QUANTITATIVE ASSESSMENT OF FLORISTIC DIVERSITY AND SPECIES POPULATIONS IN HILL FORESTS OF MEGHALAYA

By

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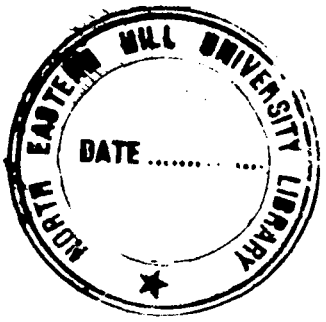

ABSTRACT

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ABSTRACT

Meghalaya, the state of northeastern region of India is very rich in floral and faunal diversity. The varied ecological conditions such as rainfall, temperature, altitude as well as soil conditions allow abundant growth of tropical and subtropical angiospermic flora in the State. The state of Meghalaya, like other parts of this region is undergoing rapid land use transformation due to deforestation (IIRS 2002, Lele and Joshi 2009, Sarma and Barik 2010, Tripathi *et al.* 2010), urbanization (Lele and Joshi 2009), *jhum* (Ramakrishnan 1992) and extraction of forest products. Due to these activities, natural forests are getting fragmented (Jha *et al.* 2005, Tripathi *et al.* 2010).

The phytosociological assessment in six forest types, viz., tropical evergreen (TEG), tropical moist mixed-deciduous (TMMD), Khasi hill sal-pine (KHSP), Khasi-Jaintia subtropical pine (KJSP), Khasi subtropical mixed-broadleaved (KSMB) and Khasi subtropical oak-dominated (KSOD) was carried out in Meghalaya. The study was aimed at a fine-scale quantitative assessment of the plant diversity, floristic composition, population structure and disturbance-based classification of forests of Meghalaya with following objectives:

- To determine species diversity, floristic composition and phytosociological structure in major forest types of Meghalaya,
- To quantify populations of economically and ecologically important plant species, and,
- To classify the forest types based on current levels of disturbance

The major forest types in Meghalaya were sampled following grid-based inventory by laying a transect of 5 to 10 m width and up to 500 m length (Murali *et al.* 1996, Uma

Shankar 2001). All individuals (stems) ≥10 cm girth at breast height (1.37 m above the ground level) were enumerated. The grids with prominent vegetation types were sampled depending on the similarity of terrain, accessibility, insurgency and other geographical and socio-political factors. The data from transects were analyzed following standard ecological methods (Misra 1968, Mueller-Dombois and Ellenberg 1974, Curtis and McIntosh 1950, 1951, Simpson 1949, Shannon and Wiener 1963, Whitford 1948, Rao *et al.* 1990, Sukumar *et al.* 1992, Uma Shankar 2001). The state of regeneration of sampled tree species was assessed based on the data on the individuals ≥10 cm to <30 cm gbh. To describe the population structure, the girth class and height class distributions of forest as well as dominant species of each forest type were plotted in 20 cm wide nine girth classes (10-<30, 30-<50, 50-<70, 70-<90, 90-<110, 110-<130, 130-<150, 150-<170, ≥170) and 5 m wide five height classes (<5, 5-<10, 10-<15, 15-<20, ≥20).

The orthorectified remote sensed imageries of IRS LISS III (Indian Remote Sensing Linear Imaging Self Scanning III) of the year of 2009 were downloaded from NRSC-Bhuvan (National Remote Sensing Center-Bhuvan, Hyderabad) (http://bhuvan-noeda.nrsc.gov.in/download/download/download.php) website. The images were downloaded as separate bands, and then stacked in ERDAS Imagine 8.5 to give the multispectral image. Meghalaya is richly endowed with the forest resources. Based on interpretation of satellite data, the total forest cover in the State is 17,275 km^2, which is 77.02% of the State's geographical area (FSI 2011).

The floristic survey of six major forest types of the State revealed that a total of 35,168 individual stems ≥10 cm gbh were recorded in 44.38 ha sampled area through 101 transects. The phytosociological analysis of woody layer as well as herb layer of six forest types yielded 931 species from 563 genera and 153 identified families.

The maximum number of woody species (233 species) were recorded from Khasi subtropical mixed-broadleaved forest followed by Khasi subtropical oak-dominated (225 species), tropical evergreen (184 species), Khasi-Jaintia subtropical pine (156 species), Khasi hill sal-pine (123 species) and tropical moist mixed-deciduous forest (95 species), respectively. Lauraceae (34 species), Rubiaceae (34 species), Fabaceae (27 species), Moraceae (27 species), Phyllanthaceae (21 species) and Euphorbiaceae (16 species) in woody layer were the most dominant families recorded in six forest types.

In herb layer, Khasi-Jaintia subtropical pine forest was characterized by maximum number of species (239 species), whereas least number of species were found in tropical moist mixed-deciduous forest (38 species). Asteraceae (38 species), Poaceae (31 species), Lamiaceae (25 species), Fabaceae & Rubiaceae (22 species each) and Acanthaceae (15 species) in herb layer were the most dominant families recorded in six forest types.

In all six forest types, the most dominant species were characterized by a high value of IVI. Approximately 58% species in tropical evergreen, 41% in tropical moist mixed-deciduous, 67% in Khasi hill sal-pine, 82% in Khasi-Jaintia subtropical pine, 70% in Khasi subtropical mixed-broadleaved and 73% in Khasi subtropical oak-dominated forest were rare as they exhibited an Importance Value of 1 or less. This is a general trend in most tropical forest in India where most species richness is due to the rare species.

The dominance-diversity curve for woody layer as well as herb layer of all forest types showed log-normal distribution, except woody layer of Khasi-Jaintia subtropical pine forest, indicating more equitable sharing of resources within the community. The dominance-diversity curve for Khasi-Jaintia subtropical pine forest showed broken stick model, depicting low equitability and high dominance.

The similarity, based on presence-absence data of six forest types, indicated that Khasi subtropical mixed-broadleaved and Khasi subtropical oak dominated forest resulted more than 50% of similarity in species composition of woody layer, whereas Khasi-Jaintia subtropical pine and Khasi subtropical mixed-broadleaved forest resulted maximum similarity (39.62%) in herb layer. Khasi hill sal pine forest exhibited *Shorea robusta* - *Schima wallichii* - *Pinus kesiya*, dominated community as these species together cover approximately 42% of total IVI.

The occurrence of different species of oak, viz., *Quercus* spp., *Castanopsis* spp. and *Lithocarpus* spp. in Khasi subtropical oak-dominated forest and broad-leaved species such as *Schima wallichii*, *Syzygium tetragonum*, *Engelhardtia spicata*, *Helicia nilagirica* in Khasi subtropical mixed-broadleaved forest form the climax vegetation in the State.

The altitudinal variation in sampled transects was high (26 to 1820 m). The altitudinal gradient is the key factor forming various mountain habitats. *Callicarpa arborea*, *Engelhardtia spicata*, *Litsea monopetala*, *Macaranga denticulata*, *Schima wallichii* and *Syzygium tetragonum* were found in all six forest types, which shows that these species can occur from very low (26 m) to very high altitude (1820 m).

All species among six forest types exhibited clumped to highly clumped dispersion. Patchy distribution of species may be due to spatially heterogeneous environmental conditions such as topography (Hubbell and Foster 1983). No species among six forest types showed regular or random dispersion.

The tree density of the present study was ranging from 598.4 stem ha^{-1} in tropical moist mixed-deciduous forest to 973.5 stem ha^{-1} in tropical evergreen forest with a mean value of 818.8 stem ha^{-1}, whereas basal area ranged from 14.31 to 27.34 m^2 ha^{-1} with mean

value of 18.86 m^2 ha^{-1}. The tropical evergreen forest was characterised by the highest density (973.5 individuals/ha), basal area (27.34 m^2/ha) and Shannon's diversity (1.983). The population structure of six forest types in the present study followed reverse J-shaped distribution, i.e., with increasing girth classes, the number of individuals decrease. Tropical evergreen, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest showed highest number of individuals in <5 m height class whereas tropical moist mixed-deciduous as well as Khasi hill sal-pine forest showed highest number of individuals in 5-<10 m and Khasi-Jaintia subtropical pine forest showed a peak in 10-<15 m height.

Tropical evergreen, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest represents a highly heterogeneous and diversified community coupled with low Simpson's dominance index and high evenness index and also shared mixed dominance of a number of species in top canopy, subcanopy and understorey.

Schima wallichii, *Cinnamomum tamala*, *Myrica nagi*, *Syzygium tetragonum*, *Shorea robusta* and *Lithocarpus fenestratus* showed higher level of regeneration as maximum number of individuals of these species were present in regenerating class (10-<30 cm). *Pinus kesiya* was one of the most dominant trees recorded in Khasi hill sal-pine, Khasi-Jaintia subtropical pine, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest. The size class distribution of *Pinus kesiya*, in these forest represented almost bell shaped curve with maximum number of individuals in medium class (70-<90 cm) and successive decline after and before this class. The height class distribution of dominant species showed different patterns in each forest types of the State.

Based on Remote sensed satellite data using Geographic Information System, six forest types of Meghalaya covered approximately 65% of total geographical area of the State.

Tropical moist mixed-deciduous including Khasi hill sal-pine forest covered maximum geographical area of the State. In terms of vegetation class, *Jhum* alongwith agriculture covered approximately 26.5% of total geographical area of the region.

The disturbance class map of Meghalaya revealed that approximately 60% of total geographical area of the State showed medium to very high disturbance. The East Khasi Hills as well as Jaintia Hills districts of the State were characterized by highly threatened areas due to large pressure of urbanization, *jhum* and coal and limestone mining. Khasi-Jaintia subtropical pine forest showed highest disturbance index (3.42) followed by tropical moist-mixed deciduous forest including Khasi hill sal pine forest (2.45).

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Dedicated to

My

Father

DEPARTMENT OF BOTANY
NORTH-EASTERN HILL UNIVERSITY
SHILLONG 793022

DECLARATION

I, Mr. Amit Kumar Tripathi, do hereby declare that the thesis entitled **'Quantitative assessment of floristic diversity and species populations in hill forests of Meghalaya'** embodies a record of original and independent research work carried out by me in the Department of Botany, North-Eastern Hill University, Shillong under the supervision of Prof. Uma Shankar. The work is original and no part of the thesis forms the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree or diploma in any University / Institute.

The thesis is being submitted to the North-Eastern Hill University for the award of the degree of Doctor of Philosophy in Botany.

North-Eastern Hill University
October 15, 2013

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CERTIFICATE

This is to certify that the thesis entitled **'Quantitative assessment of floristic diversity and species populations in hill forests of Meghalaya"** submitted by **Mr. Amit Kumar Tripathi** of the Department of Botany for the award of the degree of Doctor of Philosophy in Botany to the North-Eastern Hill University, Shillong, embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. degree. This work has not been submitted for any degree of any other University.

15/10/2013

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Dated: October 15, 2013 (Amit Kumar Tripathi)

CONTENTS

LIST OF ABBREVIATIONS

AOI	:	Area of Interest
CBD	:	Convention on Biodiversity
CBH	:	Circumference at Breast Height
CITES	:	Convention on International Trade of Endangered Species of Wild Flora and Fauna
DBH	:	Diameter at Breast Height
FAO	:	Food and Agriculture Organization
FSI	:	Forest Survey of India
GBH	:	Girth at Breast Height
GIS	:	Geographical Information System
GPS	:	Geographical Positioning System
IIRS	:	Indian Institute of Remote Sensing
IUCN	:	International Union for Conservation of Nature and Natural Resources
IVI	:	Importance Value Index
KHSP	:	Khasi Hill Sal-Pine Forest
KJSP	:	Khasi-Jaintia Subtropical Pine Forest
KSMB	:	Khasi Subtropical Mixed-Broadleaved Forest
KSOD	:	Khasi Subtropical Oak-Dominated Forest
LISS III	:	Linear Imaging Self-Scanning III
NTFP	:	Non-Timber Forest Product
PA	:	Protected Area
SOI	:	Survey of India
TEG	:	Tropical Evergreen Forest
TMMD	:	Tropical Moist Mixed-Deciduous Forest

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CHAPTER I

GENERAL INTRODUCTION

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GENERAL INTRODUCTION

The world's forests cover an area of approximately 4 billion ha, which corresponds to about 31% of the total land area. The Russian Federation, Brazil, Canada, the United States of America and the China are the five most forest-rich countries, accounting for more than half of the total forest area (FAO 2011).

There are some areas in the world that are very rich in overall diversity and endemism than others. Areas having an exceptional concentration of endemic species and loss of habitat have been termed as biodiversity hotspots (Myers 1988, 1990). Over the years the number of hotspots has increased from 10 (Myers 1988) to 18 (Myers 1990) to 25 (Myers *et al.* 2000) and finally to 34 (Conservation International 2005).

India supports a vast variety of forest types and is recognized to have four global terrestrial biodiversity hotspots, namely, Indo-Burma, Western Ghats-Sri Lanka, Sundaland and Himalaya. The Indo-Burma hotspot is richest in biodiversity covers most of the northeastern India except Arunachal Pradesh and some parts of Assam (Conservation International 2005). India is credited to be one among the world's top twelve mega diversity nations. It harbors about 47,000 species of flowering and non-flowering plants representing about 12% of the recorded world's flora. It is estimated that about 17,500 species of flowering plants are present in the India (Mao *et al.* 2009).

Forests have been classified primarily on the basis of physiognomy, floristic composition, community structure and dynamics, physical environment and history (Tripathi 2002). Champion (1936) has given preliminary survey of forest types of India and Chatterjee (1939) classified Indian forests into 8 botanical subdivisions. On the basis of floristic

composition and physiognomy, Champion and Seth (1968) divided Indian forests into 16 groups and several sub-groups. Due to their high species diversity and high level of endemism, the Western Ghats, Andaman and Nicobar Islands, the Himalaya and the northeastern region of India are areas of special significance for biodiversity conservation (Champion and Seth 1968).

The northeastern region of India is unique transitional zone between the Indian, Indo-Malayan and Indo-Chinese biogeographical zones as well as the confluence of the Himalayan region with peninsular India (Rao 1994). It is part of both Himalayas as well as Indo-Burma biodiversity hotspots in the world. It comprises of 8 States, namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura and represents 7.98% of the total geographical area of the country. The total forest cover in the region is 1,73,219 km^2 which accounts for 25% of country's forest cover (FSI 2011). The forests of northeast India are very rich in diversity of flowering plants. Due to presence of wide variety of ecological habitats, floristic richness and high level of endemism, the region is often referred to as a bowl of biodiversity. Out of 17,500 flowering plants found in India, approximately 50% are known to occur in northeast India and 40% of them are endemic (Mao *et al.* 2009).

The region is also important from an evolutionary point of view with a high concentration of many primitive plant families such as Annonaceae, Hamamelidaceae, Piperaceae, Menispermaceae and Myricaceae (Takhtajan 1969). The varied forest types found in the region are grasslands, meadows, marshes, swamps, scrub forests, mixed deciduous forests, humid evergreen forests, temperate and alpine forests which give shelter to the numerous plants and animals (Mao *et al.* 2009). The northeastern region of India harbor not only rich floristic diversity in difficult terrain but is also rich in ethnic diversity where

the local people have tremendous traditional knowledge to use the natural resources (Deb *et al.* 2008). More than 200 tribes of different ethnic groups and distinct cultural entities live in the region with main occupation of agriculture. The region exhibits rich diversity of orchids, zingibers, yams, rhododendrons, bamboos, canes and wild relatives of cultivated plants (Mao *et al.* 2009).

Floristic inventory is a prerequisite for fundamental research in community ecology such as modeling pattern of species diversity or understanding species distribution patterns (Giriraj *et al.* 2008). After the publication of Flora of British India by Hooker (1872-97), which contains about 14,384 species of plants, there has been increased awareness and activities in the botanical sphere of India. The publication of Flora of Assam by Kanjilal *et al.* (1934-40), was a landmark in the floristic of northeast India. Later on, Myrthong (1980), Balakrishnan (1981, 1983) and Haridasan and Rao (1985, 1987) carried out floristic explorations in different vegetation types of Meghalaya.

Meghalaya ($24^0$02'N to $26^0$07'N latitudes and $89^0$48'E to $92^0$51'E longitude), a hilly state of northeastern region of India, covers a total geographical area of 22,429 km^2, which constitutes 0.7% of India's total geographical area. The State of Meghalaya is bordered on the north by Assam and on the south and west by Bangladesh. It is junction of paleo-arctic, Indo-Malayan and Indo-Chinese bio-geographic realms. The total population of the State as per 2011 census is 29,64,007 with an average density of 132 persons per km^2.

Meghalaya is one of the biodiversity rich States of India. The hill forests of the State are notable for their biodiversity of plants. The rich vegetation of Meghalaya is generally ranging from tropical to subtropical forests. Appropriate varied ecological conditions such as wide variation in rainfall, temperature, altitude as well as soil conditions; allow abundant growth of tropical and subtropical angiospermic flora in the State. The

subtropical forests of Meghalaya receive abundant rainfall and support a vast variety of floristic diversity. Most of the area is hilly and records world's highest rainfall at Mawsynram. Meghalaya is richly endowed with the forest resources. The extent of total forest area in the State is 9496 km^2, which is 42.34% of the State's geographical area in which reserved forests constitute 11.72%, protected forests 0.13% and unclassed forests 88.15% (FSI 2011). The protected area network in the state of Meghalaya is meager and is represented by two national parks and three wildlife sanctuaries covering an area of 301.68 km^2 which is just 1.4% of the area of the State.

The Nokrek biosphere reserve in the West Garo Hills and the Balphakram National Park in the South Garo Hills district are considered to be the most biodiversity rich sites in the Meghalaya. About 683 species of flowering plants and 87 species of non-flowering plants have been reported from Balphakram national park by Kumar (1984). Out of three wildlife Sanctuaries, the Baghmara, is famous for insect eating pitcher plant *Nepenthes khasiana*, which is highly endangered and found only in few pockets of Meghalaya.

Forests of Meghalaya are largely composed of native species but a number of exotic species are also found in the State like *Eupatorium adenophorum, E. riparium, E. odoratum, Lantana camara, Mikania micrantha,* which have invaded the secondary forests. Based on site condition and floristic composition, a number of authors like Kanjilal *et al.* (1934), Champion and Seth (1968), Balakrishnan (1981) and Haridasan and Rao (1985) have classified the forests of Meghalaya. They have divided forests of Meghalaya into tropical evergreen, tropical semievergreen, subtropical broadleaved hill forest, tropical moist deciduous, grasslands and savannas, temperate and subtropical pine forest types.

The moist tropical and humid subtropical forests in the State are rich in plant diversity. According to the Forest Survey of India Report 2011 (FSI 2011), tropical moist deciduous forests cover a large geographical area in the State (61.62%) followed by subtropical broadleaved hill forests (17.71%), tropical wet evergreen forests (10.45%), subtropical pine forests (8.29%) and tropical semievergreen forests (1.93%). The area is highly significant from floristic point of view with a high level of endemism. It has been estimated that the State of Meghalaya contains about 3,331 species of vascular plants, out of which 1,236 (37.11%) plants are endemic (Khan *et al.* 1997).

The vanishing pristine forests of Meghalaya are now confined in the form of biosphere reserves, wildlife sanctuaries, national parks and sacred groves. One of the most remarkable features of Meghalaya is presence of large number of 'Sacred Groves'. The sacred groves are rich in plant diversity and harbor an enormous number of valuable and endangered plant species (Haridasan and Rao 1985). Tiwari *et al.* (1998) have reported the existence of 79 sacred groves in the State of Meghalaya. Many endangered species are confined to sacred groves. These isolated pockets are untouched due to the religious beliefs and myths attributed to them (Bor 1940). Fagaceae members dominate in these sacred forests (Haridasan and Rao 1985). Epiphytic flora is quite abundant and again dominated by ferns and orchids (Bor 1942, Raju 1964, Hajra 1975a, 1975b). These groves represent relic forests of Meghalaya ranging from tropical moist deciduous to subtropical wet hill broadleaved forest (Champion and Seth 1968). Kanjilal (1922) considered these forests as remainder of nature's primeval forest.

Meghalaya experiences a very high level of anthropogenic disturbance due to shifting cultivation. The intentsity of disturbance varies from one district to another. The frequency and intensity of disturbance is a key determinant of plant diversity in a

community (Tripathi and Reynald 2010). The forests of Meghalaya is home to many species of timber, medicinal plants, endemic plants and economically and ecologically important plants, which are being depleted as for fire wood, NTFP collection, horticulture development, mining (coal, limestone and other minerals), timber, *jhum* cultivation and many other purposes (IIRS 2002).

Most estimates of species loss have focused on tropical forests, as they harbor the majority of the species and are undergoing fragmentation leading to loss of habitat and subsequently erosion of biodiversity. The increasing population pressure, continuance of *jhum* cultivation and other human activities have adversely affected the forest vegetation of Meghalaya (Tripathi *et al.* 1996), which has resulted in the loss of many economically important plants from the region. There is a loss of 49 km^2 forest cover in the State during 2009 to 2011 primarily due to shifting cultivation (FSI 2011). The Indigenous shifting cultivation (locally called *jhum* cultivation) has long been practiced in all parts of Meghalaya, causing structural as well as compositional change in the forest types of the region and ultimately modifies the natural landscape, which results poor species composition (Roy and Tomar 2001).

For conserving plant biodiversity a clear approach is to map distributional patterns and look for concentrations of diversity and endemism (Gentry 1992). Satellite remote sensing data has been used extensively for the mapping of the forest types. Remote sensing and GIS is an effective tool, as it provides data for studying of biodiversity at different levels (Roy and Tomar 2000) and also very useful in providing information about extensive deforestation in several parts of the tropics (Skole and Tucker 1993).

Anthropogenic disturbances in different forest types of Meghalaya operating at different scale causing destruction to the plant habitat to a great extent and ultimately result in

biodiversity loss. Habitat destruction and over-exploitation by the local inhabitants has led to the decline in the population of many ecologically and economically important plants and ultimately, several species have been placed to the threatened categories of rare and endangered plants. The species like, *Diospyros undulata*, *Nymphaea pygmaea*, *Sageretia hamosa* are considered extinct and *Luvunga scandens* is thought to be locally extinct (Khan *et al.* 1997). Hence, it is also important to evaluate the levels and types of threats on the species populations to arrive at sustainable levels of harvesting and to develop/improve working plans for management and conservation of the forest resources.

Floristically, Meghalaya is one of the most important landscapes in northeastern region of India. Although plenty of taxonomic and ecological information is generated for vegetation of Meghalaya, only a few studies have been done to quantify the populations of species across landscapes of Meghalaya. It is thus imperative to have an assessment of current status of the plant resources, their geographic distribution and population structure. Hence, the objectives of the present study are:

- to determine species diversity, floristic composition and phytosociological structure of major forest types of Meghalaya,
- to quantify populations of economically and ecologically important plant species,
- to classify the forest types based on current levels of disturbance.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

2.1. Floristic composition, species diversity and population structure

Biodiversity is essential for human survival, economic well being and for the ecosystem function and stability. It is not evenly distributed on the earth. It increases from the poles to equator, and from high elevation to low elevation and greater on continents than on islands (Singh 2002). It is critically important for each and every nation's existence (Mittermeier *et al.* 1998).

Biodiversity has attracted the world attention because of the growing awareness of its importance on one hand and extensive decline on other hand. In the current situation, about 20% of all species are estimated to be lost within 30 years. The current rate of tropical deforestation is 0.8% per year. It has been assumed that 2 to 5 species per hour are lost from tropical forests alone (Singh 2002).

Tropical forests represent the most biologically diverse terrestrial ecosystem and harbor more than 50% of known plant species (Mayaux *et al.* 2005) in just 7% of the land area and vary in species richness from site to site and within plant communities (Okuda *et al.* 1997). Due to high species richness and concentration of endemic species, tropical forests are considered as an important terrestrial ecosystem on the earth (Mittermeier *et al.* 1998). These forests are disappearing at alarming rates worldwide (Laurance 1999). In 1990, the estimated 1150 million ha of tropical rain forests with the area of humid tropics, deforested 5.8 million ha annually and additional 2.3 million ha of humid forest is apparently degraded annually through fragmentation, logging and fire (Mayaux *et al.* 2005). Biodiversity is also being depleted because of legal and illegal trade in

economically and medicinally important plant species as levels of exploitation of these species are high (Singh and Kushwaha 2008).

It is very important that rich biological diversity of tropical rain forests be studied exhaustively to explore the complex interactions between biodiversity and ecosystem functioning (Giriraj *et al.* 2008). In spite of the recent interest in tropical rainforests, the biological diversity of different areas of dry forests is also facing threat. Tropical moist forests are the most used and threatened ecosystems, especially in India (Uma Shankar 2001).

In recent years, quantitative floristic inventories have been applied to illustrate forest vegetation all over the world (Kochummen *et al.* 1990, Valencia *et al.* 1994, Johnston and Gillman 1995, Cao and Zhang 1997, Ayyappan and Parthasarathy 1999, Upadhaya *et al.* 2003, Kalacska *et al.* 2004, Sagar *et al.* 2008, Addo-Fordjour *et al.* 2009, Pappoe *et al.* 2010). Tree diversity is basic aspect of biodiversity, as it provides habitat and resources for all other species in the forests (Cannon *et al.* 1998) and taxonomically better known among other species (Gentry 1992). Besides being dominant life forms, trees are easy to locate precisely and count (Condit *et al.* 1996). Tropical forests inhabit the maximum tree diversity in the world (Clark *et al.* 1999). It is estimated that approximately 100,000 tree species are found in the world, of which 80% are contributed to tropics only and 10% of all tree species are now threatened (Singh 2002). In general, for tree inventories, the girth at breast height (GBH) or diameter at breast height (DBH) frequently measured at 1.3 m above the ground level. The often used limits for tree size are 10 cm dbh or 30 cm gbh (Gentry 1988, Lieberaman *et al.* 1996, Ayyappan and Parthasarathy 1999, Parthasarathy 1999, Huang *et al.* 2003, Boubli *et al.* 2004). Girth class distribution is very commonly used in ecology to illustrate population structure as well as community structure of the

forests. A number of sampling methods have been engaged in tree diversity assessment over the years, in which plot methods are very common.

The plots of different sizes and shapes are in trend, for example, square plot (Upadhaya *et al.* 2003, Lu *et al.* 2010, Tripathi and Tripathi 2010) to rectangular plot (Banda *et al.* 2006, Espinosa and Cabrera 2011) to long belt transect (Boom 1986, Swamy *et al.* 2000, Uma Shankar 2001, Boubli *et al.* 2004). It is well-known that size and shape of the plots have great influence on plant diversity assessment (Condit *et al.* 1996, Laurance *et al.* 1998, Keeley and Fotheringham 2005).

A number of studies have been undertaken on large-scale permanent plots in different parts of the world such as Barro Colorado Island, Panama (Hubbell and Foster 1983, Condit *et al.* 1996), Pasoh Forest Reserve, Malaysia (Manokaran and Lafrankie 1990, Manokaran *et al.* 1990, Kochummen *et al.* 1990) and Mudumalai Game Reserve, south India (Sukumar *et al.* 1992). Permanent plots found to be very useful for inventorying plant species and for monitoring forest dynamics over time. Large plots are more efficient at sampling rare species, whereas small plots are useful in sampling variation in species distribution over larger scales (Condit 1995).

Forest vegetation can be described in terms of a number of quantitative parameters such as frequency, density, abundance and cover. Forest structure is a broad concept that relates to species distribution patterns, species quantities and species diversity (Pappoe *et al.* 2010) while plant communities are defined as an assemblage of functionally similar species populations that occur together in time and space (Magurran 1988).

A number of indices of diversity have been proposed by ecologists, which are widely used for the study of plant communities such as Sorenson (1948), Simpson (1949), Shannon and Weiner (1963), Pielou (1966) and Whittaker (1972). The most widely and

accepted tool for measuring diversity is Shannon and Weiner's (1963) index, commonly known as Shannon's index of diversity. Sorenson (1948) derived formulae to assess the similarity between habitats or community based on species composition. The Simpson's index (1949) considered as a measure of species dominance, as biodiversity increases, the Simpson's index decreases (Magurran 1988). Due to the lack of species dominance, tropical forests harbor high species diversity (Pappoe *et al.* 2010). Evenness index (Pielou 1966) used to classify the patterns of distribution of species. The Family Importance Value Index (FIVI) is used to calculate the dominance and importance of the families.

Whittaker (1972) proposed three terms for measuring biodiversity over spatial scales: alpha, beta and gamma diversity. The species richness of a forest ecosystem depends on the number of species per unit area. In case of more species per unit area, the species richness will be high. The low IVIs suggest that most of the species in the forest are rare (Pascal and Pellissier 1996). Stand structure and topography could be used as predictors for floristic composition (Giriraj *et al.* 2008). The abundance of small trees coupled with the enormous total of saplings and seedlings reflects a high regeneration potential of the forest (Pappoe *et al.* 2010) while girth class distribution analysis gives the scenario of the forest stand structure.

A large number of studies have been carried out in all over the world on various aspects of biodiversity. Connell (1978), Philips and Gentry (1994) and He *et al.* (1997) investigated different tropical rain forests of the world and reveal the existence of high species diversity within these forests. Bongers *et al.* (1988) recorded 292 tree species from one hectare plot in Mexico. Kochummen *et al.* (1990) conducted study in lowland rain forests of Malaysia. Valencia *et al.* (1994) recorded 307 tree species (DBH $\geq$10 cm) in one hectare plot of Terra firme forest in Amazonian Ecuador. Medail and Quezel

(1997, 1999) performed a global survey of plant richness and endemism in the Mediterranean Basin. Tree species diversity of tropical forests vegetation in Xishuangbanna (South West China) was studied by Cao and Zhang (1997). Cannon *et al.* (1998) studied tree species diversity in commercially logged rainforest of Borneo. Lawesson *et al.* (1998) investigated the floristic richness of different size, age and disturbances in Danish beech forest. Pitman *et al.* (1999, 2001 and 2002) investigated tree species diversity in upper Amazonian forests. Zimmerman *et al.* (1999) quantified plant species distribution, abundance and diversity in north-central Arizona, USA. Debski *et al.* (2000) and Smith *et al.* (2005) conducted studies in subtropical rain forests of Australia. Andel (2001) conducted floristic composition in mixed primary and secondary forests of Guyana.

Recently, Myers *et al.* (2000) and Pitman and Jorgensen (2002) have thoroughly discussed about global plant diversity and endemism. Huang *et al.* (2003) studied the effects of forest structure and species composition on species diversity in Tanzania. Kalacska *et al.* (2004) analyzed species composition, similarity and diversity in three successional stages of a seasonally dry tropical forest of Costa Rica. Kessler *et al.* (2005) conducted study in primary forest and different land use system of central Sulawesi, Indonesia. Zheng *et al.* (2006) studied forest structure and biomass of a tropical seasonal rainforest in Xishuangbanna, southwest China. Ozcelik (2009) investigated tree species diversity of natural mixed stands in eastern black sea and western Mediterranean region of Turkey. Rad *et al.* (2009) studied comparison of plant species diversity with different plant communities in deciduous forests, while Pappoe *et al.* (2010) studied composition and stand structure of a tropical moist semi-deciduous forest in Ghana. Culmsee and

Pitopong (2009) and Culmsee *et al.* (2011) analyzed tree diversity in tropical high mountain rain forests of Central Sulawesi, Indonesia.

India, with a total geographical area of 3,287,263 km^2 (FSI 2011), is a store house of rich biological diversity both floral and faunal. India has 47,000 species of flowering and non-flowering plants representing about 12% of the recorded world's flora. It is estimated that about 17,500 species of flowering plants are present in India in which 50% are found in northeastern region of India (Mao *et al.* 2009).

Myers (1988, 1990) identified species rich areas on the earth and termed them as 'Hotspots of biodiversity' as a biogeographic region characterized both by exceptional levels of plant endemism and by serious levels of habitat loss. To qualify as a biodiversity hotspot, a region must contain at least 1,500 (0.5%) of the world's estimated 300,000 plant species as endemics (Myers *et al.* 2000). Out of 34 global terrestrial hotspots, Indian subcontinent contains four namely; the Indo-Burma, the Western Ghats-Sri Lanka, Sundaland and the Himalaya. The northeastern region of India is part of both Himalayas as well as Indo-Burma biodiversity hotspots in the world. Broadly, most parts of Sikkim and Arunachal Pradesh fall in the Himalaya hotspot. The Indo-Burma hotspot includes Manipur, Meghalaya, Mizoram, Nagaland and Tripura and parts of Assam. The Indo-Burma hotspot harbors about 13,500 plant species, of which 7,000 (52%) are endemic to this region (Conservation International 2005). In terms of overall endemism, the tropical Andes comes first among the hotspots with 20,000 endemic plant species followed by Sundaland and Mediterranean basin, which have 15,000 and 13,000 endemic species, respectively (Myers *et al.* 2000).

Species diversity has been used by ecologists for characterizing and comparing communities and ecosystem, for example, species area curve has been used by early

ecologists to identify the minimum area of a plant community, its application for estimating the number of species for a given area (Singh 2002). Quantitative floristic sampling provides the basic context for setting up and interpreting long-term ecological research (Phillips *et al.* 2003) and these information plays a vital role in formulating a conservation plan and in understanding the ecology of the species (Uniyal *et al.* 2002).

The quantitative inventories in diverse forest types of India, were carried out by several workers in different parts of the country and these studies provide useful information about distribution and abundance of the species, such as Sukumar *et al.* (1992), Ganesh *et al.* (1996), Murali *et al.* (1996), Ganeshaiah *et al.* (1997), Joshi *et al.* (1997), Parthasarathy and Karthikeyan (1997), Parthasarathy and Sethi (1997), Uma Shankar *et al.* (1998), Kadavul and Parthasarathy (1999), Ayyappan and Parthasarathy (1999, 2001, 2004), Parthasarathy (1999, 2001), Swamy *et al.* (2000), Sagar *et al.* (2003, 2008), Ram *et al.* (2004), Sagar and Singh (2005, 2006), Davidar *et al.* (2007), Giriraj *et al.* (2008), Hussain *et al.* (2008), Uniyal *et al.* (2010) and Sahu *et al.* (2012). In addition to these studies Tripathi *et al.* (2004), Prasad *et al.* (2007), Rajkumar and Parthasarathy (2008) and Rasingam and Parathasarathy (2009a) have contributed to understanding the ecology of Andaman and Nicobar Islands, important biodiversity rich areas of our country.

The studies on Indian sal forests have been carried out by many workers such as; Gupta and Shukla (1991), Prasad and Pandey (1992), Pandey and Shukla (1999, 2003), Uma Shankar (2001), Chitale and Behera (2012) and Kushwaha and Nandy (2012).

Quantitative inventories on forest biodiversity have concentrated mainly on tree species (Cao and Zhang 1997, Parthasarathy 1999, Pitman *et al.* 1999, Upadhaya *et al.* 2003, Kumar *et al.* 2006, Ozcelik 2009) than any other life forms viz; lianas, understorey plants etc. There are few authors who have studied understorey plants (Poulsen 1996,

Annaselvam and Parthasarathy 1999, Upadhaya *et al.* 2006 and Rasingam and Parthasarathy 2009b) and included lianas in the inventories (Gentry 1988, Lieberman *et al.* 1996, Parthasarathy 1999).

Vegetation composition and structure of forests are strongly associated with ecological factors, such as climate and topography (Currie 1991). The structure and composition of tropical deciduous forests go through changes with the length of wet period, amount of rainfall, latitude, longitude and altitude (Uma Shankar 2001). The length of the dry season and precipitation are expected to determine patterns of tree species richness in tropical dry forest (Williams-Linera and Lorea 2009). However, several workers analyzed that there is no significant correlation between species richness and precipitation (Gillespie *et al.* 2000, Trejo and Dirzo 2002).

Many authors have noted the importance of topographic variation, elevation, slope, and aspect (Pausas and Austin 2001, Balvanera *et al.* 2002, Poulos *et al.* 2007, Mwaura and Kaburu 2009).

Altitude, latitude and longitude are the most important environmental factor affecting species distribution (Zhao *et al.* 2005). The altitudinal gradient is the key factor forming various mountain habitats (Xu *et al.* 2011). Changes in altitude, accompanied by changes in temperature, precipitation, and light conditions, modify the distribution of vegetation (Zhao *et al.* 2005).

Different patterns of species diversity are reported along altitudinal gradients. Lieberman *et al.* (1996), based on intensive sampling along an altitudinal gradient from 30 m to 2600 m in Costa Rica, reported highest species diversity at 300 m and progressive decrease in species richness both above and below this altitude. Several workers (Gentry 1988, Liberman *et al.* 1996, Vazquez and Givnish 1998, Aiba and Kitayama 1999, Tang and

Ohsawa 1999, Wang *et al.* 2002, Kharkwal *et al.* 2005, Grytnes and Vetaas 2002, Sharma *et al.* 2009) have noted increasing species diversity with decreasing altitude.

The unregulated and unscientific collection of large number of ecologically important plants from their natural habitats has pushed them to various categories of threatened species. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Convention on Biological Diversity (CBD) regulate the over-exploitation of many important rare and endangered species of plants.

The Botanical Survey of India published Indian Red Data Books on plants to highlight the rare, endangered, and threatened species (Nayar and Sastry 1987, 1988, 1990). Due to lack of ecological data, improper investigations and taxonomy, numerous plant species have not been placed appropriately in the red data books because classification of these species are based on herbarium collection rather than population assessment in the wild (Bhattacharyya and Sarma 2010).

The northeastern region of India is unique transitional zone between the Indian, Indo-Malayan and Indo-Chinese biogeographical zones as well as the confluence of the Himalayan region with peninsular India (Rao 1994). The total forest cover in the region is 173,219 km^2 which is 66.07% of its geographical area (FSI 2011). The northeastern region of India is significant for biodiversity conservation for its floristic richness and high level of endemism (Khan *et al.* 1997). Out of total 17500 species of flowering plants of India nearly 50% are found in the northeastern region of our country (Mao *et al.* 2009). The eastern Himalayas including northeast India and the Western Ghats are the biodiversity hotspots in India (Myers 1990, WCMC 1992). These are the richest plant biodiversity regions of the country. The eastern Himalayas and the northeast India harbor about 9,000 species of flowering plants (Rao 1988). Takhtajan (1969) considered

northeast India as the 'Cradle of ancient angiosperms' due to presence of large number of primitive and ancient flowering plants in the region. Primitive plant families such as Magnoliaceae, Lauraceae, Hamamelidaceae, Degeneriaceae, Tetracentraceae and Lardizabalaceae are well represented here (Mao *et al.* 2009). It is estimated that eastern Himalayas contains about 5000 endemic species (Mittermeier *et al.* 1998). The humid tropical forests in the eastern Himalayas and northeast India are very rich in flowering plants. Species richness of the forests of this region has been recognized by taxonomists like Hooker (1872-1897), Kanjilal *et al.* (1934-1940), Rao and Panigrahi (1961), Rao (1974), Balakrishnan (1981-1983), Deb (1981) and Hegde (1984), who carried out botanical explorations in different parts of northeastern India. Further studies on forest ecosystem of northeast India were carried out by Sundriyal *et al.* (1994), Hajra and Verma (1996), Sundriyal and Sharma (1996), Bhuyan *et al.* (2003), Arunachalam *et al.* (2004a), Khan *et al.* (2004), Nath *et al.* (2005), Devi and Yadava (2006), Deb and Sundriyal (2007, 2008), Lalfakawma *et al.* (2009) and Majumdar *et al.* (2012).

Meghalaya, a small state of northeastern region of India is very rich in floristic diversity. The richness and variety of vegetation ranging from subtropical to tropical is due to diverse topography and variations in rain fall, soil and temperature. Most of the forests of Meghalaya are owned by private individuals and local communities, who have traditional ownership and user rights over such forest areas (Tiwari and Kumar 2008).

The floristic richness of Meghalaya has attracted the attention of many eminent botanists from all over the world during the last two centuries. Buchanan and Hamilton (1820) were the first Europeans to study the flora of the region. They were followed by Roxburgh (1820-24, 1832), Wallich (1820), Griffith (1848), Hooker (1854), Hooker (1872-97), Burkill (1925a, 1925b) and Bor (1940).

U. N. Kanjilal and co-workers were the first Indian to study the flora of the region. Their work was published during 1934-1940 in the form of a Flora of (undivided) Assam (Kanjilal *et al.* 1934-40). This was a landmark publication in the field of floristic studies in India. After the publication of the flora of Assam several workers undertook detailed floristic surveys in different parts of the state. For example, Joseph (1968) studied the Flora of Nongpoh, Kataki (1973) described 350 species of Orchids from Meghalaya, Myrthong (1980) studied the monocot flora of Meghalaya. Balakrishnan (1981-1983) produced 2 volumes of Flora of Jowai district, Kumar (1984) conducted an intensive study in Balphakram National Park (one of the most important protected areas of Meghalaya). Haridasan and Rao (1985, 1987) brought out two volumes of Forest Flora of Meghalaya.

Apart from these taxonomic studies, enumeration of plants of various sacred groves in Meghalaya has been done by Raju (1964), Hajra (1975a, 1975b), Khan *et al.* (1986, 1987), Khiewtam (1986), Barik *et al.* (1992, 1996a, 1996b), Rao *et al.* (1990, 1997), Rao (1992), Khiewtam and Ramakrishnan (1993) and Tiwari *et al.* (1998), who studied various ecological aspects of these groves such as, gap phage regeneration, community composition and disturbance gradient, conservation, micro-environmental variability and species diversity. In addition to these studies, Jamir (2000), Jamir and Pandey (2003), Upadhaya (2002) and Upadhaya *et al.* (2003) performed plant diversity and community characteristics of a number of sacred groves in Jaintia Hills and reported the presence of high species diversity and low dominance in all the groves.

Khan *et al.* (1997) compiled the information on plant diversity of Meghalaya and reported the presence of 3,128 species of flowering plants, including 1,237 plant species

as endemic. Recently various studies have been carried out to quantify plant diversity and to understand the ecology of forest communities of the region.

Tripathi (2002) conducted a detailed floristic study on three major forest types in the state, i.e. subtropical evergreen, subtropical semi-evergreen and subtropical pine forests. Odyuo (2004) and Mishra *et al.* (2005) conducted ecological studies and population structure of some important tree species in subtropical humid forest of Meghalaya. Prabhu (2004) and Tripathi *et al.* (2008) conducted study in one of the protected area of Meghalaya, i.e., Nokrek Biosphere Reserve. Jamir *et al.* (2006) studied life form composition and stratification of montane humid forests in Meghalaya. Kumar *et al.* (2006) analysed the tree species diversity and distribution patterns in tropical forests of Garo Hills and reported the presence of 162 tree species in primary forests, 132 species in secondary forests, and 87 species in sal forests. Upadhaya *et al.* (2009) studied regeneration ecology and population status for a critically endangered and endemic tree species (*Ilex khasiana* Purk.) at five natural populations in Meghalaya. Tripathi *et al.* (2010) investigated diversity, dominance and population structure of tree species along fragment size gradient of a subtropical humid forest of Meghalaya. Tripathi and Tripathi (2010) analyzed plant diversity and population structure of subtropical vegetation of Meghalaya.

Work done by several other authors like Singh (1980), Khan (1986), Kataki (1986), Uma Shankar (1991), Barik (1992), Arunachalam (1996), Dam (1996), John (1998), Tomar (1999), Upadhaya *et al.* (2004), Lakadong and Barik (2006), Barik *et al.* (2007), Kharlyngdoh and Barik (2008) and Singh *et al.* (2012) also made useful contribution to understand the ecology of the State.

2.2. The ecologically and economically important plants

Apart from the floristic studies in India, several workers undertook detail study on various aspects of ecologically and economically important plants in different parts of the country, such as: population studies on *Podophyllum hexandrum* (Airi *et al.* 1997), assessment of availability and habitat preference of Jatamansi/*Nardostachys jatamansi* (Airi *et al.* 2000), rarity and distribution of *Aconitum fletcheranum* (Uma Shankar 2003), regeneration of Rudraksh or *Elaeocarpus ganitrus* (Khan *et al.* 2003), population and conservation of *Sapria himalayana* (Arunachalam *et al.* 2004b), ecological features of a critically rare medicinal plant *Swertia chirayita* (Bhatt *et al.* 2006), population status of *Gymnocladus assamicus* (Choudhary *et al.* 2007), regeneration ecology and population structure of *Cinnamomum tamala* (Ghosh 2007), regeneration ecology and population status of *Ilex khasiana* (Upadhaya *et al.* 2009), availability, ecological feature and habitat preference of the medicinal herb *Houttuynia cordata* (Bhattacharyya and Sarma 2010), conservation strategies for *Nepenthes khasiana* (Singh *et al.* 2011), effect of provenance variation on seed characteristics, germination and seedling growth of *Parkia roxburghii* (Nongrum 2012), Natural regeneration of *Taxus wallichiana* (Swer 2013). Recently, Kumar (2013) developed the distribution models of sixteen important tree species of lower Assam region of India.

2.3. Disturbance based classification of vegetation

Disturbance in tropical and subtropical forests of the world is documented the most severe ecological problem. Disturbances modify landscapes, ecosystems, communities, population structure and biodiversity, causing degradation of forests (Kaur *et al.* 2010). The lack of species dominance implies that disturbance can result in some plant species to dominate and push other species to become rare (Pappoe *et al.* 2010). Every year, more than 10 million ha of tropical forests in developing countries are cleared or converted to other land use (Tole 1998) and large parts of the remaining forests have been disturbed and fragmented due to human activities (Giambelluca *et al.* 2003, Van Laake and Sanchez-Azofeifa 2004). Deforestation as well as fragmentation seriously degrade the forest ecosystems, causing loss of biodiversity (Phillips 1997, Blasco *et al.* 2000).

Disturbances are responsible for change in floristic composition, species diversity and structure of the forests (Addo-Fordjour *et al.* 2009). The effect of disturbances on species diversity is an issue that has attracted the attention of a large number of ecologists worldwide (Tilman and Downing 1994, Burslem and Whitmore 1999, Ramirez-Marcial *et al.* 2001, Sagar *et al.* 2003, Mishra *et al.* 2004, Kumar and Ram 2005 and Uniyal *et al.* 2010).

Species richness may be high at intermediate disturbance frequency with due favor to competitive species (Collins *et al.* 1995). All species are not equally affected by disturbances. Therefore, species composition and diversity of plant communities must be carefully examined to accurately assess the effect of disturbances (Onaindia *et al.* 2004).

Gillespie *et al.* (2000) reported that in dry forests of Nicaragua and Costa Rica, there was a significant correlation between anthropogenic disturbance (intensity and frequency of fire, wood collection, grazing) and total species richness. Upadhaya *et al.* (2006) studied

understory plant diversity in subtropical humid forest of Meghalaya and observed that mild disturbance enhanced species richness of the understory community.

It is obvious that forest area, species diversity, and ecological structure are under threat from human disturbances. Many workers have studied the impact of human disturbances on forest structure and species diversity (Chittibabu and Parthasarathy 2000, Wang *et al.* 2001, Bhuyan *et al.* 2003, Sagar *et al.* 2003, Veach *et al.* 2003, Onaindia *et al.* 2004 and Top *et al.* 2009). In northeastern region of India, deforestation is mostly attributed to shifting cultivation and commercial logging of timber, which results landscape fragmentation and ultimately loss of biodiversity (Roy and Tomar 2000).

The last few years have witnessed an explosive growth in application of GIS (Geographical Information System) and remote sensing technologies to study the changes at the landscape level, and also allow us to address the problem of deforestation and biodiversity conservation (Menon and Bawa 1997). Remote sensing is being used as an effective tool for forest vegetation assessment (Behera *et al.* 2001). The satellite data along with the ground data can be used for multipurpose applications that contribute biodiversity conservation. This approach is based on extensive use of GIS methodology.

Satellite remote sensing has played a key role in generating information about forest cover, vegetation types and land use changes (Botkin *et al.* 1984, Jha *et al.* 2005). Analysis of remote sensing imagery together with adequate ground truthing provides an effective way of rapidly determining forest cover over relatively large areas, as well as to assess the health of forest ecosystem and extent of forest degradation (Menon and Bawa 1997). Multitemporal satellite data have been used to quantify tropical deforestation and habitat fragmentation (Skole and Tucker 1993). The series of sensors, Landsat TM

(Thematic Mapper) and ETM+ (Enhanced Thematic Mapper Plus) are essential tools for study the tropical forests (Trigg *et al.* 2006).

Menon and Bawa (1997) have discussed the application of GIS and remote sensing approaches for biodiversity conservation in the Western Ghats, India. Using IRS 1B false colour composite (FCC) bands (4, 3, and 2), Roy and Tomar (2000) quantified fragmentation and its impact on species diversity in Meghalaya. Behera *et al.* (2001) studied forest vegetation characterization and mapping of Eastern Himalayan region by using IRS-1C satellite images. Roy *et al.* (2002) reviewed the application of remote sensing and GIS for the assessment and monitoring of tropical forest resources. Based on Landsat TM and IRS- 1C LISS III pertaining to 1994, 1999 and 2001, Srivastava *et al.* (2002) assessed the large scale deforestation in Sonitpur district of Assam. Sarma and Barik (2010) analysed relationship between vegetation type and the geomorphological features such as, slope and drainage density in Nokrek Biosphere Reserve of Meghalaya by using IRS-1D LISS III satellite imagery. Reddy *et al.* (2013) studied spatiotemporal changes in forest cover in state of Orissa, for a period of 75 years (1924 to 2010) by using different satellite data viz; Landsat MSS, IRS 1B LISS-I and IRS P6 AWiFS.

Meghalaya is a biologically rich landscape in northeastern region of India. Anthropogenic activities such as shifting cultivation, clear felling of forests for timber and mining, have altered the natural landscape of Meghalaya into a fragmented landscape (Roy and Tomar 2001). Unregulated shifting cultivation by the locals and shortening of the *jhum* cycle are important factors causing degradation of forests. There is a loss of 49 km^2 forest cover in the State during 2009 to 2011 primarily due to shifting cultivation (FSI 2011). So far, we have made significant progress in the study of floristic botany, but one has to go a long way to document complete diversity of the region.

CHAPTER III

STUDY AREA

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3.1. Location

Meghalaya literally means 'the abode of clouds' is situated in the northeastern corner of India ($24^0$02'N to $26^0$07'N latitudes and $89^0$48'E to $92^0$51'E longitude), with a total geographical area of 22,429 km^2, which constitutes 0.7% of total geographical area of the country. It was previously part of the State of Assam. It was carved out from Assam and became a full-fledged State on January 21st, 1972. Administratively, the State comprised of seven districts namely, East Garo Hills, West Garo Hills, South Garo Hills, East Khasi Hills, West Khasi Hills, Jaintia Hills and Ri Bhoi (Census of India 2011). Recently, the State has been restructured into 11 districts, viz.; East Garo Hills, West Garo Hills, North Garo Hills, South Garo Hills, South-West Garo Hills, East Khasi Hills, West Khasi Hills, South-West Khasi Hills, Ri-Bhoi, East Jaintia Hills and West Jaintia Hills (Fig. 3.1). The State of Meghalaya is bordered on the north by Assam and on the south and west by Bangladesh. It is a meeting place of paleo-arctic, Indo-Malayan and Indo-Chinese bio-geographic realms.

Physiographically, Meghalaya correspond to a remnant of ancient plateau of the Precambrian Indian peninsular shield mass but later separated from it and uplifted to its present elevation by 'block movements' (Haridasan and Rao 1985). Biogeographically, the State is located in Zone 8, the northeast India zone (Rodgers and Panwar 1988), while floristically; it is part of the Indo-Malayan region.

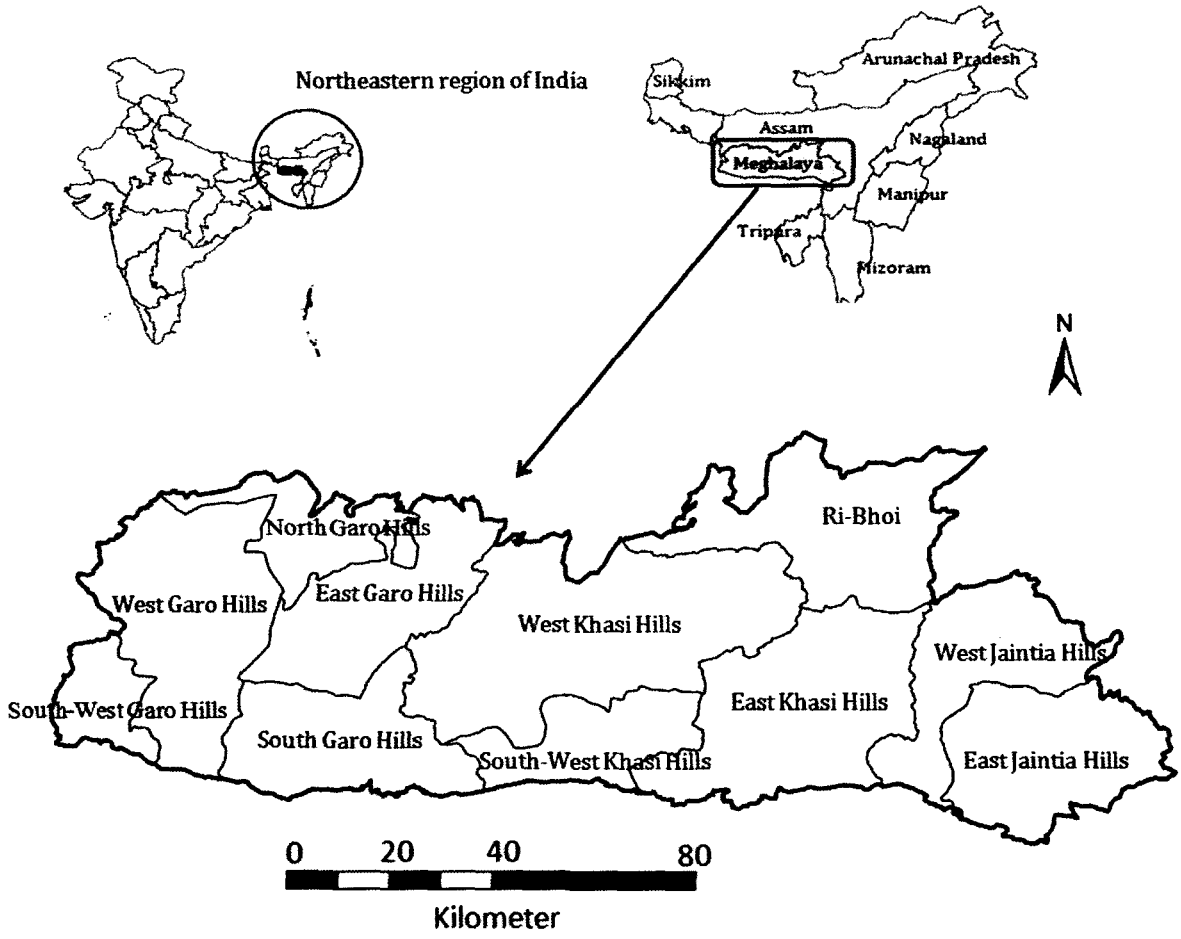

Fig. 3.1. Map of the State of Meghalaya showing the study area

3.2. Topography

The terrain of Meghalaya is characterized by hills and valleys with elevation ranging between ca. 25 m to 1950 m (Fig. 3.2). The central part comprises of the Khasi Hills boasting 'Meghalaya pleateau which has the highest elevation in 'Shillong Peak' (ca. 1950 m).

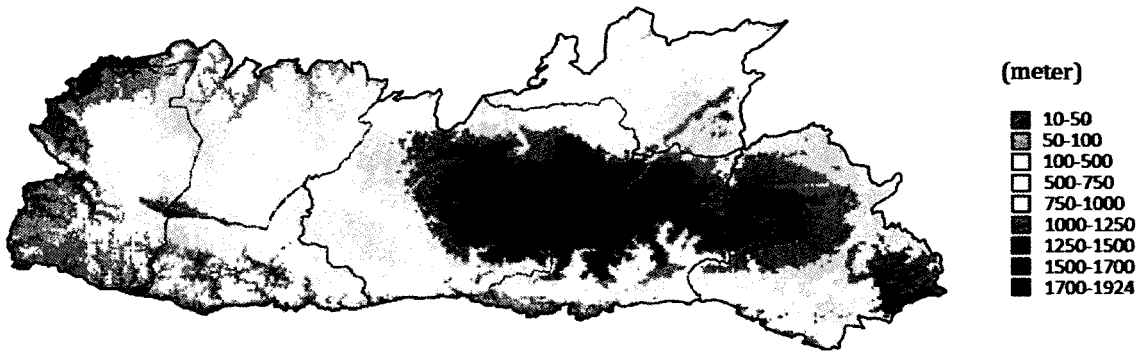

Fig. 3.2. Topographical map of Meghalaya

3.3. Geology

The State of Meghalaya shows enormous variety of topography, lithology, mineral composition and structural characteristics of rocks. The region is the northeastern extension of the huge block of Indian Peninsular shield. The Meghalaya plateau is mainly composed of (i) Archaean gneisses complex with acid and basic intrusives, (ii) Shillong group of rocks (iii) Lower Gondwana rocks, (iv) Sylhet traps, and (v) Cretaceous tertiary sediments (Haridasan and Rao 1985).

The distribution of above rock formation shows that in central and northern parts of plateau, the Archaean complex are present whereas eastern and central parts of the

plateau is characterized by Shillong group of rocks. The lower Gondwana rocks have been recognized in Garo hills while some deposits of coal have also been traced in Khasi hills. The Sylhet Traps are exposed along the southern border of Shillong plateau and southern parts of the Meghalaya plateau are engaged by cretaceous tertiary sediments (Haridasan and Rao 1985). The structural characteristics of the region are also quite complex and number of faults and folds are present in the rocks. The above rock formations contain rich deposits of valuable minerals like coal, limestone, uranium, kaolin, granite and sillimanite among others.

3.4. Soil

The diverse geological circumstances, topographical variations, climatic conditions and vegetation types are responsible for the formation of different types of soil in the State. The soils are mostly lateritic in origin and vary from sandy loam, red loam, clay loam to alluvial soil. The red loam soil is found in the central part of the Garo Hills and on the uplands of central and eastern Meghalaya. Alluvial soil occurs all along the northern, western and southern border of the state. The soils are acidic in nature and pH varies from 3-6.5 (Tripathi 2002). The soils are rich in organic carbon with high nitrogen supplying potential, but deficient in phosphorus and potassium (Tiwari and Kumar 2008).

3.5. Climate

Meghalaya has a monsoon type of climate and is directly influenced by the southwest monsoon originating from the Bay of Bengal and Arabian Sea. The climate of the State varies from western to eastern parts of the plateau depending upon altitude and

physiographical differences. The spring season (March-April) is characterized by moderate temperature and high wind velocity, with average maximum temperature goes as high as 23.8°C in the capital city Shillong (Tiwari and Kumar 2008). The lower elevated areas (western part of the State) experience fairly high temperature (Fig. 3.3.) for most period of the year having a mean temperature ranging between 12 to 25°C. The central part of the State is comparatively cooler with mean temperature ranging between 2°C to 24°C (FSI 2011).

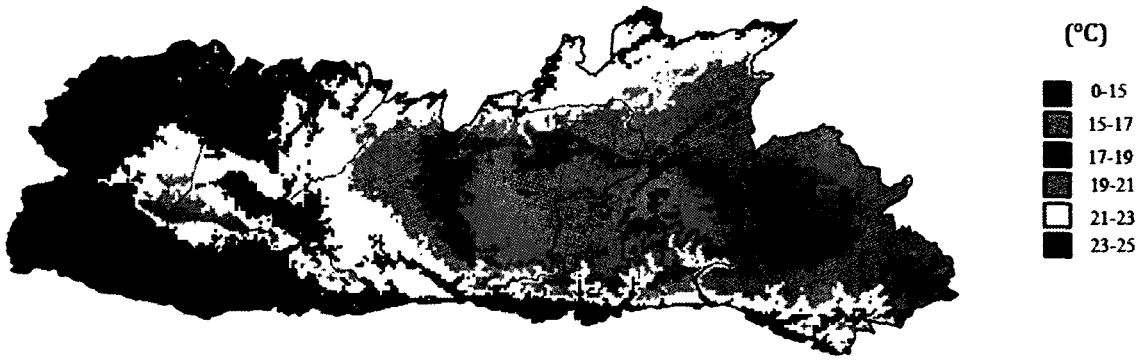

Fig. 3.3. Mean annual temperature (°C) map of Meghalaya (Source: WorldClim datasets).

The rainy season (May-September) shows a great variation in rain fall within the region. Meghalaya receives most of its rainfall from the south-west monsoon winds. The region experiences an average annual rainfall of 7,196 mm. The Ri-bhoi district, northern part of Jaintia hills, and whole Garo hills receives low rainfall (Fig. 3.4). Khasi hills and some parts of Jaintia Hills have high rainfall, moderately warm summer and severe winter with periodic depression below freezing point marked by appearance of ground frost at night and morning over higher elevated areas. In southern part of the Khasi hills (higher altitude), annual rainfall varies widely from 4,000 mm to 11,000 mm in different areas

(Tripathi 2002). Mawsynram (Sohra), a village in East Khasi Hills district claim to the highest rainfall (14,672 mm) in the world.

Fig. 3.4. Mean annual precipitation (mm) map of Meghalaya (Source: WorldClim datasets).

3.6. Demographic profile

The State of Meghalaya is inhabited by three tribes; the *Khasis*, the *Jaintias* and the *Garos*. The total population of the State as per 2011 census is 29,64,007 (Table 3.1), of which female comprises 14,92,668 and male 14,71,339. The rural population of the State is 79.92% whereas urban population is 20.08%. The average density of population is 132 persons per km^2. The sex ratio in the state is 986 females per 1000 males. The decadal population growth rate (2001-2011) is 27.82% (Table 3.1) and overall literacy rate is 75.48%.

Table 3.1. District-wise population, density/km^2 and percentage decadal growth rate (% DGR) of Meghalaya (2001-2011) (Source: Census of India 2011).

Sl.#	Districts	Year 2001		Year 2011		% DGR (2001-2011)
		No. of persons	Density/ km^2	No. of persons	Density/ km^2	
1	East Garo Hills	252399	97	317618	122	25.84
2	West Garo Hills	507309	137	642923	173	26.73
3	South Garo Hills	110244	60	142574	77	29.33
4	East Khasi Hills	660923	234	824059	292	24.68
5	West Khasi Hills	296049	56	385601	73	30.25
6	Jaintia Hills	299108	78	392852	103	31.34
7	Ri Bhoi	192790	81	258380	109	34.02
	Total	2318822	103	29,64,007	132	27.82

3.7. Protected Areas (PAs) Network of Meghalaya

The Protected Area Network in the state of Meghalaya is meager and is represented by two national parks and three wildlife sanctuaries (Fig. 3.5) covering an area of 301.68 km^2 which is just 1.4% of the geographical area of the state (Table 3.2).

Table 3.2. List of Protected Areas (PAs) of Meghalaya (Source: Wildlife Institute of India, Dehra Dun)

Name of protected areas	Area (km^2)
Balpakram National Park	220
Nokrek National Park	47.48
Nongkhyllem Wildlife Sanctuary	29
Siju Wildlife Sanctuary	5.18
Baghmara Pitcher Plant (BPP) Wildlife Sanctuary	0.02
Total	301.68

The Nokrek National Park and Biosphere Reserve in the West Garo Hills and East Garo Hills and the Balphakram National Park in the South Garo Hills district are considered to be the most biodiversity rich sites in the Meghalaya.

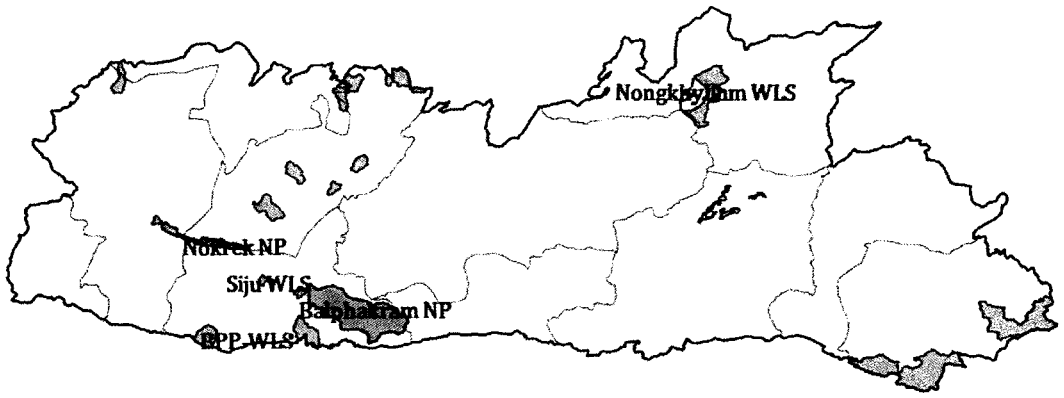

Fig. 3.5. Geographical location and distribution of Protected Areas (PAs) in Meghalaya, India.

3.8. Vegetation

Forests have been classified primarily on the basis of physiognomy, floristic composition, community structure and dynamics, physical environment and history (Tripathi 2002). Based on site condition and floristic composition, a number of authors like Kanjilal *et al.* (1934), Champion and Seth (1968), Balakrishnan (1981), Haridasan and Rao (1985) and IIRS (2002) have been classified the vegetation of Meghalaya (Table 3.3).

Kanjilal *et al.* (1934) classified the forests Meghalaya into two broad categories, i.e., evergreen forests and deciduous forests. The evergreen forests said to be present in greater parts of Khasi Hill districts and deciduous forests in isolated patches.

On the basis of floristic composition and physiognomy, Champion and Seth (1968) broadally classified and divided forests of Meghalaya into tropical evergreen, tropical semi-evergreen, subtropical broadleaved hill forest, tropical moist deciduous, grasslands and savannas, temperate and subtropical pine forest types.

Table 3.3. Forest types of Meghalaya for this study and comparison of terminologies with Champion and Seth (1968) and IIRS (2002) classification

This study	**Champion and Seth (1968)**	**IIRS (2002)**	**Major species**
Tropical evergreen forest	Cachar tropical evergreen forests (1/1B/C3)	Subtropical evergreen forests	*Schima wallichii, Macropanax undulatus, Cinnamomum tamala, Syzygium tetragonum, Boehmeria glomerulifera*
Tropical moist mixed-deciduous forest	East Himalayan moist deciduous forests (3C/C3b)	Moist mixed deciduous forests	*Microcos paniculata, Schima wallichii, Dillenia indica, Tetrameles nudiflora, Bauhinia purpurea, Aporosa octandra* var. *octandra*
Khasi hill sal-pine forest	Khasi hill sal (3C/C1 (ii))	Sal forests	*Shorea robusta, Schima wallichii, Pinus kesiya, Careya arborea, Callicarpa arborea, Semecarpus anacardium*
Khasi-Jaintia subtropical pine forest	Assam subtropical pine forests (9/C2)	Subtropical pine forests	*Pinus kesiya, Schima wallichii, Myrica esculenta, Myrica nagi, Lyonia ovalifolia, Eurya acuminata*
Khasi subtropical mixed-broadleaved forest	Khasi subtropical wet hill forests (8B/C2)	Subtropical evergreen forests	*Schima wallichii, Syzygium teragonum, Helicia nilagirica, Pinus kesiya, Engelhardtia spicata, Eurya acuminata*
Khasi subtropical oak-dominated forest	Khasi subtropical wet hill forests (8B/C2)	Subtropical evergreen forests	*Castanopsis* spp., *Lithocarpus* spp., *Quercus* spp., *Pinus kesiya, Myrica esculenta, Rhododendron arboreum*

According to Forest Flora of Meghalaya (Haridasan and Rao 1985), the vegetation of Meghalaya consists of tropical evergreen forests in the low-lying areas with high rainfall, tropical semi-evergreen forest up to the elevation of about 1,200 m with annual rainfall between 1,500 to 2,000 mm, tropical moist deciduous forests in areas with less than 1,500 mm rainfall, Grassland and Savannas on the tops of the Khasi, the Jaintia and the Garo Hills, isolated patches of temperate forest along the southern slopes of the Khasi and the

Jaintia Hills, and Subtropical pine forests with pure stands of *Pinus kesiya* confined to the higher altitudes of the Shillong Plateau.

Based on IRS-1D LISS-III data, the vegetation of Meghalaya have been classified into subtropical evergreen, subtropical semi-evergreen, sal, subtropical pine, subtropical mixed pine, degraded pine and moist mixed deciduous forests (IIRS 2002) (Table 3.3).

On the basis of above mentioned forest types classification by several authors, the present study classified the state of Meghalaya into following major forest types i.e.,

(i) Tropical Evergreen Forest

(ii) Tropical Moist Mixed-Deciduous Forest

(iii) Khasi Hill Sal-Pine Forest

(iv) Khasi-Jaintia Subtropical Pine Forest

(v) Khasi Subtropical Mixed-Broadleaved Forest

(vi) Khasi Subtropical Oak-Dominated Forest

3.9. Forest cover

Meghalaya is richly endowed with the forest resources. The extent of total forest area is 9496 km^2, which is about 42.34% of the State's geographical area. Reserved forests constitute 11.72%, protected forests 0.13% and unclassed forests 88.15% (FSI 2011).

Based on interpretation of satellite data, the total forest cover in the State is 17,275 km^2 (very dense forest- 433 km^2, moderately dense forest- 9775 km^2 and open forest- 7067 km^2), which is 77.02% of the State's geographical area (FSI 2011) (Table 3.4).

Table 3.4. District wise forest cover of Meghalaya (FSI 2011).

District	Geographical area (km^2)	Very dense forest (km^2)	Moderately dense forest (km^2)	Open forest (km^2)	Total (km^2)	% of geographical area
East Garo Hills	2603	68	1104	1045	2217	85.17
West Garo Hills	3715	0	1361	1613	2974	80.05
South Garo Hills	1849	44	1005	590	1639	88.64
East Khasi Hills	2820	0	1084	716	1800	63.83
West Khasi Hills	5247	91	2551	1366	4008	76.39
Jaintia Hills	3819	99	1578	839	2516	65.88
Ri Bhoi	2376	131	1092	898	2121	89.27
Total	22429	433	9775	7067	17275	77.02

According to Forest Survey of India report 2011 (FSI 2011), tropical moist deciduous forests cover a large geographical area in the State (61.62%) followed by subtropical broadleaved hill forests (17.71%), tropical wet evergreen forests (10.45%), subtropical pine forests (8.29%) and tropical semi-evergreen forests (1.93%).

3.10. Geographical attributes of sampled transects

The geographical attributes of sampled transects are given in Table 3.5. The transect number, sampling grid number, latitude, longitude, altitude, length, width and area of sampling are provided.

Table 3.5. Geographical attributes of sampled transects.

Transect number	Sampling grid number	Latitude	Longitude	Altitude (m)	Length (m)	Width (m)	Area (m^2)
ML001	78O14SE1	25°37'02.46"	91°54'16.80"	1342	500	5	2500
ML002	78O14SE1	25°37'05.40"	91°54'25.08"	1356	500	5	2500
ML003	78O14SE1	25°36'33.80"	91°54'41.60"	1448	500	5	2500
ML004	78O14NE2	25°40'42.60"	91°54'56.64"	1023	500	5	2500
ML005	78O14SE2	25°33'11.40"	91°53'59.60"	1698	500	5	2500
ML006	78O14SW4	25°32'40.30"	91°49'19.00"	1729	500	5	2500
ML007	78O14SE3	25°33'59.80"	91°57'25.90"	1441	500	5	2500
ML008	83C02NW1	25°43'25.40"	92°00'44.30"	914	500	10	5000
ML009	78O12NE3	25°13'05.90"	91°43'49.40"	863	500	10	5000
ML010	78O11SE3	25°19'48.10"	91°43'44.20"	1610	500	10	5000

ML011	78O14NW4	25°39'09.90"	91°50'55.00"	1086	500	10	5000
ML012	83C02SW1	25°36'04.69"	92°01'54.57"	1147	500	10	5000
ML013	78O15NW2	25°25'10.00"	91°47'40.50"	1813	300	10	3000
ML014	78O15NW1	25°28'57.50"	91°46'41.30"	1803	500	10	5000
ML015	78O06SW2	25°31'28.40"	91°17'14.30"	1400	500	10	5000
ML016	78O02SE4	25°32'22.00"	91°14'01.50"	1303	500	10	5000
ML017	78O07NW1	25°29'09.80"	91°15'56.00"	1436	500	10	5000
ML018	83C03NE1	25°29'39.10"	92°09'54.70"	1360	500	10	5000
ML019	78O14NW4	25°37'55.10"	91°52'05.70"	1076	500	10	5000
ML020	78O14NW2	25°39'02.40"	91°47'30.30"	984	500	10	5000
ML021	78O15SE2	25°17'33.80"	91°54'19.70"	1204	500	10	5000
ML022*	78O16NE3	25°12'11.90"	91°59'26.90"	372	500	10	5000
ML023	78O15SE1	25°21'42.90"	91°53'26.50"	1414	400	10	4000
ML024	78O15SW4	25°16'42.90"	91°51'50.10"	1041	300	10	3000
ML025	78O11NE3	25°26'34.40"	91°44'26.20"	1781	500	10	5000
ML026*	78N16SW4	26°01'34.60"	91°51'32.60"	166	500	10	5000
ML027*	78N16SE2	26°01'57.10"	91°53'08.40"	145	500	10	5000
ML028*	78O13NW3	25°59'31.50"	91°50'19.90"	353	500	10	5000
ML029	83C02SW4	25°30'54.50"	92°06'42.30"	1119	500	10	5000
ML030	78O15NW3	25°28'07.70"	91°49'33.90"	1695	500	10	5000
ML031	78O15NE1	25°28'40.50"	91°54'23.2"	1789	500	10	5000
ML032	78O14SE4	25°31'02.80"	91°58'58.3"	1617	500	10	5000
ML033	78O14SW3	25°36'44.70"	91°51'54.10"	1157	500	10	5000
ML034	78O14NE3	25°43'48.50"	91°58'29.20"	1000	500	10	5000
ML035	78O14NE4	25°40'37.50"	91°57'18.80"	919	500	10	5000
ML036	78O14SW2	25°31'41.40"	91°47'37.50"	1577	500	10	5000
ML037	78O11NE4	25°25'55.70"	91°43'19.70"	1705	500	10	5000
ML038	83C02NW2	25°40'29.40"	92°00'49.50"	907	500	10	5000
ML039	78O14NE1	25°42'55.30"	91°53'50.20"	920	500	10	5000
ML040	78O10SE4	25°31'43.40"	91°43'35.40"	1793	500	10	5000
ML041	78O15SW1	25°21'57.00"	91°46'13.20"	1726	500	10	5000
ML042	78O11SE4	25°17'08.60"	91°42'48.90"	1389	500	10	5000
ML043	78O11SE2	25°17'20.40"	91°40'41.40"	1327	500	10	5000
ML044	78O13SE2	25°46'10.60"	91°54'18.70"	746	500	10	5000
ML045	78O13SE4	25°48'33.90"	91°56'59.10"	764	500	10	5000
ML046	78O13SE3	25°50'43.30"	91°58'56.40"	860	500	10	5000
ML047	78O14NW3	25°43'23.50"	91°50'58.80"	706	500	10	5000
ML048	78O13SW2	25°46'35.70"	91°46'45.10"	636	400	10	4000

ML049	78O14NW1	25°43'46.00"	91°47'51.60"	740	500	10	5000
ML050	78O13SW4	25°45'28.00"	91°51'07.20"	725	500	10	5000
ML051	78O07NE3	25°27'10.20"	91°28'22.90"	1614	400	10	4000
ML052	78O11NE1	25°29'24.90"	91°39'47.40"	1820	500	10	5000
ML053	78O14SW1	25°35'08.90"	91°46'47.60"	1702	500	10	5000
ML054	78O10SE3	25°34'57.00"	91°44'02.60"	1614	500	10	5000
ML055	83C02SW2	25°32'36.40"	92°00'57.30"	1357	500	10	5000
ML056	78O07NW4	25°25'44.50"	91°21'28.90"	1505	400	10	4000
ML057	83C02SE2	25°32'06.40"	92°09'28.70"	1293	500	10	5000
ML058	83C01SW2	25°47'07.70"	92°01'04.40"	1089	500	10	5000
ML059	78O15NE3	25°28'00.10"	91°58'09.00"	1659	500	10	5000
ML060	83C01NW2	25°51'48.80"	92°06'45.20"	1019	500	10	5000
ML061	83C02SE1	25°33'52.30"	92°11'13.00"	1237	500	10	5000
ML062	83C06SE3	25°37'06.90"	92°28'16.70"	950	450	10	4500
ML063	83C02SE4	25°32'48.50"	92°13'13.20"	1234	500	10	5000
ML064	83C06SW2	25°31'11.00"	92°16'28.50"	1269	500	10	5000
ML065	83C07NW1	25°29'11.60"	92°16'52.40"	1293	500	10	5000
ML066	83C06SW4	25°33'06.90"	92°19'34.80"	1171	250	10	2500
ML067	78O15NW4	25°23'17.90"	91°51'32.50"	1414	200	10	2000
ML068	78O15NW4	25°23'58.10"	91°52'09.00"	1499	350	10	3500
ML069	78O15SW3	25°21'23.70"	91°51'32.30"	1026	350	10	3500
ML070	83C02SE3	25°34'51.90"	92°11'58.80"	1199	500	10	5000
ML071	78O16NE1	25°12'29.90"	91°53'49.30"	531	300	10	3000
ML072	78O10NE2	25°39'47.80"	91°38'27.70"	1400	500	10	5000
ML073	78O15NE2	25°24'43.90"	91°53'01.40"	1615	300	10	3000
ML074	78O15SW2	25°17'50.20"	91°45'15.00"	1415	300	10	3000
ML075	78O13SE01	25°50'53.70"	91°52'51.80"	609	500	10	5000
ML076	83C01SW1	25°51'47.00"	92°00'39.10"	759	400	10	4000
ML077	78O13SW3	25°49'43.70"	91°50'13.40"	654	500	10	5000
ML078	78O11SW4	25°17'19.60"	91°34'25.50"	1255	300	10	3000
ML079	78O11SW3	25°21'24.20"	91°36'21.10"	1594	400	10	4000
ML080	78O11NW4	25°23'46.20"	91°34'21.80"	1621	500	10	5000
ML081	78O12NW1	25°13'48.40"	91°33'05.60"	812	400	10	4000
ML082	78O11SW2	25°16'11.00"	91°33'09.90"	1240	500	10	5000
ML083*	78O04NE3	25°13'15.90"	91°14'10.50"	26	500	10	5000
ML084	78O08NW1	25°14'09.60"	91°15'34.40"	319	350	10	3500
ML085*	78O08NW3	25°12'18.70"	91°19'26.00"	93	500	10	5000
ML086	78O13NE3	25°57'39.70"	91°59'13.10"	537	500	10	5000

ML087	78O13NW4	25°54'13.80"	91°52'15.50"	628	400	10	4000
ML088	78O10SW3	25°35'20.20"	91°36'27.40"	1633	500	10	5000
ML089	78O10NW4	25°38'03.20"	91°36'32.60"	1464	500	10	5000
ML090	78O07SE3	25°21'54.80"	91°28'16.00"	1570	500	10	5000
ML091	78O07SE1	25°21'06.70"	91°25'34.10"	1476	300	10	3000
ML092	78O11NW2	25°24'23.50"	91°32'41.90"	1406	500	10	5000
ML093	78O11SW1	25°21'07.10"	91°30'10.50"	1529	250	10	2500
ML094	78O07NE4	25°24'12.90"	91°27'42.10"	1550	350	10	3500
ML095*	78O12NW3	25°12'32.20"	91°34'55.50"	434	450	10	4500
ML096	78O08NE3	25°14'56.80"	91°27'48.70"	750	400	10	4000
ML097	78O11SE1	25°22'14.30"	91°37'52.10"	1545	500	10	5000
ML098	78O11NE2	25°24'21.20"	91°39'40.30"	1623	300	10	3000
ML099	78O11NE2	25°24'25.50"	91°39'32.70"	1677	200	10	2000
ML100	78O11SW4	25°16'21.70"	91°34'51.80"	1203	400	10	4000
ML101*	78K11SE1	25°21'00.60"	90°40'14.00"	175	500	10	5000
ML102	78K11SE3	25°20'13.4"	90°41'04.40"	256	500	10	5000
ML103	78K11SE4	25°18'31.20"	90°42'25.90"	334	500	10	5000
ML104	78K11SE1	25°20'15.40"	90°40'35.60"	122	500	10	5000
ML105	78K16NW3	25°12'44.30"	90°51'25.30"	319	500	10	5000
ML106	78K16NW3	25°13'21.90"	90°51'44.00"	329	500	10	5000
ML107*	78K16NW4	25°10'24.20"	90°50'53.20"	178	500	10	5000
ML108*	78K12NE1	25°12'56.90"	90°40'34.30"	181	500	10	5000
ML109	78K02SE4	25°30'31.30"	90°13'48.00"	577	500	10	5000
ML110	78K07NW3	25°28'04.10"	90°19'13.80"	1283	500	10	5000
ML111	78K07NW1	25°28'35.70"	90°17'46.20"	1302	500	10	5000
ML112*	78K06SE3	25°34'31.80"	90°27'44.00"	403	500	10	5000
ML113*	78K11NE1	25°30'00.40"	90°38'32.20"	309	500	10	5000
ML114*	78K11SE1	25°18'57.90"	90°39'08.40"	207	500	10	5000
ML115*	78K12NE1	25°12'48.90"	90°38'35.40"	172	500	10	5000
	Total				53100	1115	513,500

* Not included in the study

3.11. Categorization of sampled transects

The altitudinal variation in sampled transects was high and the frequency of transects in 300 m interval class of altitude is given in Table 3.6. The sampling was more intense at altitudes greater than 1200 m.

Table 3.6. The altitudinal variation in sampled transects.

Sl. no.	Altitude (m)	No. of transects	Area (m^2)
1.	0-300	11	55000
2.	300-600	12	56000
3.	600-900	14	65000
4.	900-1200	19	86000
5.	1200-1500	30	127500
6.	1500-1900	29	124000
	Total	115	513500

The distribution of sampled transects in different forest types is given Table 3.7. The sampling was more intense in Khasi-Jaintia subtropical pine forest.

Table 3.7. The distribution of sampled transects in different forest types.

Forest types	Number of Transects	Area (m^2)	Transect code
Tropical evergreen forest	6	24500	ML009, ML071, ML081, ML084, ML096, ML109
Tropical moist mixed-deciduous forest	5	25000	ML102, ML103, ML104, ML105, ML106
Khasi hill sal-pine forest	11	52000	ML044, ML045, ML046, ML048, ML049, ML050, ML075, ML076, ML077, ML086, ML087
Khasi-Jaintia subtropical pine forest	41	188000	ML001, ML002, ML003, ML005, ML006, ML007, ML011, ML012, ML014, ML015, ML016, ML017, ML018, ML019, ML029, ML030, ML031, ML032, ML033, ML034, ML036, ML037, ML039, ML052, ML053, ML054, ML055, ML057, ML059, ML060, ML061, ML062, ML063, ML064, ML065, ML072, ML080, ML088, ML089, ML094, ML097
Khasi subtropical mixed-broadleaved forest	18	68500	ML004, ML020, ML023, ML024, ML038, ML051, ML058, ML066, ML067, ML068, ML069, ML070, ML073, ML078, ML090, ML093, ML110, ML111
Khasi subtropical oak-dominated forest	20	86000	ML008, ML010, ML013, ML021, ML025, ML035, ML040, ML041, ML042, ML043, ML047, ML056, ML074, ML079, ML082, ML091, ML092, ML098, ML099, ML100
Unclassified forest	14	69500	ML022, ML026, ML027, ML028, ML083, ML085, ML095, ML101, ML107, ML108, ML112, ML113, ML114, ML115

CHAPTER IV

FLORISTIC COMPOSITION AND DIVERSITY OF MAJOR FOREST TYPES OF MEGHALAYA

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4.1. Introduction

Floristic composition and structure of forests are crucial for providing information on species richness of the plants and useful for management purpose and understanding of forest ecology and ecosystem functions (Pappoe *et al.* 2010).

Meghalaya is very rich in floristic diversity. The rich diversity of plants in Meghalaya is generally ranging from tropical to subtropical hill forests and encompasses Asiatic and Indian Peninsular component (IIRS 2002). Varied ecological conditions such as rainfall, temperature, altitude as well as soil conditions allow abundant growth of tropical and subtropical angiospermic flora in the State. Several authors have studied the flora of the State (Myrthong 1980, Kumar 1984, Balakrishnan 1981-1983, Haridasan and Rao 1985-1987, Kanjilal *et al.* 1934-1940). Khan *et al.* (1997) compiled a list of 3331 species of vascular plants including 1236 (37.11%) plant species as endemics for Meghalaya.

The studies have been carried out to quantify plant diversity and to understand the ecology of forest communities of the region. Tripathi (2002) conducted a detailed floristic study on three major forest types in the State, i.e. subtropical evergreen, subtropical semi-evergreen and subtropical pine forests. A number of ecologists have quantified the plant diversity in subtropical humid forests (Rao *et al.* 1990, Jamir and Pandey 2003, Upadhaya *et al.* 2003, 2004, Odyuo 2004, Mishra *et al.* 2004, 2005, Jamir *et al.* 2006, Laloo *et al.* 2006, Tripathi *et al.* 2010, Tripathi and Reynald 2010). Apart from subtropical forests, the studies on tropical forests in the State are scanty and only limited study have been observed in these forests (Kumar *et al.* 2006).

Most of these studies have emphasized the tree species than any other life forms such as lianas and understorey plants. There are some authors who have studied understory plants and included smaller plants like herb, shrub, climber, creeper and fern in their study (Jamir and Pandey 2003, Jamir *et al.* 2006, Upadhaya *et al.* 2006).

Most of the above studies of Meghalaya mainly concentrated on particular forest types, whereas the present study emphasized major forest types of Meghalaya. This chapter presents floristic composition and species diversity of following forest types of Meghalaya:

(i) Tropical Evergreen Forest

(ii) Tropical Moist Mixed-Deciduous Forest

(iii) Khasi Hill Sal-Pine Forest

(iv) Khasi-Jaintia Subtropical Pine Forest

(v) Khasi Subtropical Mixed-Broadleaved Forest

(vi) Khasi Subtropical Oak-Dominated Forest

4.2. Field sampling

The vegetation was sampled following grid-based inventory. For this, the geographical area of Meghalaya was divided into sampling grids. A Survey of India (SOI) toposheet of 1:50,000 scale was used as the base map and each sheet subdivided into 16 sampling grids. Hence, a sampling grid corresponds 3'45" latitude x 3'45" longitude which nearly represents 6.25 km x 6.25 km or 39.0625 km^2. Thus, the the State of Meghalaya has 542 sampling grids approximately. The grids with prominent vegetation types were sampled depending on the similarity of terrain, accessibility, insurgency and other geographical and socio-political factors.

In each sampling grid, the representative vegetation was sampled by laying a transect of 5 to 10 m width and up to 500 m length (Murali *et al.* 1996, Uma Shankar 2001). Sometimes, more than one transects were laid within a sampling grid to encompass distinct vegetation types. All individuals (stems) ≥10 cm girth at breast height (1.37 m above the ground level) were enumerated. The specimens of plant species were collected, packed in polythene bags, dried in herbarium press and processed to put up on the herbarium sheets (Jain and Rao 1976). Each enumerated individual stem was measured for the girth (cm), height (m) and phenophase (flowering, fruiting, leaf flush etc.). All the stem were classified into large tree (LT), medium tree (MT), small tree (ST), shrub (SH), woody climber (WC) and scandent shrub (SS). The species which composed of top canopy, sub canopy and under canopy are considered as large tree, medium tree and small tree, respectively. The multi-stem species which were <30 cm gbh were considered as shrub and the climbers ≥10 cm girth were considered as woody climber. The scandent shrubs are the mostly erect species which show their climbing nature at the top of conopy. The habit of the species was also verified by the Forest Flora of Meghalaya (Haridasan and Rao 1985-1987).

The herbs were enumerated by placing up to quadrats of 1 m x 1 m at three different locations nested within each transect. Generally, one quadrat was placed within first 100 m, one in the middle and one in the last 100 m length of the transect.

The individual plant species were identified with the help of regional floras such as, Flora of Jowai (Balakrishnan 1981-1983), Forest Flora of Meghalaya (Haridasan and Rao 1985-1987) and Flora of Assam (Kanjilal *et al.* 1934-1940). The Herbaria of the Department of Botany, North-Eastern Hill University, Shillong was also sometimes consulted for identification. The correct identification of plant specimens was done from

the Herbarium of the Botanical Survey of India, Eastern Circle, Shillong. The accepted name of species as well as family was varified by Angiosperm Phylogeny Group III (APG III 2009) and The Plant List (http://www.theplantlist.org).

4.3. Data analysis

4.3.1. *Phytosociological structure, species diversity and floristic composition*

The data from transects were analyzed following standard ecological methods. Frequency, density and basal area were determined for each species following Mishra (1968) and Mueller-Dombois and Ellenberg (1974).

The importance value index (IVI) was calculated by the summation of relative values of frequency, density and basal area (Curtis and McIntosh 1950, 1951).

Similarity between sites was calculated by Sørensen's similarity index (Sørensen 1948).

Sørensen's similarity index: = 2 C x 100 / (A+B)

where, A = number of species in stand A

B = number of species in stand B

C = number of species common to both stands, A and B

The species richness index was estimated following Whittaker (1972).

Species richness index: = S-1 / $\log_{10}$ N

where, S = number of species

N = number of individuals

Shannon's diversity index was calculated using IVI values (Shannon and Wiener 1963).

Shannon's diversity index (H'): = $-\sum \{(n_i/N) \times \log_{10} (n_i/N)\}$

where, n_i = importance value of i^{th} species

N = sum of importance values of all species

The dominance index was calculated following Simpson (1949).

Simpson's dominance index (D): $= \sum(n_i / N) \times (n_i / N)$

where, n_i = importance value of i^{th} species

N = sum of importance values of all species

The evenness index was estimated following Pielou (1966).

Pielou's evenness index: $= -\sum \{(n_i/N) \times \log (n_i/N)\} / \log S$

Where, n_i = importance value of i^{th} species

N = sum of importance values of all species

S = number of species

The dispersion pattern of species was calculated by Whitford's index (Whitford 1948).

Whitford's index : = Abundance (A)/ Frequency (F)

When, A/F ratio ≤ 0.025 = regular distribution

A/F ratio > 0.025 to ≤ 0.05 = random distribution

A/F ratio > 0.05 = clumped distribution

4.4. Results

4.4.1. Tropical Evergreen Forest – woody layer

The floristic composition of the woody layer of tropical evergreen forest (Table 4.1) exhibited a total of 2,385 individuals of ≥10 cm gbh in 2.45 ha sampled area (six transects of 10 m width and upto 500 m length, Tables 3.5 & 3.7 in Chapter III). Overall, 184 species of 142 genera in 65 families occurred. Of all, 173 species were identified up to species level, 7 species up to genus level and 4 species could not be determined (Table 4.1). The majority of species were small tree (62 species) followed by large tree (58 species), medium tree (40 species), shrub (19 species), scandent shrub (4 species) and woody climber (1 species) (Table 4.1). A single species of a tree fern, i.e., *Cyathea khasyana* also occurred. The endemic to Meghalaya were: *Elaeocarpus prunifolius*, *Lasianthus hookeri*, *Schefflera pueckleri* and *Xylosma controversa*.

In terms of number of individuals (density), the most dominant species were: *Boehmeria glomerulifera* (150 individuals), *Macropanax undulatus* (144 individuals), *Schima wallichii* (98 individuals) and *Cinnamomum tamala* (95 individuals). Thirty seven species had only one individual each, whereas nineteen species only 2 individuals each. The remainder species were represented by 3 to 150 individuals (Table 4.1).

In terms of IVI, the most dominant species were: *Schima wallichii* (18.7), *Macropanax undulatus* (16.0), *Cinnamomum tamala* (11.0) and *Castanopsis armata* (10.0) (Table 4.1). Of all, 107 species were rare as they exhibited an Importance Value of 1 or less. A majority of species (63 species) exhibited an Importance Value between >1 and <5, and 10 species exhibited an Importance Value between >5 and <10 (Table 4.1).

Table 4.1. Floristic composition, habit (LT- Large Tree, MT- Medium Tree, ST- Small Tree, SH- Shrub, SS- Scandent Shrub, WC- Woody Climber), frequency (%), density (ha^{-1}), basal area ($cm^2\ ha^{-1}$), importance value index (IVI), maximum height (m) and abundance-to-frequency ratio (A/F) of the tropical evergreen forest of Meghalaya. Species are arranged in descending order of IVI value.

Sl. no.	Species name	Family	Habit	Freq-uency (%)	Den-sity (ha^{-1})	Basal Area ($cm^2\ ha^{-1}$)	IVI	Max height (m)	A/F ratio
1	*Schima wallichii* Choisy	Theaceae	LT	42.9	40.0	32277.3	18.7	25	2.178
2	*Macropanax undulatus* (Wall. ex G. Don) Seem.	Araliaceae	ST	40.8	58.8	19960.5	16.0	16	3.528
3	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Lauraceae	MT	30.6	38.8	13888.6	11.0	18	4.138
4	*Castanopsis armata* (Roxb.) Spach	Fagaceae	MT	14.3	22.4	18655.2	10.0	23	11.000
5	*Boehmeria glomerulifera* Miq.	Urticaceae	SH	32.7	61.2	1988.9	9.1	7	5.742
6	*Syzygium tetragonum* (Wight) Wall. ex Walp.	Myrtaceae	LT	34.7	34.7	1988.0	6.5	12	2.882
7	*Persea odoratissima* (Nees) Kosterm.	Lauraceae	MT	14.3	9.0	12046.1	6.2	23	4.400
8	*Oreocnide integrifolia* (Gaudich.) Miq.	Urticaceae	ST	34.7	30.2	2249.3	6.1	9	2.509
9	*Itea macrophylla* Wall.	Iteaceae	ST	32.7	26.5	2964.8	5.9	13	2.488
10	*Toona ciliata* M.Roem.	Meliaceae	LT	12.2	11.0	10815.6	5.9	30	7.350
11	*Stereospermum chelonoides* (L. f.) DC.	Bignoniaceae	LT	10.2	6.9	11246.8	5.5	22	6.664
12	*Sarcosperma griffithii* Hook.f. ex C.B.Clarke	Sapotaceae	MT	28.6	23.3	3392.6	5.5	21	2.850
13	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus	Fagaceae	LT	26.5	23.3	3579.2	5.4	13	3.305
14	*Xanthophyllum flavescens* Roxb.	Polygalaceae	LT	12.2	10.6	9594.7	5.4	23	7.078
15	*Helicia nilagirica* Bedd.	Proteaceae	MT	26.5	20.0	2915.5	4.8	15	2.841
16	*Macaranga indica* Wight	Euphorbiaceae	MT	34.7	14.3	3049.9	4.8	16	1.187
17	*Symplocos sumuntia* Buch.-Ham. ex D. Don	Symplocaceae	ST	28.6	25.3	496.2	4.6	8	3.100
18	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.	Fagaceae	LT	20.4	11.0	5878.8	4.6	25	2.646
19	*Magnolia hodgsonii* (Hook.f. & Thomson) H.Keng	Magnoliaceae	LT	12.2	5.3	6312.2	3.6	13	3.539
20	*Claoxylon longipetiolatum* Kurz	Euphorbiaceae	ST	14.3	18.4	2241.2	3.6	10	9.000
21	*Ostodes paniculata* Blume	Euphorbiaceae	MT	24.5	12.2	1799.4	3.5	14	2.042
22	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet	Lauraceae	LT	18.4	15.9	1795.9	3.5	21	4.719
23	*Garcinia elliptica* Wall. ex Wight	Clusiaceae	MT	12.2	20.0	1566.6	3.4	12	13.339
24	*Aidia cochinchinensis* Lour.	Rubiaceae	LT	16.3	7.3	4039.9	3.3	20	2.756
25	*Mallotus tetracoccus* (Roxb.) Kurz	Euphorbiaceae	MT	12.2	5.3	4459.2	3.0	26	3.539
26	*Saurauia roxburghii* Wall.	Actinidiaceae	ST	10.2	12.7	2165.9	2.7	12	12.152
27	*Calamus erectus* Roxb.	Arecaceae	SH	10.2	17.6	244.7	2.5	5	16.856
28	*Caryota urens* L.	Arecaceae	LT	14.3	5.3	2851.7	2.5	20	2.600
29	*Bischofia javanica* Blume	Phyllanthaceae	LT	10.2	3.7	3961.9	2.5	24	3.528
30	*Aporosa octandra* (Buch.-Ham. ex D.Don) Vickery var. *octandra*	Phyllanthaceae	ST	6.1	9.8	2837.1	2.4	14	26.133
31	*Trevesia palmata* (Roxb. ex Lindl.) Vis.	Araliaceae	ST	20.4	10.2	190.6	2.4	4	2.450

32	*Garuga pinnata* Roxb.	Burseraceae	LT	4.1	0.8	5681.9	2.4	28	4.900
33	*Dillenia indica* L.	Dilleniaceae	LT	12.2	3.3	3469.2	2.4	22	2.178
34	*Hydnocarpus kurzii* (King) Warb.	Achariaceae	LT	10.2	9.0	2215.0	2.4	16	8.624
35	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	Fagaceae	LT	18.4	9.8	516.5	2.4	15	2.904
36	*Eriobotrya bengalensis* (Roxb.) Hook. f.	Rosaceae	LT	10.2	7.8	2506.3	2.4	15	7.448
37	*Leea indica* (Burm. f.) Merr.	Vitaceae	ST	20.4	8.6	347.0	2.3	8	2.058
38	*Engelhardtia spicata* Lechen ex Blume	Juglandaceae	LT	16.3	4.9	1853.3	2.2	21	1.838
39	*Callicarpa arborea* Roxb.	Lamiaceae	MT	14.3	5.7	1816.9	2.2	15	2.800
40	*Macaranga denticulata* (Blume) Müll.Arg.	Euphorbiaceae	MT	14.3	5.3	1874.8	2.1	16	2.600
41	*Artocarpus lakoocha* Roxb.	Moraceae	LT	10.2	4.1	2726.5	2.1	16	3.920
42	*Lagerstroemia grandiflora* Roxb. ex DC.	Lythraceae	LT	14.3	4.5	1848.7	2.1	17	2.200
43	*Styrax serrulatus* Roxb.	Styracaceae	ST	14.3	9.4	442.9	2.0	10	4.600
44	*Syzygium diospyrifolium* (Wall. ex Duthie) S.N.Mitra	Myrtaceae	ST	20.4	6.1	168.7	2.0	5	1.470
45	*Wendlandia ligustrina* Wall. ex G.Don	Rubiaceae	ST	18.4	6.1	193.6	1.9	7	1.815
46	*Ficus hirta* Vahl	Moraceae	ST	16.3	6.9	258.4	1.9	8	2.603
47	*Alangium chinense* (Lour.) Harms	Cornaceae	ST	14.3	7.3	480.6	1.8	12	3.600
48	*Castanopsis tribuloides* (Sm.) A.DC.	Fagaceae	LT	14.3	5.3	770.4	1.7	12	2.600
49	*Xerospermum glabratum* Radlk.	Sapindaceae	MT	4.1	4.1	2899.9	1.7	16	24.500
50	*Crypteronia paniculata* Blume	Crypteroniaceae	LT	4.1	0.8	3639.8	1.7	24	4.900
51	*Litsea laeta* (Nees) Hook. f.	Lauraceae	MT	14.3	5.3	532.4	1.7	10	2.600
52	*Antidesma montanum* Blume var. *montanum*	Phyllanthaceae	ST	8.2	9.0	421.9	1.6	6	13.475
53	*Lithocarpus thomsonii* (Miq.) Rehder	Fagaceae	LT	6.1	5.3	1691.9	1.6	17	14.156
54	*Phoebe lanceolata* (Nees) Nees	Lauraceae	ST	14.3	3.7	490.1	1.5	11	1.800
55	*Quercus glauca* Thunb.	Fagaceae	MT	8.2	5.7	972.2	1.5	10	8.575
56	*Drimycarpus racemosus* (Roxb.) Hook.f. ex Marchand.	Anacardiaceae	LT	12.2	3.7	728.7	1.4	14	2.450
57	*Polyalthia simiarum* (Buch.-Ham. ex Hook. f. & Thomson) Benth.	Annonaceae	LT	6.1	3.7	1795.8	1.4	23	9.800
58	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	Lauraceae	ST	12.2	5.3	196.8	1.4	6	3.539
59	*Euonymus attenuatus* Wall. ex M.A.Lawson	Celastraceae	ST	10.2	6.5	203.1	1.4	10	6.272
60	*Terminalia myriocarpa* Van Heurck & Mull. Arg.	Combretaceae	LT	2.0	0.4	3303.9	1.4	27	9.800
61	*Turpinia pomifera* (Roxb.) DC.	Staphyleaceae	MT	2.0	1.2	3073.2	1.4	21	29.400
62	*Gmelina arborea* Roxb.	Lamiaceae	MT	8.2	2.9	1461.6	1.4	16	4.288
63	*Mallotus paniculatus* (Lam.) Müll.Arg. var. *paniculatus*	Euphorbiaceae	MT	14.3	2.9	336.8	1.3	13	1.400
64	*Ficus cyrtophylla* (Wall. ex Miq.) Miq.	Moraceae	ST	10.2	4.5	586.3	1.3	10	4.312
65	*Pterospermum acerifolium* (L.) Willd.	Malvaceae	LT	8.2	3.3	1009.7	1.2	13	4.900
66	*Ardisia thomsonii* Mez	Primulaceae	SH	10.2	5.3	63.5	1.2	3	5.096
67	*Viburnum odoratissimum* Ker Gawl.	Adoxaceae	ST	8.2	5.7	305.4	1.2	10	8.575
68	*Myristica* sp.	Myristicaceae	ST	6.1	6.9	310.8	1.2	8	18.511
69	*Artocarpus chaplasha* Roxb.	Moraceae	LT	8.2	2.9	1093.8	1.2	15	4.288
70	*Eurya acuminata* DC.	Pentaphylacaceae	ST	10.2	4.9	156.6	1.2	8	4.704

71	*Elaeocarpus lanceifolius* Roxb.	Elaeocarpaceae	MT	10.2	3.7	334.3	1.2	10	3.528
72	*Knema linifolia* (Roxb.) Warb.	Myristicaceae	LT	10.2	4.1	120.2	1.1	8	3.920
73	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Sapindaceae	ST	6.1	1.6	1506.7	1.1	17	4.356
74	*Morinda angustifolia* Roxb.	Rubiaceae	SH	10.2	4.1	57.8	1.1	6	3.920
75	*Amblyanthus glandulosus* (Roxb.) A.DC.	Primulaceae	SH	10.2	4.1	40.6	1.1	4	3.920
76	*Archidendron clypearia* (Jack) I.C.Nielsen	Fabaceae	ST	10.2	3.3	158.7	1.0	11	3.136
77	*Macropanax dispermus* (Blume) Kuntze	Araliaceae	ST	8.2	3.7	399.3	1.0	12	5.513
78	ML081T32	Unidentified	LT	2.0	1.2	1895.5	0.9	22	29.400
79	*Saraca indica* L.	Fabaceae	MT	8.2	3.7	93.1	0.9	5	5.513
80	*Camellia kissi* Wall.	Theaceae	ST	8.2	3.7	42.2	0.9	3	5.513
81	*Ficus benjamina* L.	Moraceae	LT	2.0	0.4	2029.2	0.9	20	9.800
82	*Lasianthus hookeri* C.B.Clarke ex Hook.f.	Rubiaceae	ST	8.2	3.7	37.7	0.9	3	5.513
83	*Schoepfia* sp.	Schoepfiaceae	ST	8.2	2.0	485.7	0.9	12	3.063
84	*Artocarpus heterophyllus* Lam.	Moraceae	LT	4.1	3.3	835.8	0.9	15	19.600
85	*Photinia integrifolia* Lindl. var. *integrifolia*	Rosaceae	MT	6.1	2.0	784.6	0.9	20	5.444
86	*Melia dubia* Cav.	Meliaceae	LT	2.0	0.4	1762.6	0.8	23	9.800
87	*Cyathea khasyana* Domin	Cyatheaceae	ST	6.1	3.3	224.4	0.8	6	8.711
88	*Pterygota alata* (Roxb.) R.Br.	Malvaceae	LT	8.2	2.4	65.9	0.8	4	3.675
89	*Actinodaphne obovata* (Nees) Blume	Lauraceae	MT	6.1	2.4	352.6	0.8	13	6.533
90	*Ficus hispida* L. f.	Moraceae	ST	8.2	2.0	96.2	0.8	8	3.063
91	*Gynocardia odorata* R.Br.	Achariaceae	LT	6.1	1.6	557.2	0.8	21	4.356
92	ML081T48	Lauraceae	LT	6.1	1.6	557.1	0.8	18	4.356
93	*Tarenna asiatica* (L.) Kuntze ex K.Schum.	Rubiaceae	ST	8.2	2.0	59.3	0.8	9	3.063
94	*Ligustrum robustum* (Roxb.) Blume	Oleaceae	MT	6.1	1.2	645.9	0.8	15	3.267
95	*Goniothalamus sesquipedalis* (Wall.) Hook.f. & Thomson	Annonaceae	SH	6.1	2.9	157.7	0.7	10	7.622
96	*Psychotria symplocifolia* Kurz	Rubiaceae	SH	6.1	3.3	31.0	0.7	3	8.711
97	*Pandanus furcatus* Roxb.	Pandanaceae	ST	6.1	2.0	355.3	0.7	7	5.444
98	*Protium serratum* (Wall. ex Colebr.) Engl.	Burseraceae	LT	6.1	2.4	231.4	0.7	15	6.533
99	*Xylosma controversa* Clos	Salicaceae	ST	6.1	2.9	43.3	0.7	4	7.622
100	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae	MT	8.2	1.6	29.6	0.7	4	2.450
101	*Mallotus philippensis* (Lam.) Müll.Arg.	Euphorbiaceae	ST	8.2	1.6	20.2	0.7	4	2.450
102	*Eurya japonica* Thunb.	Pentaphylacaceae	SH	6.1	2.9	25.2	0.7	3	7.622
103	*Lindera melastomacea* Fern.-Vill.	Lauraceae	ST	4.1	3.7	113.8	0.7	8	22.050
104	*Magnolia champaca* (L.) Baill. ex Pierre	Magnoliaceae	LT	6.1	1.2	392.9	0.7	16	3.267
105	*Microcos paniculata* L.	Malvaceae	MT	4.1	2.0	474.3	0.6	12	12.250
106	*Brassaiopsis glomerulata* (Blume) Regel	Araliaceae	ST	4.1	3.3	129.2	0.6	7	19.600
107	*Careya arborea* Roxb.	Lecythidaceae	MT	2.0	0.4	1260.0	0.6	18	9.800
108	*Fagraea ceilanica* Thunb.	Gentianaceae	ST	6.1	1.2	280.6	0.6	6	3.267
109	*Bridelia glauca* Blume	Phyllanthaceae	MT	6.1	1.6	141.2	0.6	9	4.356

110	*Albizia chinensis* (Osbeck) Merr.	Fabaceae	LT	4.1	0.8	684.6	0.6	28	4.900
111	*Schefflera pueckleri* (K.Koch) Frodin	Araliaceae	SS	4.1	2.0	335.9	0.6	6	12.250
112	*Tetrameles nudiflora* R. Br.	Tetramelaceae	LT	2.0	0.4	1135.4	0.6	24	9.800
113	*Ficus auriculata* Lour.	Moraceae	ST	4.1	1.2	533.8	0.6	15	7.350
114	*Ficus heteropleura* Blume	Moraceae	ST	6.1	1.2	158.4	0.6	12	3.267
115	*Mesua ferrea* L.	Calophyllaceae	LT	4.1	2.0	280.5	0.6	14	12.250
116	*Ceriscoides campanulata* (Roxb.) Tirveng.	Rubiaceae	ST	4.1	2.9	42.2	0.6	4	17.150
117	*Ulmus lanceifolia* Roxb. ex Wall.	Ulmaceae	LT	4.1	1.6	383.0	0.6	12	9.800
118	*Kayea floribunda* Wall.	Calophyllaceae	MT	6.1	1.2	137.7	0.6	10	3.267
119	*Sapindus attenuatus* Wall.	Sapindaceae	ST	6.1	1.6	19.6	0.6	3	4.356
120	*Vitex quinata* (Lour.) F.N.Williams	Lamiaceae	LT	2.0	0.8	906.0	0.5	26	19.600
121	*Dalbergia assamica* Benth.	Fabaceae	LT	4.1	2.4	53.7	0.5	10	14.700
122	*Plectocomia himalayana* Griff.	Arecaceae	SS	4.1	2.4	26.4	0.5	20	14.700
123	*Magnolia insignis* Wall.	Magnoliaceae	LT	2.0	0.4	927.3	0.5	17	9.800
124	*Parkia timoriana* (DC.) Merr.	Fabaceae	LT	4.1	1.2	335.2	0.5	12	7.350
125	*Firmiana colorata* (Roxb.) R.Br.	Malvaceae	MT	4.1	1.6	171.2	0.5	13	9.800
126	*Phoebe attenuata* (Nees) Nees	Lauraceae	LT	4.1	0.8	373.8	0.5	15	4.900
127	*Vitex pinnata* L.	Lamiaceae	LT	4.1	1.6	109.7	0.5	7	9.800
128	*Aglaia elaeagnoidea* (A.Juss.) Benth.	Meliaceae	ST	4.1	0.8	290.8	0.5	13	4.900
129	*Trema orientalis* (L.) Blume	Cannabaceae	MT	2.0	0.4	760.0	0.5	25	9.800
130	*Micromelum integerrimum* (Buch-Ham ex DC.) Wight & Arn ex M Roem.	Rutaceae	ST	4.1	1.6	21.8	0.4	4	9.800
131	*Maesa indica* (Roxb.) A. DC.	Primulaceae	ST	4.1	1.6	20.9	0.4	3	9.800
132	*Heritiera macrophylla* Wall. ex Kurz	Malvaceae	LT	4.1	1.6	18.8	0.4	3	9.800
133	*Dasymaschalon longiflorum* (Roxb.) Finet & Gagnep.	Annonaceae	ST	4.1	1.6	18.4	0.4	3	9.800
134	*Toddalia asiatica* (L.) Lam.	Rutaceae	SS	4.1	1.6	15.8	0.4	20	9.800
135	*Antidesma* sp.	Phyllanthaceae	ST	4.1	1.2	84.7	0.4	7	7.350
136	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	LT	2.0	0.4	636.4	0.4	17	9.800
137	*Syzygium cumini* (L.) Skeels	Myrtaceae	LT	2.0	0.4	618.3	0.4	28	9.800
138	*Xantolis assamica* (C. B. Clarke) P. Royen	Sapotaceae	MT	4.1	1.2	24.1	0.4	3	7.350
139	*Olax acuminata* Wall. ex Benth.	Olacaceae	ST	4.1	1.2	23.9	0.4	5	7.350
140	*Symplocos pyrifolia* Wall. ex G. Don	Symplocaceae	ST	2.0	2.4	31.5	0.4	6	58.800
141	*Cinnamomum* sp.	Lauraceae	LT	2.0	0.4	583.0	0.4	21	9.800
142	*Memecylon cerasiforme* Kurz	Melastomataceae	ST	4.1	0.8	89.7	0.4	8	4.900
143	*Randia* sp.	Rubiaceae	MT	2.0	0.4	503.3	0.4	13	9.800
144	*Bauhinia variegata* L.	Fabaceae	ST	4.1	0.8	28.2	0.4	4	4.900
145	*Sterculia hamiltonii* (Kuntze) Adelb.	Malvaceae	ST	4.1	0.8	15.6	0.4	3	4.900
146	*Gomphandra tetrandra* (Wall.) Sleumer	Stemonuraceae	SH	4.1	0.8	14.1	0.4	4	4.900
147	*Reevesia wallichii* R.Br.	Malvaceae	MT	2.0	1.6	107.4	0.3	7	39.200
148	*Zanthoxylum ovalifolium* Wight	Rutaceae	ST	2.0	1.2	71.8	0.3	7	29.400

149	*Elaeocarpus* sp.	Elaeocarpaceae	LT	2.0	0.4	293.0	0.3	19	9.800
150	ML071T37	Unidentified	MT	2.0	0.4	257.2	0.3	14	9.800
151	*Clerodendrum hastatum* (Roxb.) Lindl.	Lamiaceae	SH	2.0	1.2	26.1	0.3	4	29.400
152	*Tectona grandis* L. f.	Lamiaceae	LT	2.0	0.4	240.1	0.3	12	9.800
153	ML081T18	Unidentified	LT	2.0	0.4	218.3	0.3	19	9.800
154	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	MT	2.0	0.4	197.5	0.2	12	9.800
155	*Dracaena elliptica* Thunb. & Dalm.	Asparagaceae	SH	2.0	0.8	69.9	0.2	5	19.600
156	*Cinnamomum glaucescens* (Nees) Hand.-Mazz.	Lauraceae	LT	2.0	0.4	150.1	0.2	12	9.800
157	*Glochidion lanceolarium* (Roxb.) Voigt	Phyllanthaceae	ST	2.0	0.8	19.0	0.2	7	19.600
158	*Nerium oleander* L.	Apocynaceae	SH	2.0	0.8	16.0	0.2	3	19.600
159	*Benkara griffithii* (Hook.f.) Ridsdale	Rubiaceae	ST	2.0	0.8	14.6	0.2	4	19.600
160	*Ficus pyriformis* Hook. & Arn.	Moraceae	SH	2.0	0.8	14.6	0.2	3	19.600
161	*Clerodendrum bracteatum* Wall. ex Walp.	Lamiaceae	SH	2.0	0.8	11.9	0.2	4	19.600
162	*Psychotria adenophylla* Wall.	Rubiaceae	SH	2.0	0.8	10.6	0.2	3	19.600
163	*Hiptage acuminata* Wall. ex A. Juss.	Malpighiaceae	SS	2.0	0.8	7.9	0.2	8	19.600
164	*Ardisia pedunculosa* Wall.	Primulaceae	SH	2.0	0.8	6.5	0.2	3	19.600
165	*Baccaurea ramiflora* Lour.	Phyllanthaceae	MT	2.0	0.4	114.6	0.2	12	9.800
166	*Erythrina stricta* Roxb.	Fabaceae	LT	2.0	0.4	81.2	0.2	13	9.800
167	*Dendrocnide sinuata* (Blume) Chew	Urticaceae	SH	2.0	0.4	48.1	0.2	5	9.800
168	*Cynometra ramiflora* L. var. *ramiflora*	Fabaceae	LT	2.0	0.4	32.2	0.2	6	9.800
169	*Ficus* sp.1	Moraceae	MT	2.0	0.4	31.2	0.2	7	9.800
170	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	ST	2.0	0.4	30.2	0.2	6	9.800
171	*Calliandra umbrosa* (Wall.) Benth.	Fabaceae	ST	2.0	0.4	29.2	0.2	6	9.800
172	*Elaeocarpus prunifolius* Wall. ex Müll.Berol.	Elaeocarpaceae	ST	2.0	0.4	27.3	0.2	4	9.800
173	*Actinodaphne angustifolia* Nees	Lauraceae	MT	2.0	0.4	25.5	0.2	5	9.800
174	*Olea salicifolia* Wall. ex G.Don	Oleaceae	MT	2.0	0.4	17.2	0.2	4	9.800
175	*Garcinia lanceifolia* var. *oxyphylla* (Planch. & Triana) Laness.	Clusiaceae	ST	2.0	0.4	13.0	0.2	4	9.800
176	*Alchornea tiliifolia* (Benth.) Müll.Arg.	Euphorbiaceae	ST	2.0	0.4	9.4	0.2	6	9.800
177	*Litsea lancifolia* (Roxb. ex Nees) Benth. & Hook. f. ex Villar	Lauraceae	ST	2.0	0.4	9.4	0.2	5	9.800
178	*Machilus gamblei* King ex Hook. f.	Lauraceae	MT	2.0	0.4	7.7	0.2	3	9.800
179	*Bauhinia rufa* (Bong.) Steud.	Fabaceae	WC	2.0	0.4	7.3	0.2	25	9.800
180	*Flueggea virosa* (Roxb. ex Willd.) Royle	Phyllanthaceae	SH	2.0	0.4	5.5	0.2	7	9.800
181	*Areca catechu* L.	Arecaceae	MT	2.0	0.4	4.7	0.2	3	9.800
182	*Sapindus erectus* Hiern	Sapindaceae	ST	2.0	0.4	4.7	0.2	3	9.800
183	*Boehmeria macrophylla* Hornem.	Urticaceae	ST	2.0	0.4	3.2	0.2	3	9.800
184	*Mahonia napaulensis* DC.	Berberidaceae	SH	2.0	0.4	3.2	0.2	3	9.800
	Grand Total				973.5	273378.1	300		

The abundance-to-frequency (A/F) ratio suggested that all species exhibited a clumped to highly clumped dispersion. The minimum value of A/F ratio was 1.187 for *Macaranga indica* and maximum was 58.8 for *Symplocos pyrifolia*. A total of six species showed A/F ratio 2 or less and remaining species showed A/F ratio above 2 (Table 4.1).

The stand density was 973.5 individuals ha^{-1} and stand basal area was 27.34 m^2 ha^{-1} (Table 4.2). The mean basal area per individual was 280.83 cm^2 (Table 4.2). Shannon's diversity index was 1.983, Pielou's evenness index was 0.876, Simpson's dominance index was 0.018 and Whittaker's species richness index was 54.182 (Table 4.2).

Table 4.2. Phytosociological attributes and diversity indices in woody layer of tropical evergreen forest in Meghalaya.

Sl. no.	Attribute	Value
1.	Number of species	184
2.	Number of genera	142
3.	Number of families	65
4.	Density (ha^{-1})	973.5
5	Basal area (m^2 ha^{-1})	27.34
6.	Mean basal area (cm^2 $individual^{-1}$)	280.83
7.	Shannon's diversity index	1.983
8.	Evenness index	0.876
9.	Dominance index	0.018
10.	Species richness index	54.182

Of all 184 species in the woody layer, 181 species belonged to 65 identified families and 3 species were placed in an "unidentified" family (Table 4.3). Of these, 32 families were represented by one species, 13 families by two species, 7 families by three species, 4 families by four species and 10 families by more than four species. The family Lauraceae had the maximum 16 species followed by Moraceae with 11 species (Table 4.3). Fabaceae and Rubiaceae were represented by 10 species each. In terms of genera,

Fabaceae, Rubiaceae and Lauraceae were dominant representing 9, 9 and 8 genera, respectively (Table 4.3).

Table 4.3. The number of families, genera, species and individuals recorded in woody layer of the tropical evergreen forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Achariaceae	2	2	26	Malpighiaceae	1	1	2
Actinidiaceae	1	1	31	Malvaceae	7	7	33
Adoxaceae	1	1	14	Melastomataceae	1	1	2
Anacardiaceae	1	1	9	Meliaceae	3	3	30
Annonaceae	3	3	20	Moraceae	2	11	68
Apocynaceae	2	2	3	Myristicaceae	2	2	27
Araliaceae	4	5	191	Myrtaceae	1	3	101
Arecaceae	4	4	63	Olacaceae	1	1	3
Asparagaceae	1	1	2	Oleaceae	2	2	4
Berberidaceae	1	1	1	Pandanaceae	1	1	5
Bignoniaceae	2	2	18	Pentaphylacaceae	1	2	19
Burseraceae	2	2	8	Phyllanthaceae	7	8	66
Calophyllaceae	2	2	8	Polygalaceae	1	1	26
Cannabaceae	1	1	1	Primulaceae	3	4	29
Celastraceae	1	1	16	Proteaceae	1	1	49
Clusiaceae	1	2	50	Rhizophoraceae	1	1	4
Combretaceae	1	1	1	Rosaceae	2	2	24
Cornaceae	1	1	18	Rubiaceae	9	10	77
Crypteroniaceae	1	1	2	Rutaceae	3	3	11
Cyatheaceae	1	1	8	Salicaceae	1	1	7
Dilleniaceae	1	1	8	Sapindaceae	3	4	19
Elaeocarpaceae	1	3	11	Sapotaceae	2	2	60
Euphorbiaceae	5	8	148	Schoepfiaceae	1	1	5
Fabaceae	9	10	34	Staphyleaceae	1	1	3
Fagaceae	3	7	203	Stemonuraceae	1	1	2
Gentianaceae	1	1	3	Styracaceae	1	1	23
Iteaceae	1	1	65	Symplocaceae	1	2	68
Juglandaceae	1	1	12	Tetramelaceae	1	1	1
Lamiaceae	5	7	33	Theaceae	2	2	107
Lauraceae	8	16	218	Ulmaceae	1	1	4
Lecythidaceae	1	1	1	Unidentified	3	3	5
Lythraceae	1	1	11	Urticaceae	3	4	226
Magnoliaceae	1	3	17	Vitaceae	1	1	21

In terms of density, Urticaceae showed the highest number of individuals (226) followed by Lauraceae (218) and Fagaceae (203). Five families, viz., Berberidaceae, Cannabaceae, Combretaceae, Lecythidaceae and Tetramelaceae had only one individual each (Table 4.3).

The dominance-diversity curve for woody layer of tropical evergreen forest (Fig. 4.1) followed a log-normal distribution with a mixed dominance of four species in the canopy (*Schima wallichii*, *Macropanax undulatus*, *Cinnamomum tamala*, *Castanopsis armata*) and one species in the understory (*Boehmeria glomerulifera*).

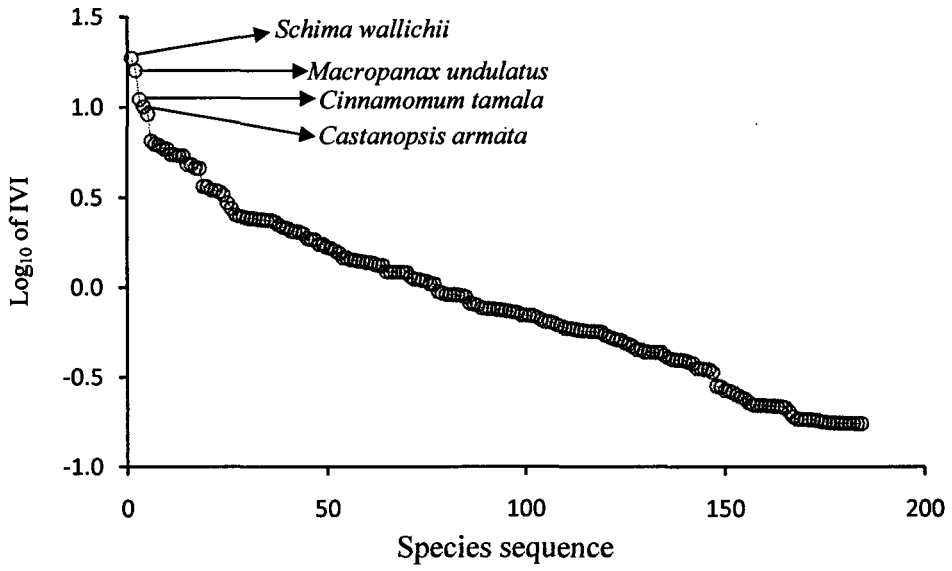

Fig. 4.1. The dominance-diversity curve based on Log_{10} of IVI for woody layer of tropical evergreen forest in Meghalaya.

4.4.2. Tropical Evergreen Forest – herb layer

The floristic composition of the herb layer of tropical evergreen forest is given in Table 4.4. A total of 233 individuals of all species (including tree seedlings) were recorded in herb layer. These belong to 34 families, 56 genera and 64 species. The most dominant species on the basis of IVI is *Strobilanthes anisophylla* (13.0) followed by *Tectaria polymorpha* (9.3), *Strobilanthes colorata* (8.9), *Oldenlandia verticellata* (7.3), *Oplismenus compositus* (7.3) and *Curcuma aromatica* (6.3) (Table 4.4). The endemic species to Meghalaya were: *Baliospermum calycinum* var. *micranthum.*

Table 4.4. Floristic composition of herb layer of tropical evergreen forest based on 20 quadrats of 1 x 1 m size. Species are arranged in descending order of IVI values.

Sl. no.	Species Name	Family	Occurrence	No. of individuals	IVI
1	*Strobilanthes anisophylla* T.Anderson	Acanthaceae	6	15	13.0
2	*Tectaria polymorpha* (Wall. ex Hook.) Copel.	Dryopteridaceae	3	14	9.3
3	*Strobilanthes colorata* T.Anderson	Acanthaceae	3	13	8.9
4	*Oldenlandia verticillata* L.	Rubiaceae	2	12	7.3
5	*Oplismenus compositus* (L.) P. Beauv.	Poaceae	2	12	7.3
6	*Curcuma aromatica* Salisb.	Zingiberaceae	3	7	6.3
7	*Chloranthus elatior* Link	Chloranthaceae	2	8	5.6
8	*Trigonostemon semperflorens* (Roxb.) Mull.Arg.	Euphorbiaceae	3	5	5.4
9	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet	Lauraceae	3	4	5.0
10	*Dracaena spicata* Roxb.	Asparagaceae	2	5	4.3
11	*Mussaenda roxburghii* Hook.f.	Rubiaceae	2	5	4.3
12	*Oldenlandia cristata* (Willd. ex Roem. & Schult.) ined.	Rubiaceae	1	7	4.1
13	*Piper pedicellosum* Wall.	Piperaceae	2	4	3.9
14	*Pterygota alata* (Roxb.) R. Br.	Malvaceae	2	4	3.9
15	*Syzygium tetragonum* (Wight) Wall. Ex Walp.	Myrtaceae	2	4	3.9
16	*Wallichia disticha* T.Anderson	Arecaceae	2	4	3.9
17	*Strobilanthes brunoniana* Nees	Acanthaceae	1	6	3.7
18	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Lauraceae	2	3	3.5
19	*Clerodendrum wallichii* Merr.	Lamiaceae	2	3	3.5
20	*Tabernaemontana divaricata* (L.) R. Br. ex Roem. & Schult.	Apocynaceae	2	3	3.5
21	*Anoectochilus setaceus* Blume	Orchidaceae	1	5	3.2
22	*Elatostema rupestre* (Buch.-Ham. ex D.Don) Wedd.	Urticaceae	1	5	3.2
23	*Morinda angustifolia* Roxb.	Rubiaceae	1	5	3.2

24	*Pogostemon parviflorus* Benth.	Lamiaceae	1	5	3.2
25	*Chloranthus brachystachys* Blume	Chloranthaceae	1	4	2.8
26	*Microlepia speluncae* (L.) T. Moore	Dennstaedtiaceae	1	4	2.8
27	*Pilea glaberrima* (Blume) Blume	Urticaceae	1	4	2.8
28	*Achyrospermum wallichianum* Benth. ex Hk.f.	Lamiaceae	1	3	2.4
29	*Albizia chinensis* (Osbeck) Merr.	Fabaceae	1	3	2.4
30	*Baliospermum calycinum* var. *micranthum* (Mull.Arg.) Chakrab. & N. P. Balakr.	Euphorbiaceae	1	3	2.4
31	*Dichrocephala integrifolia* (L.f.) Kuntze	Asteraceae	1	3	2.4
32	*Psychotria silhetensis* Hook.f.	Rubiaceae	1	3	2.4
33	*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda	Poaceae	1	3	2.4
34	*Utricularia bifida* L.	Lentibulariaceae	1	3	2.4
35	*Amomum aromaticum* Roxb.	Zingiberaceae	1	2	2.0
36	*Begonia hatacoa* Buch.-Ham. ex D.Don var. *hatacoa*	Begoniaceae	1	2	2.0
37	*Boehmeria macrophylla* Hornem.	Urticaceae	1	2	2.0
38	*Canthium parvifolium* Roxb.	Rubiaceae	1	2	2.0
39	*Jasminum listeri* King ex Gage	Oleaceae	1	2	2.0
40	*Lobelia zeylanica* L.	Campanulaceae	1	2	2.0
41	*Aralia gigantea* J.Wen	Araliaceae	1	2	2.0
42	*Mycetia longifolia* (Wall.) Kuntze	Rubiaceae	1	2	2.0
43	*Psychotria calocarpa* Kurz	Rubiaceae	1	2	2.0
44	*Reinwardtia indica* Dumort.	Linaceae	1	2	2.0
45	*Setaria plicata* (Lam.) T.Cooke	Poaceae	1	2	2.0
46	*Zingiber zerumbet* (L.) Roscoe ex Sm.	Zingiberaceae	1	2	2.0
47	*Acacia pennata* (L.) Willd.	Fabaceae	1	1	1.5
48	*Adenostemma viscosum* J.R.Forst. & G.Forst.	Asteraceae	1	1	1.5
49	*Clerodendrum infortunatum* L.	Lamiaceae	1	1	1.5
50	*Dioscorea glabra* Roxb.	Dioscoreaceae	1	1	1.5
51	*Disporum cantoniense* (Lour.) Merr.	Asparagaceae	1	1	1.5
52	*Goniothalamus sesquipedalis* (Wall.) Hook.f. & Thomson	Annonaceae	1	1	1.5
53	*Impatiens* sp.	Balsaminaceae	1	1	1.5
54	*Impatiens bracteata* Colebr.	Balsaminaceae	1	1	1.5
55	*Ixora subsessilis* Wall. ex G.Don	Rubiaceae	1	1	1.5
56	*Lasianthus biermannii* King ex Hook.f.	Rubiaceae	1	1	1.5
57	*Mesua ferrea* L.	Calophyllaceae	1	1	1.5
58	*Myrioneuron nutans* Wall. ex Hook.f.	Rubiaceae	1	1	1.5
59	*Ostodes paniculata* Blume	Euphorbiaceae	1	1	1.5
60	*Phrynium pubinerve* Blume	Marantaceae	1	1	1.5
61	*Sabia lanceolata* Colebr.	Sabiaceae	1	1	1.5
62	*Scutellaria discolor* Colebr.	Lamiaceae	1	1	1.5
63	*Stephania japonica* var. *discolor* (Blume) Forman	Menispermaceae	1	1	1.5
64	*Tetrastigma serrulatum* (Roxb.) Planch.	Vitaceae	1	1	1.5
	Grand Total			233	200

The density was 1165 individuals/100 m^2 (Table 4.5). The Shannon's diversity index was 1.725, evenness index was 0.955, dominance index was 0.023 and species richness index was 26.61 (Table 4.5).

Table 4.5. Phytosociological attributes and diversity indices in herb layer of the tropical evergreen forest in Meghalaya.

Sl. No.	Attribute	Value
1.	Number of species	64
2.	Number of genera	56
3.	Number of families	34
4.	Density (100 m^{-2})	1165
5.	Shannon's diversity index	1.725
6.	Evenness index	0.955
7.	Dominance index	0.023
8.	Species richness index	26.612

Rubiaceae was the most dominant family with 9 genera, 11 species and 41 individuals (Table 4.6).

Table 4.6. The number of families, genera, species and individuals recorded in herb layer of the tropical evergreen forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Acanthaceae	1	3	34	Lamiaceae	4	5	13
Annonaceae	1	1	1	Lauraceae	1	2	7
Apocynaceae	1	1	3	Lentibulariaceae	1	1	3
Araliaceae	1	1	2	Linaceae	1	1	2
Arecaceae	1	1	4	Malvaceae	1	1	4
Asparagaceae	2	2	6	Marantaceae	1	1	1
Asteraceae	2	2	4	Menispermaceae	1	1	1
Balsaminaceae	1	2	2	Myrtaceae	1	1	4
Begoniaceae	1	1	2	Oleaceae	1	1	2
Calophyllaceae	1	1	1	Orchidaceae	1	1	5
Campanulaceae	1	1	2	Piperaceae	1	1	4
Chloranthaceae	1	2	12	Poaceae	3	3	17
Dennstaedtiaceae	1	1	4	Rubiaceae	9	11	41
Dioscoreaceae	1	1	1	Sabiaceae	1	1	1
Dryopteridaceae	1	1	14	Urticaceae	3	3	11
Euphorbiaceae	3	3	9	Vitaceae	1	1	1
Fabaceae	2	2	4	Zingiberaceae	3	3	11

The dominance-diversity curve for herb layer of tropical evergreen forest (Fig. 4.2) followed a log-normal distribution with a mixed dominance of *Strobilanthes anisophylla*, *Tectaria polymorpha*, *Strobilanthes colorata*, *Oldenlandia verticillata* and *Oplismenus compositus*.

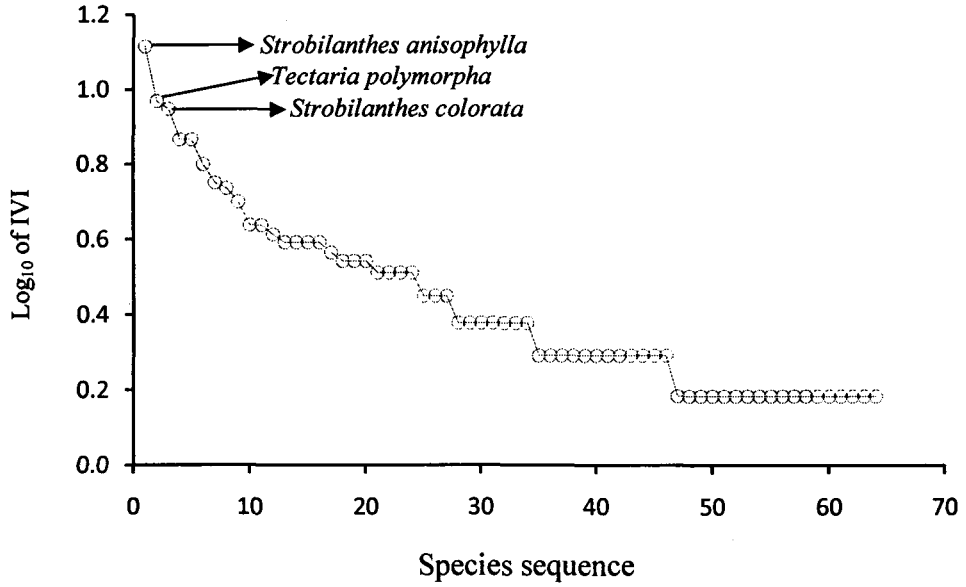

Fig. 4.2. The dominance-diversity curve based on Log_{10} of IVI for herb layer of tropical evergreen forest in Meghalaya.

4.4.3. Tropical Moist Mixed-Deciduous Forest – woody layer

The floristic composition of the woody layer of tropical moist mixed deciduous forest (Table 4.7) exhibited a total of 1,496 individuals of ≥10 cm gbh in 2.5 ha sampled area (five transects of 10 m width and 500 m length, Tables 3.5 & 3.7 in Chapter III). Overall, 95 species of 75 genera in 36 families occurred. Of all, 92 species were identified up to species level, and 3 species up to genus level (Table 4.7). The majority of species were medium tree (37 species) followed by large tree (24 species), small tree (22 species), shrub (5 species), woody climber (5 species) and scandent shrub (2 species) (Table 4.7).

In terms of number of individuals (density), the most dominant species were: *Microcos paniculata* (209 individuals), *Bauhinia purpurea* (96 individuals), *Aporosa octandra* var. *octandra* (67 individuals), *Schima wallichii* (66 individuals) and *Callicarpa arborea* (64 individuals). Seven species had only one individual each, whereas twelve species only 2 individuals each. The remainder species were represented by 3 to 209 individuals (Table 4.7).

In terms of IVI, the most dominant species were: *Microcos paniculata* (28.2), *Schima walllichii* (24.2), *Dillenia indica* (20.6), *Tetrameles nudiflora* (18.7) and *Bauhinia purpurea* (16.6) (Table 4.7). Of all, 39 species were rare as they exhibited an Importance Value of 1 or less. A majority of species (39 species) exhibited an Importance Value between >1 and <5, and 12 species exhibited an Importance Value between >5 and <10 (Table 4.7).

Table 4.7. Floristic composition, habit (LT- Large Tree, MT- Medium Tree, ST- Small Tree, SH- Shrub, SS- Scandent Shrub, WC- Woody Climber), frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), maximum height (m) and abundance-to-frequency ratio (A/F) of tropical moist mixed-deciduous forest type in Meghalaya. Species are arranged in descending order of IVI values.

Sl. no.	Species name	Family	Habit	Freq-ency (%)	Den-sity (ha^{-1})	Basal Area (cm^2 ha^{-1})	IVI	Max height (m)	A/F ratio
1	*Microcos paniculata* L.	Malvaceae	MT	70	83.6	13237.1	28.2	15	1.706
2	*Schima wallichii* Choisy	Theaceae	LT	56	26.4	24545.1	24.2	27	0.842
3	*Dillenia indica* L.	Dilleniaceae	LT	38	14.0	24619.7	20.6	25	0.970
4	*Tetrameles nudiflora* R. Br.	Tetramelaceae	LT	20	14.8	23967.8	18.7	26	3.700
5	*Bauhinia purpurea* L.	Fabaceae	ST	42	38.4	10721.6	16.6	15	2.177
6	*Aporosa octandra* (Buch.-Ham. ex D.Don) Vickery var. *octandra*	Phyllanthaceae	ST	42	26.8	1973.9	9.4	11	1.519
7	*Ochna wallichii* Planch.	Ochnaceae	MT	30	18.0	4648.5	8.5	15	2.000
8	*Callicarpa arborea* Roxb.	Lamiaceae	MT	24	25.6	3423.6	8.5	12	4.444
9	*Syzygium cumini* (L.) Skeels	Myrtaceae	LT	22	12.4	5599.8	7.4	16	2.562
10	*Dalbergia stipulacea* Roxb.	Fabaceae	ST	42	19.2	693.3	7.3	12	1.088
11	*Phoebe lanceolata* (Nees) Nees	Lauraceae	ST	28	15.2	3672.1	7.2	13	1.939
12	*Wrightia arborea* (Dennst.) Mabb.	Apocynaceae	ST	32	13.2	2489.1	6.5	13	1.289
13	*Polyalthia simiarum* (Buch.-Ham. ex Hook. f. & Thomson) Benth.	Annonaceae	LT	32	13.6	674.2	5.5	13	1.328
14	*Lithocarpus thomsonii* (Miq.) Rehder	Fagaceae	LT	14	5.2	5531.7	5.4	24	2.653
15	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	LT	16	7.6	4498.1	5.4	16	2.969
16	*Holarrhena pubescens* Wall.	Apocynaceae	ST	26	13.6	1340.8	5.4	12	2.012
17	*Vitex pinnata* L.	Lamiaceae	LT	16	7.6	4417.9	5.4	24	2.969
18	*Mallotus roxburghianus* Müll.Arg.	Euphorbiaceae	ST	24	13.2	449.2	4.6	9	2.292
19	*Litsea laeta* (Nees) Hook. f.	Lauraceae	MT	20	8.0	2338.4	4.5	22	2.000
20	*Leea indica* (Burm. f.) Merr.	Vitaceae	ST	26	11.2	428.9	4.4	8	1.657
21	*Vitex peduncularis* Wall. ex Schauer	Lamiaceae	LT	18	7.2	1759.0	3.9	14	2.222
22	*Machilus glaucescens* (Nees) Wight	Lauraceae	MT	16	10.4	1099.4	3.8	11	4.063
23	*Lagerstroemia parviflora* Roxb.	Lythraceae	MT	16	8.8	1279.2	3.7	16	3.438
24	*Pterospermum acerifolium* (L.) Willd.	Malvaceae	LT	20	6.0	1411.7	3.6	20	1.500
25	*Mitrephora tomentosa* Hook. f. & Thomson	Annonaceae	LT	16	11.2	363.7	3.5	12	4.375
26	*Pterospermum lanceifolium* Roxb.	Malvaceae	MT	6	10.8	1054.8	3.0	10	30.000
27	*Actinodaphne angustifolia* Nees	Lauraceae	MT	14	6.0	982.3	2.8	12	3.061
28	*Licuala peltata* Roxb. ex Buch.-Ham.	Arecaceae	ST	16	6.8	429.2	2.8	6	2.656
29	*Zanthoxylum rhetsa* DC.	Rutaceae	LT	12	2.8	2080.7	2.8	23	1.944

30	*Lepisanthes* sp.	Sapindaceae	LT	12	4.0	1243.3	2.5	20	2.778
31	*Aphania* sp.	Sapindaceae	MT	12	5.6	667.9	2.4	12	3.889
32	*Balakata baccata* (Roxb.) Esser	Euphorbiaceae	MT	16	4.4	299.9	2.3	10	1.719
33	*Syzygium formosum* (Wall.) Masam.	Myrtaceae	MT	10	6.8	440.8	2.3	8	6.800
34	*Streblus ilicifolius* (Vidal) Corner	Moraceae	SH	10	7.6	189.4	2.3	5	7.600
35	*Bauhinia malabarica* Roxb.	Fabaceae	MT	10	3.2	738.5	1.9	13	3.200
36	*Aphanamixis polystachya* (Wall.) R. Parker	Meliaceae	MT	10	4.0	335.6	1.8	11	4.000
37	*Chukrasia tabularis* A. Juss.	Meliaceae	LT	10	4.0	257.1	1.7	9	4.000
38	*Persea odoratissima* (Nees) Kosterm.	Lauraceae	MT	10	4.0	156.5	1.6	6	4.000
39	*Kydia calycina* Roxb.	Malvaceae	MT	4	4.8	788.0	1.6	12	30.000
40	*Aglaia* sp.	Meliaceae	MT	10	3.2	301.5	1.6	16	3.200
41	*Dillenia scabrella* (D.Don) Roxb. ex Wall.	Dilleniaceae	LT	10	3.2	160.2	1.5	7	3.200
42	*Croton joufra* Roxb.	Euphorbiaceae	MT	10	2.8	186.1	1.5	8	2.800
43	*Pterygota alata* (Roxb.) R.Br.	Malvaceae	LT	8	3.2	329.1	1.4	9	5.000
44	*Trichilia connaroides* (Wight & Arn.) Bentv. var. *connaroides*	Meliaceae	MT	10	2.8	82.8	1.4	9	2.800
45	*Ficus semicordata* Buch.-Ham. ex Sm.	Moraceae	MT	8	1.6	700.5	1.4	15	2.500
46	*Ligustrum robustum* (Roxb.) Blume	Oleaceae	MT	4	2.8	929.1	1.4	10	17.500
47	*Cleidion javanicum* Blume	Euphorbiaceae	MT	8	3.6	118.1	1.4	6	5.625
48	*Streblus asper* Lour.	Moraceae	ST	6	2.0	808.8	1.4	16	5.556
49	*Hibiscus macrophyllus* Roxb. ex Hornem.	Malvaceae	MT	6	2.0	708.7	1.3	12	5.556
50	*Diospyros pilosiuscula* G.Don	Ebenaceae	LT	6	1.6	806.5	1.3	13	4.444
51	*Glochidion sphaerogynum* (Mull.Arg.) Kurz	Phyllanthaceae	MT	8	2.4	224.4	1.2	7	3.750
52	*Oxyceros longiflorus* (Lam.) T. Yamaz.	Rubiaceae	SS	8	2.4	89.5	1.2	8	3.750
53	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	Lauraceae	ST	8	2.4	73.1	1.2	6	3.750
54	*Firmiana colorata* (Roxb.) R.Br.	Malvaceae	MT	8	2.0	91.0	1.1	7	3.125
55	*Boehmeria glomerulifera* Miq.	Urticaceae	SH	8	2.0	47.2	1.1	6	3.125
56	*Macaranga denticulata* (Blume) Müll.Arg.	Euphorbiaceae	MT	4	3.6	156.4	1.0	5	22.500
57	*Aspidopterys elliptica* (Blume) A.Juss.	Malpighiaceae	WC	6	2.4	71.6	1.0	13	6.667
58	*Dillenia pentagyna* Roxb.	Dilleniaceae	LT	2	1.2	956.0	1.0	15	30.000
59	*Lagerstroemia speciosa* (L.) Pers.	Lythraceae	ST	4	2.4	306.9	0.9	12	15.000
60	*Olax acuminata* Wall. ex Benth.	Olacaceae	ST	6	2.0	66.9	0.9	6	5.556
61	*Knema linifolia* (Roxb.) Warb.	Myristicaceae	LT	6	2.0	57.1	0.9	5	5.556
62	*Saraca indica* L.	Fabaceae	MT	6	2.0	44.0	0.9	5	5.556
63	*Hyptianthera stricta* (Roxb. ex Schult.) Wight & Arn.	Rubiaceae	ST	6	2.0	38.0	0.9	5	5.556
64	*Engelhardtia spicata* Lechen ex Blume	Juglandaceae	LT	4	2.0	296.8	0.9	10	12.500
65	*Ficus hispida* L. f.	Moraceae	ST	4	2.8	57.4	0.9	4	17.500
66	*Garcinia xanthochymus* Hook.f. ex T.Anderson	Clusiaceae	MT	6	1.6	57.6	0.8	7	4.444
67	*Mallotus philippensis* (Lam.) Müll.Arg.	Euphorbiaceae	ST	6	1.6	37.1	0.8	5	4.444
68	*Leea aequata* L.	Vitaceae	SH	6	1.6	14.1	0.8	3	4.444

69	*Croton persimilis* Müll.Arg.	Euphorbiaceae	MT	4	2.0	187.0	0.8	8	12.500
70	*Amblyanthus glandulosus* (Roxb.) A.DC.	Primulaceae	SH	4	2.4	30.3	0.8	4	15.000
71	*Sterculia villosa* Roxb.	Malvaceae	MT	6	1.2	61.8	0.8	8	3.333
72	*Symplocos ferruginea* Roxb.	Symplocaceae	ST	4	1.6	49.3	0.7	5	10.000
73	*Murraya paniculata* (L.) Jack	Rutaceae	ST	4	1.6	30.9	0.6	4	10.000
74	*Spatholobus parviflorus* (DC.) Kuntze	Fabaceae	WC	4	1.2	118.6	0.6	15	7.500
75	*Stereospermum chelonoides* (L. f.) DC.	Bignoniaceae	LT	2	0.4	614.8	0.6	18	10.000
76	*Careya arborea* Roxb.	Lecythidaceae	MT	4	1.2	25.3	0.6	4	7.500
77	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	ST	4	0.8	125.1	0.6	10	5.000
78	*Albizia lebbeck* (L.) Benth.	Fabaceae	LT	2	0.4	497.2	0.5	16	10.000
79	*Bridelia glauca* Blume	Phyllanthaceae	MT	4	0.8	90.8	0.5	8	5.000
80	*Bridelia retusa* (L.) A. Juss.	Phyllanthaceae	MT	4	0.8	66.0	0.5	8	5.000
81	*Antidesma acidum* Retz.	Phyllanthaceae	ST	4	0.8	9.6	0.5	3	5.000
82	*Pandanus furcatus* Roxb.	Pandanaceae	ST	4	0.8	8.5	0.5	3	5.000
83	*Combretum album* Pers.	Combretaceae	WC	2	1.6	71.0	0.5	18	40.000
84	*Caryota urens* L.	Arecaceae	LT	2	0.4	344.1	0.5	18	10.000
85	*Ficus lamponga* Miq.	Moraceae	MT	2	0.8	185.6	0.4	12	20.000
86	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	MT	2	0.8	143.8	0.4	12	20.000
87	*Litsea glutinosa* (Lour.) C.B. Rob. var. *glutinosa*	Lauraceae	ST	2	0.8	90.2	0.4	10	20.000
88	*Dendrocnide sinuata* (Blume) Chew	Urticaceae	SH	2	0.8	54.7	0.3	7	20.000
89	*Artocarpus chaplasha* Roxb.	Moraceae	LT	2	0.8	46.5	0.3	6	20.000
90	*Macaranga indica* Wight	Euphorbiaceae	MT	2	0.8	41.4	0.3	7	20.000
91	*Bridelia stipularis* (L.) Blume	Phyllanthaceae	SS	2	0.8	6.7	0.3	6	20.000
92	*Chisocheton cumingianus* subsp. *balansae* (C.DC.) Mabb.	Meliaceae	MT	2	0.4	41.2	0.3	8	10.000
93	*Chionanthus ramiflorus* Roxb.	Oleaceae	MT	2	0.4	18.3	0.3	5	10.000
94	*Acacia concinna* (Willd.) DC.	Fabaceae	WC	2	0.4	14.0	0.3	15	10.000
95	*Acacia pennata* (L.) Willd.	Fabaceae	WC	2	0.4	10.3	0.3	10	10.000
	Grand Total				598.4	165647.1	300		

The abundance-to-frequency ratio suggested that all species exhibited a clumped to highly clumped dispersion. The minimum value of A/F ratio was 0.842 for *Schima wallichii* and maximum 40.0 for *Combretum album*. A total of fourteen species showed A/F ratio 2 or less and remaining species showed A/F ratio above 2 (Table 4.7).

The stand density was 598.4 individuals ha^{-1} and stand basal area was 16.56 m^2 ha^{-1} (Table 4.8). The mean basal area per individual was 276.82 cm^2 (Table 4.8). Shannon's diversity index was 1.665, Pielou's evenness index was 0.842, Simpson's dominance index was 0.036 and Whittaker's species richness index was 29.607 (Table 4.8).

Table 4.8. Phytosociological attributes and diversity indices in woody layer of tropical moist mixed-deciduous forest in Meghalaya.

Sl. No.	Attribute	Value
1.	Number of species	95
2.	Number of genera	75
3.	Number of families	36
4.	Density (ha^{-1})	598.4
5	Basal area (m^2 ha^{-1})	16.56
6.	Mean basal area (cm^2 $individual^{-1}$)	276.82
7.	Shannon's diversity index	1.665
8.	Evenness index	0.842
9.	Dominance index	0.036
10.	Species richness index	29.607

A total 36 families were recorded. Of these, 14 families were represented by one species and remainder by 2-8 species. The family Euphorbiaceae, Fabaceae, Lauraceae and Malvaceae had the highest number of 8 species each. In terms of genera, Malvaceae and Fabaceae were dominant representing 7 and 6 genera, respectively (Table 4.9).

Table 4.9. The number of families, genera, species and individuals recorded in woody layer of the tropical moist mixed-deciduous forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Annonaceae	2	2	62	Meliaceae	5	5	36
Apocynaceae	2	2	67	Moraceae	3	6	39
Arecaceae	2	2	18	Myristicaceae	1	1	5
Bignoniaceae	2	2	3	Myrtaceae	1	2	48
Clusiaceae	1	1	4	Ochnaceae	1	1	45
Combretaceae	2	2	23	Olacaceae	1	1	5
Dilleniaceae	1	3	46	Oleaceae	2	2	8
Ebenaceae	1	1	4	Pandanaceae	1	1	2
Euphorbiaceae	5	8	80	Phyllanthaceae	4	6	81
Fabaceae	6	8	163	Primulaceae	1	1	6
Fagaceae	1	1	13	Rubiaceae	2	2	11
Juglandaceae	1	1	5	Rutaceae	2	2	11
Lamiaceae	2	3	101	Sapindaceae	2	2	24
Lauraceae	5	8	119	Symplocaceae	1	1	4
Lecythidaceae	1	1	3	Tetramelaceae	1	1	37
Lythraceae	1	2	28	Theaceae	1	1	66
Malpighiaceae	1	1	6	Urticaceae	2	2	7
Malvaceae	7	8	284	Vitaceae	1	2	32

In terms of density, Malvaceae showed the highest number of individuals (284) followed by Fabaceae (163), Lauraceae (119) and Lamiaceae (101). Thirteen families were represented by <10 individuals (Table 4.9).

The dominance-diversity curve for woody layer of tropical moist mixed-deciduous forest (Fig. 4.3) followed a log-normal distribution with a mixed dominance of three species in the top canopy (*Tetrameles nudiflora, Dillenia indica, Schima wallichii*) and two species in subcanopy (*Bauhinia purpurea, Microcos paniculata*).

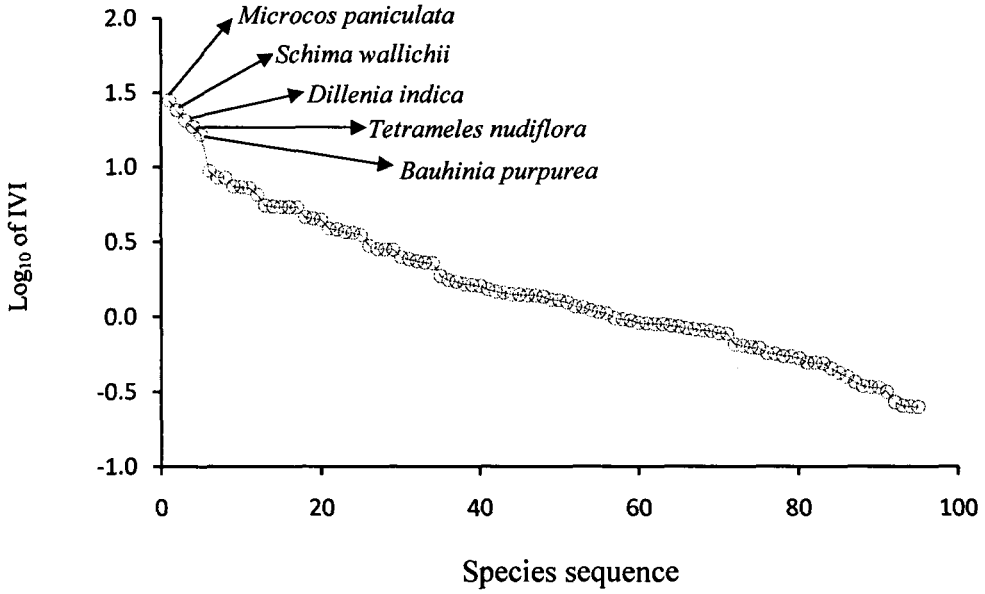

Fig. 4.3. The dominance-diversity curve based on Log_{10} of IVI for woody layer of tropical moist mixed-deciduous forest in Meghalaya.

4.4.4. Tropical Moist Mixed-Deciduous Forest – herb layer

The floristic composition of herb layer of tropical moist mixed-deciduous forest is given in Table 4.10. A total of 206 individuals of all species (including tree seedlings) were recorded in herb layer. These belong to 25 families, 36 genera and 38 species. The most dominant species on the basis of IVI are *Lepidagathes incurva* (30.2) and *Chromolaena odorata* (19.8) (Table 4.10).

The endemic species to Meghalaya were: *Strobilanthes acrocephala.*

Table 4.10. Floristic composition of herb layer of tropical moist mixed-deciduous forest based on 19 quadrats of 1 x 1 m size. Species are arranged in descending order of IVI values.

Sl. no.	Species Name	Family	Occurrence	No. of individuals	IVI
1	*Lepidagathis incurva* Buch.-Ham. ex D. Don	Acanthaceae	6	41	30.2
2	*Chromolaena odorata* (L.) R.M. King & H. Rob.	Asteraceae	5	23	19.8
3	*Mallotus roxburghianus* Müll.Arg.	Euphorbiaceae	4	10	11.8
4	*Elatostema lineolatum* Wight	Urticaceae	1	16	9.5
5	*Oplismenus compositus* (L.) P. Beauv.	Poaceae	3	8	9.1
6	*Achyrospermum wallichianum* Benth. ex Hk.f.	Lamiaceae	2	11	8.8
7	*Lygodium japonicum* (Thunb.) Sw.	Schizaeaceae	3	5	7.6
8	*Phaulopsis imbricata* subsp. *madagascariensis* Manktelow	Acanthaceae	1	10	6.6
9	*Impatiens rutenbergii* O. Hoffm.	Balsaminaceae	2	5	5.9
10	*Cheilocostus speciosus* (J. Koenig) C. D. Specht	Costaceae	1	8	5.6
11	*Elatostema platyphyllum* Wedd.	Urticaceae	1	8	5.6
12	*Clerodendrum infortunatum* L.	Lamiaceae	2	3	4.9
13	*Dracaena spicata* Roxb.	Asparagaceae	1	6	4.6
14	*Persicaria chinensis* (L.) H. Gross	Polygonaceae	2	2	4.4
15	*Acmella paniculata* (Wall. ex DC.) R. K. Jansen	Asteraceae	1	5	4.2
16	*Angiopteris indica* Desv.	Marattiaceae	1	4	3.7
17	*Bambusa* sp.2	Poaceae	1	4	3.7
18	*Elephantopus scaber* L.	Asteraceae	1	3	3.2
19	*Lindenbergia urticifolia* Lehm.	Plantaginaceae	1	3	3.2
20	*Strobilanthes acrocephala* T. Anderson	Acanthaceae	1	3	3.2
21	*Strobilanthes anisophylla* T. Anderson	Acanthaceae	1	3	3.2
22	*Torenia indica* C. J. Saldanha	Linderniaceae	1	3	3.2
23	*Aglaonema hookerianum* Schott	Araceae	1	2	2.7
24	*Alternanthera sessilis* (L.) DC.	Amaranthaceae	1	2	2.7
25	*Chassalia curviflora* (Wall.) Thwaites	Rubiaceae	1	2	2.7
26	*Cyanthillium cinereum* (L.) H.Rob.	Asteraceae	1	2	2.7
27	*Dillenia indica* L.	Dilleniaceae	1	2	2.7
28	*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda	Poaceae	1	2	2.7
29	*Aesculus assamica* Griff.	Sapindaceae	1	1	2.2
30	*Ardisia colorata* Link	Primulaceae	1	1	2.2
31	*Bauhinia purpurea* L.	Fabaceae	1	1	2.2
32	*Cyclea bicristata* (Griff.) Diels	Menispermaceae	1	1	2.2
33	*Gomphostemma parviflorum* Wall. ex Benth.	Lamiaceae	1	1	2.2
34	*Leea indica* (Burm. f.) Merr.	Vitaceae	1	1	2.2
35	*Merremia vitifolia* (Burm. f.) Hallier f.	Convolvulaceae	1	1	2.2
36	*Tabernaemontana divaricata* (L.) R.Br. ex Roem. & Schult.	Apocynaceae	1	1	2.2
37	*Tadehagi triquetrum* (L.) H.Ohashi	Fabaceae	1	1	2.2
38	*Vitex peduncularis* Wall. ex Schauer	Lamiaceae	1	1	2.2
	Grand Total			206	200

The density was 1084.2 individuals/100 m^2 (Table 4.11). The Shannon's diversity index was 1.437, evenness index was 0.910, dominance index was 0.054 and species richness index was 15.991 (Table 4.11).

Table 4.11. Phytosociological attributes and diversity indices in herb layer of the tropical moist mixed-deciduous forest in Meghalaya.

Sl. No.	Attribute	Value
1.	Number of species	38
2.	Number of genera	36
3.	Number of families	25
4.	Density (100 m^{-2})	1084.2
5.	Shannon's diversity index	1.437
6.	Evenness index	0.910
7.	Dominance index	0.054
8.	Species richness index	15.991

Acanthaceae, Asteraceae and Lamiaceae were the most dominant families with 4 species each (Table 4.12). In terms of genera, Asteraceae (4 genera) and Lamiaceae (4 genera) were dominant (Table 4.12). Acanthaceae was the most dominant family in terms of number of individuals (57 individuals) followed by Asteraceae (33 individuals) and Urticaceae (24 individuals) (Table 4.12).

The dominance-diversity curve for herb layer of tropical moist mixed-deciduous forest (Fig. 4.4) followed a log-normal distribution with a mixed dominance of *Lepidagathis incurva, Chromolaena odorata, Mallotus roxburghianus* and *Elatostema lineolatum.*

Table 4.12. The number of families, genera, species and individuals recorded in herb layer of the tropical moist mixed-deciduous forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Acanthaceae	3	4	57	Linderniaceae	1	1	3
Amaranthaceae	1	1	2	Marattiaceae	1	1	4
Apocynaceae	1	1	1	Menispermaceae	1	1	1
Araceae	1	1	2	Plantaginaceae	1	1	3
Asparagaceae	1	1	6	Poaceae	3	3	14
Asteraceae	4	4	33	Polygonaceae	1	1	2
Balsaminaceae	1	1	5	Primulaceae	1	1	1
Convolvulaceae	1	1	1	Rubiaceae	1	1	2
Costaceae	1	1	8	Sapindaceae	1	1	1
Dilleniaceae	1	1	2	Schizaeaceae	1	1	5
Euphorbiaceae	1	1	10	Urticaceae	1	2	24
Fabaceae	2	2	2	Vitaceae	1	1	1
Lamiaceae	4	4	16				

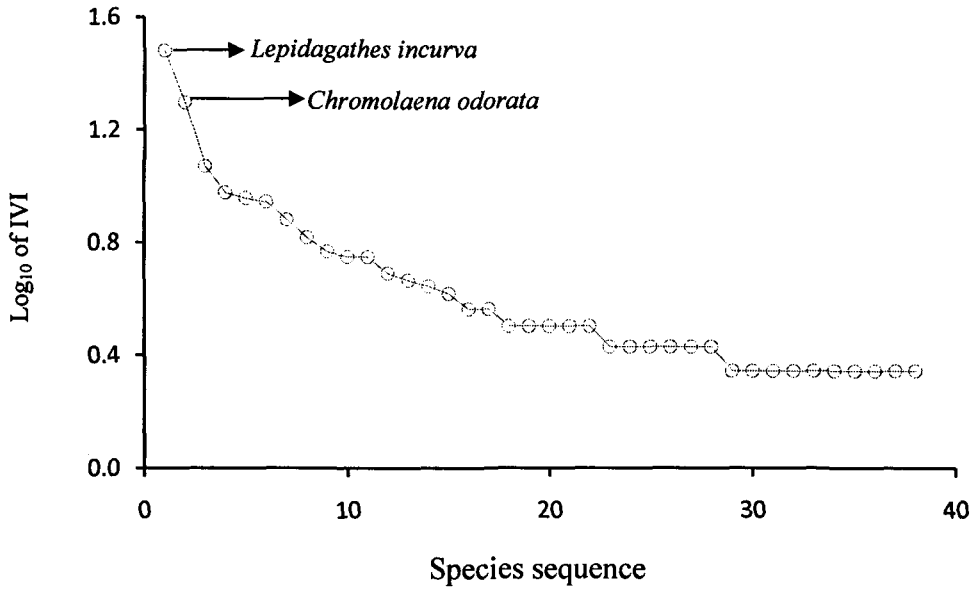

Fig. 4.4. The dominance-diversity curve based on Log_{10} of IVI for herb layer of tropical moist mixed-deciduous forest in Meghalaya.

4.4.5. Khasi Hill Sal-Pine Forest – woody layer

The floristic composition of the woody layer of Khasi hill sal-pine forest (Table 4.13) exhibited a total of 4,589 individuals of ≥10 cm gbh in 5.2 ha sampled area (11 transects of 10 m width and upto 500 m length, Tables 3.5 & 3.7 in Chapter III). Overall, 123 species of 89 genera in 47 families occurred. Of all, 119 species were identified up to species level, 2 species up to genus level and 2 species could not be determined (Table 4.13). The majority of species were small tree (41 species) followed by large tree (36 species), medium tree (36 species), shrub (5 species), woody climber (3 species) and scandent shrub (2 species) (Table 4.13). The endemic species to Meghalaya were: none.

In terms of of number of individuals (density), the most dominant species were: *Shorea robusta* (1061 individuals), *Schima wallichii* (749 individuals), *Pinus kesiya* (266 individuals) and *Careya arborea* (255 individuals). Fourteen species had only one individual each, whereas eighteen species only 2 individuals each. The remainder species were represented by 3 to 1061 individuals (Table 4.13).

In terms of IVI, the most dominant species were: *Shorea robusta* (55.7), *Schima walllichii* (47.2), *Pinus kesiya* (22.5) and *Careya arborea* (14.8) (Table 4.13). Of all, 83 species were rare as they exhibited an Importance Value of 1 or less. A majority of species (27 species) exhibited an Importance Value between >1 and <5, and 9 species exhibited an Importance Value between >5 and <10 (Table 4.13).

Table 4.13. Floristic composition, habit (LT- Large Tree, MT- Medium Tree, ST- Small Tree, SH- Shrub, SS- Scandent Shrub, WC- Woody Climber), frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), maximum height (m) and abundance-to-frequency ratio (A/F) of Khasi hill sal-pine forest type in Meghalaya. Species are arranged in descending order of IVI values.

Sl. no.	Species name	Family	Habit	Frequency (%)	Density (ha^{-1})	Basal Area (cm^2 ha^{-1})	IVI	Max height (m)	A/F ratio
1	*Shorea robusta* Gaertn.	Dipterocarpaceae	LT	70.2	204.0	40328.4	55.7	25	4.141
2	*Schima wallichii* Choisy	Theaceae	LT	89.4	144.0	34757.6	47.2	22	1.801
3	*Pinus kesiya* Royle ex Gordon	Pinaceae	LT	30.8	51.2	21452.8	22.5	20	5.403
4	*Careya arborea* Roxb.	Lecythidaceae	MT	52.9	49.0	6505.7	14.8	16	1.753
5	*Callicarpa arborea* Roxb.	Lamiaceae	MT	53.8	27.3	2291.1	9.8	13	0.942
6	*Semecarpus anacardium* L.f.	Anacardiaceae	MT	37.5	31.7	2589.6	8.9	12	2.256
7	*Syzygium cumini* (L.) Skeels	Myrtaceae	LT	42.3	22.3	3367.6	8.8	13	1.246
8	*Aporosa octandra* (Buch.-Ham. ex D.Don) Vickery var. *octandra*	Phyllanthaceae	ST	35.6	20.6	2291.9	7.2	13	1.626
9	*Lagerstroemia parviflora* Roxb.	Lythraceae	MT	34.6	22.1	1068.5	6.5	11	1.846
10	*Phyllanthus emblica* L.	Phyllanthaceae	ST	37.5	19.2	840.6	6.3	10	1.368
11	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus	Fagaceae	LT	21.2	11.5	3289.8	5.5	17	2.579
12	*Vitex peduncularis* Wall. ex Schauer	Lamiaceae	LT	23.1	14.0	2112.9	5.2	16	2.636
13	*Engelhardtia spicata* Lechen ex Blume	Juglandaceae	LT	27.9	14.8	1094.9	5.1	12	1.904
14	*Croton joufra* Roxb.	Euphorbiaceae	MT	20.2	16.5	1496.3	4.8	12	4.056
15	*Erythrina stricta* Roxb.	Fabaceae	LT	11.5	7.3	4082.1	4.5	16	5.489
16	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	ST	16.3	15.2	522.2	3.6	8	5.686
17	*Sterculia villosa* Roxb.	Malvaceae	MT	21.2	6.0	1104.1	3.4	15	1.332
18	*Saurauia roxburghii* Wall.	Actinidiaceae	ST	11.5	15.2	838.9	3.4	13	11.411
19	*Albizia chinensis* (Osbeck) Merr.	Fabaceae	LT	17.3	5.2	1361.2	3.1	17	1.733
20	*Syzygium nervosum* A.Cunn. ex DC.	Myrtaceae	MT	16.3	10.2	599.9	3.1	8	3.815
21	*Casearia glomerata* Roxb.	Salicaceae	MT	17.3	10.0	426.0	3.1	8	3.338
22	*Ziziphus rugosa* Lam.	Rhamnaceae	ST	17.3	9.8	377.9	3.0	8	3.274
23	*Castanopsis purpurella* (Miq.) N. P. Balakr.	Fagaceae	LT	9.6	4.4	2483.6	3.0	20	4.784
24	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	MT	13.5	7.1	1295.9	2.9	16	3.927
25	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	MT	15.4	6.5	779.0	2.7	16	2.763
26	*Pavetta indica* L.	Rubiaceae	ST	16.3	8.8	204.2	2.7	6	3.311
27	*Castanopsis armata* (Roxb.) Spach	Fagaceae	MT	7.7	3.8	1600.4	2.2	18	6.500
28	*Trema orientalis* (L.) Blume	Cannabaceae	MT	3.8	10.6	524.1	1.9	8	71.500
29	*Macaranga denticulata* (Blume) Müll.Arg.	Euphorbiaceae	MT	10.6	4.6	470.2	1.8	12	4.126

30	*Gmelina arborea* Roxb.	Lamiaceae	MT	8.7	3.5	883.1	1.8	12	4.622
31	*Leea asiatica* (L.) Ridsdale	Vitaceae	SH	10.6	6.3	80.4	1.8	4	5.673
32	*Castanopsis tribuloides* (Sm.) A.DC.	Fagaceae	LT	6.7	3.7	1027.6	1.7	13	8.065
33	*Ficus hispida* L. f.	Moraceae	ST	8.7	5.4	409.5	1.7	10	7.190
34	*Eurya acuminata* DC.	Pentaphylacaceae	ST	10.6	5.0	175.4	1.7	12	4.469
35	*Holarrhena pubescens* Wall.	Apocynaceae	ST	9.6	4.0	275.2	1.6	12	4.368
36	*Garuga pinnata* Roxb.	Burseraceae	LT	6.7	2.5	817.5	1.5	15	5.518
37	*Premna mollissima* Roth	Lamiaceae	MT	3.8	4.2	945.9	1.5	15	28.600
38	*Dalbergia stipulacea* Roxb.	Fabaceae	ST	7.7	4.8	256.5	1.5	11	8.125
39	*Bridelia retusa* (L.) A. Juss.	Phyllanthaceae	MT	8.7	2.7	158.8	1.2	12	3.595
40	*Symplocos khasiana* Brand	Symplocaceae	ST	6.7	3.3	261.8	1.2	10	7.216
41	*Ilex umbellulata* (Wall.) Loes.	Aquifoliaceae	LT	5.8	2.7	201.7	1.0	13	8.089
42	*Wendlandia tinctoria* (Roxb.) DC.	Rubiaceae	ST	5.8	2.7	135.6	0.9	9	8.089
43	*Acacia pennata* (L.) Willd.	Fabaceae	WC	3.8	2.9	116.8	0.8	15	19.500
44	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	Fagaceae	LT	4.8	1.3	223.7	0.8	10	5.824
45	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	ST	4.8	1.5	150.5	0.7	12	6.656
46	*Artocarpus heterophyllus* Lam.	Moraceae	LT	1.0	0.2	918.2	0.7	13	20.800
47	*Smilax zeylanica* L.	Smilacaceae	SS	4.8	1.9	19.3	0.7	15	8.320
48	*Mangifera indica* L.	Anacardiaceae	LT	2.9	0.6	537.6	0.7	12	6.933
49	*Elaeocarpus floribundus* Blume	Elaeocarpaceae	LT	1.9	1.2	558.4	0.7	16	31.200
50	*Stereospermum chelonoides* (L. f.) DC.	Bignoniaceae	LT	2.9	0.6	497.1	0.7	16	6.933
51	*Wendlandia puberula* DC.	Rubiaceae	ST	3.8	1.7	122.2	0.6	11	11.700
52	ML077T21	Meliaceae	MT	3.8	1.0	226.5	0.6	15	6.500
53	*Ficus hirta* Vahl	Moraceae	ST	2.9	2.3	132.0	0.6	13	27.733
54	*Grewia eriocarpa* Juss.	Malvaceae	MT	2.9	1.2	333.3	0.6	12	13.867
55	*Antidesma bunius* (L.) Spreng.	Phyllanthaceae	ST	1.9	1.7	374.3	0.6	13	46.800
56	*Ficus curtipes* Corner	Moraceae	LT	1.9	0.4	605.4	0.6	19	10.400
57	*Kydia calycina* Roxb.	Malvaceae	MT	4.8	1.0	51.6	0.6	11	4.160
58	*Bombax ceiba* L.	Malvaceae	LT	2.9	0.6	390.4	0.6	15	6.933
59	*Toona ciliata* M.Roem.	Meliaceae	LT	3.8	1.2	131.2	0.6	12	7.800
60	*Ficus racemosa* L.	Moraceae	LT	1.0	0.2	720.3	0.6	17	20.800
61	*Artocarpus lakoocha* Roxb.	Moraceae	LT	2.9	1.2	256.8	0.6	16	13.867
62	*Ficus* sp.2	Moraceae	MT	1.0	0.4	662.4	0.6	12	41.600
63	*Dillenia pentagyna* Roxb.	Dilleniaceae	LT	2.9	1.2	225.4	0.6	11	13.867
64	*Litsea glutinosa* (Lour.) C.B. Rob. var. *glutinosa*	Lauraceae	ST	3.8	1.2	57.4	0.5	7	7.800
65	*Albizia odoratissima* (L. f.) Benth.	Fabaceae	LT	3.8	1.0	36.8	0.5	6	6.500
66	*Glochidion coccineum* (Buch.-Ham.) Müll.Arg.	Phyllanthaceae	ST	1.9	1.3	234.1	0.5	10	36.400
67	ML044T18	Sapindaceae	MT	1.9	1.2	245.7	0.5	16	31.200
68	*Itea macrophylla* Wall.	Iteaceae	ST	1.9	1.3	143.9	0.4	8	36.400

69	*Archidendron bigeminum* (L.) I.C.Nielsen	Fabaceae	ST	2.9	0.8	86.7	0.4	9	9.244
70	*Styrax serrulatus* Roxb.	Styracaceae	ST	1.9	1.5	92.6	0.4	9	41.600
71	*Syzygium tetragonum* (Wight) Wall. ex Walp.	Myrtaceae	LT	2.9	0.6	113.7	0.4	10	6.933
72	*Olea salicifolia* Wall. ex G.Don	Oleaceae	MT	2.9	0.8	63.2	0.4	11	9.244
73	*Bridelia tomentosa* Blume	Phyllanthaceae	ST	2.9	0.6	40.9	0.4	9	6.933
74	*Caryota obtusa* Griff.	Arecaceae	LT	1.0	0.4	343.9	0.4	24	41.600
75	*Saurauia fasciculata* Wall.	Actinidiaceae	ST	1.9	1.2	29.4	0.3	3	31.200
76	*Entada rheedii* Spreng.	Fabaceae	WC	1.9	0.4	148.6	0.3	30	10.400
77	*Ficus fistulosa* Reinw. ex Blume	Moraceae	ST	1.9	1.0	40.3	0.3	7	26.000
78	*Acronychia pedunculata* (L.) Miq.	Rutaceae	ST	1.9	0.6	95.9	0.3	12	15.600
79	*Ehretia acuminata* R.Br.	Boraginaceae	LT	1.9	0.8	54.5	0.3	11	20.800
80	*Neolitsea umbrosa* (Nees) Gamble	Lauraceae	MT	1.9	0.6	74.6	0.3	11	15.600
81	*Mallotus philippensis* (Lam.) Müll.Arg.	Euphorbiaceae	ST	1.0	1.0	149.4	0.3	12	104.000
82	*Symplocos racemosa* Roxb.	Symplocaceae	ST	1.9	0.6	68.9	0.3	8	15.600
83	*Helicia nilagirica* Bedd.	Proteaceae	MT	1.9	0.6	66.1	0.3	7	15.600
84	*Wendlandia glabrata* DC.	Rubiaceae	ST	1.9	0.8	30.8	0.3	7	20.800
85	*Archidendron clypearia* (Jack) I.C.Nielsen	Fabaceae	ST	1.9	0.4	68.2	0.3	11	10.400
86	*Meliosma arnottiana* (Wight) Walp.	Sabiaceae	ST	1.9	0.6	28.6	0.3	7	15.600
87	*Firmiana colorata* (Roxb.) R.Br.	Malvaceae	MT	1.9	0.6	11.8	0.3	3	15.600
88	*Guidonia vareca* (Roxb.) Baill. ex Kurz	Salicaceae	ST	1.9	0.6	7.5	0.3	3	15.600
89	*Toxicodendron succedaneum* (L.) Kuntze var. *succedaneum*	Anacardiaceae	MT	1.0	1.3	16.3	0.3	4	145.600
90	*Wendlandia ligustrina* Wall. ex G.Don	Rubiaceae	ST	1.9	0.4	40.7	0.3	8	10.400
91	*Premna pinguis* C.B.Clarke	Lamiaceae	SH	1.9	0.4	39.8	0.3	8	10.400
92	*Eriobotrya bengalensis* (Roxb.) Hook. f.	Rosaceae	LT	1.0	0.4	155.3	0.2	16	41.600
93	*Machilus glaucescens* (Nees) Wight	Lauraceae	MT	1.9	0.4	4.4	0.2	3	10.400
94	*Pterospermum lanceifolium* Roxb.	Malvaceae	MT	1.0	0.8	72.8	0.2	12	83.200
95	*Machilus gamblei* King ex Hook. f.	Lauraceae	MT	1.0	0.8	56.2	0.2	11	83.200
96	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.	Fagaceae	LT	1.0	0.6	79.4	0.2	13	62.400
97	*Spatholobus parviflorus* (DC.) Kuntze	Fabaceae	WC	1.0	0.8	20.1	0.2	15	83.200
98	*Magnolia champaca* (L.) Baill. ex Pierre	Magnoliaceae	LT	1.0	0.2	115.0	0.2	16	20.800
99	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet	Lauraceae	LT	1.0	0.6	46.6	0.2	9	62.400
100	*Bauhinia purpurea* L.	Fabaceae	ST	1.0	0.4	68.8	0.2	10	41.600
101	*Mallotus paniculatus* (Lam.) Müll.Arg. var. *paniculatus*	Euphorbiaceae	MT	1.0	0.6	19.6	0.2	5	62.400
102	*Morus macroura* Miq.	Moraceae	LT	1.0	0.6	19.3	0.2	7	62.400
103	*Hymenodictyon orixense* (Roxb.) Mabb.	Rubiaceae	LT	1.0	0.4	46.2	0.2	8	41.600
104	*Actinodaphne obovata* (Nees) Blume	Lauraceae	MT	1.0	0.6	6.6	0.2	3	62.400
105	*Spondias pinnata* (L. f.) Kurz	Anacardiaceae	MT	1.0	0.6	5.9	0.2	3	62.400
106	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	LT	1.0	0.2	68.7	0.2	11	20.800
107	*Decaspermum parviflorum* subsp. *parviflorum*	Myrtaceae	ST	1.0	0.4	30.0	0.2	7	41.600

108	*Ficus subincisa* Buch.-Ham. ex Sm.	Moraceae	SH	1.0	0.4	22.9	0.2	7	41.600
109	*Albizia lebbeck* (L.) Benth.	Fabaceae	LT	1.0	0.2	53.2	0.1	14	20.800
110	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	Lauraceae	ST	1.0	0.4	17.0	0.1	5	41.600
111	*Pandanus furcatus* Roxb.	Pandanaceae	ST	1.0	0.4	16.5	0.1	4	41.600
112	*Actinodaphne citrata* (Blume) Hayata	Lauraceae	ST	1.0	0.2	40.4	0.1	13	20.800
113	*Brassaiopsis hainla* (Buch.-Ham.) Seem.	Araliaceae	ST	1.0	0.4	5.6	0.1	3	41.600
114	*Maesa montana* A. DC.	Primulaceae	SH	1.0	0.4	5.5	0.1	3	41.600
115	*Macaranga indica* Wight	Euphorbiaceae	MT	1.0	0.4	3.7	0.1	3	41.600
116	*Glochidion khasicum* (Müll.Arg.) Hook.f.	Phyllanthaceae	MT	1.0	0.2	28.5	0.1	10	20.800
117	*Garcinia cowa* Roxb. ex Choisy	Clusiaceae	MT	1.0	0.2	5.9	0.1	4	20.800
118	*Glochidion heyneanum* (Wight & Arn.) Wight	Phyllanthaceae	ST	1.0	0.2	2.8	0.1	2.5	20.800
119	*Wendlandia wallichii* Wight & Arn.	Rubiaceae	ST	1.0	0.2	2.4	0.1	3	20.800
120	*Ardisia humilis* Vahl	Primulaceae	SH	1.0	0.2	2.0	0.1	3	20.800
121	*Glochidion sphaerogynum* (Mull.Arg.) Kurz	Phyllanthaceae	MT	1.0	0.2	1.9	0.1	3	20.800
122	*Calamus latifolius* Roxb.	Arecaceae	SS	1.0	0.2	1.5	0.1	4	20.800
123	*Meliosma* sp.	Sabiaceae	ST	1.0	0.2	1.5	0.1	3	20.800
	Grand Total				882.5	156496.4	300		

The abundance-to-frequency ratio suggested that all species exhibited a clumped to highly clumped dispersion. The minimum value of A/F ratio was 0.942 for *Callicarpa arborea* and maximum was 145.6 for *Toxicodendron succedaneum* var. *succedaneum*. A total of ten species showed A/F ratio 2 or less and remaining species showed A/F ratio above 2 (Table 4.13).

The stand density was 882.5 individuals ha^{-1} and stand basal area was 15.65 m^2 ha^{-1} (Table 4.14). The mean basal area per individual was 177.33 cm^2 (Table 4.14). Shannon's diversity index was 1.493, Pielou's evenness index was 0.714, Simpson's dominance index was 0.075 and Whittaker's species richness index was 33.318 (Table 4.14).

Table 4.14. Phytosociological attributes and diversity indices in woody layer of Khasi hill sal-pine forest in Meghalaya.

Sl. No.	Attribute	Value
1.	Number of species	123
2.	Number of genera	89
3.	Number of families	47
4.	Density (ha^{-1})	882.5
5	Basal area (m^2 ha^{-1})	15.65
6.	Mean basal area (cm^2 $individual^{-1}$)	177.33
7.	Shannon's diversity index	1.493
8.	Evenness index	0.714
9.	Dominance index	0.075
10.	Species richness index	33.318

All 123 species in the woody layer were belonged to 47 families (Table 4.15). Of these, 27 families were represented by one species, 9 families by two species, 0 family by three species, 1 family by four species and 10 families by more than four species. The family Fabaceae had the maximum 11 species followed by Moraceae with 10 species (Table

4.15). Phyllanthaceae and Lauraceae were represented by 9 species each. In terms of genera, Fabaceae and Malvaceae were dominant representing 8 and 6 genera, respectively (Table 4.15).

In terms of density, Dipterocarpaceae showed the highest number of individuals (1061) followed by Theaceae (749). The family Pinaceae (266), Lamiaceae (257), Lecythidaceae (255), Phyllanthaceae (243) and Anacardiaceae (215) were also contributed a large number of individuals. Two families, Clusiaceae and Magnoliaceae had only one individual each (Table 4.15).

Table 4.15. The number of families, genera, species and individuals recorded in woody layer of the Khasi hill sal-pine forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Actinidiaceae	1	2	85	Malvaceae	6	6	52
Anacardiaceae	5	5	215	Meliaceae	2	2	11
Apocynaceae	2	2	22	Moraceae	3	10	62
Aquifoliaceae	1	1	14	Myrtaceae	2	4	174
Araliaceae	1	1	2	Oleaceae	1	1	4
Arecaceae	2	2	3	Pandanaceae	1	1	2
Bignoniaceae	2	2	11	Pentaphylacaceae	1	1	26
Boraginaceae	1	1	4	Phyllanthaceae	5	9	243
Burseraceae	1	1	13	Pinaceae	1	1	266
Cannabaceae	1	1	55	Primulaceae	2	2	3
Clusiaceae	1	1	1	Proteaceae	1	1	3
Dilleniaceae	1	1	6	Rhamnaceae	1	1	51
Dipterocarpaceae	1	1	1061	Rosaceae	1	1	2
Elaeocarpaceae	1	1	6	Rubiaceae	4	8	157
Euphorbiaceae	3	5	120	Rutaceae	1	1	3
Fabaceae	8	11	125	Sabiaceae	1	2	4
Fagaceae	2	6	132	Salicaceae	2	2	55
Iteaceae	1	1	7	Sapindaceae	1	1	6
Juglandaceae	1	1	77	Smilacaceae	1	1	10
Lamiaceae	4	5	257	Styracaceae	1	1	8
Lauraceae	5	9	58	Symplocaceae	1	2	20
Lecythidaceae	1	1	255	Theaceae	1	1	749
Lythraceae	1	1	115	Vitaceae	1	1	33
Magnoliaceae	1	1	1				

The dominance-diversity curve for woody layer of Khasi hill sal-pine forest (Fig. 4.5) followed a log-normal distribution with a mixed dominance of three species in the top canopy (*Shorea robusta*, *Schima wallichii* and *Pinus kesiya*) and one species in subcanopy (*Careya arborea*).

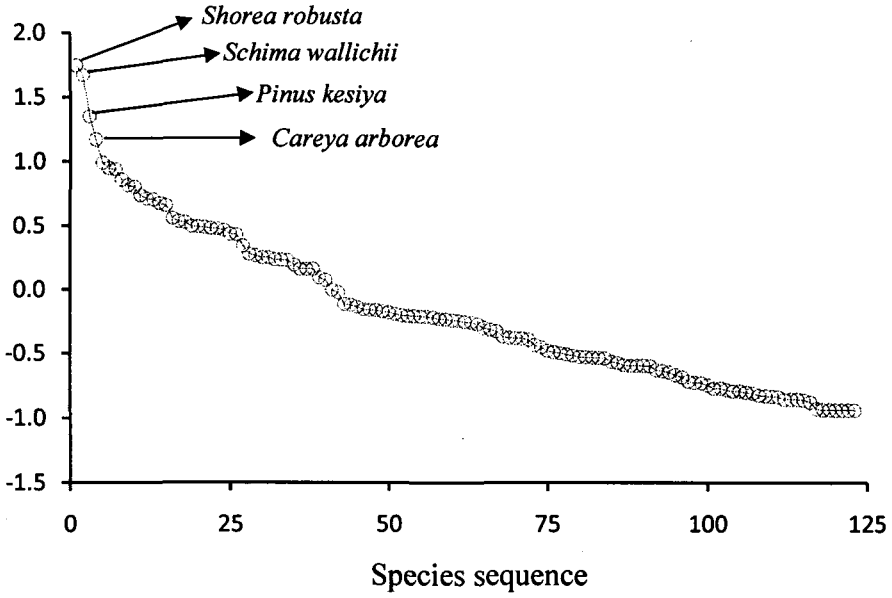

Fig. 4.5. The dominance-diversity curve based on Log_{10} of IVI for woody layer of Khasi hill sal-pine forest in Meghalaya.

4.4.6. Khasi Hill Sal-Pine Forest – herb layer

The floristic composition of herb layer of Khasi hill sal-pine forest is given in Table 4.16. A total of 674 individuals of all species (including tree seedlings) were recorded in herb layer. These belong to 38 families, 83 genera and 92 species. The most dominant species on the basis of IVI is *Mucuna bracteata* followed by *Chromolaena odorata* with an Importance Value of 12.4 and 10.8 respectively (Table 4.16).

Table 4.16. Floristic composition of herb layer of Khasi hill sal-pine forest based on 34 quadrats of 1 x 1 m size. Species are arranged in descending order of IVI values.

Sl. no.	Species Name	Family	Occurrence	No. of individuals	IVI
1	*Mucuna bracteata* DC.	Fabaceae	15	27	12.4
2	*Chromolaena odorata* (L.) R.M. King & H. Rob.	Asteraceae	10	35	10.8
3	*Curcuma aromatica* Salisb.	Zingiberaceae	9	27	9.0
4	*Imperata cylindrica* (L.) Raeusch.	Poaceae	5	40	8.7
5	*Mikania micrantha* Kunth	Asteraceae	5	40	8.7
6	*Panicum* sp.	Poaceae	3	39	7.5
7	*Arundinella setosa* Trin.	Poaceae	3	36	7.0
8	*Oplismenus compositus* (L.) P. Beauv.	Poaceae	3	21	4.8
9	*Shorea robusta* Gaertn.	Dipterocarpaceae	5	12	4.6
10	*Lantana camara* L.	Verbenaceae	4	15	4.5
11	*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda	Poaceae	3	18	4.3
12	*Ageratum houstonianum* Mill.	Asteraceae	3	17	4.2
13	*Phyllanthus emblica* L.	Phyllanthaceae	5	9	4.1
14	*Osmunda cinnamomea* L.	Osmundaceae	2	18	3.8
15	*Tadehagi triquetrum* (L.) H.Ohashi	Fabaceae	4	9	3.6
16	*Oplismenus burmannii* (Retz.) P.Beauv.	Poaceae	1	20	3.5
17	*Cuphea carthagenensis* (Jacq.) J.F.Macbr.	Lythraceae	2	14	3.2
18	*Urena lobata* L.	Malvaceae	3	10	3.2
19	*Leea asiatica* (L.) Ridsdale	Vitaceae	3	8	2.9
20	*Spermacoce articularis* L.f.	Rubiaceae	1	15	2.8
21	*Ageratum conyzoides* (L.) L.	Asteraceae	2	10	2.6
22	*Tadehagi* sp.	Fabaceae	2	10	2.6
23	*Lygodium flexuosum* (L.) Sw.	Schizaeaceae	3	4	2.3
24	*Morinda angustifolia* Roxb.	Rubiaceae	3	4	2.3
25	*Schima wallichii* Choisy	Theaceae	2	7	2.2
26	*Capillipedium assimile* (Steud.) A.Camus	Poaceae	1	10	2.0
27	*Selaginella wallichii* (Hook. & Grev.) Spring	Selaginellaceae	1	10	2.0
28	*Flemingia strobilifera* (L.) W.T.Aiton	Fabaceae	2	6	2.0
29	*Bidens pilosa* L.	Asteraceae	1	9	1.9
30	*Dalbergia stipulacea* Roxb.	Fabaceae	2	5	1.9
31	*Holmskioldia sanguinea* Retz.	Lamiaceae	2	5	1.9
32	*Paspalum longifolium* Roxb.	Poaceae	2	5	1.9
33	*Stachytarpheta indica* (L.) Vahl	Verbenaceae	2	5	1.9
34	*Rubus moluccanus* L.	Rosaceae	1	8	1.7
35	*Geodorum densiflorum* (Lam.) Schltr.	Orchidaceae	2	4	1.7
36	*Polypodium penangianum* Hook.	Polypodiaceae	2	4	1.7
37	*Breynia retusa* (Dennst.) Alston	Phyllanthaceae	2	3	1.6
38	*Peristylus goodyeroides* (D.Don) Lindl.	Orchidaceae	2	3	1.6
39	*Cissampelos pareira* L.	Menispermaceae	1	6	1.4

40	*Spermacoce neohispida* Govaerts	Rubiaceae	1	6	1.4
41	*Asparagus racemosus* Willd.	Asparagaceae	2	2	1.4
42	*Chassalia curviflora* (Wall.) Thwaites	Rubiaceae	2	2	1.4
43	*Cyperus* sp.2	Cyperaceae	1	5	1.3
44	*Erianthus longesetosus* Andersson	Poaceae	1	5	1.3
45	*Fimbristylis dichotoma* (L.) Vahl	Cyperaceae	1	5	1.3
46	*Sphenomeris chinensis* (L.) Maxon	Dennstaedtiaceae	1	5	1.3
47	*Alpinia roxburghii* Sweet	Zingiberaceae	1	4	1.2
48	*Hedyotis scandens* Roxb.	Rubiaceae	1	4	1.2
49	*Lindsaea ensifolia* Sw.	Dennstaedtiaceae	1	4	1.2
50	*Stahlianthus involucratus* (King ex Baker) Craib ex Loes.	Zingiberaceae	1	4	1.2
51	*Codariocalyx motorius* (Houtt.) H.Ohashi	Fabaceae	1	3	1.0
52	*Conyza canadensis* (L.) Cronquist	Asteraceae	1	3	1.0
53	*Cyanthillium cinereum* (L.) H.Rob.	Asteraceae	1	3	1.0
54	*Engelhardtia spicata* Lechen ex Blume	Juglandaceae	1	3	1.0
55	*Holarrhena pubescens* Wall.	Apocynaceae	1	3	1.0
56	*Murdannia japonica* (Thunb.) Faden	Commelinaceae	1	3	1.0
57	*Panicum sarmentosum* Roxb.	Poaceae	1	3	1.0
58	*Pavetta indica* L.	Rubiaceae	1	3	1.0
59	*Polygonum microcephalum* D. Don	Polygonaceae	1	3	1.0
60	*Rungia parviflora* Nees	Acanthaceae	1	3	1.0
61	*Sida rhombifolia* L.	Malvaceae	1	3	1.0
62	*Tetrastigma serrulatum* (Roxb.) Planch.	Vitaceae	1	3	1.0
63	*Acmella paniculata* (Wall. ex DC.) R. K. Jansen	Asteraceae	1	2	0.9
64	*Artemisia parviflora* D.Don	Asteraceae	1	2	0.9
65	*Brachycorythis obcordata* (Lindl.) Summerh.	Orchidaceae	1	2	0.9
66	*Dicranopteris linearis* (Burm. f.) Underw.	Gleicheniaceae	1	2	0.9
67	*Gonostegia hirta* (Blume ex Hassk.) Miq.	Urticaceae	1	2	0.9
68	*Kyllinga brevifolia* Rottb.	Cyperaceae	1	2	0.9
69	*Lobelia zeylanica* L.	Campanulaceae	1	2	0.9
70	*Manihot esculenta* Crantz	Euphorbiaceae	1	2	0.9
71	*Oldenlandia cristata* (Willd. ex Roem. & Schult.) ined.	Rubiaceae	1	2	0.9
72	*Rotheca serrata* (L.) Steane & Mabb.	Lamiaceae	1	2	0.9
73	*Saccharum procerum* Roxb.	Poaceae	1	2	0.9
74	*Solanum anguivi* Lam.	Solanaceae	1	2	0.9
75	*Vernonia saligna* DC.	Asteraceae	1	2	0.9
76	*Wendlandia glabrata* DC.	Rubiaceae	1	2	0.9
77	*Archidendron clypearia* (Jack) I.C.Nielsen	Fabaceae	1	1	0.7
78	*Blumea repanda* (Roxb.) Hand.-Mazz.	Asteraceae	1	1	0.7
79	*Canthium parvifolium* Roxb.	Rubiaceae	1	1	0.7
80	*Cyperus cyperoides* (L.) Kuntze	Cyperaceae	1	1	0.7
81	*Cyperus* sp.3	Cyperaceae	1	1	0.7
82	*Dioscorea bulbifera* L.	Dioscoreaceae	1	1	0.7
83	*Dioscorea pentaphylla* L.	Dioscoreaceae	1	1	0.7
84	*Ficus fulva* Reinw. ex Blume	Moraceae	1	1	0.7

85	*Inula cappa* (Buch.-Ham. ex D.Don) DC.	Asteraceae	1	1	0.7
86	*Iteadaphne caudata* (Nees) H.W. Li	Lauraceae	1	1	0.7
87	*Smilax* sp.1	Smilacaceae	1	1	0.7
88	*Smilax oxyphylla* Wall. ex Kunth	Smilacaceae	1	1	0.7
89	*Solena amplexicaulis* (Lam.) Gandhi	Cucurbitaceae	1	1	0.7
90	*Triumfetta rhomboidea* Jacq.	Malvaceae	1	1	0.7
91	*Tupistra nutans* Wall. ex Lindl.	Asparagaceae	1	1	0.7
92	*Vitex peduncularis* Wall. ex Schauer	Lamiaceae	1	1	0.7
	Grand Total			674	200

The density was 1982.4 individuals/100 m^2 (Table 4.17). The Shannon's diversity index was 1.795, evenness index was 0.914, dominance index was 0.023 and species richness index was 13.080 (Table 4.17).

Table 4.17. Phytosociological attributes and diversity indices in herb layer of the Khasi hill sal-pine forest in Meghalaya.

Sl. No.	Attribute	Value
1.	Number of species	92
2.	Number of genera	83
3.	Number of families	38
4.	Density (100 m^{-2})	1982.4
5.	Shannon's diversity index	1.795
6.	Evenness index	0.914
7.	Dominance index	0.023
8.	Species richness index	13.080

Asteraceae, Poaceae, Rubiaceae and Fabaceae were the most dominant family with 12, 11, 9 and 7 species respectively. In terms of genera, Asteraceae (11 genera) and Poaceae (10 genera) were dominant (Table 4.18). Poaceae was most dominant in terms of number of individuals (199 individuals) followed by Asteraceae (125 individuals) (Table 4.18).

Table 4.18. The number of families, genera, species and individuals recorded in herb layer of the Khasi hill sal-pine forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Acanthaceae	1	1	3	Menispermaceae	1	1	6
Apocynaceae	1	1	3	Moraceae	1	1	1
Asparagaceae	2	2	3	Orchidaceae	3	3	9
Asteraceae	11	12	125	Osmundaceae	1	1	18
Campanulaceae	1	1	2	Phyllanthaceae	2	2	12
Commelinaceae	1	1	3	Poaceae	9	11	199
Cucurbitaceae	1	1	1	Polygonaceae	1	1	3
Cyperaceae	3	5	14	Polypodiaceae	1	1	4
Dennstaedtiaceae	2	2	9	Rosaceae	1	1	8
Dioscoreaceae	1	2	2	Rubiaceae	8	9	39
Dipterocarpaceae	1	1	12	Schizaeaceae	1	1	4
Euphorbiaceae	1	1	2	Selaginellaceae	1	1	10
Fabaceae	6	7	61	Smilacaceae	1	2	2
Gleicheniaceae	1	1	2	Solanaceae	1	1	2
Juglandaceae	1	1	3	Theaceae	1	1	7
Lamiaceae	3	3	8	Urticaceae	1	1	2
Lauraceae	1	1	1	Verbenaceae	2	2	20
Lythraceae	1	1	14	Vitaceae	2	2	11
Malvaceae	3	3	14	Zingiberaceae	3	3	35

The dominance-diversity curve for herb layer of Khasi hill sal-pine forest (Fig. 4.6) followed a log-normal distribution with a mixed dominance of *Mucuna bracteata, Chromolaena odorata, Curcuma aromatica, Imperata cylindrica* and *Mikania micrantha.*

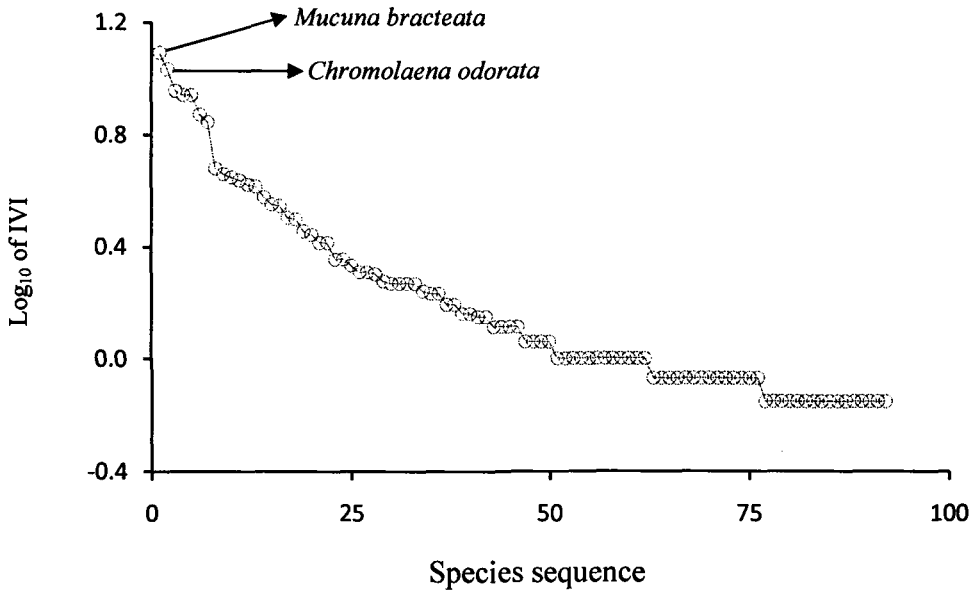

Fig. 4.6. The dominance-diversity curve based on Log_{10} of IVI for herb layer of Khasi hill sal-pine forest in Meghalaya.

4.4.7. Khasi-Jaintia Subtropical Pine Forest – woody layer

The floristic composition of the woody layer of Khasi-Jaintia subtropical pine forest (Table 4.19) exhibited a total of 13,018 individuals of ≥10 cm gbh in 18.8 ha sampled area (41 transects of 5-10 m width and upto 500 m length, Tables 3.5 & 3.7 in Chapter III). Overall, 156 species of 112 genera in 55 families occurred. Of all, 152 species were identified up to species level and 4 species up to genus level (Table 4.19). The majority of species were small tree (65 species) followed by medium tree (42 species), large tree (35 species), shrub (12 species), scandent shrub (2 species) and woody climber (0 species) (Table 4.19). Two species of tree fern, i.e., *Cyathea gigantea* and *C. khasyana* also occurred alongwith three another species of gymnosperms namely; *Cryptomeria japonica*, *Pinus petula*? and *Taxus wallichiana*. The endemic species were: *Citrus latipes*, *Lindera latifolia*, *Schefflera pueckleri*, *Schima khasiana* and *Viburnum simonsii*.

In terms of number of individuals (density), *Pinus kesiya* was the most dominant species with 9,301 individuals (71.4%). The co-dominant species were *Schima wallichii* (634 individuals), *Myrica nagi* (235 individuals), *Myrica esculenta* (194 individuals), *Lyonia ovalifolia* (169 individuals) and *Symplocos paniculata* (152 individuals). Twenty seven species were represented by only one individual, whereas twelve species by 2 individuals and remainder by 3 to 141 individuals (Table 4.19).

In terms of IVI, the most dominant species were: *Pinus kesiya* (176.9), *Schima wallichii* (20.1) (Table 4.19). Approximately 82% of all species (128 species) were rare as they exhibited an Importance Value of 1 or less. A majority of species (23 species) exhibited an Importance Value between >1 and <5, and 3 species exhibited an Importance Value between >5 and <10 (Table 4.19).

Table 4.19. Floristic composition, habit (LT- Large Tree, MT- Medium Tree, ST- Small Tree, SH- Shrub, SS- Scandent Shrub, WC- Woody Climber), frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), maximum height (m) and abundance-to-frequency ratio (A/F) of Khasi-Jaintia subtropical pine forest type in Meghalaya. Species are arranged in descending order of IVI values.

Sl. no.	Species name	Family	Habit	Freq-uency (%)	Den-sity (ha^{-1})	Basal Area (cm^2 ha^{-1})	IVI	Max height (m)	A/F ratio
1	*Pinus kesiya* Royle ex Gordon	Pinaceae	LT	96.0	494.7	178339.7	176.9	29	5.019
2	*Schima wallichii* Choisy	Theaceae	LT	39.6	33.7	12067.2	20.1	26	2.016
3	*Myrica nagi* Thunb.	Myricaceae	MT	16.7	12.5	1522.8	6.6	14	4.209
4	*Myrica esculenta* Buch.-Ham. ex D. Don	Myricaceae	MT	16.9	10.3	1975.7	6.6	18	3.373
5	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae	ST	13.9	9.0	595.7	5.0	13	4.333
6	*Symplocos paniculata* Miq.	Symplocaceae	ST	10.4	8.1	549.9	4.0	8	6.928
7	*Eurya acuminata* DC.	Pentaphylacaceae	ST	10.7	7.5	258.0	3.8	12	6.131
8	*Engelhardtia spicata* Lechen ex Blume	Juglandaceae	LT	8.7	4.4	1273.7	3.4	26	5.448
9	*Betula alnoides* Buch.-Ham. ex D.Don	Betulaceae	LT	6.7	4.4	1462.4	3.0	22	9.044
10	*Wendlandia glabrata* DC.	Rubiaceae	ST	6.2	5.7	494.2	2.6	14	13.893
11	*Albizia chinensis* (Osbeck) Merr.	Fabaceae	LT	5.5	2.6	1352.6	2.3	22	7.974
12	*Castanopsis purpurella* (Miq.) N. P. Balakr.	Fagaceae	LT	4.2	4.6	1184.2	2.3	26	24.203
13	*Iteadaphne caudata* (Nees) H.W. Li	Lauraceae	ST	6.5	3.6	162.5	2.2	14	7.969
14	*Callicarpa arborea* Roxb.	Lamiaceae	MT	5.2	3.5	672.1	2.1	18	12.033
15	*Helicia nilagirica* Bedd.	Proteaceae	MT	5.5	3.1	463.2	2.0	14	9.635
16	*Alnus nepalensis* D.Don	Betulaceae	MT	4.5	4.1	536.6	1.9	12	19.356
17	*Rhododendron arboreum* Sm.	Ericaceae	MT	5.7	2.9	226.2	1.9	12	8.207
18	*Castanopsis tribuloides* (Sm.) A.DC.	Fagaceae	LT	3.0	2.8	1610.3	1.9	23	29.592
19	*Syzygium cumini* (L.) Skeels	Myrtaceae	LT	3.7	2.8	831.8	1.7	23	18.581
20	*Phyllanthus emblica* L.	Phyllanthaceae	ST	4.7	2.2	127.1	1.5	9	9.131
21	*Lithocarpus dealbatus* (Hook.f. & Thomson ex Miq.) Rehder	Fagaceae	ST	3.2	3.0	616.3	1.5	12	27.117
22	*Wendlandia paniculata* (Roxb.) DC.	Rubiaceae	ST	4.2	2.2	137.0	1.4	11	11.684
23	*Viburnum cylindricum* Buch.-Ham. ex D. Don	Adoxaceae	ST	4.2	1.9	91.0	1.4	7	10.015
24	*Lithocarpus fenestratus* (Roxb.) Rehder	Fagaceae	MT	3.5	2.6	174.6	1.3	13	19.690
25	*Elaeagnus pyriformis* Hook.f.	Elaeagnaceae	SS	4.0	1.6	67.7	1.2	13	9.736
26	*Cornus oblonga* Wall.	Cornaceae	ST	3.2	2.1	69.2	1.1	9	19.030
27	*Albizia odoratissima* (L. f.) Benth.	Fabaceae	LT	3.0	2.1	111.0	1.1	15	22.333
28	*Symplocos cochinchinensis* var. *laurina* (Retz.) Noot.	Symplocaceae	ST	3.2	1.7	104.8	1.1	6	15.224
29	*Erythrina stricta* Roxb.	Fabaceae	LT	2.5	1.4	498.3	1.0	14	20.904

30	*Toona ciliata* M.Roem.	Meliaceae	LT	2.7	1.0	243.5	0.9	18	11.960
31	*Glochidion khasicum* (Müll.Arg.) Hook.f.	Phyllanthaceae	MT	3.0	1.0	69.5	0.9	10	10.608
32	*Ficus auriculata* Lour.	Moraceae	ST	3.0	0.9	108.8	0.9	11	8.933
33	*Wendlandia wallichii* Wight & Arn.	Rubiaceae	ST	2.2	1.8	125.4	0.9	8	32.756
34	*Glochidion acuminatum* Müll.Arg.	Phyllanthaceae	MT	2.7	1.0	81.4	0.9	12	12.625
35	*Toxicodendron succedaneum* (L.) Kuntze var. *succedaneum*	Anacardiaceae	MT	2.7	0.7	163.0	0.9	20	9.302
36	*Schima khasiana* Dyer	Theaceae	LT	2.0	1.4	329.0	0.8	13	32.663
37	*Eurya japonica* Thunb.	Pentaphylacaceae	SH	2.7	1.1	14.1	0.8	4	13.289
38	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus	Fagaceae	LT	2.0	0.7	431.5	0.8	23	17.588
39	*Photinia integrifolia* Lindl. var. *integrifolia*	Rosaceae	MT	2.0	1.6	117.2	0.8	7	37.688
40	*Careya arborea* Roxb.	Lecythidaceae	MT	2.0	1.3	202.0	0.8	17	30.150
41	*Pinus patula* Schiede ex Schltdl. & Cham. ?	Pinaceae	LT	0.7	2.0	533.5	0.7	13	339.467
42	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	MT	2.0	0.9	196.2	0.7	12	21.356
43	*Persea odoratissima* (Nees) Kosterm.	Lauraceae	MT	2.2	0.7	41.7	0.7	9	12.904
44	*Bombax ceiba* L.	Malvaceae	LT	1.7	0.4	371.3	0.7	24	13.127
45	*Premna* sp.1	Lamiaceae	MT	2.0	0.9	81.7	0.7	14	21.356
46	*Trichilia connaroides* (Wight & Arn.) Bentv. var. *connaroides*	Meliaceae	MT	2.0	0.6	77.9	0.6	22	13.819
47	*Pyrus pashia* Buch.-Ham. ex D. Don	Rosaceae	MT	1.7	0.9	76.4	0.6	10	27.894
48	*Corylopsis himalayana* Griff.	Hamamelidaceae	ST	1.7	1.0	23.2	0.6	7	29.535
49	*Quercus serrata* Murray	Fagaceae	MT	1.7	0.7	73.3	0.6	16	22.971
50	*Erythrina arborescens* Roxb.	Fabaceae	ST	1.7	0.8	38.2	0.6	6	24.612
51	*Schefflera hypoleuca* (Kurz) Harms	Araliaceae	ST	1.7	0.5	56.8	0.5	9	16.408
52	*Taxus wallichiana* Zucc.	Taxaceae	MT	0.7	0.8	505.4	0.5	14	134.000
53	*Maesa indica* (Roxb.) A. DC.	Primulaceae	ST	1.5	1.0	17.6	0.5	5	40.200
54	*Gmelina arborea* Roxb.	Lamiaceae	MT	1.2	0.7	191.2	0.5	13	41.808
55	*Meyna spinosa* Roxb. ex Link	Rubiaceae	ST	1.2	1.0	105.5	0.5	12	57.888
56	*Magnolia doltsopa* (Buch.-Ham. ex DC.) Figlar	Magnoliaceae	LT	0.7	0.6	484.0	0.5	22	98.267
57	*Ficus neriifolia* Sm.	Moraceae	MT	1.5	0.7	20.5	0.5	5	31.267
58	*Rhus chinensis* Mill.	Anacardiaceae	ST	1.5	0.6	24.2	0.5	6	24.567
59	*Symplocos racemosa* Roxb.	Symplocaceae	ST	1.5	0.5	40.8	0.5	8	22.333
60	*Rapanea capitellata* (Wall.) Mez	Primulaceae	MT	0.7	1.2	195.2	0.4	23	205.467
61	*Quercus lineata* Blume	Fagaceae	MT	1.0	0.5	276.8	0.4	18	50.250
62	*Docynia indica* (Wall.) Decne.	Rosaceae	LT	1.0	0.3	349.5	0.4	23	25.125
63	*Wendlandia tinctoria* (Roxb.) DC.	Rubiaceae	ST	1.5	0.4	22.1	0.4	7	17.867
64	*Lindera latifolia* Hook. f.	Lauraceae	MT	0.7	0.8	297.5	0.4	14	134.000
65	*Macropanax dispermus* (Blume) Kuntze	Araliaceae	ST	1.0	0.8	83.0	0.4	9	75.375
66	*Saurauia roxburghii* Wall.	Actinidiaceae	ST	1.0	0.8	80.5	0.4	7	75.375
67	*Schoepfia fragrans* Wall.	Schoepfiaceae	MT	0.5	0.3	485.2	0.4	15	120.600
68	*Semecarpus anacardium* L.f.	Anacardiaceae	MT	1.2	0.4	27.1	0.4	8	22.512

69	*Meliosma arnottiana* (Wight) Walp.	Sabiaceae	ST	1.2	0.3	25.3	0.4	10	19.296
70	*Elaeocarpus lanceifolius* Roxb.	Elaeocarpaceae	MT	0.5	0.2	391.6	0.3	22	60.300
71	*Cryptomeria japonica* (Thunb. ex L.f.) D.Don	Taxodiaceae	LT	0.5	0.6	238.6	0.3	16	221.100
72	*Glochidion heyneanum* (Wight & Arn.) Wight	Phyllanthaceae	ST	1.0	0.4	14.8	0.3	8	40.200
73	*Saurauia fasciculata* Wall.	Actinidiaceae	ST	0.7	0.8	14.8	0.3	5	134.000
74	*Artocarpus heterophyllus* Lam.	Moraceae	LT	0.5	0.3	288.4	0.3	16	120.600
75	*Actinodaphne citrata* (Blume) Hayata	Lauraceae	ST	1.0	0.3	5.8	0.3	8	30.150
76	*Cyathea khasyana* Domin	Cyatheaceae	ST	0.7	0.4	63.6	0.3	5	71.467
77	*Luculia pinceana* Hook.	Rubiaceae	ST	0.7	0.4	42.3	0.3	6	71.467
78	*Itea macrophylla* Wall.	Iteaceae	ST	0.7	0.5	22.5	0.3	9	80.400
79	*Shorea robusta* Gaertn.	Dipterocarpaceae	LT	0.2	0.4	302.1	0.3	18	643.200
80	*Aporosa octandra* (Buch.-Ham. ex D.Don) Vickery var. *octandra*	Phyllanthaceae	ST	0.7	0.3	77.7	0.3	19	44.667
81	*Quercus griffithii* Hook.f. & Thomson ex Miq.	Fagaceae	MT	0.7	0.3	57.4	0.3	19	53.600
82	*Machilus glaucescens* (Nees) Wight	Lauraceae	MT	0.7	0.4	33.2	0.3	11	62.533
83	*Schefflera pueckleri* (K.Koch) Frodin	Araliaceae	SS	0.2	0.9	128.8	0.3	11	1366.800
84	*Holarrhena pubescens* Wall.	Apocynaceae	ST	0.7	0.3	36.1	0.2	8	53.600
85	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	ST	0.7	0.3	34.9	0.2	11	53.600
86	*Lagerstroemia parviflora* Roxb.	Lythraceae	MT	0.5	0.3	155.2	0.2	21	120.600
87	*Citrus latipes* (Swingle) Yu.Tanaka	Rutaceae	ST	0.7	0.3	16.7	0.2	10	44.667
88	*Cinnamomum camphora* (L.) J.Presl	Lauraceae	LT	0.7	0.3	11.7	0.2	5	44.667
89	*Bischofia javanica* Blume	Phyllanthaceae	LT	0.5	0.3	133.2	0.2	12	100.500
90	*Dalbergia assamica* Benth.	Fabaceae	LT	0.5	0.2	133.9	0.2	22	80.400
91	*Stereospermum chelonoides* (L. f.) DC.	Bignoniaceae	LT	0.5	0.5	44.7	0.2	7	180.900
92	*Viburnum simonsii* Hook.f. & Thomson	Adoxaceae	ST	0.5	0.5	28.9	0.2	6	180.900
93	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	ST	0.5	0.4	41.0	0.2	5	160.800
94	*Syzygium tetragonum* (Wight) Wall. ex Walp.	Myrtaceae	LT	0.5	0.2	117.0	0.2	13	60.300
95	*Millettia pulchra* Kurz	Fabaceae	ST	0.5	0.4	13.2	0.2	6	140.700
96	*Kydia calycina* Roxb.	Malvaceae	MT	0.5	0.4	13.0	0.2	8	140.700
97	*Archidendron bigeminum* (L.) I.C.Nielsen	Fabaceae	ST	0.5	0.3	28.8	0.2	8	120.600
98	*Artocarpus lakoocha* Roxb.	Moraceae	LT	0.5	0.2	71.8	0.2	16	60.300
99	*Sorbus polycarpa* (Hook. f.) Rehder	Rosaceae	ST	0.5	0.2	57.0	0.2	11	60.300
100	*Ficus subincisa* Buch.-Ham. ex Sm.	Moraceae	SH	0.5	0.3	4.4	0.2	5	100.500
101	*Ziziphus incurva* Roxb.	Rhamnaceae	MT	0.2	0.4	95.7	0.2	16	562.800
102	*Saurauia napaulensis* DC.	Actinidiaceae	ST	0.5	0.2	25.8	0.2	8	60.300
103	*Buddleja macrostachya* Benth.	Scrophulariaceae	SH	0.5	0.2	2.3	0.2	4	80.400
104	*Croton joufra* Roxb.	Euphorbiaceae	MT	0.5	0.2	16.0	0.2	8	60.300
105	*Glochidion lanceolarium* (Roxb.) Voigt	Phyllanthaceae	ST	0.5	0.2	8.4	0.1	6	60.300
106	*Casearia glomerata* Roxb.	Salicaceae	MT	0.5	0.1	23.2	0.1	10	40.200
107	*Ehretia acuminata* R.Br.	Boraginaceae	LT	0.5	0.1	21.1	0.1	12	40.200

108	*Viburnum foetidum* Wall.	Adoxaceae	SH	0.5	0.2	1.3	0.1	3	60.300
109	*Exbucklandia populnea* (R.Br. ex Griff.) R.W.Br.	Hamamelidaceae	MT	0.5	0.1	14.1	0.1	11	40.200
110	*Debregeasia longifolia* (Burm.f.) Wedd.	Urticaceae	SH	0.5	0.1	7.9	0.1	6	40.200
111	*Ficus hispida* L. f.	Moraceae	ST	0.5	0.1	1.7	0.1	6	40.200
112	*Choerospondias axillaris* (Roxb.) B.L.Burtt & A.W.Hill	Anacardiaceae	MT	0.2	0.4	42.7	0.1	12	562.800
113	*Styrax* sp.	Styracaceae	ST	0.2	0.2	92.7	0.1	11	321.600
114	*Grewia serrulata* DC.	Malvaceae	ST	0.2	0.2	72.4	0.1	11	241.200
115	*Elaeocarpus floribundus* Blume	Elaeocarpaceae	LT	0.2	0.1	83.2	0.1	13	160.800
116	*Ternstroemia japonica* Thunb.	Pentaphylacaceae	ST	0.2	0.3	11.5	0.1	2	482.400
117	*Phlogacanthus pubinervius* T.Anderson	Acanthaceae	SH	0.2	0.3	9.4	0.1	5	402.000
118	*Cleyera japonica* var. *grandiflora* (Wall. ex Choisy) Kobuski	Pentaphylacaceae	ST	0.2	0.2	42.4	0.1	13	241.200
119	*Wightia speciosissima* (D. Don) Merr.	Paulowniaceae	MT	0.2	0.2	10.9	0.1	6	321.600
120	*Ficus virens* Aiton	Moraceae	LT	0.2	0.1	57.0	0.1	11	80.400
121	*Macaranga indica* Wight	Euphorbiaceae	MT	0.2	0.2	17.5	0.1	13	241.200
122	*Dalbergia stipulacea* Roxb.	Fabaceae	ST	0.2	0.2	17.1	0.1	7	241.200
123	*Ligustrum lucidum* W.T.Aiton	Oleaceae	ST	0.2	0.2	3.1	0.1	3	241.200
124	*Symplocos* sp.1	Symplocaceae	ST	0.2	0.1	19.5	0.1	8	160.800
125	*Gymnosporia rufa* (Wall. ex Roxb.) M.A.Lawson	Celastraceae	ST	0.2	0.2	2.6	0.1	4	241.200
126	*Dillenia pentagyna* Roxb.	Dilleniaceae	LT	0.2	0.1	16.1	0.1	9	160.800
127	*Quercus glauca* Thunb.	Fagaceae	MT	0.2	0.1	20.4	0.1	11	80.400
128	*Psidium guajava* L.	Myrtaceae	ST	0.2	0.1	3.1	0.1	2	160.800
129	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.	Fagaceae	LT	0.2	0.1	18.1	0.1	13	80.400
130	ML088T08	Rosaceae	ST	0.2	0.1	1.3	0.1	3	160.800
131	*Brassaiopsis glomerulata* (Blume) Regel	Araliaceae	ST	0.2	0.1	1.0	0.1	3	160.800
132	*Mussaenda macrophylla* Wall.	Rubiaceae	SH	0.2	0.1	0.8	0.1	5	160.800
133	*Haldina cordifolia* (Roxb.) Ridsdale	Rubiaceae	LT	0.2	0.1	15.0	0.1	9	80.400
134	*Mallotus nepalensis* Müll.Arg.	Euphorbiaceae	ST	0.2	0.1	12.8	0.1	12	80.400
135	*Syzygium fruticosum* DC.	Myrtaceae	ST	0.2	0.1	10.6	0.1	3	80.400
136	*Clerodendrum bracteatum* Wall. ex Walp.	Lamiaceae	SH	0.2	0.1	10.2	0.1	8	80.400
137	*Cyathea gigantea* (Wall. ex Hook.) Holttum	Cyatheaceae	ST	0.2	0.1	7.8	0.1	3	80.400
138	*Decaspermum parviflorum* subsp. *parviflorum*	Myrtaceae	ST	0.2	0.1	7.8	0.1	10	80.400
139	*Macaranga denticulata* (Blume) Müll.Arg.	Euphorbiaceae	MT	0.2	0.1	7.5	0.1	10	80.400
140	*Mussaenda roxburghii* Hook.f.	Rubiaceae	SH	0.2	0.1	6.2	0.1	8	80.400
141	*Lindera pulcherrima* (Nees) Hook. f.	Lauraceae	ST	0.2	0.1	5.5	0.1	8	80.400
142	*Leucosceptrum canum* Sm.	Lamiaceae	ST	0.2	0.1	5.4	0.1	7	80.400
143	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	LT	0.2	0.1	5.2	0.1	8	80.400
144	*Chukrasia tabularis* A. Juss.	Meliaceae	LT	0.2	0.1	4.6	0.1	10	80.400
145	*Symplocos sumuntia* Buch.-Ham. ex D. Don	Symplocaceae	ST	0.2	0.1	3.2	0.1	6	80.400
146	*Magnolia caveana* (Hook.f. & Thomson) D.C.S.Raju & M.P.Nayar	Magnoliaceae	MT	0.2	0.1	2.0	0.1	7	80.400

147	*Derris robusta* (DC.) Benth.	Fabaceae	MT	0.2	0.1	1.2	0.1	4	80.400
148	*Agapetes variegata* (Roxb.) D.Don ex G.Don	Ericaceae	SH	0.2	0.1	1.0	0.1	3	80.400
149	*Camellia kissi* Wall.	Theaceae	ST	0.2	0.1	1.0	0.1	3	80.400
150	*Maclura cochinchinensis* (Lour.) Corner	Moraceae	SH	0.2	0.1	1.0	0.1	6	80.400
151	*Myrsine semiserrata* Wall.	Primulaceae	ST	0.2	0.1	0.8	0.1	3	80.400
152	*Xylosma longifolia* Clos	Salicaceae	ST	0.2	0.1	0.8	0.1	4	80.400
153	*Litsea glutinosa* (Lour.) C.B. Rob. var. *glutinosa*	Lauraceae	ST	0.2	0.1	0.6	0.1	4	80.400
154	*Machilus duthiei* King	Lauraceae	ST	0.2	0.1	0.6	0.1	3	80.400
155	*Melastoma malabathricum* L.	Melastomataceae	SH	0.2	0.1	0.5	0.1	3	80.400
156	*Fraxinus floribunda* Wall.	Oleaceae	LT	0.2	0.1	0.4	0.1	3	80.400
	Grand Total				692.4	217758.1	300		

The abundance-to-frequency ratio suggested that all species exhibited a clumped to highly clumped dispersion. The minimum value of A/F ratio was 2.016 for *Schima wallichii* and maximum was 1366.8 for *Schefflera pueckleri*. No species showed A/F ratio 2 or less and all species showed A/F ratio above 2 (Table 4.19).

The stand density was 692.4 individuals ha^{-1} whereas basal area was 21.78 m^2 ha^{-1} and mean basal area 314.48 cm^2 $individual^{-1}$ (Table 4.20). The Shannon's diversity index was 1.012, Pielou's evenness index was 0.462, Simpson's dominance index was 0.355 and Whittaker's species richness index was 37.671 (Table 4.20).

Table 4.20. Phytosociological attributes and diversity indices in woody layer of Khasi-Jaintia subtropical pine forest in Meghalaya.

Sl. No.	Attribute	Value
1.	Number of species	156
2.	Number of genera	112
3.	Number of families	55
4.	Density (ha^{-1})	692.4
5	Basal area (m^2 ha^{-1})	21.78
6.	Mean basal area (cm^2 $individual^{-1}$)	314.48
7.	Shannon's diversity index	1.012
8.	Evenness index	0.462
9.	Dominance index	0.355
10.	Species richness index	37.671

Of all 156 species in the woody layer, all 156 species belonged to 55 identified families (Table 4.21). Of these, 23 families were represented by one species, 11 families by two species, 7 families by three species, 4 families by four species and 10 families by more than four species. The families Fagaceae, Lauraceae and Rubiaceae had the maximum 10 species each followed by Fabaceae with 9 species and Moraceae with 8 species (Table

4.21). In terms of genera, Lauraceae, Fabaceae and Rubiaceae were dominant representing 7, 6 and 6 genera, respectively (Table 4.21).

In terms of density, Pinaceae showed the highest number of 9,339 individuals (71.7%). Theaceae (661 individuals), Myricaceae (429 individuals), Fagaceae (291 individuals), Rubiaceae (229 individuals) and Ericaceae (224 individuals) also contributed significantly. Twenty two families were represented by <10 individuals (Table 4.21). Melastomataceae had only one individual.

Table 4.21. The number of families, genera, species and individuals recorded in woody layer of the Khasi-Jaintia subtropical pine forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Acanthaceae	1	1	5	Malvaceae	3	3	18
Actinidiaceae	1	3	33	Melastomataceae	1	1	1
Adoxaceae	1	3	48	Meliaceae	3	3	30
Anacardiaceae	4	4	39	Moraceae	3	8	48
Apocynaceae	2	2	7	Myricaceae	1	2	429
Araliaceae	3	4	44	Myrtaceae	3	5	59
Betulaceae	2	2	160	Oleaceae	2	2	4
Bignoniaceae	2	2	15	Paulowniaceae	1	1	4
Boraginaceae	1	1	2	Pentaphylacaceae	3	4	170
Celastraceae	1	1	3	Phyllanthaceae	4	7	100
Cornaceae	1	1	40	Pinaceae	1	2	9339
Cyatheaceae	1	2	9	Primulaceae	3	3	42
Dilleniaceae	1	1	2	Proteaceae	1	1	58
Dipterocarpaceae	1	1	8	Rhamnaceae	1	1	7
Elaeagnaceae	1	1	31	Rosaceae	5	5	57
Elaeocarpaceae	1	2	5	Rubiaceae	6	10	229
Ericaceae	3	3	224	Rutaceae	1	1	5
Euphorbiaceae	3	4	8	Sabiaceae	1	1	6
Fabaceae	6	9	150	Salicaceae	2	2	3
Fagaceae	3	10	291	Schoepfiaceae	1	1	6
Hamamelidaceae	2	2	20	Scrophulariaceae	1	1	4
Iteaceae	1	1	9	Styracaceae	1	1	4
Juglandaceae	1	1	83	Symplocaceae	1	5	197
Lamiaceae	5	5	98	Taxaceae	1	1	15
Lauraceae	7	10	133	Taxodiaceae	1	1	11
Lecythidaceae	1	1	24	Theaceae	2	3	661
Lythraceae	1	1	6	Urticaceae	1	1	2
Magnoliaceae	1	2	12				

The dominance-diversity curve for woody layer of Khasi-Jaintia subtropical pine forest (Fig. 4.7) followed a broken-stick distribution with single species dominance in the top canopy (*Pinus kesiya*).

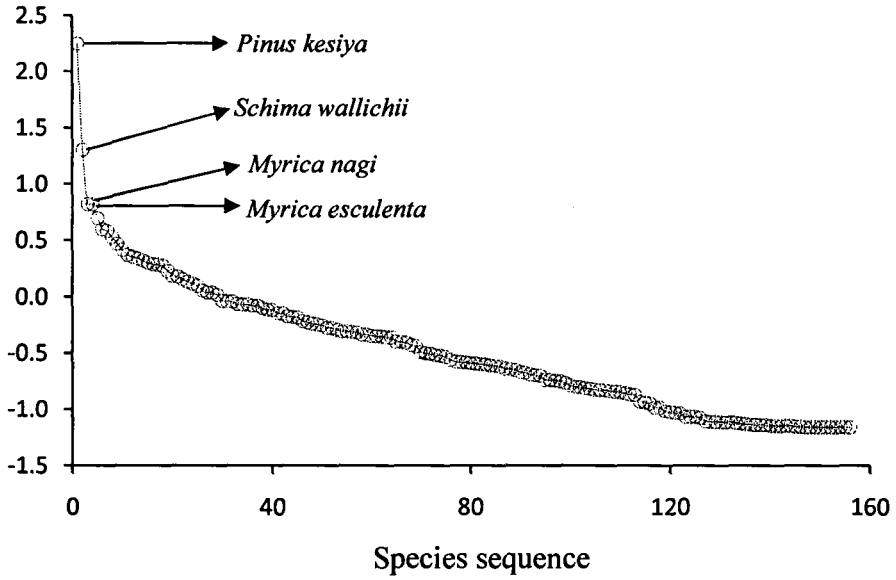

Fig. 4.7. The dominance-diversity curve based on Log_{10} of IVI for woody layer of Khasi-Jaintia subtropical pine forest in Meghalaya.

4.4.8. Khasi-Jaintia Subtropical Pine Forest – herb layer

The floristic composition of herb layer of Khasi-Jaintia subtropical pine forest is given in Table 4.22. A total of 3,537 individuals of all species (including tree seedlings) were recorded in herb layer. These belong to 72 families, 187 genera and 239 species. The most dominant species on the basis of IVI is *Ageratina adenophora* followed by *Pinus kesiya* with an Importance Value of 12.2 and 10.3, respectively (Table 4.22). The endemic species to Meghalaya were: *Osbeckia capitata* and *Trachyspermum khasianum*.

Table 4.22. Floristic composition of herb layer of Khasi-Jaintia subtropical pine forest based on 124 quadrats of 1 x 1 m size. Species are arranged in descending order of IVI values.

Sl. no.	Species Name	Family	Occurrence	No. of individuals	IVI
1	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Asteraceae	32	273	12.2
2	*Pinus kesiya* Royle ex Gordon	Pinaceae	40	168	10.3
3	*Lantana camara* L.	Verbenaceae	26	101	6.5
4	*Spermacoce articularis* L.f.	Rubiaceae	6	189	6.2
5	*Lindernia crustacea* (L.) F.Muell.	Linderniaceae	1	190	5.5
6	*Rubus moluccanus* L.	Rosaceae	24	69	5.3
7	*Dicranopteris linearis* (Burm. f.) Underw.	Gleicheniaceae	14	77	4.1
8	*Oplismenus compositus* (L.) P. Beauv.	Poaceae	8	99	3.9
9	*Gonostegia hirta* (Blume ex Hassk.) Miq.	Urticaceae	12	65	3.5
10	*Cyanotis vaga* (Lour.) Schult. & Schult.f.	Commelinaceae	6	86	3.3
11	*Phyllanthus urinaria* L.	Phyllanthaceae	10	64	3.2
12	*Spermacoce neohispida* Govaerts	Rubiaceae	6	69	2.8
13	*Eulalia trispicata* (Schult.) Henrard	Poaceae	5	69	2.6
14	*Arundinella setosa* Trin.	Poaceae	7	59	2.6
15	*Imperata cylindrica* (L.) Raeusch.	Poaceae	6	61	2.6
16	*Anaphalis adnata* Wall. ex DC.	Asteraceae	11	33	2.5
17	*Osbeckia stellata* Buch.-Ham. ex Ker Gawl.	Melastomataceae	7	43	2.2
18	*Eurya japonica* Thunb.	Pentaphylacaceae	9	32	2.2
19	*Dicranopteris splendida* (Hand.-Mazz.) Ching	Gleicheniaceae	8	32	2.0
20	*Rubus ellipticus* Sm.	Rosaceae	9	21	1.8
21	*Potentilla lineata* Trevir.	Rosaceae	4	45	1.8
22	*Ageratum conyzoides* (L.) L.	Asteraceae	7	29	1.8
23	*Breynia retusa* (Dennst.) Alston	Phyllanthaceae	7	25	1.7
24	*Oldenlandia lineata* (Roxb.) Kuntze	Rubiaceae	6	29	1.7
25	*Eriosema chinense* Vogel	Fabaceae	4	38	1.6
26	*Setaria pumila* (Poir.) Roem. & Schult.	Poaceae	5	33	1.6
27	*Galium rotundifolium* L.	Rubiaceae	5	32	1.6
28	*Gaultheria fragrantissima* Wall.	Ericaceae	6	27	1.6
29	*Commelina benghalensis* L.	Commelinaceae	5	30	1.5
30	*Ageratina riparia* (Regel) R.M.King & H.Rob.	Asteraceae	6	25	1.5
31	*Emilia sonchifolia* (L.) DC. ex DC.	Asteraceae	7	20	1.5
32	*Melastoma malabathricum* L.	Melastomataceae	4	34	1.5
33	*Prunella vulgaris* L.	Lamiaceae	4	32	1.5
34	*Inula cappa* (Buch.-Ham. ex D.Don) DC.	Asteraceae	7	17	1.5
35	*Eragrostiella leioptera* (Stapf) Bor	Poaceae	3	35	1.4
36	*Senecio cappa* Buch.-Ham. ex D.Don	Asteraceae	7	15	1.4
37	*Ainsliaea latifolia* (D.Don) Sch.Bip.	Asteraceae	5	24	1.4
38	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae	6	15	1.3

39	*Rungia parviflora* Nees	Acanthaceae	5	19	1.2
40	*Oplismenus burmannii* (Retz.) P.Beauv.	Poaceae	3	28	1.2
41	*Desmodium laxiflorum* DC.	Fabaceae	5	17	1.2
42	*Rhus chinensis* Mill.	Anacardiaceae	5	16	1.1
43	*Anemone rivularis* Buch.-Ham. ex DC.	Ranunculaceae	2	30	1.1
44	*Anaphalis contorta* (D.Don) Hook.f.	Asteraceae	4	19	1.1
45	*Osbeckia capitata* Benth. ex Naudin	Melastomataceae	4	19	1.1
46	*Teucrium quadrifarium* Buch.-Ham.	Lamiaceae	5	13	1.1
47	*Urena lobata* L.	Malvaceae	5	12	1.0
48	*Neanotis wightiana* (Wall. ex Wight & Arn.) W.H.Lewis	Rubiaceae	5	11	1.0
49	*Valeriana jatamansi* Jones	Caprifoliaceae	5	11	1.0
50	*Scutellaria discolor* Colebr.	Lamiaceae	4	15	1.0
51	*Isodon lophanthoides* var. *graciliflorus* (Benth.) H.Hara	Lamiaceae	4	14	0.9
52	*Lycopodium japonicum* Thunb.	Lycopodiaceae	4	14	0.9
53	*Vernonia saligna* DC.	Asteraceae	5	9	0.9
54	*Pogostemon quadrifolius* (Benth.) F.Muell.	Lamiaceae	4	12	0.9
55	*Hypericum japonicum* Thunb.	Hypericaceae	1	25	0.8
56	*Digitaria compacta* (Roth ex Roem. & Schult.) Veldkamp	Poaceae	2	20	0.8
57	*Oxalis corniculata* L.	Oxalidaceae	2	20	0.8
58	*Myrica esculenta* Buch.-Ham. ex D. Don	Myricaceae	4	10	0.8
59	*Tadehagi triquetrum* (L.) H.Ohashi	Fabaceae	4	10	0.8
60	*Capillipedium assimile* (Steud.) A.Camus	Poaceae	3	14	0.8
61	*Diplopterygium glaucum* (Thunb. ex Houtt.) Nakai	Gleicheniaceae	3	14	0.8
62	*Flemingia procumbens* Roxb.	Fabaceae	4	9	0.8
63	*Iteadaphne caudata* (Nees) H.W. Li	Lauraceae	4	9	0.8
64	*Mucuna bracteata* DC.	Fabaceae	4	9	0.8
65	*Trachyspermum khasianum* H.Wolff	Apiaceae	4	9	0.8
66	*Brachiaria villosa* (Lam.) A.Camus	Poaceae	2	18	0.8
67	*Hemiphragma heterophyllum* Wall.	Plantaginaceae	3	13	0.8
68	*Viola sikkimensis* W. Becker	Violaceae	3	13	0.8
69	*Arisaema consanguineum* Schott	Araceae	4	8	0.8
70	*Smilax aspera* L.	Smilacaceae	4	7	0.8
71	*Mimosa pudica* L.	Fabaceae	2	16	0.7
72	*Curcuma angustifolia* Roxb.	Zingiberaceae	3	11	0.7
73	*Rubia cordifolia* L.	Rubiaceae	3	11	0.7
74	*Senecio griffithii* Hook.f. & Thomson ex C.B.Clarke	Asteraceae	3	11	0.7
75	*Solanum capsicoides* All.	Solanaceae	4	6	0.7
76	*Gentiana quadrifaria* Blume	Gentianaceae	1	20	0.7
77	*Exacum tetragonum* Roxb.	Gentianaceae	1	20	0.7
78	*Hedychium coccineum* Buch.-Ham. ex Sm.	Zingiberaceae	3	10	0.7
79	*Anthactinia nepalensis* M.Roem.	Passifloraceae	2	14	0.7
80	*Calamus* sp.	Arecaceae	3	9	0.7
81	*Sphenomeris chinensis* (L.) Maxon	Dennstaedtiaceae	3	9	0.7
82	*Centella asiatica* (L.) Urb.	Apiaceae	2	13	0.6

83	*Crassocephalum crepidioides* (Benth.) S.Moore	Asteraceae	3	8	0.6
84	*Duchesnea indica* (Andrews) Focke	Rosaceae	3	8	0.6
85	*Pteridium aquilinum* (L.) Kuhn	Dennstaedtiaceae	3	8	0.6
86	*Gnaphalium affine* D.Don	Asteraceae	3	8	0.6
87	*Impatiens benthamii* Steenis	Balsaminaceae	3	8	0.6
88	*Ageratum houstonianum* Mill.	Asteraceae	2	12	0.6
89	*Agrimonia pilosa* var. *nepalensis* (D. Don) Nakai	Rosaceae	2	12	0.6
90	*Tetrastigma serrulatum* (Roxb.) Planch.	Vitaceae	2	12	0.6
91	*Wendlandia glabrata* DC.	Rubiaceae	2	12	0.6
92	*Artemisia nilagirica* (C.B.Clarke) Pamp.	Asteraceae	3	7	0.6
93	*Elsholtzia blanda* (Benth.) Benth.	Lamiaceae	3	7	0.6
94	*Gerbera maxima* (D.Don) Beauverd	Asteraceae	3	7	0.6
95	*Lysimachia japonica* Thunb.	Primulaceae	3	7	0.6
96	*Rubus birmanicus* Hook. f.	Rosaceae	3	7	0.6
97	*Brachycorythis obcordata* (Lindl.) Summerh.	Orchidaceae	3	6	0.6
98	*Osbeckia nepalensis* Hook. f.	Melastomataceae	3	6	0.6
99	*Pteris* sp.	Pteridaceae	1	15	0.6
100	*Adenophora khasiana* (Hook.f. & Thomson) Oliv. ex Collett & Hemsl.	Campanulaceae	2	10	0.6
101	*Campylotropis thomsonii* (Baker) Schindl.	Fabaceae	3	5	0.6
102	*Symplocos paniculata* Miq.	Symplocaceae	3	5	0.6
103	*Ixeris polycephala* Cass.	Asteraceae	2	9	0.5
104	*Rubus paniculatus* Sm.	Rosaceae	3	4	0.5
105	*Smilax orthoptera* A.DC.	Smilacaceae	3	4	0.5
106	*Zeuxine affinis* (Lindl.) Benth. ex Hook.f.	Orchidaceae	3	4	0.5
107	*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda	Poaceae	2	8	0.5
108	*Lygodium flexuosum* (L.) Sw.	Schizaeaceae	3	3	0.5
109	*Saccharum procerum* Roxb.	Poaceae	3	3	0.5
110	*Chamaecrista mimosoides* (L.) Greene	Fabaceae	2	7	0.5
111	*Smilax elegans* subsp. *subrecta* Noltie	Smilacaceae	2	7	0.5
112	*Chromolaena odorata* (L.) R.M. King & H. Rob.	Asteraceae	2	6	0.4
113	*Dalbergia stipulacea* Roxb.	Fabaceae	2	6	0.4
114	*Desmodium heterocarpon* (L.) DC.	Fabaceae	2	6	0.4
115	*Paspalum scrobiculatum* L.	Poaceae	2	6	0.4
116	*Panicum humidorum* Buch.-Ham. ex Hook.f.	Poaceae	1	10	0.4
117	*Richardia scabra* L.	Rubiaceae	1	10	0.4
118	*Bidens pilosa* L.	Asteraceae	2	5	0.4
119	*Blumeopsis falcata* (D.Don) Merr.	Asteraceae	2	5	0.4
120	*Salomonia cantoniensis* Lour.	Polygalaceae	2	5	0.4
121	*Smilax oxyphylla* Wall. ex Kunth	Smilacaceae	2	5	0.4
122	*Isodon hispidus* (Benth.) Murata	Lamiaceae	1	9	0.4
123	*Achyranthes aspera* L.	Amaranthaceae	2	4	0.4
124	*Craniotome furcata* (Link) Kuntze	Lamiaceae	2	4	0.4
125	*Eurya acuminata* DC.	Pentaphylacaceae	2	4	0.4
126	*Gerbera piloselloides* (L.) Cass.	Asteraceae	2	4	0.4

127	*Lycopodiella cernua* (L.) Pic. Serm.	Lycopodiaceae	2	4	0.4
128	*Macropanax dispermus* (Blume) Kuntze	Araliaceae	2	4	0.4
129	*Viburnum foetidum* Wall.	Adoxaceae	2	4	0.4
130	*Persicaria nepalensis* (Meisn.) Miyabe	Polygonaceae	1	8	0.4
131	*Prinsepia utilis* Royle	Rosaceae	1	8	0.4
132	*Setaria plicata* (Lam.) T.Cooke	Poaceae	1	8	0.4
133	*Callicarpa rubella* Lindl.	Lamiaceae	2	3	0.4
134	*Habenaria acuifera* Wall. ex Lindl.	Orchidaceae	2	3	0.4
135	*Alectra sessiliflora* var. *monticola* (Engl.) Melch.	Orobanchaceae	2	3	0.4
136	*Rhododendron arboreum* Sm.	Ericaceae	2	3	0.4
137	*Strobilanthes colorata* T.Anderson	Acanthaceae	2	3	0.4
138	*Dennstaedtia scabra* (Wall. ex Hook.) T. Moore	Dennstaedtiaceae	1	7	0.3
139	*Asplenium ensiforme* Wall. ex Hook. & Grev.	Aspleniaceae	1	7	0.3
140	*Lithocarpus dealbatus* (Hook.f. & Thomson ex Miq.) Rehder	Fagaceae	1	7	0.3
141	*Ficus fulva* Reinw. ex Blume	Moraceae	2	2	0.3
142	*Meizotropis buteiformis* Voigt	Fabaceae	2	2	0.3
143	*Dryopteris sparsa* (D. Don) Kuntze	Dryopteridaceae	2	2	0.3
144	*Bolbitis aspleniifolia* K.Iwats.	Lomariopsidaceae	1	6	0.3
145	*Neillia thyrsiflora* D. Don	Rosaceae	1	6	0.3
146	*Platostoma palustre* (Blume) A.J.Paton	Lamiaceae	1	6	0.3
147	*Bambusa* sp.1	Poaceae	1	5	0.3
148	*Colocasia* sp.	Araceae	1	5	0.3
149	*Eulalia* sp.	Poaceae	1	5	0.3
150	*Comastoma tenellum* (Rottb.) Toyok.	Gentianaceae	1	5	0.3
151	*Justicia procumbens* L.	Acanthaceae	1	5	0.3
152	*Leucas lanata* Benth.	Lamiaceae	1	5	0.3
153	*Ophiopogon intermedius* D. Don	Asparagaceae	1	5	0.3
154	*Pennisetum glaucum* (L.) R.Br.	Poaceae	1	5	0.3
155	*Persicaria chinensis* (L.) H. Gross	Polygonaceae	1	5	0.3
156	*Taxus wallichiana* Zucc.	Taxaceae	1	5	0.3
157	*Cyperus* sp.4	Cyperaceae	1	4	0.3
158	*Dichrocephala integrifolia* (L.f.) Kuntze	Asteraceae	1	4	0.3
159	*Hedychium spicatum* Sm.	Zingiberaceae	1	4	0.3
160	*Dryopteris* sp.	Dryopteridaceae	1	4	0.3
161	*Stachytarpheta indica* (L.) Vahl	Verbenaceae	1	4	0.3
162	*Viburnum cylindricum* Buch.-Ham. ex D. Don	Adoxaceae	1	4	0.3
163	*Adenostemma viscosum* J.R.Forst. & G.Forst.	Asteraceae	1	3	0.2
164	*Amorphophallus bulbifer* (Roxb.) Blume	Araceae	1	3	0.2
165	*Anisomeles indica* (L.) Kuntze	Lamiaceae	1	3	0.2
166	*Asparagus filicinus* Buch.-Ham. ex D.Don	Asparagaceae	1	3	0.2
167	*Carex cruciata* Wahlenb.	Cyperaceae	1	3	0.2
168	*Crotalaria ferruginea* Benth.	Fabaceae	1	3	0.2
169	*Cuphea carthagenensis* (Jacq.) J.F.Macbr.	Lythraceae	1	3	0.2
170	*Cyanthillium cinereum* (L.) H.Rob.	Asteraceae	1	3	0.2

171	*Desmodium microphyllum* (Thunb.) DC.	Fabaceae	1	3	0.2
172	*Disporum cantoniense* (Lour.) Merr.	Asparagaceae	1	3	0.2
173	*Gynura* sp.	Asteraceae	1	3	0.2
174	*Hypochaeris radicata* L.	Asteraceae	1	3	0.2
175	*Isodon ternifolius* (D.Don) Kudô	Lamiaceae	1	3	0.2
176	*Kyllinga brevifolia* Rottb.	Cyperaceae	1	3	0.2
177	*Lepidagathis incurva* Buch.-Ham. ex D. Don	Acanthaceae	1	3	0.2
178	*Lithocarpus fenestratus* (Roxb.) Rehder	Fagaceae	1	3	0.2
179	*Murdannia japonica* (Thunb.) Faden	Commelinaceae	1	3	0.2
180	*Myrsine semiserrata* Wall.	Primulaceae	1	3	0.2
181	*Strobilanthes glomerata* T. Anderson	Acanthaceae	1	3	0.2
182	*Cirsium verutum* (D.Don) Spreng.	Asteraceae	1	2	0.2
183	*Codariocalyx motorius* (Houtt.) H.Ohashi	Fabaceae	1	2	0.2
184	*Crotalaria occulta* Benth.	Fabaceae	1	2	0.2
185	*Curcuma aromatica* Salisb.	Zingiberaceae	1	2	0.2
186	*Cyperus cyperoides* (L.) Kuntze	Cyperaceae	1	2	0.2
187	*Desmodium concinnum* DC.	Fabaceae	1	2	0.2
188	*Dimeria fuscescens* Trin.	Poaceae	1	2	0.2
189	*Elephantopus scaber* L.	Asteraceae	1	2	0.2
190	*Impatiens* sp.	Balsaminaceae	1	2	0.2
191	*Leea asiatica* (L.) Ridsdale	Vitaceae	1	2	0.2
192	*Leucas ciliata* Benth.	Lamiaceae	1	2	0.2
193	*Tricyrtis maculata* (D.Don) J.F.Macbr.	Asparagaceae	1	2	0.2
194	*Pogostemon stellatus* (Lour.) Kuntze	Lamiaceae	1	2	0.2
195	*Polygonum microcephalum* D. Don	Polygonaceae	1	2	0.2
196	*Polygonum molle* D. Don var. *molle*	Polygonaceae	1	2	0.2
197	*Quercus griffithii* Hook.f. & Thomson ex Miq.	Fagaceae	1	2	0.2
198	*Ranunculus diffusus* DC.	Ranunculaceae	1	2	0.2
199	*Rotheca serrata* (L.) Steane & Mabb.	Lamiaceae	1	2	0.2
200	*Sacciolepis indica* (L.) Chase	Poaceae	1	2	0.2
201	*Spiranthes sinensis* (Pers.) Ames	Orchidaceae	1	2	0.2
202	*Torenia vagans* Roxb.	Linderniaceae	1	2	0.2
203	*Vigna marina* (Burm.) Merr.	Fabaceae	1	2	0.2
204	*Albizia chinensis* (Osbeck) Merr.	Fabaceae	1	1	0.2
205	*Ardisia neriifolia* Wall. ex A.DC.	Primulaceae	1	1	0.2
206	*Argyreia roxburghii* (Wall.) Arn. ex Choisy	Convolvulaceae	1	1	0.2
207	*Blechnum orientale* L.	Blechnaceae	1	1	0.2
208	*Carex stramentitia* Boott ex Boeckeler	Cyperaceae	1	1	0.2
209	*Clerodendrum glandulosum* Lindl.	Lamiaceae	1	1	0.2
210	*Cynoglossum zeylanicum* (Lehm.) Brand	Boraginaceae	1	1	0.2
211	*Daphne papyracea* Wall. ex W.W.Sm. & Cave	Thymelaeaceae	1	1	0.2
212	*Dianella ensifolia* (L.) DC.	Xanthorrhoeaceae	1	1	0.2
213	*Dioscorea hamiltonii* Hook.f.	Dioscoreaceae	1	1	0.2
214	*Dioscorea pubera* Blume	Dioscoreaceae	1	1	0.2
215	*Galium mollugo* L.	Rubiaceae	1	1	0.2

216	*Houttuynia cordata* Thunb.	Saururaceae	1	1	0.2
217	*Inula eupatorioides* Wall. ex DC.	Asteraceae	1	1	0.2
218	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	1	1	0.2
219	*Lobelia nummularia* Lam.	Campanulaceae	1	1	0.2
220	*Lonicera macrantha* (D. Don) Spreng.	Caprifoliaceae	1	1	0.2
221	*Maclura fruticosa* (Roxb.) Corner	Moraceae	1	1	0.2
222	*Athyrium* sp.	Woodsiaceae	1	1	0.2
223	*Botrychium lanuginosum* Wall. ex Hook. & Grev.	Ophioglossaceae	1	1	0.2
224	*Burmannia disticha* L.	Burmanniaceae	1	1	0.2
225	*Mucuna pruriens* (L.) DC.	Fabaceae	1	1	0.2
226	*Mussaenda roxburghii* Hook.f.	Rubiaceae	1	1	0.2
227	*Paspalum conjugatum* P.J.Bergius	Poaceae	1	1	0.2
228	*Persicaria perfoliata* (L.) H. Gross	Polygonaceae	1	1	0.2
229	*Phyllanthus cochinchinensis* Spreng.	Phyllanthaceae	1	1	0.2
230	*Potentilla polyphylla* Wall. ex Lehm.	Rosaceae	1	1	0.2
231	*Ranunculus cantoniensis* DC.	Ranunculaceae	1	1	0.2
232	*Rubus niveus* Thunb.	Rosaceae	1	1	0.2
233	*Schima wallichii* Choisy	Theaceae	1	1	0.2
234	*Solanum rudepannum* Dunal	Solanaceae	1	1	0.2
235	*Solanum sisymbriifolium* Lam.	Solanaceae	1	1	0.2
236	*Syzygium cumini* (L.) Skeels	Myrtaceae	1	1	0.2
237	*Triumfetta bogotensis* DC.	Malvaceae	1	1	0.2
238	*Viburnum simonsii* Hook. f. & Thomson	Adoxaceae	1	1	0.2
239	*Zingiber* sp.	Zingiberaceae	1	1	0.2
	Grand Total			3537	200

The density was 2852.4 individuals/100 m^2 (Table 4.23). The Shannon's diversity index was 2.099, evenness index was 0.882, dominance index was 0.015 and species richness index was 67.07 (Table 4.23).

Table 4.23. Phytosociological attributes and diversity indices in herb layer of the Khasi-Jaintia subtropical pine forest in Meghalaya.

Sl. No.	Attribute	Value
1.	Number of species	239
2.	Number of genera	187
3.	Number of families	72
4.	Density (100 m^{-2})	2852.4
5.	Shannon's diversity index	2.099
6.	Evenness index	0.882
7.	Dominance index	0.015
8.	Species richness index	67.068

Asteraceae (29 species) was the most dominant family followed by Poaceae (21 species), Fabaceae (19 species) and Lamiaceae (17 species) respectively. In terms of genera, Asteraceae, Poaceae, Fabaceae and Lamiaceae were again dominanted with 23, 17, 13 and 13 genera respectively (Table 4.24). Asteraceae was most dominant in terms of number of individuals (567 individuals) followed by Poaceae (491 individuals) and Rubiaceae (365 individuals) (Table 4.24).

Table 4.24. The number of families, genera, species and individuals recorded in herb layer of the Khasi-Jaintia subtropical pine forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Acanthaceae	4	5	33	Melastomataceae	2	4	102
Adoxaceae	1	3	9	Moraceae	2	2	3
Amaranthaceae	1	1	4	Myricaceae	1	1	10
Anacardiaceae	1	1	16	Myrtaceae	1	1	1
Apiaceae	2	2	22	Ophioglossaceae	1	1	1
Araceae	3	3	16	Orchidaceae	4	4	15
Araliaceae	1	1	4	Orobanchaceae	1	1	3
Arecaceae	1	1	9	Oxalidaceae	1	1	20
Asparagaceae	4	4	13	Passifloraceae	1	1	14
Aspleniaceae	1	1	7	Pentaphylacaceae	1	2	36
Asteraceae	23	29	567	Phyllanthaceae	2	3	90
Balsaminaceae	1	2	10	Pinaceae	1	1	168
Blechnaceae	1	1	1	Plantaginaceae	1	1	13
Boraginaceae	1	1	1	Poaceae	17	21	491
Burmanniaceae	1	1	1	Polygalaceae	1	1	5
Campanulaceae	2	2	11	Polygonaceae	2	5	18
Caprifoliaceae	2	2	12	Primulaceae	3	3	11
Commelinaceae	3	3	119	Pteridaceae	1	1	15
Convolvulaceae	1	1	1	Ranunculaceae	2	3	33
Cyperaceae	3	5	13	Rosaceae	6	11	182
Dennstaedtiaceae	3	3	24	Rubiaceae	8	10	365
Dioscoreaceae	1	2	2	Saururaceae	1	1	1
Dryopteridaceae	1	2	6	Schizaeaceae	1	1	3
Ericaceae	3	3	45	Smilacaceae	1	4	23
Fabaceae	14	19	141	Solanaceae	1	3	8
Fagaceae	2	3	12	Symplocaceae	1	1	5
Gentianaceae	2	3	45	Taxaceae	1	1	5
Gleicheniaceae	2	3	123	Theaceae	1	1	1
Hypericaceae	1	1	25	Thymelaeaceae	1	1	1
Lamiaceae	13	17	133	Urticaceae	1	1	65
Lauraceae	2	2	10	Verbenaceae	2	2	105
Linderniaceae	2	2	192	Violaceae	1	1	13
Lomariopsidaceae	1	1	6	Vitaceae	2	2	14
Lycopodiaceae	2	2	18	Woodsiaceae	1	1	1
Lythraceae	1	1	3	Xanthorrhoeaceae	1	1	1
Malvaceae	2	2	13	Zingiberaceae	3	5	28

The dominance-diversity curve for herb layer of Khasi-Jaintia subtropical pine forest (Fig. 4.8) followed a log-normal distribution with a mixed dominance of *Ageratina adenophora,* seedlings of *Pinus kesiya, Lantana camara, Spermacoce articularis, Lindernia crustacea* and *Rubus moluccanus.*

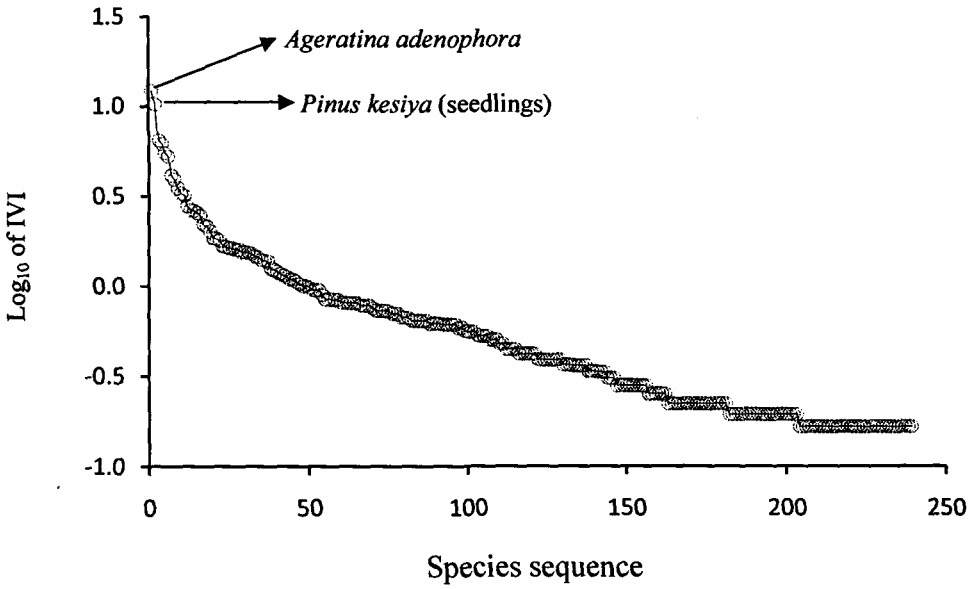

Fig. 4.8. The dominance-diversity curve based on Log_{10} of IVI for herb layer of Khasi-Jaintia subtropical pine forest in Meghalaya.

4.4.9. Khasi Subtropical Mixed-Broadleaved Forest – woody layer

The floristic composition of woody layer of Khasi subtropical mixed-broadleaved forest (Table 4.25) exhibited a total of 5,905 individuals of ≥ 10 cm gbh in 6.85 ha sampled area (18 transect of 5 to 10 m width and upto 500 m length, Tables 3.5 & 3.7 in Chapter III). Overall, 233 species of 158 genera in 69 families occurred. Of all, 203 species were identified up to species level, 11 species up to genus level and 9 species could not be determined (Table 4.25). The majority of species were small tree (96 species) followed by medium tree (63 species), large tree (46 species), shrub (21 species), scandent shrub (6 species) and woody climber (1 species) (Table 4.25). Three gymnosperm species occurred: *Cephalotaxus griffithii*, *Pinus kesiya* and *Podocarpus neriifolius*. Nine endemic species occurred: *Ilex khasiana*, *Ilex venulosa*, *Lasianthus hookeri*, *Lindera latifolia*, *Nostolachma jenkinsii*, *Schefflera pueckleri*, *Schima khasiana*, *Sycopsis griffithiana* and *Viburnum simonsii*.

In terms of number of individuals (density), the most dominant species were: *Schima wallichii* (712 individuals), *Syzygium tetragonum* (307 individuals), *Helicia nilagirica* (283 individuals) and *Pinus kesiya* (221 individuals). Thirty five species were represented by only one individual each, whereas twenty nine species by 2 individuals each. The remainder species were represented by 3 to 134 individuals (Table 4.25).

In terms of IVI, the most dominant species were: *Schima wallichii* (27.9), *Pinus kesiya* (16.9), *Syzygium tetragonum* (13.3) and *Engelhardtia spicata* (11.6) (Table 4.25). Of all, 163 species were rare as they exhibited an Importance Value of 1 or less. A majority of species (59 species) exhibited an Importance Value between >1 and <5, and 7 species exhibited an Importance Value between >5 and <10 (Table 4.25).

Table 4.25. Floristic composition, habit (LT- Large Tree, MT- Medium Tree, ST- Small Tree, SH- Shrub, SS- Scandent Shrub, WC- Woody Climber), frequency (%), density (ha^{-1}), basal area (cm^2 ha^{-1}), importance value index (IVI), maximum height (m) and abundance-to-frequency ratio (A/F) of Khasi subtropical mixed-broadleaved forest type in Meghalaya. Species are arranged in descending order of IVI values.

Sl. no.	Species name	Family	Habit	Freq-uency (%)	Den-sity (ha^{-1})	Basal Area (cm^2 ha^{-1})	IVI	Max height (m)	A/F ratio
1	*Schima wallichii* Choisy	Theaceae	LT	52.8	103.9	19249.1	27.9	24	3.595
2	*Pinus kesiya* Royle ex Gordon	Pinaceae	LT	28.9	32.3	18455.4	16.9	24	3.734
3	*Syzygium tetragonum* (Wight) Wall. ex Walp.	Myrtaceae	LT	34.5	44.8	8681.4	13.3	24	3.631
4	*Engelhardtia spicata* Lechen ex Blume	Juglandaceae	LT	40.8	26.4	8404.6	11.6	28	1.528
5	*Ficus virens* Aiton	Moraceae	LT	0.7	0.9	18851.2	10.9	29	170.400
6	*Aesculus assamica* Griff.	Sapindaceae	LT	10.6	16.5	12154.1	9.8	28	14.263
7	*Helicia nilagirica* Bedd.	Proteaceae	MT	35.2	41.3	2666.7	9.5	16	3.215
8	*Schima khasiana* Dyer	Theaceae	LT	5.6	16.4	7208.7	6.5	22	49.700
9	*Betula alnoides* Buch.-Ham. ex D.Don	Betulaceae	LT	15.5	7.6	7381.3	6.5	32	3.051
10	*Eurya acuminata* DC.	Pentaphylacaceae	ST	35.2	19.7	535.4	5.8	10	1.534
11	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	Fagaceae	LT	23.9	13.4	3512.5	5.8	25	2.260
12	*Syzygium megacarpum* (Craib) Rathakr. & N.C.Nair	Myrtaceae	MT	7.0	7.4	5712.5	4.8	27	14.484
13	*Schefflera hypoleuca* (Kurz) Harms	Araliaceae	ST	28.2	14.2	938.9	4.8	12	1.722
14	*Iteadaphne caudata* (Nees) H.W. Li	Lauraceae	ST	22.5	17.2	451.3	4.3	11	3.273
15	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	Lauraceae	ST	14.1	19.6	1187.5	4.2	12	9.514
16	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus	Fagaceae	LT	13.4	14.2	1533.4	3.7	22	7.631
17	*Drimycarpus racemosus* (Roxb.) Hook.f. ex Marchand.	Anacardiaceae	LT	10.6	3.8	3888.2	3.6	32	3.282
18	*Sarcosperma griffithii* Hook.f. ex C.B.Clarke	Sapotaceae	MT	12.7	10.5	1685.4	3.3	15	6.311
19	*Symplocos pyrifolia* Wall. ex G. Don	Symplocaceae	ST	14.1	15.5	339.8	3.3	6	7.526
20	*Persea odoratissima* (Nees) Kosterm.	Lauraceae	MT	17.6	10.2	597.5	3.1	12	3.181
21	*Dysoxylum excelsum* Blume	Meliaceae	LT	6.3	4.7	3338.9	3.0	28	11.220
22	*Myrica esculenta* Buch.-Ham. ex D. Don	Myricaceae	MT	12.7	9.6	1168.4	2.9	12	5.785
23	*Heritiera macrophylla* Wall. ex Kurz	Malvaceae	LT	4.9	4.2	3300.2	2.8	26	16.808
24	*Vernonia volkameriifolia* DC.	Asteraceae	ST	15.5	10.7	284.2	2.8	6	4.283
25	*Macropanax dispermus* (Blume) Kuntze	Araliaceae	ST	11.3	9.1	1206.8	2.8	18	6.878
26	*Eurya japonica* Thunb.	Pentaphylacaceae	SH	12.0	12.7	289.2	2.7	6	8.549
27	*Drypetes indica* (Mull.Arg.) Pax & K. Hoffm.	Putranjivaceae	LT	4.2	4.4	2821.0	2.5	25	23.667
28	*Daphniphyllum himalayense* (Benth.) Mull.Arg.	Daphniphyllaceae	MT	10.6	7.6	992.4	2.4	12	6.564
29	*Castanopsis purpurella* (Miq.) N. P. Balakr.	Fagaceae	LT	9.2	8.3	1058.9	2.4	16	9.579

30	*Ficus neriifolia* Sm.	Moraceae	MT	14.1	7.2	422.8	2.4	19	3.479
31	*Lithocarpus dealbatus* (Hook.f. & Thomson ex Miq.) Rehder	Fagaceae	ST	9.2	10.1	583.5	2.3	10	11.595
32	*Callicarpa arborea* Roxb.	Lamiaceae	MT	9.2	7.9	887.7	2.3	12	9.075
33	*Wendlandia paniculata* (Roxb.) DC.	Rubiaceae	ST	9.9	8.6	561.4	2.2	10	8.549
34	*Glochidion khasicum* (Müll.Arg.) Hook.f.	Phyllanthaceae	MT	13.4	7.3	178.0	2.2	7	3.934
35	*Photinia integrifolia* Lindl. var. *integrifolia*	Rosaceae	MT	8.5	6.9	772.1	2.0	10	9.269
36	*Itea macrophylla* Wall.	Iteaceae	ST	8.5	8.9	320.6	2.0	11	12.031
37	*Symplocos paniculata* Miq.	Symplocaceae	ST	6.3	10.4	300.6	2.0	7	24.894
38	*Myrica nagi* Thunb.	Myricaceae	MT	9.9	4.4	812.0	1.9	13	4.347
39	*Albizia chinensis* (Osbeck) Merr.	Fabaceae	LT	9.2	4.2	882.4	1.8	26	4.873
40	*Ficus auriculata* Lour.	Moraceae	ST	8.5	5.0	778.3	1.8	12	6.706
41	*Toxicodendron succedaneum* (L.) Kuntze var. *succedaneum*	Anacardiaceae	MT	9.9	5.7	394.7	1.8	13	5.651
42	*Machilus gamblei* King ex Hook. f.	Lauraceae	MT	9.2	5.5	532.1	1.8	14	6.386
43	*Maesa indica* (Roxb.) A. DC.	Primulaceae	ST	12.7	4.8	69.6	1.8	4	2.893
44	*Saurauia napaulensis* DC.	Actinidiaceae	ST	7.0	7.9	288.7	1.7	7	15.336
45	*Turpinia pomifera* (Roxb.) DC.	Staphyleaceae	MT	4.9	3.8	1350.2	1.7	27	15.069
46	*Wendlandia tinctoria* (Roxb.) DC.	Rubiaceae	ST	7.0	7.7	161.6	1.6	6	15.052
47	*Luculia pinceana* Hook.	Rubiaceae	ST	8.5	6.7	141.9	1.6	7	9.072
48	*Macaranga indica* Wight	Euphorbiaceae	MT	7.0	7.0	249.8	1.6	8	13.632
49	*Pandanus furcatus* Roxb.	Pandanaceae	ST	4.2	6.6	772.4	1.6	9	35.500
50	*Ostodes paniculata* Blume	Euphorbiaceae	MT	4.2	4.5	1173.4	1.6	20	24.456
51	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet	Lauraceae	LT	7.0	4.7	613.9	1.5	18	9.088
52	*Garcinia xanthochymus* Hook.f. ex T.Anderson	Clusiaceae	MT	5.6	3.9	949.6	1.5	17	11.981
53	*Erythroxylum parishii* (Hook.f.) ined.	Erythroxylaceae	SH	9.2	5.0	109.9	1.5	7	5.714
54	*Symplocos sumuntia* Buch.-Ham. ex D. Don	Symplocaceae	ST	8.5	4.7	202.9	1.4	11	6.311
55	*Diospyros* sp.3	Ebenaceae	LT	1.4	0.7	2110.9	1.4	28	35.500
56	*Castanopsis tribuloides* (Sm.) A.DC.	Fagaceae	LT	2.8	2.2	1573.0	1.4	20	26.625
57	*Garcinia cowa* Roxb. ex Choisy	Clusiaceae	MT	5.6	3.1	926.5	1.4	18	9.319
58	*Syzygium cumini* (L.) Skeels	Myrtaceae	LT	8.5	2.9	475.7	1.4	12	3.944
59	*Ilex venulosa* Hook.f.	Aquifoliaceae	MT	7.7	3.8	357.9	1.4	10	6.102
60	*Itea chinensis* Hook. & Arn.	Iteaceae	ST	7.0	5.3	152.4	1.3	6	10.224
61	*Agapetes setigera* (Wall.) D.Don ex G.Don	Ericaceae	SH	5.6	6.6	107.8	1.3	4	19.969
62	*Symplocos cochinchinensis* var. *laurina* (Retz.) Noot.	Symplocaceae	ST	7.7	4.1	212.2	1.3	9	6.572
63	*Olea salicifolia* Wall. ex G.Don	Oleaceae	MT	2.1	0.7	1783.4	1.3	24	15.778
64	*Wendlandia wallichii* Wight & Arn.	Rubiaceae	ST	6.3	5.0	195.5	1.3	7	11.921
65	*Actinodaphne citrata* (Blume) Hayata	Lauraceae	ST	8.5	3.5	144.0	1.3	11	4.733
66	*Ficus hirta* Vahl	Moraceae	ST	8.5	3.6	84.7	1.2	5	4.931
67	*Saurauia macrotricha* Kurz ex Dyer	Actinidiaceae	ST	7.0	4.4	142.7	1.2	7	8.520
68	*Cornus* sp.	Cornaceae	ST	2.1	7.3	315.9	1.2	10	157.778

69	*Alchornea tiliifolia* (Benth.) Müll.Arg.	Euphorbiaceae	ST	7.0	3.8	97.9	1.1	6	7.384
70	*Lindera latifolia* Hook. f.	Lauraceae	MT	4.9	2.6	548.6	1.1	14	10.433
71	*Sapindus saponaria* L.	Sapindaceae	MT	1.4	0.4	1440.3	1.0	32	21.300
72	*Trema cannabina* Lour. var. *cannabina*	Cannabaceae	MT	2.8	4.7	270.5	1.0	8	56.800
73	ML066T02	Rutaceae	LT	1.4	0.9	1258.7	0.9	25	42.600
74	*Phyllanthus emblica* L.	Phyllanthaceae	ST	6.3	2.5	112.4	0.9	7	5.960
75	*Erythrina arborescens* Roxb.	Fabaceae	ST	4.9	2.6	154.1	0.8	12	10.433
76	*Camellia kissi* Wall.	Theaceae	ST	4.2	3.5	63.5	0.8	6	18.933
77	*Benkara griffithii* (Hook.f.) Ridsdale	Rubiaceae	ST	2.8	3.2	347.3	0.8	11	39.050
78	*Corylopsis himalayana* Griff.	Hamamelidaceae	ST	5.6	1.8	51.0	0.7	11	5.325
79	*Prunus* sp.	Rosaceae	LT	4.2	1.0	401.2	0.7	23	5.522
80	*Saprosma ternatum* (Wall.) Hook. f.	Rubiaceae	ST	3.5	2.9	77.3	0.7	6	22.720
81	*Ligustrum robustum* (Roxb.) Blume	Oleaceae	MT	3.5	2.6	123.7	0.7	11	20.448
82	*Saurauia fasciculata* Wall.	Actinidiaceae	ST	2.8	3.2	105.5	0.7	8	39.050
83	*Erythrina stricta* Roxb.	Fabaceae	LT	4.2	1.9	141.4	0.7	11	10.256
84	*Polyalthia cerasoides* (Roxb.) Benth. & Hook. f. ex Bedd.	Annonaceae	ST	4.2	1.6	156.8	0.7	10	8.678
85	*Phoebe attenuata* (Nees) Nees	Lauraceae	LT	4.2	1.8	124.4	0.7	12	9.467
86	*Leea asiatica* (L.) Ridsdale	Vitaceae	SH	4.2	2.2	21.2	0.7	3	11.833
87	*Toddalia asiatica* (L.) Lam.	Rutaceae	SS	4.2	2.0	27.9	0.6	11	11.044
88	*Ehretia acuminata* R.Br.	Boraginaceae	LT	2.8	1.9	274.7	0.6	13	23.075
89	*Quercus glauca* Thunb.	Fagaceae	MT	2.1	3.4	83.9	0.6	6	72.578
90	*Myrsine semiserrata* Wall.	Primulaceae	ST	3.5	2.2	82.2	0.6	12	17.040
91	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	MT	2.8	1.8	279.5	0.6	12	21.300
92	*Macaranga denticulata* (Blume) Müll.Arg.	Euphorbiaceae	MT	3.5	2.0	56.7	0.6	8	15.904
93	*Micromelum integerrimum* (Buch-Ham. ex DC.) Wight & Arn ex M.Roem.	Rutaceae	ST	4.2	1.6	27.4	0.6	5	8.678
94	*Styrax serrulatus* Roxb.	Styracaceae	ST	2.1	2.9	90.1	0.6	8	63.111
95	*Acer cappadocicum* Gled.	Sapindaceae	LT	2.8	1.2	295.1	0.6	27	14.200
96	*Schefflera pueckleri* (K.Koch) Frodin	Araliaceae	SS	2.8	1.5	191.5	0.5	12	17.750
97	*Toona ciliata* M.Roem.	Meliaceae	LT	2.8	1.6	149.5	0.5	12	19.525
98	*Ixora* sp.1	Rubiaceae	ST	2.1	2.6	49.2	0.5	4	56.800
99	*Viburnum foetidum* Wall.	Adoxaceae	SH	3.5	1.6	21.3	0.5	7	12.496
100	*Diospyros glandulosa* Lace	Ebenaceae	ST	3.5	1.5	33.2	0.5	5	11.360
101	*Viburnum simonsii* Hook.f. & Thomson	Adoxaceae	ST	3.5	1.0	120.2	0.5	11	7.952
102	*Garcinia lanceifolia* var. *oxyphylla* (Planch. & Triana) Laness.	Clusiaceae	ST	3.5	1.2	41.2	0.5	6	9.088
103	*Syzygium diospyrifolium* (Wall. ex Duthie) S.N.Mitra	Myrtaceae	ST	2.8	1.6	61.2	0.5	6	19.525
104	*Eriobotrya bengalensis* (Roxb.) Hook. f.	Rosaceae	LT	3.5	0.9	86.5	0.5	15	6.816
105	*Magnolia insignis* Wall.	Magnoliaceae	LT	2.8	1.2	127.4	0.5	11	14.200
106	*Caryota urens* L.	Arecaceae	LT	2.1	0.4	348.0	0.4	19	9.467
107	*Ficus subincisa* Buch.-Ham. ex Sm.	Moraceae	SH	2.8	1.5	21.4	0.4	3	17.750

108	*Exbucklandia populnea* (R.Br. ex Griff.) R.W.Br.	Hamamelidaceae	MT	2.8	1.0	103.0	0.4	11	12.425
109	*Alangium chinense* (Lour.) Harms	Cornaceae	ST	2.1	1.9	34.2	0.4	8	41.022
110	*Macropanax undulatus* (Wall. ex G. Don) Seem.	Araliaceae	ST	2.8	1.2	66.4	0.4	8	14.200
111	*Microtropis discolor* (Wall.) Wall. ex Meisn.	Celastraceae	ST	2.1	1.3	146.8	0.4	8	28.400
112	*Symplocos lucida* (Thunb.) Siebold & Zucc.	Symplocaceae	MT	2.1	1.6	79.1	0.4	12	34.711
113	*Elaeagnus pyriformis* Hook.f.	Elaeagnaceae	SS	2.8	1.3	23.8	0.4	5	15.975
114	*Phyllanthus reticulatus* Poir.	Phyllanthaceae	SH	2.8	1.2	15.2	0.4	3	14.200
115	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae	MT	0.7	0.1	551.9	0.4	27	28.400
116	*Lithocarpus fenestratus* (Roxb.) Rehder	Fagaceae	MT	2.8	1.0	24.5	0.4	6	12.425
117	*Neolitsea zeylanica* (Nees & T. Nees) Merr.	Lauraceae	MT	2.8	1.0	15.1	0.4	5	12.425
118	*Trevesia palmata* (Roxb. ex Lindl.) Vis.	Araliaceae	ST	2.1	1.3	68.8	0.4	6	28.400
119	*Nostolachma jenkinsii* (Hook.f.) Deb & Lahiri	Rubiaceae	ST	2.1	1.5	25.3	0.4	4	31.556
120	*Meliosma arnottiana* (Wight) Walp.	Sabiaceae	ST	1.4	1.2	187.6	0.4	14	56.800
121	*Buddleja macrostachya* Benth.	Scrophulariaceae	SH	2.8	0.9	15.5	0.4	4	10.650
122	*Litsea lancifolia* (Roxb. ex Nees) Benth. & Hook. f. ex Villar	Lauraceae	ST	2.1	1.0	83.4	0.4	10	22.089
123	ML069T20	Unidentified	MT	2.1	0.9	103.6	0.4	12	18.933
124	*Alseodaphne khasyana* (Meisn.) Kosterm.	Lauraceae	LT	1.4	1.3	122.0	0.4	6	63.900
125	*Ilex khasiana* Purkay.	Aquifoliaceae	MT	0.7	0.3	435.9	0.3	32	56.800
126	*Pyrus pashia* Buch.-Ham. ex D. Don	Rosaceae	MT	2.1	0.6	115.1	0.3	10	12.622
127	*Litsea elongata* (Nees) Hook. f.	Lauraceae	MT	2.1	1.0	20.4	0.3	4	22.089
128	*Radermachera gigantea* (Blume) Miq.	Bignoniaceae	LT	1.4	1.0	111.8	0.3	12	49.700
129	*Schefflera khasiana* (C.B.Clarke) R.Vig.	Araliaceae	ST	1.4	1.3	50.5	0.3	7	63.900
130	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae	ST	1.4	1.0	105.7	0.3	8	49.700
131	*Calophyllum polyanthum* Wall. ex Planch. & Triana	Calophyllaceae	MT	2.1	0.9	19.5	0.3	6	18.933
132	ML066T11	Unidentified	LT	0.7	0.1	384.7	0.3	28	28.400
133	*Elaeocarpus lanceifolius* Roxb.	Elaeocarpaceae	MT	1.4	0.3	226.6	0.3	12	14.200
134	*Dalbergia stipulacea* Roxb.	Fabaceae	ST	2.1	0.6	53.7	0.3	7	12.622
135	*Litsea* sp.1	Lauraceae	MT	1.4	0.9	106.5	0.3	14	42.600
136	*Saurauia punduana* Wall.	Actinidiaceae	ST	2.1	0.7	15.4	0.3	5	15.778
137	*Saurauia roxburghii* Wall.	Actinidiaceae	ST	2.1	0.6	33.3	0.3	7	12.622
138	ML058T25	Unidentified	LT	1.4	0.3	189.9	0.3	17	14.200
139	*Litsea laeta* (Nees) Hook. f.	Lauraceae	MT	2.1	0.6	15.8	0.3	6	12.622
140	*Rhododendron arboreum* Sm.	Ericaceae	MT	0.7	0.9	178.2	0.3	8	170.400
141	ML078T34	Unidentified	MT	1.4	0.7	90.6	0.3	12	35.500
142	*Holarrhena pubescens* Wall.	Apocynaceae	ST	1.4	1.0	29.9	0.3	7	49.700
143	*Psychotria symplocifolia* Kurz	Rubiaceae	SH	2.1	0.6	5.6	0.3	3	12.622
144	*Docynia indica* (Wall.) Decne.	Rosaceae	LT	0.7	0.4	259.5	0.3	12	85.200
145	*Psychotria calocarpa* Kurz	Rubiaceae	SH	1.4	1.0	17.1	0.3	4	49.700
146	*Acer oblongum* Wall. ex DC.	Sapindaceae	MT	0.7	0.1	297.3	0.3	27	28.400

147	*Echinocarpus murex* Benth.	Elaeocarpaceae	LT	0.7	0.1	293.6	0.2	16	28.400
148	*Rhus chinensis* Mill.	Anacardiaceae	ST	2.1	0.4	5.8	0.2	3	9.467
149	ML058T26	Unidentified	ST	0.7	0.4	230.7	0.2	10	85.200
150	*Clerodendrum glandulosum* Lindl.	Lamiaceae	SH	1.4	0.9	22.8	0.2	5	42.600
151	*Wallichia disticha* T.Anderson	Arecaceae	ST	1.4	0.6	72.8	0.2	10	28.400
152	*Psychotria erratica* Hook.f.	Rubiaceae	SH	1.4	0.9	9.0	0.2	3	42.600
153	*Glycosmis cyanocarpa* var. *cymosa* Kurz	Rutaceae	ST	1.4	0.7	35.5	0.2	8	35.500
154	*Premna milleflora* C.B.Clarke	Lamiaceae	LT	0.7	0.7	147.7	0.2	10	142.000
155	*Brassaiopsis* sp.	Araliaceae	ST	1.4	0.7	14.0	0.2	4	35.500
156	*Calamus latifolius* Roxb.	Arecaceae	SS	1.4	0.7	12.3	0.2	4	35.500
157	*Desmos* sp.	Annonaceae	ST	0.7	0.9	95.7	0.2	6	170.400
158	*Livistona jenkinsiana* Griff.	Arecaceae	ST	1.4	0.4	68.3	0.2	8	21.300
159	*Cephalotaxus griffithii* Hook.f.	Cephalotaxaceae	ST	1.4	0.6	24.0	0.2	5	28.400
160	*Wendlandia ligustrina* Wall. ex G.Don	Rubiaceae	ST	1.4	0.4	49.3	0.2	11	21.300
161	*Sycopsis griffithiana* Oliv.	Hamamelidaceae	ST	1.4	0.6	11.7	0.2	5	28.400
162	*Quercus lineata* Blume	Fagaceae	MT	0.7	0.1	211.6	0.2	14	28.400
163	*Lindera melastomacea* Fern.-Vill.	Lauraceae	ST	1.4	0.6	6.7	0.2	4	28.400
164	*Ardisia pedunculosa* Wall.	Primulaceae	SH	1.4	0.6	5.8	0.2	3	28.400
165	*Podocarpus neriifolius* D.Don	Podocarpaceae	LT	0.7	0.1	188.8	0.2	13	28.400
166	*Glochidion acuminatum* Müll.Arg.	Phyllanthaceae	MT	1.4	0.3	41.6	0.2	10	14.200
167	*Gordonia dipterosperma* Kurz	Theaceae	ST	1.4	0.3	41.5	0.2	10	14.200
168	*Wightia speciosissima* (D. Don) Merr.	Paulowniaceae	MT	1.4	0.4	9.8	0.2	6	21.300
169	*Mahonia napaulensis* DC.	Berberidaceae	SH	1.4	0.4	4.2	0.2	3	21.300
170	*Cleyera japonica* var. *grandiflora* (Wall. ex Choisy) Kobuski	Pentaphylacaceae	ST	0.7	0.9	18.3	0.2	3	170.400
171	*Archidendron clypearia* (Jack) I.C.Nielsen	Fabaceae	ST	1.4	0.3	23.0	0.2	9	14.200
172	*Trichilia connaroides* (Wight & Arn.) Bentv. var. *connaroides*	Meliaceae	MT	1.4	0.3	21.0	0.2	9	14.200
173	*Ficus prostrata* (Wall. ex Miq.) Buch.-Ham. ex Miq.	Moraceae	ST	1.4	0.3	18.4	0.2	5	14.200
174	*Magnolia doltsopa* (Buch.-Ham. ex DC.) Figlar	Magnoliaceae	LT	1.4	0.3	15.5	0.2	6	14.200
175	*Miliusa roxburghiana* Hook.f. & Thomson	Annonaceae	ST	1.4	0.3	6.3	0.2	4	14.200
176	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Lauraceae	MT	1.4	0.3	6.3	0.2	5	14.200
177	*Castanopsis armata* (Roxb.) Spach	Fagaceae	MT	0.7	0.4	80.5	0.2	12	85.200
178	*Ilex* sp.	Aquifoliaceae	MT	0.7	0.3	109.3	0.2	13	56.800
179	*Dendropanax trifidus* (Thunb.) Makino ex H.Hara	Araliaceae	ST	0.7	0.7	9.4	0.2	3	142.000
180	*Ardisia* sp.	Primulaceae	ST	0.7	0.6	23.3	0.1	6	113.600
181	*Bischofia javanica* Blume	Phyllanthaceae	LT	0.7	0.6	19.2	0.1	6	113.600
182	*Citrus hystrix* DC.	Rutaceae	ST	0.7	0.4	42.2	0.1	5	85.200
183	*Olax* sp.	Olacaceae	MT	0.7	0.1	97.2	0.1	13	28.400
184	*Antidesma bunius* (L.) Spreng.	Phyllanthaceae	ST	0.7	0.3	65.2	0.1	10	56.800
185	*Leucosceptrum canum* Sm.	Lamiaceae	ST	0.7	0.3	62.5	0.1	8	56.800

186	*Vitex quinata* (Lour.) F.N.Williams	Lamiaceae	LT	0.7	0.4	32.2	0.1	8	85.200
187	*Compsoneura sprucei* (A. DC.) Warb.	Myristicaceae	MT	0.7	0.4	27.6	0.1	7	85.200
188	*Syzygium formosum* (Wall.) Masam.	Myrtaceae	MT	0.7	0.4	27.0	0.1	5	85.200
189	*Ilex umbellulata* (Wall.) Loes.	Aquifoliaceae	LT	0.7	0.1	84.7	0.1	13	28.400
190	*Sterculia villosa* Roxb.	Malvaceae	MT	0.7	0.1	82.9	0.1	15	28.400
191	*Albizia lucidior* (Steud.) I.C.Nielsen	Fabaceae	MT	0.7	0.3	41.2	0.1	8	56.800
192	*Debregeasia longifolia* (Burm.f.) Wedd.	Urticaceae	SH	0.7	0.4	8.8	0.1	3	85.200
193	*Wendlandia puberula* DC.	Rubiaceae	ST	0.7	0.4	8.4	0.1	6	85.200
194	*Vitex glabrata* R. Br.	Lamiaceae	LT	0.7	0.3	22.7	0.1	12	56.800
195	*Millettia piscidia* (Roxb.) Wight	Fabaceae	MT	0.7	0.3	11.3	0.1	4	56.800
196	*Guidonia vareca* (Roxb.) Baill. ex Kurz	Salicaceae	ST	0.7	0.3	10.3	0.1	4	56.800
197	*Sapindus attenuatus* Wall.	Sapindaceae	ST	0.7	0.3	9.2	0.1	6	56.800
198	*Xylosma longifolia* Clos	Salicaceae	ST	0.7	0.3	9.1	0.1	4	56.800
199	*Sterculia hamiltonii* (Kuntze) Adelb.	Malvaceae	ST	0.7	0.3	6.5	0.1	6	56.800
200	*Maclura fruticosa* (Roxb.) Corner	Moraceae	SS	0.7	0.3	5.4	0.1	5	56.800
201	*Morinda angustifolia* Roxb.	Rubiaceae	SH	0.7	0.3	4.2	0.1	3	56.800
202	*Entada rheedii* Spreng.	Fabaceae	WC	0.7	0.1	33.9	0.1	30	28.400
203	*Trema orientalis* (L.) Blume	Cannabaceae	MT	0.7	0.3	3.5	0.1	3	56.800
204	*Casearia glomerata* Roxb.	Salicaceae	MT	0.7	0.3	3.2	0.1	3	56.800
205	ML038T19	Unidentified	ST	0.7	0.1	32.9	0.1	7	28.400
206	*Machilus glaucescens* (Nees) Wight	Lauraceae	MT	0.7	0.1	32.6	0.1	10	28.400
207	*Camellia caudata* Wall.	Theaceae	ST	0.7	0.3	2.8	0.1	3	56.800
208	*Acer laevigatum* Wall.	Sapindaceae	MT	0.7	0.3	2.7	0.1	3	56.800
209	*Ardisia khasiana* C.B. Clarke	Primulaceae	SH	0.7	0.3	2.7	0.1	3	56.800
210	*Viburnum cylindricum* Buch.-Ham. ex D. Don	Adoxaceae	ST	0.7	0.3	2.6	0.1	5	56.800
211	*Beilschmiedia gammieana* King ex Hook.f.	Lauraceae	MT	0.7	0.1	24.6	0.1	8	28.400
212	ML093T42	Unidentified	ST	0.7	0.1	16.3	0.1	8	28.400
213	*Bombax ceiba* L.	Malvaceae	LT	0.7	0.1	13.4	0.1	9	28.400
214	*Mallotus paniculatus* (Lam.) Müll.Arg. var. *paniculatus*	Euphorbiaceae	MT	0.7	0.1	13.4	0.1	7	28.400
215	*Gynocardia odorata* R.Br.	Achariaceae	LT	0.7	0.1	10.5	0.1	6	28.400
216	*Ilex triflora* Blume	Aquifoliaceae	ST	0.7	0.1	7.9	0.1	4	28.400
217	*Symplocos racemosa* Roxb.	Symplocaceae	ST	0.7	0.1	6.3	0.1	6	28.400
218	*Zanthoxylum armatum* DC.	Rutaceae	ST	0.7	0.1	6.1	0.1	6	28.400
219	*Balakata baccata* (Roxb.) Esser	Euphorbiaceae	MT	0.7	0.1	5.8	0.1	5	28.400
220	*Nostolachma khasiana* (Korth.) Deb & Lahiri	Rubiaceae	ST	0.7	0.1	5.6	0.1	7	28.400
221	*Tarenna asiatica* (L.) Kuntze ex K.Schum.	Rubiaceae	ST	0.7	0.1	5.1	0.1	5	28.400
222	*Grewia serrulata* DC.	Malvaceae	ST	0.7	0.1	3.4	0.1	3	28.400
223	*Clerodendrum bracteatum* Wall. ex Walp.	Lamiaceae	SH	0.7	0.1	2.2	0.1	4	28.400
224	*Embelia subcoriacea* (C.B.Clarke) Mez	Primulaceae	SS	0.7	0.1	2.2	0.1	11	28.400

225	*Oreocnide integrifolia* (Gaudich.) Miq.	Urticaceae	ST	0.7	0.1	2.0	0.1	4	28.400
226	*Vaccinium vacciniaceum* subsp. *vacciniaceum*	Ericaceae	SH	0.7	0.1	1.5	0.1	3	28.400
227	*Antidesma khasianum* Hook.f.	Phyllanthaceae	ST	0.7	0.1	1.4	0.1	3	28.400
228	*Brassaiopsis glomerulata* (Blume) Regel	Araliaceae	ST	0.7	0.1	1.4	0.1	3	28.400
229	*Melastoma malabathricum* L.	Melastomataceae	SH	0.7	0.1	1.4	0.1	3	28.400
230	*Phlogacanthus pubinervius* T.Anderson	Acanthaceae	SH	0.7	0.1	1.4	0.1	3	28.400
231	*Antidesma acidum* Retz.	Phyllanthaceae	ST	0.7	0.1	1.2	0.1	3	28.400
232	*Elaeocarpus floribundus* Blume	Elaeocarpaceae	LT	0.7	0.1	1.2	0.1	3	28.400
233	ML067T15	Unidentified	ST	0.7	0.1	1.2	0.1	3	28.400
	Grand Total				862.0	175244.4	300		

The abundance-to-frequency ratio suggested that all species exhibited a clumped to highly clumped dispersion. The minimum value of A/F ratio was 1.528 for *Engelhardtia spicata* and maximum was 170.4 for *Ficus virens*. A total of three species showed A/F ratio 2 or less and remaining species showed A/F ratio above 2 (Table 4.25).

The stand density was 862.0 individuals ha^{-1} and basal area was 17.52 m^2 ha^{-1} (Table 4.26). The mean basal area was 203.29 cm^2 $individual^{-1}$ (Table 4.26). The Shannon's diversity index was 1.930, Pielou's evenness index was 0.815, Simpson's dominance index was 0.024 and Whittaker's species richness index was 61.519 (Table 4.26).

Table 4.26. Phytosociological attributes and diversity indices in woody layer of Khasi subtropical mixed-broadleaved forest in Meghalaya.

Sl. No.	Attribute	Value
1.	Number of species	233
2.	Number of genera	158
3.	Number of families	69
4.	Density (ha^{-1})	862.0
5	Basal area (m^2 ha^{-1})	17.52
6.	Mean basal area (cm^2 $individual^{-1}$)	203.29
7.	Shannon's diversity index	1.930
8.	Evenness index	0.815
9.	Dominance index	0.024
10.	Species richness index	61.519

Of all 233 species in the woody layer, 225 species belonged to 69 identified families and 8 species were placed in an "unidentified" family (Table 4.27). Of these, 31 families were represented by one species, 8 families by two species, 9 families by three species, 2 families by four species and 19 families by more than four species. The family Lauraceae had the maximum 19 species followed by Rubiaceae with 16 species (Table 4.27). In

terms of genera, Lauraceae and Rubiaceae were again dominant with 11 and 9 genera, respectively (Table 4.27).

Table 4.27. The number of families, genera, species and individuals recorded in woody layer of the Khasi subtropical mixed-broadleaved forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Acanthaceae	1	1	1	Magnoliaceae	1	2	10
Achariaceae	1	1	1	Malvaceae	4	5	34
Actinidiaceae	1	5	115	Melastomataceae	1	1	1
Adoxaceae	1	3	20	Meliaceae	3	3	45
Anacardiaceae	3	3	68	Moraceae	2	7	128
Annonaceae	3	3	19	Myricaceae	1	2	96
Apocynaceae	1	1	7	Myristicaceae	1	1	3
Aquifoliaceae	1	5	32	Myrtaceae	1	5	392
Araliaceae	5	9	206	Olacaceae	1	1	1
Arecaceae	4	4	15	Oleaceae	2	2	23
Asteraceae	1	1	73	Pandanaceae	1	1	45
Berberidaceae	1	1	3	Paulowniaceae	1	1	3
Betulaceae	1	1	52	Pentaphylacaceae	2	3	228
Bignoniaceae	1	1	7	Phyllanthaceae	4	8	85
Boraginaceae	1	1	13	Pinaceae	1	1	221
Calophyllaceae	1	1	6	Podocarpaceae	1	1	1
Cannabaceae	1	2	34	Primulaceae	4	6	59
Celastraceae	1	1	9	Proteaceae	1	1	283
Cephalotaxaceae	1	1	4	Putranjivaceae	1	1	30
Clusiaceae	1	3	56	Rhizophoraceae	1	1	1
Cornaceae	2	2	63	Rosaceae	5	5	67
Daphniphyllaceae	1	1	52	Rubiaceae	9	16	289
Ebenaceae	1	2	15	Rutaceae	6	6	40
Elaeagnaceae	1	1	9	Sabiaceae	1	1	8
Elaeocarpaceae	2	3	4	Salicaceae	3	3	6
Ericaceae	4	4	59	Sapindaceae	3	6	129
Erythroxylaceae	1	1	34	Sapotaceae	1	1	72
Euphorbiaceae	5	6	121	Scrophulariaceae	1	1	6
Fabaceae	6	8	71	Staphyleaceae	1	1	26
Fagaceae	3	9	364	Styracaceae	1	1	20
Hamamelidaceae	3	3	23	Symplocaceae	1	6	249
Iteaceae	1	2	97	Theaceae	3	5	852
Juglandaceae	1	1	181	Unidentified	8	8	20
Lamiaceae	5	7	73	Urticaceae	2	2	4
Lauraceae	11	19	506	Vitaceae	1	1	15

In terms of density, Theaceae showed the highest number of individuals (852) followed by Lauraceae (506), Myrtaceae (392) and Fagaceae (364). Six families, viz., Acanthaceae, Achariaceae, Melastomataceae, Olacaceae, Podocarpaceae and Rhizophoraceae had only one individual each (Table 4.27).

The dominance-diversity curve for woody layer of Khasi subtropical mixed-broadleaved forest (Fig. 4.9) followed a log-normal distribution with a mixed dominance of three species in the top canopy (*Schima wallichii*, *Pinus kesiya*, *Engelhardtia spicata*) and one species in the sub canopy (*Syzygium tetragonum*).

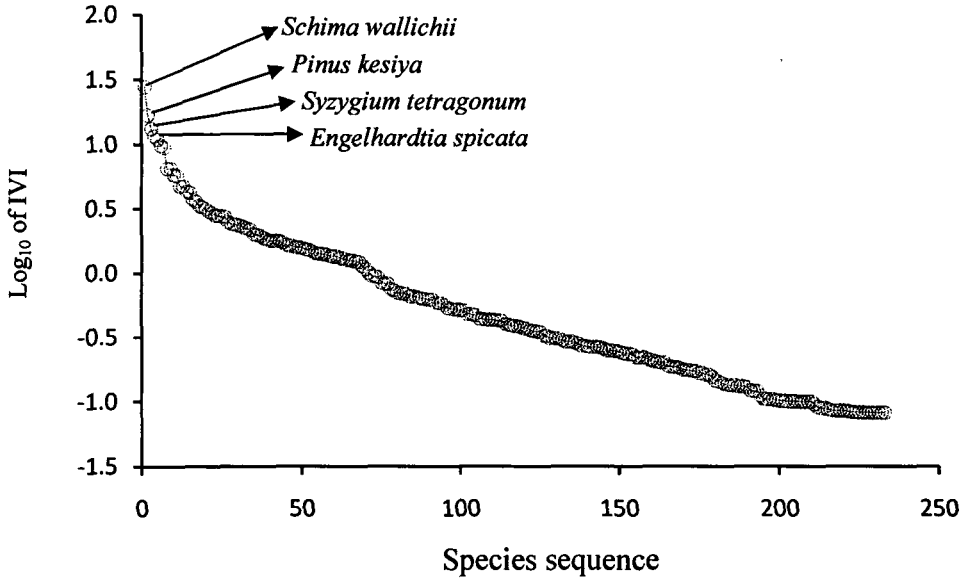

Fig. 4.9. The dominance-diversity curve based on Log_{10} of IVI for woody layer of Khasi subtropical mixed-broadleaved forest in Meghalaya.

4.4.10. Khasi Subtropical Mixed-Broadleaved Forest – herb layer

The floristic composition of herb layer of Khasi subtropical mixed-broadleaved forest is given in Table 4.28. A total of 1,431 individuals of all species (including tree seedlings) were recorded in herb layer. These belong to 70 families, 155 genera and 180 species. The most dominant species on the basis of IVI is *Rotala rotundifolia* (8.8) followed by *Agreratina adenophora*, *Begonia palmata*, *Thysanolaena latifolia*, *Elatostema lineolatum* and *Strobilanthes colorata* with an Importance Value of 6.7, 5.1, 4.4, 4.2 and 4.1 respectively (Table 4.28). The endemic species to Meghalaya were: *Baliospermum calycinum* var. *micranthum*, *Citrus indica*, *Persicaria bistorta*, *Smilax myrtillus* and *Trachyspermum khasianum*.

Table 4.28. Floristic composition of herb layer of Khasi subtropical mixed-broadleaved forest based on 59 quadrats of 1 x 1 m size. Species are arranged in descending order of IVI values.

Sl. no.	Species Name	Family	Occurrence	No. of individuals	IVI
1	*Rotala rotundifolia* (Buch.-Ham. ex Roxb.) Koehne	Lythraceae	1	121	8.8
2	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Asteraceae	10	49	6.7
3	*Begonia palmata* D.Don	Begoniaceae	10	25	5.1
4	*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda	Poaceae	7	29	4.4
5	*Elatostema lineolatum* Wight	Urticaceae	6	32	4.2
6	*Strobilanthes colorata* T.Anderson	Acanthaceae	6	30	4.1
7	*Oxalis corniculata* L.	Oxalidaceae	2	45	3.8
8	*Gonostegia hirta* (Blume ex Hassk.) Miq.	Urticaceae	6	20	3.4
9	*Ophiorrhiza rugosa* var. *prostrata* (D.Don) Deb & Mondal	Rubiaceae	6	20	3.4
10	*Oplismenus compositus* (L.) P. Beauv.	Poaceae	4	26	3.1
11	*Rubus moluccanus* L.	Rosaceae	6	16	3.1
12	*Lantana camara* L.	Verbenaceae	5	18	2.9
13	*Senecio cappa* Buch.-Ham. ex D.Don	Asteraceae	5	18	2.9
14	*Selaginella monospora* Spring	Selaginellaceae	3	27	2.9
15	*Stachytarpheta indica* (L.) Vahl	Verbenaceae	1	36	2.8
16	*Urena lobata* L.	Malvaceae	4	21	2.8
17	*Tectaria polymorpha* (Wall. ex Hook.) Copel.	Dryopteridaceae	4	15	2.4
18	*Artemisia nilagirica* (C.B.Clarke) Pamp.	Asteraceae	2	23	2.3
19	*Justicia procumbens* L.	Acanthaceae	2	23	2.3

20	*Phrynium pubinerve* Blume	Marantaceae	3	18	2.3
21	*Oplismenus burmannii* (Retz.) P.Beauv.	Poaceae	2	22	2.2
22	*Chromolaena odorata* (L.) R.M. King & H. Rob.	Asteraceae	3	17	2.2
23	*Polypodium penangianum* Hook.	Polypodiaceae	3	17	2.2
24	*Capillipedium assimile* (Steud.) A.Camus	Poaceae	2	21	2.1
25	*Helicia nilagirica* Bedd.	Proteaceae	5	6	2.1
26	*Houttuynia cordata* Thunb.	Saururaceae	3	15	2.0
27	*Isachne globosa* (Thunb.) Kuntze	Poaceae	1	24	2.0
28	*Ageratum houstonianum* Mill.	Asteraceae	3	14	2.0
29	*Centella asiatica* (L.) Urb.	Apiaceae	2	17	1.9
30	*Hydrocotyle javanica* Thunb.	Araliaceae	1	21	1.8
31	*Selaginella* sp.2	Selaginellaceae	1	20	1.7
32	*Chrysopogon gryllus* (L.) Trin.	Poaceae	1	18	1.6
33	*Smilax myrtillus* A.DC.	Smilacaceae	3	8	1.6
34	*Fimbristylis* sp.2	Cyperaceae	1	17	1.5
35	*Persicaria capitata* (Buch.-Ham. ex D.Don) H.Gross	Polygonaceae	1	17	1.5
36	*Desmodium heterocarpon* (L.) DC.	Fabaceae	2	12	1.5
37	*Duchesnea indica* (Andrews) Focke	Rosaceae	2	12	1.5
38	*Curcuma aromatica* Salisb.	Zingiberaceae	3	7	1.5
39	*Ageratum conyzoides* (L.) L.	Asteraceae	1	16	1.5
40	*Imperata cylindrica* (L.) Raeusch.	Poaceae	1	16	1.5
41	*Bolbitis sinensis* K.Iwats.	Lomariopsidaceae	2	11	1.4
42	*Dicranopteris splendida* (Hand.-Mazz.) Ching	Gleicheniaceae	3	6	1.4
43	*Mimosa pudica* L.	Fabaceae	1	15	1.4
44	*Strobilanthes glomerata* T. Anderson	Acanthaceae	2	10	1.4
45	*Curcuma angustifolia* Roxb.	Zingiberaceae	3	5	1.3
46	*Spermacoce articularis* L.f.	Rubiaceae	1	14	1.3
47	*Floscopa scandens* Lour.	Commelinaceae	2	9	1.3
48	*Solanum capsicoides* All.	Solanaceae	3	4	1.3
49	*Clitoria mariana* L.	Fabaceae	1	12	1.2
50	*Commelina benghalensis* L.	Commelinaceae	1	12	1.2
51	*Eranthemum indicum* (Nees) C.B. Clarke	Acanthaceae	2	7	1.2
52	*Scutellaria discolor* Colebr.	Lamiaceae	2	7	1.2
53	*Viola sikkimensis* W. Becker	Violaceae	2	7	1.2
54	*Ageratina riparia* (Regel) R.M.King & H.Rob.	Asteraceae	1	11	1.1
55	*Disporum cantoniense* (Lour.) Merr.	Asparagaceae	2	6	1.1
56	*Lithocarpus fenestratus* (Roxb.) Rehder	Fagaceae	2	6	1.1
57	*Plantago erosa* Wall.	Plantaginaceae	2	6	1.1
58	*Wendlandia puberula* DC.	Rubiaceae	2	6	1.1
59	*Arundinella setosa* Trin.	Poaceae	1	10	1.0
60	*Persicaria perfoliata* (L.) H. Gross	Polygonaceae	1	10	1.0
61	*Bidens pilosa* L.	Asteraceae	2	5	1.0
62	*Eriosolena involucrata* (Wall.) ined.	Thymelaeaceae	2	5	1.0
63	*Ophiopogon intermedius* D. Don	Asparagaceae	2	5	1.0
64	*Dalbergia stipulacea* Roxb.	Fabaceae	2	4	0.9

65	*Melastoma malabathricum* L.	Melastomataceae	2	4	0.9
66	*Persicaria chinensis* (L.) H. Gross	Polygonaceae	2	4	0.9
67	*Anemone rivularis* Buch.-Ham. ex DC.	Ranunculaceae	1	8	0.9
68	*Baliospermum calycinum* var. *micranthum* (Mull.Arg.) Chakrab. & N. P. Balakr.	Euphorbiaceae	2	3	0.9
69	*Citrus indica* Tanaka	Rutaceae	2	3	0.9
70	*Rubia sikkimensis* Kurz	Rubiaceae	2	3	0.9
71	*Achyrospermum wallichianum* Benth. ex Hk.f.	Lamiaceae	1	7	0.8
72	*Clinopodium umbrosum* (M.Bieb.) Kuntze	Lamiaceae	1	7	0.8
73	*Pennisetum glaucum* (L.) R.Br.	Poaceae	1	7	0.8
74	*Polystichum lentum* (D. Don) T. Moore	Dryopteridaceae	1	7	0.8
75	*Mycetia longifolia* (Wall.) Kuntze	Rubiaceae	2	2	0.8
76	*Tadehagi triquetrum* (L.) H.Ohashi	Fabaceae	2	2	0.8
77	*Crotalaria micans* Link	Fabaceae	1	6	0.8
78	*Impatiens chinensis* L.	Balsaminaceae	1	6	0.8
79	*Sphenomeris chinensis* (L.) Maxon	Dennstaedtiaceae	1	6	0.8
80	*Themeda triandra* Forssk.	Poaceae	1	6	0.8
81	*Trachyspermum khasianum* H.Wolff	Apiaceae	1	6	0.8
82	*Ambrosia artemisiifolia* L.	Asteraceae	1	5	0.7
83	*Dicranopteris linearis* (Burm. f.) Underw.	Gleicheniaceae	1	5	0.7
84	*Galium rotundifolium* L.	Rubiaceae	1	5	0.7
85	*Ophiorrhiza mungos* L.	Rubiaceae	1	5	0.7
86	*Paspalum scrobiculatum* L.	Poaceae	1	5	0.7
87	*Pteris biaurita* L.	Pteridaceae	1	5	0.7
88	*Symplocos paniculata* Miq.	Symplocaceae	1	5	0.7
89	*Thelypteris esquirolii* (H. Christ) Ching	Thelypteridaceae	1	5	0.7
90	*Acmella paniculata* (Wall. ex DC.) R. K. Jansen	Asteraceae	1	4	0.6
91	*Caryota urens* L.	Arecaceae	1	4	0.6
92	*Gnaphalium affine* D.Don	Asteraceae	1	4	0.6
93	*Inula eupatorioides* Wall. ex DC.	Asteraceae	1	4	0.6
94	*Panicum sarmentosum* Roxb.	Poaceae	1	4	0.6
95	*Passiflora subpeltata* Ortega	Passifloraceae	1	4	0.6
96	*Rubus calycinus* Wall. ex D. Don	Rosaceae	1	4	0.6
97	*Rubus ellipticus* Sm.	Rosaceae	1	4	0.6
98	*Sacciolepis indica* (L.) Chase	Poaceae	1	4	0.6
99	*Sida rhombifolia* L.	Malvaceae	1	4	0.6
100	*Sigesbeckia orientalis* L.	Asteraceae	1	4	0.6
101	*Strobilanthes boerhaavioides* T.Anderson	Acanthaceae	1	4	0.6
102	*Archidendron clypearia* (Jack) I.C.Nielsen	Fabaceae	1	3	0.5
103	*Calamus erectus* Roxb.	Arecaceae	1	3	0.5
104	*Codonacanthus pauciflorus* (Nees) Nees	Acanthaceae	1	3	0.5
105	*Gleichenia longissima* Blume	Gleicheniaceae	1	3	0.5
106	*Didymocarpus acuminatus* R.Br.	Gesneriaceae	1	3	0.5
107	*Lasianthus hookeri* C.B.Clarke ex Hook.f.	Rubiaceae	1	3	0.5
108	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	Lauraceae	1	3	0.5

109	*Luculia pinceana* Hook.	Rubiaceae	1	3	0.5
110	*Macropanax dispermus* (Blume) Kuntze	Araliaceae	1	3	0.5
111	*Mazus pumilus* (Burm. f.) Steenis var. *pumilus*	Phrymaceae	1	3	0.5
112	*Persicaria bistorta* (L.) Samp.	Polygonaceae	1	3	0.5
113	*Piper attenuatum* Buch.-Ham. ex Miq.	Piperaceae	1	3	0.5
114	*Pogostemon dasianus* A.B.De & Mukerjee	Lamiaceae	1	3	0.5
115	*Rhaphidophora glauca* (Wall.) Schott	Araceae	1	3	0.5
116	*Rhus chinensis* Mill.	Anacardiaceae	1	3	0.5
117	*Sonerila maculata* Roxb.	Melastomataceae	1	3	0.5
118	*Acanthephippium* sp.	Orchidaceae	1	2	0.5
119	*Achyranthes aspera* L.	Amaranthaceae	1	2	0.5
120	*Arisaema consanguineum* Schott	Araceae	1	2	0.5
121	*Asplenium phyllitidis* D. Don	Aspleniaceae	1	2	0.5
122	*Chassalia curviflora* (Wall.) Thwaites	Rubiaceae	1	2	0.5
123	*Cissus repanda* (Wight & Arn.) Vahl	Vitaceae	1	2	0.5
124	*Hedyotis scandens* Roxb.	Rubiaceae	1	2	0.5
125	*Isodon lophanthoides* var. *graciliflorus* (Benth.) H.Hara	Lamiaceae	1	2	0.5
126	*Kaempferia rotunda* L.	Zingiberaceae	1	2	0.5
127	*Loxostigma griffithii* (Wight) C.B. Clarke	Gesneriaceae	1	2	0.5
128	*Lygodium flexuosum* (L.) Sw.	Schizaeaceae	1	2	0.5
129	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae	1	2	0.5
130	*Meizotropis buteiformis* Voigt	Fabaceae	1	2	0.5
131	*Osbeckia nepalensis* Hook. f.	Melastomataceae	1	2	0.5
132	*Oxyspora paniculata* (D. Don) DC.	Melastomataceae	1	2	0.5
133	*Piper hymenophyllum* (Miq.) Wight	Piperaceae	1	2	0.5
134	*Platostoma palustre* (Blume) A.J.Paton	Lamiaceae	1	2	0.5
135	*Ranunculus diffusus* DC.	Ranunculaceae	1	2	0.5
136	*Smithia blanda* Wall.	Fabaceae	1	2	0.5
137	*Swertia macrosperma* (C.B. Clarke) C.B. Clarke	Gentianaceae	1	2	0.5
138	*Syzygium cumini* (L.) Skeels	Myrtaceae	1	2	0.5
139	*Triumfetta tomentosa* Bojer ex Bouton	Malvaceae	1	2	0.5
140	*Wendlandia tinctoria* (Roxb.) DC.	Rubiaceae	1	2	0.5
141	*Argyreia roxburghii* (Wall.) Arn. ex Choisy	Convolvulaceae	1	1	0.4
142	*Boehmeria* sp.	Urticaceae	1	1	0.4
143	*Breynia retusa* (Dennst.) Alston	Phyllanthaceae	1	1	0.4
144	*Clerodendrum wallichii* Merr.	Lamiaceae	1	1	0.4
145	*Cyathula tomentosa* (Roth) Moq.	Amaranthaceae	1	1	0.4
146	*Cyclea bicristata* (Griff.) Diels	Menispermaceae	1	1	0.4
147	*Dianella ensifolia* (L.) DC.	Xanthorrhoeaceae	1	1	0.4
148	*Dioscorea bulbifera* L.	Dioscoreaceae	1	1	0.4
149	*Dioscorea hamiltonii* Hook.f.	Dioscoreaceae	1	1	0.4
150	*Erythrina arborescens* Roxb.	Fabaceae	1	1	0.4
151	*Ficus fulva* Reinw. ex Blume	Moraceae	1	1	0.4
152	*Gaultheria fragrantissima* Wall.	Ericaceae	1	1	0.4
153	*Pteridium aquilinum* (L.) Kuhn	Dennstaedtiaceae	1	1	0.4

154	*Hypoxis aurea* Lour.	Hypoxidaceae	1	1	0.4
155	*Inula cappa* (Buch.-Ham. ex D.Don) DC.	Asteraceae	1	1	0.4
156	*Iteadaphne caudata* (Nees) H.W. Li	Lauraceae	1	1	0.4
157	*Jasminum lanceolaria* Roxb.	Oleaceae	1	1	0.4
158	*Lasianthus lucidus* Blume	Rubiaceae	1	1	0.4
159	*Lecanthus peduncularis* (Wall. ex Royle) Wedd.	Urticaceae	1	1	0.4
160	*Ligustrum robustum* (Roxb.) Blume	Oleaceae	1	1	0.4
161	*Machilus gamblei* King ex Hook. f.	Lauraceae	1	1	0.4
162	*Mikania micrantha* Kunth	Asteraceae	1	1	0.4
163	*Murdannia nudiflora* (L.) Brenan	Commelinaceae	1	1	0.4
164	*Passiflora edulis* Sims	Passifloraceae	1	1	0.4
165	*Phyllanthus emblica* L.	Phyllanthaceae	1	1	0.4
166	*Piper mullesua* Buch.-Ham. ex D. Don	Piperaceae	1	1	0.4
167	*Pothos scandens* L.	Araceae	1	1	0.4
168	*Pteris semipinnata* L.	Pteridaceae	1	1	0.4
169	*Rhododendron formosum* Wall.	Ericaceae	1	1	0.4
170	*Rubus hexagynus* Roxb.	Rosaceae	1	1	0.4
171	*Schima wallichii* Choisy	Theaceae	1	1	0.4
172	*Setaria pumila* (Poir.) Roem. & Schult.	Poaceae	1	1	0.4
173	*Smilax orthoptera* A.DC.	Smilacaceae	1	1	0.4
174	*Solanum spirale* Roxb.	Solanaceae	1	1	0.4
175	*Solena amplexicaulis* (Lam.) Gandhi	Cucurbitaceae	1	1	0.4
176	*Tetrastigma serrulatum* (Roxb.) Planch.	Vitaceae	1	1	0.4
177	*Tupistra nutans* Wall. ex Lindl.	Asparagaceae	1	1	0.4
178	*Vaccinium griffithianum* Wight	Ericaceae	1	1	0.4
179	*Viburnum foetidum* Wall.	Adoxaceae	1	1	0.4
180	*Vigna marina* (Burm.) Merr.	Fabaceae	1	1	0.4
	Grand Total			1431	200

The density was 2425.4 individuals/100 m^2 (Table 4.29). The Shannon's diversity index was 2.103, evenness index was 0.932, dominance index was 0.011 and species richness index was 56.724 (Table 4.29).

Table 4.29. Phytosociological attributes and diversity indices in herb layer of the Khasi subtropical mixed-broadleaved forest in Meghalaya.

Sl. No.	Attribute	Value
1.	Number of species	180
2.	Number of genera	155
3.	Number of families	70
4.	Density (100 m^{-2})	2425.4
5.	Shannon's diversity index	2.103
6.	Evenness index	0.932
7.	Dominance index	0.011
8.	Species richness index	56.724

Asteraceae (15 species) was the most dominant family followed by Poaceae (14 species), Rubiaceae (13 species) and Fabaceae (11 species). In terms of genera, Poaceae, Asteraceae, Fabaceae and Rubiaceae were dominant with 13, 12, 11 and 10 genera, respectively (Table 4.30). Poaceae was most dominant in terms of number of individuals (193 individuals) followed by Asteraceae (176 individuals) and Lythraceae (121 individuals) (Table 4.30).

Table 4.30. The number of families, genera, species and individuals recorded in herb layer of the Khasi subtropical mixed-broadleaved forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Acanthaceae	4	6	77	Menispermaceae	1	1	1
Adoxaceae	1	1	1	Moraceae	1	1	1
Amaranthaceae	2	2	3	Myrtaceae	1	1	2
Anacardiaceae	1	1	3	Oleaceae	2	2	2
Apiaceae	2	2	23	Orchidaceae	1	1	2
Araceae	3	3	6	Oxalidaceae	1	1	45
Araliaceae	2	2	24	Passifloraceae	1	2	5
Arecaceae	2	2	7	Phrymaceae	1	1	3
Asparagaceae	3	3	12	Phyllanthaceae	2	2	2
Aspleniaceae	1	1	2	Piperaceae	1	3	6
Asteraceae	12	15	176	Plantaginaceae	1	1	6
Balsaminaceae	1	1	6	Poaceae	13	14	193
Begoniaceae	1	1	25	Polygonaceae	1	4	34
Commelinaceae	3	3	22	Polypodiaceae	1	1	17
Convolvulaceae	1	1	1	Proteaceae	1	1	6
Cucurbitaceae	1	1	1	Pteridaceae	1	2	6
Cyperaceae	1	1	17	Ranunculaceae	2	2	10
Dennstaedtiaceae	2	2	7	Rosaceae	2	5	37
Dioscoreaceae	1	2	2	Rubiaceae	10	13	68
Dryopteridaceae	2	2	22	Rutaceae	1	1	3
Ericaceae	4	4	5	Saururaceae	1	1	15
Euphorbiaceae	1	1	3	Schizaeaceae	1	1	2
Fabaceae	11	11	60	Selaginellaceae	1	2	47
Fagaceae	1	1	6	Smilacaceae	1	2	9
Gentianaceae	1	1	2	Solanaceae	1	2	5
Gesneriaceae	2	2	5	Symplocaceae	1	1	5
Gleicheniaceae	2	3	14	Theaceae	1	1	1
Hypoxidaceae	1	1	1	Thelypteridaceae	1	1	5
Lamiaceae	7	7	29	Thymelaeaceae	1	1	5
Lauraceae	3	3	5	Urticaceae	4	4	54
Lomariopsidaceae	1	1	11	Verbenaceae	2	2	54
Lythraceae	1	1	121	Violaceae	1	1	7
Malvaceae	3	3	27	Vitaceae	2	2	3
Marantaceae	1	1	18	Xanthorrhoeaceae	1	1	1
Melastomataceae	4	4	11	Zingiberaceae	2	3	14

The dominance-diversity curve for herb layer of Khasi subtropical mixed-broadleaved forest (Fig. 4.10) followed a log-normal distribution with a mixed dominance of *Rotala rotundifolia*, *Ageratina adenophora* and *Begonia palmata*.

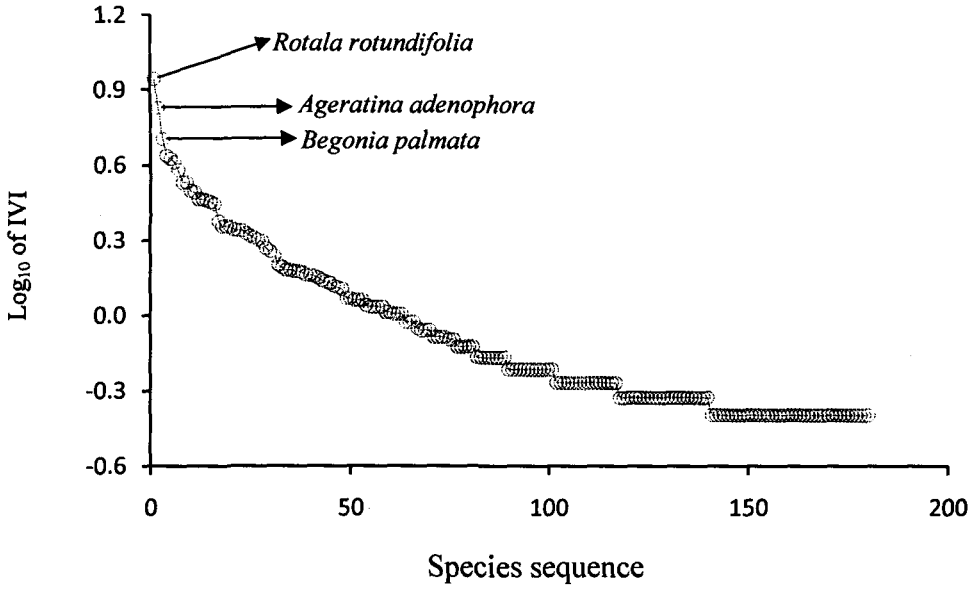

Fig. 4.10. The dominance-diversity curve based on Log_{10} of IVI for herb layer of Khasi subtropical mixed-broadleaved forest in Meghalaya.

4.4.11. Khasi Subtropical Oak-Dominated Forest – woody layer

The floristic composition of the woody layer of Khasi subtropical oak-dominated forest (Table 4.31) exhibited a total of 7,775 individuals of ≥10 cm gbh in 8.6 ha sampled area (20 transects of 10 m width and upto 500 m length, Tables 3.5 & 3.7 in Chapter III). Overall, 225 species of 144 genera in 64 families occurred. Of all, 205 species were identified up to species level, 12 species up to genus level and 8 species could not be determined (Table 4.31). The majority of species were small tree (109 species) followed by medium tree (54 species), large tree (29 species), shrub (23 species), scandent shrub (8 species) and woody climber (2 species) (Table 4.31). Three species of gymnosperms occurred: *Pinus kesiya*, *Podocarpus neriifolius* and *Taxus wallichiana*. Following fourteen endemic species were recorded: *Adinandra griffithii*, *Elaeocarpus prunifolius*, *Fissistigma verrucosum*, *Ilex embelioides*, *Ilex khasiana*, *Ilex venulosa*, *Lindera latifolia*, *Nostolachma jenkinsii*, *Salix psilostigma*, *Schefflera pueckleri*, *Schima khasiana*, *Sycopsis griffithiana*, *Viburnum simonsii* and *Xylosma controversa*.

In terms of number of individuals (density), the most dominant species were: *Lithocarpus fenestratus* (536 individuals), *Rhododendron arboreum* (431), *Castanopsis tribuloides* (348) and *Castanopsis purpurella* (334). Thirty nine species were represented by only one and 14 species by 2 individuals each. The remainder species had 3 to 325 individuals (Table 4.31).

In terms of IVI, the most dominant species were: *Pinus kesiya* (15.4), *Castanopsis purpurella* (13.5), *Lithocarpus fenestratus* (13.1) and *Myrica esculenta* (12.3) (Table 4.31). Of all, 165 species were rare as they exhibited an Importance Value of 1 or less. A majority of species (43 species) exhibited an Importance Value between >1 and <5, and 13 species exhibited an Importance Value between >5 and <12 (Table 4.31).

Table 4.31. Floristic composition, habit (LT- Large Tree, MT- Medium Tree, ST- Small Tree, SH- Shrub, SS- Scandent Shrub, WC- Woody Climber), frequency (%), density (ha^{-1}), basal area ($cm^2\ ha^{-1}$), importance value index (IVI), maximum height (m) and abundance-to-frequency ratio (A/F) of Khasi subtropical oak-dominated forest type in Meghalaya. Species are arranged in descending order of IVI values.

Sl. no.	Species name	Family	Habit	Freq-uency (%)	Den-sity (ha^{-1})	Basal Area ($cm^2\ ha^{-1}$)	IVI	Max height (m)	A/F ratio
1	*Pinus kesiya* Royle ex Gordon	Pinaceae	LT	23.3	33.6	13831.6	15.4	28	6.214
2	*Castanopsis purpurella* (Miq.) N. P. Balakr.	Fagaceae	LT	25.0	38.8	9982.1	13.5	16	6.214
3	*Lithocarpus fenestratus* (Roxb.) Rehder	Fagaceae	MT	20.3	62.3	6331.6	13.1	21	15.052
4	*Myrica esculenta* Buch.-Ham. ex D. Don	Myricaceae	MT	36.6	33.5	7735.0	12.3	15	2.496
5	*Rhododendron arboreum* Sm.	Ericaceae	MT	22.7	50.1	6219.8	11.9	15	9.748
6	*Schima wallichii* Choisy	Theaceae	LT	36.0	31.6	6893.2	11.5	18	2.434
7	*Castanopsis tribuloides* (Sm.) A.DC.	Fagaceae	LT	17.4	40.5	7801.9	11.4	15	13.301
8	*Schima khasiana* Dyer	Theaceae	LT	17.4	11.4	10553.4	10.2	24	3.746
9	*Helicia nilagirica* Bedd.	Proteaceae	MT	39.0	29.8	3279.0	9.0	13	1.962
10	*Lithocarpus dealbatus* (Hook.f. & Thomson ex Miq.) Rehder	Fagaceae	ST	29.1	37.8	3199.8	9.0	14	4.472
11	*Castanopsis armata* (Roxb.) Spach	Fagaceae	MT	12.2	15.3	8306.5	8.6	17	10.297
12	*Quercus lineata* Blume	Fagaceae	MT	12.2	17.3	7313.1	8.1	21	11.623
13	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	Fagaceae	LT	22.1	14.0	3796.6	6.1	20	2.859
14	*Quercus semiserrata* Roxb.	Fagaceae	LT	5.8	6.5	6615.7	5.9	18	19.264
15	*Syzygium tetragonum* (Wight) Wall. ex Walp.	Myrtaceae	LT	26.7	18.3	1918.5	5.7	12	2.552
16	*Eurya japonica* Thunb.	Pentaphylacaceae	SH	25.0	28.3	367.1	5.6	7	4.521
17	*Engelhardtia spicata* Lechen ex Blume	Juglandaceae	LT	30.2	14.1	1914.0	5.5	17	1.539
18	*Neolitsea zeylanica* (Nees & T. Nees) Merr.	Lauraceae	MT	19.8	16.2	1985.4	4.9	16	4.136
19	*Ficus neriifolia* Sm.	Moraceae	MT	26.7	13.8	853.4	4.5	11	1.935
20	*Symplocos cochinchinensis* var. *laurina* (Retz.) Noot.	Symplocaceae	ST	21.5	15.1	501.8	3.9	8	3.267
21	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus	Fagaceae	LT	8.1	15.7	2074.9	3.9	13	23.694
22	*Schefflera hypoleuca* (Kurz) Harms	Araliaceae	ST	23.3	8.7	749.9	3.5	14	1.613
23	*Persea odoratissima* (Nees) Kosterm.	Lauraceae	MT	16.9	6.7	1585.5	3.3	16	2.372
24	*Exbucklandia populnea* (R.Br. ex Griff.) R.W.Br.	Hamamelidaceae	MT	15.7	7.2	1572.9	3.3	18	2.926
25	*Symplocos pyrifolia* Wall. ex G. Don	Symplocaceae	ST	9.3	10.2	1005.0	2.6	11	11.825
26	*Eurya acuminata* DC.	Pentaphylacaceae	ST	16.9	7.4	193.5	2.4	12	2.618
27	*Sycopsis griffithiana* Oliv.	Hamamelidaceae	ST	5.2	9.4	1071.1	2.2	12	34.400
28	*Magnolia insignis* Wall.	Magnoliaceae	LT	6.4	4.0	1664.0	2.2	21	9.666
29	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet	Lauraceae	LT	7.6	4.1	1460.5	2.1	15	7.124

30	*Camellia kissi* Wall.	Theaceae	ST	10.5	9.8	166.5	2.1	9	8.919
31	*Betula alnoides* Buch.-Ham. ex D.Don	Betulaceae	LT	9.3	4.4	1073.4	2.1	30	5.106
32	*Ilex venulosa* Hook.f.	Aquifoliaceae	MT	9.9	4.0	991.3	2.0	20	4.047
33	*Pandanus furcatus* Roxb.	Pandanaceae	ST	9.9	5.8	627.1	1.9	9	5.952
34	*Photinia integrifolia* Lindl. var. *integrifolia*	Rosaceae	MT	8.7	7.9	414.8	1.9	8	10.396
35	*Symplocos sumuntia* Buch.-Ham. ex D. Don	Symplocaceae	ST	11.0	7.0	261.8	1.9	8	5.717
36	*Myrica nagi* Thunb.	Myricaceae	MT	9.3	5.9	490.3	1.8	11	6.853
37	*Quercus griffithii* Hook.f. & Thomson ex Miq.	Fagaceae	MT	8.1	3.4	1036.0	1.8	13	5.090
38	*Itea macrophylla* Wall.	Iteaceae	ST	5.8	8.4	521.5	1.8	10	24.768
39	*Elaeocarpus lanceifolius* Roxb.	Elaeocarpaceae	MT	9.3	3.6	817.0	1.8	14	4.166
40	*Acer laevigatum* Wall.	Sapindaceae	MT	9.3	4.8	383.6	1.6	12	5.509
41	*Vaccinium* sp.1	Ericaceae	ST	7.6	7.3	146.6	1.6	10	12.824
42	*Corylopsis himalayana* Griff.	Hamamelidaceae	ST	5.8	7.1	241.8	1.5	9	20.984
43	*Syzygium diospyrifolium* (Wall. ex Duthie) S.N.Mitra	Myrtaceae	ST	5.2	7.9	168.2	1.4	7	28.879
44	*Quercus glauca* Thunb.	Fagaceae	MT	7.6	3.4	548.3	1.4	8	5.903
45	*Symplocos lucida* (Thunb.) Siebold & Zucc.	Symplocaceae	MT	5.2	5.7	391.3	1.4	9	20.810
46	*Myrsine semiserrata* Wall.	Primulaceae	ST	8.7	4.4	139.7	1.3	10	5.810
47	*Glochidion khasicum* (Müll.Arg.) Hook.f.	Phyllanthaceae	MT	10.5	3.5	64.4	1.3	7	3.185
48	*Pavetta indica* L.	Rubiaceae	ST	4.7	7.6	143.2	1.3	8	34.938
49	*Nostolachma jenkinsii* (Hook.f.) Deb & Lahiri	Rubiaceae	ST	8.7	4.7	90.6	1.3	6	6.116
50	*Machilus gamblei* King ex Hook. f.	Lauraceae	MT	8.1	3.5	282.5	1.3	15	5.265
51	*Mahonia napaulensis* DC.	Berberidaceae	SH	9.9	3.6	34.3	1.3	4	3.690
52	*Phyllanthus emblica* L.	Phyllanthaceae	ST	8.7	3.8	105.3	1.3	8	5.045
53	*Iteadaphne caudata* (Nees) H.W. Li	Lauraceae	ST	8.7	3.4	110.5	1.2	11	4.434
54	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Lauraceae	MT	7.6	2.8	286.1	1.2	14	4.885
55	*Wendlandia wallichii* Wight & Arn.	Rubiaceae	ST	8.1	3.4	84.0	1.1	7	5.090
56	*Actinidia callosa* Lindl.	Actinidiaceae	SS	3.5	2.4	753.9	1.1	9	20.067
57	*Xylosma controversa* Clos	Salicaceae	ST	7.0	3.5	107.5	1.1	7	7.167
58	*Sarcosperma griffithii* Hook.f. ex C.B.Clarke	Sapotaceae	MT	7.0	3.4	114.4	1.1	8	6.928
59	*Toxicodendron succedaneum* (L.) Kuntze var. *succedaneum*	Anacardiaceae	MT	3.5	3.6	480.6	1.0	13	29.622
60	*Sterculia hamiltonii* (Kuntze) Adelb.	Malvaceae	ST	4.7	2.7	451.5	1.0	13	12.363
61	*Viburnum simonsii* Hook.f. & Thomson	Adoxaceae	ST	5.8	3.6	122.7	1.0	9	10.664
62	*Litsea elongata* (Nees) Hook. f.	Lauraceae	MT	7.6	2.3	101.4	1.0	12	4.071
63	*Erythroxylum parishii* (Hook.f.) ined.	Erythroxylaceae	SH	6.4	3.3	60.9	1.0	5	7.960
64	*Maesa indica* (Roxb.) A. DC.	Primulaceae	ST	7.0	2.9	39.3	1.0	6	5.972
65	*Schefflera khasiana* (C.B.Clarke) R.Vig.	Araliaceae	ST	4.7	3.1	246.8	0.9	8	14.513
66	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae	ST	5.2	3.3	138.8	0.9	7	11.891
67	*Fagraea ceilanica* Thunb.	Gentianaceae	ST	4.7	2.4	306.6	0.9	11	11.288
68	*Elaeagnus conferta* Roxb.	Elaeagnaceae	SS	6.4	2.7	50.9	0.9	16	6.539
69	*Syzygium cumini* (L.) Skeels	Myrtaceae	LT	6.4	2.3	102.2	0.9	11	5.686

70	*Acronychia pedunculata* (L.) Miq.	Rutaceae	ST	4.7	2.0	344.3	0.9	12	9.138
71	*Vernonia volkameriifolia* DC.	Asteraceae	ST	5.8	2.6	97.0	0.9	8	7.568
72	*Wendlandia glabrata* DC.	Rubiaceae	ST	5.8	2.2	117.0	0.8	9	6.536
73	*Padus napaulensis* (Ser.) C.K. Schneid.	Rosaceae	LT	1.2	0.8	916.2	0.8	21	60.200
74	*Aporosa octandra* (Buch.-Ham. ex D.Don) Vickery var. *octandra*	Phyllanthaceae	ST	4.1	2.8	190.4	0.8	10	16.849
75	*Toona ciliata* M.Roem.	Meliaceae	LT	4.1	2.7	184.6	0.8	10	16.147
76	*Archidendron bigeminum* (L.) I.C.Nielsen	Fabaceae	ST	5.2	2.3	67.0	0.8	8	8.494
77	*Ligustrum lucidum* W.T.Aiton	Oleaceae	ST	2.9	4.1	72.2	0.8	6	48.160
78	*Agapetes variegata* (Roxb.) D.Don ex G.Don	Ericaceae	SH	4.7	2.2	115.2	0.7	8	10.213
79	*Lindera melastomacea* Fern.-Vill.	Lauraceae	ST	4.1	2.3	140.4	0.7	8	14.041
80	*Quercus serrata* Murray	Fagaceae	MT	3.5	1.5	283.4	0.7	14	12.422
81	*Agapetes setigera* (Wall.) D.Don ex G.Don	Ericaceae	SH	2.9	3.4	44.0	0.7	4	39.904
82	*Viburnum foetidum* Wall.	Adoxaceae	SH	4.7	2.0	18.8	0.6	4	9.138
83	*Turpinia pomifera* (Roxb.) DC.	Staphyleaceae	MT	4.1	2.1	64.0	0.6	11	12.637
84	*Millettia pulchra* Kurz	Fabaceae	ST	4.7	1.6	50.9	0.6	5	7.525
85	*Ixora* sp.1	Rubiaceae	ST	4.1	1.6	108.4	0.6	6	9.829
86	*Carpinus viminea* Wall. ex Lindl.	Betulaceae	MT	2.9	2.6	104.4	0.6	10	30.272
87	*Luculia pinceana* Hook.	Rubiaceae	ST	3.5	2.3	50.4	0.6	5	19.111
88	*Eriobotrya bengalensis* (Roxb.) Hook. f.	Rosaceae	LT	3.5	1.3	210.6	0.6	13	10.511
89	*Garcinia xanthochymus* Hook.f. ex T.Anderson	Clusiaceae	MT	3.5	1.4	189.9	0.6	8	11.467
90	*Pyrus pashia* Buch.-Ham. ex D. Don	Rosaceae	MT	3.5	1.6	146.4	0.6	12	13.378
91	*Daphniphyllum himalayense* (Benth.) Mull.Arg.	Daphniphyllaceae	MT	4.1	1.3	106.7	0.6	11	7.722
92	*Nostolachma khasiana* (Korth.) Deb & Lahiri	Rubiaceae	ST	3.5	2.1	43.1	0.6	6	17.200
93	*Elaeagnus pyriformis* Hook.f.	Elaeagnaceae	SS	3.5	2.0	56.7	0.6	7	16.244
94	*Cinnamomum curvifolium* (Lam.) Nees	Lauraceae	ST	3.5	2.0	39.4	0.6	10	16.244
95	*Phlogacanthus pubinervius* T.Anderson	Acanthaceae	SH	4.1	1.2	88.0	0.5	7	7.020
96	ML040T20	Unidentified	LT	0.6	0.1	679.3	0.5	23	34.400
97	*Vaccinium duclouxii* (H. Lév.) Hand.-Mazz.	Ericaceae	ST	2.3	2.6	67.8	0.5	6	47.300
98	*Styrax serrulatus* Roxb.	Styracaceae	ST	3.5	1.6	67.9	0.5	10	13.378
99	*Ilex khasiana* Purkay.	Aquifoliaceae	MT	2.9	1.4	170.6	0.5	14	16.512
100	*Zanthoxylum ovalifolium* Wight	Rutaceae	ST	3.5	1.0	145.1	0.5	13	8.600
101	*Drimycarpus racemosus* (Roxb.) Hook.f. ex Marchand.	Anacardiaceae	LT	4.1	1.3	34.1	0.5	5	7.722
102	*Adinandra griffithii* Dyer	Pentaphylacaceae	ST	2.3	0.9	305.0	0.5	14	17.200
103	*Ficus auriculata* Lour.	Moraceae	ST	2.3	1.3	248.9	0.5	9	23.650
104	*Saurauia macrotricha* Kurz ex Dyer	Actinidiaceae	ST	2.9	1.7	97.0	0.5	7	20.640
105	*Symplocos glomerata* King ex C.B. Clarke	Symplocaceae	ST	2.3	2.1	87.1	0.5	8	38.700
106	*Rapanea capitellata* (Wall.) Mez	Primulaceae	MT	2.9	1.7	52.5	0.5	8	20.640
107	*Cinnamomum glaucescens* (Nees) Hand.-Mazz.	Lauraceae	LT	2.9	1.6	17.2	0.4	3	19.264
108	*Callicarpa arborea* Roxb.	Lamiaceae	MT	2.9	0.9	96.8	0.4	9	11.008
109	*Symplocos paniculata* Miq.	Symplocaceae	ST	2.9	1.3	34.7	0.4	4	15.136

110	*Gymnosporia* sp.	Celastraceae	ST	1.7	2.0	68.8	0.4	10	64.978
111	*Litsea* sp.	Lauraceae	ST	0.6	2.1	185.1	0.4	11	619.200
112	*Garcinia elliptica* Wall. ex Wight	Clusiaceae	MT	2.3	1.3	94.7	0.4	7	23.650
113	*Wendlandia paniculata* (Roxb.) DC.	Rubiaceae	ST	2.3	0.8	110.0	0.4	11	15.050
114	*Psychotria erratica* Hook.f.	Rubiaceae	SH	2.9	0.9	13.9	0.4	3	11.008
115	*Macropanax undulatus* (Wall. ex G. Don) Seem.	Araliaceae	ST	2.3	1.0	68.0	0.4	8	19.350
116	*Balakata baccata* (Roxb.) Esser	Euphorbiaceae	MT	1.2	0.3	317.8	0.4	16	25.800
117	*Benkara griffithii* (Hook.f.) Ridsdale	Rubiaceae	ST	2.3	1.2	29.8	0.4	5	21.500
118	*Sorbus polycarpa* (Hook. f.) Rehder	Rosaceae	ST	1.7	1.2	99.9	0.4	12	38.222
119	*Mussaenda wallichii* G.Don	Rubiaceae	SH	2.3	1.2	24.9	0.3	4	21.500
120	*Decaspermum parviflorum* subsp. *parviflorum*	Myrtaceae	ST	1.2	0.7	241.8	0.3	15	51.600
121	*Daphne papyracea* Wall. ex W.W.Sm. & Cave	Thymelaeaceae	SH	2.3	1.2	17.1	0.3	3	21.500
122	*Taxus wallichiana* Zucc.	Taxaceae	MT	2.3	1.0	25.5	0.3	5	19.350
123	*Fissistigma verrucosum* (Hook.f. & Thomson) Merr.	Annonaceae	WC	2.3	0.8	47.9	0.3	8	15.050
124	ML041T17	Unidentified	ST	2.3	0.9	17.2	0.3	4	17.200
125	*Schefflera pueckleri* (K.Koch) Frodin	Araliaceae	SS	2.3	0.6	70.3	0.3	8	10.750
126	*Ligustrum robustum* (Roxb.) Blume	Oleaceae	MT	1.7	0.9	87.4	0.3	8	30.578
127	*Wendlandia ligustrina* Wall. ex G.Don	Rubiaceae	ST	2.3	0.8	29.4	0.3	10	15.050
128	*Lasianthus tubiferus* Hook.f.	Rubiaceae	ST	2.3	0.9	8.0	0.3	3	17.200
129	ML042T31	Unidentified	MT	0.6	0.1	346.3	0.3	13	34.400
130	*Camellia caudata* Wall.	Theaceae	ST	2.3	0.8	17.6	0.3	6	15.050
131	*Livistona jenkinsiana* Griff.	Arecaceae	ST	2.3	0.7	24.7	0.3	6	12.900
132	*Dalbergia stipulacea* Roxb.	Fabaceae	ST	2.3	0.7	22.9	0.3	11	12.900
133	*Sterculia villosa* Roxb.	Malvaceae	MT	1.7	0.5	123.4	0.3	20	15.289
134	*Vaccinium vacciniaceum* subsp. *vacciniaceum*	Ericaceae	SH	1.7	0.7	66.9	0.3	4	22.933
135	*Eriosolena involucrata* (Wall.) ined.	Thymelaeaceae	SH	1.7	1.0	11.3	0.3	3	34.400
136	*Cinnamomum camphora* (L.) J.Presl	Lauraceae	LT	2.3	0.5	28.9	0.3	12	8.600
137	*Baliospermum calycinum* var. *micranthum* (Mull.Arg.) Chakrab. & N. P. Balakr.	Euphorbiaceae	SH	2.3	0.6	7.6	0.3	4	10.750
138	*Croton oblongus* Burm.f.	Euphorbiaceae	ST	1.7	0.8	13.2	0.3	3	26.756
139	*Saurauia punduana* Wall.	Actinidiaceae	ST	1.7	0.7	21.3	0.2	6	22.933
140	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	Lauraceae	ST	1.7	0.6	38.1	0.2	4	19.111
141	*Albizia chinensis* (Osbeck) Merr.	Fabaceae	LT	1.2	0.3	143.2	0.2	18	25.800
142	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	MT	1.7	0.5	41.8	0.2	8	15.289
143	*Choerospondias axillaris* (Roxb.) B.L.Burtt & A.W.Hill	Anacardiaceae	MT	1.2	0.3	131.4	0.2	16	25.800
144	*Debregeasia wallichiana* (Wedd.) Wedd.	Urticaceae	ST	1.2	0.9	33.7	0.2	7	68.800
145	*Cerasus cerasoides* (Buch.-Ham. ex D. Don) S.Y. Sokolov	Rosaceae	LT	1.7	0.3	49.8	0.2	13	11.467
146	*Erythrina arborescens* Roxb.	Fabaceae	ST	1.7	0.6	11.7	0.2	4	19.111
147	*Medinilla rubicunda* (Jack) Blume	Melastomataceae	ST	1.7	0.6	6.9	0.2	4	19.111
148	*Kydia calycina* Roxb.	Malvaceae	MT	1.7	0.3	19.5	0.2	9	11.467
149	*Ilex odorata* Buch.-Ham. ex D.Don	Aquifoliaceae	ST	1.2	0.7	34.2	0.2	5	51.600

150	*Viburnum odoratissimum* Ker Gawl.	Adoxaceae	ST	1.7	0.3	11.7	0.2	7	11.467
151	*Dendropanax trifidus* (Thunb.) Makino ex H.Hara	Araliaceae	ST	1.7	0.3	7.3	0.2	6	11.467
152	*Lagerstroemia parviflora* Roxb.	Lythraceae	MT	1.7	0.3	5.7	0.2	5	11.467
153	*Euonymus bullatus* Wall. ex Lodd	Celastraceae	ST	0.6	0.6	85.6	0.2	8	172.000
154	*Antidesma acidum* Retz.	Phyllanthaceae	ST	1.2	0.6	7.9	0.2	4	43.000
155	*Macropanax dispermus* (Blume) Kuntze	Araliaceae	ST	0.6	0.6	78.8	0.2	11	172.000
156	*Neolitsea umbrosa* (Nees) Gamble	Lauraceae	MT	1.2	0.5	11.5	0.2	6	34.400
157	*Schefflera venulosa* (Wight & Arn.) Harms	Araliaceae	SS	1.2	0.5	6.9	0.2	3	34.400
158	*Buddleja macrostachya* Benth.	Scrophulariaceae	SH	1.2	0.5	5.9	0.2	3	34.400
159	*Agapetes affinis* (Griff.) Airy Shaw	Ericaceae	SH	1.2	0.5	4.9	0.2	3	34.400
160	*Macaranga denticulata* (Blume) Müll.Arg.	Euphorbiaceae	MT	1.2	0.5	3.9	0.2	3	34.400
161	*Magnolia kingii* (Dandy) Figlar	Magnoliaceae	ST	1.2	0.3	14.7	0.2	6	25.800
162	*Leucosceptrum canum* Sm.	Lamiaceae	ST	1.2	0.3	12.5	0.1	4	25.800
163	*Holarrhena pubescens* Wall.	Apocynaceae	ST	1.2	0.3	10.4	0.1	8	25.800
164	*Elaeocarpus simplex* Kurz	Elaeocarpaceae	ST	0.6	0.6	44.2	0.1	8	172.000
165	*Erythrina stricta* Roxb.	Fabaceae	LT	0.6	0.2	98.6	0.1	16	68.800
166	*Machilus glaucescens* (Nees) Wight	Lauraceae	MT	1.2	0.3	6.9	0.1	6	25.800
167	*Cleyera japonica* var. *grandiflora* (Wall. ex Choisy) Kobuski	Pentaphylacaceae	ST	1.2	0.3	5.3	0.1	3	25.800
168	*Flueggea virosa* (Roxb. ex Willd.) Royle	Phyllanthaceae	SH	1.2	0.3	3.3	0.1	3	25.800
169	*Trichilia connaroides* (Wight & Arn.) Bentv. var. *connaroides*	Meliaceae	MT	1.2	0.2	16.4	0.1	7	17.200
170	*Wendlandia budleioides* Wall. ex Wight & Arn.	Rubiaceae	ST	0.6	0.6	33.6	0.1	7	172.000
171	*Itea chinensis* Hook. & Arn.	Iteaceae	ST	1.2	0.2	13.8	0.1	8	17.200
172	*Cornus macrophylla* Wall.	Cornaceae	MT	1.2	0.2	11.7	0.1	8	17.200
173	ML079T27	Unidentified	ST	1.2	0.2	2.0	0.1	3	17.200
174	*Ilex embelioides* Hook.f.	Aquifoliaceae	ST	0.6	0.6	8.2	0.1	3	172.000
175	ML047T17	Unidentified	MT	0.6	0.3	44.9	0.1	13	103.200
176	*Mallotus philippensis* (Lam.) Müll.Arg.	Euphorbiaceae	ST	0.6	0.3	14.7	0.1	7	103.200
177	*Eriobotrya* sp.	Rosaceae	MT	0.6	0.2	32.8	0.1	12	68.800
178	*Phoebe attenuata* (Nees) Nees	Lauraceae	LT	0.6	0.3	13.7	0.1	6	103.200
179	*Ehretia acuminata* R.Br.	Boraginaceae	LT	0.6	0.3	13.2	0.1	6	103.200
180	*Ficus* sp.3	Moraceae	ST	0.6	0.3	12.5	0.1	4	103.200
181	*Lindera latifolia* Hook. f.	Lauraceae	MT	0.6	0.1	36.4	0.1	15	34.400
182	*Mallotus paniculatus* (Lam.) Müll.Arg. var. *paniculatus*	Euphorbiaceae	MT	0.6	0.1	34.4	0.1	12	34.400
183	*Elaeocarpus prunifolius* Wall. ex Müll.Berol.	Elaeocarpaceae	ST	0.6	0.2	13.1	0.1	7	68.800
184	ML025T04	Unidentified	ST	0.6	0.1	26.0	0.1	9	34.400
185	*Wendlandia tinctoria* (Roxb.) DC.	Rubiaceae	ST	0.6	0.2	4.9	0.1	4	68.800
186	*Platostoma* sp.	Lamiaceae	ST	0.6	0.2	4.0	0.1	3	68.800
187	*Castanopsis indica* (Roxb. ex Lindl.) A. DC.	Fagaceae	LT	0.6	0.2	3.1	0.1	3	68.800
188	*Cornus oblonga* Wall.	Cornaceae	ST	0.6	0.1	21.5	0.1	12	34.400
189	*Archidendron clypearia* (Jack) I.C.Nielsen	Fabaceae	ST	0.6	0.1	21.3	0.1	11	34.400

190	*Photinia* arguta Lindl. var. *arguta*	Rosaceae	ST	0.6	0.2	2.7	0.1	4	68.800
191	*Viburnum cylindricum* Buch.-Ham. ex D. Don	Adoxaceae	ST	0.6	0.2	2.5	0.1	3	68.800
192	*Ardisia pedunculosa* Wall.	Primulaceae	SH	0.6	0.2	2.2	0.1	3	68.800
193	*Cinnamomum* sp.1	Lauraceae	ST	0.6	0.2	1.8	0.1	3	68.800
194	*Ficus hispida* L. f.	Moraceae	ST	0.6	0.1	15.5	0.1	7	34.400
195	*Nyssa javanica* (Blume) Wangerin	Cornaceae	LT	0.6	0.1	10.4	0.1	7	34.400
196	*Symplocos* sp.2	Symplocaceae	ST	0.6	0.1	8.3	0.1	7	34.400
197	*Careya arborea* Roxb.	Lecythidaceae	MT	0.6	0.1	6.3	0.1	5	34.400
198	*Machilus duthiei* King	Lauraceae	ST	0.6	0.1	5.3	0.1	4	34.400
199	*Antidesma khasianum* Hook.f.	Phyllanthaceae	ST	0.6	0.1	4.2	0.1	3	34.400
200	*Actinodaphne citrata* (Blume) Hayata	Lauraceae	ST	0.6	0.1	3.7	0.1	5	34.400
201	*Embelia* sp.	Primulaceae	SS	0.6	0.1	3.7	0.1	6	34.400
202	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	ST	0.6	0.1	3.3	0.1	8	34.400
203	*Phyllanthus reticulatus* Poir.	Phyllanthaceae	SH	0.6	0.1	3.1	0.1	4	34.400
204	*Ficus prostrata* (Wall. ex Miq.) Buch.-Ham. ex Miq.	Moraceae	ST	0.6	0.1	3.0	0.1	3	34.400
205	*Symplocos racemosa* Roxb.	Symplocaceae	ST	0.6	0.1	3.0	0.1	5	34.400
206	*Dasymaschalon longiflorum* (Roxb.) Finet & Gagnep.	Annonaceae	ST	0.6	0.1	2.2	0.1	3	34.400
207	*Aralia subcordata* (Wall. ex G.Don) J.Wen	Araliaceae	ST	0.6	0.1	1.8	0.1	5	34.400
208	*Hiptage acuminata* Wall. ex A. Juss.	Malpighiaceae	SS	0.6	0.1	1.7	0.1	6	34.400
209	*Microtropis discolor* (Wall.) Wall. ex Meisn.	Celastraceae	ST	0.6	0.1	1.6	0.1	3	34.400
210	*Premna pinguis* C.B.Clarke	Lamiaceae	SH	0.6	0.1	1.6	0.1	5	34.400
211	*Sophora benthamii* Steenis	Fabaceae	SH	0.6	0.1	1.6	0.1	3	34.400
212	*Ilex triflora* Blume	Aquifoliaceae	ST	0.6	0.1	1.3	0.1	3	34.400
213	ML025T03	Unidentified	ST	0.6	0.1	1.3	0.1	3	34.400
214	*Cinnamomum* sp.2	Lauraceae	ST	0.6	0.1	1.2	0.1	5	34.400
215	*Maesa montana* A. DC.	Primulaceae	SH	0.6	0.1	1.2	0.1	3	34.400
216	*Podocarpus neriifolius* D.Don	Podocarpaceae	LT	0.6	0.1	1.2	0.1	3	34.400
217	*Casearia glomerata* Roxb.	Salicaceae	MT	0.6	0.1	1.1	0.1	3	34.400
218	*Leea asiatica* (L.) Ridsdale	Vitaceae	SH	0.6	0.1	1.1	0.1	3	34.400
219	*Meyna spinosa* Roxb. ex Link	Rubiaceae	ST	0.6	0.1	1.1	0.1	3	34.400
220	*Derris* sp.	Fabaceae	WC	0.6	0.1	1.0	0.1	8	34.400
221	*Antidesma montanum* Blume var. *montanum*	Phyllanthaceae	ST	0.6	0.1	0.9	0.1	3	34.400
222	*Embelia subcoriacea* (C.B.Clarke) Mez	Primulaceae	SS	0.6	0.1	0.9	0.1	8	34.400
223	*Guidonia vareca* (Roxb.) Baill. ex Kurz	Salicaceae	ST	0.6	0.1	0.9	0.1	2.5	34.400
224	ML047T43	Unidentified	ST	0.6	0.1	0.9	0.1	3	34.400
225	*Skimmia laureola* (DC.) Siebold & Zucc. ex Walp.	Rutaceae	SH	0.6	0.1	0.9	0.1	4	34.400
	Grand Total				904.1	143091.8	300		

The abundance-to-frequency ratio suggested that all species exhibited a clumped to highly clumped dispersion. The minimum value of A/F ratio was 1.539 for *Engelhardtia spicata* and maximum was 619.2 for *Litsea* sp. A total of four species showed A/F ratio 2 or less and remaining species showed A/F ratio above 2 (Table 4.31).

The stand density was 904.1 individuals ha^{-1} and stand basal area was 14.31 m^2 ha^{-1} (Table 4.32). The mean basal area per individual was 158.28 cm^2 (Table 4.32). Shannon's diversity index was 1.900, Pielou's evenness index was 0.808, Simpson's dominance index was 0.022 and Whittaker's species richness index was 57.573 (Table 4.32).

Table 4.32. Phytosociological attributes and diversity indices in woody layer of Khasi subtropical oak-dominated forest in Meghalaya.

Sl. No.	Attribute	Value
1.	Number of species	225
2.	Number of genera	144
3.	Number of families	64
4.	Density (ha^{-1})	904.1
5	Basal area (m^2 ha^{-1})	14.31
6.	Mean basal area (cm^2 $individual^{-1}$)	158.28
7.	Shannon's diversity index	1.900
8.	Evenness index	0.808
9.	Dominance index	0.022
10.	Species richness index	57.573

Of all 225 species in the woody layer, 217 species belonged to 64 identified families and 8 species were placed in an "unidentified" family (Table 4.33). Of these, 27 families were represented by one species, 10 families by two species, 9 families by three species, 5 families by four species and 14 families by more than four species. The family Lauraceae

had the maximum 22 species followed by Rubiaceae with 16 species and Fagaceae with 13 species (Table 4.33). In terms of genera, Rubiaceae and Lauraceae were dominant with 10 and 9 genera, respectively (Table 4.33).

Table 4.33. The number of families, genera, species and individuals recorded in woody layer of the Khasi subtropical oak-dominated forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Acanthaceae	1	1	10	Magnoliaceae	1	2	37
Actinidiaceae	2	3	42	Malpighiaceae	1	1	1
Adoxaceae	1	4	53	Malvaceae	2	3	30
Anacardiaceae	3	3	45	Melastomataceae	1	1	5
Annonaceae	2	2	8	Meliaceae	2	2	25
Apocynaceae	1	1	3	Moraceae	1	5	135
Aquifoliaceae	1	5	58	Myricaceae	1	2	339
Araliaceae	4	8	129	Myrtaceae	2	4	251
Arecaceae	1	1	6	Oleaceae	1	2	43
Asteraceae	1	1	22	Pandanaceae	1	1	50
Berberidaceae	1	1	31	Pentaphylacaceae	3	4	318
Betulaceae	2	2	60	Phyllanthaceae	5	8	98
Bignoniaceae	1	1	1	Pinaceae	1	1	289
Boraginaceae	1	1	3	Podocarpaceae	1	1	1
Celastraceae	3	3	23	Primulaceae	5	7	83
Clusiaceae	1	2	23	Proteaceae	1	1	256
Cornaceae	2	3	4	Rosaceae	6	8	117
Daphniphyllaceae	1	1	11	Rubiaceae	10	16	263
Elaeagnaceae	1	2	40	Rutaceae	3	3	27
Elaeocarpaceae	1	3	38	Salicaceae	3	3	32
Ericaceae	4	8	602	Sapindaceae	1	1	41
Erythroxylaceae	1	1	28	Sapotaceae	1	1	29
Euphorbiaceae	5	6	23	Scrophulariaceae	1	1	4
Fabaceae	7	9	53	Staphyleaceae	1	1	18
Fagaceae	3	13	2208	Styracaceae	1	1	14
Gentianaceae	1	1	21	Symplocaceae	1	8	358
Hamamelidaceae	3	3	204	Taxaceae	1	1	9
Iteaceae	1	2	74	Theaceae	2	4	461
Juglandaceae	1	1	121	Thymelaeaceae	2	2	19
Lamiaceae	4	4	14	Unidentified	8	8	18
Lauraceae	9	22	433	Urticaceae	1	1	8
Lecythidaceae	1	1	1	Vitaceae	1	1	1
Lythraceae	1	1	3				

In terms of density, Fagaceae showed the highest number of individuals (2208) followed by Ericaceae (602), Theaceae (461) and Lauraceae (433). Five families, viz.,

Bignoniaceae, Lecythidaceae, Malpighiaceae, Podocarpaceae and Vitaceae had only one individual each (Table 4.33).

The dominance-diversity curve for woody layer of Khasi subtropical oak-dominated forest (Fig. 4.11) followed a log-normal distribution with a mixed dominance of five species in the top canopy (*Pinus kesiya*, *Castanopsis purpurella*, *Schima wallichii*, *Castanopsis tribuloides*, *Schima khasiana*), six species in the subcanopy (*Lithocarpus fenestratus*, *Myrica esculenta*, *Rhododendron arboreum*, *Helicia nilagirica*, *Castanopsis armata*, *Quercus lineata*) and one species in the under canopy (*Lithocarpus dealbatus*).

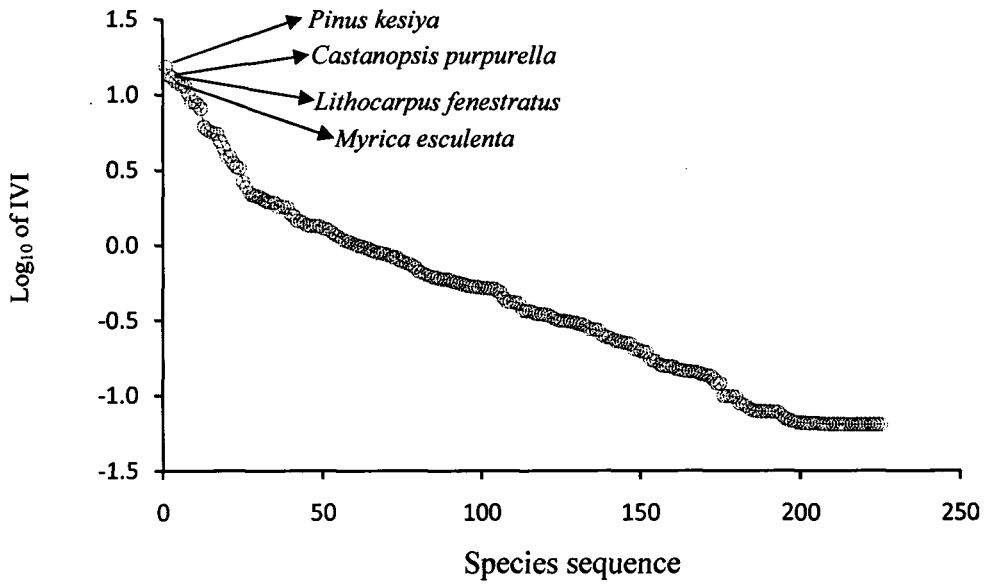

Fig. 4.11. The dominance-diversity curve based on Log_{10} of IVI for woody layer of Khasi subtropical oak-dominated forest in Meghalaya.

4.4.12. Khasi Subtropical Oak-Dominated Forest – herb layer

The floristic composition of herb layer of Khasi subtropical oak-dominated forest is given in Table 4.34. A total of 1287 individuals of all species (including tree seedlings) were recorded in herb layer. These belong to 76 families, 146 genera and 172 species. The most dominant species on the basis of IVI is *Selaginella monosperma* (5.3) followed by *Eragrostiella leioptera* (4.8), *Tripterospermum fasciculatum* (4.8), *Eriocaulon cristatum* (4.4) and *Sonerila maculata* (4.4) (Table 4.34). The endemic species to Meghalaya were: *Agapetes obovata, Baliospermum calycinum* var. *micranthum, Nepenthes khasiana, Osbeckia capitata, Persicaria bistorta* and *Smilax myrtillus.*

Table 4.34. Floristic composition of herb layer of Khasi subtropical oak-dominated forest based on 60 quadrats of 1 x 1 m size. Species are arranged in descending order of IVI.

Sl. no.	Species Name	Family	Occurrence	No. of ind	IVI
1	*Selaginella monospora* Spring	Selaginellaceae	6	42	5.3
2	*Eragrostiella leioptera* (Stapf) Bor	Poaceae	3	49	4.8
3	*Tripterospermum fasciculatum* (Wall.) Chater	Gentianaceae	4	44	4.8
4	*Eriocaulon cristatum* Mart.	Eriocaulaceae	3	44	4.4
5	*Sonerila maculata* Roxb.	Melastomataceae	2	48	4.4
6	*Dennstaedtia scabra* (Wall. ex Hook.) T. Moore	Dennstaedtiaceae	7	24	4.2
7	*Chimonocalamus griffithianus* (Munro) Hsueh & T.P.Yi	Poaceae	3	38	4.0
8	*Imperata cylindrica* (L.) Raeusch.	Poaceae	3	31	3.4
9	*Dicranopteris splendida* (Hand.-Mazz.) Ching	Gleicheniaceae	5	22	3.4
10	*Eurya japonica* Thunb.	Pentaphylacaceae	5	20	3.2
11	*Curcuma angustifolia* Roxb.	Zingiberaceae	5	16	2.9
12	*Oplismenus burmannii* (Retz.) P.Beauv.	Poaceae	4	20	2.9
13	*Smilax oxyphylla* Wall. ex Kunth	Smilacaceae	4	17	2.7
14	*Chromolaena odorata* (L.) R.M. King & H. Rob.	Asteraceae	3	21	2.6
15	*Dicranopteris linearis* (Burm. f.) Underw.	Gleicheniaceae	3	20	2.6
16	*Ophiorrhiza rugosa* var. *prostrata* (D.Don) Deb & Mondal	Rubiaceae	2	21	2.3
17	*Oplismenus compositus* (L.) P. Beauv.	Poaceae	3	16	2.3
18	*Pteris linearis* Poir.	Pteridaceae	4	11	2.2
19	*Stachytarpheta indica* (L.) Vahl	Verbenaceae	1	24	2.2
20	*Arundinella setosa* Trin.	Poaceae	2	19	2.2
21	*Pogostemon stellatus* (Lour.) Kuntze	Lamiaceae	2	19	2.2
22	*Begonia palmata* D.Don	Begoniaceae	4	10	2.1

23	*Gentiana* sp.2	Gentianaceae	2	18	2.1
24	*Huperzia javanica* (Sw.) Fraser-Jenk.	Lycopodiaceae	2	18	2.1
25	*Rubus moluccanus* L.	Rosaceae	4	9	2.1
26	*Spermacoce neohispida* Govaerts	Rubiaceae	1	22	2.0
27	*Osbeckia stellata* Buch.-Ham. ex Ker Gawl.	Melastomataceae	3	13	2.0
28	*Viola sikkimensis* W. Becker	Violaceae	3	13	2.0
29	*Carex* sp.5	Cyperaceae	2	17	2.0
30	*Myrica esculenta* Buch.-Ham. ex D. Don	Myricaceae	4	8	2.0
31	*Pothos scandens* L.	Araceae	3	12	1.9
32	*Bolbitis* sp.	Lomariopsidaceae	1	20	1.9
33	*Strobilanthes anisophylla* T.Anderson	Acanthaceae	1	20	1.9
34	*Paris polyphylla* Sm.	Melanthiaceae	3	11	1.9
35	*Selaginella decipiens* Warb.	Selaginellaceae	2	14	1.8
36	*Carex baccans* Nees	Cyperaceae	2	12	1.6
37	*Neolitsea zeylanica* (Nees & T. Nees) Merr.	Lauraceae	3	7	1.6
38	*Rhododendron formosum* Wall.	Ericaceae	3	7	1.6
39	*Agrimonia pilosa* var. *nepalensis* (D. Don) Nakai	Rosaceae	2	10	1.5
40	*Carex* sp.4	Cyperaceae	2	10	1.5
41	*Ligustrum lucidum* W.T.Aiton	Oleaceae	2	10	1.5
42	*Polystichum pseudosemifertile* Nakaike & V.L.Gurung	Dryopteridaceae	2	10	1.5
43	*Pogostemon* sp.	Lamiaceae	1	14	1.4
44	*Agapetes obovata* (Wight) Benth. & Hook.f.	Ericaceae	3	5	1.4
45	*Breynia retusa* (Dennst.) Alston	Phyllanthaceae	3	5	1.4
46	*Chloranthus glaber* (Thunb.) Makino	Chloranthaceae	2	9	1.4
47	*Polypodium penangianum* Hook.	Polypodiaceae	2	9	1.4
48	*Daphne papyracea* Wall. ex W.W.Sm. & Cave	Thymelaeaceae	3	4	1.3
49	*Machilus gamblei* King ex Hook. f.	Lauraceae	3	4	1.3
50	*Vigna marina* (Burm.) Merr.	Fabaceae	3	4	1.3
51	*Vitis* sp.	Vitaceae	3	4	1.3
52	*Schefflera hypoleuca* (Kurz) Harms	Araliaceae	2	8	1.3
53	*Baliospermum calycinum* var. *micranthum* (Mull.Arg.) Chakrab. & N. P. Balakr.	Euphorbiaceae	2	7	1.2
54	*Rubia cordifolia* L.	Rubiaceae	2	7	1.2
55	*Microlepia marginata* (Panz.) C. Chr.	Dennstaedtiaceae	2	6	1.1
56	*Drosera peltata* Thunb.	Droseraceae	2	6	1.1
57	*Helicia nilagirica* Bedd.	Proteaceae	2	6	1.1
58	*Osbeckia capitata* Benth. ex Naudin	Melastomataceae	2	6	1.1
59	*Phyllanthus emblica* L.	Phyllanthaceae	2	6	1.1
60	*Ainsliaea angustifolia* Hook.f. & Thomson ex C.B.Clarke	Asteraceae	1	10	1.1
61	*Polystichum lentum* (D. Don) T. Moore	Dryopteridaceae	1	10	1.1
62	*Arisaema fraternum* Schott	Araceae	2	5	1.1
63	*Bambusa* sp.2	Poaceae	2	5	1.1
64	*Elephantopus scaber* L.	Asteraceae	2	5	1.1
65	*Persicaria bistorta* (L.) Samp.	Polygonaceae	2	5	1.1
66	*Polygala persicariifolia* DC.	Polygalaceae	2	5	1.1

67	*Pothos chinensis* (Raf.) Merr.	Araceae	2	5	1.1
68	*Rubus ellipticus* Sm.	Rosaceae	2	5	1.1
69	*Strobilanthes colorata* T.Anderson	Acanthaceae	2	5	1.1
70	*Garcinia elliptica* Wall. ex Wight	Clusiaceae	1	9	1.0
71	*Myrsine semiserrata* Wall.	Primulaceae	2	4	1.0
72	*Symplocos cochinchinensis* var. *laurina* (Retz.) Noot.	Symplocaceae	2	4	1.0
73	*Urena lobata* L.	Malvaceae	2	4	1.0
74	*Gaultheria fragrantissima* Wall.	Ericaceae	1	8	1.0
75	*Macropanax dispermus* (Blume) Kuntze	Araliaceae	2	3	0.9
76	*Mimosa pudica* L.	Fabaceae	2	3	0.9
77	*Peranema aspidioides* (Blume) Mett.	Dryopteridaceae	2	3	0.9
78	*Rhus chinensis* Mill.	Anacardiaceae	2	3	0.9
79	*Smilax myrtillus* A.DC.	Smilacaceae	2	3	0.9
80	*Symplocos pyrifolia* Wall. ex G. Don	Symplocaceae	2	3	0.9
81	*Tadehagi triquetrum* (L.) H.Ohashi	Fabaceae	2	3	0.9
82	*Chrysopogon gryllus* (L.) Trin.	Poaceae	1	7	0.9
83	*Goniothalamus sesquipedalis* (Wall.) Hook.f. & Thomson	Annonaceae	1	7	0.9
84	*Hypericum japonicum* Thunb.	Hypericaceae	1	7	0.9
85	*Panicum luzonense* J.Presl	Poaceae	1	7	0.9
86	*Cyclea bicristata* (Griff.) Diels	Menispermaceae	2	2	0.8
87	*Dipteris wallichii* (R. Br.) T. Moore	Dipteridaceae	1	6	0.8
88	*Microsorum* sp.	Polypodiaceae	1	5	0.7
89	*Disporum cantoniense* (Lour.) Merr.	Asparagaceae	1	5	0.7
90	*Lindsaea odorata* Roxb.	Dennstaedtiaceae	1	5	0.7
91	*Melastoma malabathricum* L.	Melastomataceae	1	5	0.7
92	*Sarcopyramis napalensis* Wall.	Melastomataceae	1	5	0.7
93	*Setaria pumila* (Poir.) Roem. & Schult.	Poaceae	1	5	0.7
94	*Vaccinium griffithianum* Wight	Ericaceae	1	5	0.7
95	*Adiantum flabellulatum* L.	Adiantaceae	1	4	0.6
96	*Alchornea tiliifolia* (Benth.) Müll.Arg.	Euphorbiaceae	1	4	0.6
97	*Camellia kissi* Wall.	Theaceae	1	4	0.6
98	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Lauraceae	1	4	0.6
99	*Litsea salicifolia* (Roxburgh ex Nees) Hook. f.	Lauraceae	1	4	0.6
100	*Lygodium flexuosum* (L.) Sw.	Schizaeaceae	1	4	0.6
101	*Nepenthes khasiana* Hook.f.	Nepenthaceae	1	4	0.6
102	*Oxyspora paniculata* (D. Don) DC.	Melastomataceae	1	4	0.6
103	*Strobilanthes brunoniana* Nees	Acanthaceae	1	4	0.6
104	*Swertia chirata* Buch.-Ham. ex Wall.	Gentianaceae	1	4	0.6
105	*Ainsliaea latifolia* (D.Don) Sch.Bip.	Asteraceae	1	3	0.6
106	*Anoectochilus setaceus* Blume	Orchidaceae	1	3	0.6
107	*Cinnamomum curvifolium* (Lam.) Nees	Lauraceae	1	3	0.6
108	*Houttuynia cordata* Thunb.	Saururaceae	1	3	0.6
109	*Impatiens puberula* DC.	Balsaminaceae	1	3	0.6
110	*Lycopodium japonicum* Thunb.	Lycopodiaceae	1	3	0.6
111	*Lysimachia debilis* Wall.	Primulaceae	1	3	0.6

112	*Maesa indica* (Roxb.) A. DC.	Primulaceae	1	3	0.6
113	*Neillia thyrsiflora* D. Don	Rosaceae	1	3	0.6
114	*Ranunculus diffusus* DC.	Ranunculaceae	1	3	0.6
115	*Scutellaria discolor* Colebr.	Lamiaceae	1	3	0.6
116	*Sphenomeris chinensis* (L.) Maxon	Dennstaedtiaceae	1	3	0.6
117	*Tainia latifolia* (Lindl.) Rchb.f.	Orchidaceae	1	3	0.6
118	*Viburnum foetidum* Wall.	Adoxaceae	1	3	0.6
119	*Aeginetia indica* L.	Orobanchaceae	1	2	0.5
120	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	Asteraceae	1	2	0.5
121	*Archidendron clypearia* (Jack) I.C.Nielsen	Fabaceae	1	2	0.5
122	*Canscora andrographioides* Griff. ex C.B.Clarke	Gentianaceae	1	2	0.5
123	*Craniotome furcata* (Link) Kuntze	Lamiaceae	1	2	0.5
124	*Gleichenia longissima* Blume	Gleicheniaceae	1	2	0.5
125	*Dioscorea pubera* Blume	Dioscoreaceae	1	2	0.5
126	*Elatostema sikkimense* C.B.Clarke	Urticaceae	1	2	0.5
127	*Emilia sonchifolia* (L.) DC. ex DC.	Asteraceae	1	2	0.5
128	*Euonymus theifolius* Wall. ex M.A.Lawsen	Celastraceae	1	2	0.5
129	*Hypoxis aurea* Lour.	Hypoxidaceae	1	2	0.5
130	*Inula eupatorioides* Wall. ex DC.	Asteraceae	1	2	0.5
131	*Maesa montana* A. DC.	Primulaceae	1	2	0.5
132	*Neanotis wightiana* (Wall. ex Wight & Arn.) W.H.Lewis	Rubiaceae	1	2	0.5
133	*Oldenlandia lineata* (Roxb.) Kuntze	Rubiaceae	1	2	0.5
134	*Peliosanthes griffithii* Baker	Asparagaceae	1	2	0.5
135	*Pinus kesiya* Royle ex Gordon	Pinaceae	1	2	0.5
136	*Salix psilostigma* Andersson	Salicaceae	1	2	0.5
137	*Sarcococca pruniformis* Lindl.	Buxaceae	1	2	0.5
138	*Syzygium cumini* (L.) Skeels	Myrtaceae	1	2	0.5
139	*Taxus wallichiana* Zucc.	Taxaceae	1	2	0.5
140	*Tetrastigma serrulatum* (Roxb.) Planch.	Vitaceae	1	2	0.5
141	*Thelypteris* sp.	Thelypteridaceae	1	2	0.5
142	*Acanthus leucostachyus* Wall. ex Nees	Acanthaceae	1	1	0.4
143	*Adenostemma viscosum* J.R.Forst. & G.Forst.	Asteraceae	1	1	0.4
144	*Anaphalis adnata* Wall. ex DC.	Asteraceae	1	1	0.4
145	*Anisadenia saxatilis* Wall. ex Meisn.	Linaceae	1	1	0.4
146	*Arisaema galeatum* N.E.Br.	Araceae	1	1	0.4
147	*Begonia pedunculosa* Wall.	Begoniaceae	1	1	0.4
148	*Berchemia floribunda* (Wall.) Brongn.	Rhamnaceae	1	1	0.4
149	*Castanopsis purpurella* (Miq.) N. P. Balakr.	Fagaceae	1	1	0.4
150	*Cayratia japonica* (Thunb.) Gagnep.	Vitaceae	1	1	0.4
151	*Cotoneaster symondsii* Standish ex T. Moore	Rosaceae	1	1	0.4
152	*Curcuma aromatica* Salisb.	Zingiberaceae	1	1	0.4
153	*Drynaria quercifolia* (L.) J. Sm.	Polypodiaceae	1	1	0.4
154	*Elsholtzia blanda* (Benth.) Benth.	Lamiaceae	1	1	0.4
155	*Erigeron* sp.	Asteraceae	1	1	0.4
156	*Hedyotis scandens* Roxb.	Rubiaceae	1	1	0.4

157	*Jasminum nervosum* Lour.	Oleaceae	1	1	0.4
158	*Lasianthus lucidus* Blume	Rubiaceae	1	1	0.4
159	*Lycopodiella cernua* (L.) Pic. Serm.	Lycopodiaceae	1	1	0.4
160	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae	1	1	0.4
161	*Morinda angustifolia* Roxb.	Rubiaceae	1	1	0.4
162	*Mucuna bracteata* DC.	Fabaceae	1	1	0.4
163	*Piper attenuatum* Buch.-Ham. ex Miq.	Piperaceae	1	1	0.4
164	*Piper falconeri* C.DC.	Piperaceae	1	1	0.4
165	*Psychotria symplocifolia* Kurz	Rubiaceae	1	1	0.4
166	*Rubus hexagynus* Roxb.	Rosaceae	1	1	0.4
167	*Salomonia cantoniensis* Lour.	Polygalaceae	1	1	0.4
168	*Smilax orthoptera* A.DC.	Smilacaceae	1	1	0.4
169	*Strobilanthes furcatus* Biswas	Acanthaceae	1	1	0.4
170	*Symplocos glomerata* King ex C.B. Clarke	Symplocaceae	1	1	0.4
171	*Symplocos sumuntia* Buch.-Ham. ex D. Don	Symplocaceae	1	1	0.4
172	*Toddalia asiatica* (L.) Lam.	Rutaceae	1	1	0.4
	Grand Total			1287	200

The density was 2145 individuals/100 m^2 (Table 4.35). The Shannon's diversity index was 2.116, evenness index was 0.947, dominance index was 0.010 and species richness index was 54.991 (Table 4.35).

Table 4.35. Phytosociological attributes and diversity indices in herb layer of the Khasi subtropical oak-dominated forest in Meghalaya.

Sl. No.	Attribute	Value
1.	Number of species	172
2.	Number of genera	146
3.	Number of families	76
4.	Density (100 m^{-2})	2145
5.	Shannon's diversity index	2.116
6.	Evenness index	0.947
7.	Dominance index	0.010
8.	Species richness index	54.991

Asteraceae and Poaceae were the most dominant family with 10 species each followed by Rubiaceae (9 species). In terms of genera, Asteraceae, Poaceae and Rubiaceae were equally dominant with 9 genera each (Table 4.36). Poaceae was most dominant in terms of number of individuals (197 individuals) followed by Melastomataceae (81 individuals) and Gentianaceae (68 individuals) (Table 4.36).

Table 4.36. The number of families, genera, species and individuals recorded in herb layer of the Khasi subtropical oak-dominated forest in Meghalaya.

Family	No. of genera	No. of species	No. of ind	Family	No. of genera	No. of species	No. of ind
Acanthaceae	2	5	31	Menispermaceae	1	1	2
Adiantaceae	1	1	4	Myricaceae	1	1	8
Adoxaceae	1	1	3	Myrtaceae	1	1	2
Anacardiaceae	1	1	3	Nepenthaceae	1	1	4
Annonaceae	1	1	7	Oleaceae	2	2	11
Araceae	2	4	23	Orchidaceae	2	2	6
Araliaceae	2	2	11	Orobanchaceae	1	1	2
Asparagaceae	2	2	7	Pentaphylacaceae	1	1	20
Asteraceae	9	10	48	Phyllanthaceae	2	2	11
Balsaminaceae	1	1	3	Pinaceae	1	1	2
Begoniaceae	1	2	11	Piperaceae	1	2	2
Buxaceae	1	1	2	Poaceae	9	10	197
Celastraceae	1	1	2	Polygalaceae	2	2	6
Chloranthaceae	1	1	9	Polygonaceae	1	1	5
Clusiaceae	1	1	9	Polypodiaceae	3	3	15
Cyperaceae	1	3	39	Primulaceae	3	4	12
Dennstaedtiaceae	4	4	38	Proteaceae	1	1	6
Dioscoreaceae	1	1	2	Pteridaceae	1	1	11
Dipteridaceae	1	1	6	Ranunculaceae	1	1	3
Droseraceae	1	1	6	Rhamnaceae	1	1	1
Dryopteridaceae	2	3	23	Rosaceae	4	6	29
Ericaceae	5	5	26	Rubiaceae	9	9	58
Eriocaulaceae	1	1	44	Rutaceae	1	1	1
Euphorbiaceae	2	2	11	Salicaceae	1	1	2
Fabaceae	5	5	13	Saururaceae	1	1	3
Fagaceae	1	1	1	Schizaeaceae	1	1	4
Gentianaceae	4	4	68	Selaginellaceae	1	2	56
Gleicheniaceae	2	3	44	Smilacaceae	1	3	21
Hypericaceae	1	1	7	Symplocaceae	1	4	9
Hypoxidaceae	1	1	2	Taxaceae	1	1	2
Lamiaceae	4	5	39	Theaceae	1	1	4
Lauraceae	4	5	22	Thelypteridaceae	1	1	2
Linaceae	1	1	1	Thymelaeaceae	1	1	4
Lomariopsidaceae	1	1	20	Urticaceae	1	1	2
Lycopodiaceae	3	3	22	Verbenaceae	1	1	24
Malvaceae	1	1	4	Violaceae	1	1	13
Melanthiaceae	1	1	11	Vitaceae	3	3	7
Melastomataceae	5	6	81	Zingiberaceae	1	2	17

The dominance-diversity curve for herb layer of Khasi subtropical oak-dominated forest (Fig. 4.12) followed a log-normal distribution with a mixed dominance of *Selaginella monosperma*, *Eragrostiella leioptera*, *Tripterospermum fasciculatum*, *Eriocaulon cristatum* and *Sonerila maculata*.

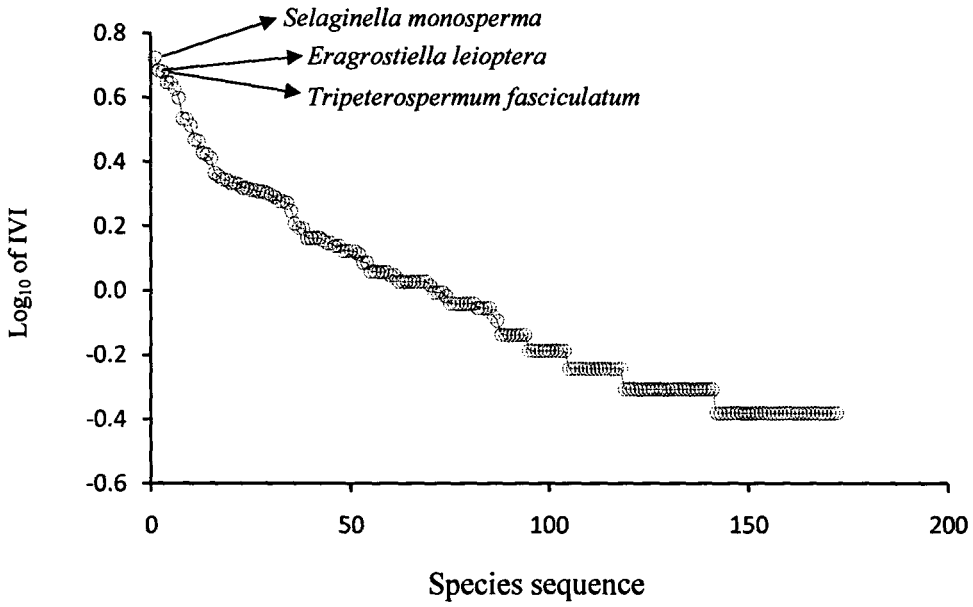

Fig. 4.12. The dominance-diversity curve based on Log_{10} of IVI for herb layer of Khasi subtropical oak-dominated forest in Meghalaya.

4.4.13. Similarity among six forest types

The Sørensen's similarity indices between any two forest types varied from 13.41 to 58.08% for woody layer (Table 4.37) and from 5.71 to 39.62% for herb layer (Table 4.38).

Table 4.37. Sørensen's similarity index (%) for woody layer.

Forest types	TEG	TMMD	KHSP	KJSP	KSMB	KSOD
Tropical evergreen (TEG)	1	27.96	29.97	25.88	37.89	33.74
Tropical moist mixed-deciduous (TMMD)		1	30.28	18.33	13.41	15.63
Khasi hill sal-pine (KHSP)			1	42.29	33.15	33.91
Khasi-Jaintia subtropical pine (KJSP)				1	47.30	49.34
Khasi subtropical mixed-broadleaved (KSMB)					1	58.08
Khasi subtropical oak-dominated (KSOD)						1

Table 4.38. Sørensen's similarity index (%) for herb layer.

Forest types	TEG	TMMD	KHSP	KJSP	KSMB	KSOD
Tropical evergreen (TEG)	1	11.76	10.26	8.58	10.66	11.86
Tropical moist mixed-deciduous (TMMD)		1	12.31	5.78	9.17	5.71
Khasi hill sal-pine (KHSP)			1	27.19	29.41	17.42
Khasi-Jaintia subtropical pine (KJSP)				1	39.62	33.09
Khasi subtropical mixed-broadleaved (KSMB)					1	35.80
Khasi subtropical oak-dominated (KSOD)						1

The Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest showed maximum similarity (58.08%) in woody layer (Table 4.37), whereas Khasi-Jaintia subtropical pine forest and Khasi subtropical mixed broad-leaved forest showed maximum similarity (39.62%) in herb layer (Table 4.38). The six forest types were clustered according to Bray-Curtis method using similarity index matrix separately for the woody layer (Fig. 4.13) and for herb layer (Fig. 4.14).

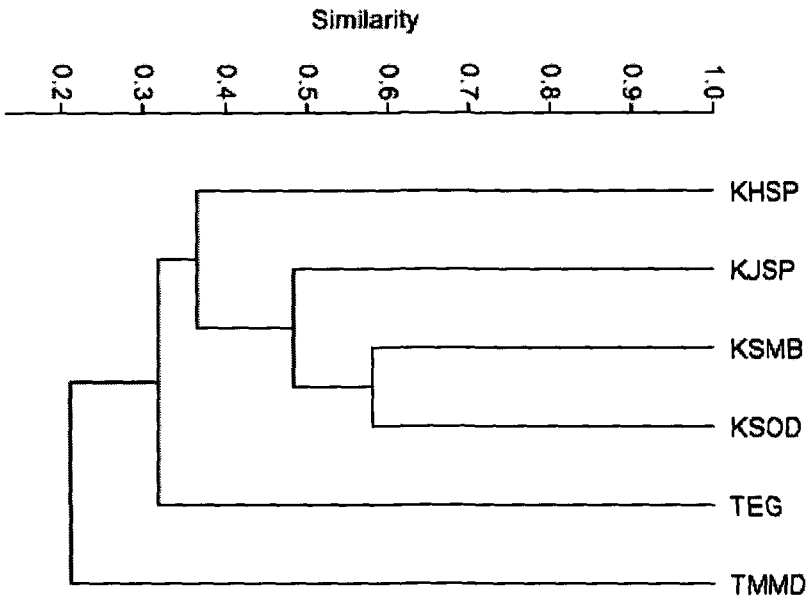

Fig. 4.13. A cluster analysis of woody layer of six forest types using Bray-Curtis method.

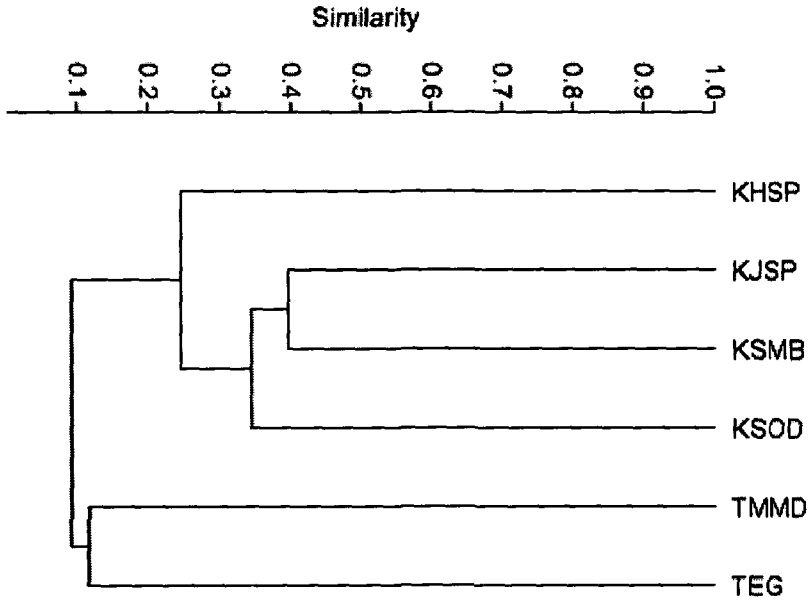

Fig. 4.14. A cluster analysis of herb layer of six forest types using Bray-Curtis method

4.4.14. Discussion

The floristic survey of six forest types (tropical evergreen, tropical moist mixed-deciduous, Khasi hill sal-pine, Khasi-Jaintia subtropical pine, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forests) of Meghalaya revealed that a total of 35,168 individual stems ≥10 cm gbh were recorded in 44.38 ha sampled area through 101 transects. The phytosociological analysis of woody layer as well as herb layer of six forest types yielded 931 species of vascular plants from 563 genera and 153 identified families. The names of the families for 19 species were undetermined. Out of 931 species, 510 species belonged to trees (502 angiosperms, 6 gymnosperms and 2 species of tree fern) and 421 species belonged to herbs including climber and creeper (372 angiosperms and 49 pterydophytes).

The ecological conditions such as wide variation in rainfall, temperature, topography as well as soil conditions, seems to be the major factor contributing to the floristic richness of Meghalaya. Several primitive families such as Annonaceae, Ranunculaceae, Hamamelidaceae, Piperaceae, Menispermaceae, Lauraceae and Myricaceae (Takhtajan 1969) were well represented among six forest types. Thus the forest of Meghalaya seems to be rich in primitive families. Due to occurrence of such a large number of primitive flowering plants, Takhtajan (1969) considered northeast region as the '*cradle of ancient angiosperms*'.

A number of authors from time to time have studied the flora of the State. Myrthong (1980) studied the monocot flora of Meghalaya and reported the presence of 736 monocotyledonous plants from this region which belonged to 298 genera and 35 families. Kumar (1984) reported 683 flowering plants in Balpakram Wildlife Sanctuary from 453 genera and 130 families whereas Prabhu (2004) recorded a total of 710 species (678

angiosperms, 03 gymnosperms and 29 pteridophytes) belonging to 465 genera and 140 families in different forest ecosystem of Nokrek Biosphere Reserve. In a floristic survey of Meghalaya, Haridasan and Rao (1985-1987) have described 1151 dicotyledonous forest plants from 119 families. Tiwari *et al.* (1998) conducted study in 79 sacred groves of Meghalaya and reported 514 species including endemic, rare and endangered plants.

In comparison to the above findings, the present study is characterized by 931 vascular plant species from 563 genera and 153 families. Of these species, approximately 94% species (874 species) belong to angiosperms followed by Pteridophytes (51 species) and Gymnosperms (6 species). The major concentration of angiosperms in the flora of the State has also been reported by many earlier workers (Balakrishnan 1981-1983, Haridasan and Rao 1985-1987, Kanjilal *et al.* 1934-1940, Khan *et al.* 1997). Dominance of flowering plants, number of families and presence of congeneric species contribute high species richness and diversity among six forest types in the State.

The maximum number of species (233 species) was recorded from Khasi subtropical mixed-broadleaved forest whereas tropical moist mixed-deciduous forest was characterised by the least number of species (95 species) despite the fact that all the sampling were done in 2 protected areas of Meghalaya namely Balpakram National Park and Siju Wildlife Sanctuary. This may be due to less sampling (2.5 ha) done in this forest. In case of herb layer, Khasi-Jaintia subtropical pine forest showed the highest number of species (239 species) which might be because of more sampling and open canopy of this forest, which favours high species richness.

The dominance-diversity curve for woody layer as well as herb layer of all forest types showed log-normal distribution, except woody layer of Khasi-Jaintia subtropical pine forest. The log normal distribution of these forest types is characteristics of complex,

species rich community (Magurran 1988) indicating more equitable sharing of resources within the communities. The dominance-diversity curve for Khasi-Jaintia subtropical pine forest showed broken-stick model, depicting low equitability and high dominance. Clearly, pine is the most dominanted species in this forest commanding a very high proportion of total importance value.

The comparison of different phytosociological attributes in the present study with other studies is difficult because of different sampling protocols such as DBH/GBH class, sampled area and methodology adopted by different workers. The different phytosociological attributes like species richness, basal area (m^2 ha^{-1}), density (ha^{-1}) and diversity indices (Shannon's, Pielou's, Simpson's) from the present study are comparable with the other studies of Meghalaya such as Jamir 2000, Upadhaya *et al.* 2003, Prabhu 2004, Mishra *et al.* 2004, Mishra *et al.* 2005, Kumar *et al.* 2006, Tripathi & Tripathi (2010) and Tripathi *et al.* (2010) (Table 4.39). The species richness recorded in the present study (95 to 233 species) is higher than those reported by earlier workers from Meghalaya (Table 4.39). The Shannon's diversity index in the present study was lower than the other studies as it was calculated by $\log_{10}$ value, despite of ln value, where it comes approximately double of $\log_{10}$ value.

Composition of large tree, medium tree, small tree, shrub, woody climber and scandent shrub as well as herb species including climber and creeper resulted in high heterogeneity among the forest types.

Tropical evergreen, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest represent a highly heterogeneous and diversified community coupled with low Simpson's dominance index and high evenness index (Table 4.39) and also shared mixed dominance of a number of species in top canopy, subcanopy and

understorey. The single species dominance, i.e. *Pinus kesiya*, in top canopy of Khasi-Jaintia subtropical pine forest corresponded with very low evenness (0.462) and high dominance (0.355) of this forest type.

Based on presence-absence data, the similarity indices are commonly used in ecology for comparing two or more communities with respect to the species overlap. All the six forest types showed differences as well as similarity in their species composition. Khasi subtropical mixed-broadleaved and Khasi subtropical oak dominated forest showed 58% similarity in species composition of woody layer. This may be due to similar climatic conditions and also altitude, which was not showing much difference in sampling plots. Champion and Seth (1968) classified both of these forests under Khasi subtropical wet hill forest (8B/C2). Tropical moist mixed-deciduous and Khasi subtropical mixed-broadleaved forest showed the least similarity in species composition, because of much variation in altitude as all the sampling of tropical moist mixed-deciduous forest was done in very low altitude of Garo Hills. Khasi hill sal pine forest exhibited *Shorea robusta* - *Schima wallichii* - *Pinus kesiya*, dominated community as these species together cover approximately 42% of total IVI of this forest. These forests also show their similarity with tropical moist mixed-deciduous forest in species composition.

According to Champion and Seth (1968), the climax vegetation of Meghalaya is characterized by Khasi subtropical broadleaved wet hill forest. The sacred groves represent most relic vegetation of Meghalaya, where Fagaceae members are most dominant among other species (Haridasan and Rao 1985). Though, *Pinus kesiya* topped with IVI in Khasi subtropical oak-dominated forest but overall family Fagaceae contributed maximum IVI to this forest. The occurrence of different species of oak viz; *Quercus* spp., *Castanopsis* spp. and *Lithocarpus* spp. in Khasi subtropical oak-dominated

forest and broad-leaved species such as *Schima wallichii*, *Syzygium tetragonum*, *Engelhardtia spicata*, *Helicia nilagirica* in Khasi subtropical mixed-broadleaved forest form the climax vegetation in the State. The increasing population pressure is also intensifying the age old practices of shifting cultivation, which is the main livelihood of the people.

The dominance of *Pinus kesiya* was also observed in Khasi subtropical mixed-broadleaved forest, where it was at second position. The dominance of *Pinus kesiya* in Khasi subtropical oak-dominated as well as Khasi subtropical mixed-broadleaved forest indicates increasing intensity of disturbances, which allow *Pinus kesiya* to invade both of these natural forests of Meghalaya.

Altitude, latitude and longitude are the most important topographical factors affecting species distribution (Zhao *et al.* 2005). The altitudinal gradient is the key factor forming various mountain habitats (Xu *et al.* 2011). *Callicarpa arborea*, *Engelhardtia spicata*, *Litsea monopetala*, *Macaranga denticulata*, *Schima wallichii* and *Syzygium tetragonum* were found in all six forest types, which shows that these species have capacity to occur in a wide variety of climatic conditions ranging from very low (26 m) to very high altitude (1820 m).

The higher frequency of occurrences of one or more than one tree influences the species diversity (Huang *et al.* 2003). *Schima wallichii* showed highest occurrence (74 transects) followed by *Pinus kesiya* (62 transects) and *Engelhardtia spicata* (52 transects).

In nature, only few species are distributed in regular manner and most of the species are clumped or randomly distributed (Greig-Smith 1983). All species among six forest types exhibited clumped to highly clumped dispersion. Patchy distribution of species may be due to spatially heterogeneous environmental conditions like, topography (Hubbell and

Foster 1983). In comparison to common species, rare species are less aggregated and most of the randomly distributed species are rare (He *et al.* 1997). No species among six forest types showed regular dispersion. Regular dispersion is very rarely observed which may be due to intraspecific competition at a local scale (He *et al.* 1997).

The tropical evergreen forest was characterised by highest density (973.5 individuals/ha), basal area (27.34 m^2/ha) and Shannon's diversity (1.983). The highest tree density ha^{-1} of this forest is probably due to the presence of large number of stems in lower girth class (10-<30 to 30-<50 cm). The tree species richness (184 species) in tropical evergreen forest recorded in this study was much greater than other tropical evergreen forest of northeastern region of India (16-54 species; Bhuyan *et al.* 2003, 94 species; Nath *et al.* 2005) as well as other tropical evergreen forest of Western Ghats, India (122 species; Parthasarathy 1999, 68 species; Giriraj *et al.* 2008).

The tree density of the present investigation was ranging from 598.4 stem ha^{-1} in tropical moist mixed-deciduous forest to 973.5 stem ha^{-1} in tropical evergreen forest with an overall mean value of 818.8 stem ha^{-1}. It can be comparable to the value reported by Parthasarathy and Karthikeyan (1997) in Thirumanikkuzhi, Western Ghats (974 stem ha^{-1}), Kadavul and Parthasarathy (1999) in Shervaryan and Kalrayan hills of Eastern Ghats (640 to 986 stem ha^{-1}), Parthasarathy (1999) in Kalakad forest, Western Ghats (575 to 855 stem ha^{-1}), Reddy *et al.* (2008) in tropical dry-deciduous forest of Andhra Pradesh (674 to 796 stem ha^{-1}), and Rasingam and Parthasarathy (2009a) in Andaman Islands (488 to 935 stem ha^{-1}).

The species richness (123 species) and stand density (882.5 stem ha^{-1}) of Khasi hill sal-pine forest was greater than other sal forest of the country, as reported by Pandey and Shukla (1999) in Gorakhpur (29 species, 451 stem ha^{-1}), Uma Shankar (2001) in

Mahananda Wildlife Sanctuary, West Bengal (87 species, 484 stem ha^{-1}), Majumdar *et al.* (2012) in Tripura (105 species, 464.77 stem ha^{-1}).

The basal area in the present study ranged from 14.31 to 27.34 m^2 ha^{-1} with an overall mean value of 18.86 m^2 ha^{-1}, which is comparable with the study of Parthasarathy and Karthikeyan (1997) in Western Ghats, India (15.44 to 29.48 m^2 ha^{-1}), Reddy *et al.* (2008) in Eastern Ghats, India (8.55 to 26.89 m^2 ha^{-1}). The highest basal area (27.34 m^2 ha^{-1}) in the present study was found in tropical evergreen forest, which was in the range of rain forest of Malaysia (24.2 m^2 ha^{-1}; Poore 1968), Brazilian amazon (27.6 to 32.0 m^2 ha^{-1}; Campbell *et al.* 1986) and Costa-Rica (27.8 m^2 ha^{-1}; Lieberman *et al.* 1985).

Overall for all 6 forest types, out of 91 family in woody layer, Lauraceae and Rubiaceae were the most speciose families with 34 species each followed by Fabaceae (27 species), Moraceae (27 species), Phyllanthaceae (21 species) and Euphorbiaceae (16 species), but when we include Phyllanthaceae together with Euphorbiaceae, it became most speciose family (37 species), as these two families were taken together by earlier workers. In a study of sal forest of Mahananda Wildlife Sanctuary of West Bengal, Uma Shankar (2001) reported that Euphorbiaceae was the most speciose family followed by Lauraceae. Kadavul and Parthasarathy (1999) also reported the dominance of Moraceae and Rubiaceae in semievergreen forests of Shemarayan hills of Eastern Ghats. Chittibabu and Parthasarathy (2000) found Moraceae, Lauraceae and Rubiaceae as the most dominant family in Kolli hills, Western Ghats. Upadhaya *et al.* (2003) also reported the dominance of Lauraceae, Moraceae and Rubiaceae in subtropical broadleaved forests of Meghalaya. Among 92 families in the herb layer, Asteraceae (38 species) was the most dominant family followed by Poaceae (31 species), Lamiaceae (25 species), Fabaceae & Rubiaceae

(22 species each) and Acanthaceae (15 species) apparantly due to number of ground species are characterized by these families.

In all six forest types the most dominant species were characterized by the high value of IVI. The low IVIs suggest that most of the species in the forest are rare (Pascal and Pellissier 1996). In woody layer, approximately 58% in tropical evergreen, 41% in tropical moist mixed-deciduous, 67% in Khasi hill sal-pine, 82% in Khasi-Jaintia subtropical pine, 70% in Khasi subtropical mixed-broadleaved and 73% in Khasi subtropical oak-dominated forest were rare as they exhibited an Importance Value of 1 or less. This is a general trend in most tropical forest in India where the species richness is mostly due to the rare species (Sukumar *et al.* 1992, Parthasarathy and Karthikeyen 1997, Pandey and Shukla 2003, Murali *et al.* 1996, Uma Shankar 2001, Ayyappan and Parthasarathy 2004, Nath *et al.* 2005, Deb and Sundriyal 2011, Majumdar *et al.* 2012).

Table 4.39. A comparison of the phytosociological attributes of the six forest types of this study with other studied carried out in Meghalaya (H'; Shannon's diversity index, E'; Pielou's evenness index, D'; Simpsons dominance index).

Study area	Forest types	GBH/DBH	Sampled area (ha)	# of species	Den/ha	BA (m^2/ha)	Diversity indices			Reference
							H'	E'	D'	
Meghalaya	Tropical evergreen	≥10 GBH	2.45	184	973.5	27.34	1.983	0.876	0.018	Present study
Meghalaya	Tropical moist mixed-deciduous	≥10 GBH	2.5	95	598.4	16.56	1.665	0.842	0.036	Present study
Meghalaya	*Khasi hill sal-pine*	≥10 GBH	5.2	123	882.5	15.65	1.493	0.714	0.075	Present study
Meghalaya	Khasi-Jaintia subtropical pine	≥10 GBH	18.8	156	692.4	21.78	1.012	0.462	0.355	Present study
Meghalaya	Khasi subtropical mixed-broadleaved	≥10 GBH	6.85	233	862	17.52	1.93	0.815	0.024	Present study
Meghalaya	Khasi subtropical oak dominated	≥10 GBH	8.6	225	904.1	14.31	1.9	0.808	0.022	Present study
Sacred grove, Jaintia hills	Subtropical humid	≥5 DBH	0.8	135	1070	–	3.74	0.91	0.019	Jamir (2000)
Sacred grove, Jaintia hills	Subtropical broad-leaved	≥5 DBH	0.5	82	1476	57.46	3.42	0.53	0.067	Upadhaya *et al.* (2003)
Sacred grove, Jaintia hills	Subtropical broad-leaved	≥5 DBH	0.5	80	938	71.44	3.55	0.56	0.052	Upadhaya *et al.* (2003)
Nokrek BR	Montane forest	≥5 GBH	0.2	88	2595	49.95	3.80	0.85	0.04	Prabhu (2004)
Nokrek BR	*Lowland forest*	≥5 GBH	0.2	89	1555	38.25	4.10	0.91	0.02	Prabhu (2004)
Nokrek BR	Riverain forest	≥5 GBH	0.2	86	1180	28.15	4.19	0.94	0.02	Prabhu (2004)
Swer sacred grove	Undisturbed	≥15 CBH	15	168	2103	26.9	2.2	0.4	0.1	Mishra *et al.* (2004)
Swer sacred grove	Moderately disturbed	≥15 CBH	15	192	1268	18.6	2.3	0.4	0.2	Mishra *et al.* (2004)
Swer sacred grove	Highly disturbed	≥15 CBH	10	132	852	7.1	2.0	0.4	0.2	Mishra *et al.* (2004)
Mawnai sacred grove	Subtropical humid	>15 GBH	0.5	133	1256	42.8	4.5	–	0.014	Mishra *et al.* (2005)
Garo Hills	Primary forest	≥30 GBH	21	162	–	–	4.27	–	–	Kumar *et al.* (2006)
Garo Hills	Secondary forest	≥30 GBH	10	132	–	–	3.78	–	–	Kumar *et al.*(2006)
Garo Hills	Sal forest	≥30 GBH	4	87	–	–	2.47	–	–	Kumar *et al.* (2006)
Meghalaya	Subtropical Evergreen	>15 DBH	1	76	1023	33.3	4.2	–	0.02	Tripathi & Tripathi (2010)
Meghalaya	Subtropical Semi-evergreen	>15 DBH	1	77	838	49.5	4.21	–	0.02	Tripathi & Tripathi (2010)
Meghalaya	Subtropical Pine	>15 DBH	0.3	26	1050	37.4	2.19	–	0.06	Tripathi & Tripathi (2010)
Laitryngew (EKH)	Subtropical humid	≥5 DBH	1	49	1280	35.12	3.21	–	0.07	Tripathi *et al.* (2010)
Laitryngew (EKH)	Subtropical humid	≥5 DBH	2	53	1290	33.89	3.3	–	0.06	Tripathi *et al.* (2010)
Laitryngew (EKH)	Subtropical humid	≥5 DBH	5	58	1203	40.63	3.16	–	0.08	Tripathi *et al.* (2010)
Laitryngew (EKH)	Subtropical humid	≥5 DBH	>5	64	1620	45.11	3.57	–	0.05	Tripathi *et al.* 2010

CHAPTER V

QUANTIFICATION OF POPULATION OF IMPORTANT SPECIES OF EACH FOREST TYPE

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QUANTIFICATION OF POPULATION OF IMPORTANT SPECIES OF EACH FOREST TYPE

5.1. Introduction

Girth class distribution is very commonly used in ecology to illustrate the population structure as well as regeneration status of the forests. The successful establishment of a community depends on its regeneration efficacy under varied environmental conditions. Many authors have quantified regeneration status of tree species based on age and diameter structure of their population (Saxena and Singh 1984, Khan *et al.* 1987, Bhuyan *et al.* 2003). The height structure of the forests generally simplifies the stratum of canopy layer such as top canopy, subcanopy and understorey. The girth class as well as height class distribution of individuals provide complete scenarios of the forests. The population structure in several ecological studies had been characterised by number or percentage of individuals in different girth/diameter classes as well as height classes (Murali *et al.* 1996, Uma Shankar 2001, Pandey and Shukla 2003, Ghosh 2007, Reddy *et al.* 2008, Nongrum 2012, Swer 2013, Kumar 2013).

A large number of authors had studied the population structure of forests as well as populations of important plants in Meghalaya (Rao *et al.* 1990, Barik 1992, Jamir 2000, Upadhaya *et al.* 2003, 2004, Mishra *et al.* 2004, 2005, Prabhu 2004, Tripathi *et al.* 2010, Tripathi and Reynald 2010). Most of these studies are limited to subtropical forest only.

The present chapter presents results of the girth-class (population) structure and height-class structure of six major forest types described in Chapter IV. In addition, the girth-

class (population) structure and height-class structure of the major species in each of these forest types are analyzed.

5.2. Methodology

The girth class distributions of individuals of six major forest types of Meghalaya were plotted in nine 20 cm wide girth classes (10-<30, 30-<50, 50-<70, 70-<90, 90-<110, 110-<130, 130-<150, 150-<170, ≥170). The height class distribution of major forest types was plotted in five 5 m wide height classes (<5, 5-<10, 10-<15, 15-<20, ≥20).

The regeneration behaviour of forest as well as important species of each forest types was assessed based on girth measurement. All stems in the forests which had girth ≥10 cm to <30 cm over the bark at breast height (1.37 m) were considered as saplings and ≥30 cm were considered as adults (Uma Shankar 2001). The state of regeneration was deduced in each forest type as follows:

a) Good regeneration, if seedlings > saplings > adults
b) Fair regeneration, if seedlings > saplings ≤ adults
c) Poor regeneration, if a species survive only at sapling stage, but no seedlings (saplings may be >, < or = adults)
d) No regeneration, if a species is present only in adult form
e) New regeneration, if the species has no adults but only seedlings or saplings

The larger number of stems in ≥10 cm to <30 class indicates high regeneration, whereas the small number of stems in this class suggests low regeneration. The individuals less than 10 cm girth (seedlings) were not measured and hence the state of regeneration was based only on saplings and adult categories.

Selection of economically and ecologically important species

Among each forest types, top three tree species which have highest IVI values were selected for population structure. A girth class distribution (density-diameter distribution) as well as height class distribution was prepared for these species. The state of regeneration were assessed based on data on the individuals ≥10 cm to <30 cm gbh. The girth class distribution of stems of dominant species were plotted in 20 cm wide interval for nine girth classes (10-<30, 30-<50, 50-<70, 70-<90, 90-<110, 110-<130, 130-<150, 150-<170 and ≥170 cm) and height class distribution were plotted in 5 m wide interval for five height classes (<5, 5-<10, 10-<15, 15-<20 and ≥20 m).

5.3. Results

5.3.1. *Girth class distribution*

The number of individuals recorded in different girth classes of six forest types, namely, tropical evergreen, tropical moist mixed-deciduous, Khasi hill sal-pine, Khasi-Jaintia subtropical pine, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest are given in Table 5.1. A plot of this data showed a reverse J-shaped curve, i.e., with increasing girth size, the numbers of individuals decreased in all forest types (Fig. 5.1 a, b, c, d, e, f). The lower gbh class A (10-<30 cm) was most prominent in most of the cases which shows that these forests have good regeneration potential.

Table 5.1. Number of individuals in different girth classes (cm) for six forest types.

Forest types	10-<30	30-<50	50-<70	70-<90	90-<110	110-<130	130-<150	150-<170	≥ 170	Total
I) TEG	1240	463	242	178	99	50	54	21	38	2385
% of total	52.0	19.4	10.1	7.5	4.2	2.1	2.3	0.9	1.6	100
II) TMMD	563	477	203	119	49	19	31	3	32	1496
% of total	37.6	31.9	13.6	8.0	3.3	1.3	2.1	0.2	2.1	100
III) KHSP	2077	1251	703	331	136	55	22	5	9	4589
% of total	45.3	27.3	15.3	7.2	3.0	1.2	0.5	0.1	0.2	100
IV) KJSP	2946	3119	2946	2511	1005	291	118	40	42	13018
% of total	22.6	24.0	22.6	19.3	7.7	2.2	0.9	0.3	0.3	100
V) KSMB	3547	1233	434	320	169	74	50	22	56	5905
% of total	60.07	20.88	7.35	5.42	2.86	1.25	0.85	0.37	0.95	100
VI) KSOD	4260	1827	896	476	174	62	43	13	24	7775
% of total	54.8	23.5	11.5	6.1	2.2	0.8	0.6	0.2	0.3	100

The number of individuals for lowest size class (10-<30 cm) contributed approximately 52% in tropical evergreen forest, 37.6% in tropical moist mixed-deciduous forest, 45.3% in Khasi hill sal-pine forest, 22.6% in Khasi-Jaintia subtropical pine forest, 60.1% in Khasi subtropical mixed-broadleaved forest and 54.8% in Khasi subtropical oak-dominated forest. The Khasi-Jaintia subtropical pine forest showed almost equal dominance of number of individuals for gbh class A to D (10-<30 to 70-<90). This was due to single species dominance of this forest i.e. *Pinus kesiya*. The higher gbh class (110-<130, 130-<150, 150-<170 and ≥170 cm) were characterised by a very less number of individuals in each forest type (Fig. 5.1 a, b, c, d, e, f).

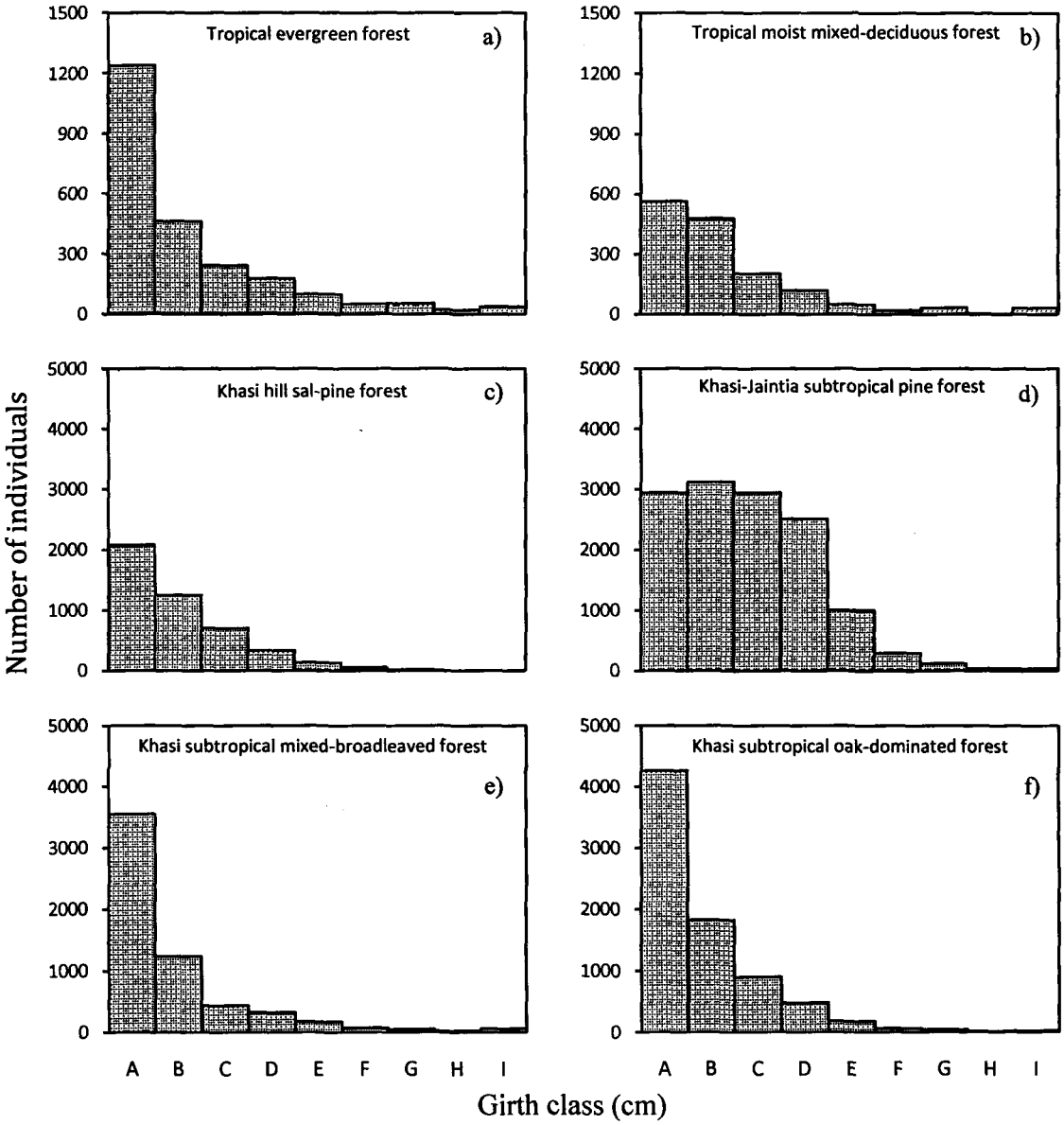

Fig. 5.1. Population structure of six forest types in different girth classes (A; 10-<30, B; 30-<50, C; 50-<70, D; 70-<90, E; 90-<110, F; 110-<130, G; 130-<150, H; 150-<170, I; ≥170).

5.3.2. *Height class distribution*

The number of individuals recorded in different height classes of six forest types, namely, tropical evergreen, tropical moist mixed-deciduous, Khasi hill sal-pine, Khasi-Jaintia subtropical pine, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-

dominated forest are given in Table 5.2. A plot of this data showed varied patterns for different forest types (Fig. 5.2 a, b, c, d, e, f).

Table 5.2. Number of individuals in different height classes (m) for six forest types.

Forest types	<5	5-<10	10-<15	15-<20	≥20	Total
I) TEG	1004	629	472	184	96	2385
% of total	42.1	26.4	19.8	7.7	4.0	100
II) TMMD	324	650	378	79	65	1496
% of total	21.7	43.4	25.3	5.3	4.3	100
III) KHSP	1423	1625	1054	459	28	4589
% of total	31.0	35.4	23.0	10.0	0.6	100
IV) KJSP	2335	3432	3632	3024	595	13018
% of total	17.9	26.4	27.9	23.2	4.6	100
V) KSMB	2606	1969	781	389	160	5905
% of total	44.1	33.3	13.2	6.6	2.7	100
VI) KSOD	3037	3003	1406	289	40	7775
% of total	39.06	38.62	18.08	3.72	0.51	100

The tropical evergreen, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest showed a successive decline of number of individuals from lower to next higher class (Fig. 5.2 a, e and f). The tropical moist mixed deciduous forest and Khasi hill sal-pine forest showed highest number of individuals for 5-<10 m (Fig. 5.2 b, c). In case of Khasi-Jaintia subtropical pine forest, the height class distribution of individuals showed a peak in 10-<15 m (Fig. 5.2d). Only few individuals in each forest types were characterized by ≥20 m height, viz., 4% in tropical evergreen forest, 4.3% in tropical moist mixed-deciduous forest, 0.6% in Khasi hill sal-pine forest, 4.6% in Khasi-Jaintia subtropical pine forest, 2.7% in Khasi subtropical mixed-broadleaved forest and 0.5% in Khasi subtropical oak-dominated forest.

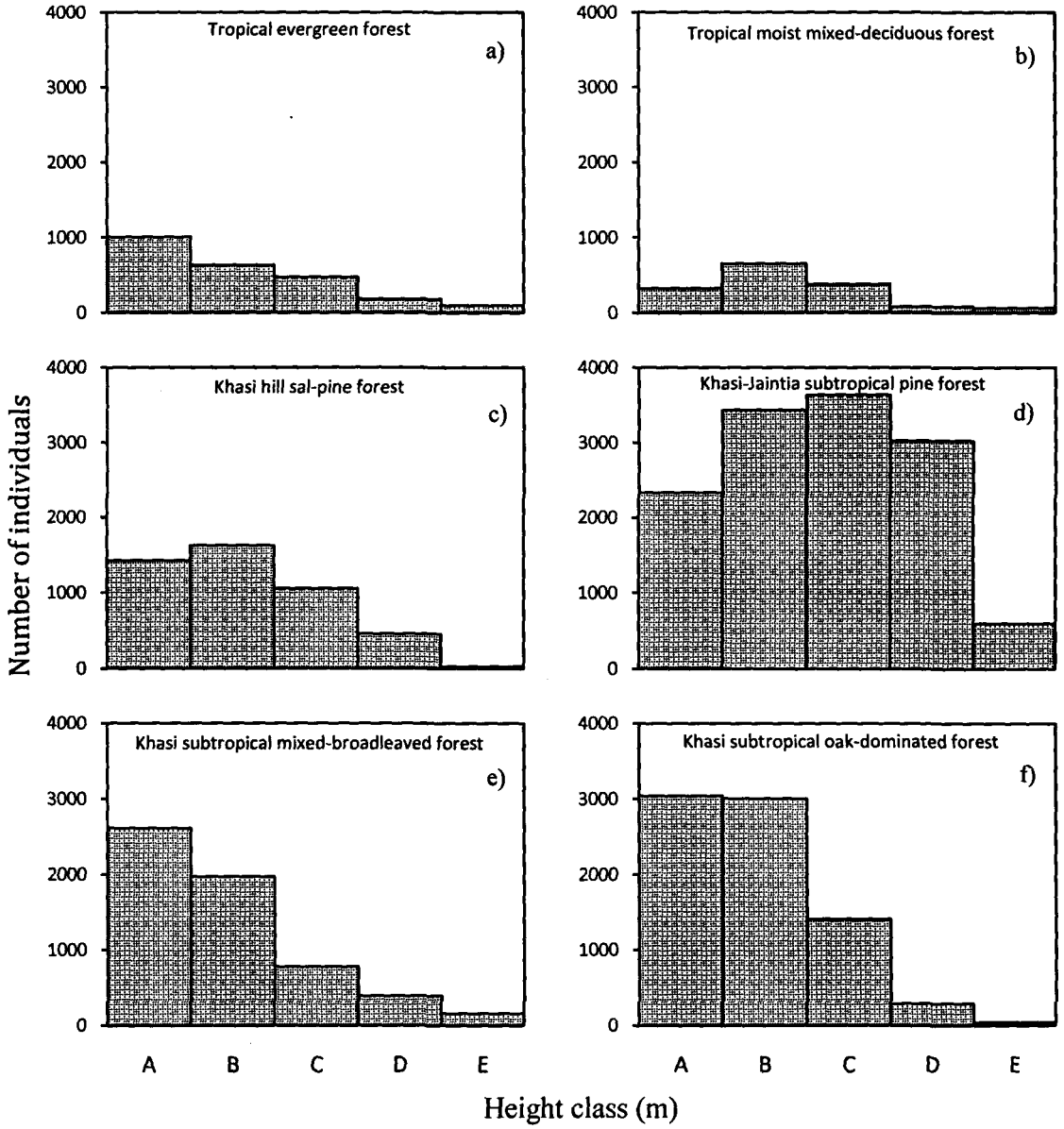

Fig. 5.2. Height structure of six forest types in different height classes (A; <5, B; 5-<10, C; 10-<15, D; 15-<20, E; ≥20).

5.4. Population structure of economically and ecologically important plant species

The economically and ecologically important species were identified from among the dominant tree species recoded in different forest types. The size of populations of these tree species was determined based on the phytosociological data from the transect

inventory. Recently, the importance of population structure of many economically and ecologically plants had been seen through various study in Meghalaya such as *Cinnamomum tamala* (Ghosh 2007), *Ilex khasiana* (Upadhaya *et al.* 2009), *Parkia roxburghii* (Nongrum 2012), *Taxus wallichiana* (Swer 2013) and 16 species in lower Assam region of India (Kumar 2013).

5.5. Population structure of important species of tropical evergreen forest

The tropical evergreen forest showed a mixed dominance of a number of species in top canopy, subcanopy and under canopy. Out of 184 species, the top three important plant species selected on the basis of IVI in this forest were *Schima wallichii*, *Macropanax undulatus* and *Cinnamomum tamala* with an importance value of 18.7, 16.0 and 11.0, respectively (Table 4.1 in Chapter IV). These species together cover 15.2% of total IVI.

The population structure of *S. wallichii* (35.7%) and *C. tamala* (29.5%) was characterised by the highest number of individuals in gbh class 10-<30 cm, whereas *M. undulatus* showed highest number of individuals in gbh class 50-<70 cm (28.5%). *S. wallichii* showed lowest number of individuals in size class 30-<50 cm. *M. undulatus* showed an increasing trend of number of individuals from lower gbh class 10-<30 to 50-<70 cm and successive decline afterwards. In case of *C. tamala* showed reverse J-shaped curve. The higher gbh class (150-<170 and ≥170 cm) were absent in *M. undulatus* and *C. tamala*. *S. wallichii* had highest number of individuals in <5 m height class whereas *M. undulatus* and *C. tamala* showed a peak in 10-<15 m (Fig. 5.2d, e, f). Approximately, 68.8% individuals of *M. undulatus* were in 10-<15 m height. The number of individuals for ≥20 m were absent in *M. undulatus* and *C. tamala* but were 16.3% for *S. Wallichii*.

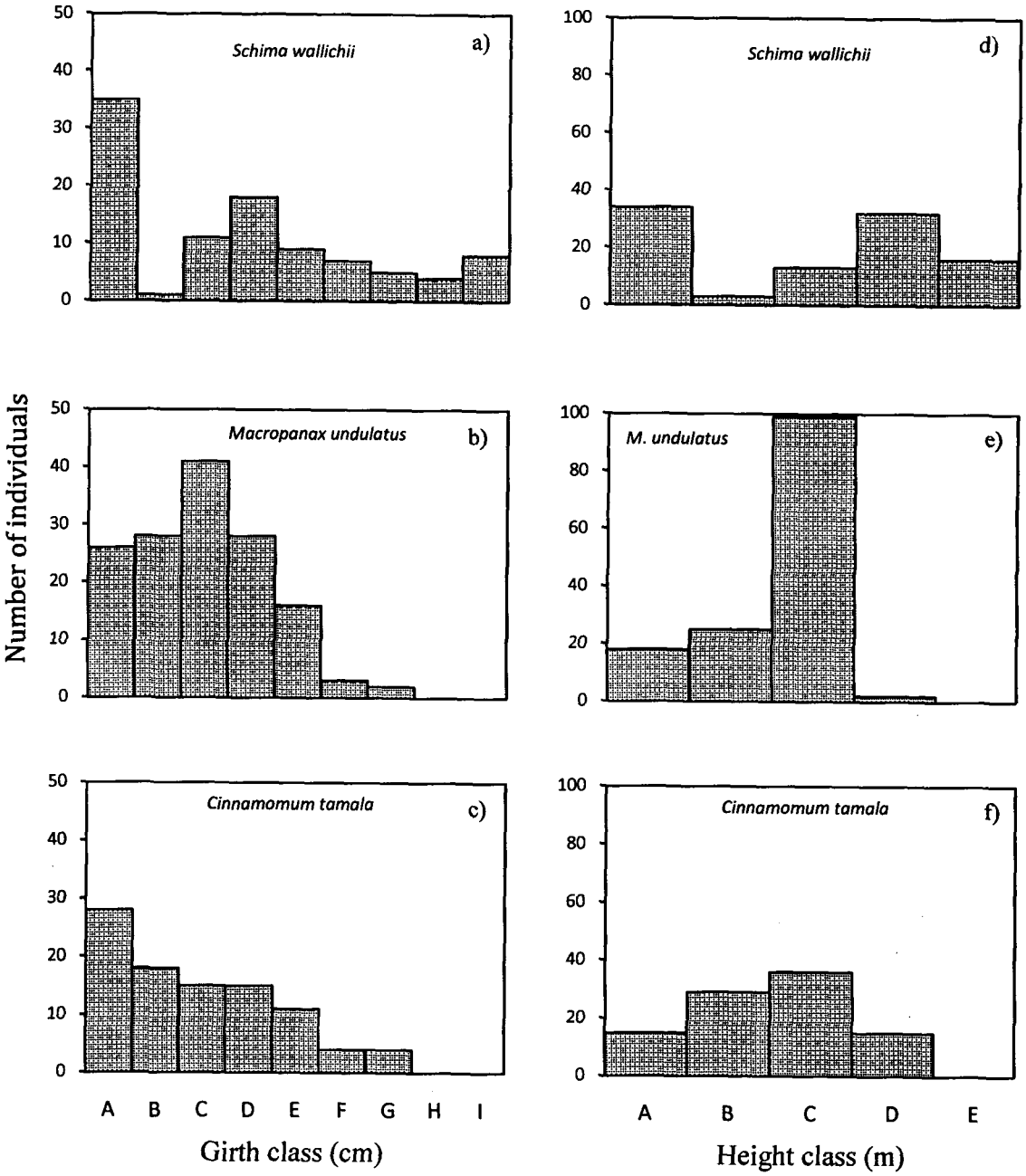

Fig. 5.3. Population structure of three important plant species in tropical evergreen forest in different girth classes (A; 10-<30, B; 30-<50, C; 50-<70, D; 70-<90, E; 90-<110, F; 110-<130, G; 130-<150, H; 150-<170, I; ≥170) and height classes (A; <5, B; 5-<10, C; 10-<15, D; 15-<20, E; ≥20).

5.6. Population structure of important species of tropical moist mixed-deciduous forest

The tropical moist mixed deciduous forest showed a mix dominance of a number of species in top canopy, subcanopy and under canopy. Out of 65 species, the top three important plant species selected on the basis of IVI in this forest were *Microcos paniculata*, *Schima wallichii*, and *Dillenia indica* with an importance value of 28.2, 24.2 and 20.6, respectively (Table 4.7 in Chapter IV). These species together cover 24.3% of total IVI.

The three species exhibited different density-diameter patterns. *M. paniculata* was characterised by highest number of individuals in gbh class 30-<50 cm (42.6%), *S. wallichii* in 90-<110 cm (25.8%) and *D. indica* in highest gbh class i.e. ≥170 cm (31.4%) (Fig. 5.4 a, b, c). In case of *M. paniculata*, gbh class 90-<110 cm to ≥ 170 cm and in *S. wallichii* 150-<170 cm were absent. Three classes were absent in *D. indica*, i.e., 30-<50, 90-<110 and 110-<130 cm. The state of regeneration (10-<30 cm) was maximum in *M. paniculata* (30.1%) followed by *D. indica* (17.1%). Very few individuals (1.5%) were showing regeneration in *S. wallichii*.

M. paniculata had highest number of individuals in 5-<10 m height class (53.6%) whereas *S. wallichii* (33.3%) and *D. indica* (37.1%) showed a peak in ≥20 m (Fig. 5.4 d, e, f). With increasing tree height, the numbers of individuals also increased in case of *S. wallichii* and *D. indica*.

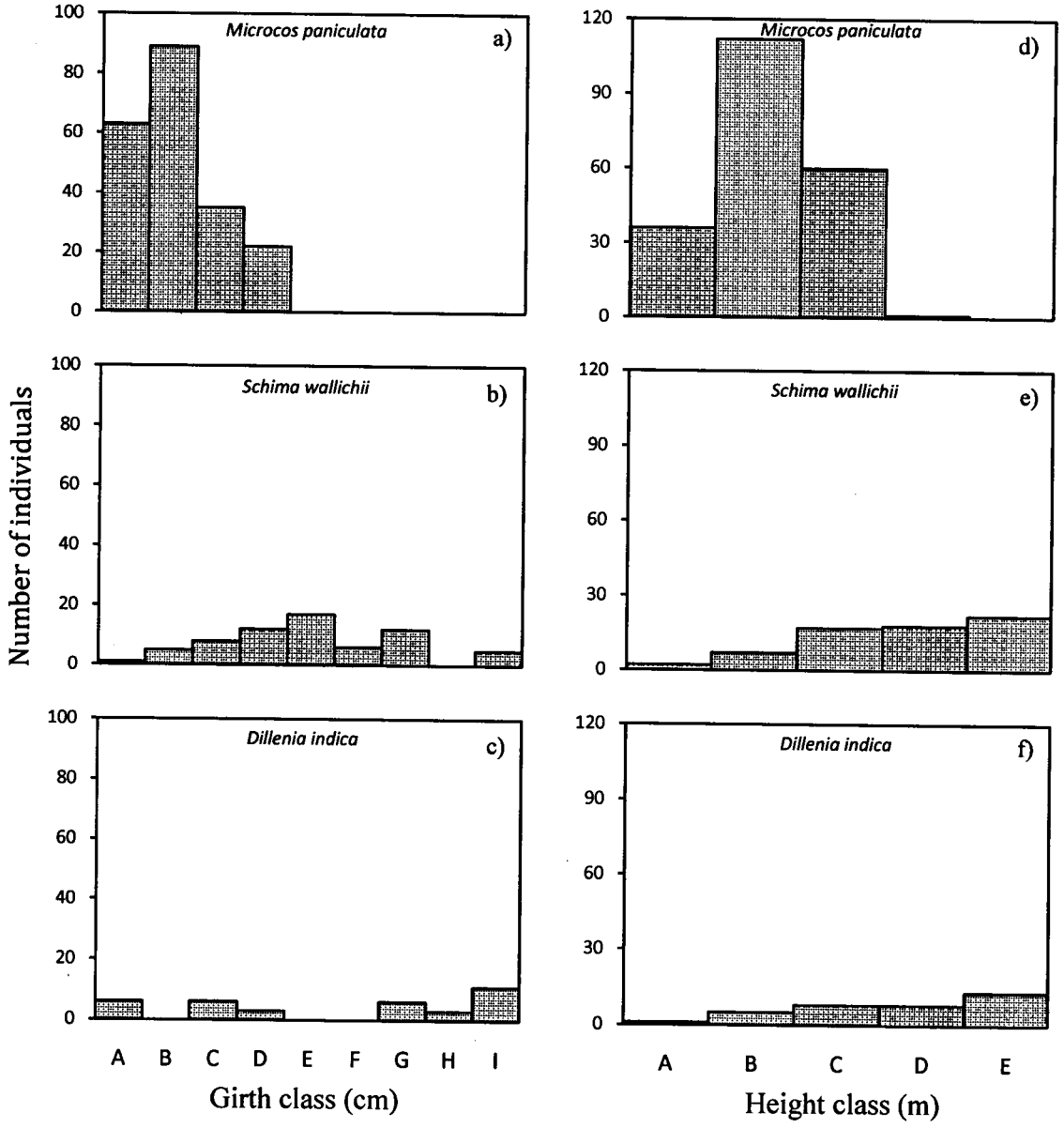

Fig. 5.4. Population structure of three important plant species in tropical moist mixed-deciduous forest in different girth classes (A; 10-<30, B; 30-<50, C; 50-<70, D; 70-<90, E; 90-<110, F; 110-<130, G; 130-<150, H; 150-<170, I; ≥170) and height classes (A; <5, B; 5-<10, C; 10-<15, D; 15-<20, E; ≥20).

5.7. Population structure of important species of Khasi hill sal-pine forest

The Khasi hill sal-pine forest showed a mix dominance of a number of species in top canopy. Out of 123 species, the top three important plant species selected on the basis of IVI in this forest were *Shorea robusta*, *Schima wallichii*, and *Pinus kesiya* with an importance value of 55.7, 47.2 and 22.5, respectively (Table 4.13 in Chapter IV). These species together cover 41.8% of total IVI of this forest.

The population structure of *S. robusta* and *S. wallichii* showed a reverse J-shaped curve. *P. kesiya* represented increasing number of individuals with increasing girth classes upto 70-<90 cm and reverse trend seen after that (Fig. 5.5 a, b, c). *S. robusta* were characterised by highest number of individuals in gbh class 10-<30 cm (37.0%), *S. wallichii* in 30-<50 cm (29.4%) and *P. kesiya* in 70-<90 cm gbh class (36.5%). In case of *S. robusta*, gbh class ≥ 170 cm were absent. Two classes were absent in *P. kesiya* i.e. 150-<170 and ≥ 170 cm. The state of regeneration (10-<30 cm) were maximum in *S. robusta* (55.7%) followed by *S. wallichii* (28.7%). Very few numbers of individuals (1.5%) were showing regenerating stage in *P. kesiya*.

The height class distribution of *S. robusta*, *S. wallichii* and *P. kesiya* were showing different trends. *S. robusta* had highest number of individuals in 5-<10 m height class (31.7%), whereas *S. wallichii* (38.1%) and *P. kesiya* (45.9%) showed a peak in 10-<15 m (Fig. 5.5 d, e, f). The numbers of individuals for ≥20 m height were very less in all three species.

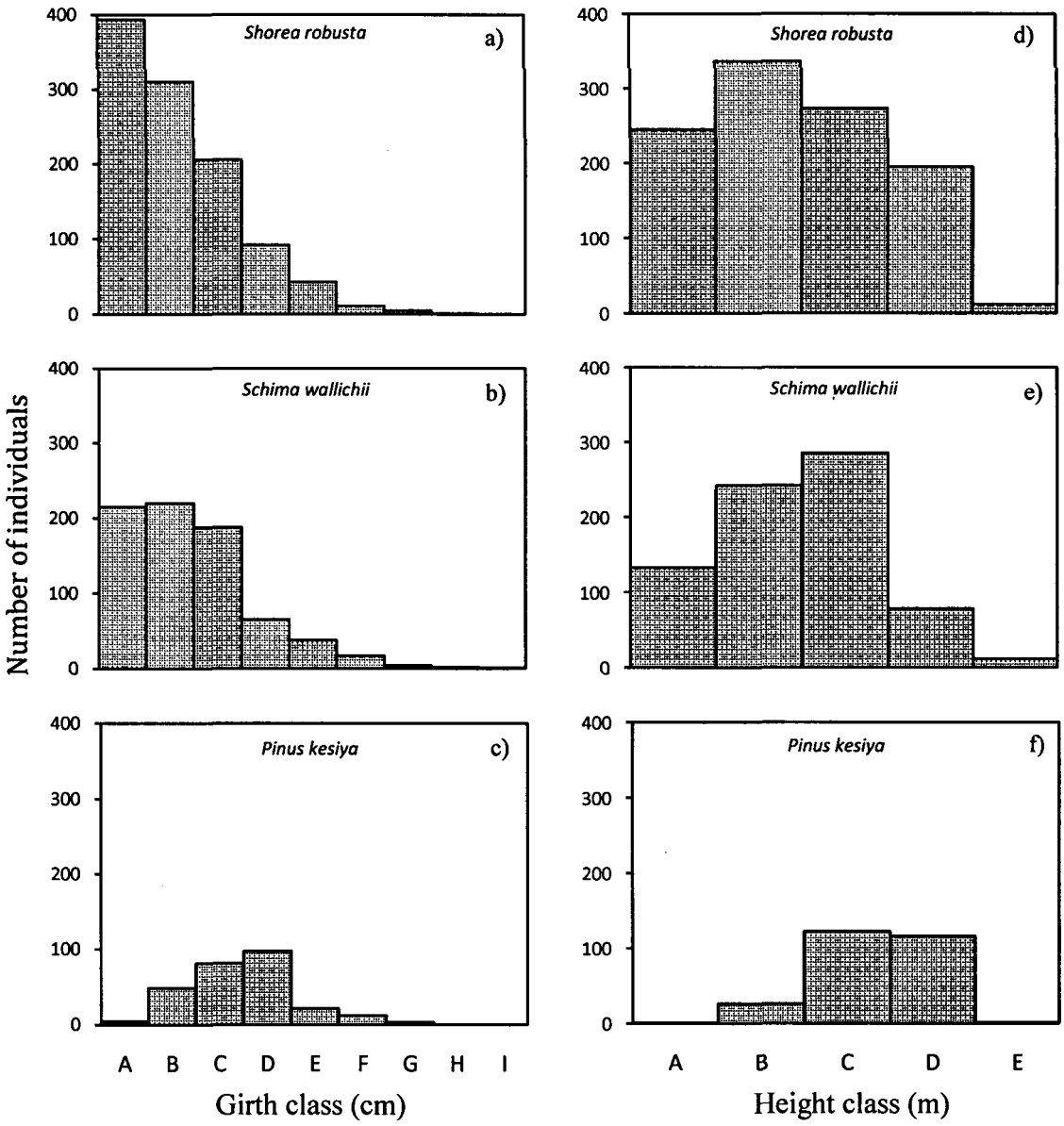

Fig. 5.5. Population structure of three important plant species in Khasi hill sal-pine forest in different girth classes (A; 10-<30, B; 30-<50, C; 50-<70, D; 70-<90, E; 90-<110, F; 110-<130, G; 130-<150, H; 150-<170, I; ≥170) and height classes (A; <5, B; 5-<10, C; 10-<15, D; 15-<20, E; ≥20).

5.8. Population structure of important species of Khasi-Jaintia subtropical pine forest

The Khasi-Jaintia subtropical pine forest showed a single species dominance in top canopy. Out of 156 species, *Pinus kesiya* topped with more than 50% of total IVI (176.9), followed by *Schima wallichii* (20.1) and *Myrica nagi* (6.6) (Table 4.19 in Chapter IV). These selected species together cover 67.9% of total IVI.

The density-diameter distribution of *P. kesiya* and *S. wallichii* showed a similar trend, i.e., increasing number of individuals with increasing girth classes upto 50-<70 cm and decreasing afterwards. *M. nagi* showed decreasing number of individuals with increasing girth classes (Fig. 5.6 a, b, c). *P. kesiya* (26.1%) and *S. wallichii* (26.7%) contributed highest number of individuals in gbh class 50-<70 cm. In case of *M. nagi*, gbh class ≥ 170 cm were absent. The state of regeneration (10-<30 cm) was maximum in *M. nagi* (48.5%) followed by *S. wallichii* (21%) and *P. kesiya* (12.9%).

The height class distributions for *P. kesiya*, *S. wallichii* and *M. nagi* were showing different trends. *S. robusta* had highest number of individuals in 10-<15 m height class (32.4%), whereas *S. wallichii* (28.4%) and *M. nagi* (51.5%) showed a peak in 5-<10 m (Fig. 5.6 d, e, f). In case of *M. nagi*, height class 15-<20 and ≥20 m were absent.

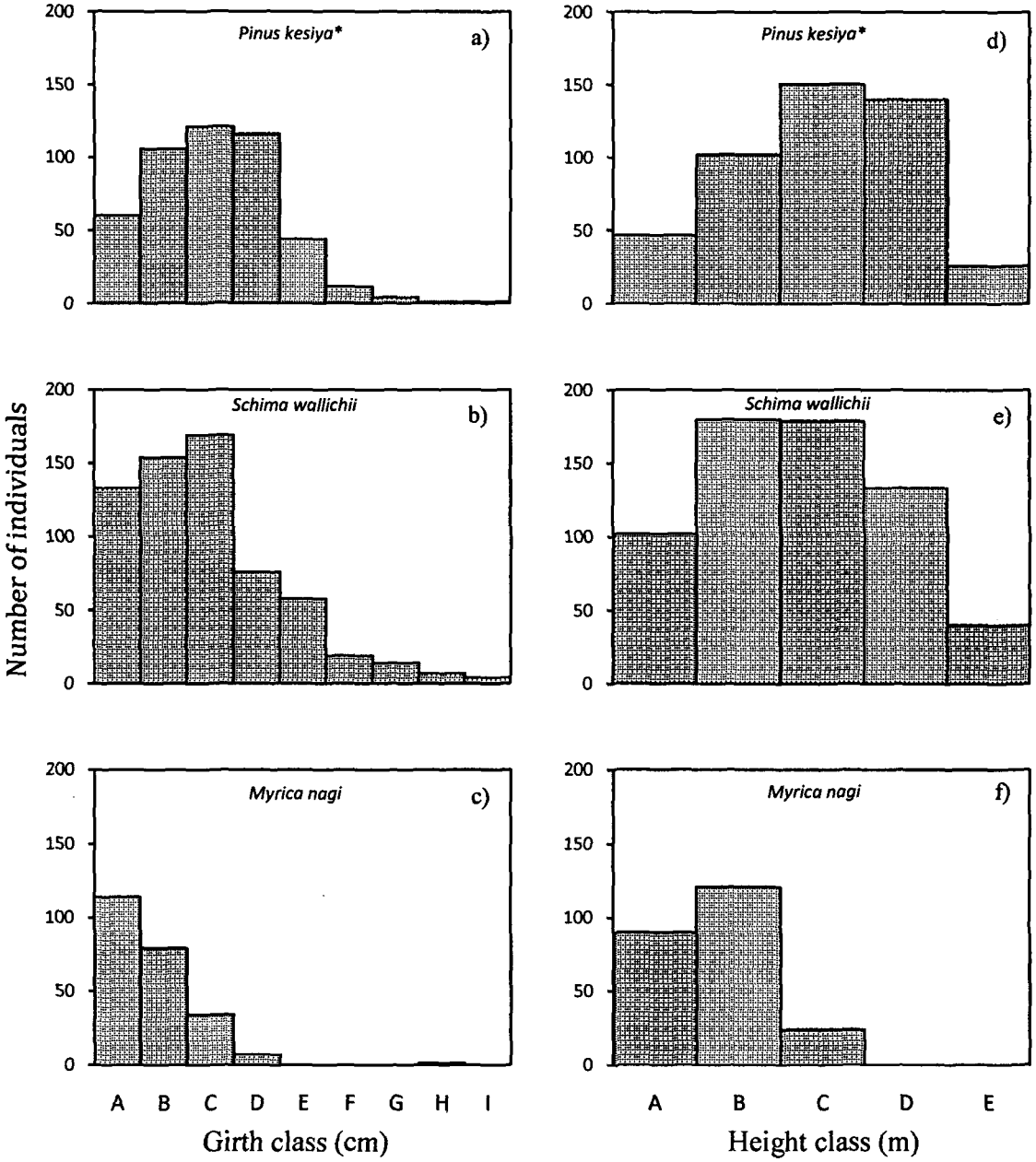

Fig. 5.6. Population structure of three important plant species in Khasi-Jaintia subtropical pine forest in different girth classes (A; 10-<30, B; 30-<50, C; 50-<70, D; 70-<90, E; 90-<110, F; 110-<130, G; 130-<150, H; 150-<170, I; ≥170) and height classes (A; <5, B; 5-<10, C; 10-<15, D; 15-<20, E; ≥20).* indicates value divided by 20.

5.9. Population structure of important species of Khasi subtropical mixed-broadleaved forest

The Khasi subtropical mixed-broadleaved forest showed a mix dominance of a number of species in top canopy, sub canopy and under canopy. Out of 233 species, the top three important plant species selected on the basis of IVI in this forest were *Schima wallichii*, *Pinus kesiya* and *Syzygium tetragonum* with an importance value of 27.9, 16.9 and 13.3 respectively (Table 4.25 in Chapter IV). These species together cover 19.4% of total IVI.

The population structure of *S. wallichii* and *S. tetragonum* showed more or less a reverse J-shaped curve. *P. kesiya* showed increasing number of individuals with increasing girth classes up to 70-<90 cm and reverse trend seen after that (Fig. 5.7 a, b, c). The lowest size class 10-<30 cm (regenerating class) contributed maximum in *S. wallichii* (38.9%) and *S. tetragonum* (53.1%). *P. kesiya* had highest number of individuals in 70-<90 cm gbh class (31.2%) and very less number of individuals (5.4%) in lowest size class (10-<30cm). In case of *S. tetragonum*, gbh class 150-<170 cm were absent.

The height class distributions for all three species were showing different trends. *S. wallichii* had highest number of individuals in 5-<10 m height class (37.1%) whereas *P. kesiya* showed a peak in 15-<20 m (56.1%) (Fig. 5.7 d, e). With increasing tree height classes, numbers of individual for *S. tetragonum* were decreased (Fig. 5.7 f). The lowest height class (<5 m) contributed maximum (40.4%) in *S. tetragonum*. The numbers of individuals for ≥20 m height were very less in all three species.

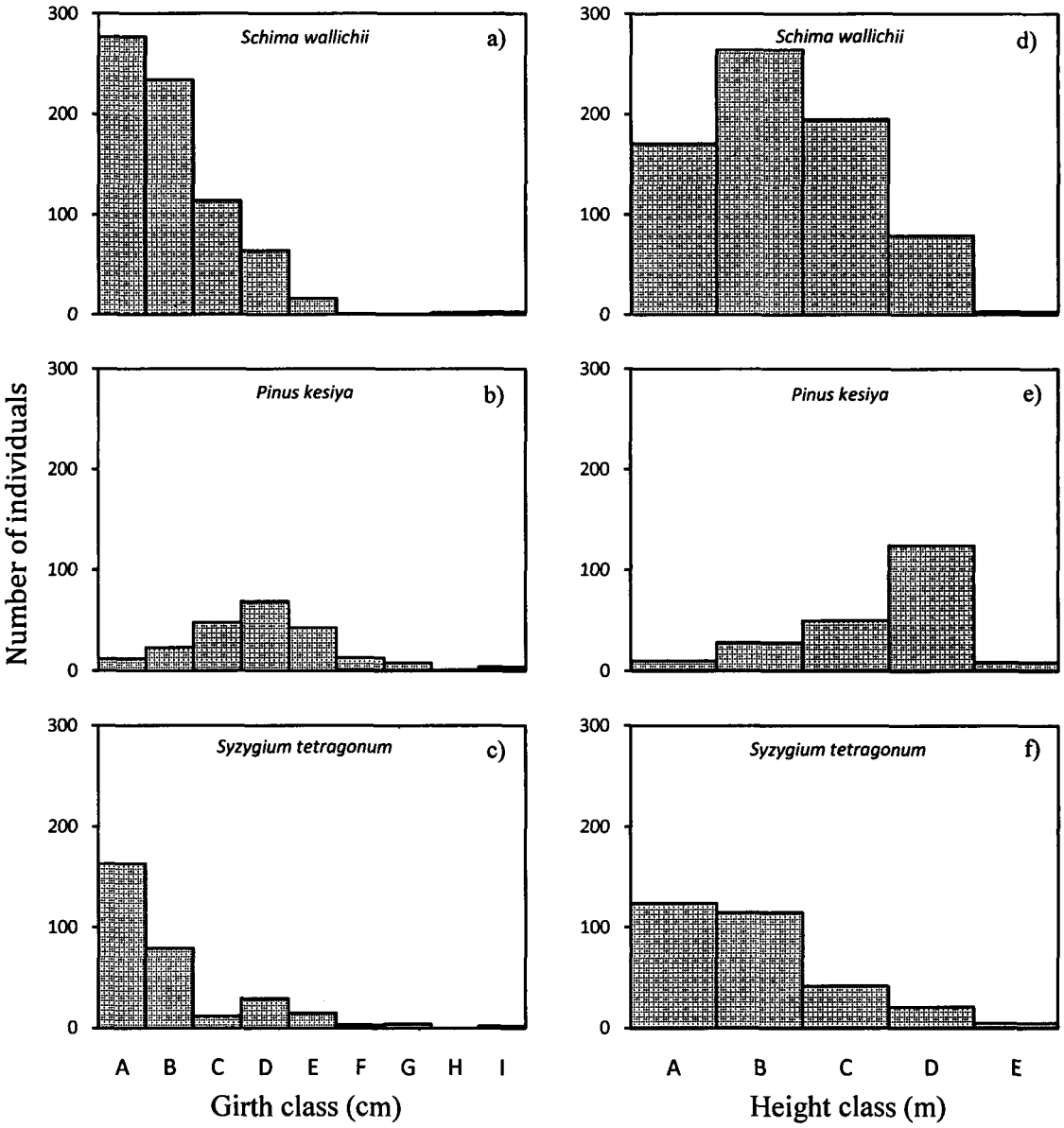

Fig. 5.7. Population structure of three important plant species in Khasi subtropical mixed broadleaved forest in different girth classes (A; 10-<30, B; 30-<50, C; 50-<70, D; 70-<90, E; 90-<110, F; 110-<130, G; 130-<150, H; 150-<170, I; ≥170) and height classes (A; <5, B; 5-<10, C; 10-<15, D; 15-<20, E; ≥20).

5.10. Population structure of important species of Khasi subtropical oak-dominated forest

The Khasi subtropical oak-dominated forest showed a mix dominance of a number of species in top canopy, sub canopy and under canopy. Out of 225 species, *Pinus kesiya* topped with IVI (15.4), but overall oak family (Fagaceae) contributed maximum IVI (56.9) with occurrence of 13 species, viz; *Castanopsis purpurella*, *Lithocarpus fenestratus*, *Castanopsis tribuloides*, *Lithocarpus dealbatus*, *Castanopsis armata*, *Quercus lineata*, *Lithocarpus elegans*, *Quercus semiserrata*, *Castanopsis lanceaefolia*, *Quercus griffithii*, *Quercus glauca*, *Quercus serrata* and *Castanopsis indica*. On the basis of IVI, the top three species selected in this forest were: *Pinus kesiya*, *Castanopsis purpurella* and *Lithocarpus fenestratus* with an importance value of 15.4, 13.5 and 13.1 respectively (Table 4.31 in Chapter IV). These species together cover 14% of total IVI.

All three species exhibited different density-diameter pattern. *P. kesiya* showed increasing number of individuals with increasing girth classes up to 70-<90 cm and decreasing after that. *C. purpurella* represented decreasing number of individuals from gbh class 30-<50 cm to 110-<130 cm. *L. fenestratus* showed more or less reverse J-shaped curve. (Fig. 5.8 a, b, c). The lowest size class 10-<30 cm (regenerating class) contributed maximum in *L. fenestratus* (56.7%) followed by *C. purpurella* (14.7%) and *P. kesiya* (10.7%). *P. kesiya* had highest number of individuals in 70-<90 cm gbh class (33.9%) and *C. purpurella* in 30-<50 cm gbh class. *L. fenestratus* showed highest number of individuals (56.7%) in lowest size class (10-<30cm). In case of *P. kesiya*, gbh class 150-<170 and ≥170 cm were absent. Three highest gbh classes (130-<150, 150-<170 and ≥170 cm) were absent in *C. Purpurella* and *L. fenestratus.*

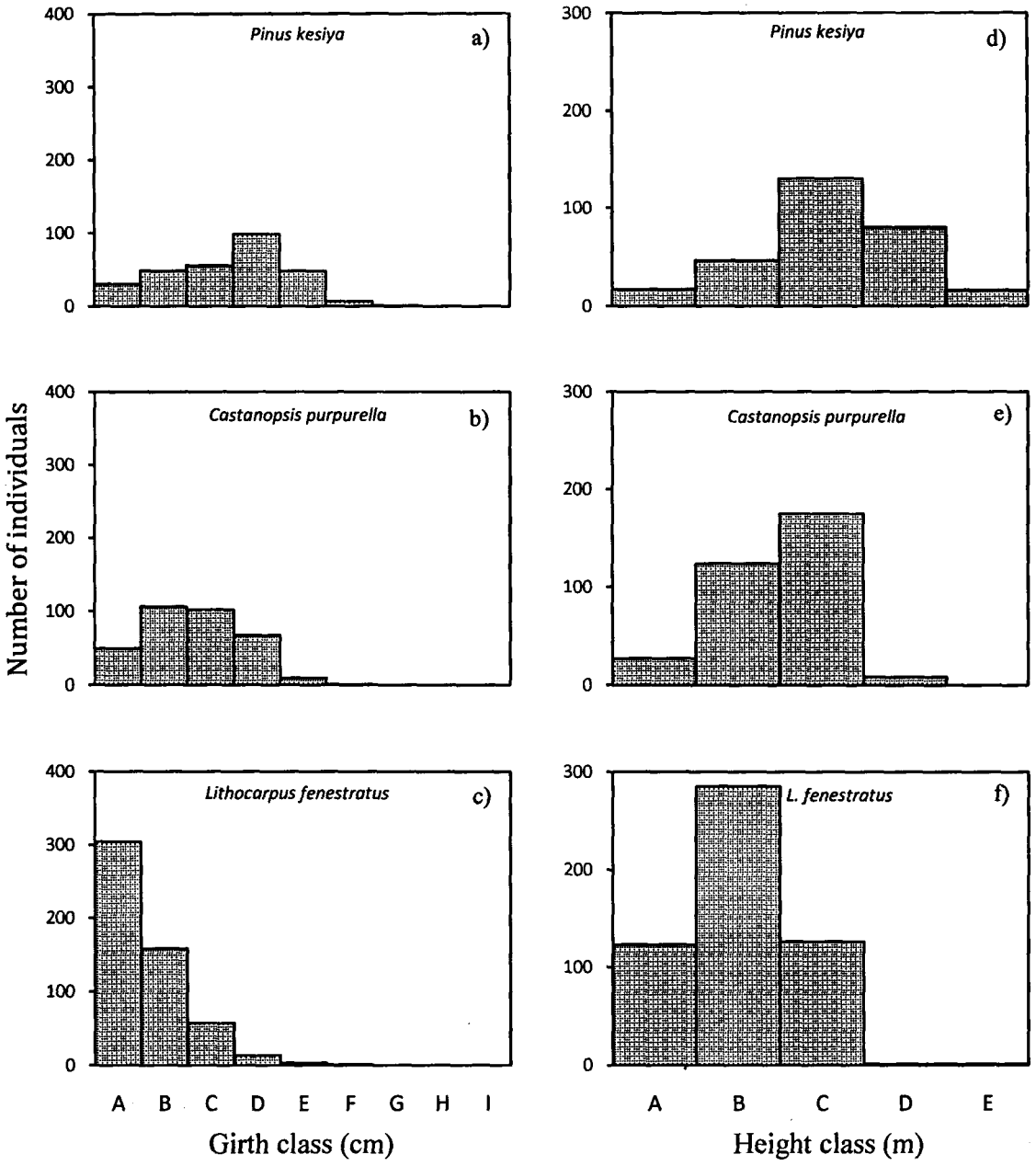

Fig. 5.8. Population structure of three important plant species in Khasi subtropical oak-dominated forest in different girth classes (A; 10-<30, B; 30-<50, C; 50-<70, D; 70-<90, E; 90-<110, F; 110-<130, G; 130-<150, H; 150-<170, I; ≥170) and height classes (A; <5, B; 5-<10, C; 10-<15, D; 15-<20, E; ≥20).

The height class distribution for *P. kesiya* (45%) and *C. purpurella* (52.4%) were showing more or less similar trends, with highest number of individuals in 10-<15 m height class whereas *Lithocarpus fenestratus* showed peak in 5-<10 m height (53.2%) (Fig. 5.8 d, e, f). The numbers of individuals for ≥20 m height were very less in *P. kesiya* and *L. fenestratus*, whereas it was absent in *C. purpurella*.

5.11. Discussion

All six forest types in the present study followed reverse J-shaped distribution, i.e., with increasing girth class, the number of individuals decreased. Such trends have been reported by Poore (1968) in Malaysia, Kadavul and Parthasarathy (1999) in tropical semi-evergreen forests in Eastern Ghats, India, Upadhaya *et al.* (2004) in subtropical forest of Meghalaya, Padalia *et al.* (2004) and Tripathi *et al.* (2004) in the forests of Andaman Islands, Reddy *et al.* (2008) in tropical dry-deciduous forest of Andhra Pradesh, and Majumdar *et al.* (2012) in moist-deciduous forest in Tripura. The preponderance of individuals in lower gbh class shows that these forests have a good potential of regeneration. The number of individuals for regenerating class (10-<30 cm) contributed approximately 52% in tropical evergreen forest, 37.6% in tropical moist mixed-deciduous forest, 45.3% in Khasi hill sal-pine forest, 22.6% in Khasi-Jaintia subtropical pine forest, 60.1% in Khasi subtropical mixed-broadleaved forest and 54.8% in Khasi subtropical oak-dominated forest.

The distribution of girth classes for six forest types was showing similar pattern, with exception of the dominance of lowest to medium size class (10-<30 to 70-<90 cm) in Khasi-Jaintia subtropical pine forest, which contributed approximately 90% of total individuals. This forest shows a relatively mature stand than other forests due to dominance of a large tree, i.e., *Pinus kesiya*. The number of individuals for higher gbh

class in all forest types is very less, this is because of good proportion of small tree, shrub and woody climber species in the forests, as these species do not attain much girth.

The height class distribution of forest types showed that the tropical evergreen, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest have highest number of individuals in <5 m class. The dominance of <5 m height class has also been reported by Reddy *et al.* (2008) in tropical dry-deciduous forest of Andhra Pradesh. The tropical moist mixed-deciduous forest and Khasi hill sal-pine forest show highest number of individuals for 5-<10 m, whereas Khasi-Jaintia subtropical pine forest showed a peak in 10-<15 m. Only a few individuals were characterised by ≥20 m height; 4% in tropical evergreen forest, 4.3% in tropical moist mixed-deciduous forest, 0.6% in Khasi hill sal-pine forest, 4.6% in Khasi-Jaintia subtropical pine forest, 2.7% in Khasi subtropical mixed-broadleaved forest and 0.5% in Khasi subtropical oak-dominated forest.

The population structure of dominant species in each forest type revealed that *Schima wallichii* was one among the top three species in most of the forests except Khasi subtropical oak dominated forest. The girth class distribution of *Schima wallichii* showed decreasing number of individuals with increasing girth classes in all forest types except tropical moist mixed-deciduous forest, which shows regeneration ability of the species.

The size class distribution for *Cinnamomum tamala*, *Myrica nagi*, *Syzygium tetragonum*, *Shorea robusta* and *Lithocarpus fenestratus* followed more or less similar pattern, where the number of individuals decreased with increasing girth classes. All these species showed higher level of regeneration as maximum number of individuals in these species were present in regenerating class (10-<30 cm).

Pinus kesiya was one of the most dominant tree scpecies found throughout Shillong plateau. Out of six forest types, it was dominating in four forest types, i.e. Khasi hill sal-pine, Khasi-Jaintia subtropical pine, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest. The size class distribution showed almost bell-shaped curve with maximum number of individuals in medium size class (70-<90 cm) and successive decline after and before this class. The *Microcos paniculata* rarely attains a very large girth and this may be a possible reason for absence of higher size class in this species. Being a large to medium tree, the absence of higher gbh class in *Schima wallichii*, *Castanopsis purpurella* and *Lithocarpus fenestratus* were observed. This may be due to the reason that the larger girth of these species is preferred for charcoal making as well as household timber by the local people.

In conclusion, the number of individuals in all six forest types showed preponderance of lower girth classes which represents good regeneration, but at the same time absence or very less number of individuals in higher gbh class also suggest the occurrence of past disturbances in these forests.

CHAPTER VI

DISTURBANCE-BASED CLASSIFICATION OF VEGETATION

CHAPTER VI

DISTURBANCE-BASED CLASSIFICATION OF VEGETATION

6.1. Introduction

The anthropogenic disturbances in forest ecosystems are the most severe ecological problems recognized world-wide. Every year, more than 10 million ha of tropical forests in developing countries are cleared or converted to other land use (Tole 1998) and a large part is disturbed and fragmented due to human activities (Giambelluca *et al.* 2003, Van Laake and Sanchez-Azofeifa 2004). Disturbances are responsible for change in floristic composition, biodiversity and population structure of forests (Addo-Fordjour *et al.* 2009). Meghalaya, an important landscape of northeastern region of India, experiences a high level of anthropogenic disturbances, which varies from one forest type to another. The agriculture, which is practiced in less than 10% of the land, provides livelihood to about 80% people in rural Meghalaya (Tiwari and Kumar 2008). The large forest area (88.15%) in the State is under 'unclassified' category (FSI 2011). The unclassified area is owned by traditional community institutions, clans, private individuals, village councils, and district councils (Tripathi *et al.* 2005) where the local people have rights to use the different forests resources (Tiwari *et al.* 2010).

The people of Meghalaya are largely dependent on forests for their livelihoods leading to varied disturbances. Besides timber species, a number of non-timber forest products (NTFPs) including cane, bayleaf, tree bean, bamboos, broomgrass, mushrooms, orchids, commercially important grass species, oil yielding trees, honey, wax, medicinal and wild edible plants are extracted from the forests in large quantities (Tripathi *et al.* 2005, Ghosh 2007, Nogrum 2012). The recurrent fire in the dry season also adversely affects the forests. Shifting agriculture, logging, mining and other human activities have been

responsible for fragmentation, destruction and degradation of the forests in the State (IIRS 2002, Tripathi *et al.* 2005, Lele and Joshi 2009). The indigenous shifting cultivation (locally called '*jhum*') has long been practiced in all parts of Meghalaya, causing structural as well as compositional change in the forest types of the region and ultimately modifies the natural landscape (Ramakrishnan 1992, Roy and Tomar 2001, Kerkhoff and Sharma 2006).

Anthropogenic disturbances ultimately result in biodiversity loss in Meghalaya. Many species of timber, medicinal plants, endemic plants and economically and ecologically important plants are being depleted for firewood, NTFP collection, horticulture development, mining (coal, limestone and other minerals), timber, *jhum* cultivation and other purposes (Uma Shankar *et al.* 1993a, Tripathi *et al.* 1996, Sarma 2005, Tripathi *et al.* 2005, Tiwari and Kumar 2008)). Hence, forests are degraded to different degrees and degraded habitats such as marginal lands and grasslands are expanding (Uma Shankar 1991) and resulting in loss of biomass stocks and opening of nutrient cycling (Pandey *et al.* 1993, Uma Shankar *et al.* 1993b).

Satellite remote sensing has played a key role in generating information about forest cover, vegetation types and land use and land cover changes (Botkin *et al.* 1984, IIRS 2002, Jha *et al.* 2005, Lele and Joshi 2009). Remote sensing coupled with GIS (Geographical Information System) and GPS (Global Positioning System) techniques is useful in mapping different types of bioresources. Using this technique, current scenario of forest cover, deforestation rate and loss in forest cover have been estimated in many tropical regions (Mayaux *et al.* 2005, Lele and Joshi 2009). In the present study, a disturbance-based classification of the landscape of Meghalaya was done to delineate the area of anthropogenic disturbance with varying degree. The objective of this exercise is

to quantify the magnitude of principal disturbances and to identify the areas (forest types) in which they operate using a disturbance index. This is expected to aid immensely the forest conservators in framing suitable policy for preserving biodiversity in Meghalaya.

6.2. Methods

6.2.1. *Field data collection*

The observations on geographical parameters of the sampling sites were taken on topography, altitude and aspect using altimeter, compass and GPS. The anthropogenic disturbance factors operating in each sampling location were recorded. These were listed in following categories; fire, grazing, forage removal, fuelwood collection, lopping, thatch collection, soil removal, litter collection, root collection and NTFPs collection. The intensity of each factor was scaled in three classes: 1, if it is absent or very little; 2, if it is occasional and 3, if it is recurrent (Table 6.1). During the field visit different types of GCPs (Ground Control Points) collected in different land use types which are not covered in forests sampling viz. coal and limestone mining, tea gardens, *jhum*, agriculture, areca plantation, orange orchards, etc. to classifying the final current disturbance based map of Meghalaya.

Table 6.1. Different types of disturbance classes operating in the study and their weightage score.

Disturbance	Absent/very little	Occasional	Recurrent
Fire	1	2	3
Grazing	1	2	3
Forage removal	1	2	3
Fuelwood collection	1	2	3
Lopping	1	2	3
Thatch collection	1	2	3
Soil removal	1	2	3
Litter collection	1	2	3
Root collection	1	2	3
NTFP collection	1	2	3

Apart from field survey, visual image interpretation in all these disturbances, urban and rural settlements, *jhum*, large scale coal mining areas, rubber and tea plantation, road, settlements and distance from village/town were also taken into consideration in each sampled grid separately, for preparing the final output disturbance classes map of Meghalaya.

6.2.2. *Image acquisition, processing and geometric correction*

The orthorectified remote sensed imageries of IRS LISS III (Indian Remote Sensing, Linear Imaging Self Scanning III) of the year of 2009 were downloaded from NRSC-Bhuvan (National Remote Sensing Center-Bhuvan, Hyderabad) (http://bhuvan-noeda.nrsc.gov.in/download/download/download.php) website. The images were downloaded as separate bands, and then stacked in ERDAS Imagine 8.5 to give the multispectral image. Apart from this IRS satellite data, Survey of India (SOI) toposheets of 1:250,000 scale was used as a base line map for the Area of Interest (AOI) i.e. Meghalaya, ERDAS Imagine 8.5 for image processing, classification and analysis and Arc GIS 9.2 for generation of map and other raster and vector analysis. Different imageries of IRS LISS III images were registered geometrically using rectified topographical map of SOI of 1:50,000 scale. The common uniformly GCPs were marked with root mean square of one pixel and image was resampled at nearest neighbor algorithms. After that the study area (Area of Interest) extracted from georeferenced image by boundary data provided by SOI.

6.2.3. *Disturbance based classification of Vegetation*

For mapping the vegetations type classification of Meghalaya, a supervised classification algorithm was used. This has been frequently used in image classification. In supervised

classification, the area of known identity was used to classify pixels of unknown area and training sites is closely controlled by analyst. The spectral behavior of training sites gives information of the classes of vegetation cover such as tropical evergreen, tropical moist mixed-deciduous* (including Khasi hill sal-pine), Khasi-Jaintia subtropical pine, Khasi subtropical mixed-broadleaved, Khasi subtropical oak-dominated forests as well as water, *jhum*/agriculture and others classes in remote sensed imageries. The selection of training sites and classification of different classes of vegetation types of the study area using ERDAS Imagine 8.5 software under the process of Maximum likelihood classifier.

[*Note: Here, in the vegetations type map of Meghalaya, Tropical moist-mixed deciduous and Khasi hill sal-pine forests merged together, because its gives approximately similar spectral signature.]

The disturbance class map of Meghalaya was generated by classifying the image into following classes i.e., Very low, Low, Medium, High and Very high using supervised classification in ERDAS 8.5. Here the training sites were based on three important features, 1; GCPs formulated and generated by various disturbance score based on field forests inventories, discussed in Table 6.1, 2; The GCPs collected during the field visits in different areas i.e., another anthropogenic disturbance which are not included in forest inventories and 3; visual image interpretation of imageries.

6.2.4. *Disturbance Index*

The disturbance index (Rao *et al.* 1990) was calculated using following formula based on number of cut stems in different vegetation classes of Meghalaya.

$$\text{Disturbance Index (DI)} = \frac{\text{Number of cut stems}}{\text{Total stems including cut stems}} \times 100$$

6.3. Results

6.3.1. *Forest types map of Meghalaya*

The six forest types of Meghalaya covered approximately 65% of total geographical area of the State (Table 6.2, Fig. 6.1). Tropical moist mixed-deciduous forest including Khasi hill sal-pine forest covered the maximum geographical area (26%). In terms of vegetation class, *jhum* covered approximately 26.5% of total geographical area of the region (Table 6.2, Fig. 6.1).

Table 6.2. The classification of area (%) covered by different forest types and other land use classes in Meghalaya.

Vegetation Class	Area (km^2)	Area (%)
Tropical evergreen	3001.1	13.4
Tropical moist mixed-deciduous (including Khasi hill sal-pine)	5825.5	26.0
Khasi-Jaintia subtropical pine	1645.6	7.3
Khasi subtropical mixed-broadleaved	2023.6	9.0
Khasi subtropical oak-dominated	2013.0	9.0
Agriculture/ *jhum*	5947.2	26.5
Urban	1408.6	6.3
Water	17.3	0.1
Sand/barren	547.3	2.4
Total	22,429	100

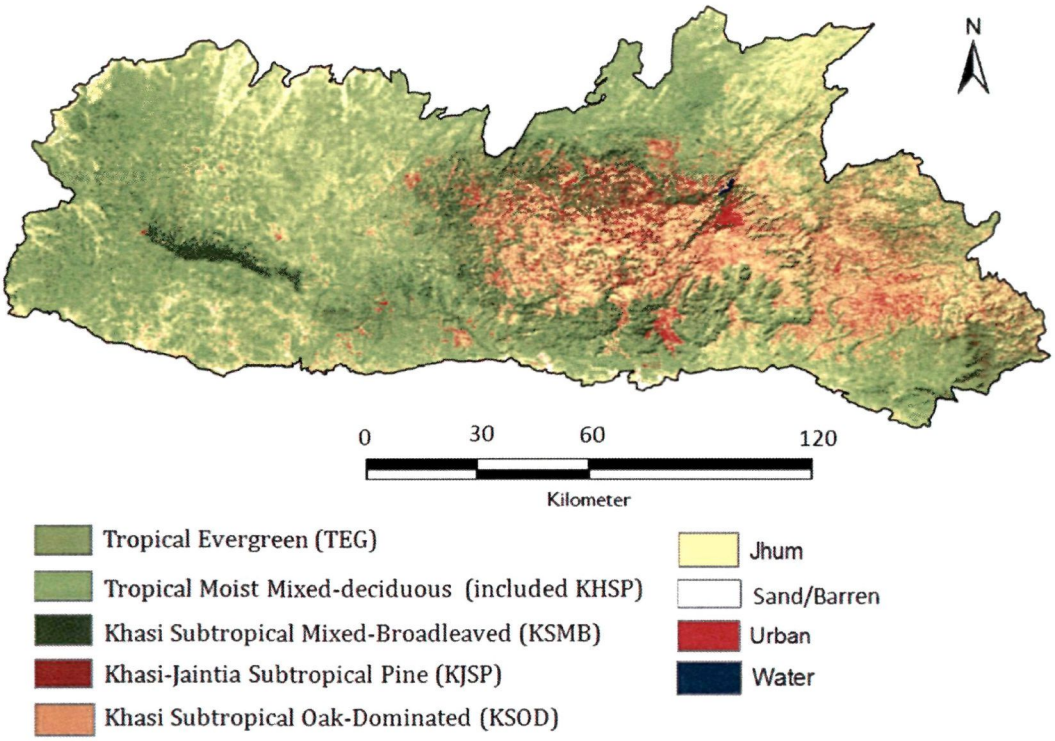

Fig. 6.1. A map of different forest types in Meghalaya based on supervised classification of IRS LISS III image for 2009. *The Khasi hill sal-pine forest is merged with tropical moist mixed-deciduous.

6.3.2. Disturbance class map of Meghalaya

The disturbance class map of Meghalaya suggests that approximately 60% of total geographical area of the State showed medium to very high disturbance (Fig. 6.2). The East Khasi Hills as well as Jaintia Hills districts of the State were characterized by highly threatened areas due to large pressure of urbanization, *jhum* and coal and limestone mining. Almost all types of threats such as fire, forage removal, fuelwood collection, grazing, lopping, NTFPs collection, soil removal, thatch, litter and root collection were found in these areas.

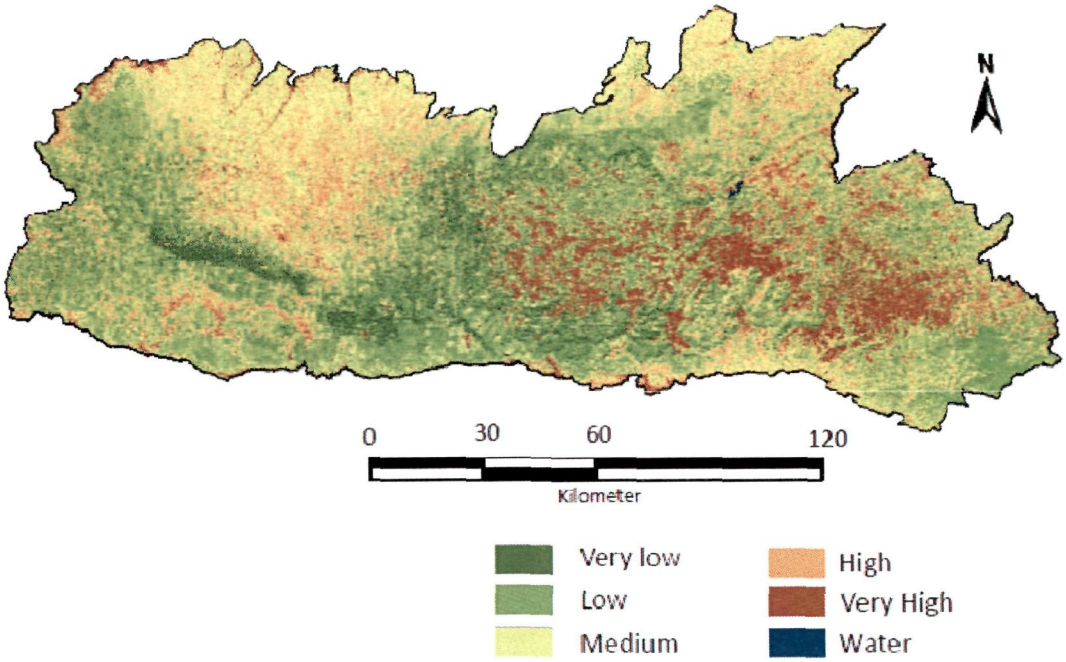

Fig. 6.2. A disturbance class map of Meghalaya based on supervised classification of images of LISS III 2009.

The area covered in disturbance classes is given in Table 6.3. Almost 16.9% geographical area is affected by very high disturbance and 45% area is experiences medium to high disturbance. The area under very low and low categories amounts to about 38% only.

Table 6.3. Area covered by different disturbance index classes in Meghalaya.

Class	Area (km^2)	Area (%)
Very low	2786.5	12.4
Low	5782.3	25.8
Medium	5070.3	22.6
High	4991.8	22.3
Very High	3781.6	16.9
Water	16.5	0.1
Total	22,429	100

The Khasi-Jaintia subtropical pine forest showed highest disturbance index (3.42) followed by tropical moist-mixed deciduous forest including Khasi hill sal pine forest (2.45) (Table 6.4).

Table 6.4. Disturbance Index for individual forest types in Meghalaya.

Forest types	No. of cut stems	Total stems including cut stems	Disturbance Index
TEG	23	2408	0.96
TMMD (+KHSP)	153	6238	2.45
KJSP	461	13479	3.42
KSMB	87	5992	1.45
KSOD	144	7919	1.82
All Forest	868	36036	2.41

6.4. Discussion

The six forest types in the present investigation covered approximately 65% of total geographical area of the State. Based on interpretation of remote sensed imageries, the total forest cover in the State is 17,275 km^2, which is 77.02% of the State's geographical area (FSI 2011). Tropical moist mixed-deciduous including Khasi hill sal-pine forest covered maximum geographical area of the State. According to recent Forest Survey of India Report 2011 (FSI 2011), tropical moist deciduous forest covers a large geographical area in the State.

The tribes of Meghalaya are largely dependent on forests for their livelihood. The natural forests of Meghalaya are main source of economically and ecologically important plants. The people of Meghalaya use to collect various non-timber forest products and medicinal and aromatic plants such as bay leaf (*Cinnamomum tamala*), tree bean (*Parkia roxburghii*), *Taxus wallichiana*, broomgrass, wild pepper, bamboo, nuts and tubers from the forests (Tiwari and Kumar 2008, Ghosh 2007, Swer 2013). The *jhum* cultivation

has long been practiced in all parts of Meghalaya, causing structural as well as compositional change in the forest types of the region and ultimately modifies the natural landscape, which results in poor species composition (Mishra and Ramakrishnan 1984, Ramakrishnan 1992, Roy and Tomar 2001, IIRS 2002). The agriculture along with *jhum* covered approximately 5,947.2 km^2 area, which is 26.5% of total geographical area of the State. The Forest Survey of India report 2011 (FSI 2011), clearly mentioned that the decrease in forest cover in the State is due to shortening of shifting cultivation cycle and biotic pressure. The large scale deforestation in the form of *jhum*, coal and limestone mining and for urbanization are major factors responsible for disturbances in these areas, which is adversely changing the forest vegetation of Meghalaya. There is a loss of 49 km^2 forest cover in the State during 2009 to 2011 primarily due to shifting cultivation (FSI 2011). This loss is quite high in case of a small State like Meghalaya.

All six forest types of the State showed different intensities of disturbances. During the field survey, it was examined that Khasi-Jaintia subtropical pine and Khasi hill sal-pine forests were found to have highest degree of anthropogenic disturbances such as fire, shifting cultivation, fuelwood and timber collection, lopping, grazing which ultimately degraded these forests. This may be due to easy access, as these forests belong to Shillong plateau, which are close to human population. The logging of *Pinus kesiya* for timber is largely responsible for higher disturbance index (3.42) in Khasi-Jaintia subtropical pine forest. The tropical evergreen forest showed the least anthropogenic disturbances, probably due to more distance from the population. The Nokrek and Balpakram National Park and Siju Wildlife Sanctuary showed negligible disturbance, as these are well protected areas of Meghalaya.

Anthropogenic disturbances in different districts of Meghalaya are operating at different scale, which is easily observed from disturbance class map of Meghalaya (Fig. 6.2). Among the districts, East Khasi Hills and Jaintia hills are characterized by very high disturbance due to urbanization, continuance of *jhum* cycle and coal mining, which may cause permanent loss of many ecologically and economically plants from the State. The extensive coal mining in Jaintia hills district has resulted into degraded lands, which creates unfavourable habitat for plant growth (Uma Shankar *et al.* 1993, Sarma 2005). The species like, *Diospyros undulata*, *Nymphaea pygmaea*, *Sageretia hamosa* are considered extinct and *Luvunga scandens* are believed to be locally extinct (Khan *et al.* 1997). Therefore, the areas, which are more prone to disturbances, should be prioritized for biodiversity conservation.

The present investigation confirms the disturbances which are going on near the boundary of PAs and thick forests areas including sacred groves and RFs (Reserve Forests) of Meghalaya which are home of various endangered and endemic flora and fauna. The present trend of deforestation and anthropogenic activities shall reach alarming leves leading to further losses of vegetation cover of Meghalaya. Present issues also suggested that the urgent need of monitoring the change in vegetation cover, landuse and current status of all forests in PAs of Meghalaya to make the challenge for effective management and implications of refined conservation strategies at high spatial and temporal scale.

CHAPTER VII

GENERAL DISCUSSION

CHAPTER VII

GENERAL DISCUSSION

Tropical forests represent the most biologically diverse terrestrial ecosystem and harbor more than 50% of known plant species (Mayaux *et al.* 2005) in just 7% of the land area and vary in species richness from site to site and within plant communities (Okuda *et al.* 1997). Due to high species richness and concentration of endemic species the north-eastern region of India are considered as two important biodiversity hotspots of India, i.e., Indo-Burma and Himalaya. These forests are disappearing at alarming rates worldwide (Laurance 1999).

Meghalaya, the state of north-eastern region of India is very rich in floral and faunal diversity. The rich diversity of plants in Meghalaya is generally ranging from tropical to subtropical hill forests and encompasses Asiatic and Indian Peninsular component (IIRS 2002). Varied ecological conditions such as rainfall, temperature, altitude as well as soil conditions allow abundant growth of tropical and subtropical angiospermic flora in the State. The state of Meghalaya, like other parts of the region is undergoing rapid transformation due to deforestation (Kushwaha and Hazarika 2004, Tripathi *et al.* 2005, IIRS 2002, Lele and Joshi 2009, Sarma and Barik 2010, Tripathi *et al.* 2010), urbanization (IIRS 2002, Lele and Joshi 2009), *jhum* (Ramakrishnan 1992, IIRS 2002) and extraction of forest products (Ghosh 2007, Nogrum 2012, Swer 2013). Due to these activities, natural forests are getting fragmented (Srivastava *et al.* 2002, Jha *et al.* 2005, Tripathi *et al.* 2010).

The present study on phytosociological analysis of six forest types, viz., tropical evergreen, tropical moist mixed-deciduous, Khasi hill sal-pine, Khasi-Jaintia subtropical

pine, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forests revealed that the state of Meghalaya is very rich in floristic diversity. The altitudinal variation of sampled transects was very high ranging from 26 m to 1820 m. Approximately 44 ha area was sampled for inventory of woody species ≥10 cm gbh, including 35,168 stems of 510 species belonging to 297 genus and 91 identified families in woody layer and 421 species belonging to 286 genus and 92 families in herb layer.

A total of 931 species of vascular plants (510 woody species and 421 ground species) from 563 genera and 153 identified families were recorded in 44.38 ha area of sampling plots through 101 transects. Of 931 species, 874 species of angiosperms, 6 species of gymnosperms and 51 species of pteridophytes including two tree fern i.e. *Cyathea gigantea* and *C. khasiana* were occurred. Composition of large tree, medium tree, small tree, shrub, woody climber and scandent shrub as well as herb species including climber and creeper resulted in high heterogeneity among the forest types.

In woody layer, the small tree contributed major proportion of species richness (38.8%) followed by medium tree (24.7%), large tree (22%), shrub (9.8%), scandent shrub (2.9%) and woody climber (1.8%), respectively.

The floristic diversity also suggests that the flowering plants contribute 94% (874 species) of total vascular plants in the State. Khan *et al.* also reported that out of total 3,331 species of vascular plants in Meghalaya, about 94% (3128 plant species) belong to flowering plants. The highest concentration of angiosperms in Meghalaya were also reported by a number of authors like Balakrishnan (1981-83), Kumar (1984), Haridasan and Rao (1985-87), Kanjilal *et al.* (1934-40), Tripathi (2002) and Prabhu (2004).

The maximum number of species (233 species) recorded from Khasi subtropical mixed-broadleaved forest whereas tropical moist mixed-deciduous forest characterised by least

number of species (95 species), despite the fact that all the sampling were done in 2 protected areas of Meghalaya namely Balpakram National Park and Siju Wildlife Sanctuary. This may be due to less sampling (2.5 ha) done in this forest.

All the six forest types were characterised by a number of families, genera and species. The flora of the state is also unique in terms of primitive families such as Annonaceae, Ranunculaceae, Hamamelidaceae, Piperaceae, Menispermaceae, Lauraceae and Myricaceae (Takhtajan 1969) and insectivorous family, viz., Nepenthaceae, Droseraceae. The six species of gymnosperms occurred, including two IUCN red listed species *Podocarpus nerrifolius* and *Taxus wallichiana*. The *Taxus wallichiana* is highly demanding species for taxol, which is extracted from the leaves and used in cancer treatment; some population of species occurred in mid altitude of Meghalaya (Swer 2013). Apart from this, some new populations of important and threatened species, viz., *Adinandra griffithii*, *Streblus ilicifolius*, *Sycopsis griffithiana*, *Wightia speciossima*, *Ilex khasiana*, *Ilex venulosa*, *Nepenthes khasiana*, *Parkia timoriana* and *Hydnocarpus kurzii* were located in the State. Some of these species like *Adinandra griffithii* and *Streblus ilicifolius* were probably collected after a long time period.

All the six forest types, except Khasi-Jaintia subtropical pine forest showed high equitability and low dominance, with a stable community. The dominance-diversity curve for woody layer as well as herb layer of all forest types showed a log normal distribution, except woody layer of Khasi-Jaintia subtropical pine forest. The log normal distribution of these forests is characteristics of a complex and species rich community (Magurran 1988) and indicating more equitable sharing of resources within the community. The dominance-diversity curve for Khasi- Jaintia subtropical pine forest showed broken-stick model, depicting low equitability and high dominance.

Champion and Seth (1968) classified Khasi subtropical mixed-broadleaved and Khasi subtropical oak dominated forest into Khasi subtropical broadleaved wet hill forest (8B/C2). Based on presence-absence data, similarity indices are commonly used in ecology for comparing two or more community with respect to their species overlap. The similar climatic conditions such as soil and rainfall and also altitude in Khasi subtropical mixed-broadleaved and Khasi subtropical oak dominated forest resulted in 58% similarity in species composition of woody layer. Khasi hill sal pine forest exhibited *Shorea robusta* - *Schima wallichii* - *Pinus kesiya*, dominated community as these species together cover approximately 42% of total IVI of this forest.

According to Champion and Seth (1968), the climax vegetation of Meghalaya is characterized by subtropical broadleaved wet hill forest. Though, *Pinus kesiya* topped with IVI in Khasi subtropical oak-dominated forest but overall Fagaceae, which is characteristics family of relic vegetation of Meghalaya, contributed maximum IVI to this forest. The occurrence of different species of oak, viz., *Quercus* spp., *Castanopsis* spp. and *Lithocarpus* spp. in Khasi subtropical oak-dominated forest and broad-leaved species such as *Schima wallichii*, *Syzygium tetragonum*, *Engelhardtia spicata*, *Helicia nilagirica* in Khasi subtropical mixed-broadleaved forest form the climax vegetation in the State.

In nature, only few species show regular distribution, while most species are clumped or appear to be randomly distributed (Greig-Smith 1983). All species among six forest types exhibited clumped to highly clumped dispersion. Patchy distribution of some species may be due to spatially heterogeneous environmental conditions like topography (Hubbell and Foster 1983). In comparison to common species, rare species are less aggregated and most of the randomly distributed species are rare (He *et al.* 1997, Kumar 2013). No species among six forest types showed regular dispersion. Regular dispersion is very

rarely observed due to intraspecific competition at a local scale (He *et al.* 1997, Kumar 2013).

In all six forest types the most dominant species were characterized by high value of IVI. The low IVIs suggest that most of the species in the forest are rare (Pascal and Pellissier 1996). Approximately 58% in tropical evergreen, 41% in tropical moist mixed-deciduous, 67% in Khasi hill sal-pine, 82% in Khasi-Jaintia subtropical pine, 70% in Khasi subtropical mixed-broadleaved and 73% in Khasi subtropical oak-dominated forest were rare as they exhibited an Importance Value of 1 or less. This is a general trend in most tropical forests in India where the species richness is mostly due to the rare species (Sukumar *et al.* 1992, Parthasarathy and Karthikeyen 1997, Pandey and Shukla 1999, Murali *et al.* 1996, Uma Shankar 2001, Sagar *et al.* 2003, Ayyappan and Parthasarathy 2004, Nath *et al.* 2005, Deb and Sundriyal 2011).

Overall for all 6 forest types, out of 91 family in woody layer, Lauraceae and Rubiaceae was most speciose family with 34 species each followed by Fabaceae (27 species), Moraceae (27 species), Phyllanthaceae (21 species) and Euphorbiaceae (16 species), but when we include Phyllanthaceae together with Euphorbiaceae, it became the most speciose family (37 species), as these two families were taken together by earlier workers. Among 92 families in the herb layer, Asteraceae (38 species) was the most dominant family followed by Poaceae (31 species), Lamiaceae (25 species), Fabaceae & Rubiaceae (22 species each) and Acanthaceae (15 species) apparantly due to number of ground species are characterized by these families.

The population structure of six forests and dominated tree species in each forest type were examined at the level of girth size and height-class distribution. The regeneration behaviour of forest as well as dominant tree species of each forest types was assessed

based on girth measurements. All stems in the forests which had girth ≥10 cm to <30 cm over the bark at breast height (1.37 m) were considered as saplings and ≥30 cm were considered as adults (Uma Shankar 2001).

All six forest types in the present study followed reverse J-shaped distribution, i.e., with increasing girth class, the number of individuals decreased. Such trends have been reported by Poore (1968) in Malaysia, Kadavul and Parthasarathy (1999) in tropical semi-evergreen forests in Eastern Ghats, India, Upadhaya *et al.* (2004) in subtropical forest of Meghalaya, Padalia *et al.* (2004) and Tripathi *et al.* (2004) in the forests of Andaman Islands, Reddy *et al.* (2008) in tropical dry-deciduous forest of Andhra Pradesh, and Majumdar *et al.* (2012) in moist-deciduous forest in Tripura. The preponderance of individuals in lower gbh class showed that these forests have a good potential of regeneration. The number of individuals for regenerating class (10-<30 cm) contributed approximately 52% in tropical evergreen forest, 37.6% in tropical moist mixed-deciduous forest, 45.3% in Khasi hill sal-pine forest, 22.6% in Khasi-Jaintia subtropical pine forest, 60.1% in Khasi subtropical mixed-broadleaved forest and 54.8% in Khasi subtropical oak-dominated forest.

The distribution of girth classes for six forest types was showing similar pattern, with exception of the dominance of lowest to medium size class (10-<30 to 70-<90 cm) in Khasi-Jaintia subtropical pine forest, which contributed approximately 90% of total individuals. This forest shows a relatively mature stand than other forests due to dominance of a large tree, i.e., *Pinus kesiya.* The number of individuals for higher gbh class in all forest types is very less, this is because of good proportion of small tree, shrub and woody climber species in the forests, as these species do not attain much girth.

The population structure of dominant species in each forest type revealed that *Schima wallichii* was one among the top three species in most of the forests except Khasi subtropical oak dominated forest. The girth class distribution of *Schima wallichii* showed decreasing number of individuals with increasing girth classes in all forest types except tropical moist mixed-deciduous forest, which shows good regeneration ability of this species.

The size class distribution for *Cinnamomum tamala*, *Myrica nagi*, *Syzygium tetragonum*, *Shorea robusta* and *Lithocarpus fenestratus* followed more or less similar pattern, where the number of individuals decreased with increasing girth classes. All these species showed higher level of regeneration as maximum number of individuals in these species were present in regenerating class (10-<30 cm).

Pinus kesiya was one of the most dominant tree species found throughout Shillong plateau. Out of six forest types, it was dominating in four forest types, i.e. Khasi hill sal-pine, Khasi-Jaintia subtropical pine, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest. The size class distribution showed almost bell-shaped curve with maximum number of individuals in medium size class (70-<90 cm) and successive decline after and before this class. The *Microcos paniculata* rarely attains a very large girth and this may be a possible reason for absence of higher size class in this species. Being a large to medium tree, the absence of higher gbh class in *Schima wallichii*, *Castanopsis purpurella* and *Lithocarpus fenestratus* were observed. This may be due to the reason that the larger girth of these species is preferred for charcoal making as well as household timber by the local people.

In conclusion, the number of individuals in all six forest types showed preponderance of lower girth classes which represents good regeneration, but at the same time absence or

very less number of individuals in higher gbh class also suggest the occurrence of past disturbances in these forests.

The disturbance based vegetation classification and disturbance class map of Meghalaya, were prepared using a supervised classification algorithm. A Disturbance Index in different forest types was calculated. The six forest types of in the present investigations covered approximately 65% of total geographical area of the State. Based on interpretation of remote sensed imageries, the total forest cover in the State is 17,275 km^2, which is 77.02% of the State's geographical area (FSI 2011). Tropical moist mixed-deciduous including Khasi hill sal-pine forest covered maximum geographical area of the State.

All six forest types of the State showed different intensities of disturbances. During the field survey, it was examined that Khasi-Jaintia subtropical pine and Khasi hill sal-pine forest were found to be highest degree of anthropogenic disturbances such as fire, shifting cultivation, fuelwood and timber collection, lopping, grazing which ultimately degrading these forests. This may be due to easy access, as these forests belong to Shillong plateau, which are close to human population. The logging of *Pinus kesiya* for timber is largely responsible for higher disturbance index (3.42) in Khasi-Jaintia subtropical pine forest. The tropical evergreen forest showed the least anthropogenic disturbance which might be due to less sampling, and also far distance from the population. The Nokrek and Balpakram National Park and Siju Wildlife Sanctuary showed negligible disturbance as these are well protected areas.

Anthropogenic disturbances in different districts of Meghalaya are operating at different scale, which is easily observed from disturbance class map of Meghalaya. Among the districts, East Khasi Hills and Jaintia hills are characterized by very high disturbances due

to urbanization, continuance of *jhum* and coal and limestone mining, which may cause permanent loss of many ecologically and economically plants from the State. The extensive coal mining in Jaintia hills district has resulted into degraded lands which creates unfavourable habitat for plant growth. Therefore, the areas, which are more prone to disturbances, should be prioritized for biodiversity conservation.

In Meghalaya, the anthropogenic activities are gaining momentum with increasing population of local people and also due to influx from outside. The unprecedented demographic change has created an imbalance in forest and resource utilization which include increased tapping of forest resources, depletion of water sources and enhanced levels of pollution. The good regeneration potential of the six forest types studied here is a good hope for conservation of resources if the policies are properly planned and effrectively implemented with a focus on sustainable utilization of forest resources and conservation of biodiversity in Meghalaya.

SUMMARY

SUMMARY

Meghalaya, the state of northeastern region of India is very rich in floral and faunal diversity. The varied ecological conditions such as rainfall, temperature, altitude as well as soil conditions allow abundant growth of tropical and subtropical angiospermic flora in the State. The state of Meghalaya, like other parts of this region is undergoing rapid land use transformation due to deforestation (IIRS 2002, Lele and Joshi 2009, Sarma and Barik 2010, Tripathi *et al.* 2010), urbanization (Lele and Joshi 2009), *jhum* (Ramakrishnan 1992) and extraction of forest products. Due to these activities, natural forests are getting fragmented (Jha *et al.* 2005, Tripathi *et al.* 2010).

The phytosociological assessment in six forest types, viz., tropical evergreen (TEG), tropical moist mixed-deciduous (TMMD), Khasi hill sal-pine (KHSP), Khasi-Jaintia subtropical pine (KJSP), Khasi subtropical mixed-broadleaved (KSMB) and Khasi subtropical oak-dominated (KSOD) was carried out in Meghalaya. The study was aimed at a fine-scale quantitative assessment of the plant diversity, floristic composition, population structure and disturbance-based classification of forests of Meghalaya with following objectives:

- To determine species diversity, floristic composition and phytosociological structure in major forest types of Meghalaya,
- To quantify populations of economically and ecologically important plant species, and,
- To classify the forest types based on current levels of disturbance

The major forest types in Meghalaya were sampled following grid-based inventory by laying a transect of 5 to 10 m width and up to 500 m length (Murali *et al.* 1996, Uma Shankar 2001). All individuals (stems) ≥10 cm girth at breast height (1.37 m above the

ground level) were enumerated. The grids with prominent vegetation types were sampled depending on the similarity of terrain, accessibility, insurgency and other geographical and socio-political factors. The data from transects were analyzed following standard ecological methods (Misra 1968, Mueller-Dombois and Ellenberg 1974, Curtis and McIntosh 1950, 1951, Simpson 1949, Shannon and Wiener 1963, Whitford 1948, Rao *et al.* 1990, Sukumar *et al.* 1992, Uma Shankar 2001). The state of regeneration of sampled tree species was assessed based on the data on the individuals ≥10 cm to <30 cm gbh. To describe the population structure, the girth class and height class distributions of forest as well as dominant species of each forest type were plotted in 20 cm wide nine girth classes (10-<30, 30-<50, 50-<70, 70-<90, 90-<110, 110-<130, 130-<150, 150-<170, ≥170) and 5 m wide five height classes (<5, 5-<10, 10-<15, 15-<20, ≥20).

The orthorectified remote sensed imageries of IRS LISS III (Indian Remote Sensing Linear Imaging Self Scanning III) of the year of 2009 were downloaded from NRSC-Bhuvan (National Remote Sensing Center-Bhuvan, Hyderabad) (http://bhuvan-noeda.nrsc.gov.in/download/download/download.php) website. The images were downloaded as separate bands, and then stacked in ERDAS Imagine 8.5 to give the multispectral image. Meghalaya is richly endowed with the forest resources. Based on interpretation of satellite data, the total forest cover in the State is 17,275 km^2, which is 77.02% of the State's geographical area (FSI 2011).

The floristic survey of six major forest types of the State revealed that a total of 35,168 individual stems ≥10 cm gbh were recorded in 44.38 ha sampled area through 101 transects. The phytosociological analysis of woody layer as well as herb layer of six forest types yielded 931 species from 563 genera and 153 identified families.

The maximum number of woody species (233 species) were recorded from Khasi subtropical mixed-broadleaved forest followed by Khasi subtropical oak-dominated (225 species), tropical evergreen (184 species), Khasi-Jaintia subtropical pine (156 species), Khasi hill sal-pine (123 species) and tropical moist mixed-deciduous forest (95 species), respectively. Lauraceae (34 species), Rubiaceae (34 species), Fabaceae (27 species), Moraceae (27 species), Phyllanthaceae (21 species) and Euphorbiaceae (16 species) in woody layer were the most dominant families recorded in six forest types.

In herb layer, Khasi-Jaintia subtropical pine forest was characterized by maximum number of species (239 species), whereas least number of species were found in tropical moist mixed-deciduous forest (38 species). Asteraceae (38 species), Poaceae (31 species), Lamiaceae (25 species), Fabaceae & Rubiaceae (22 species each) and Acanthaceae (15 species) in herb layer were the most dominant families recorded in six forest types.

In all six forest types, the most dominant species were characterized by a high value of IVI. Approximately 58% species in tropical evergreen, 41% in tropical moist mixed-deciduous, 67% in Khasi hill sal-pine, 82% in Khasi-Jaintia subtropical pine, 70% in Khasi subtropical mixed-broadleaved and 73% in Khasi subtropical oak-dominated forest were rare as they exhibited an Importance Value of 1 or less. This is a general trend in most tropical forest in India where most species richness is due to the rare species.

The dominance-diversity curve for woody layer as well as herb layer of all forest types showed log-normal distribution, except woody layer of Khasi-Jaintia subtropical pine forest, indicating more equitable sharing of resources within the community. The dominance-diversity curve for Khasi-Jaintia subtropical pine forest showed broken stick model, depicting low equitability and high dominance.

The similarity, based on presence-absence data of six forest types, indicated that Khasi subtropical mixed-broadleaved and Khasi subtropical oak dominated forest resulted more than 50% of similarity in species composition of woody layer, whereas Khasi-Jaintia subtropical pine and Khasi subtropical mixed-broadleaved forest resulted maximum similarity (39.62%) in herb layer. Khasi hill sal pine forest exhibited *Shorea robusta* - *Schima wallichii* - *Pinus kesiya*, dominated community as these species together cover approximately 42% of total IVI.

The occurrence of different species of oak, viz., *Quercus* spp., *Castanopsis* spp. and *Lithocarpus* spp. in Khasi subtropical oak-dominated forest and broad-leaved species such as *Schima wallichii*, *Syzygium tetragonum*, *Engelhardtia spicata*, *Helicia nilagirica* in Khasi subtropical mixed-broadleaved forest form the climax vegetation in the State.

The altitudinal variation in sampled transects was high (26 to 1820 m). The altitudinal gradient is the key factor forming various mountain habitats. *Callicarpa arborea*, *Engelhardtia spicata*, *Litsea monopetala*, *Macaranga denticulata*, *Schima wallichii* and *Syzygium tetragonum* were found in all six forest types, which shows that these species can occur from very low (26 m) to very high altitude (1820 m).

All species among six forest types exhibited clumped to highly clumped dispersion. Patchy distribution of species may be due to spatially heterogeneous environmental conditions such as topography (Hubbell and Foster 1983). No species among six forest types showed regular or random dispersion.

The tree density of the present study was ranging from 598.4 stem ha^{-1} in tropical moist mixed-deciduous forest to 973.5 stem ha^{-1} in tropical evergreen forest with a mean value of 818.8 stem ha^{-1}, whereas basal area ranged from 14.31 to 27.34 m^2 ha^{-1} with mean

value of 18.86 m^2 ha^{-1}. The tropical evergreen forest was characterised by the highest density (973.5 individuals/ha), basal area (27.34 m^2/ha) and Shannon's diversity (1.983).

The population structure of six forest types in the present study followed reverse J-shaped distribution, i.e., with increasing girth classes, the number of individuals decrease. Tropical evergreen, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest showed highest number of individuals in <5 m height class whereas tropical moist mixed-deciduous as well as Khasi hill sal-pine forest showed highest number of individuals in 5-<10 m and Khasi-Jaintia subtropical pine forest showed a peak in 10-<15 m height.

Tropical evergreen, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest represents a highly heterogeneous and diversified community coupled with low Simpson's dominance index and high evenness index and also shared mixed dominance of a number of species in top canopy, subcanopy and understorey.

Schima wallichii, *Cinnamomum tamala*, *Myrica nagi*, *Syzygium tetragonum*, *Shorea robusta* and *Lithocarpus fenestratus* showed higher level of regeneration as maximum number of individuals of these species were present in regenerating class (10-<30 cm). *Pinus kesiya* was one of the most dominant trees recorded in Khasi hill sal-pine, Khasi-Jaintia subtropical pine, Khasi subtropical mixed-broadleaved and Khasi subtropical oak-dominated forest. The size class distribution of *Pinus kesiya*, in these forest represented almost bell shaped curve with maximum number of individuals in medium class (70-<90 cm) and successive decline after and before this class. The height class distribution of dominant species showed different patterns in each forest types of the State.

Based on Remote sensed satellite data using Geographic Information System, six forest types of Meghalaya covered approximately 65% of total geographical area of the State. Tropical moist mixed-deciduous including Khasi hill sal-pine forest covered maximum geographical area of the State. In terms of vegetation class, *Jhum* alongwith agriculture covered approximately 26.5% of total geographical area of the region.

The disturbance class map of Meghalaya revealed that approximately 60% of total geographical area of the State showed medium to very high disturbance. The East Khasi Hills as well as Jaintia Hills districts of the State were characterized by highly threatened areas due to large pressure of urbanization, *jhum* and coal and limestone mining. Khasi-Jaintia subtropical pine forest showed highest disturbance index (3.42) followed by tropical moist-mixed deciduous forest including Khasi hill sal pine forest (2.45).

REFERENCES

REFERENCES

Addo-Fordjour, P., Obeng, S., Anning, A. K. and Addo, M. G. 2009. Floristic composition, structure and natural regeneration in a moist semideciduous forest following anthropogenic disturbances and plant invasion. International Journal of Biodiversity and Conservation 1: 21-37.

Aiba, S. I. and Kitayama, K. 1999. Structure, composition and species diversity in an altitude-substrate matrix of rain forest tree communities on Mount Kinabalu, Borneo. Plant Ecology 140: 139-157.

Airi, S., Rawal, R. S., Dhar, U. and Purohit, A. N. 1997. Population studies on *Podophyllum hexandrum* Royle-a dwindling, medicinal plant of the Himalaya. Plant Genetic Resource Newsletter 110: 29-34.

Airi, S., Rawal, R. S., Dhar, U. and Purohit, A. N. 2000. Assessment of availability and habitat preference of *Jatamansi*- A critically endangered medicinal plant of west Himalaya. Current Science 79: 1467-1471.

Andel, T. V. 2001. Floristic composition and diversity of mixed primary and secondary forests in northwest Guyana. Biodiversity and Conservation 10: 1645–1682.

Annaselvam, J. and Parthasarathy, N. 1999. Inventories of understory plants in a tropical evergreen forest in the Anamalais, Western Ghats, India. Ecotropica 5: 197-211.

APG III 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Botanical Journal of the Linnean Society 161: 105-121.

Arunachalam, A. 1996. The role of litter and fine roots in organic matter and nutrient dynamics during the recovery of degraded subtropical forest ecosystems. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Arunachalam, A., Adhikari, D., Sarmah, R., Majumdar, M. and Khan M. L. 2004b. Population and conservation of *Sapria himalayana* Griffith. in Namdapha national park, Arunachal Pradesh, India. Biodiversity and Conservation 13: 2391-2397.

Arunachalam, A., Sarmah, R., Adhikari, D., Majumdar, M. and Khan M. L., 2004a. Anthropogenic threats and biodiversity conservation in Namdapha Nature Reserve in the Indian Eastern Himalayas. Current Science 87: 447-454.

Ayyappan, N. and Parthasarathy, N. 1999. Biodiversity inventory of trees in a large-scale permanent plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, India. Biodiversity and Conservation 8: 1533-1554.

Ayyappan, N. and Parthasarathy, N. 2001. Patterns of tree diversity within a large-scale permanent plot of tropical evergreen forest, Western Ghats, India. Ecotropica 7: 61–76.

Ayyappan, N. and Parthasarathy, N. 2004. Short-term changes in tree populations in a tropical evergreen forest atVaragalaiar,Western Ghats, India. Biodiversity and Conservation 13: 1843–1851.

Balakrishnan, N. P. 1981. Flora of Jowai and Vicinity, Meghalaya, Volume I. Botanical Survey of India, Howrah, India.

Balakrishnan, N. P. 1983. Flora of Jowai and Vicinity, Meghalaya, Volume II. Botanical Survey of India, Howrah, India.

Balvanera, P., Lott, E., Segura, G., Siebe, C. and Islas, A. 2002. Patterns of beta-diversity in a Mexican tropical dry forest. Journal of Vegetation Science 13: 145-158.

Banda, T., Schwartz, M. W. and Caro, T. 2006. Woody vegetation structure and composition along a protection gradient in a miombo ecosystem of western Tanzania. Forest Ecology and Management 230: 179-185.

Barik, S. K. 1992. Ecology of tree regeneration along a disturbance gradient in subtropical wet hill forest of Meghalaya. . Ph. D. Thesis, North-eastern Hill University, Shillong, India.

Barik, S. K., Haridasan, K. and Lakadong, N. J. 2007. Medicinal Plant Resources of Meghalaya: Endemism, Threat Status and Consumption Pattern. ENVIS Forestry Bulletin 7: 17-26.

Barik, S. K., Pandey, H. N., Tripathi, R. S. and Rao, P. 1992. Microenvironmental variability and species diversity in tree fall gaps in a subtropical broad-leaved forest. Vegetatio 103: 31-40.

Barik, S. K., Rao, P., Tripathi, R. S. and Pandey, H. N. 1996a. Dynamics of tree seedling populations in a humid subtropical forest of northeast India as related to disturbance. Canadian Journal of Forest Research 26: 584-589.

Barik, S. K., Tripathi, R. S., Pandey, H. N. and Rao, P. 1996b. Tree regeneration in a subtropical humid forest: effect of cultural disturbance on seed production, dispersal and germination. Journal of Applied Ecology 33: 1551-1560.

Behera, M. D., Kushwaha, S. P. S. and Roy, P. S. 2001. Forest vegetation characterization and mapping using IRS-1C satellite images in Eastern Himalayan region. Geocarto International 16(3): 53-62.

Bhatt, A., Rawal, R. S., and Dhar, U. 2006. Ecological features of a critically rare medicinal plant, *Swertia chirayita*, in Himalaya. Plant Species Biology 21: 49-52.

Bhattacharyya, N. and Sarma, S. 2010. Assessment of availability, ecological feature, and habitat preference of the medicinal herb *Houttuynia cordata* Thunb. in the Brahmaputra Valley of Assam, India. Environmental Monitoring and Assessment 160: 277-287.

Bhuyan, P., Khan, M. L. and Tripathi, R. S. 2003. Tree diversity and population structure in undisturbed and human-impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India. Biodiversity and Conservation 12: 1753-1773.

Blasco, F., Whitmore, T. C. and Gers, C. 2000. A framework for the worldwide comparison of tropical woody vegetation types. Biological Conservation 95: 175-189.

Bongers, F., Popma, J., Castillo, J. M. D. and Carabias, J. 1988. Structure and floristic composition of the lowland rain forest of Los Tuxtlas, Mexico. Vegetatio 74: 55-80.

Boom, B. 1986. A forest inventory in Amazonian Bolivia. Biotropica 18: 287-294.

Bor, N. L. 1940. Graminae. In: Kanjilal *et al.*, Flora of Assam Volume 5. Government Press, Shillong.

Bor, N. L. 1942. Relic vegetation of the Shillong plateau, Assam. Indian Forest Records (Botany) 3: 153-195.

Botkin, D. B., Estes, J. E., MacDonald, R. M. and Wilson, M. V. 1984. Studying the Earth's Vegetation from Space. BioScience 34: 508-514.

Boubli, J. P., Eriksson, J., Wich, S., Hohmann, G. and Fruth, B. 2004. Mesoscale transect sampling of trees in the Lomako-Yekokora interfluvium, Democratic Republic of the Congo. Biodiversity and Conservation 13: 2399-2417.

Buchanan-Hamilton, F. 1820. An account of Assam, with some notices concerning the neighbouring territories. London.

Burkill, I. H. 1925a. The botany of the Abor expedition, Records of Botanical Survey of India 10: 1-154.

Burkill, I. H. 1925b. The botany of the Abor expedition, Records of Botanical Survey of India 10: 155-420.

Burslem, D. F. R. P. and Whitmore, T. C. 1999. Species diversity, susceptibility to disturbance and tree population dynamics in tropical rain forest. Journal of Vegetation Science 10: 767-776.

Campbell, D. G., Daly, D. C., Prance, G. T. and Macial, U. N. 1986. Quantitative ecological inventory of terra firme and varzea tropical forest on the Rio Zingu, Brazilian Amazon. Brittonia 38: 369-393.

Cannon, C. H., Peart D. R. and Leighton, M. 1998. Tree species diversity in commercially logged bornean rainforest. Science 281: 1366-1368.

Cao, M. and Zhang, J. 1997. Tree species diversity of tropical forest vegetation in Xishuang banna, southwest China. Biodiversity and Conservation 6: 995-1006.

Champion, H. G. 1936. A preliminary survey of forest types of India and Burma. Indian Forest Records (New Series) 1: 1-286.

Champion, H. G. and Seth, S. K. 1968. A revised survey of the forest types of India. Govt. of India, New Delhi.

Chatterjee, D. 1939. Studies on the endemic flora of India and Burma. Journal of the Asiatic Society of Bengal 5: 19-67.

Chitale, V. S. and Behera, M. D. 2012. Can the distribution of sal (*Shorea robusta* Gaertn. f.) shift in the northeastern direction in India due to changing climate. Current Science 102(8): 1126-1135.

Chittibabu, C. V. and Parthasarathy, N. 2000. Attenuated tree species diversity in human-impacted tropical evergreen forest sites at Kolli hills, Eastern Ghats, India. Biodiversity and Conservation 9: 1493-1519.

Choudhary, B. I., Khan, M. L., Arunachalam, A. and Das A. K. 2007. Population status of *Gymnocladus assamicus*, a critically endangered tree species in Arunachal Pradesh. Current Science 93(11): 1489-1491.

Clark, D. B., Palmer, M. W. and Clark, D. A. 1999. Edaphic factors and the landscape-scale distributions of tropical rain forest trees. Ecology 80: 2662-2675.

Collins, S. L., Glenn, S. M. and Gibson, D. J. 1995. Experimental analysis of intermediate disturbance and initial floristic composition: decoupling cause and effect. Ecology 76: 486- 492.

Condit, R. 1995. Research in large, long-term tropical forest plots. Trends in Ecology and Evolution 10(1): 18-22.

Condit, R., Hubbel, S. P., LaFrankie, J. V., Sukumar, R., Manokaran, N., Foster, R. B. and Ashton, P. S. 1996. Species-area and species-individual relationships for tropical tree: a comparison of three 50 ha plots. Journal of Ecology 84: 549-562.

Connell, J. H. 1978. Diversity in tropical rain forests and coral reefs. Science 199: 1302-1310.

Conservation International 2005. Biodiversity hot-spots. www.biodiversityhotspots.org.

Culmsee, H. and Pitopang, R. 2009. Tree diversity in sub-montane and lower montane primary rain forests in Central Sulawesi. Blumea 54: 119–123.

Culmsee, H., Pitopang, R., Mangopo, H. and Sabir S. 2011. Tree diversity and phytogeographical patterns of tropical high mountain rain forests in Central Sulawesi, Indonesia. Biodiversity and Conservation 20: 1103-1123.

Currie, D. J. 1991. Energy and large-scale patterns of animal- and plant- species richness. American Naturalist 137:27-49.

Curtis, J. T. and McIntosh, R. P. 1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology 31: 434-455.

Curtis, J. T. and McIntosh, R. P. 1951. The upland forest continuum in prairie forest border region of Wisconsin. Ecology 32: 476-496.

Dam, N. 1996. Flora of Cherrapunji sub-division, East Khasi Hills, Meghalaya. Ph. D. Thesis. Gauhati University, Guwahati, India.

Davidar, P., Mohandass, D. and Vijayan, S. L. 2007. Floristic inventory of woody plants in a tropical montane (shola) forest in the Palni hills of the Western Ghats, India. Tropical Ecology 48: 15-25.

Deb, D. B. 1981. Flora of Tripura state, volume I and II. Today and Tomorrow's Printer Private Limited, New Delhi.

Deb, P. and Sundriyal, R. C. 2007. Tree species gap phase performance in the buffer zone area of Namdapha National Park, Eastern Himalaya, India. Tropical Ecology 48: 209-225.

Deb, P. and Sundriyal, R. C. 2008. Tree regeneration and seedling survival patterns in old-growth lowland tropical rainforest in Namdapha National Park, North-East India. Forest Ecology and Management 255: 3995-4006.

Deb, P. and Sundriyal, R. C. 2011. Vegetation dynamics of an old-growth lowland tropical rainforest in North-east India: Species composition and stand heterogeneity. International Journal of Biodiversity and Conservation 3(9): 405-430.

Deb, S., Barbhuiya, A. R., Arunachalam, A. and Arunachalam, K. 2008. Ecological analysis of traditional agroforest and tropical forest in the foothills of Indian eastern Himalaya: vegetation, soil and microbial biomass. Tropical Ecology 49(1): 73-78.

Debski, I., Burslem, D. F. R. P. and Lamb, D. 2000. Ecological processes maintaining differential tree species distributions in an Australian subtropical rain forest: implications for models of species coexistence. Journal of Tropical Ecology 16: 387-415.

Devi, L. S. and Yadava, P. S. 2006. Floristic diversity assessment and vegetation analysis of tropical semievergreen forest of Manipur, north east India. Tropical Ecology 47: 89-98.

Espinosa C. I. and Cabrera, O. 2011. What factors affect diversity and species composition of endangered tumbesian dry forests in southern Ecuador? Biotropica 43: 15-22.

FAO 2011. Food and Agriculture Organization. State of the world's forests, Rome, Italy.

FSI 2011. India State of forest report 2011. Forest Survey of India, Ministry of Environment and Forests, Dehra Dun, India.

Ganesh, T., Ganesan, M., Devy, S., Davidar, P. and Bawa, K. S. 1996. Assessment of plant biodiversity at a mid-elevation evergreen forest of Kalakad-Mundanthurai Tiger Reserve, Western Ghats, India. Current Science 71: 379-392.

Ganeshaiah, K. N., Shanker, R. V. and Bawa, K. S. 1997. Diversity of species assemblages of Islands: Predictions and their test using tree species composition of Shola fragments. Current Science 73: 188-194.

Gentry, A. H. 1988. Changes in plant community diversity and floristic composition on environmental and geological gradients. Annals of Missouri Botanical Garden 75: 1-34.

Gentry, A. H. 1992. Tropical forest biodiversity distributional patterns and their conservational significance. Oikos 63: 19-28.

Ghosh, B. 2007. Regeneration ecology and sustainability of harvest of bay leaf, *Cinnamomum tamala* Fr. Nees (Lauraceae) in Meghalaya. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Giambelluca, T. W., Ziegler, A. D., Nullet, M. A., Truong, D. M. and Tran, L. T. 2003. Transpiration in a small tropical forest patch. Agricultural and Forest Meteorology 117: 1-22.

Gillespie, T. W., Grijalva, A. and Farris, C. N. 2000. Diversity, composition, and structure of tropical dry forests in Central America. Plant Ecology 147: 37-47.

Giriraj, A., Murthy, M. S. R. and Ramesh, B. R. 2008. Vegetation composition, structure and patterns of diversity: a case study from the tropical wet evergreen forests of the Western Ghats, India. Edinburgh journal of botany 65: 1-22.

Greig-Smith, P. 1983. Quantitative plant ecology, Blackwell Scientific, Oxford, 3rd edition.

Griffith, W. 1848. Journals of travels in Assam, Myanmar, Bhutan, Afghanistan and neighbouring countries. Calcutta.

Grytnes, J. A. and Vetaas, O. R. 2002. Species Richness and Altitude: A Comparison between Null Models and Interpolated Plant Species Richness along the Himalayan Altitudinal Gradient, Nepal. The American Naturalist 159: 294-304.

Gupta, O. P. and Shukla, R. P. 1991. The composition and dynamics of associated plant communities of sal plantations. Tropical Ecology 32: 296-309.

Hajra, P. K. 1975a. Law-Lyngdoh or sacred groves at Mawphlang, Visitor's guide, Govt. Press, Shillong.

Hajra, P. K. 1975b. Law-Lyngdoh or sacred groves at Mawphlang, Visitor's guide, Govt. Press, Shillong.

Hajra, P. K. and Verma, D. M. 1996. Flora of Sikkim, volume I. Botanical Survey of India, Calcutta.

Haridasan, K. and Rao, R. R. 1985. Forest flora of Meghalaya. Volume I. Bishen Singh Mahendra Pal Singh, Dehra Dun, India.

Haridasan, K. and Rao, R. R. 1987. Forest flora of Meghalaya. Volume II. Bishen Singh Mahendra Pal Singh, Dehra Dun, India.

He, F., Legendre, P. and LaFrankie, J. V. 1997. Distribution patterns of tree species in a Malaysian tropical rain forest. Journal of Vegetation Science 8: 105-114.

Hegde, S. N. 1984. Orchids of Arunachal Pradesh. Government of Arunachal Pradesh, Itanagar.

Hooker, J. D. 1854. Himalayan Journals Vol. 1 and 2, London.

Hooker, J. D. 1872-97. The Flora of British India (in 7 volumes) London.

Huang, W., Pohjonen, V., Johansson, S., Nashanda, M., Katigula, M. I. L. and Luukkanen, O. 2003. Species diversity, forest structure and species composition in Tanzanian tropical forests. Forest Ecology and Management 173: 11-24.

Hubbell, S. P. and Foster, R. B. 1983. Diversity of canopy tree in a neotropical forest and implications for conservation. In: Tropical Rainforest: Ecology and Management (Sutton, S. L., Whitmore, T. C. and Chadwick, A. C. eds.), pp. 25-41. Blackwell Scientific Publications, Oxford.

Hussain, M. S., Sultana, A., Khan, J. A. and Khan, A. 2008. Species composition and community structure of forest stands in Kumaon Himalaya, Uttarakhand, India. Tropical Ecology 49: 167-181.

IIRS 2002. Biodiversity characterisation at landscape level in North East India using Remote Sensing and Geographic Information System. Dehra Dun, India, p. 296.

Jain, S. K. and Rao, R. R. 1976. A handbook of field and herbarium methods. Today and Tomorrow Printers and Publishers, New Delhi.

Jamir, S. A. 2000. Studies on plant biodiversity, community structure and population behaviour of dominant tree species of some sacred groves of Jaintia hills, Meghalaya. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Jamir, S. A. and Pandey, H. N. 2003. Vascular plant diversity in the sacred groves of Jaintia Hills in northeast India. Biodiversity and Conservation 12: 1497-1510.

Jamir, S. A., Upadhaya, K. and Pandey, H. N. 2006. Life form composition and stratification of montane humid forests in Meghalaya, northeast India. Tropical Ecology 47: 183-190.

Jha, C. S., Goparaju, L., Tripathi, A., Gharai, B., Raghubanshi, A. S. and Singh, J. S. 2005. Forest fragmentation and its impact on species diversity: an analysis using remote sensing and GIS. Biodiversity and Conservation 14: 1681-1698.

John, B. 1998. Dynamics of fine roots in pine forest ecosystem. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Johnston, M. and Gillman, M. 1995. Tree population studies in low-diversity forest, Guyana. I. Floristic composition and stand structure. Biodiversity and Conservation 4: 339-463.

Joseph, J. 1968. Flora of Nongpoh and its vicinity. Ph. D. Thesis, Gauhati University. Guwahati, India.

Joshi, N. V., Suresh, H. S. and Prabhakar, R. 1997. Hierarchial partitioning of tree diversity across spatial scales. A case study from the Nilgiri Biosphere Reserve, Southern India. International Journal of Environmental Sciences 23: 185-196.

Kadavul, K. and Parthasarathy, N. 1999. Structure and composition of woody species in tropical semi-evergreen forest of Kalrayan hills, Eastern Ghats, India. Tropical Ecology 40: 247-260.

Kalacska, M., Sanchez-Azofeifa, G. A., Calvo-Alvarado, J. C., Quesada, M., Rivard, B. and Janzen, D. H. 2004. Species composition, similarity and diversity in three successional stages of a seasonally dry tropical forest. Forest Ecology and Management 200: 227-247.

Kanjilal, U. N. 1922. A brief ecological sketch of the botany of Assam. In: Kanjilal *et al.*, 'Flora of Assam' Volume I (a) 1934. Government of Assam, Shillong.

Kanjilal, U. N., Kanjilal, P. C., Das, A., De, R. N. and Bor, N. L. 1934-1940. Flora of Assam 5 Volumes. Govt. Press, Shillong.

Kataki, S. K. 1973. Orchids of united Khasi and Jaintia Hills (Assam) D. Phil. Thesis, Guwahati University.

Kataki, S. K. 1986. Orchids of Meghalaya. Forest department Shillong.

Kaur, R., Joshi, V. and Joshi, S. P. 2010. Impact of degradation on biodiversity status and management of an alpine meadow within Govind Wildlife Sanctuary and National Park, Uttarkashi, India. International Journal of Biodiversity Science, Ecosystem Services and Management 6: 146-156.

Keeley, J. E. and Fotheringham, C. J. 2005. Plot shape effects on plant species diversity measurements. Journal of Vegetation Science 16:.249-256.

Kerkhoff, E. and Sharma, E. 2006. Debating shifting cultivation in the eastern Himalaya. Farmers' innovation as lesson for policy. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Kessler, M., Keber, P.J.A., Gradstein, S. R., Bach, K., Schmull, M. and Pitopang, R. 2005. Tree diversity in primary forest and different land use systems in Central Sulawesi, Indonesia. Biodiversity and Conservation 14: 547-560.

Khan, M. L. 1986. Ecological studies on regeneration of a few tree species in subtropical wet hill forests of Meghalaya. Ph. D. Thesis, North-eastern Hill University, Shillong, India.

Khan, M. L., Bhuyan, P. and Tripathi, R. S. 2003. Regeneration of Rudraksh (*Elaeocarpus ganitrus* Roxb.), a threatened tree species: germination strategies. International Journal of Ecology and Environmental Sciences 29: 255-260.

Khan, M. L., Bhuyan, P. and Tripathi, R. S. 2004. The conservation status of Rudraksh (*Elaeocarpus ganitrus* Roxb.) in tropical wet evergreen forests of Arunachal Pradesh. Current Science 86: 646-650.

Khan, M. L., Rai, J. P. N. and Tripathi, R. S. 1986. Regeneration and survival of tree seedlings and sprouts in tropical deciduous and sub-tropical forest of Meghalaya, India. Forest Ecology and Management 14: 293-304.

Khan, M. L., Rai, J. P. N. and Tripathi, R. S. 1987. Population structure of some tree species in disturbed and protected sub-tropical forests of northeast India. Acta Oecologia 8: 247-255.

Khan, M. L., Shaily, M. And Bawa, K. S. 1997. Effectiveness of the protected area network in Biodiversity conservation, a case study of Meghalaya state; Biodiversity and Conservation 6: 853-868.

Kharkwal, G., Mehrotra, P., Rawat, Y. S. and Pangtey, Y. P. S. 2005. Phytodiversity and growth form in relation to altitudinal gradient in the Central Himalayan (Kumaun) region of India. Current Science 89: 873-878.

Kharlyngdoh, E. and Barik, S. K. 2008. Diversity, distribution pattern and use of bamboos in Meghalaya. Journal of Bamboo and Rattan 7: 73-90.

Khiewtam, R. S. 1986. Ecosystem function of protected forests of Cherrapunji and adjoining areas. Ph. D. Thesis, North-Eastern Hill University Shillong, India.

Khiewtam, R. S. and Ramakrishnan, P. S. 1993. Litter and fine root dynamics of relic sacred grove forest of Cherrapunjee in northeastern India. Forest Ecology and Management 60: 327-344.

Kochummen, K. M., LaFrankie, J. V. and Manokaran, N. 1990. Floristic composition of Pasoh Forest Reserve, a lowland rain forest in Peninsular Malaysia. Journal of Tropical Forest Science 3: 1-13.

Kumar, A. and Ram, J. 2005. Anthropogenic disturbances and plant biodiversity in forests of Uttaranchal, Central Himalaya. Biodiversity and Conservation 14: 309-331.

Kumar, A., Marcot, B. G. and Saxena, A. 2006. Tree species diversity and distribution patterns in tropical forests of Garo Hills. Current Science 91: 1370-1381.

Kumar, D. 2013. Distribution and mapping of selected tree species in different forest types of lower Assam region of India. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Kumar, Y. 1984. Studies on the flora of Balphakram wild life sanctuary, Garo Hills, Meghalaya. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Kushwaha, S. P. S. and Hazarika, R. 2004. Assessment of habitat loss in Kameng and Sonitpur Elephant Reseves. Current Science 87(10): 1447-1453.

Kushwaha, S. P. S. and Nandy, S. 2012. Species diversity and community structure in sal (*Shorea robusta*) forests of two different rainfall regimes in West Bengal, India. Biodiversity and Conservation 21: 1215-1228.

Lakadong, N. J. and Barik, S. K. 2006. Diversity and distribution of endemic plant species of Meghalaya, India. In: Pandey, H. N and Barik, S. K. (eds.), Ecology, Diversity and Conservation of plants and ecosystems in India. Regency Publications, New Delhi. pp. 274-311.

Lalfakawma, Sahoo, U. K., Roy, S., Vanlalhriatpuia, K., Vanalalhluna, P. C. 2009. Community composition and tree population structure in undisturbed and disturbed tropical semi-evergreen forest stands of north-east India. Applied Ecology and Environmental Research 7(4): 303-318.

Laloo, R. C., Kharlukhi, L., Jeeva, S. and Mishra, B. P. 2006. Status of medicinal plants in the disturbed and the undisturbed sacred forests of Meghalaya, northeast India: population structure and regeneration efficacy of some important tree species. Current Science 90: 225-232.

Laurance, W. F. 1999. Reflections on the tropical deforestation crisis. Biological Conservation 91: 109-117.

Laurance, W. F., Ferreira, L. V., Rankin–de-Merona, J. M. and Hutchings, R. W. 1998. Influence of plot shape on estimates of trees diversity and community composition in central Amazonia. Boitropica 30: 662 - 665.

Lawesson, J. E., de Blust, G., Grashof, C., Firbank, L., Honnay, O, Hermy, M., Hobitz, P., Jensen, L. M. 1998. Species diversity and area-relationships in Danish beech forests. Forest Ecology and Management 106: 235-245.

Lele, N. and Joshi, P. K. 2009. Analyzing deforestation rates, spatial forest cover changes and identifying critical area of forest cover changes in North-East India during 1972-1999. Environmental Monitoring Assessment 156: 159-170.

Lieberman, D., Liberman, M., Hartshorn, G. and Peralta, R. 1985. Growth rates and age-size relationships of tropical wet forest trees in Costa Rica. Journal of Tropical Ecology 1(2): 97-109.

Lieberman, D., Lieberman, M., Peralta, R. and Hartshorn, G. S. 1996. Tropical forest structure and composition on a large-scale altitudinal gradient in Costa Rica. Journal of Ecology 84: 137-152.

Lu, X. T., Yin, J. X. and Tang, J. W. 2010. Structure, tree species diversity and composition of tropical seasonal rainforests in xishuangbanna, south-west china. Journal of Tropical Forest Science 22: 260-270.

Magurran, A. E. 1988. Ecological Diversity and its Measurement. University Press, Cambridge.

Majumdar, K., Uma Shankar and Datta, B. K. 2012. Tree species diversity and stand structure along major community types in lowland primary and secondary moist deciduous forests in Tripura, Northeast India. Journal of Forestry Research 23(4): 553-568.

Manokaran, N. and Lafrankie, J. V. 1990. Stand structure of Pasoh Forest Reserve, a lowland rain forest in Peninsular Malaysia. Journal of Tropical Forest Science 3: 14-24.

Manokaran, N., LaFrankie, J. V., Kochummen, K. M., Quah, E. S., Klahn, J., Ashton, P. S. and Hubbell, S. P. 1990. Methodology for the 50-hectare research plot at Pasoh Forest Reserve. Research Pamphlet no. 102. Forest Research Institute of Malaysia, Kepong.

Mao, A. A., Hynniewta, T. M. and Sanjappa, M. 2009. Plant wealth of Northeast India with reference to ethnobotany. Indian Journal of Traditional Knowledge 8: 96-103.

Mayaux, P., Holmgren, P., Achard, F., Eva, H., Stibig, H-J. and Branthomme, A. 2005. Tropical forest cover change in the 1990s and options for future monitoring. Philosophical Transactions of the Royal Society 360: 373-384.

Medail, F., and Quezel, P. 1997. Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. Annals of the Missouri Botanical Garden 84: 112-127.

Medail, F., and Quezel, P. 1999. Biodiversity hotspots in the Mediterranean Basin: setting global conservation priorities. Conservation Biology 13: 1510-1513.

Menon, S. and Bawa, K. S. 1997. Application of geographical information systems, remote sensing and landscape ecology approach to biodiversity conservation in the Western Ghats. Current Science 73: 134-145.

Mishra, B. K. and Ramakrishnan, P. S. 1984. Nitrogen budget under rotational bush fallow agriculture (jhum) at higher elevations of Meghalaya in north-eastern India. Plant and Soil 81: 37-46.

Mishra, B. P., Tripathi, O. P. and Laloo, R. C. 2005. Community characteristics of a climax subtropical humid forest of Meghalaya and population structure of ten important tree species. Tropical Ecology 46: 241-251.

Mishra, B. P., Tripathi, R. S., Tripathi, O. P. and Pandey, H. N. 2004. Effects of anthropogenic disturbance on plant diversity and community structure of a sacred grove of Meghalaya, north-east India. Biodiversity and Conservation 13: 421-436.

Misra, R. 1968. Ecology workbook. Oxford and IBH Publishing Company, Calcutta, India.

Mittermeier, R. A., Myers, N., Thomsen J. B., Da Fonseca G. A. B. and Olivieri, S. 1998. Boidiversity hot spots and major tropical wilderness areas: approaches to setting conservation priorities. Conservation Biology 12: 516-520.

Muller-Dombois, D. and Ellenberg, H. 1974. Aims and methods of vegetation ecology, John Wiley and sons, Inc.

Murali, K. S., Uma Shankar, Uma Shaanker, R., Ganeshaiah K. N. and Bawa, K. S. 1996. Extraction of non-timber forest products in the forest of Biligiri Rangan hills, India. 2. Impact of NTFP extraction on regeneration, population structure and species composition. Economic Botany 50: 252-269.

Mwaura, F. and Kaburu, H. M. 2009. Spatial variability in woody species richness along altitudinal gradient in a lowland-dryland site, Lokapel Turkana, Kenya. Biodiversity and Conservation 18: 19-32.

Myers, N. 1988. Threatened biotas: "Hot Spots" in tropical forests. The Environmentalist 8: 187-208.

Myers, N. 1990. The biodiversity challenge: expanded hot-spots analysis. The Environmentalist 10: 243-256.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. B. and Kent, J. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853-858.

Myrthong, S. 1980. Studies on the monocot flora of Meghalaya. Ph. D. Thesis, NEHU, Shillong.

Nath, P. C., Arunachalam, A., Khan, M. L., Arunachalam, K. and Barbhuiya, A. R. 2005. Vegetation analysis and tree population structure of tropical wet evergreen forests in and around Namdapha National Park, northeast India. Biodiversity and Conservation 14: 2109-2136.

Nayar, M. P. and Sastry, A. R. K. 1987. Red Data Book of Indian Plants. Volume I. Botanical Survey of India.

Nayar, M. P. and Sastry, A. R. K. 1988. Red Data Book of Indian Plants. Volume II. Botanical Survey of India.

Nayar, M. P. and Sastry, A. R. K. 1990. Red Data Book of Indian Plants. Volume III. Botanical Survey of India.

Nongrum, K. 2012. Effect of provenance variation on seed characteristics, germination and seedling growth of tree bean (*Parkia roxburghii* G. Don). Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Odyuo, N. 2004. Ecological studies of some important tree species of subtropical humid forest of Meghalaya. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Okuda, T., Naoki, K., Yap, S. K. and Manokaran, N. 1997. Tree distribution pattern and fate of juveniles in a lowland tropical rain forest– implication for regeneration and maintenance of species diversity. Plant Ecology 131: 155-171.

Onaindia, M., Dominguez, I., Albizu, I., Garbisu, C. and Amezaga, I. 2004. Vegetation diversity and vertical structure as indicators of forest disturbance. Forest Ecology and Management 195: 341-354.

Ozcelik R. 2009. Tree species diversity of natural mixed stands in eastern Black sea and western Mediterranean region of Turkey. Journal of Environmental Biology 30: 761-766.

Padalia, H., Chauhan, N., Porwal, M. C. and Roy, P. S. 2004. Phytosociological observations on tree species diversity of Andaman Islands, India. Current Science 87: 799-806.

Pandey, H. N., Tripathi, R. S. and Uma Shankar 1993. Nutrient cycling in an excessively rainfed subtropical grassland at Cherrapunji. Journal of Biosciences 18: 395-406.

Pandey, S. K. and Shukla, R. P. 1999. Plant diversity and community patterns along the disturbance gradient in plantation forests of sal (Shorea robusta Gaertn). Current Science 77: 814-818.

Pandey, S. K. and Shukla, R. P. 2003. Plant diversity in managed sal (*Shorea robusta* Gaertn.) forests of Gorakhpur, India: species composition, regeneration and conservation. Biodiversity and Conservation 12: 2295-2319.

Pappoe, A. N. M., Armah, F. A., Quaye, E. C., Kwakye, P. K. and Buxton, G. N. T. 2010. Composition and stand structure of a tropical moist semi-deciduous forest in Ghana. International Research Journal of Plant Science 1: 95-106.

Parthasarathy, N. 1999. Tree diversity and distribution in undisturbed and human-impacted sites of tropical wet evergreen forest in southern Western Ghats, India. Biodiversity and Conservation 8: 1365-1381.

Parthasarathy, N. 2001. Changes in forest composition and structure in three sites of tropical evergreen forests around Sengaltheri, Western Ghats. Current Science 80: 389-393.

Parthasarathy, N. and Karthikeyan, R. 1997. Population structure of Grewia pandaica, a rare and endemic tree species in south-west India. International Journal of Ecology and Environmental Sciences 23: 85-90.

Parthasarathy, N. and Sethi, P. 1997. Trees and liana species diversity and population structure in a tropical dry evergreen forest in south India. Tropical Ecology 38: 19-30.

Pascal, J. P. and Pelissier, R. 1996. Structure and floristic composition of tropical evergreen forest in southern India. Journal of Tropical Ecology, 12: 195-218.

Pausas, J. G. and Austin, M. P. 2001. Patterns of plant species richness in relation to different environments: an appraisal. Journal of Vegetation Science 12: 153-166.

Phillips, O. L. 1997. The changing ecology of tropical forests. Biodiversity and Conservation 6: 291-311.

Phillips, O. L. and Gentry, A. H. 1994. Increasing turnover through time in tropical forests. Science 263: 954-958.

Phillips, O. L., Martinez, R. V., Vargas, P. N., Monteagudo, A. L., Zans, M. C., Sanchez, W. Z., Cruz, A. P., Timana, M., Yli-Halla, M. and Rose, S. 2003. Efficient plot-based floristic assessment of tropical forests. Journal of Tropical Ecology 19: 629-645.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13: 131-144.

Pitman, N. C. A. and Jorgensen, P. M. 2002. Estimating the size of the world's threatened flora. Science 298: 989.

Pitman, N. C. A., Terborgh J. W., Silman M. R. and Percy, N. V. 1999. Tree species distributions in an upper Amazonian forest. Ecology 80: 2651-2661.

Pitman, N. C. A., Terborgh, J. W., Silman ,M. R., P. Nunez V., Neill, D. A., Ceron, C. E., Palacios, W. A. and Aulestia, M. 2002. A comparison of tree species diversity in two upper Amazonian forests. Ecology 83: 3210-3224.

Pitman, N. C. A., Terborgh, J. W., Silman, M. R., P. Nunez V., Neill, D. A., Ceron, C. E., Palacios, W. A., and Aulestia, M. 2001. Dominance and distribution of tree species in upper Amazonian terra firme forests. Ecology 82: 2101-2117.

Poore, M. E. D. 1968. Studies in Malaysian rainforest: I. The forest on Triassic sediments in Jengka forest reserve. Journal of Ecology 56: 143-196.

Poulos, H. M., Taylor, A. H. and Beaty, R. M. 2007. Environmental controls on dominance and diversity of woody plant species in a Madrean, Sky Island ecosystem, Arizona, USA. Plant Ecology 193: 15-30.

Poulsen, A. D. 1996. Species richness and diversity of ground herbs within a plot of lowland rainforest in north-west Borneo. Journal of Tropical Ecology 12: 843-851.

Prabhu, S. D. 2004. Impact of human activities on plant biodiversity of Nokrek Biosphere Reserve of Meghalaya. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Prasad, P. R. C., Reddy, C. S. and Dutt, C. B. S. 2007. Phytodiversity assessment of tropical rainforest of north Andaman Islands, India. Research Journal of Forestry 1: 27-39.

Prasad, R. and Pandey, R. K. 1992. An observation on plant diversity of sal and teak forests in relation to intensity of biotic impact at various distances from habitation in Madhya Pradesh: a case study. Tropical Ecology 8: 62-83.

Rad, J. E., Manthey. M. and Mataji, A. 2009. Comparison of plant species diversity with different plant communities in deciduous forests. International Journal of Environmental Science and Technology 6: 389-394.

Rajkumar, M. and Parthasarathy, N. 2008. Tree Diversity and Structure of Andaman Giant Evergreen Forests, India. Taiwania 53: 356-368.

Raju, D. C. S. 1964. Studies on the flora of sacred groves near Shillong. Journal of Assam Science Society 7: 21-30.

Ram, J., Kumar, A. and Bhatt, J. 2004. Plant diversity in six forest types of Uttaranchal, Central Himalaya, India. Current Science 86: 975-978.

Ramakrishnan, P. S. 1992. Shifting agriculture & sustainable development: An interdisciplinary study from northeastern India. Man and the Biosphere Book Series 10, Paris: UNESCO and Caernforth (UK): Parthenon publishing (Republished by Oxford University Press, New Delhi, 1993).

Ramirez-Marcial, N., Gonzalez-Espinosa, M. and Williams-Linera, G. 2001. Anthropogenic disturbance and tree diversity in montane rain forests in Chiapas, Mexico. Forest Ecology and Management 154: 311-326.

Rao, A. S. 1974. The vegetation and phytogeography of Assam-Burma. In M. S. Mani, Dr. W. Junk (eds.), Ecology and Biogeography in India. b.v. publ. The Hague.

Rao, P. 1992. Ecology of gap phase regeneration in a subtropical broad-leaved climax forest of Meghalaya. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Rao, P., Barik, S. K., Pandey, H. N. and Tripathi R. S. 1997. Tree seed germination and seedling establishment in treefall gaps and understorey in a subtropical forest of northeast India. Australian Journal of Ecology 22: 136-145.

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

Rao, R. R. 1988. Biodiversity of North –East India- A national heritage for conservation. In Workshop on 'Agriculture, Biodiversity and Climate changes.' North-Eastern Hill University, Shillong.

Rao, R. R. 1994. Biodiverstiy in India. Floristic Aspects. Bishen Singh Mahendra Pal Singh, Dehradun, India.

Rao, R. S. and Panigrahi, G. 1961. Distributional or vegetational types and their dominant species in Eastern India. Journal of the Indian Botanical Society 40: 274-285.

Rasingam, L. and Parthasarathy, N. 2009a. Tree species diversity and population structure across major forest formations and disturbance categories in Little Andaman Island, India. Tropical Ecology 50(1): 89-102.

Rasingam, L. and Parthasarathy, N. 2009b. Diversity of understory plants in undisturbed and disturbed tropical lowland forests of Little Andaman Island, India. Biodiversity and Conservation 18: 1045-1065.

Reddy, C. S., Babar, S., Giriraj, A., Reddy, K. N. and Rao, K. T. 2008. Structure and floristic composition of tree diversity in tropical dry deciduous forest of Eastern Ghats, Andhra Pradesh, India. Asian Journal of Scientific Research 1(1): 57-64.

Reddy, C. S., Jha, C. S. and Dadhwal, V. K. 2013. Assessment and monitoring of long-term forest cover changes in Odisha, India using remote sensing and GIS. Environmental Monitoring and Assessment 185:4399-4415.

Rodgers, W. A. and Panwar, H. S., 1988. Biogeographical classification of India. Wildlife Institute of India, Dehra Dun.

Roxburgh, W. 1820-24. Flora Indica. A description of Indian plant serampore.

Roxburgh, W. 1832 (ed. Carey). Flora Indica. Today and Tomorrow Printers and Publishers, New Delhi.

Roy, P. S. and Tomar, S. 2000. Biodiversity characterisation at landscape level using geospatial-modelling technique. Biological Conservation 95: 95-109.

Roy, P. S. and Tomar, S. 2001. Landscape cover dynamics in Meghalaya. Indian Journal of Remote Sensing 22: 3813-3825.

Roy, P. S., Dutt, C. B. S. and Joshi, P. K. 2002. Tropical forest resource assessment and monitoring. Tropical Ecology 43: 21-37.

Sagar, R. and Singh, J. S. 2005. Structure, diversity, and regeneration of tropical dry deciduous forest of northern India. Biodiversity and Conservation 14: 935–959.

Sagar, R. and Singh, J. S. 2006. Tree density, basal area and species diversity in a disturbed dry tropical forest of northern India: implications for conservation. Environmental Conservation 33: 256-262.

Sagar, R., Raghubanshi, A. S. and Singh, J. S. 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. Forest Ecology and Management 186: 61-71.

Sagar, R., Raghubanshi, A. S. and Singh, J. S. 2008. Comparison of community composition and species diversity of understorey and overstorey tree species in a

dry tropical forest of northern India. Journal of Environmental Management 88: 1037-1046.

Sahu, S. C., Dhal, N. K. and Mohanty, R. C. 2012. Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri hill ranges, Eastern Ghats, India. Tropical Ecology 53(2): 163-168.

Sarma, K. 2005. Impact of coal mining on vegetation: a case study in Jaintia Hills district of Meghalaya, India. M. Sc. Thesis. International Institute for Geo-information Science and Earth Observation (ITC). Enschede. The Netherlands.

Sarma, K. and Barik, S. K. 2010. Geomorphological risk and conservation imperatives in Nokrek Biosphere Reserve, Meghalaya using geoinformatics. NeBIO 1(2): 14-24.

Saxena, A. K. and Singh, J. S. 1984. Tree population structure of certain Himalayan forest associations and implications concerning their future composition. Vegetatio 58: 61-69.

Shannon, C. E. and Wiener, W. 1963. The mathematical theory of communities. University of Illinois press, Urbana.

Sharma, C. M., Suyal, S., Gairola, S. and Ghildiyal, S. K. 2009. Species richness and diversity along an altitudinal gradient in moist temperate forest of Garhwal Himalaya. Journal of American Science 5: 119-128.

Simpson, E. M. 1949. Measurement of diversity. Nature 163: 688.

Singh J. S. 2002. The biodiversity crisis: A multifaceted review. Current Science 82: 638-647.

Singh, B., Phukan, S. J., Sinha, B. K., Singh, V. N. and Borthakur, S. K. 2011. Conservation strategies for *Nepenthes khasiana* in the Nokrek Biosphere Reserve of Garo Hills, northeast, India. International Journal of Conservation Science 2: 55-64.

Singh, B., Sinha, B. K., Phukan, S. J., Borthakur, S. K. and Singh, V. N. 2012. Wild edible plants used by Garo tribes of Nokrek Biosphere Reserve in Meghalaya, India. Indian Journal of Traditional Knowledge 11(1): 166-171.

Singh, J. 1980. Studies on structural and functional aspects of two sub-tropical humid forest types of Meghalaya. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Singh, J. S. and Kushwaha, S. P. S. 2008. Forest biodiversity and its conservation in India. International Forestry Review 10: 292-304.

Skole, D. and Tucker, C. J. 1993. Tropical deforestation and habitat fragmentation in the Amazon: satellite data from 1987 to 1988. Science 260: 1905-1910.

Smith, R. G. B., Nichols, J. D. and Vanclay, J. K. 2005. Dynamics of tree diversity in undisturbed and logged subtropical rainforest in Australia. Biodiversity and Conservation 14: 2447-2463.

Sorensen, T. 1948. A method of establishing groups equal amplitude in plant sociology based on similarity of species content. Det. Kong. Danske Vidensk, Selsk Biology Skr (Copenhagen) 5: 1-34.

Srivastava, S., Singh, T. P., Singh, H., Kushwaha, S. P. S. and Roy, P. S. 2002. Assessment of large-scale deforestation in Sonitpur district of Assam. Current Science 82(12): 1479-1484.

Sukumar, R., Dattaraja, H. S., Radhakrishnan, J., Vasudeva, R., Nirmala, S. and Joshi, N. V. 1992. Long term monitoring of vegetation in a tropical deciduous forest in Mudumalai, Southern India. Current Science 62: 608-616.

Sundriyal, R. C. and Sharma, E. 1996. Anthropogenic pressure on tree structure and biomass in temperate forest of Mamlay watershed in Sikkim. Forest Ecology and Management 81: 113-134.

Sundriyal, R. C., Sharma, E., Rai, L. K. and Rai, S. C. 1994. Tree structure, regeneration and woody biomass removal in a subtropical forest of Mamlay watershed in the Sikkim Himalaya. Vegetation 113: 53-63.

Swamy, P. S., Sundarapandian, S. M., Chandrasekar, P. and Chandrasekaran, S. 2000. Plant species diversity and tree population structure of a humid tropical forest in TamilNadu, India. Biodiversity and Conservation 9: 1643-1669.

Swer, M. 2013. Population structure and natural regeneration of Himalayan yew (*Taxus wallichiana* Zucc.) in subtropical forests of Meghalaya. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Takhtajan, A. 1969. Flowering plants: Origin and dispersal. Bishen Singh Mahendra Pal Singh and Otto Koeltz Science publishers.

Tang, C. Q. and Ohsawa, M. 1999. Altitudinal distribution of evergreen broad-leaved trees and their leaf-size pattern on a humid subtropical mountain, Mt. Emei, Sichuan, China. Plant Ecology 145: 221-233.

Tilman, D. and Downing, J. A. 1994. Biodiversity and stability in grasslands. Nature 367: 363-365.

Tiwari, B. K. and Kumar, C. 2008. Forest products of Meghalaya. Present status and future perspective. Regional Centre, National Afforestation and Eco-development Board NEHU, Shillong, India.

Tiwari, B. K., Barik, S. K. and Tripathi, R. S. 1998. Biodiversity value, status and strategies for conservation of sacred groves of Meghalaya, India. Ecosystem Health 4: 20-32.

Tiwari, B. K., Tynsong, H. & Lynser, M. B. 2010. Forest management practices of the tribal people of Meghalaya, northeast India. Journal of Tropical Forest Science 22(3): 329-342.

Tole, L. 1998. Sources of deforestation in tropical developing countries. Environmental Management 22: 19-33.

Tomar, S. 1999. Vegetation type mapping and monitoring land cover dynamics in Meghalaya (North East Himalaya). Ph. D. Thesis, H.N.B. Garhwal University, Srinagar, India.

Top, N., Mizoue, N., Ito, S., Kai, S., Nakao, T. and Ty, S. 2009. Effects of population density on forest structure and species richness and diversity of trees in Kampong Thom Province, Cambodia. Biodiversity and Conservation 18: 717-738.

Trejo, I. and Dirzo, R. 2002. Floristic diversity of Mexican seasonally dry tropical Forests. Biodiversity and Conservation 11: 2063-2084.

Trigg, S. N., Curran, L. M. and McDonald, A. K. 2006. Utility of Landsat 7 satellite data for continued monitoring of forest cover change in protected areas in Southeast Asia. Singapore Journal of Tropical Geography 27: 49-66.

Tripathi, K. P., Tripathi, S., Selvan, T., Kumar, K., Singh, K. K., Mehrotra, S. and Pushpangadan, P. 2004. Community structure and species diversity of Saddle Peak forest in Andaman Island. Tropical Ecology 45: 241-250.

Tripathi, O. P. 2002. Study of distribution pattern and ecological analysis of major forest types of Meghalaya. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Tripathi, O. P. and Reynald, K. R. 2010. Effect of forest fragment size on tree diversity and population structure of humid subtropical forest of Meghalaya, India. Biodiversity Science 18(2): 208-214.

Tripathi, O. P. and Tripathi, R. S. 2010. Community composition, structure and management of subtropical vegetation of forests in Meghalaya State, northeast India. International Journal of Biodiversity Science, Ecosystem Services and Management 6: 157-163.

Tripathi, O. P., Pandey, H. N. and Tripathi, R. S. 2008. Effect of anthropogenic activities on structure and composition of woody species of Nokrek Biosphere Reserve of Meghalaya, northeast India. Journal of Plant Ecology 32: 73-79.

Tripathi, O. P., Upadhaya, K., Tripathi, R. S. and Pandey, H. N. 2010. Diversity, dominance and population structure of tree species along fragment size gradient of a subtropical humid forest of northeast India. Research Journal of Environmental and Earth Sciences 2: 97-105.

Tripathi, R. S., Pandey, H. N. and Tiwari, B. K. 1996. State of Environment of Meghalaya. North-Eastern Hill University, Shillong.

Uma Shankar 2003. *Aconitum fletcheranum* G. Taylor (Ranunculaceae) in eastern Himalayas: occurrence and conservation. Current Science 84 (2): 148-151.

Uma Shankar 1991. Nutrient cycling in degraded ecosystems (grasslands) of Meghalaya. Ph. D. Thesis, North- Eastern Hill University, Shillong, India.

Uma Shankar 2001. A case of high tree diversity in sal (*Shorea robusta*) –dominated lowland forest of eastern Himalaya: floristic composition, regeneration and conservation. Current Science 81: 776-786.

Uma Shankar, Boral, L., Pandey, H. N. and Tripathi, R. S. 1993a. Degradation of land due to coal mining and its natural recovery pattern. Current Science 65(9): 680-687.

Uma Shankar, Murali, K. S., Uma Shaanker, R., Ganeshaiah, K. N. & Bawa, K. S. 1998. Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India 4. Impact on floristic diversity and population structure in a thorn scrub forest. Economic Botany 52: 302-315.

Uma Shankar, Pandey, H. N. and Tripathi, R. S. 1993b. Phytomass dynamics and primary productivity in humid grasslands along altitudinal and rainfall gradients. Acta Oecologica 14: 197-209.

Uma Shankar., Lama S. D. and Bawa, K. S. 1998c. Ecosystem reconstruction through 'taungya' plantations following commercial logging of a dry, mixed deciduous forest in Darjeeling Himalaya. Forest Ecology and Management 102: 131-142.

Uniyal, P., Pokhriyal, P., Dasgupta, S., Bhatt, D. and Todaria, N. P. 2010. Plant diversity in two forest types along the disturbance gradient in Dewalgarh Watershed, Garhwal Himalaya. Current Science 98: 938-943.

Uniyal, S. K., Awasthi, A., and Rawat, G. S. 2002. Current status and distribution of commercially exploited medicinal and aromatic plants in upper Gori Valley, Kumaon Himalaya, Uttaranchal. Current Science 82: 1246-1252.

Upadhaya, K. 2002. Studies on plant diversity and ecosystem function in sacred groves of Meghalaya. Ph. D. Thesis, North-Eastern Hill University, Shillong, India.

Upadhaya, K., Barik, S. K., Adhikari, D., Baishya, R. and Lakadong, N. J. 2009. Regeneration ecology and population status of a critically endangered and endemic tree species (*Ilex khasiana* Purk.) in north-eastern India. Journal of Forestry Research 20: 223-228.

Upadhaya, K., Pandey, H. N. and Tripathi, R. S. 2006. Understory plant diversity in subtropical humid forest of Meghalaya. International Journal of Ecology and Environmental Sciences 32: 207-209.

Upadhaya, K., Pandey, H. N., Law, P. S. and Tripathi, R. S. 2003. Tree diversity in sacred groves of Jaintia Hills in Meghalaya, northeast India. Biodiversity and Conservation 12: 583-597.

Upadhaya, K., Pandey, H. N., Law, P. S. and Tripathi, R. S. 2004. Diversity and population characteristics of woody species in subtropical humid forests exposed to cultural disturbance in Meghalaya, northeast India. Tropical Ecology 45: 1-12.

Valencia, R., Balsley, H., Guillermo, P. Y. and Mino, C. 1994. High tree alpha diversity in Amazonian Ecuador. Biodiversity and Conservation 3: 21-28.

Van Laake, P. E. and Sanchez-Azofeifa, G. A. 2004. Focus on deforestation: zooming in on hot spots in highly fragmented ecosystems in Costa Rica. Agriculture Ecosystem and Environment 102: 3-15.

Vazquez, G. J. A. and Givnish, T. J. 1998. Altitudinal gradients in tropical forest composition, structure, and diversity in the Sierra de Manantlan. Journal of Ecology 86: 999-1020.

Veach, R., Lee, D. and Philippi, T. 2003. Human disturbance and forest diversity in the Tansa Valley, India. Biodiversity and Conservation 12: 1051-1072.

Wallich, N. 1820. Description of some rare Indian plants. Asiat. Res. 13: 369-415.

Wang, G., Zhou, G., Yang, L. and Li, Z. 2002. Distribution, species diversity and life-form spectra of plant communities along an altitudinal gradient in the northern slopes of Qilianshan Mountains, Gansu, China. Plant Ecology 165: 169-181.

Wang, X., Feng, Z. and Ouyang, Z. 2001. The impact of human disturbance on vegetative carbon storage in forest ecosystems in China. Forest Ecology and Management 148: 117-123.

WCMC 1992. Global biodiversity strategy (ed.), Groombridge B. World conservation and monitoring centre. Chapman and Hall. London.

Whitford, P. B. 1948. Distribution of woodland plants in relation to succession and clonal growth. Ecology 30: 199-208.

Whittaker, R. H. 1972. Evolution and measurement of species diversity. Taxon 21: 213-251.

Williams-Linera, G. and Lorea, F. 2009. Tree species diversity driven by environmental and anthropogenic factors in tropical dry forest fragments of central Veracruz, Mexico. Biodiversity and Conservation 18: 3269-3293.

Xu, Y., Chen, Y., Li, W., Fu, A., Ma, X., Gui, D. and Chen, Y. 2011. Distribution pattern of plant species diversity in the mountainous Region of Ili River Valley, Xinjiang. Environmental Monitoring and Assessment 177: 681-694.

Zhao, C. M., Chen, W. L., Tian, Z. Q. and Xie, Z. Q. 2005. Altitudinal pattern of plant species diversity in Shennongjia Mountains, Central China. Journal of Integrative Plant Biology 47: 1431-1449.

Zheng, Z., Feng, Z., Cao, M., Li, Z. and Zhang, J. 2006. Forest structure and biomass of a tropical seasonal rainforest in Xishuangbanna, southwest China. Biotropica 38 (3): 318-327.

Zimmerman, J. C., Dewald, L. E. and. Rowlands, P. G. 1999. Vegetation diversity in an interconnected ephemeral riparian system of north-central Arizona, USA. Biological Conservation 90: 217-228.

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Ph.D. (2013) Thesis title:

- **"Quantitative assessment of floristic diversity and species populations in hill forests of Meghalaya"** under the supervision of **Prof. Uma Shankar**, Department of Botany, North-Eastern Hill University, Shillong 793 022.