FRAGMENTATION AND PLANT DIVERSITY STATUS OF MAJOR FOREST TYPES IN MEGHALAYA, NORTH-EAST INDIA

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Introduction

India possesses almost all major types of natural forest ecosystems. The panorama of Indian forests ranges from evergreen tropical rain forests in the Andman and Nicobar Islands, the Western Ghats, and the North-eastern states to dry alpine scrub in the Himalayas. Between the two extremes, the country has semi-evergreen rain forests, deciduous monsoon forests, thorn forests, sub-tropical pine forests in the lower montane zones and temperate montane forest (Lal, 1989). One of the most important forest classifications for greater India was given by Champion (1936) and later on revised for the present-day India by Champion and Seth (1968). Puri *et al.* (1983) while broadly agreeing to their classification, have argued that biotic factors such as shifting cultivation, fire and grazing have played important role the development, floristic composition and stability of forest community in India.

North-East India, the transitional zone between Indian, Indo-Burman-Malaysian and Indo-Chinese biogeographic regions (Puri, 1960), is unique due to presence of large number of primitive flowering plants, high floristic richness and endemism (Takhtanjan, 1969). About 50% of Indian flora (*ca.* 8,000 species) is confined to this region (Rao, 1994). The complex interaction of climatic, 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 vegetation of Meghalaya has been classified by Kanjilal *et al.* (1934-1940), Champion and Seth (1968), Haridasan and Rao (1985), Rao and Hajara (1986) and Chauhan and Singh (1992). They have divided the vegetation into tropical evergreen forest, tropical semi-evergreen forest, sub-tropical broad-leaved hill forest, tropical moist deciduous forest, temperate and subtropical pine forest and savanna based on site condition and floristic composition.

Meghalaya is a part of the richest botanical regions of the country and harbors about 1,151 dicotyledonous (Haridasan and Rao, 1985) and 736 monocotyledonous species (Myrthong and Rao, 1980). This paper analyses the distribution and fragmentation pattern of the major forest types of Meghalaya on the basis classified map of IRS remote sensed data and evaluates their biodiversity status in light of anthropogenic stresses.

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Material and Methods

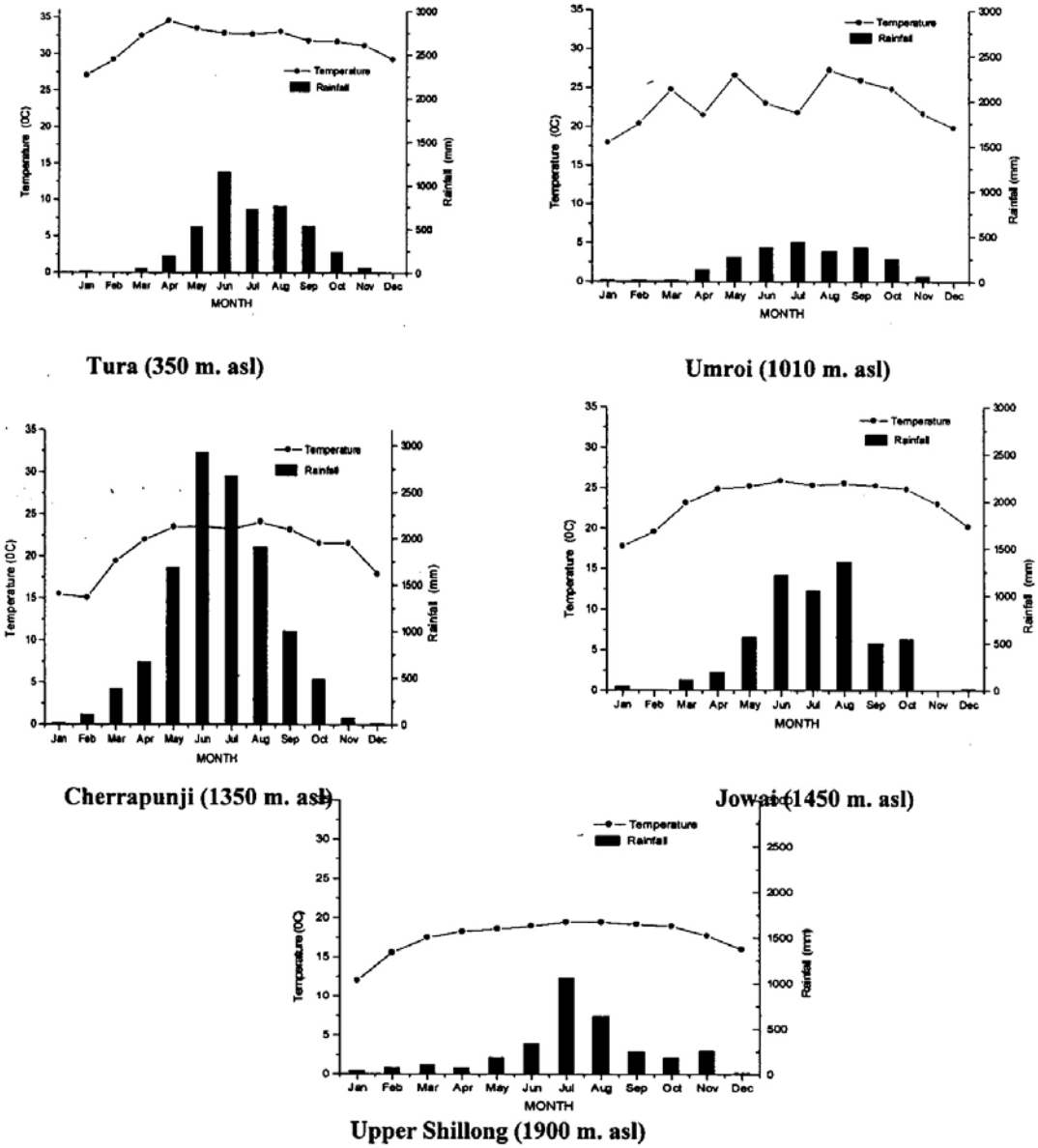
The State of Meghalaya (25° to 26°10' N lat. and 89° 45' to 92°47' E long.), having a total geographical area of 22,429 km^2 is bordered on the North-West, North and East by Assam and on the South and South-West by Bangladesh. It is a predominantly hilly state with an altitude range of 40 to 1,960 m asl. Based on the physiography, the state could be divided into western, central and eastern region, northern undulating hills and southern precipitous zone (Tripathi *et al*., 1996). The climate is monsoonic. Based on atmospheric condition, year may be divided into mild summer (March to mid-May), rainy (mid-May to Sepetember), autumn (October-November) and winter (December-February) seasons. Wide variation in climatic condition, partcularly rainfall and temperature is observed throughout the state mainly due to variation in altitude. Average annual rainfall ranges from 1,300 - 11,195 mm and the mean maximum and minimum temperatures varies between 17.7 - 31.7°C and 10.1 - 16.5°C, respectively. The climatic diagrams of five stations along an altitudinal gradient (350 - 1,900 m asl) are shown in Fig. 1.

The study was carried-out in five major forest types *viz.,* subtropical evergreen, and sub-tropical semievergreen, broad-leaved, sal and pine forests of the state. Soil samples were collected randomly from the two depths *viz.,* 0-15 and 15-30 cm at 5-10 places on annual basis from selected forest stands during October, 1999 and September, 2001. These samples were air-dried, sieved through 2mm mesh and used for the physico-chemical analysis using standard method following Allen *et al*. (1974) and Anderson and Ingram (1993). The forest area under each type was determined on the basis of IRS 1B, 1995 data using GIS (ILWIS Software) and Curvy-meter based on the vegetation/forest types map prepared by Indian Institute of Remote Sensing, Dehra Dun (Tomer, 1998). The area of forest patches under each type was calculated and they were grouped into different size classes. Each of the five forest types was surveyed and three representative plots were identified in each case for quantitative analysis of community structure. Quadrats of 20m x 20m, 5m x 5m and 1m x 1m were used for the study of trees, shrubs and herbs, respectively. They were laid randomly in each plot and species composition and other structural characters of plant community were determined according to Misra (1968) and Mueller-Dombois and Ellenberg (1974). The species richness at different layer of the forest, density, basal cover and diversity indices in each forest type is given in Table 2.

Results

Soil : The soils of semi-evergreen forest were comparatively more acidic (pH ranges from 5 to 5.3), and contain less organic carbon (1.18 to 2.18%), organic matter (2.03 to 3.76%), total Kjeldahl nitrogen (0.18 to 0.28%), and available phosphorus (12.8 to 31.7 μg g^{-1}) than the other three forest sites. Concentrations of soil organic carbon, organic matter, total Kjeldahl nitrogen and available phosphorus were higher in upper layer of soil than the lower layer in both the stands (Tripathi, 2002). However, pine forests occur on well drained, porous acidic (pH 4.65 to 5.12) soils with partially exposed to fully exposed rocks, primarily limestones. Soil development is minimal where recurrent fire has consumed litter and under-story vegetation. The

Fig. 1



Ombrothermic diagrams of study sites in Meghalaya along altitudinal gradient

underlying rocks are overlain with a thin layer of poor soil, which serves as the rooting medium for pine. Soils of the pine stands had relatively low organic carbon (1.2 to 3.2%), organic matter (1.81 to 4.1%), total Kjeldahl nitrogen (0.11 to 0.17%) and available phosphorus (9.6 to 11.6 μg g^{-1}) than the soils of the broad-leaved forests.

Table 1

Community characteristics of the studied forest stands.

Variables	Forest Types				
	Evergreen	Semi-evergreen	Broad-leaved	Sal	Pine
Trees :					
Density ha^{-1}	1023.00	838.00	1432.00	876.00	1050.00
Basal cover (m^2 ha^{-1})	33.30	49.50	34.20	40.90	37.40
Species richness	82.00	102.00	95.00	22.00	26.00
Shannon diversity index	4.20	4.21	4.17	2.31	2.19
Margalef species richness index	11.70	14.98	14.28	8.23	3.59
Simpson dominance index	0.02	0.02	0.02	0.05	0.06
Shrubs :					
Density ha^{-1}	1747.00	2145.00	1954.00	1365.00	1953.00
Species richness	20.00	27.00	31.00	5.00	21.00
Shannon diversity index	2.77	3.14	3.61	2.03	2.39
Margalef species richness index	4.12	4.11	4.96	3.98	4.21
Simpson dominance index	0.07	0.05	0.03	0.08	0.12
Herbs :					
Density per 100 m^2	1554.00	3013.00	2843.00	876.00	1354.00
Species richness	44.00	70.00	68.00	11.00	57.00
Shannon diversity index	3.40	3.97	3.82	2.98	3.53
Margalef species richness index	5.84	8.56	7.84	6.52	7.77
Simpson dominance index	0.04	0.02	0.03	0.06	0.04

The concentration of all these constituents was higher in the upper soil layer than the lower layer.

The sub-tropical evergreen forest, sub-tropical semi-evergreen forest, sal forest, sub-tropical broad-leaved forest and sub-tropical pine forests covered 11.4%, 21.4%, 0.7%, 0.6% and 7.6% of the total geographical area, respectively of the State of Meghalaya. The physiognomy, species composition and fragmentation pattern of each type is described below.

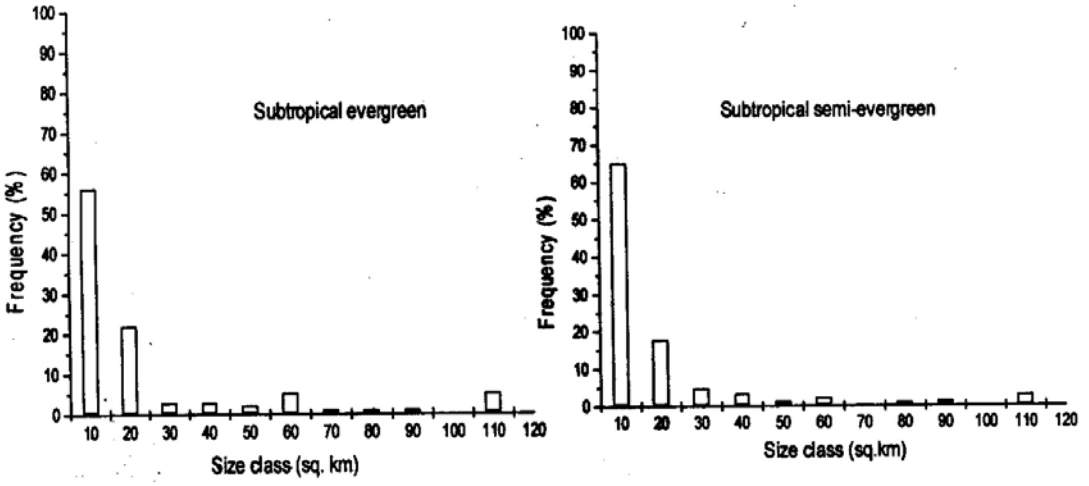
Sub-tropical evergreen forest : The sub-tropical evergreen forest has dense canopy cover (*ca.*80%) with tall trees (>20 m height). It supports luxuriant growth of species-rich tropical flora. At places the forest is moderately disturbed by shifting cultivation and tree felling. This forest covered an area of about 2,547 km^2 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 . It generally occurs above 1,200 m asl where average annual rainfall ranges between 300 and 500 cm and temperature shows a noticeable difference between summer and winter season. The ground frost is common in December-January. The forest patches of varying size ranging from 1 km^2 to 110 km^2 are found mainly at inaccessible sites, thereby restricting their degradation. Large continuous patches are rare. About 56% of 99 patches measured were in the range of <10 km^2-size class (Fig. 2).

The canopy is composed of *Mesua ferrea* Linn., *Castonopsis indica* A. Dc., *Elaeocarpus* spp., *Bischofia javanica* Bl., *Terminalia bellirica* (Gaertn.) Roxb, *Dysoxylum gobara* (Buch.-Ham.) Merr., *Acrocarpus fraxinifolius* Arn. ex Wt., *Dillenia pentagyna* Roxb., *Lannea coromandelica* (Houtt.) Merr., *Lithocarpus fenestratus* (Roxb.) Rehder., *Vitex peduncularis* Wall. ex Sch., etc. The subcanopy is constituted of *Garcinia paniculata* (G.Don.) Roxb., *Syzygium oblatum* (Roxb.) Wall ex Cowan & Cowan, *Ficus* spp., *Heritiera macrophylla* Kurz., *Mangifera sylvatica* Roxb., *Antidesma acuminatum* Wall. ex Wt., *Aporusa dioica* (Roxb.) Muell.-Arg., *Garcinia* species. The lower most tree layer was made up of *Alchornea tiliaefolia* Muell.-Arg., *Antidesma bunius* (Linn.) Spreng., *Grewia disperma* Roth., *Premna barbata* Wall. ex Sch. etc. Besides trees, shrubs, herbs, lianas and epiphytes (orchids, ferns, bryophytes, etc.) were abundantly found in the forest.

Sub-tropical semi-evergreen forest : The altitudinal limits of distribution and climatic conditions prevailing in the sub-tropical semi-evergreen forest area are similar to those of evergreen forest. A transitional zone between tropical and sub-tropical forests is distinguishable at certain places between 1,000-1,400 m. The sub-

Fig. 2



Frequency distribution of patch-size class of sub-tropical evergreen and sub-tropical semi-evergreen forests.

tropical evergreen forest is richer in species content than the evergreen forest. Presence of few deciduous species, which shed their leaves during the dry months between February and April, give semi-evergreen appearance to the forest. The number of deciduous trees, however, varies from site to site. Prickly and thorny species are commonly found in the forest.

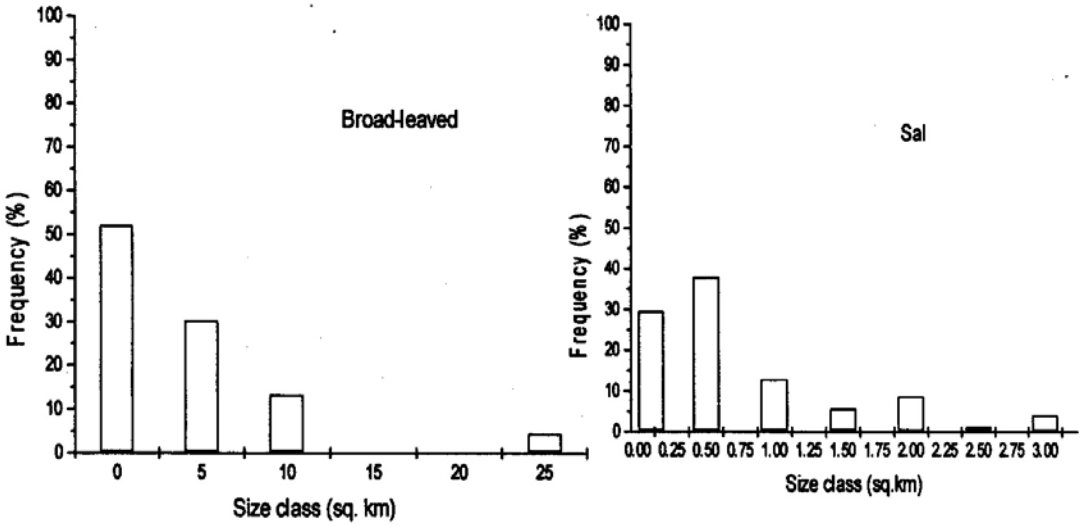
This forest type is found on North-eastern slopes of Jaintia Hills (some areas of Saipung and Narpuh reserve forest), in Khasi Hills (Mawsynram, Ryngud, Mosing), Ri-bhoi (Mawjyragong, Mopon, Mayang, Umsaw) and Garo Hills (Damlgiri, Rangira, Sembu Nokatgiri, Songsak, Rongrengiri) District of the state. It covers about 4788.7 km^2 area (Fig. 2). Compared to the evergreen forest, the trees were short (15-20 m height) but canopy was dense (>60% cover). Climbers and lianas were abundant in the forest. Due to timber extraction and shifting agriculture the forest has been highly fragmented into small patches not exceeding 10 km^2 area. Forest patches larger than 10 km^2 were rare.

The canopy was composed of *Elaeocarpus floribundus* Bl., *Daphniphyllum himalayense* (Benth.) Muell.-Arg., *Terminalia myriocarpa* Heurck & Muell.-Arg., *Mesua ferrea* Linn., *Caryota urens* Linn., *Croton* spp., *Shorea robusta* Gaertn., *Morus indica* Thunb., *Cordia fragrantissima* Kurz., *Glochidion khasicum* Hk.f., *Helicia nilagirica* Bedd., *Persea bombycina* King. ex Hk.f., *Camellia caudata* Wall., *Meliosma pinnata* (Roxb.) Walp., *Pandanus odoratissimus* (Lamk.) Linn., *Rhus semialata* Murr., *Dillenia pentagyna* Roxb., *Dillenia indica* Linn., *Hovenia acerba* Lindl. The sub canopy species included *Clerodendrum fragrans* Willd., *Eurya japonica* Thunb., *Litsea salicifolia* (Roxb. ex Nees) Hk.f., *Elatostemma* spp., *Eupatorium adenophorum* Spreng., *Lindera caudata* Benth., *Garcinia lancifolia* (G. Don.) Roxb., *Sapium* spp., *Rhus acuminata* DC., *Dalbergia assamica* Linn.

Broad-leaved hill forest : This forest type, believed to be the dominant formation of the Shillong plateau in the past, is at present confined to the slopes of Khasi Hills (upper Shillong, Mawphlang, Mawsynram, Shora) and Jaintia Hills (Saipung reserve forest and Jerain) above 1400m. The average annual rainfall at these places ranges from 2,300 to 11,000 mm. The forest though covers a small area of about 124.8 km^2 in the state, it is very rich in plant biodiversity (Fig. 3). Most trees are of medium height; only a few exceed 20 m. Epiphytes, mosses and ferns grow abundantly in this forest. Small patches of forest are found near villages in the form of sacred groves, preserved for a long time by the local tribal communities due to their strong religious beliefs. Some of the important trees found in these sacred forests are *Quercus* spp., *Manglietia insignis* (Wall.) Bl., *Cinnamomum* spp., *Schima wallichii* (DC.) Korth., *Schima khasiana* Dyer., *Alnus nepalensis* D. Don., *Exbucklandia populnea* (R.Br. ex Griff.) R.W. Br., *Eurya japonica* Thunb., *Acacia dealbata* Link., *Elaeocarpus lancifolius* Roxb., *Erythrina arborescens* Roxb., *Myrica esculenta* Buch.-Ham. ex D. Don.

Sal forest : Small patches (<1 km^2) of sal forest occur at low elevation in Garo Hills (Rongrengiri, Sangsuk, Darugiri and Baghmara area) where annual rainfall is less than 1,500 mm (Fig. 3). Largest patch was of 3.5 km^2 (Williamnagar). Along with *Shorea robusta (*Gaertn.), several other

Fig. 3



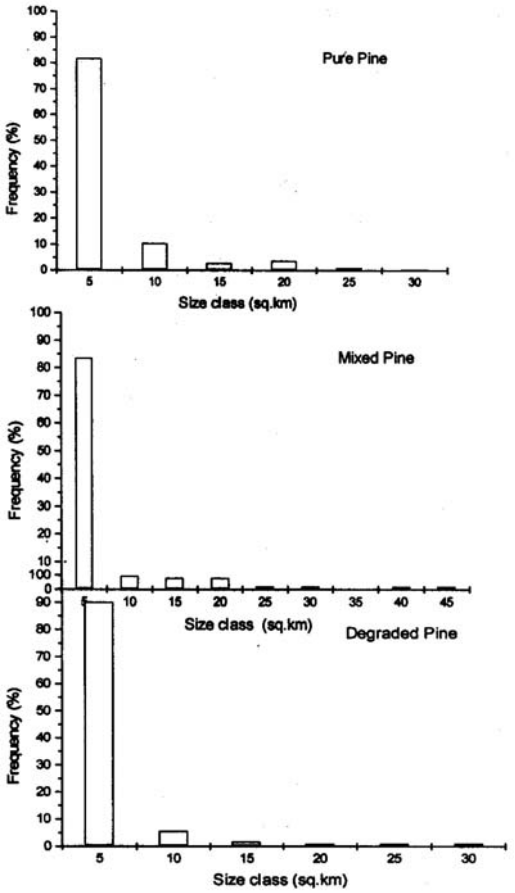
Frequency distribution of patch-size class of broad-leaved and sal forests.

tree species like *Tectona grandis* Linn. f., *Terminalia myriocarpa* Heurck & Muell.-Arg., *Sterculia villosa* Roxb. *Calliandra* spp., *Styrax serrulatum* Roxb., *Cordia grandis* Roxb., *Picrasma javanica* Bl., *Embelia floribunda* Wall., *Callicarpa arborea* Roxb., *Bauhinia variegata* Linn., *Aporusa roxburghii* Baill., *Dysoxylum binectariferum* Hk. f. et Bedd., *Lagerstroemia parviflora* Roxb., *Schima wallichii* (DC) Korth., *Dillenia scabrella* (D.Don) Roxb. ex Wall., *Grewia elastica* Royle were found in the forest. The under storey vegetation consisted of *Clerodendrum viscosum* Vent., *Eupatorium adenophorum* Spreng., *Psychotria monticola* Kurz., *Panicum* spp., *Melatostoma malabathricum* Linn., *Pongomia* spp., *Sabia purpurea* Hk. f. & Th., *Ardisia neriifolia* DC., *Digitaria* spp., *Desmodium* spp., *Glycania* spp. and *Vandelia* spp.

Pine forest : Pine forest occurs either as pure or mixed stand. They support seral communities where succession is arrested due to constant biotic stress and unfavorable soil condition/seasonal dry soil. They are under tremendous biotic pressure due to annual fire, fuelwood collection, timber extraction, grazing and shifting cultivation. As a result of these activities, the forest has been fragmented into small patches. More than 90% of the patches are less than 1 km^2 area. They are confined to Khasi and Jaintia Hills above 800 m. The area covered by this forest is *ca.* 1,694.3 km^2 (Fig. 4).

Biologically they are very poor in species composition. The average tree height ranges between 20 and 25 m, however, on degraded sites the height may be less. Few small-scattered trees of other species form the second story in the forest. Annual fire prevents establishment of shrubs and other woody elements. However, weeds and perennial grasses form dense undergrowth during monsoon. The forests are heavily grazed. At places *Schima wallichii* (DC.) Korth., *Prunus* spp., *Rhus javanica* Linn., *Quercus* spp.,

Fig. 4



Frequency distribution of patch-size class of pine forests.

Magnolia spp., *Lyonia ovalifolia* (Wall) Drude., *Rhododendron arboreum* Sm., *Ilex khasiana* Purk., *Rhus semialata* Murr., *Alnus nepalensis* D. Don., *Exbucklandia populnea* (R. W. Br. ex Griff.) R.W. Br. is also found in the forest. The shrub species found in the forest include *Rubus* spp., *Myrsine semiserrata* Wall., *Osbeckia crinita* Naud, *Desmodium* spp., *Eupatorium* spp., *Lantana camara* Linn., *Pteris* spp., *Artemisia* spp, *Bidens pilosa* Linn., *Viburnum foetidum* Wall., *Leptodermis* spp. etc.

Discussion

Distribution pattern and structure of forest communities are the function of climatic, geologic and edaphic factors as well as natural and anthropogenic disturbances (Whitmore 1978, 1984; Basnet 1992, 1993). The differential growth and survival rates of tree also determine distribution of forest in time and space (Goldberg, 1985; Basnet, 1990). A broad scale distribution pattern of forest types allows efficient extrapolation of information to arrive at an estimate of area coverage and biodiversity status of the state.

The tropical and sub-tropical broad-leaved forests found at lower and higher altitudes, respectively, represent the climax plant communities in the state. The evergreen forest is found where rainfall is relatively high and soil moisture condition remains favourable for most part of the year. The areas, where annual rainfall is relatively low and retention of water in soil is low due to coarse texture, or higher slope gradient or both, support semi-evergreen forest (Tripathi, 2002). Shifting agriculture, logging, mining and other human activities have been responsible for fragmentation, destruction and degradation of these climax communities giving rise to large number of secondary successional communities, which are found on the degraded sites. High rainfall and hilly terrain have further accentuated the human impact on the forest. Human intervention in both evergreen and semi-evergreen broad-leaved forests have paved the way for the development of pine forests, which represent edaphic and biotic climax community between 800 and 2,000m altitude in the state. Pine forest is a stable secondary community on disturbed

sites, which are seasonally dry and nutrient poor.

The soil profile in broad-leaved forest is well developed, acidic and rich in organic matter and nutrients. On the contrary, the soil in the pine forest is more acidic and poor in organic matter and nutrients. The species composition and stability of these communities depend on site condition and biotic stress. The tropical and sub-tropical evergreen and semi-evergreen forests are very rich in plant diversity and harbour large number of rare and endemic species. Contrary to these forests, pine forests are poor in the species richness. They have developed as a stable disclimax community, on the disturbed sub-tropical broad-leaved forest sites under the influence of annual fire and other biotic disturbances.

The State of Meghalaya, like other parts of North-East 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 fragmentation of large tracts of natural forests into small patches. None of the above forest types are found in the vast continuous stretches, rather all of them is highly fragmented; the size of the patch ranges from 1 km^2 to 110 km^2. All forest types in the state are highly disturbed as is clearly evident from the high frequency of small-size forest patches. However, pine forests are most disturbed and very highly fragmented. Fragmentation of the forest may alter species composition due to microclimate changes, and decrease in genetic heterozygosity, on the one hand, and by species invasion from surrounding vegetation, on the other (Tilman *et al.,* 1994; Chatelaine *et al.,* 1996). The change in land cover and land-use has profound consequence on the biodiversity and economic well being of the people.

A comparison of plant diversity status of the five major forest types has been presented in Table 1 on the basis of species richness and it clearly indicate that evergreen, semi-evergreen and broad-leaved forests in the state are very rich in tree as well as other plant species as compared to sal and pine forests. Fragmentation of these forests under human pressure has a serious implication on their diversity status. Already there are reports that tree felling during the past few decades, have degraded forests in the state (Tripathi *et al.,* 1996). As a result, a number of species have become rare, and endangered (Tiwari *et al.,* 1995) and few indigenous species e.g. *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).

The study indicates high degree of fragmentation of the forests, except sal forests that are under direct control of the State Forest Department. Although disturbance is common in all the natural forests, it was comparatively less in semi-evergreen forests due mainly to their location on the steep slopes. The pine forests are most disturbed.

Acknowledgement

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SUMMARY

The varied physiography, soil and climatic conditions are responsible for the development of sub-tropical evergreen, sub-tropical semi-evergreen, broad-leaved, sal and sub-tropical pine forests in the State of Meghalaya. The sub-tropical evergreen, semi-evergreen, and broad leaved forests are very rich in tree as well as other plant species as compared to sal and pine forests. Biotic factor, particularly human interference in the form of shifting agriculture, timber extraction and fuelwood collection, and to a lesser extent, cattle grazing have accelerated the fragmentation process of these forests, except at few places where continuous forest patch exceeds 50 km² area. Fragmentation of the forest may have serious consequences on species composition and community structure of trees in the forest communities of the state. This study shows that all of them are highly disturbed as is evident from high frequency of small-size patches. Pine forests are most disturbed. An obvious approach to conserve plant biodiversity would be to map distribution pattern and determine concentration of biodiversity and endemic species in the forest fragments.

मेघालय उत्तर–पूर्वी भारत के प्रमुख वन प्ररूपों में विखण्डन और पादप विविधता की स्थिति

ओ०पी० त्रिपाठी, एच०एन० पाण्डेय व आर०एस० त्रिपाठी

सारांष

मेघालय राज्य में उपोष्ण सदाहरित, उपोष्ण उपसदाहरित, पृथुपर्ण, शाल और उपोष्ण चीड़ वनों का विकास होन के लिए विविध भूवृत्तीय मृदा और जलवायु दशाएं ही उत्तरदायी हैं। उपोष्ण सदाहरित, उपसदाहरित, और पृथुपर्ण वन वृक्षों तथा अन्य पादप जातियों की दृष्टि से शाल और चीड़ वनों की तुलना में बहुत अधिक सम्पन्न हैं। जैव कारकों ने विशेषतः स्थानपरिवर्ती खेती, प्रकाष्ठ निष्कासन, और ईंधनकाष्ठ संग्रह के रूप में, और इनसे कुछ कम मात्रा में पशु–चराई ने कुछ जगहों को छोड़कर, जहां 50 वर्ग किमी से अधिक क्षेत्रफल वाले नैरन्तरिक वन खण्ड मिल जाते हैं, इन वनों के विखण्डित होते जाने की प्रक्रिया में तेजी ला दी है। वनों के विखण्डन का जातिगत रचना और राज्य के वन समुदायों में वृक्षों की समुदाय रचना पर गंभीर दुष्परिणाम पड़ सकता है। यह अध्ययन दिखाता है कि लगभग सभी वन अत्यधिक विक्षुब्ध स्थिति में हैं, जैसा कि उनमें जगह–जगह छोटे–छोटे टुकडों के पाए जाने से स्पष्ट हो जाता है। सबसे ज्यादा विक्षुब्ध चीड़ वन हैं। इनकी पादप विविधता को संरक्षित बनाए रखने का स्पष्ट तरीका यही है कि इन विखण्डित क्षेत्रों की पादप वितरण सज्जा का मानचित्रण किया जाए और इनकी और स्थानसीमित पादपजातियों की विविधता और संकेन्द्रणों को निश्चित किया जाए।

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