forest patches are of ≤10 sq. km area. The pine forests are most fragmented with more than 90% patches having an area of less than 5 sq. km. These small patches are extremely poor in tree species content. The fragmentation of forests in a hilly and high rainfall area like Meghalaya has an adverse effect on land and soil properties, and causes depletion in plant diversity and brings about qualitative change in the floristic composition by favouring

colonization of a large number of exotic weed species in the fragmented forest communities.

Key words: *Forest types, forest fragmentation, patch size, plant diversity, northeast India.*

Introduction

The panorama of Indian forests ranges from evergreen tropical rainforests in the Andman and Nicobar Islands, the Western Ghats, and the north-eastern states to dry alpine scrubs in the Himalayas. Between the two extremes, the country has tropical semi-evergreen forests, deciduous monsoon forests, thorn forests, and subtropical forests in the lower montane zones and temperate forest in the upper montane zones (Puri, 1960; Lal, 1989).

The vegetation of north-east India is unique due to presence of large number of primitive flowering plants, Indo-Burma-Malaysian and Indo-Chinese elements, and high endemism (Takhtajan, 1969). About 50% of Indian flora (*ca.* 8000 species) is confined to this region (Rao, 1994). The complex interaction of climatic, physiographic, edaphic and biotic factors including shifting agriculture and other human activities has given rise to very intricate pattern of vegetation development in the region. The resultant distribution of vegetation has been described in terms of plant assemblages assigned to different vegetation types (Pascal, 1988).

The natural vegetation of Meghalaya has been classified into tropical evergreen forest, tropical semi-evergreen forest, tropical moist deciduous forest, subtropical broad-leaved wet hill forest, temperate and subtropical pine forests and savanna, based on site condition and floristic composition (Kanjilal *et al.*, 1934–40; Champion and Seth, 1968; Haridasan and Rao, 1985–87; Rao and Hajra, 1986; Chauhan and Singh, 1992). The tropical moist deciduous forest, subtropical evergreen forest, subtropical semi-evergreen forest, and pine forest cover 1.3%, 11.6%, 21.5% and 7.8%, respectively of the total geographical area of the state. The state is a part of the richest botanical region of the country and harbours about 1151 dicotyledonous (Haridasan and Rao, 1985–87) and 736 monocotyledonous species (Myrthong and Rao, 1980). Human activities have altered the natural landscape to a great extent resulting in mosaic of natural forests and degraded communities at different stages of their development. The fragmentation of the forests caused

by a variety of human activities has serious ecological and environmental implications, since it often causes depletion of biodiversity and elimination of resources or their rearrangement into a new configuration (Kareiva, 1994; Matlack, 1994).

The present paper analyses the fragmentation pattern of the four major forest types of Meghalaya on the basis of IRS ID data of the year 2000 and evaluates their present plant diversity status and discusses future implications in light of anthropogenic stresses.

Study Sites and Methodology

The state of Meghalaya (25°2′ to 26°07′ N and 89°49′ to 92°50′ E), having a total geographical area of 22,429 sq. km is bordered in the northwest, north and east by Assam and in the south and southwest by Bangladesh. It is a predominantly hilly state with an altitude range of 60 to 2040 m asl. Based on the topography, the state could be divided into western, central and eastern upland regions, northern undulating hills and southern precipitous zone (Tripathi *et al.*, 1996).

In general, soils of the state are derived *in situ* from the underlying gneisses, schists and granite rocks of Archaen age and may be grouped under latosol (oxisol) type (Pascoe, 1950). These are broadly grouped into red loam, red and yellow latosol and alluvial types having brick-red colour at higher altitude to blackish colour in the low lying areas. These are highly leached, poor in nutrients and acidic (pH 4.7–6.5) in reaction. TKN, available phosphorus and soil organic matter varies from 0.11%–0.44%, 0.001%–0.004% and 2.5%–4.7%, respectively. The concentration of organic matter and nutrients is higher in the topsoil layer (0–10 cm) than the subsoil layer (10–20 cm) (Tripathi, 2002).

The climate of Meghalaya is monsoonic. Based on atmospheric condition, year may be divided into mild summer (March-mid May), rainy (mid May to September), autumn (October–November) and winter (December–February) seasons. Climatic conditions, particularly rainfall and temperature, vary widely throughout the state mainly due to variation in altitude. Average annual rainfall ranges from 160 cm to 1,146 cm and the mean maximum and minimum temperatures varies between 12–31.7°C and 5–16.5°C, respectively. The climatic analogues of five stations located along an altitudinal gradient of 350–1900 m asl are given in Table 1.

Table 1. Average annual rainfall (mm), maximum and minimum temperature (°C) and relative humidity (%) at different altitudes in Meghalaya

Parameters	Stations				
	Tura	Umroi	Cherrapunji	Jowai	Upper Shillong
Altitude (m asl)	350	1010	1350	1450	1900
Rainfall (cm yr^{-1})	432	185	1,146	570	288
Maximum temperature (°C)	31.7	24.1	20.9	23.4	20.6
Minimum temperature (°C)	16.5	12.9	13.5	13.8	5.6
Relative humidity (%)	66.4	67.8	78.5	66.9	80

The study was carried out in tropical moist deciduous, subtropical evergreen, subtropical semi-evergreen and subtropical pine forests of the state. All the four forest types were surveyed and two representative stands of about 20 ha were demarcated in each case for quantitative analysis of community structure. Twenty quadrats, each of 10 m × 10 m for trees (>15 cm cbh), 5 m × 5 m for small trees/shrubs (5–15 cm cbh) and forty quadrats of 1 m × 1 m for herbs were sampled in each forest type. The quadrats were laid randomly in each plot and species composition and other structural characters of plant community such as frequency, density and dominance were determined according to Misra (1968) and Mueller-Dombois and Ellenberg (1974).

The forest area under each type was determined on the basis of IRS 1D data using GIS and Curvy-meter based on the vegetation/forest types map prepared by Indian Institute of Remote Sensing, Dehradun. About 50–100 forest patches of different sizes under each type were recognized and their area was determined, and the forest patches were grouped into 9 to 11 size classes.

Results

Plant diversity

Tropical moist deciduous forest: The tropical moist deciduous forest had 59 tree species belonging to 47 genera and 24 families in 0.4 ha area. *Shorea robusta, Tectona grandis, Terminalia myriocarpa, Sterculia villosa, Cordia grandis, Embelia floribunda, Callicarpa arborea, Bauhinia variegata, Dysoxylum binectariferum, Lagerstroemia parviflora,*

Schima wallichii, Dillenia scabrella, Mallotus philippensis were the common tree species of the forest canopy. The under storey vegetation (shrubs, tree saplings/seedlings, herbs) consisted of 62 species from 45 genera and 21 families. *Clerodendrum viscosum, Eupatorium adenophorum, Panicum* sp., *Melatostoma malabathricum, Pongamia* sp., *Ardisia neriifolia, Digitaria* sp., *Desmodium* sp., *Gleichenia* sp., and *Vandelia* species were common species in this layer (Table 2).

Subtropical evergreen forest: The forest has almost continuous canopy with indistinct stratification in the valleys but clear on the hill-tops. The shrubby and herbaceous under growth are clearly seen in the forest. At places, the forest is moderately disturbed by shifting cultivation and tree felling. Altogether, 82 tree species belonging to 59 genera and 36 families were recorded from the two representative plots.

The canopy (tree height >20 m) layer is composed of *Mesua ferrea, Castanopsis indica, Elaeocarpus rugosus, E. floribundus, Terminalia bellirica, Dysoxylum alliarium, D. gobara, Dillenia*

Table 2. Plant diversity in major forest types of Meghalaya (TMD= Tropical moist deciduous, SEV= Subtropical evergreen SSEV= Subtropical semi-evergreen and SP= Subtropical pine forests)

	TMD		SEV		SSEV		SP	
	Stand -1	Stand -2	Stand -1	Stand -2	Stand -1	Stand -2	Stand -1	Stand -2
Tree species								
Area sampled (ha)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Number of species	39	42	65	58	67	72	9	26
Number of genera	27	29	51	43	45	51	7	13
Number of families	19	21	32	30	32	36	5	7
Small tree/shrub species								
Area sampled (ha)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Number of species	16	21	20	18	21	29	10	16
Number of genera	13	17	12	10	15	17	7	9
Number of families	10	12	8	8	13	10	5	5
Herbs/tree saplings								
Area sampled (m^2)	40	40	40	40	40	40	40	40
Number of species	37	42	51	48	57	50	68	52
Number of genera	26	31	40	36	45	39	53	36
Number of families	17	20	28	21	26	25	35	27

pentagyna, Tetrameles nudiflora. The under-canopy layer with height range between 10–20 m is constituted by *Garcinia paniculata, Syzygium tetragonum, Persea gamblei, Antidesma acuminatum* and *Aporusa dioica*. The lowermost layer, where plant height range between 2 and 10 m height, is made up of *Alchornea tiliaefolia, Antidesma acidum, Grewia disperma* and *Premna barbata*. Shrubs, herbs, lianas and epiphytic orchids, ferns, and bryophytes are abundantly found in the forest and were represented by a total of 74 species belonging to 61 genera and 34 families (Table 2).

The subtropical evergreen forests generally occur above 1200 m asl where average annual rainfall ranges between 300 cm and 500 cm with noticeable difference between summer (mean maximum temperature 24°C) and winter temperature (mean minimum temperature 14°C). This forest type covers about 2,547 sq. km in Jaintia hills (Narpuh and Saipung reserve forest), Khasi hills (Mawphlong and Cherrapunji), Ri-bhoi (Langbi, Kariong, Umter, Mopon and Nogpydem), and Garo hills (upper reaches of Tura and Siju reserve forest) districts.

Subtropical semi-evergreen forest: This forest type is found on the northeastern slopes of Jaintia hills (some areas of Saipung and Narpuh reserve forest), in Khasi hills (Mawsynram, Ryngud, Mosing), Ri-bhoi (Mawjyragong, Mopon, Mayang, Umsaw) and Garo hills (Damlgiri, Rangira, Sembu, Nokatgiri, Songsak, Rongrengiri). It covers about 4,788.7 sq. km area above 1200 m asl, where average annual rainfall varies between 150 and 300 cm.

A transitional zone between tropical and subtropical forests is found at certain places between 1000–1400 m a.s.l. The altitudinal limits of distribution and climatic condition prevailing in the subtropical semi-evergreen forest areas are similar to those of evergreen forest.

In the subtropical semi-evergreen forest the tree height and species richness is more than the evergreen forest. A total of 102 tree species from 79 genera and 46 families was recorded from the representative plots. The canopy is composed of *Elaeocarpus floribundus, Terminalia myriocarpa, Persea kingii, Celtis tetrandra, Schima wallichii, Engelhardtia spicata, Echinocarpus murex, Nauclea griffithii, Persea bombycina* and *Paramichelia baillonii*. The under canopy species included *Callicarpa arborea, Litsea salicifolia, Ficus elastica, Lindera latifolia, Glochidion acuminatum* and *Rhus acuminata*.

In the tree-let layer, *Psychotria adenophylla, Eurya japonica, Camelia kissi, Ligustrum lucidum* and *Daphne involucrata* are common species. Climbers and lianas are abundant in the forest.

Small trees/shrubs, tree saplings/seedlings and herbs were represented by 97 species, 76 genera and 39 families (Table 2). *Symplocos paniculata, Psychotria erratica, Adenia trilobata, Achronychia pedunculata* and *Ardisia griffithii* are among the abundant shrub species. *Annotis oxyphylla, Hemiphragma hetrophyllum, Davaellia* sp., *Aspleinium* sp., *Crysopogon aciculatus* and *Cymbopogon khasianus* are dominant herbaceous species.

Subtropical pine forest: The pine forests occur either as pure or mixed stand in the central upland of Shillong plateau between 800–2000 m a.s.l. The climatic conditions are similar to those of subtropical evergreen and subtropical semi-evergreen forests. The pine forests are considered as pre-climax communities where succession is arrested due to constant biotic stress and unfavourable soil condition.

They are very poor in tree species composition. Altogether, 26 species belonging to 17 genera and 11 families were recorded from the studied plots. The average height of pine trees ranges between 15 and 20 m, however, on degraded sites the tree height is less. The canopy is almost exclusively composed of pine; few scattered broadleaved trees often form the second storey in the forest. At places *Schima wallichii, Prunus undulata, P. cerasoides, Rhus javanica, Quercus* sp., *Lyonia ovalifolia, Rhododendron arboreum, Rhus acuminata, Alnus nepalensis* and *Exbucklandia populnea* are also found in the forest. Annual fire and grazing prevent establishment of shrubs and other woody species in the forest.

The shrub layer in the forest includes *Rubus ellipticus, R. rugosus, Myrsine semiserrata, Osbeckia crinita, Eupatorium* sp., *Lantana camara, Viburnum foetidum,* and *Leptodermis* species. The forest floor is covered with a large number of annual and perennial flowering plants, tree seedlings and saplings and ferns during monsoon period. *Lindenbergia hispida, Paspalum* sp., *Ophiopogon wallichii, Hedychium coccinium, Senecio cappa* and *Galinsoga parviflora* are common species of the ground flora. The shrub and herb layers together had 78 species from 52 genera and 29 families (Table 2).

Forest fragmentation

Measurement of the area of 991 forest patches of all four major forest types indicated great variability in the patch size from 1 sq. km to more than 100 sq. km. Large patches (>20 sq. km) of the tropical moist deciduous forest were found especially in the northern and western parts of the state up to 1000 m asl, where annual rainfall is less than 150 cm and mean minimum and maximum temperature ranges between 24°C and 28°C. Small patches (<5 sq. km) of sal and teak forests occur at low elevation in Garo hills (Rongrengiri, Sangsuk, Darugiri and Baghmara area), Ri-bhoi and Khasi hills districts. About 80% of the 99 forest patches of the tropical moist deciduous forest were of small size (≤ 5 sq. km) (Fig. 1a).

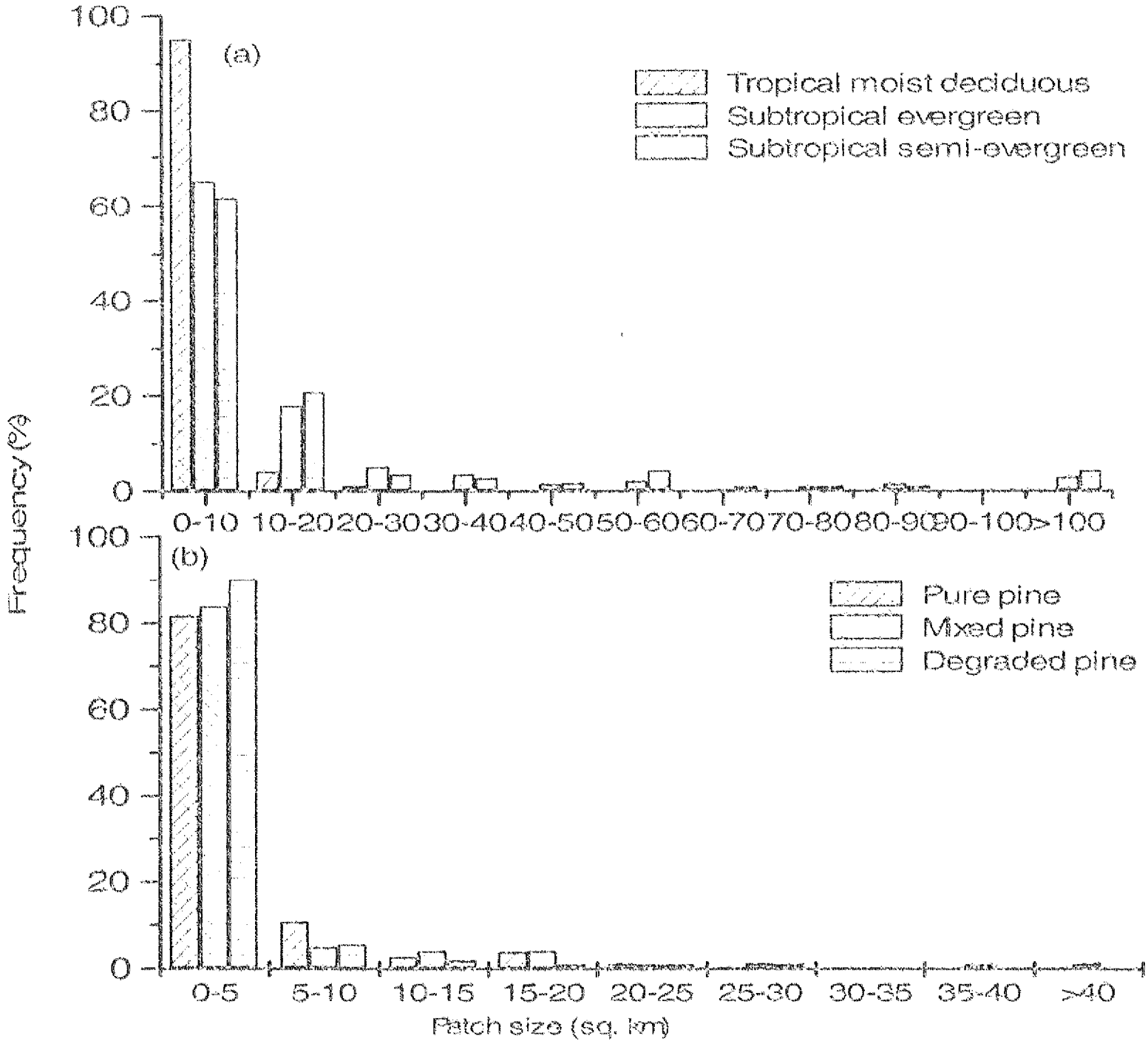

Fig. 1. Frequency distribution of patch size-classes in the tropical moist deciduous, subtropical evergreen, subtropical semi-evergreen and subtropical pine forests of Meghalaya.

The patches of subtropical evergreen forest size are found mainly at inaccessible sites, where they are least disturbed. Although forest patches of wide size range (from 1 sq. km to 100 sq. km) were found in the state, large continuous patches (>60 sq. km) are rather rare. About 65% of the 107 forest patches measured, were in the range of ≤10 sq. km size class (Fig. 1a).

The subtropical semi-evergreen forest has been fragmented mainly due to timber extraction and shifting agriculture. About 62% of 258 patches measured, were in the range of <10 sq. km-size class. The forest patches larger than 10 sq. km area are rare (Fig. 1a).

The pine forests are under tremendous biotic pressure due to annual surface fire, fuel-wood collection, logging, grazing and age-old practice of shifting cultivation. As a result of these activities, the forest has been fragmented into very small patches. More than 90% of the 527 measured patches are less than 5 sq km area. Forest patches in the size classes 20–25 sq. km and 25–30 sq. km were very few, and there was no patch beyond 30 sq. km area (Fig. 1b).

Discussion

A comparison of biodiversity status of the four major forest types presented in Fig. 2 clearly indicates that the subtropical evergreen and subtropical semi-evergreen forests of the state are very rich in plant species as compared to the tropical moist deciduous and subtropical pine forests. The pine forests that have developed as a stable community on the disturbed subtropical broad-leaved forest sites under the influence of annual fire and other biotic disturbances are extremely poor in tree species richness.

The state of Meghalaya, like other parts of northeast India, is undergoing rapid transformation due to urbanization, commissioning of hydroelectric projects, mining and extraction of forest products, besides age-old practice of shifting agriculture. All these activities have led to the fragmentation of large tracts of natural forests into small patches. Fragmentation of the forest may alter species composition due to microclimate changes, and decrease in genetic heterozygosity, on one hand, and favours colonization by invasive species from the surrounding vegetation, on the other (Tilman *et al.*, 1994; Chaterlain *et al.*, 1996).

Fragmentation of large size forests into many smaller forest patches disrupts the equilibrium of the original systems, resulting

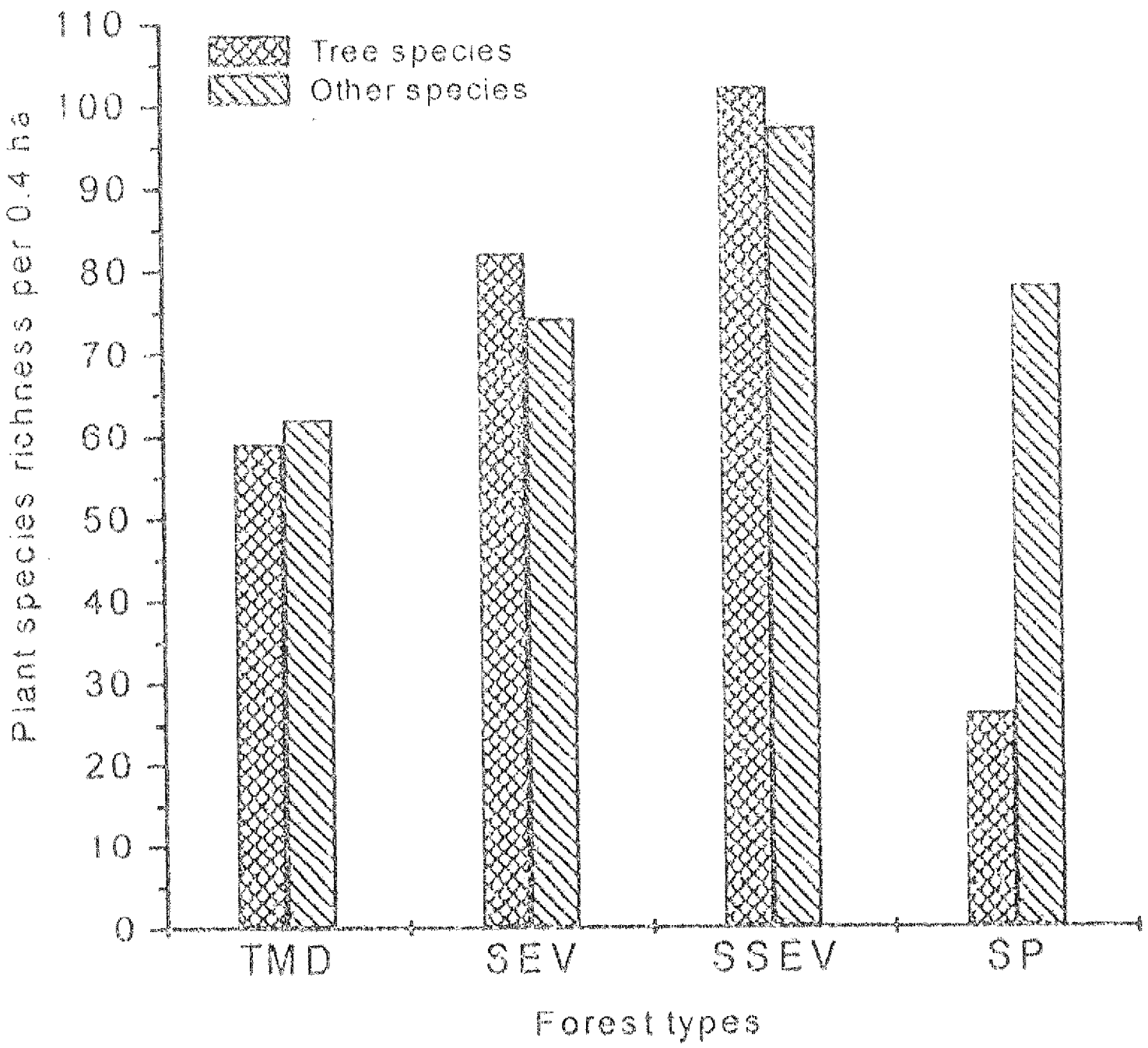

Fig. 2. Plant species richness in major forest types in Meghalaya (TMD = Tropical moist deciduous, SEV = Subtropical evergreen, SSEV = Subtropical semi-evergreen and SP = Subtropical pine forests).

in reduced plant diversity and instability (Burgess and Sharpe, 1981; Levenson, 1981). It causes emergence of two different types of forest ecosystems, interior forests that are virtually identical to the original, and the edge forest that is different from the original in respect of species composition and microclimatic conditions. The size reduction as a result of fragmentation also alters soil compaction and quality (Hoehne, 1981) and intensifies its degradation Hill (1995).

The study reveals that although disturbance is common in all the forests, it is comparatively less in the subtropical evergreen and subtropical semi-evergreen forests due mainly to their occurrence on the inaccessible steep slopes. There are reports which suggest that tree felling during the past few decades has led to forest degradation in the state (Tripathi *et al.*, 1996). As a result, a number of species have become rare, and endangered (Tiwari *et al.*, 1998) and few indigenous species such as *Cycas pectinata* and

Dipteris wallichi reported by Hooker (1854), have been eliminated due to inundation of large forest tract by hydroelectric reservoirs such as Brarapani lake (Kataki, 1983). Therefore, an obvious approach to conserve plant biodiversity of the state would be to map distribution of biodiversity-rich large forest fragments and protect them from further fragmentation and degradation.

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