IMPACT OF HUMAN ACTIVITIES ON PLANT BIODIVERSITY OF NOKREK BIOSPHERE RESERVE OF MEGHALAYA

By

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THESIS SUBMITTED IN FULFILMENT OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN BOTANY

NORTH-EASTERN HILL UNIVERSITY
SHILLONG, INDIA

2004

NORTH-EASTERN HILL UNIVERSITY
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April, 2004

I, Ms. Swapna D. Prabhu, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of thesis did not form 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 in any other University / Institute.

This is being submitted to the North-Eastern Hill University, Shillong for the award of degree of Doctor of Philosophy in Botany.

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Acknowledgements

I am extremely indebted to my supervisor Prof. R. S. Tripathi, *FNA*, Department of Botany, North-Eastern Hill University for his invaluable guidance, moral support and constant encouragement throughout the course of this study.

I express my gratitude towards my Joint-supervisor Dr. S. K. Barik for his guidance and support. I am also grateful to Prof. H. N. Pandey, Department of Botany, North-Eastern Hill University for his valuable suggestions and encouragement.

I thank the Head of the Department, Prof. A. K. Misra for providing necessary facilities. I also thank the other faculty members especially Dr. Uma Shankar and Dr. P. B. Gurung for their help and suggestions.

I am grateful to Dr. K. Haridasan, SFRI, Itanagar, Dr. S. N. Hegde, SFRI, Itanagar, and Prof. A. P. Das, North Bengal University, Siliguri for helping me in the difficult task of identification of plants. My sincere thanks are also due to Dr. K. P. Singh, Dr. Hynniewtta and Dr. Mao, BSI, Shillong and Dr. Sanjappa and Mr. Bhattacharya, CNH, Howrah for providing the required facilities for confirmation of the plant identity in the respective Herbaria. I also thank Shri Shankar Das, Ms. Pinokio and Mr. Pankaj, BSI, Shillong for their cooperation.

I am particularly thankful to my colleagues, Dr. Babu John (Research Associate) and Ms Vanlalhruaii Ralte (Research Fellow), who worked in the same project as myself and Mr. Robin Syndor (Driver of the Project vehicle), and also Mr. Pilosh Marak and Mr. Phillipson Sangma of the Forest Department, Meghalaya, for their help and cooperation during the fieldwork. I owe a great deal of gratitude to the hospitable and cooperative Garo villagers, particularly the *ozas* - Shri Jingnang Marak, Shri Betgeng J. Momin, Shri Sengchang Ch. Marak and Shri Gojan Marak who shared their priceless knowledge with me without any hesitation.

I appreciate and acknowledge the suggestions and cooperation extended to me by my senior colleagues and friends, Dr. Subhasish Das Gupta, Dr. Sanjivan Goswami, Dr. S. A. Jamir, Dr. B. P. Mishra, Mr. Nripemo Odyuo, Dr. Krishna Upadhaya, Dr. Pynsakhiat Law, Dr. O. P. Tripathi, Dr. Kiranmay Sarma, Ms. Shairi Nongbri, Ms. Biswarupa Ghosh, Ms. Kh. Ashalata Devi, Ms. Jenpuiru Kamei and Mr. John Nigyal. I also thank Shri Rameshwar Rai for his untiring assistance in the laboratory.

I am grateful to Dr. (Mrs.) Asha Rani Tripathi and my friends Vineeta, Sangeeta, Debipreeta, Anindita, Memma, Premabati, Audrey and friends from the hostel whose affection made me feel at home in Shillong.

I am thankful to Dr. Gautam Talukdar and Mr. Nikhil Lele, IIRS, Dehradun, for providing me the Remote Sensing imageries of the study sites.

I am grateful to the officials of the State Forest Department, Government of Meghalaya for granting permission to work in the Nokrek Biosphere Reserve and for extending necessary help during field studies.

Thanks are due to Dr. Archana Godbole, Mr. Jayant Sarnaik, Dr. Aparna Watve, Mr. Swapnil Kumbhojkar, Mr. Atul Sowni, Padmashri A. M. Gokhale, Ms. Shubhangi Shah, Ms. Manjusha Sawant, Ms. Mugdha Lad and Dr. Rosalin Mishra for their love and inspiration.

The financial support received from the Ministry of Environment and Forests, Government of India (vide sanction No.F.10/41/97-CS/BR dated 15.2.1999) in the form of a Junior Research Fellowship under the project "Study on the impact of human activities on the buffer zone ecosystems of the Nokrek Biosphere Reserve, Meghalaya" is gratefully acknowledged.

Last but not the least, I am highly indebted to my parents, sister, brother and nieces, Shweta and Shyamli, for their love, inspiration and patience.

- Swapna D. Prabhu

Place: Shillong

Date: 2nd April, 2004

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List of abbreviations used

B	**Bamboo groves**
BR	**Biosphere Reserve**
CM	**Coalmine spoils**
J_1	**1-yr. old jhum fallow**
J_{12}	**10-12 yr. old jhum fallow**
J_3	**3-4 yr. old jhum fallow**
J_6	**6-8 yr. old jhum fallow**
L	**Lowland forest**
LM	**Limestone mine spoils**
M	**Montane forest**
O	**Orchards**
R	**Riverain forest**

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CHAPTER I

INTRODUCTION

Man is dependent on biological resources for his sustenance and survival. Over a long period of his existence on this planet, he has discovered several elements of biodiversity, which are useful for him in different ways. With increase in human population and over-utilization of biological resources by man, the biodiversity has been adversely influenced. Biodiversity can be studied at three hierarchical levels, viz. genetic, species and ecosystem. These three major components of biodiversity are recognized in the definition adopted in the Convention on Biological Diversity (CBD), which was a major outcome of the Rio Conference, 1992. The CBD defines the biological diversity as "the variability among living organisms from all sources, including *inter alia,* terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and ecosystems'.

Genetic diversity refers to the variation of genes within population, species, variety or breed, which may not be expressed phenologically. It is the genetic diversity within a species, which allows a species an opportunity to evolve under changing environment and selection pressure.

Species diversity refers to the variety of species within a region and it is often referred to as taxonomic diversity. The species level is the most natural level describing the organismic diversity and is the basis of evolution. The origin and extinction of species are the principal agents for the existence of biological diversity (UNEP 1992). Such diversity can be measured in many ways, and scientists have not settled on a single best method. The number of species in a region, i.e. species richness, is often used to measure the species diversity. The global diversity as mentioned in terms of the number of species, comprises about 1.7 million species, which are known and classified under different taxonomic groups. Some biologists feel that certain species are more important than others from taxonomic point of view or from conservation point of view and should be given higher weightage. Such species form an important component of taxonomic diversity and are categorised as keystone species, endemic species and threatened species.

Ecosystem diversity refers to the diversity among habitats, communities, and associations. It includes three major components viz., composition, structure and function of the biota within an area (Noss 1990). Many community characteristics such as relative abundance of species, pattern of communities in a region, changes in community composition and structure over time, population attributes such as the age structure of populations, and even ecological processes such as parasitism, predation and mutualism are important from biodiversity point of view.

The biodiversity values, human influences on biodiversity, as well as the measures for the conservation and sustainable use of biodiversity vary greatly within and between different cultures. Cultural diversity reveals the adaptations of human societies in response to changing environmental conditions. Thus, cultural diversity becomes the fourth aspect of biodiversity, which recognises the important role of sociological, ethical, religious and ethnobiological values in human activities and cuts across all the three levels of biodiversity described earlier.

The global concern for the biodiversity is both, for its loss as well as its economic, social, aesthetic or moral values. The benefits of biological diversity can roughly be categorised into direct uses (e.g. biological resources), and indirect uses providing a wide variety of ecosystem services, and social benefits. Biological resources, which are a small portion of the biodiversity of actual or potential use, are being exploited since the time of human origin. One of the major causes of species loss is overexploitation of species serving as biological resources. These include species for food, medicines, and materials for shelter and for fuel. Social benefits cover recreation, cultural and aesthetic values of biodiversity. There is a need to manipulate the relationship between human being and this portion of biological diversity upon which his welfare depends.

Besides the direct benefits of the biodiversity, its significance lies in its role extended for the well being of an ecosystem, which in turn, provides a variety of ecosystem services to the human society. These include protection of water sources, nutrient storage and cycling, pollution breakdown etc. Though the exact relationship between the species diversity and the ecosystem stability is not yet thoroughly understood, a number of studies have been carried out to support the importance of diversity in the functioning of any ecosystem. Especially, the simple hypothesis stating that greater diversity leads to longer stability (MacAthur 1965) has provoked much research into this subject. Two important hypotheses about the significance of biodiversity for the stability of ecosystems have been put forward viz., the 'rivet hypothesis' (Ehrlich and Ehrlich 1981) and the 'functional redundancy hypothesis' (Walker 1992, Lawton and Brown 1993). The rivet hypothesis states that within an ecosystem there are a certain number of species that may disappear without making the system unstable. However, the next species that disappears will make the system unstable. Thus, every species has potential of becoming crucial to the functioning of the ecosystem (Mooney *et al.* 1995). The functional redundancy hypothesis is based on the division of the ecosystem into functional groups. In every functional group there is one species that is optimally adapted to the prevailing environmental conditions and attains highest abundance. Most other species become redundant. However, with changing environmental conditions, one of these 'redundant' species could be the one that is best adapted to those conditions and would take over as the most abundant species (Lawton 1997). Some species known as keystone species play a role in ecosystems that seems out of proportion to their number such that even small changes in their abundance may have great impacts on the ecosystems in which they live (Paine 1966). Functional importance of keystone species and the functional groups in ecosystem functioning is poorly known. However, biodiversity buffers changes in environmental conditions and might be considered as a kind of insurance (Aarts and Nienhuis 1999) which leads to stability.

Anthropogenic disturbances operating at different scales cause destruction to the plant and animal habitats to varying degrees that bring about a number of changes in various ecosystem properties and processes including biodiversity loss. Disturbances caused due to various human activities play a major role in structuring ecological systems by producing a spatio-temporal mosaic of patches (Moloney and Levin 1996). The effects of diversity on ecosystem processes and the impact of disturbances on them have been the centre of focus of biodiversity research in recent years. Many recent ecological works have centred around the disturbance-diversity-stability debate and a number of observational, experimental and theoretical studies have contributed substantially towards our understanding of biodiversity- disturbance interface. To understand the accelerating effects of human activities and how the loss of biodiversity alters ecosystem functioning are two core issues that the recent ecologists are trying to address (Hobbs 1992, Davis and Richardson 1995, Lamont 1995).

Global Biodiversity Assessment (1995) of the United Nations Environmental Program (UNEP) has identified four major causes of decrease in biodiversity, which are land use, introduction of alien species, pollution and toxicity, and climate change. Of these four causes, change in land use pattern is the principal contributor to the habitat loss and fragmentation, which has ultimately resulted into the current decline in biodiversity. The pressure on terrestrial resources and land depends very much on population growth and the demands of early stages of economic development. Moreover, land acquisition, especially for agriculture and development, focuses initially on those areas which have the most fertile soils and equable climates, and which are often the areas of greatest biological diversity. Globally, the rate of loss of tropical forests for the 1980s has been estimated at about 1% per year. The rates of extinction of local species that accompany these rapid changes in land cover may soon be far in excess of what is found today, reaching as high as 10,000 times the natural background extinction rate (Janetos 1997).

India comprises of two natural realms, Palearctic realm represented by Himalayan and Trans-Himalayan region and Indo- Malayan realms represented by the rest of the sub-continent (Udvardy 1975). Three biomes cover most of India viz., tropical humid forests, tropical dry deciduous forests and warm deserts and semi-deserts. Besides these biomes, coniferous forests and alpine meadows also form two additional biomes. The country is further classified into 12 bio-geographic provinces and three bioregions (Cox and Moore 1993).

It is estimated that about 17,000 vascular plant species (angiosperms, gymnosperms and pteridophytes) are present in India out of which as many as 5,725 species are endemic to it (Rao 1994). It contains 7% of the world's biodiversity and supports a number of major ecosystems, varying from alpine pastures to mangroves in coastal ecosystems. The country has established a network of protected areas including 89 National Parks, 495 Wildlife Sanctuaries (including 27 tiger reserves and 11 elephant reserves) and 13 biosphere reserves under Indian Wildlife (Protection) Act of 1972. The area covered under protected area network is 1,56,300 km^2 which accounts for 4.7 % of the total geographic area of the country (Anonymous 2003).

The northeastern region of India is important from biodiversity point of view, because of its floristic richness and high endemism. It is a unique transitional zone between Indian, Indo-Malayan and Indo-Chinese biogeographical zones as well as the confluence of the Himalayan region with peninsular India (Rao 1994). It is one of the 12 mega-centres of biodiversity and also one of the 25 hotspots in terms of threats to biodiversity. The undulating topography, high rainfall and varied altitudes are main factors that have contributed to its rich ecosystem diversity. The region represents about 50% of the floristic wealth of India and contains about 8000 species of flowering plants including several representatives of primitive or ancient angiosperms (Takhtajan 1969). It abounds in gene pool of cultivars and land races of crop plants. About 64 species of *Citrus* have been recorded from the north-east of which several most primitive species viz., *C. assamensis*, *C. indica* and *C. letipes* are concentrated in Nokrek area of Meghalaya giving a strong evidence that this region is the centre of origin of *Citrus* (Singh 1984).

Besides this, within a given landscape, the tribal farmers of north-east India practice a variety of land use systems contributing towards biodiversity at all levels ranging from the sub-specific, through the species, population and the ecosystem. However, this biodiversity is dwindling at an alarming rate due to high population pressure and injudicious exploitation of the available natural resources. Consequently *ca.* 700 taxa of plants in this region have fallen under different categories of threat (Jain and Sastry 1980). Loss of biodiversity in the form of crop varieties is near zero significance in terms of overall global diversity, but genetic erosion in these populations is of particular human concern in so far as it has implications for food supply and the sustainability of locally-adapted agricultural practices. For domesticated populations, loss of wild relatives of crop or economically important plants is of special concern for the same reason. Thus, the protected areas become the only refuges of the relic pristine vegetation harbouring precious biodiversity of the region.

The Khasi, Jaintia and Garo hills of Meghalaya have long been a focal point of botanical attention. As many as 3331 vascular plant species have been recorded from the state, out of which 1236 (37.11%) are endemic (Khan *et al.* 1997). According to Champion and Seth (1968), Assam sub-tropical hill savanna, Khasi sub-tropical hill forests, Assam sub-tropical pine forests and Assam sub-tropical pine savanna are the major forest types in the state of Meghalaya. Haridasan and Rao (1985-87) described the vegetation of Meghalaya as follows: tropical evergreen forests in low-lying areas, with high rainfall; tropical semievergreen forests (up to elevations of 1200 m) where annual rainfall is 1500-2000 mm; tropical moist and deciduous forests in areas with less than 1500 mm rainfall; grasslands and savanna on the tops of Khasi, Jaintia and Garo hills.

Isolated patches of temperate forests are found at higher altitudes in Khasi and Jaintia hills. Sub-tropical pine forests are also found at higher altitudes in such areas where the original broad-leaved forests were felled or disturbed otherwise. A large network of legally protected areas including two National Parks, three Sanctuaries and more than twenty-five reserved forests has been established in the state. Besides, there are several sacred groves, which are protected by the local communities.

In the tropical world, biodiversity concentrations are largely tied up with regions where traditional societies live. These traditional societies by their very nature of the livelihood activities are part of the ecosystem/ landscape functions rather than being external players (Ramakrishnan 1992). Biodiversity is not only an important regulator of ecosystem functioning in a biological sense, but is also crucial for satisfying a variety of social needs and functions. Such an integrated approach is necessary for developing strategies for sustainable management of biological resources and conservation of biodiversity. Biosphere reserves, having the human beings as the major integral component of their concept provide an excellent example for exploring the impact of anthropogenic activities on the vegetation and biodiversity.

In 1968, United Nations Educational, Scientific and Cultural Organisation (UNESCO) organized the "Biosphere Conference" in Paris, as a result of which, UNESCO's Man and Biosphere Programme (MAB) was initiated in 1971. Currently, the International Biosphere network includes over 350 reserves in more than 80 countries. Biosphere reserves are protected areas, which serve to provide scientific knowledge, training and human values needed to support sustainable development. They are multipurpose areas identified by the respective National Committees of Man and Biosphere (MAB) Programme, designated by the respective governments and endorsed by the UNESCO. These sites serve as demonstration areas for cooperation in building harmonious relationship between human activities and the conservation of ecosystems and biological diversity. Each biosphere reserve exemplifies the characteristic ecosystem of one of the worlds major bio-geographic regions. These are land areas and/or coastal marine areas involving human communities as integral component with objectives ranging from complete protection (core zone) to intensive yet sustainable use of resources. Thus, the biosphere reserve concept is a key to achieving MAB's objective of striking a balance between conserving biodiversity, encouraging economic and social development and preserving cultural values (UNESCO 1971). Specific objectives of the establishment of the biosphere reserves are:

- In-situ conservation of biodiversity (genetic resources, species, ecosystems) of natural and semi-natural ecosystems and landscapes
- Contribution to foster sustainable economic development of the human population living within and around the biosphere reserve
- To provide facilities for long-term ecological studies, environmental education and training, and research and monitoring related to local, national and global issues of conservation and sustainable development.

The National Biosphere Reserve programme in India was initiated in 1986 broadly following UNESCO's guidelines. As a result, 13 Biosphere Reserves have so far been established all over India (Table 1.1).

Table 1.1 The details of biosphere reserves established in India.

Biosphere Reserve	State	Date of notification	Total area (sq. km)	Area of the core zone (sq. km)
Agasthyamalai	Kerala	12/11/2001	1,701.00	1701.00
Dehang Debang	Arunachal Pradesh	02/09/1998	5111.50	4094.00
Dibru-Saikhowa	Assam	28/07/1997	765.00	340.00
Great Nicobar	Andaman and Nicobar Islands	06/01/1989	885.00	520.00+185.00
Gulf of Mannar	Tamil Nadu	18/02/1989	10500.00	---
Kangchendzonga	Sikkim	07/02/2000	2619.92	1784.00
Manas	Assam	18/03/1989	2837.00	520.00
Nanda Devi	Uttaranchal ~~Uttar Pradesh~~	18/01/1988 (Revised on 07/02/2000	5860.69	624.62+87.50
Nilgiri	Karnataka, Kerala, Tamil Nadu	01/08/1986	5520.00	1240.00
Nokrek	Meghalaya	01/09/1988	820.00	47.48
Pachmarhi	Madhya Pradesh	03/03/1999	4926.28	524.37
Similipal	Orissa	21/06/1994	4374.00	845.00
Sunderbans	West Bengal	29/03/1989	9630.00	1700.00

In the state of Meghalaya, Nokrek was designated as National Park (NP) on 11th November 1986. While making attempts to identify suitable areas in Meghalaya for conservation and maintenance of genetic diversity, the Indian Council of Agricultural Research through its National Bureau of Plant Genetic Resources identified this area as a reservoir of a large variety of wild relatives of *Citrus* species cultivated throughout the north-eastern India. Thus, in order to conserve the Citrus gene pool, the concept of Citrus Gene Pool Sanctuary within the network of Nokrek NP came up, with a view to develop a national-scale Citrus improvement programme. However, various anthropogenic stresses especially jhum cultivation, coal mining and limestone extraction, were posing serious problems for the conservation and management of the Nokrek NP. Considering the importance of Nokrek NP from the biodiversity point of view, the Nokrek NP was recommended as a biosphere reserve by a committee established by the MoEF (Ministry of Environment and Forests, Government of India), with the objectives of striking a balance between conserving biodiversity, encouraging economic and social development at local level and preserving cultural values. The vegetation of the BR is comprised of tropical and subtropical evergreen forests, semi-evergreen forests, deciduous forests, bamboo patches, grasslands and riverain forests. The area harbours great variety of plant communities of economic, medicinal and botanical significance.

Shifting cultivation is the major means of subsistence for a majority of the local people (85%). It is widely practiced in the buffer zone of the BR. The total land area under shifting cultivation within BR is *ca.* 31400 ha. (38 % of the total land area). Orchards, tea gardens and valley cultivation are the secondary land use systems, which occupy *ca.* 3500 ha. area, within the buffer zone. Unscientific surface coal mining and lime stone extraction activities are being operated in the southern part of the BR leading to the land degradation and loss of biodiversity of the area. The factors like poverty, inadequate educational facilities for the locals, and absence of location-specific sustainable eco-development programme with community participation have contributed to the forest fragmentation and loss of biodiversity.

Effective management is required to halt the continued decline of the species in the wild and to restore their populations and habitat against the threat of destruction due to various anthropogenic activities. A sound understanding of biology of the species and their population dynamics in response to the anthropogenic activities is a prerequisite for their conservation. The identification of species, communities and ecosystems that are likely to be damaged by human activities forms an essential part of any nature conservation management (Nilsson and Grelsson 1995).

The present study was carried out in the core as well as buffer zones of the Nokrek Biosphere Reserve to study the biodiversity in different ecosystems of the Biosphere Reserve and to determine the impact of human activities on the plant diversity. To achieve this goal, the study was carried out with the following specific objectives:

1. Inventorying the plant diversity of different ecosystems found in the Nokrek biosphere reserve
2. Assessing the impact of human activities on plant diversity of the Biosphere Reserve
3. Identification of biodiversity-rich vegetation patches containing endemic, rare, endangered and medicinal plant species.

The data collected on above-mentioned aspects have been dealt with in detail in chapters IV to VII. The chapter II i.e. "Review of Literature" gives an overview of research work done on the aspects related to the present study. A brief introduction about the study area, which includes location, climate, geology, soil, demographic features, and vegetation types and fauna of the study area, has been given in chapter III (Study Area and Methods). It also gives an account of the methodology adopted to achieve the research objectives. Chapter IV includes the characterization of different ecosystems of the BR. Chapter V deals with the biodiversity and community characteristics of the undisturbed ecosystems of the BR, while impact of human activities on these attributes of disturbed ecosystems of the buffer zone have been discussed in the chapter VI. A detailed account of endemic, threatened and rare as well as medicinal plants of the BR has been given in the chapter VII. The results of chapters IV to VII are critically discussed in an integrated manner in the "General Discussion". In the end are appended the "Summary" and "References".

CHAPTER II

REVIEW OF LITERATURE

Concern for global biodiversity and its conservation is based on the realization that the state of the earth's biological system is of fundamental importance for human society and that our influence on these systems is increasing exponentially. Recognizing the urgent need to place a premium on identifying priorities for the areas of conservation, Myers (1988), in his first paper on biodiversity hotspots, identified ten tropical rain forest hotspots containing an estimated 13% of all plant diversity in just 0.2% of the total land area of the planet. In a subsequent analysis, Myers (1990) added several other rain forest areas and four Mediterranean type ecosystems to the list of biodiversity hotspots bringing the total number of such areas to 25 that account for 20 % of global plant diversity in just 0.5 % of the total land area of the world. Simultaneously, Myers (1988, 1990) and Mittermeier *et al.* (1998) developed the concept of major tropical wilderness areas. Whereas, the hotspots consist mainly of heavily exploited and often highly fragmented ecosystems, greatly reduced in extent (usually 25% of original pristine vegetation remaining), the major wilderness areas are still largely intact (more than 75% of original pristine vegetation remaining) and have low human population density (less than 5 people per km^2). Besides these, there are 17 countries recognised as mega-biodiversity centres owing to their high species richness and endemism. This categorization means that a very high percentage of global terrestrial biodiversity can be protected in a very small portion of Earth's land surface and thus international efforts to conserve terrestrial biodiversity should focus heavily, but not exclusively on these areas.

However, even before the concept of hotspots of diversity came into existence, different trends in composition, structure and diversity have been studied in detail in the tropics. Measures of species diversity play a central role in ecology and conservation biology (Whittaker 1960, 1972, Williams 1964, MacArthur 1965, Peet 1974, Pielou 1975, Grassle *et al.* 1979, Magurran 1988, Noss and Cooperider 1994). Whittaker (1960,1972) defined the important concepts of species diversity within and among communities (α- and β-diversity, respectively), and the total species diversity in a set of communities (γ- diversity). Various measures of species diversity among communities have been proposed, especially for patterns of species richness along environmental gradients (Whittaker 1960,1972, MacArthur 1965, 1972, Pielou 1975, Allan 1975, Routledge 1977, Wilson and Mohler 1983, Wilson and Shmida 1984, Magurran 1988).

Although the concept of taxonomic isolation and taxonomic diversity has been understood for a while, until recently there were no precise measures by which these concepts could be quantified. Initial suggestions by May (1990), Faith (1992) and Vane-Wright *et al.* (1991) led to proposals for a quantitative frame work, which is further developed with examples of applications to conservation evaluation. Recently, taxonomic diversity has been worked out by Viroleinen *et al.* (1998) who has demonstrated its application in identifying the areas for conservation. Many workers have attempted to generalize the theories regarding different aspects of biodiversity viz., its role in ecosystem functioning and sustainability, its components and causes, etc. (Huston 1979, Routledge 1984, Ehrlich and Wilson 1991, Tilman 1996,1999, Grime 1998, Aarts and Nienhuis 1999)

The world records for species richness are 473 tree species (considering individuals with dbh ≥ 10 cm) in one hectare plot in Amazonian Ecuador (Valencia *et al.* 1994), which supersedes the previously known record of 300 woody species (trees and lianas of dbh ≥ 10 cm) in a one ha plot in Ecuador (Gentry 1988 b).

Connell (1978) studied diversity in tropical rain forests and coral reefs. Tanner (1977) carried out quantitative characterisation of floristics and other ecological attributes in four montane rain forests of Jamaica. Similar studies giving account of species diversity have been carried out by Meave and Kellman (1994) in neotropical savanna in Central America, Tackaberry and Kellman (1996) in Venezuela, Pendry and Proctor (1996 a, b) in Bukit Belalong, Brunei, Cao and Zhang (1997) in SW China, He *et al.* (1997) in Malaysia, Pitman *et al.* (1999,2001) in Amazonian Terra Firme forests and Gonzalez and Zak (1994) in tropical dry forests of St. Lucia, West Indies. Simmons and Cowling (1996) have discussed richness of the forest based on different components of diversity (α, β and γ) within the Cape peninsula of South Africa.

Simultaneously, similar studies were undertaken by a number of workers in the ecosystems other than the tropical forests. Lawesson *et al.* (1998) investigated the floristic richness of forests of different sizes, ages and disturbances and have analyzed the relationships between species richness and forest area in Danish Beech forests. Ohlson *et al.* (1997) has examined the role of habitat qualities and long-term continuity of forests on the biodiversity of boreal swamp forests. Hare *et al.* (1997) compared the structure of subtropical dry forests of Mao, Dominican Republic with that of Guánica, Puerto Rico. Alpine plant diversity has been analysed by Grabherr *et al.* (1995) and Pauli *et al.* (1999). The work by Menalled and Adamoli (1995) is the first attempt to analyze the relationships among the floristics, ecological and historical elements of deltaic communities on a regional scale of analysis.

Recently, Oldfield and Sheppard (1997) discussed the importance of baseline data including species and ecosystem inventories in the development of biodiversity conservation strategies. Stapanian *et al.* (1997b) have developed a method suitable for monitoring changes in species richness and canopy cover for a large-scale synoptic monitoring survey of large forests. A new technique has been designed by Tackaberry *et al.* (1997) to estimate species richness in the tropical forest while Phillips and Raven (1997) have described the strategy for sampling the Neotropical forests.

A number of workers have attempted to explain the causes or factors controlling species richness and diversity in different parts of the world. It is now well established that the tropics harbour much larger number of species than the colder regions. The species richness along latitudinal gradients has been discussed by many authors (MacArthur 1965, Ricklefs 1973, Pielou 1975, Connell 1978, Huston 1979, Rohde 1992). Recently, several detailed studies have focussed on trends in the composition, structure and diversity of tropical forests along various gradients, including rainfall (Gentry 1982, 1986), edaphic conditions (Huston 1980, Gentry 1988a, Ashton 1989), climate and topography (Schall and Pianka 1978). The effect of altitudinal gradients on community properties including species richness has been examined by Vázquez and Givnish (1998) in the Sierra de Manantlán Biosphere Reserve, South-west Mexico and by Pendry and Proctor (1996 a, b) in Bukit Belalong, Brunei. Vertical as well as horizontal variations in soil characteristics are imperative in controlling species diversity. The relationship is reported to be positive by Ashton (1982) and negative by Huston (1980).

Bell *et al.* (2000) studied the environmental heterogeneity (canopy cover, ground cover and soil pH) and its effect on species diversity of forest sedges. Whereas, Grace (1999) evaluated the relationship of species diversity of herbaceous communities with various factors such as total community biomass, disturbance, regional species pool, plant density, soil microbial characteristics, colonization and spatial heterogeneity. Similarly, Xiong and Nilsson (1999) have analysed the effects of plant litter on species richness and concluded that litter plays an important role in constructing the community. Barik *et al.* (1992) examined the effect of microenvironmental variability (air and soil temperature, soil moisture, photon flux density, relative humidity) on species diversity in forest gaps.

The number of woody species in tropical forests tends to increase with precipitation, forest stature, soil fertility, rate of canopy turn over and time since catastrophic disturbance and decrease with seasonality, latitude, altitude and diameter at breast height (Givnish 1999). He *et al.* (1997) studied the distribution pattern of tree species in Malaysian tropical rain forest and suggested that the high diversity is subjected to multiple controlling factors. e.g. topography, spacing effect, density- dependent processes and species diversity. The relative importance of any factor could change across spatial and temporal scales.

In India several floristic as well as ecological studies have been carried out on the similar lines, especially, in Western Ghats, Himalayan region and the northeastern India. Recent quantitative plant diversity inventories in peninsular Indian forests include those from the deciduous forests of Mudumalai (Sukumar *et al.* 1992) and of Uttar Kannada (Bhat *et al.* 2000), dry evergreen forests of the Coromandel coast (Visalakshi 1995, Parthasarathy and Karthikeyan 1997, Parthasarathy and Sethi 1997, Reddy and Parthasarathy 2003), tropical semi evergren forests of Eastern Ghats (Kadavul and Parthasarathy 1999a, 1999b), evergreen forests of Eastern Ghats (Chittibabu and Parthasarathi 2000) and from the wet evergreen forests of Western Ghats (Rai and Proctor 1986, Parthasarathy *et al.* 1992, Pascal and Pelissier 1996, Ganesh *et al.* 1996, Ghate *et al.* 1997, Ayyappan and Parthasarathy 1999, 2001a, 2001b, Bhat *et al.* 2000). Joshi and Suresh (1997) have carried out diversity analysis in Nilgiri Biosphere Reserve. Adhikari *et al.* (1991) investigated the species composition and diversity in a high altitude forest of Kumaun region in Western Himalaya.

Ramakrishnan and his associates initiated the work related to different aspects of forest ecosystems in Meghalaya as well as other states in northeast India (Singh 1980, Prakash 1980, Bhooj 1981, Kushwaha *et al.* 1981, Ramakrishnan et al. 1981, Saxena and Ramakrishnan 1984, Baruah 1986, Swamy 1986, Rao 1986). During recent years, several in-depth studies have been carried out on the structure and functions of the broad-leaved forest ecosystems of Meghalaya (Tripathi and Khan 1992, Barik *et al.*1992, Rao 1992, Arunachalam *et al.* 1996, Maithani 1996, Tiwari *et al.* 1998, Jamir 2000, Tripathi *et al.* 2001, Upadhaya *et al.* 2003). Recently, Barik *et al.* (1996a, b), Mishra *et al.* (2003, 2004) analysed the effect of anthropogenic disturbance on plant diversity, community attributes and regeneration behaviour of few dominant species of a sacred grove (montane subtropical forest) of Meghalaya. Bhuyan *et al.* (2003) studied diversity, population structure and regeneration potential of tree species in undisturbed and human-impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India.

Floristic works in the northeastern India

The botanical works in the northeastern India were initiated during 1793-1855 with the extensive collections by Sir Francis Jenkins and his collectors along Brahmaputra valley. In 1854 Sir J.D. Hooker and T. Thomson collected about 3000 plant specimens from Khasi Hills, Jaintia Hills and Sylhet whereas another 1000 from plains. Later, Sir J. D. Hooker (1872-1897) published his monumental work in seven volumes of 'The Flora of British India'. Collections made by several collectors working in northeast region contributed to the initiation of the floristic works of the region. Among these contributors were the collections made by Burkill (1925) from Khasi Hills, Mrs. Parry from Garo Hills, etc. U.N. Kanjilal's extensive collections, careful observations in his field notes and drafts were later compiled by his successors in the form of four volumes of 'Flora of Assam' during 1934-1940. N.L. Bor (1940) brought out the fifth volume of the 'Flora of Assam', which was exclusively on the grasses.

Several papers on the enumeration of certain taxa or smaller areas have also been published, such as those on ferns and fern allies of Eastern India (Panigrahi 1960a) and that of Meghalaya (Baishya and Rao 1982), on tropical evergreen and semi-evergreen vegetation (Panigrahi 1960b, Rao 1969a), on plants of Garo Hills (Ghosh and Biswas 1978), on flora of Shillong (Bordoloi 1980), on flora of Balphakram (Kumar 1984), on sacred groves near Shillong (Raju 1964) and of Meghalaya (Tiwari *et al.* 1998, 1999)

The floristic works such as Flora of Jowai (Balakrishnan 1981-83), Flora of Nongpoh and its vicinity (Joseph 1982), Forest flora of Meghalaya (Haridasan and Rao 1985-87), Graminae (Shukla 1996), Monocots flora of Meghalaya (Myrthong 1980), Orchids of Meghalaya (Rao 1969b, Kataki 1986) reveal the high plant diversity and endemism in the state of Meghalaya, and also have contributed greatly to our understanding of the biodiversity of Meghalaya.

Spatial distribution

Among many processes that have contributed to the spatial patterning of species is the well-known Janzen-Connell model, which generated a meaningful debate among ecologists (Janzen 1970, Connell 1971, Hubbell 1979,1980). Ashton (1976) and Austin *et al.* (1972) indicated that in the absence of major disturbance, soil and water conditions play major role in controlling species distribution. Greig-Smith (1983) described the general pattern of spatial dispersion and stated that only a few species in nature are distributed in a regular way, and most of them are clumped or appear to be randomly distributed at any given observation scale. He *et al.* (1997) have analysed the spatial patterns of tree species in a Malaysian tropical rain forest and have found that the spacing effect was one of the factors controlling the high diversity.

Profile diagram

Since its introduction by Davis and Richards (1933-34) for a study in British Guiana, profile diagram has been very widely used as an aid to the description of tropical rain forests (Richards 1936,1939). Beard (1946) used it for portraying the structural characteristics of tropical forests in South America. Profile diagrams have been used to study the vertical layering of tree canopies.

Vertical complexity is itself, an indicator of species richness, because complexity is an expression of the variety of plant life forms and species-specific morphologies. Layering will be most marked in the stands containing a few species or only one, and is least likely in a forest of numerous dissimilar species where individuals of a given species are scattered (Whitmore 1975). It has been employed for comparing different forest communities and vegetation types such as two tropical dry evergreen forests in southern India (Visalakshi 1995), three sacred groves in Meghalaya (Jamir 2000) and four different tropical vegetation types of Xishuangbanna (Cao and Zhang 1997).

Biological spectrum

The concept of life form in the study of vegetation was proposed for the first time by Humboldt (1806) who suggested grouping of vegetation types on the basis of physiognomy. Grisebach (1873) and Drude (1890) have emphasized the dependence of life forms on climate and assessed the role of species in vegetation with special reference to duration of protection of the perennating organs and mode of propagation. This concept was established by Raunkiaer (1934,1937) and was further extended by Braun-Blanquet (1951). Raunkiaer's system is based primarily on the position of the buds or organs from which new shoots or foliage develop after an unfavourable season. When the life forms of all species are listed for a community, it results in a biological spectrum. Pandeya (1954) and Tiwari (1955) have demonstrated that the biological spectrum not only represents climatic conditions but also the most potent environmental factor representing the ecosystem. The essence of Raunkiaer's biological spectrum has also been examined by Fekete and Lacza (1971) with emphasis on how it could become an important tool in phytogeography and plant ecology.

A biological spectrum reflects the adaptation of plant to environment and primary climate (Smith 1980). Geographically widely separated plant communities can be very usefully compared with one another on the basis of their biological spectrum. Hence, the information on biological spectrum is also valuable for expressing differences and similarities among communities (Yadava and Singh 1977, Dagar and Balakrishna 1984). Since the life forms are related to the environment, biological spectrum is also an indicator of the prevailing environment (Meher-Homji 1981) and so, it can be a rough guide to the degree of disturbance in the disturbed areas (Dagar and Singh 1999).

Population structure

Population structure expressed in terms of size distribution of the individuals interprets the forest succession (Harper 1977, Saxena *et al.* 1984, Ogden 1985, Khan *et al.* 1987, Hart *et al.* 1989). Size distribution has often been used by ecologists as an effective tool to indicate the health of a population. Several recent studies have employed population structure to analyse the forest health (Rao *et al.* 1990, Tripathi and Khan 1992, Kadavul and Parthasarathy 1999a, 1999b, Jamir 2000, Ayyappan and Parthasarathy 2001a, Law 2002, Bhuyan *et al.* 2003).

Endemism and rarity

The research on endemism pertaining to vascular plants in temperate areas, and several reviews on the subject have appeared over the past two decades (Kruckeberg and Rabinowitz 1985, Gentry 1986, Major 1988). The study by Turner (1996) has suggested that isolated fragments of forests suffer reduction in species richness with time after excision from continuous forest. A large number of indigenous species that are very sparsely distributed and intolerant to changing conditions are particularly prone to local extinction. It is estimated that about 26,106 plant species are globally threatened (Anonymous 1992) out of which at least 1500 plant species are threatened with extinction.

Several phyto-geographers after critical analysis of flora have convincingly concluded that India has a flora of its own and as many as 5000 (30%) taxa of its flora are endemic to the present Indian boundaries (Takhtajan 1969). The Eastern Himalaya has 1500 endemic species out of 4500 endemics found in India. About 17 species have been reported to have become extinct from eastern Himalaya and northeastern India (Nayar and Sastry 1990). In Meghalaya out of 3331 vascular plant species, 1236 species are endemic and 67 species are listed in the Red Data Book of Threatened plants (Khan *et al.* 1997). An account on endemic plants of Meghalaya has been given by Hajra (1974), and Shukla (1983) has focussed on endemic grasses in this region.

Medicinal plants

A major part of biological resources is used in traditional medicinal systems all over the world. According to Jain (2000), 'ethnobotany has been used as an organizing focus from which to access human adaptive responses and impact on biodiversity. An exhaustive compendium of medicinal plants of the country and their biological activities is available (Rastogi and Mehrotra 1991). Similarly, Jain (1991) provides a comprehensive list of Indian folk medicines. Medicinal plant wealth of Himalayan region has been documented by several other workers (Biswas 1956; Samant *et al.* 1998; Saini 2000; Nautiyal *et al.* 2001; Prakash 2002). A number of studies have been carried out revealing the medicinal plant wealth of the northeastern region during the past four decades (e.g. Rao 1979, Rao 1981, Joseph and Kharkongor 1981, Kumar *et al.* 1982). Besides this, the ethnobotanical works related to Khasi and Jaintia Hills (Kharkongor and Joseph 1981, Hajra 1981) and Garo Hills (Rao and Shanpru 1981) have also added to the knowledge of the medicinal plants of this region.

Maikhuri *et al.* (1998) have depicted the role of medicinal plants in the traditional health care system in Nanda Devi Biosphere Reserve, Himalaya, whereas Nautiyal *et al.* (1998) emphasized the importance and potential of these medicinal plants for economic betterment of the people while helping the cause of conservation in a protected area.

Disturbance

Disturbance can be described as a force, often abrupt and unpredictable, that kills or damages the organisms and alters the availability of resources. The effects of large-scale disturbances include denudation which in turn leads to the habitat loss, soil erosion, siltation, threats to indigenous people, and destabilization of watersheds (Janetos 1997). The primary cause of the decline in the diversity of rain forest taxa is the habitat destruction (Ehrlich 1988), which results in habitat fragmentation, thus causing further loss of original habitat, reduces size of habitat fragments and increases their isolation (Andrén 1994). Habitat fragmentation may influence local and regional patterns of biological diversity in several ways, including the loss of unique microhabitats, habitat insularization and associated changes in dispersal and migration patterns and small- and large-scale soil erosion (Soulé and Kohm 1989). According to FAO (1993) report, tropical closed forests were being destroyed at a rate of at least 110.5 million ha per year. Rates of loss of forest cover vary greatly by continent and habitat type, and true deforestation rates are difficult to determine because satellite data are incomplete and ground truthing is available for relatively few areas (Myers 1994).

The intermediate disturbance hypothesis (Connell 1978, Levin and Paine 1974) states that disturbances such as tree fall gaps lead to a predictable successional sequence in which one tree species replaces another, culminating in dominance by a few canopy tree species. If disturbances are rare, almost all the sites are dominated by late successional canopy species and total stand diversity is low. If disturbances are frequent, almost all sites are dominated by early successional pioneer species and diversity is again low. However, at intermediate rates of disturbance, there is a range of sites: some are newly disturbed, some are of intermediate age and some are old enough to be dominated by late successional canopy species. This would allow the full range of species traits to coexist and to lead to maximal species diversity.

The fragility and stability of an ecosystem relate to degree of change in species abundance and composition, following disturbance. High rates of species turnover or population fluctuations characterize fragile ecosystems, and vice versa. The diversity of ecological processes related to these changes makes ecosystem fragility a central evaluation criterion in conservation management. Fragility is also closely related to many frequently used criteria in evaluation and assessment of conservation.

The role of disturbance has been emphasized in many systems such as tropical rain forests (Connell 1978), coral reefs (Connell 1978, Karlson and Hurd 1993), herbaceous vegetation (Grime 1973), temperate forests (Horn 1975), and pasture communities (Lavorel *et al.* 1998). Huston (1979, 1994) proposed a theoretical model of diversity variation, which postulates that disturbance and competitive exclusion are the two fundamental processes controlling diversity, whereas, Mackey and Currie (2000) have examined the models of community dynamics in the face of disturbance, and have derived quantitative predictions regarding relationships between species richness, evenness and disturbance. A number of studies deal with the plant communities or functional groups, which emerge as a response to the disturbance (Sumina 1994, Lavorel *et al.* 1998, McIntyre *et al.* 1999). Burel *et al.* (1998) compared the biodiversity in contrasted landscape units within a small region and studied the impact of agricultural activities on the biodiversity. Stapanian *et al.* (1997b) analysed the regional patterns of tree diversity in relation to the anthropogenic disturbances. Young and Zhi-jun (1989) compared the secondary and primary forests in Yunnan, China, in order to generate a baseline data, which can be utilized for the management of Xujiaba Nature Reserve in southwestern China.

Recently, Chittibabu and Parthasarathy (2000) have studied the changes in tree species diversity and stand attributes in relation to the varying human disturbance in the evergreen forests of Eastern Ghats of India. Several site-specific studies have been carried out to study the impact of shifting cultivation and mining practices, both of which have been identified as major causes of disturbance to forest ecosystems in the state of Meghalaya. Shifting cultivation is practiced almost throughout the world (Hauck 1974). In India, it is mainly practiced in the northeastern region and some parts of Orissa and the Western Ghats. Shifting cultivation or *jhum,* as it is locally called in northeast India, has been extensively studied by Toky and Ramakrishnan (1981,1982), Misra and Ramakrishnan (1981, 1983), Gangwar and Ramakrisnan (1987), Misra *et al.* (1992) covering the aspects like socio-economics, energetics, weed population dynamics and succession. All these studies have concluded that increasing population pressure against limited land resources has resulted into the shortened jhum cycles which in turn cause a negative impacts on the soil quality, leading to reduced crop yield and vegetation cover in abandoned fallows as well. Tawnenga (1990) studied the shifting agriculture as practiced in Mizoram and suggested innovative approaches.

As mentioned above, coal mining is one of the major factors contributing to the degradation of forest ecosystems in some parts of northeastern region. Although the major coalmines are located in Raniganj in West Bengal, Jharia in Bihar, and Singrauli in Madhya Pradesh, coal mining is also a common practice in northeast India. In the northeast, coal-mining was initiated by Medlicott, followed by initial excavations by Fox in the Garo Hills. In the subsequent years, extensive coal mining was carried out in Garo Hills, Jaintia Hills and Khasi Hills Meghalaya. In Garo hills the coal deposits are found in West Darranggiri, Siju, Pyndengru-Balphakram and Selsella block. Coal mining has received considerable attention, particularly its impact on soil properties and vegetation. Floristic composition on the reclaimed spoils has been studied by Fitter and Bradshaw (1974), Gemmell (1977), Johnson and Bradshaw (1979), Powell *et al.* (1983), Bradshaw (1987), Brenner *et al.* (1994), Lal (1984) and several other researchers.

In Meghalaya, several studies have been carried out in the coalmine-damaged areas by Lyngdoh *et al.* (1992), Uma Shankar *et al.* (1993), Lyngdoh (1995), Tiwari (1996) and Das Gupta (1999). These studies have mainly focused on the vegetation dynamics, edaphic changes and vegetational as well as microbiological processes on the coalmine spoils of different ages undergoing natural recovery in Jaintia Hills district of Meghalaya.

The review of literature clearly indicates that several ecological issues particularly those connected with forest ecology, plant diversity, and ecological implications of shifting cultivation and coal mining have been addressed to by a number of researchers. However, such studies are mostly restricted to the forested areas (including sacred groves) of Khasi and Jaintia hills of the state of Meghalaya, and the biodiversity of the forest vegetation in Garo hills has been grossly neglected although there is a huge protected area (Nokrek Biosphere Reserve), which is very rich in plant diversity. The buffer zone of this biosphere reserve is subjected to a variety of anthropogenic disturbances including shifting cultivation and mining, which are causing substantial depletion in plant diversity of biosphere reserve. The impact of these disturbances on the plant diversity has not engaged the attention of researchers. Therefore, the present study was aimed at studying the changes in plant diversity and community parameters of the Nokrek Biosphere Reserve, caused by the major anthropogenic disturbances such as shifting cultivation and mining.

CHAPTER III

STUDY AREA AND METHODS

Study area

Nokrek Biosphere Reserve (NBR), where this study was carried out, is spread over an area of 820 sq. km covering parts of East Garo Hills, West Garo Hills and South Garo Hills districts in Meghalaya. It lies between $90^0 13'$ E and $90^0 35'$ E longitudes and $25^0 20'$ N and $25^0 29'$N latitudes (Fig 1.1a). It is situated on hilly terrain of Tura ranges of mountain system with altitude ranging from 200 m to 1415 m asl. The highest peak of this ridge called Nokrek Peak (1415 m asl) lies within the Core Zone of the NBR. The core zone of the NBR, which is also designated as Nokrek National Park, covers 47.48 sq. km area of the ridge of Nokrek Hills, spread in east-west direction. The northern aspect of the National Park is comparatively of gentle slope while the southern flank consists of hills with very steep to moderate slopes. The core zone of the BR has the distinctive virgin vegetation of Meghalaya. The major rivers of the Garo Hills viz., Simsang, Dedari, Dareng and Ganol, originate from the Nokrek BR. The area surrounding the core zone is the buffer zone, covering 772.52 sq. km area of the BR.

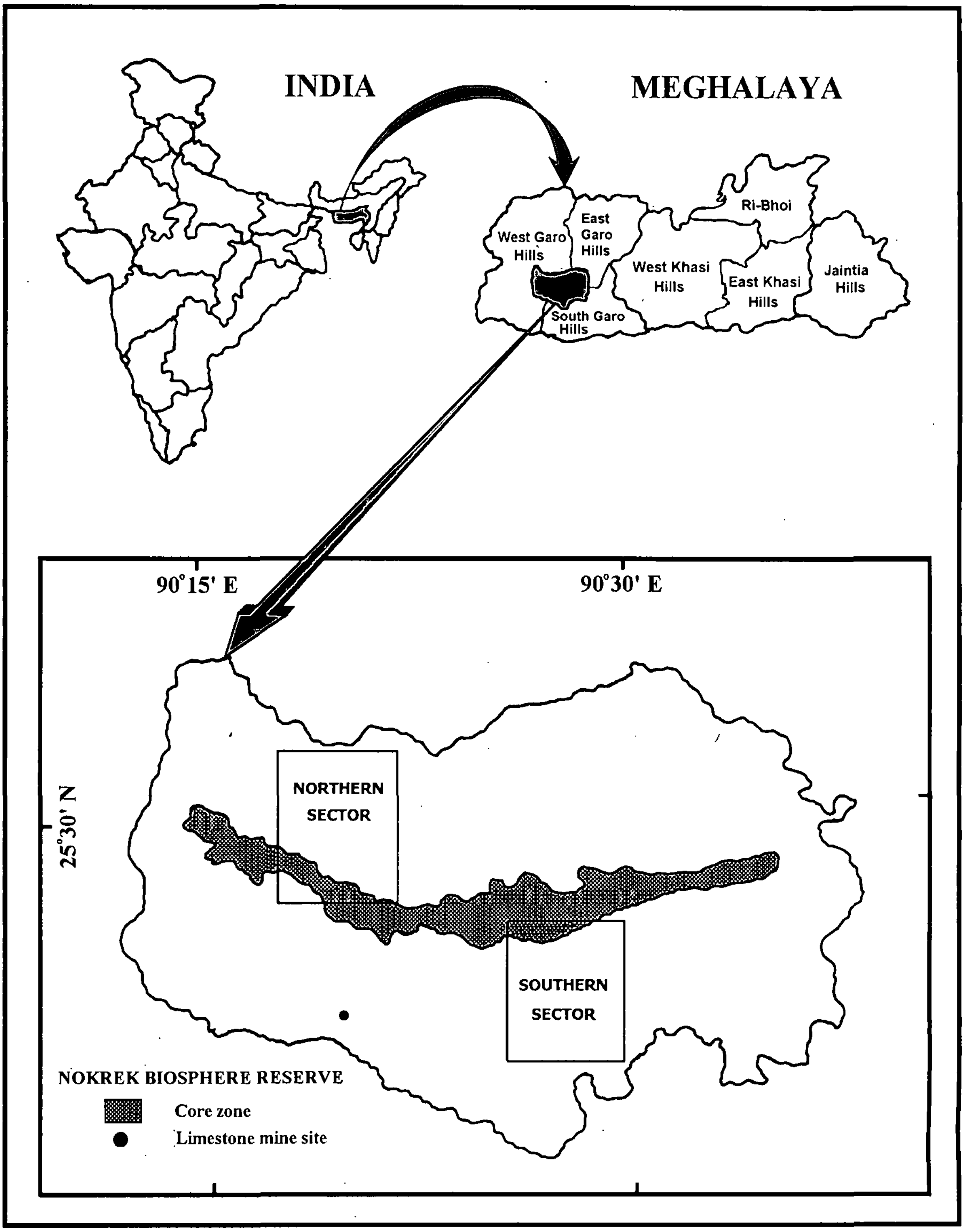


Fig. 1.1a Map showing the location of study sites in the Nokrek Biosphere Reserve in Meghalaya.

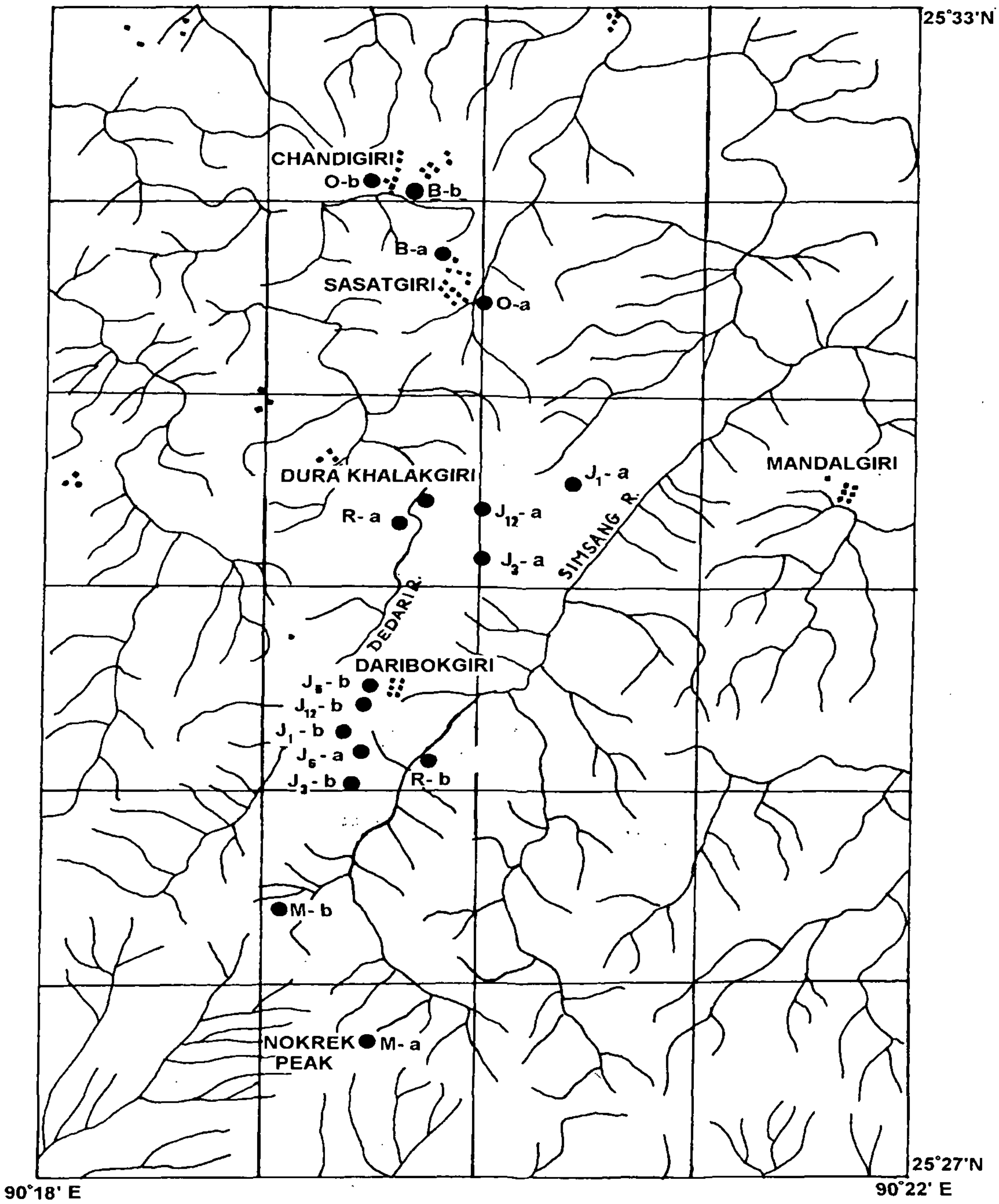


Fig. 1.1b Map showing the locations of the study sites within the northern sector of the Nokrek BR (● - sites studied, M- montane forests, R- riverain forests, $J_{1,3,6,12}$ - jhum fallows of different ages, B- bamboo groves, O- orchards).

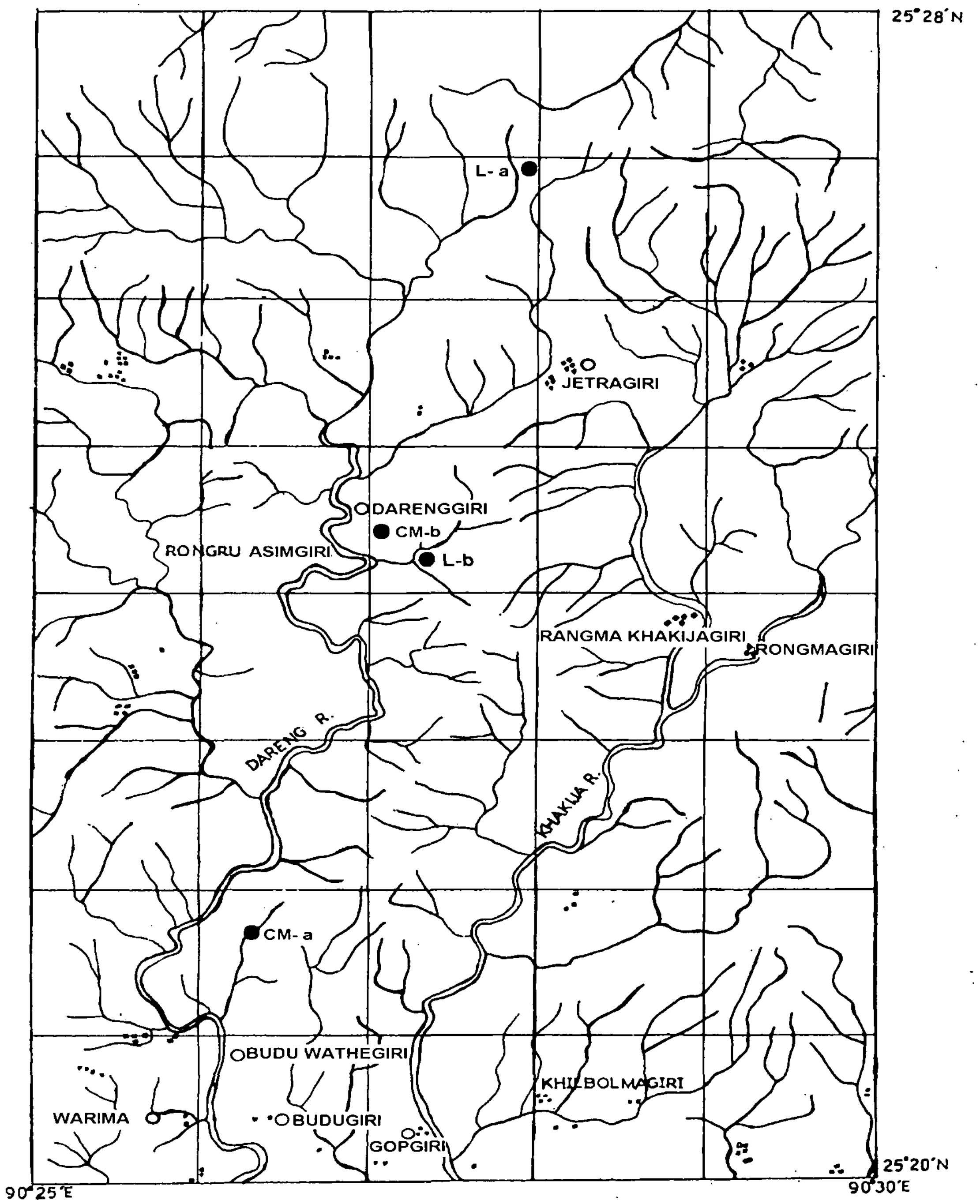


Fig. 1.1c Map showing the locations of the study sites within the southern sector of the Nokrek BR (● - sites studied, ○ -villages with coalmines, L-lowland forests, CM- coal mining affected area).

Climate

The area enjoys tropical climate with high rainfall, high humidity, mild summers and moderately cold winters. Monsoon rains are received from April to October with occasional rainfall during November to March. It has three seasons of which summer corresponds to the months from March to April, rainy season from May to October and winter from November to February.

NBR receives highest rainfall during the months of June to August. The average annual rainfall recorded at Sangsanggre, Tura during last three years (1999-2001) was 3012 mm (Fig 1.2), which was spread over 117 days.

Temperature varies from place to place depending on aspect, altitude and vegetation. The southern part of the BR is slightly warmer than the northern part. The northern aspect of the BR is the coldest area of the Garo Hills. The average temperature during the study period ranged from 33.4 ^{0}C to 14.8 ^{0}C. The highest temperature recorded was 39^{0}C (April) and the lowest was 10 ^{0}C (Jan-Feb)(Fig 1.2).

The mean minimum and mean maximum relative humidity for the same period was 23 % and 98 %, respectively.

Geology and soil

The Garo Hills region of the Meghalaya Plateau is an extensively dissected tract formed of gneissic rocks with old inlier, and rocks of Sela group. Some patches in the northern and southern parts are formed of recent alluvium and Jaintia Series/ Simsang Series of rocks, respectively. The basement of Gneissic Complex covering an area of about 60 % of the Garo Hills of Pre-

Cambrian age is the oldest litho unit exposed in central and northern parts of Garo Hills and is composed of gneissic, granulites, migmatites, amphibolites and Bonded Iron-Formation (BIF) intruded by basic and ultra basic bodies. Over the Pre-Cambrian crest localized patchy occurrences of sedimentary rocks belonging to the Gondwana group are found comprising of pebble bed, sandstone and carboniferous shells with streak and lenses of coal. Occurrences of basaltic trap rock and rhyolitic crystals tuff as detached sheet lenses, are indicative of Cretaceous- Paleocene volcanic activity in West Garo Hills districts. Sediments of tertiary age occur extensively around Siju, Adugre, Baghmara, Rongram and many other localities towards southern part of Garo Hills. The Shella formation is composed of sandstone, lithomargic clay, shells and coal seams. The important minerals found in the region are coal, limestone, pyrite, phosphorite gypsum, glass sand, clay and iron. A strip of vast coal deposit occurs in the southern part of the Garo Hills districts. This coal is of Lower Eocene geological horizon. The concerned rocks belong to the Jaintia Series. In the entire Garo hills districts the total reserve of coal has been estimated to be 39500 million tonnes and West Darenggre area has more than 35 % of it. A considerable portion of this deposit falls under the Nokrek Biosphere Reserve, and lies in the southern and eastern buffer zone of the BR. Because of the ecological setting, peculiar land holding systems and lack of infrastructure, unscientific extraction of coal in unorganized sector is going on and the area affected by coal mining is increasing day by day.

Soil is sandy to loamy sand, and red, brown to dark brown in colour. It is acidic in nature throughout the core zone. Within the buffer zone pH of the soil was lowest in the coalmine areas (4.02) and highest in the limestone mining areas where the soil reaction was alkaline (8.08). The core zone soils are rich in organic matter and nutrients (N, P, K) compared with the buffer zone soils. Within the buffer zone itself the soil properties varied significantly from site to site (Table 1.1).

Table 3.1: The physico-chemical characteristics of soil in different sites in Nokrek Biosphere Reserve.

Site	Texture	Moisture content (%)	pH	N (%)	P (μg/g)	K (μg/g)	SOM (%)
M	Loamy sand-Sandy loam	22.91 ± 1.83	5.78 ± 0.12	0.57 ± 0.11	4.1 ± 0.56	225.00 ± 45.00	6.70 ± 0.42
L	Loamy sand	14.60 ± 0.46	5.79 ± 0.02	0.26 ± 0.003	3.3 ± 0.1	60.00 ± 3.00	5.14 ± 0.23
R	Loamy sand	28.87 ± 0.44	5.79 ± 0.16	0.69 ± 0.06	2.5 ± 0.3	65.00 ± 5.00	6.68 ± 0.22
J_{12}	Sandy loam	20.86 ± 1.70	5.56 ± 0.06	0.54 ± 0.04	4.3 ± 0.05	160.00 ± 30.00	5.80 ± 0.32
J_6	Sandy loam	21.27 ± 1.68	5.98 ± 0.11	0.53 ± 0.10	2.6 ± 0.20	150.00 ± 20.00	5.12 ± 0.34
J_3	Loamy sand-Sandy loam	24.99 ± 1.05	5.99 ± 0.13	0.38 ± 0.01	2.6 ± 0.2	75.00 ± 15.00	5.62 ± 0.41
J_1	Sandy loam	21.27 ± 2.83	5.95 ± 0.17	0.56 ± 0.06	3.3 ± 0.6	205.00 ± 45.00	5.68 ± 0.19
B	Sandy loam	28.11	6.03	0.43	2.35	55.00	4.50

		± 0.54	± 0.03	± 0.06	± 0.15	± 5.00	± 0.17
O	Sandy clay	34.04 ± 1.46	5.63 ± 0.06	0.48 ± 0.056	2.5 ± 0.4	65.00 ± 15.00	4.66 ± 0.40
CM	Sandy	5.51 ± 0.72	4.02 ± 0.44	0.20 ± 0.065	2.95 ± 0.35	125.00 ± 5.00	4.74 ± 0.55
LM	Sandy clay-loam/ clay-loam	7.14 ± 1.90	8.08 ± 0.18	0.15 ± 0.030	2.70 ± 0.20	205.00 ± 45.00	2.50 ± 0.15

M- Montane forest (Core zone), L- Lowland forest, R- Riverain forests, J_{12}, J_6, J_3, J_1- Jhum fallows of different ages (10-12 years, 6-8 years, 3-4 years and 1-year old respectively), B- Bamboo groves, O- Orchards, CM- Coal mining affected ecosystems, LM- Limestone mining affected ecosystems.

Vegetation

On the basis of altitude, the climax vegetation of the area can be grouped into tropical and subtropical moist hill forests.

i) Tropical evergreen forest (altitude 200-1000 m) - This type of forest is found in the southern ridge of the core zone of the BR. It covers 137.71 sq. km area, which is 16.79 % of the total area of the BR. The forests in this zone are characterised by the presence of species like *Vitex peduncularis, Cyanometra polyantha, Aporusa wallichii, Ficus* spp. etc. Woody climbers and twiners are also abundant.

ii) Tropical semievergreen forest (altitude 200-1000 m) – This type of vegetation is restricted to certain rocky areas and steep slopes. The areas affected by coal mining show this type of vegetation. The deciduous trees like *Shorea robusta, Dillenia pentagyna, Albizzia* spp., *Parkia roxburghii,* *Rhus javanica* are commonly seen. It covers 109.25 sq. km (i.e. 13.52 %) of the total area of the BR.

iii) Tropical moist deciduous forest (altitude 200-1000 m) – Major part of the forested vegetation type is represented by the moist deciduous forests, which are confined to the buffer zone. These forests are mostly dominated by deciduous species especially *Shorea robusta*.

iv) Riverain forests (riparian fringing forests)– These forests are found in the vicinity and along the course of the rivers. The vegetation is dominated by trees like *Drimycarpus racemosa, Aesculus assamica, Sapium baccatum, Ficus* spp., etc. The presence of a variety of epiphytes, ferns and lianas makes these forests physiognomically similar to those mentioned above. These riparian fringing forests are the continuous stretches of the core area vegetation but lie outside the boundary of the core area and are affected by the disturbance to some extent due to the shifting agricultural activities in the adjoining areas.

v) Bamboo groves – The patches of bamboo are found scattered with other types of vegetation on the areas of moderate slopes mostly along the streamlets. They are spread over 15.66 sq. km and constitute 1.91 % of the total area of the BR. These are the seral stages of the above vegetation types and mainly comprise *Melocana* sp., *Dendrocalamus hamiltonii*, etc.

vi) Subtropical broad-leaved hill forest (altitude 1000-1412 m) – This forest type is confined to the core zone. Major part of the core area (63%) is covered by this forest type, which is spread over 30.54 sq. km (i.e. 3.7 %

of the entire BR). The dominant tree species in this zone are *Helicia robusta, Callophyllum polyanthum, Gynocardia odorata, Elaeocarpus rugosus, Castanopsis armata, Castanopsis tribuloides, and Engelhardtia spicata.*

In spite of the occurrence of deciduous elements, the vegetation can be described as subtropical evergreen forest, since majority of the tree species in the canopy layer is evergreen. The ground vegetation is dominated by *Impatiens* spp., *Polygonum* spp., *Ophiorrhiza* sp., *Globba clarkei*, *Hedychium* spp., *Costos specious* etc. ~~Ground~~ ferns and other pteridophytes are common on the forest floor. The tree trunks and branches are covered with profuse growth of mosses, ferns and other epiphytes.

Fauna

The area is also rich in faunal diversity. The NBR and its surrounding area harbour a variety of mammals, birds, fishes, reptiles, amphibians and invertebrates as well. The mammals found in the BR area are tiger, Indian elephant, Indian bison, leopard, leopard cat, sambar, barking deer, Indian wolf, common fox, wild pig, Malay bear, black bear, capped langur, Assamese macaque, pig tailed macaque, stump tailed macaque, Rhesus macaque, giant squirrel, binturong, slow loris, pangolin, flying squirrel, civet, five stripped palm squirrel, hare, Indian porcupine, mongoose, golden cat, hog badger, ferret badger etc.

Among the birds crested serpent eagle, great pied hornbill, Indian pied hornbill, forest eagle owl, Barn owl, scops Owl, cuckoo shrike, Indian three-toed forest kingfisher, crow pheasant, Himalayan golden back woodpecker and Indian forest night jars are the important birds. Besides, there are many varieties of ducks, parakeets, pigeons, doves, swifts, swallows, bee-eaters, wagtails, mynahs, barbets etc. A variety of lizards, snakes and other reptiles are also found in the BR.

Though this area supports a wide variety of animals, their numbers are small and thus many of these species may be under rare, endangered and threatened categories. According to one report (Anonymous, 2000), census of animals inhabiting the BR needs to be done on an urgent basis.

Demographic features

In total, 129 villages are located within the buffer zone of the NBR. The majority of the population consists of Garo tribe. The total human population within the BR is 39,432 with average density of 48.08 persons per sq. km. Population per village ranges from 20 to 2200. Ratio of female population to the male population is 1.106. The population of the children below 15 years age is 15,591.

~~The local population residing within the BR is mainly the Ga~~ros. The tribe is divided into exogamous divisions called "*chatchis*" *viz*. Sangma, Marak, Momin, Areng and Shira. Most of the Garos are Christians by faith and only a small population (10%) still follows the original Garo religion. Garo society is matrilineal and have certain institutions to control the cohesive structure of family kinship and social relationships among the clans within their respective territorial jurisdictions called "*A'khings*". The major means of subsistence is shifting cultivation, whereas some families also have orchards, paddy fields or tea gardens as the source of subsidiary earnings.

Methodology

1. Characterisation of human activities and identification of various ecosystem types in the BR

Characterisation of human activities

Various human activities having important role in altering the vegetation of the BR were identified as follows-

1. The practice of shifting cultivation
2. Coal and lime stone mining
3. Permanent agricultural and horticultural practices (viz., paddy cultivation in permanent paddy fields, planting of orchards and tea gardens etc.)

An attempt has been made to determine the relative importance of these activities causing disturbance in the BR by studying spatial pattern of disturbance i.e. proportion of area under different disturbance types caused due to human activities. This has been attempted by mapping selected sites as well as collecting secondary data from different sources with the help of questionnaires and semi-structured interviews and GIS imagery.

The above-mentioned parameters were studied through extensive field visits for characterisation of human activities.

Identification of different ecosystem types

Based on the field observations, different ecosystems were identified within the BR. Different natural ecosystem types were identified based on environmental gradients i.e. along the altitudinal gradients and dominant vegetation types. Besides these, various other undisturbed ecosystems, and man-damaged and man- managed ecosystems based on the type of human activities operating within them were also identified. These ecosystem types have been discussed in detail in Chapter IV.

Site selection for detailed study

The attempt was made to select the sites as widely as possible to represent variation among all the identified ecosystems in the northern as well as the southern region of the BR (Fig. 1.1b and 1.1c). Two sites selected from the core area of the BR, (C-a at 1412m altitude and C-b at 1300m altitude) were from the northwestern region. In southern region, two sites in the lowland forests (L-a 708m altitude and L-b 314m altitude) were selected from buffer zone. Similarly, two sites R-a (altitude 915m) and R-b (altitude 968m) were selected from the riverain forests associated with two major rivers viz., Simsang and Dedari, respectively. ~~These riparian fringing forests are the continuous stretches of the core area vegetation but lie outside the boundary of the core area and are affected to some extent by shifting agricultural activities in the adjoining areas.~~ All these sites constituted undisturbed ecosystems. The shifting cultivation fallows of different ages, which were of common occurrence in the northern region of the buffer zone of the BR, were grouped under four age groups; 10-12 year old, 6-8 year old, 3-4 year old and 1 year old fallows. Each of these four groups was studied by selecting two sites each (J_{12}a-b, J_6a-b, J_3a-b, J_1a-b). Similarly, two sites were selected from each of the two, orchards (O-a, O-b) and bamboo groves (B-a, B-b). In the southern region, from coal mining areas two sites (CM-a, CM-b) whereas from limestone mining area only one site (LM) were selected.

Table 3.2 List of the selected sites representing different ecosystems within the BR along with their altitudes.

Ecosystems		Sites	Altitude (m)	Sampled area (ha)
Undisturbed	Montane forest in core zone	M-a	1412	0.1
		M-b	1300	0.1
	Low land forest in buffer zone	L-a	708	0.1
		L-b	314	0.1
	Riverain forest in buffer zone	R-a	915	0.1
		R-b	968	0.1
Disturbed	Jhum fallows (12-yr. old)	J_{12}-a	1100	0.1
		J_{12}-b	1228	0.1
	Jhum fallows (6-yr. old)	J_6-a	1078	0.1
		J_6-b	1133	0.1
	Jhum fallows (3-yr. old)	J_3-a	1226	0.1
		J_3-b	1005	0.1
	Jhum fallows (1-yr. old)	J_1-a	1120	0.1
		J_1-b	1291	0.1
	Bamboo groves	B-a	920	0.1
		B-b	828	0.1
	Orchards	O-a	938	0.1
		O-b	831	0.1
	Coal mine spoils	CM-a	250	0.1
		CM-b	314	0.1
	Limestone mine spoils	LM	149	0.2
	Total			**2.2**

In each of these sites ten quadrats of 10m x 10m were laid randomly for all the woody individuals including trees and lianas with CBH ≥ 5 cm were enumerated. The height of the trees was measured using a calibrated bamboo stick as well as a clinometer, wherever suitable and circumference at breast height (CBH) of each individual was recorded at 1.37 m from the ground level. Shrub species were enumerated separately from these quadrats. Similarly, for the ground cover twenty quadrats of 1m x 1m were studied randomly in each site in two different seasons (dry and wet seasons).

Identification of plant species

The voucher specimens were collected from all the quadrats and identified with the help of local florae (Kanjilal *et al.* 1997, Haridasan and Rao 1985-87, Balkrishnan 1981-83). Tentative identifications were confirmed by matching the specimens with the herbarium sheets in BSI Herbarium, North-Eastern Circle, Shillong, Herbarium of Department of Botany, NEHU, Shillong and CNH, Howrah. All the identified species were recorded along with their habit and habitat details. Besides the quadrats, the plant samples were randomly collected to inventorise the plant biodiversity and were recorded under different ecosystem types identified within the study area.

Analysis of biodiversity

The analysis of biodiversity was carried out by calculating Shannon Diversity Index (H′), Simpson Dominance Index (D) and Pielou Evenness Index

(E). These indices were adopted for their low sensitivity to the sample size (Magurran 1988).

Shannon Diversity Index (H′) $= - \Sigma\ p_i \ln p_i$

i.e. $= - \Sigma\ n_i/N\ [\ln (n_i/N)]$

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

N = Importance value of all the species

Simpson's Index of dominance (D) $= \Sigma\ p_i^{\ 2}$

i.e. $= \Sigma\ (n_i/N)^2$

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

N = Importance value of all the species

Pielou Evenness Index (E) $= H'/ \ln S$

Where, H′ = Shannon Diversity Index

S = Total number of species

α diversity (D) was calculated according to Whittaker(1960)

$$D = S/ \log N$$

Where, S = Total number of species in the sample

N= Total number of individuals in the sample

β diversity (β_w) was calculated according to Whittaker(1960)

$$\beta_w = (S/ \alpha) - 1$$

Where, S = Total number of species in a system

α= The mean species richness

Enumeration of endemic, rare, threatened and medicinal plants of the BR

List of endangered, rare and endemic plants was prepared using available literature (Deb 1958, Balakrishnan 1981-83, Rao and Haridasan 1983, Das and Deori 1983, Haridasan and Rao 1985-1987, Kumar 1991, Samant *et al.* 1998, Kataki 1983, Chauhan 1983, Khan *et al.* 1997). Besides, an attempt has been made to categorize all the species encountered during this study into different forms of rarity following Rabinowitz's method (Rabinowitz 1981, Rabinowitz *et al.* 1986).

Data on medicinal plants occurring in the BR were collected from primary as well as secondary sources. The techniques such as participatory observations, semi-structured interviews were used to collect the primary data regarding medicinal plants used by the local Garo people inhabiting the BR. Four local herbal practitioners (locally known as *oza*) were interviewed and relevant information about the medicinal plants *viz.*, their local names, habitat, parts used and their different uses were documented. The voucher specimens were collected and identified with the help of local florae as well as the herbaria in the Botany department, NEHU, BSI, North-Eastern Circle, Shillong and CNH, Howrah.

An extensive literature survey was carried out to record all the well-known medicinal plants occurring in the BR. ~~The plants were collected, identified and~~ their uses were noted down with the help of available literature (Dymok *et al.* 1890, Kirtikar and Basu 1933, Rao 1981, Rao and Shanpru 1981, Bentley and Trimen 1983, Neogi *et al.* 1989, Warrier *et al.* 1993).

Analysis of community structure

Kershaw (1973) distinguishes three components of vegetation structure:

a) Quantitative structure (i.e. abundance of each species in the community)

b) Horizontal structure (spatial distribution)

c) Vertical structure (distribution into different layers/ strata)

a) Quantitative structure was studied by determining density, frequency, basal cover and IVI of each species in the selected communities following the methods given by Müeller-Dombois and Ellenberg (1974).

Frequency indicates number of sampling units in which a given species occurs and thus expresses the distribution or dispersion of various species in a community. It was calculated using the following formula:

$$\% \text{ Frequency} = \frac{\text{Number of sampling units in which the species occurred}}{\text{Total number of sampling units studied}} \times 100$$

All the species are then classified into five frequency classes as follows,

A	1-20 %
B	21-40 %
C	41-60 %
D	61-80 %
E	81-100%

The normal distribution according to Raunkiaer's law of frequency class is A>B>C D<E. The proportion of the species in different frequency classes gives the homogeneity or heterogeneity of the community. The higher the value of class E, the more is the homogeneity.

Density and abundance represent the numerical strength of species in the community.

Density is expressed as the number of individuals of a species per unit area and is calculated as follows:

Density (number of plants per sample unit) =

$$\frac{\text{Total number of individuals of a species in all the sample units}}{\text{Total number of sample units studied}}$$

Abundance is expressed as the number of individuals per quadrat of occurrence and is calculated as follows:

$$\text{Abundance} = \frac{\text{Total no of individuals of a species}}{\text{Number of quadrats of occurrence of the species}}$$

Basal cover refers to the area of ground penetrated by the stem and is measured as,

$$\text{Basal cover} = \frac{(CBH)^2}{4\pi}$$

Dominance is the function of density and basal cover which is given as,

Dominance = Mean basal area per individual x Total number of individuals in a species

Relative density, relative frequency, relative dominance and Importance Value Index (IVI) were calculated from above data. IVI was calculated as,

IVI (trees)

= Relative frequency + Relative Density + Relative Dominance

and

IVI (shrubs and herbs) = Relative frequency + Relative Density

b) Horizontal structure of selected communities was analysed by the formula outlined by Whitford (1948)

$$\text{Whitford's Index} = \frac{\text{Abundance}}{\text{Frequency}}$$

A/F ratio	=	< 0.025	(Regular distribution)
A/F ratio	=	0.025 – 0.05	(Random distribution)
A/F ratio	=	> 0.05	(Clumped distribution)

c) Vertical structure of selected communities was analysed with the help of life form spectra and profile diagrams.

Life forms

Life forms provide description of the vegetation on physiognomic basis. The species are classified on the basis of the position of perennating organs/ buds, which provide an indication of the manner in which the plant survives the unfavourable season.

All the species encountered in the study area were identified and classified under different life forms as per the Raunkiaer's classification (1934).

Phanerophytes	Trees and shrubs having perennating buds above 0.3 m
Chamaephytes	Herbs or low woody plants having perennating buds just above the ground level up to 0.3 m
Hemicryptophytes	Perennating buds borne close to ground/ half hidden in soil

Cryptophytes	Perennating buds below soil/ water surface
Therophytes	Annuals, which survive unfavourable season through seeds or spores.
Lianas	Woody climbers
Pseudo-lianas (Hemi-epiphytes)	plants, which germinate on other plants and establish their roots in the ground, or germinate on the ground and grow on other trees disconnecting from the soil.
Epiphytes	Plants germinating and rooting on other plants

Profile diagrams

Profile diagrams of the selected communities dominated by tree components (core zone communities, jhum fallows, and mining areas) were prepared to illustrate the details in vertical spacing of the species. A transect of 30 m-60 m x 5.0 m was established in each of these stands. The dominant individuals were drawn to the scale on a graph paper indicating their position, height, bole height and crown cover.

Comparison of stands

The qualitative comparison between the pair of sites representing same or different communities was carried out by calculating Sorensen Index (Magurran 1988)

$$\text{Sorensen Index} = \frac{2j}{(a + b)} \text{ X } 100$$

where, j = the number of species common to both sites

a = the number of species in site A, and

b = the number of species in site B.

The quantitative similarity between the stands representing different ecosystems has been worked out following Morisita-Horn index (C_{MH}),

$$C_{MH} = \frac{2\sum (an_i \, X bn_i)}{(da+db) \, aN \, X bN}$$

where, aN = the number of individuals in site A

bN = the number of individuals in site B

an_i = the number of individuals in the i^{th} species in site A

bn_i = the number of individuals in the i^{th} species in site B

$$da = \frac{\sum an_i^2}{aN^2} \quad , \quad \text{and} \quad db = \frac{\sum bn_i^2}{bN^2}$$

CHAPTER IV

IDENTIFICATION OF ECOSYSTEM TYPES IN THE BIOSPHERE RESERVE AND THREATS TO BIODIVERSITY

Introduction

Conservation requires the protection of sufficient diversity to underwrite the resilience of ecological systems within and outside the protected areas such as biosphere reserves (BRs). To identify different major ecosystems within a BR, and to assess the diversity within each one of them, becomes the first and foremost step in the process of comparing the ecosystems. This needs to be followed by studies, which focus more specifically on how the structural characteristics of ecosystems change along a gradient of increasing human modifications.

Ecosystems are dynamic units of nature possessing structural and functional characteristics, which vary in magnitude or rate in space and time. The biological components of ecosystems are populations of species, which share a common environment. An ecosystem, as defined by Fosberg (1967), is 'the sum total of vegetation, animal and physical environment, in whatever size segment of the world'. Biogeocenosis, which is synonymous to ecosystem, is defined as 'an assembly or a specific area of land surface of homogeneous natural elements (atmosphere, mineral strata, vegetation, animals and microorganisms, soils and hydrological conditions), with its own specific interrelationships among these components and a definite type of inter-change of materials and energy among themselves and with other natural phenomena and representing an internally contradictory dialectical unity, being in constant movement and development' [Sukachev and Dylis (1964) as cited by Johnson and French (1981)]. Thus, the concept of ecosystem is based on continuity in structure and dynamics, specific spatial limits and homogeneity. Vegetation is the driving element in a dynamic system influenced by all the elements of both the biocoenosis and the biotope. Any type of vegetation stand, whether wild, man-managed or purely artificial, represents an ecosystem.

The operational design divides the BR into two structural components pertaining to different levels of protection viz., strictly protected core zone which denies the disturbance activities, and multipurpose buffer zone which is established around the core zone as site for development related activities. The entire landscape of the BR is highly heterogeneous and shows a mosaic of different elements such as forests, fields, rivers, villages and corridors. Patchworks of active fields, orchards, abandoned fields, secondary growth forests and primary forest are the norm. But the scene is ever-changing interplay of active use by initial colonizers, abandonment, partial recovery through natural processes and then subsequent re-use of the land. This variation in the landscape within the BR is mainly a reflection of the abiotic factors in the core zone, while in the buffer zone the human activities are responsible for modifying the natural communities.

Major ecosystems of the BR were thus identified at community level, based on the extent of human impact as a broad criterion. They are as follows:

A. Undisturbed natural ecosystems

1. Sub-tropical evergreen forests
2. Tropical evergreen forests
3. Tropical semi-evergreen forests
4. Tropical moist deciduous forests
5. Riverain forests

B. Human-impacted ecosystems

a. Secondary (semi-natural) ecosystems

6. Successional communities on shifting cultivation areas
7. Bamboo groves

b. Man-managed (artificial) ecosystems

8. Orchards
9. Paddy fields
10. Tea gardens

c. Man-damaged ecosystems

11. Coal mining areas
12. Limestone mining areas

Out of these ecosystem types, all except five (tropical evergreen, semi-evergreen, moist deciduous, the paddy fields and tea gardens) were studied in detail during the present study. Based on the satellite imageries (Roy *et al.* unpublished), mapping of all the above-mentioned ecosystems except riverain forests and tea gardens has been carried out (Fig 4.1 and 4.2). Table 4.1 gives an account of the area occupied by the different undisturbed and disturbed (human –impacted) ecosystems in the Nokrek BR. It reveals that the core zone shows only natural ecosystems. In the buffer zone, 421.71 sq km (45. 71 %) area is occupied by the natural ecosystems, while 346.72 sq. km (44.88 %) area is covered by the semi-natural and modified ecosystems, out of which 40.69 % of the buffer zone area is under shifting cultivation alone.

Table 4.1 Ecosystem types and the area under each type in the Nokrek BR.

Vegetation Type		Area sq. km	Area %
Undisturbed Natural Ecosystems			
Core zone	Sub-tropical evergreen Forests	30.54	3.7
Core and Buffer zone	Tropical Evergreen Forests	137.71	16.79
	Tropical semi-evergreen Forests	109.25	13.52
	Tropical moist deciduous Forests	191.69	23.37
Human-impacted ecosystems			
Buffer zone	Abandoned Jhum	210.99	25.73
	Current Jhum	103.38	12.61
	Settled agriculture (mostly paddy)	7.14	0.87
	Bamboo groves	15.66	1.91
	Orchard	9.55	1.16
Water bodies		4.09	0.49
Total		**820.00**	**100.00**

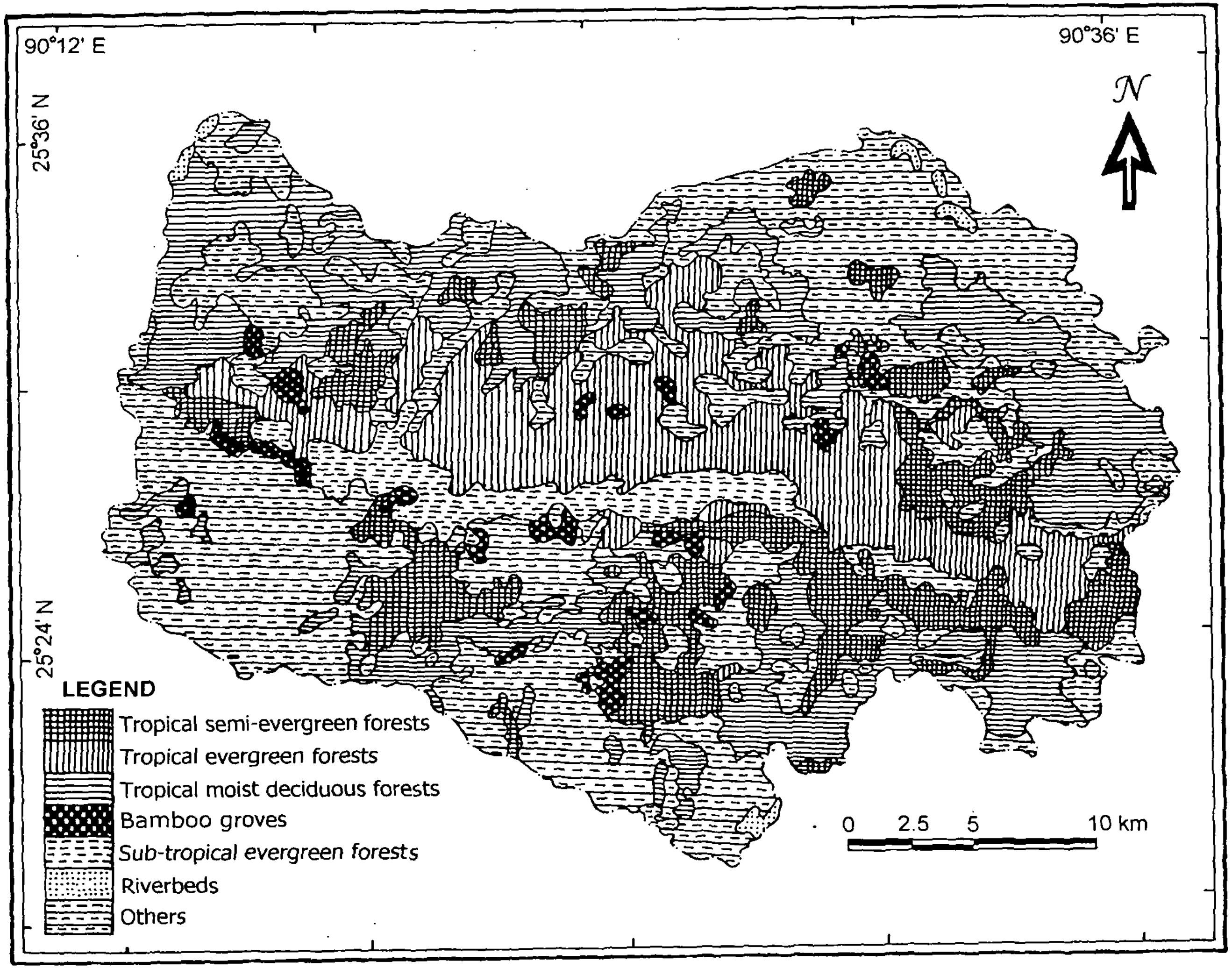


Fig. 4.1 Map showing different vegetation types of the Nokrek Biosphere Reserve.

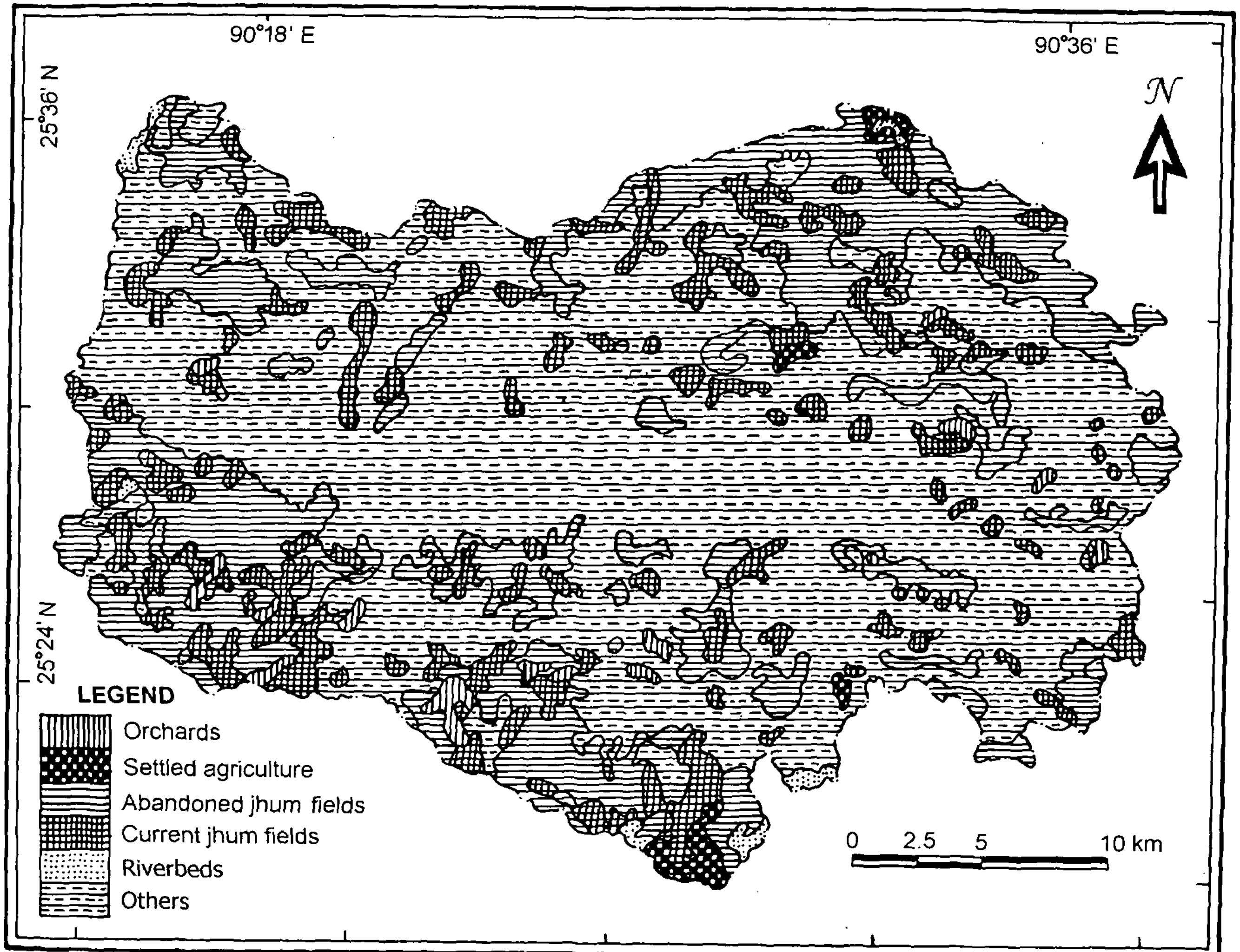


Fig. 4.2 Map showing various human activities within the Nokrek Biosphere Reserve.

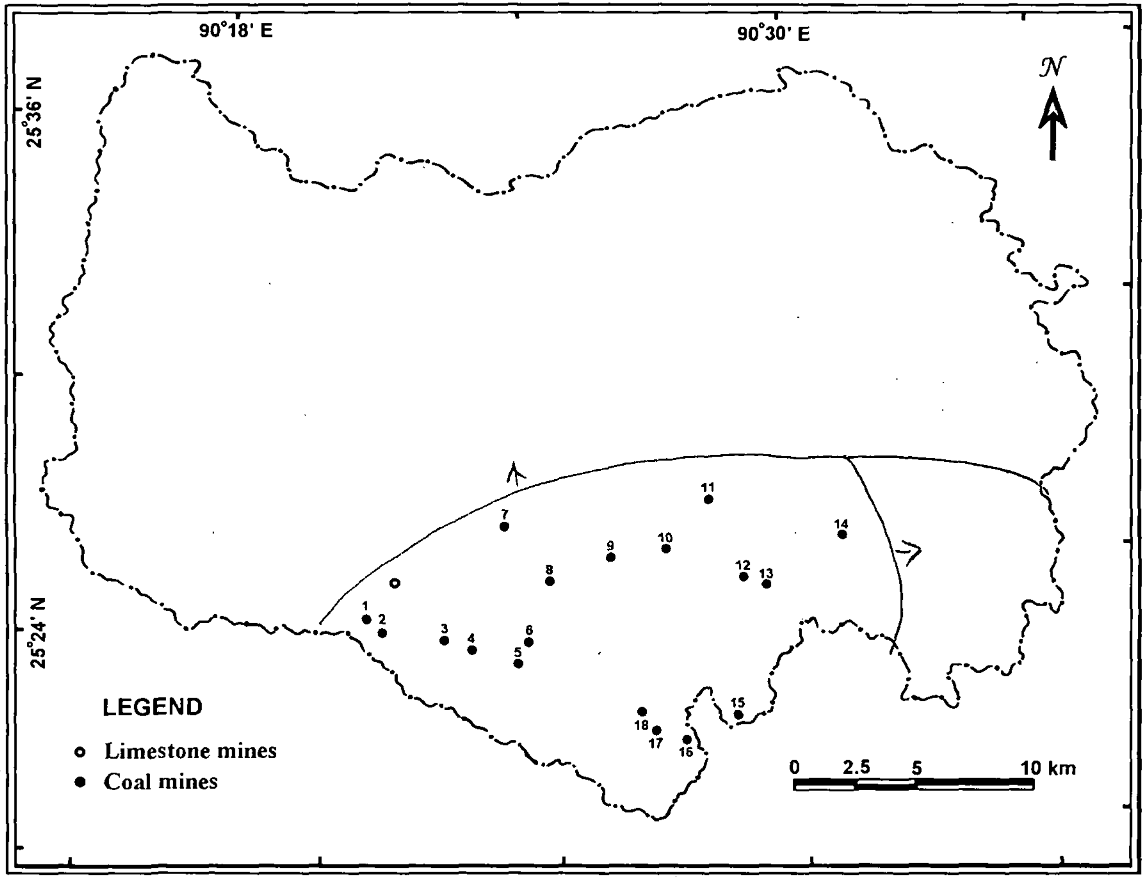


Fig. 4.2 Map showing locations of villages practicing limestone and coal mining the Nokrek BR.

1. Bandarigre, 2. Rongdianchengre 3. Rongragre, 4. Khamalgre, 5. Rongphakgre
6. Anchenggre, 7. Ruabangagre, 8. Rongmigre, 9. Rongrugre, 10. Darenggre,
11. Jetragre, 12. Khakijagre, 13. Rongmagre, 14. Pharamgre, 15. Khibalamagre,
16. Gopgre, 17. Budugre, 18. Budu Wathegre.

A. Undisturbed natural ecosystems

The Nokrek BR is spread between the altitudinal range of 200 to 1415 m asl. This altitudinal range divides the Nokrek BR into tropical zone covering the area up to 1000 m asl and sub-tropical zone, which is further above. The tropical zone harbours evergreen, and semi-evergreen forest types, and riverain forests depending upon the rainfall and soil conditions.

1. Subtropical evergreen forest (altitude 1000-1412 m)

It is also described as sub-tropical broad-leaved hill forest by Champion and Seth (1968). This forest type is confined to the core zone. Major part of the core area (64.32 %) represents this forest type, which is spread over 30.54 sq. km (i.e. 3.7 % of the entire BR). The dominant tree species in this zone are *Helicia robusta, Callophyllum polyanthum*, *Gynocardia odorata*, *Elaeocarpus rugosus*, *Castanopsis armata, Castanopsis tribuloides* and *Engelhardtia spicata,* which are densely interwoven by lianas. The shrub species include *Dendrocnide sinuata, Lasianthus hookerii, Rhynchotechum ellipticum*, *Boehmeria platyphylla, Leea crispa* and *Allophyllus distachys.* During wet season members of Acanthaceae are quite abundant (Plate 1 and 3).

The ground vegetation is dominated by *Impatiens* spp., *Polygonum* spp., *Ophiorrhiza* sp., *Globba clarkei*, *Hedychium* spp., *Costos specious* etc. Ground ferns and other pteridophytes are common on the forest floor. The tree trunks and branches are covered with profuse growth of mosses, ferns, orchids and other epiphytes. This forest type has been referred to as the montane forest in the subsequent chapters.

2. Tropical evergreen forest (altitude 200-1000 m)

This type of forest is found northern to the ridge of the core zone of the BR. It covers 137.71 sq. km area, which is 16.79 % of the total area of the BR. However, the core zone comprises comparatively very small proportion of evergreen forest spread over approximately 16 sq. km. The forests in this zone are characterised by the presence of species like *Mesua ferrea*, *Vitex peduncularis, Cyanometra polyantha, Aporusa wallichii*, *Polyalthia cerasoides*, *Ficus* spp. etc. Woody climbers and twiners are abundant.

Shrub components are *Dracaena elliptica*, *Leea edgeworthii*, *Ardisia thomsonii*, *Trigonostemon semperflorens*, *Actephila excelsa*, etc. Ground vegetation includes species such as, *Elatostemma sikkimense*, *Begonia palmifolia*, *Pilea umbrosa*, *Acanthus leucostachys*, ferns and many members of family Liliaceae. This forest type has been referred to as the lowland forest in the subsequent chapters (Plate 2 and 4).

Tropical and sub-tropical evergreen forests are the major ecosystem types in the core zone. They are characterized by the dense canopy, high humidity, low infiltration of light, diverse composition, abundant evergreen species and luxuriant growth of the epiphytes. These two ecosystem types also constitute a very important watershed system. Three major river systems of the state namely, Simsang and Ganol in the northern part, and Dareng in the sothern part of the BR originate from this area. In addition, other rivers such as Dedari, Mandal, Kampil, Chibe, Rombong etc. also originate from the core zone of the BR.

The proposed 'Citrus gene pool Sanctuary' is also situated in these forests, the concept of which came into existence since the National Bureau of Plant Genetic Resources of Indian Council for Agricultural Research (I.C.A.R.), Shillong discovered through their intensive investigation and research that this region is the reservoir of large varieties of the cultivated Citrus fruits which are grown all over the northeast India.

Prior to the acquisition of the land for the National Park, it belonged to the Village communities (*A'khings*) and there was a free access to the forest resources including timber at times. The commonly collected non-timber forest products include cane, medicinal plants/ plant parts, thatch grass and also Agar-wood from the southern sector. After the declaration of the National Park (1986) the encroachments have been ceased apparently. Besides the legal protection, remoteness and low accessibility have contributed towards the protection of these forests.

3. Tropical semi-evergreen forest (altitude 200-1000 m)

This type of vegetation is restricted to some rocky areas and steep slopes. It shows relatively less dense canopy due to the presence of deciduous tree species in the canopy layer. The deciduous trees like *Shorea robusta, Dillenia pentagyna, Albizzia* spp, *Parkia roxburghii, Rhus javanica* are commonly seen. It covers 109.25 sq. km (i.e. 13.52 %) of the total area of the BR. Lianas are scarce, however, the shrub and herbaceous layers have many species in common with the tropical evergreen forests.

4. Tropical moist deciduous forest (altitude 200-1000 m)

Major part of the forested vegetation type is represented by the moist deciduous forests, which are confined to the buffer zone. These forests are mostly dominated by deciduous tree species especially *Shorea robusta.* Other dominant species are *Prunus jenkinsii, Lagerstroemia parviflora, Albizia chinensis, Gmelina arborea*, *Careya arborea* and *Bridelia retusa.*

Shrub layer is dense with *Desmodium* spp., *Flemingia macrophylla*, *Holarrhena antidysenterica*, *Smilax* spp. etc. The herbaceous layer is luxurious with site-specific wide range of species, dominated by grasses and also invasive weeds such as *Epatorium odoratum*, *Lantana camara*, etc. Spelling?

5. Riverain forests

These forests are found in the vicinity of and along the course of the rivers (Plate 5). They form the seral type of tropical forests and are described as edaphic formations of the riverbanks due to the constant supply of telluric moisture (Champion and Seth 1968). The vegetation is dominated by trees like *Caryota urens*, *Drymicarpus racemosa, Aesculus assamica, Sapium baccatum, Ficus* spp. etc. The species such as, *Leea indica*, *Leea edgeworthii*, *Dracaena elliptica*, *D. angustifolia*, *Rhinchotechum* spp., *Piper* sp. form the shrub layer. The presence of variety of epiphytes, ferns and lianas makes these forests physiognomically similar to evergreen forests mentioned above. These riparian fringing forests are the continuous stretches of the core area vegetation but lie outside the boundary of the core area. These are also evergreen in nature and have majority of the floral components in common with those of core zone


Plate 1


Plate 2


Plate 3


Plate 4


Plate 5

forest. The sites selected for the present study are the forests along the river Simsang and river Dedari, which originate from the core zone, and run parallel to each other in north-south direction. Being within the buffer zone these are surrounded by the agricultural land and are facing high risk of encroachment, though they are least disturbed at present.

B. Human – impacted ecosystems

a) Secondary ecosystems on shifting cultivation areas and bamboo groves

6. Successional communities on shifting cultivation areas

The basic principle of this form of agriculture is the alternation of the short crop phase with the relatively long phase of natural vegetation fallow. It maintains diversity in the cropping phase through mixed cropping, the perennial shrubs and trees being separated in time and confined to the regenerative fallow phase. It is during the latter phase that soil fertility recovery occurs, which in turn determines economic yield. The cycle of the shifting cultivation, i.e. length of the fallow period before returning to the same site for another cropping phase, within the BR varies from village to village and depends on the availability of land and population of the village. In northeast Indian hills, a minimum of 10 yr cycle was found to be necessary for its sustainability, economic and ecological efficiency, based on sustainable soil fertility management (Ramakrishnan 1992). However, it has been observed that in the villages in the northern sector of the BR jhum cycle is 6-10 years, whereas in the southern sector it has been further reduced to 3-4 years. The crop phase in majority of the villages is for two years. The main crops cultivated in jhum system are paddy, maize, millets, potato, tapioca, ginger and a variety of vegetables.

Being the major means of subsistence, shifting cultivation or jhum is practiced by 85% of the families within the BR. According to the previous records (Maikhuri *et al.* 1988), the total land area under shifting cultivation was 13,418 ha (134.18 sq. km) which is 16.4 % of total land area of the BR. However, the calculated values in the table 4.1 show that the area occupied by current as well as abandoned shifting cultivation fallows is over 300 sq. km.

The abandoned jhum fields pass through a series of successional phases, each being dominated by different species, from weeds and pioneers in the early stages to the more diverse near-climax vegetation. Once the fields are abandoned, within a year a dense cover of weeds such as *Eupatorium adenophorum*, *E. odoratum*, *Ageratum conyzoides*, *Blumea balsamifera* and grasses becomes visible (Plate 6). About three years after the harvest, woody plants developing from the coppice sprouts and root suckers begin to overtop the weed cover and form a scrub. A fallow of around 2-3 years of age shows abundance of saplings of *Macaranga indica* in this area, which grows simultaneously into a pure stand (Plate 7). The scrub gradually develops into secondary forest, which increasingly suppresses the weeds through shading. The latter stages are dominated by species such as *Macaranga indica*, *Eurya accuminata*, *Callicarpa arborea* and *Saurauia* spp (Plate 8). The mature fallows in this area have been observed to have a low height, dense growth, dominance of a few species, and simplicity of structure with only one or two layers of trees composed of more or less even-aged individuals (Plate 9). Thus, each successional phase itself represents a different ecosystem with different sets of communities and soil characteristics.

7. Bamboo groves

The Bamboo groves are scattered in small patches sporadically among the jhum fallows (Plate 10). These can be described as the arrested successional vegetation type, which follows the disturbance, mainly due to activities related to jhum, in this case. The dominant species of bamboo are *Melocana bambusoides*, *Bambusa tulda*, with a few other tree species. The ground vegetation is dense and diverse. They are spread over 15.66 sq. km and constitute 1.91 % of the total area of the BR.

b) Man-managed ecosystems (orchards, tea gardens, paddy fields)

8. Orchards

Orchards form another major land use next to shifting cultivation. Total area under orchards within the BR is 9.55 sq. km, which is about 1.16 % of the total area of the BR. Average area under orchards per village is 20.3 ha. The major fruit crop plants are Citrus species, with few other species like litchi, jackfruit, banana, peach, pears, mulberry etc. In the southern part of the BR, areca nut and cashew nut plantations are also common.

It represents a simple ecosystem with a few species of cultivated trees and associated weeds (Plate 11).

9. Settled agriculture

In addition to shifting cultivation, majority of the villages within the BR have wet rice cultivation along the valleys. This type of settled agriculture is scarce in the northern part of the BR due to the lack of suitable land. These fields represent a totally different ecosystem. They are subject to inundation, lack tree species, and comprise a number of herbaceous weeds associated with paddy crop (Plate 12).

10. Tea gardens

These have been recently introduced in this region and are found in the northern sector. However, compared with other land use systems they cover very small area. The system is totally artificial since the entire vegetation is replaced by tea, with a few deciduous tree species scattered all over the tea plantation area (Plate 13). The management practices include regular weeding and application of inorganic fertilizers.

c) Man-damaged ecosystems on mining areas

11. Coal mining areas

Coal mining operations are confined to the southern part of the Nokrek BR spread between 200 m to 500 m asl (Plate 14 and 15). The surrounding vegetation is tropical evergreen to semi-evergreen type. Commercial extraction of the coal started within the BR in 1985 at Darenggre area. Since then the number of coal mines in the BR has been increasing exponentially. At present, eighteen villages are engaged in this activity. These villages are, Darenggre, Jetragre, Budugre, Budu Wathegre, Rongragre, Khamalgre, Rongmagre, Gopgre, Khakijagre, Khibalamagre, Pharamgre, Anchenggre, Rongphakgre, Rongmigre, Rongrugre, Ruabangagre, Bandarigre, Rongdianchengre (Fig. 4.2). The thickness of the seam of coal ranges from 1.5 to 7 ft. Each of these villages has 50- 300 quarries depending on the number of families in each village. Each quarry occupies an area with approximately 60-100 m diameter. While the spoils in each quarry vary from 40-50 m in diameter, the felling of trees in the areas affected by quarries causes decrease in the forest canopy. The spoil areas are devoid of any herbaceous cover.

12. Limestone mining areas

Limestone mines are also confined to the southern part and are located just inside the boundary of the BR. The natural vegetation of this area varies from tropical semi-evergreen to moist deciduous type. Compared with the area under coalmines, limestone mines occupy much less area within the BR and thus have less impact (Plate 16 and 17).

Major threats to biodiversity

The following activities have been identified as the major threats to the plant diversity of the BR.

Plate 6

Plate 7

Plate 8

Plate 9

Plate 10

Plate 11

Plate 12

Plate 13


Plate 14


Plate 15


Plate 16


Plate 17

Shifting cultivation

Basically, shifting cultivation involves the rapid transformation of potential energy and of the biogenic matter, which has been slowly stocked by wild ecosystems into food and even production. The system of cultivation is primarily based on the concept of conservation and economical use of natural resources. This is however only true, provided that sufficient time is allowed for the regeneration of the forest and presumption of its normal ecological productivity. It is essential not to prolong the crop phase beyond the threshold level and to leave the land until its fertility is completely restored.

However, due to the rapid increase in the human population, the pressure on natural forests is increasing exponentially. Encroachment and exploitation of the various forest resources are directly or indirectly affecting the plant diversity of the area. Extensive cutting and burning activities during shifting cultivation is the major cause of denudation, which in turn, is resulting in the degradation of the area, habitat destruction and ultimately depletion of the biodiversity. Though the length of the shifting cultivation cycles varies from village to village, it is remarkably reduced in the southern parts of the BR. While in the northern part it varies from 6-10 years, in the southern parts it has been reduced to 3-4 years. Reduced shifting cultivation cycles could further prove inadequate to reclaim soil conditions required for vegetation recovery. Besides this, the enormous growth of the weeds during fallow phase arrests the growth of indigenous species affecting the local diversity.

Mining

Extensive and unscientific coal mining activities in the buffer zone of the BR have led to the increase in patchiness in the existing forest vegetation and creation of landscape dotted with mine spoils. Though limestone quarries are located near the boundary of the BR, they are growing in extent, while the coal mines are being operated in the villages very close to the core area. Both, coal as well as limestone-mining activities are causing tremendous land degradation and loss of vegetation cover, resulting ultimately in the loss of plant diversity.

Surface mining of coal causes enormous damage to the flora, fauna, hydrological relations and soil biological systems since destruction of the vegetal cover during surface mining is invariably accompanied by an extensive damage and loss to the system. Nutrient-deficient sandy spoils are generally hostile to plant growth and the revegetation and reclamation strategies other than natural colonization on mine spoils are a very tardy process. Coal minespoils represent extreme rigid substrata for plant growth and development. Among the factors, which hinder the growth of plant species on these spoils, acidity merits special mention. Extreme acidity is caused due to the oxidation of iron pyrites (FeS_2) (Chadwick 1973, Caruccio 1975) which when exposed to atmosphere produces H_2SO_4 (Bradshaw 1995). Besides acids, coal minespoils contain toxic levels of soluble elements such as Fe, Al, Mn and Cu. The physical factors, which limit plant establishment and survival, include high temperature, moisture stress (Richardson 1975), soil particle size (Down 1974), surface instability leading to erosion (Brierley 1956, Down 1975) and compaction (Hall 1957, Richardson 1975).

Soil fertility is also a major factor regulating plant growth. The two limiting nutrients on coal minespoils are nitrogen and phosphorus (William 1975, Wittwer *et al.* 1981). The shortage of organic matter is attributed to the absence of litter.

Besides these two major threats, the excessive collection of the NTFP from the forested areas within the BR, may cause depletion of the local diversity. Even today, the villagers residing within the BR are dependent on the traditional medicinal practices for their well-being. The majority of these medicinal plants are extracted from the wild, which may have a serious impact on the populations of rare or endangered species of the area. The extraction of agar wood (*Aquilaria agalocha*) from the forests was a regular practice in the southern parts of the BR (Anonymous 2000), which has contributed to the population depletion of this particular species.

CHAPTER V

PLANT DIVERSITY AND COMMUNITY CHARACTERISTICS OF UNDISTURBED MONTANE, LOWLAND AND RIVERAIN FOREST ECOSYSTEMS

Introduction

As mentioned earlier (chapter IV), the undisturbed forests present in the Nokrek BR represented five major forest types. Out of these, the subtropical evergreen forests (montane forests), tropical evergreen forests (lowland forests) and the riverain forests were studied in detail. The subtropical evergreen forests, also described as Khasi subtropical wet hill forests under the subgroup sub-tropical broadleaved hill forests (Champion and Seth 1968) are confined to the core zone of the BR and constitute 30.54 km^2 area, which is 63% of the total core zone (Roy *et al.,* unpublished). This forest type has been referred to as the montane forests in the present and subsequent chapters.

The tropical evergreen forest is found on the northern side of the core zone of the BR. Though this forest type covers a very small portion of the core zone, it occurs widely in the buffer zone. The area covered by this forest is 137.71 sq. km, which is 16.79 % of the total area of the BR. The plant diversity and community characteristics of this forest type were studied in the buffer zone of the BR. This forest type has been referred to as lowland forest in the present and subsequent chapters.

The riverain forests are located in the buffer zone of the NBR and are found in small patches fringing along the banks of the rivers. They form the seral type of tropical forests and can be described as edaphic formations developed along the riverbanks due to the constant supply of sub-soil moisture. These forests too are predominantly evergreen in nature.

Floristic composition

In total, 590 vascular species including angiosperms, gymnosperms and pteridophytes were recorded from the undisturbed montane forest, lowland forest and riverain forest. Of these, 392 species were recorded from the montane forest, 338 from the lowland forest and 327 species from the riverain forest (Appendix I).

The montane forests had several tropical as well as temperate elements. The important tropical species are, *Dysoxylum gobara*, *Mesua ferrea*, *Elaeocarpus* spp. and *Cinnamomum* spp. A few temperate species such as, *Betula alnoides*, *Castanopsis indica*, *Euonymus lawsonii*, *Viburnum coriaceum* etc. were also abundant in the community.

The lowland and riverain forests mostly comprised the tropical elements. The common species included *Calophyllum polynthum*, *Caryota urens*, *Talauma hodgsonii*, *Macropanax undulatus*, *Actephila excelsa*, *Duabunga grandiflora*, *Shorea robusta*, *Toddalia asiatica*, *Aphanamixis wallichii*, *Ficus* spp., *Syzygium* spp. and *Elaeocarpus* spp.

All the three forest communities (i.e. undisturbed montane, lowland and riverain forests) are inhabited by several primitive taxa, such as, *Actinodaphnae angustifolia*, *A. obovata*, *Beilschmiedia assamica*, *B. roxburghiana*, *Betula alnoides*, *Dillenia scabrella*, *Fissistigma verrucosum*, *Goniothalamus simonsii*, *Helicia excelsa*, *Helicia nilagirica*, *Holboellia latifolia*, *Houttuynia cordata*, *Knema angustifolia*, *Michelia oblonga*, *Myrica esculenta*, *Paramichelia baillonii*, *Polyalthia cerrasoides*, *Sarcandra glabra*, and *Talauma hodgsonii*. Thus these three forests seem to be rich in primitive taxa. Takhtajan (1969) has also stated that eastern Himalaya, Assam and upper Burma show high concentration of primitive angiosperms.

The prevalence of primitive species in the flora of these forests may throw light on the floral affinities of the NBR. According to Takhtajan (1988), the nucleus of the flora of Khasi- Manipur Province consists of eastern Asiatic elements. The list of the species recorded from the BR (Appendix I) supports this view. The list also shows that the flora of Nokrek BR has got strong affinity with the flora of Sino-Himalayan, and Burma-Malayan regions. *Bruinsmia, Bulbophyllum, Camellia, Cymbidium, Kadsura* are few of the Chinese and Himalayan genera, while *Balanophora*, *Engelhardtia*, *Miliusa*, *Rubus*, *Talauma* are the Burma-Malayan genera. Besides, a few Sino-Japanese elements such as, *Eurya accuminata*, *Pericampylos glaucus*, were also present. In addition, the flora of the BR exhibits several floral elements of peninsular India such as *Helicia nilagirica, Munronia pinnata, Ficus nervosa*, *Mastixia arborea* and *Syzygium cumini*.

Taxonomic diversity

The total number of species (590 species) recorded from these three the forests include 558 angiosperms, which is 94.6% of the total, followed by 29 pteridophytes and 3 gymnosperms (Appendix I).

The total number of families recorded was 134 of which 119 families were angiospermic, and 3 were gymnospermic while 12 belonged to pteridophytes. Out of 115 families recorded in the montane forests Rubiaceae was the most dominant family contributing 22 species and 17 genera, whereas Lauraceae (22 species, 9 genera), Euphorbiaceae (19 species, 14 genera), and Orchidaceae (14 species, 11 genera) were the co-dominant families. Forty eight families were represented by only one species, and 19 families by two species.

In the lowland forests, 107 families were recorded. In this forest also Rubiaceae was the dominant family contributing 22 species and 17 genera. The co-dominant families were Euphorbiaceae (17 species, 16 genera) and Lauraceae (15 species, 9 genera). Forty one families were represented by only one species and 24 families by two species in this forest.

In the riverain forests, in all, 104 families were recorded of which Euphorbiaceae was found to be the richest with 15 species and 11 genera. The co-dominant families in these forests were Rubiaceae (14 species, 12 genera), Lauraceae (13 species, 7 genera) and Moraceae (11 species, 3 genera). Thirty-nine families were represented by only one species and 22 families by two species.

These three forest ecosystems had 88 families in common. Twelve families were recorded exclusively from the montane forests, 5 from the lowland forests, and 4 families from the riverain forests.

A total of 390 genera (275 genera from the montane forests, 260 from the lowland forests and 240 genera from the riverain forests) were recorded from these three forests out of which angiosperms, gymnosperms and pteridophytes were represented by 366, 3 and 21 genera, respectively. Out of these, 261 genera were represented by only one species while 92 genera were represented by more than one species. *Ficus* was the largest genus with 12 species, followed by *Syzygium* with 10 species, *Litsea* with 7 species and *Castanopsis* and *Garcinia* with 5 species each.

Table 5.1 Family-wise distribution of genera and species encountered in the undisturbed montane forest, lowland forest and riverain forest of the Nokrek BR.

Family	Montane forest		Lowland forest		Riverain forest	
	No. of genera	No. of species	No. of genera	No. of species	No. of genera	No. of species
Angiosperms						
Rubiaceae	17	22	17	22	12	14
Lauraceae	9	22	9	15	7	13
Euphorbiaceae	14	19	16	17	11	15
Orchidaceae	11	14	9	9	10	10
Annonaceae	7	10	6	8	3	6
Rutaceae	8	10	6	6	6	6
Urticaceae	6	9	4	8	6	8
Zingiberaceae	6	8	5	7	4	6
Verbenaceae	4	8	4	6	3	7
Clusiaceae	4	8	3	5	3	5
Gesneriaceae	5	8	3	5	3	5

Sapindaceae	6	7	7	9	4	4
Fagaceae	3	7	2	3	3	7
Asteraceae	6	7	2	2	7	8
Araceae	5	6	6	7	6	7
Myrsinaceae	3	6	4	6	1	2
Arecaceae	4	6	4	6	2	3
Myrtaceae	1	6	1	6	1	3
Meliaceae	5	6	5	5	1	1
Araliaceae	5	6	3	3	3	3
Rosaceae	4	6	1	2	4	8
Elaeocarpaceae	1	6	1	1	2	5
Vitaceae	4	5	4	7	2	2
Moraceae	1	5	4	5	3	11
Asclepiadaceae	3	5	3	4	2	3
Liliaceae	5	5	3	3	5	5
Theaceae	4	5	1	1	3	3
Lamiaceae	4	4	5	5	1	1
Acanthaceae	2	4	5	5	5	6
Flacaurtiaceae	4	4	4	4	5	5
Celastraceae	3	4	2	2	2	3
Melastomataceae	3	4	2	2	3	4
Oleaceae	2	4	2	2	2	4
Piperaceae	1	4	1	2	2	4
Balsaminaceae	1	4	1	1	1	3
Leeaceae	1	4	1	1	1	4
Sterculiaceae	2	3	3	5	1	2
Sabiaceae	2	3	2	3	2	2
Smilacaceae	1	3	1	3	1	2
Apocynaceae	3	3	3	3	3	3
Anacardiaceae	3	3	3	3	5	5
Menispermaceae	3	3	2	2	3	3
Cyperaceae	3	3	1	2	3	5
Aqifoliaceae	1	3	1	1	0	0
Tiliaceae	2	3	1	1	2	3
Poaceae	2	2	9	10	7	7
Scrophulariaceae	2	2	4	5	2	2
Fabaceae	2	2	4	5	6	8
Begoniaceae	1	2	1	3	1	1
Symplocaceae	1	2	1	3	1	1
Commelinaceae	1	2	2	3	1	2

Polygonaceae	1	2	1	3	1	3
Dracaenaceae	1	2	1	2	1	2
Sapotaceae	1	2	1	2	1	2
Staphylaceae	1	2	1	2	1	2
Malvaceae	2	2	1	1	2	2
Saurauiaceae	1	2	1	1	1	2
Aceraceae	1	2	0	0	0	0
Proteaceae	1	2	0	0	0	0
Solanaceae	1	2	0	0	1	1
Apiaceae	2	2	0	0	2	2
Mimosaceae	1	1	2	4	2	2
Caesalpiniaceae	1	1	2	2	1	1
Malpighiaceae	1	1	1	2	1	1
Myristicaceae	1	1	1	2	1	1
Magnoliaceae	1	1	2	2	2	2
Betulaceae	1	1	1	1	0	0
Caprifoliaceae	1	1	1	1	0	0
Ebenaceae	1	1	1	1	0	0
Lardizabalaceae	1	1	1	1	0	0
Loranthaceae	1	1	1	1	0	0
Soneraceaceae	1	1	1	1	0	0
Thymeleaceae	1	1	1	1	0	0
Amarantaceae	1	1	1	1	1	1
Baringtoniaceae	1	1	1	1	1	1
Capparidaceae	1	1	1	1	1	1
Chloranthaceae	1	1	1	1	1	1
Cornaceae	1	1	1	1	1	1
Crypteroniaceae	1	1	1	1	1	1
Hypoxidaceae	1	1	1	1	1	1
Marantaceae	1	1	1	1	1	1
Ranunculaceae	1	1	1	1	1	1
Taccaceae	1	1	1	1	1	1
Vacciniaceae	1	1	1	1	1	1
Aristolochiacaea	1	1	1	1	1	2
Balanophoraceae	1	1	0	0	0	0
Elaeagnaceae	1	1	0	0	0	0
Erythroxylaceae	1	1	0	0	0	0
Iteaceae	1	1	0	0	0	0
Juglandaceae	1	1	0	0	0	0
Lobeliaceae	1	1	0	0	0	0

Orobanchaceae	1	1	0	0	0	0
Pandanaceae	1	1	0	0	0	0
Pittosporaceae	1	1	0	0	0	0
Violaceae	1	1	0	0	0	0
Caryophyllaceae	1	1	0	0	1	1
Hypoxidaceae	1	1	0	0	1	1
Oxalidaceae	1	1	0	0	0	1
Plantaginaceae	1	1	0	0	1	1
Cucurbitaceae	1	1	0	0	2	2
Connaraceae	0	0	2	3	1	1
Dilleniaceae	0	0	1	2	0	0
Combretaceae	0	0	1	2	1	2
Dioscoreaceae	0	0	1	2	1	2
Rhamnaceae	0	0	1	2	1	3
Bignoniaceae	0	0	1	1	0	0
Dipterocarpaceae	0	0	1	1	0	0
Rhizophoraceae	0	0	1	1	0	0
Semaraubaceae	0	0	1	1	0	0
Stemonaceae	0	0	1	1	0	0
Bischofiaceae	0	0	1	1	1	1
Convolvulaceae	0	0	1	1	1	1
Lythraceae	0	0	1	1	1	1
Ulmaceae	0	0	1	1	1	1
Loganiaceae	0	0	1	1	2	2
Olacaceae	0	0	0	0	1	1
Passifloraceae	0	0	0	0	1	1
Santalaceae	0	0	0	0	1	1
Saururaceae	0	0	0	0	1	1
Gymnosperms						
Taxaceae	1	1	1	1	0	0
Podocarpacaeae	1	1	0	0	1	1
Gnetaceae	1	1	0	0	0	0
Pteridophytes						
Aspidiaceae	5	5	4	4	3	3
Aspleniaceae	2	3	2	3	1	1
Polypodiaceae	3	3	1	2	2	4
Adiantaceae	2	2	2	2	2	2
Pteridaceae	1	2	2	2	1	2
Thalypteridaceae	1	2	0	0	1	1
Lycopodiaceae	1	1	1	2	1	1

Selaginellaceae	1	1	1	2	1	1
Lygodiaceae	1	1	1	1	1	1
Marathiaceae	1	1	1	1	1	1
Davaliaceae	1	1	1	1	0	0
Ophioglossaceae	1	1	0	0	0	0
Total	**275**	**392**	**260**	**338**	**240**	**328**

Distribution of the total species encountered from all the three undisturbed ecosystems into different synusiae (Table 5.2) shows that except shrubs all other categories were more numerous in the montane forests than in the riverain forests. All the forests showed preponderance of tree species followed by herb species.

Table 5.2 Distribution of species in different synusiae in the undisturbed montane forest, lowland forest and riverain forest of the Nokrek BR.

	Montane forest		Lowland forest		Riverain forest	
Trees	174	(44.39)	141	(41.72)	121	(36.89)
Shrubs	59	(15.05)	48	(14.20)	63	(19.21)
Scandents or lianas	29	(7.40)	32	(9.47)	27	(8.23)
Climbers	21	(5.36)	21	(6.21)	21	(6.40)
Herbs	82	(20.92)	76	(22.49)	71	(21.65)
Epiphytes	27	(6.89)	20	(5.92)	25	(7.62)
Total	**392**	**(100)**	**338**	**(100)**	**328**	**(100)**

(Values in the parentheses are the percentages of the total)

Community characteristics

Species –area relationship

Fig. 5.1 demonstrates the species –area relationship in these forests. The number of species increased with the area. The number of tree species recorded within the first 2000 m^2 area and the number of herb species recorded within 40 m^2 area, were more or less same in all three types of forests. In case of shrubs the species saturation was observed within 1500-2000 m^2. However, the asymptote level was not obtained for trees and herbs in both these forests depicting the inadequate sampling.

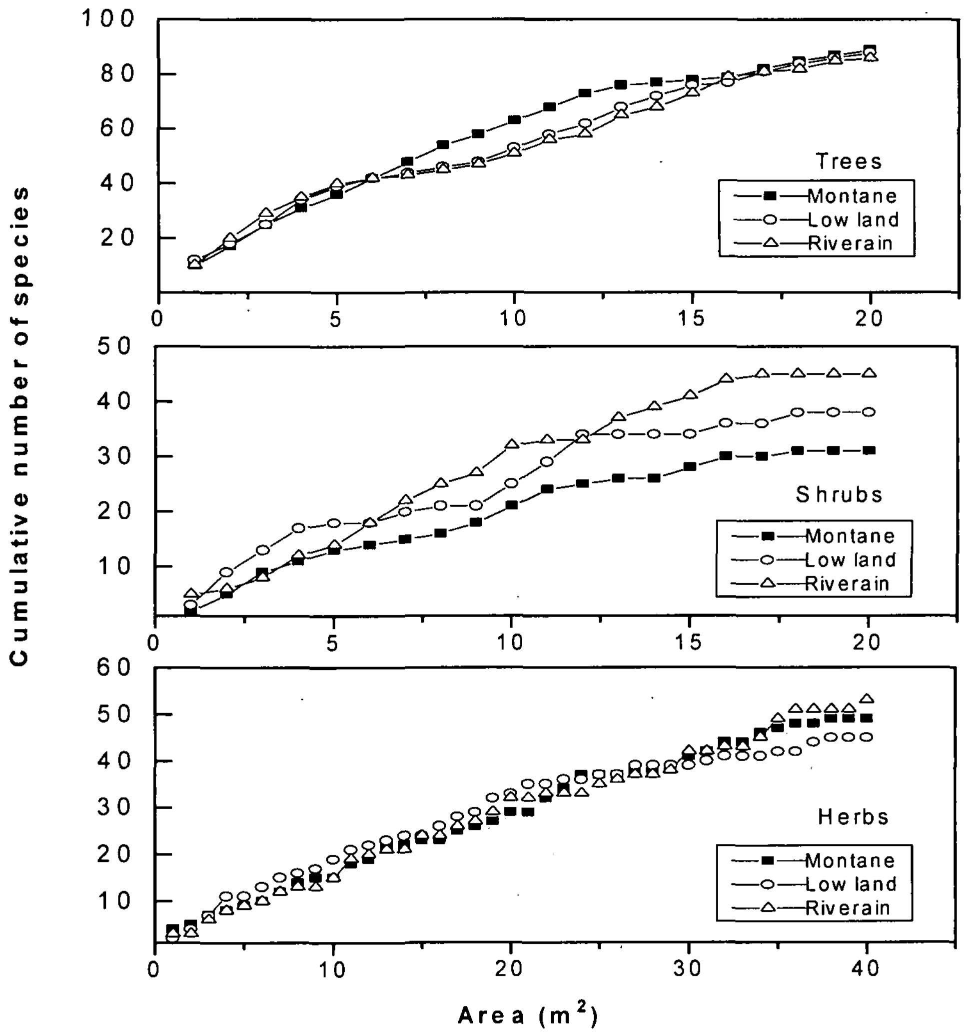


Fig.5.1 **Species-area curves for tree, shrub and herb species in the undisturbed montane, lowland and riverain forests of the Nokrek BR (Area : x 100 for trees and shrubs, and x 1 for herbs).**

Species richness

A total of 200 woody species including trees and lianas belonging to 61 families and 140 genera were recorded from 0.6 ha area from all the three forests (montane forest, lowland forest as well as riverain forest) taken together. Out of these, 89 species were recorded from 0.2 ha of the montane forest, 88 from 0.2 ha of the lowland forest and 86 species were from 0.2 ha of the riverain forest with 9 species (4.5 % of the total species) being common to all the three forest types (Table 5.3).

In case of shrubs, a total number of 79 species was recorded from these three forests, out of which 31 species were from the montane forest, 38 from the lowland forest and 45 species from the riverain forest with 8 (10 %) species common to all the three forest types. Similarly, out of a total of 101 herb species recorded from these three types of forests, 49 species were from the montane forest, 45 from the lowland forest and 53 species were from the riverain forest, and only 9 (9 %) species were common to all three forest types (Table 5.3).

Species richness of woody species per $100m^2$ varied from 7 to 26 species in the montane forest, 9 to 20 species in the lowland forest and from 5 to 15 species in the riverain forest. When the frequency of plots ($100m^2$) were plotted against different species richness classes, it revealed that 47% of the plots possessed 10-15 species, 27 % of the plots had 5-10 species whereas 23% of the plots had 15-20 species. Tree species richness of the lowland forest was more or less evenly distributed in two classes, i.e. 5-10, 10-15 species per plot with comparatively small proportion in the class 15- 20 species per plot. In the montane and lowland forests no plot was with less than 5 species. On the other hand, in the riverain forest majority of the plots (75%) had 5-10 species followed by 20 % plots having 10-15 species (Fig. 5.2).

Species richness distribution of tree species within the different girth classes showed a similar pattern in all the three forest types (Fig. 5.3). It was highest in the lowermost GBH class, and decreased gradually in the higher girth classes except the girth class >95 cm.

Table.5.3 Density and basal cover of tree, shrub and herb species of the undisturbed montane forest, lowland forest and riverain forest of the Nokrek BR, and the numbers of families and genera to which they belong.

	Montane forest			Lowland forest			Riverain forest		
	Trees	**Shrubs**	**Herbs**	**Trees**	**Shrubs**	**Herbs**	**Trees**	**Shrubs**	**Herbs**
No. of species	88	31	49	89	38	45	86	45	53
No. of families	64	25	45	77	34	43	66	36	46
No. of genera	35	16	29	43	22	31	36	26	25
Density (ha^{-1})	2595	37250	115250	1555	43750	92750	1180	44500	104000
Basal area (m^2ha^{-1})	45.95	---	---	38.25	---	---	28.15	---	---

Table 5.4 Spatial distribution of tree, shrub and herb species in the undisturbed montane forest, lowland forest and riverain forest in the Nokrek BR.

	Montane forest			Lowland forest			Riverain forest		
	Trees	**Shrubs**	**Herbs**	**Trees**	**Shrubs**	**Herbs**	**Trees**	**Shrubs**	**Herbs**
Contiguous	80 (90.9)	31 (100)	49 (100)	83 (93.2)	36 (94.7)	45 (100)	75 (87.21)	44 (97.8)	53 (100)
Random	8 (9.1)	0	0	3 (3.4)	2 (5.3)	0	11 (12.79)	1 (2.2)	0
Regular	0	0	0	3 (3.4)	0	0	0	0	0

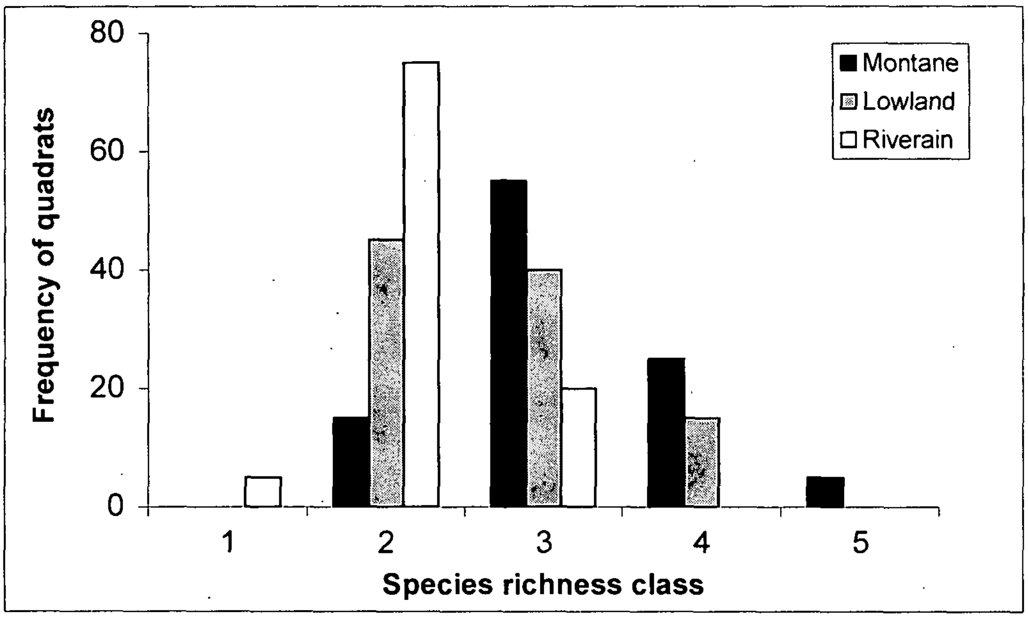


Fig 5.2 **Distribution of species richness per quadrat ($100m^2$) of tree species in the undisturbed montane, lowland and riverain forests. (Species richness classes are: (1) 0 to 5 species, (2) 6 to 10 species, (3) 11 to 15 species, (4) 16 to 20 species and (5) 21 to 25 species.**

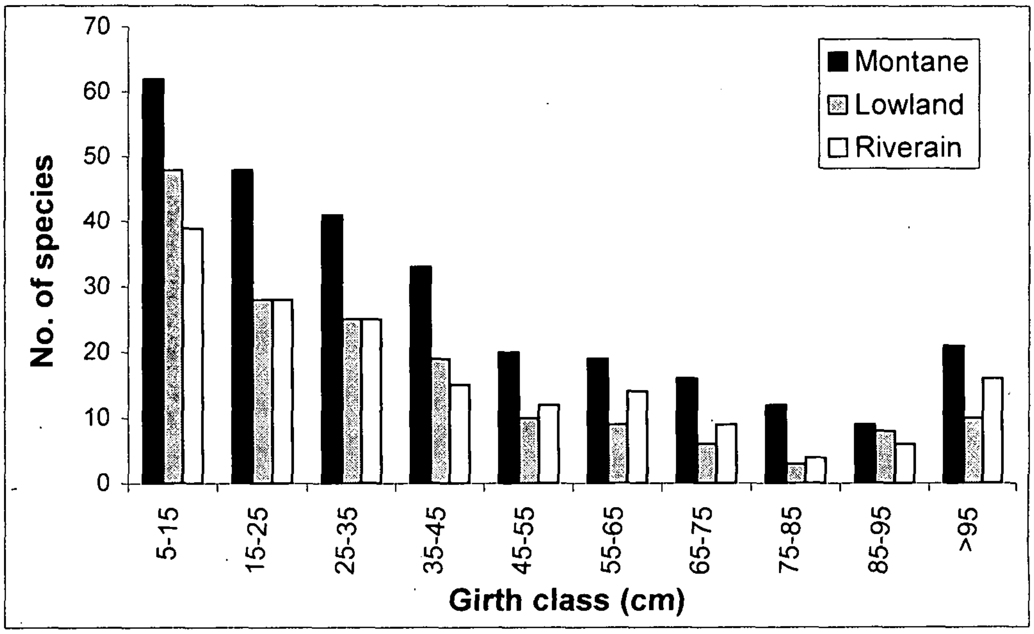


Fig 5.3 **Distribution of species richness of tree species in different girth classes in the undisturbed montane, lowland and riverain forests.**

Stratification

In all the three forests there were four distinct layers viz. (i) canopy, (ii) subcanopy, (iii) undercanopy and (iv) ground vegetation. The first three layers were composed of trees, lianas and shrubs, while ground vegetation was composed of herbs, and seedlings and saplings of the tree and shrub species. For making the profile diagrams, however, only upper three layers were considered.

The vertical structures of the vegetation of two sites at two different altitudes in the undisturbed montane forest, one in the lowland forest and one in the riverain forest are illustrated through profile diagrams presented in Fig. 5.4 a, b, c and d, respectively. Fig. 5.4-a shows the profile of a stand located at lower altitude (1250m) in the montane forest. In all 38 individuals representing 28 species were recorded. The average canopy height was 30m. Seven species comprised this layer, which also included emergent trees like *Celtis trimorensis*, *Betula alnoides* and *Syzygium grandis*. Other species forming this layer were *Mesua ferrea, Calophyllum polyanthum, Aesculus assamica* and *Gynocardia odorata.* One liana species, *Tetrastigma rumicispermum* was also present in this layer. The sub-canopy layer had more number of species (11 species), and also was more continuous than the canopy layer. *Dysoxylum gobara*, *Macropanax dispermus* and *Litsea salicifolia* were the most dominant species of this layer. The lowermost stratum of undercanopy trees and shrubs was composed of 9 species.

Fig. 5.4 b shows the profile of a stand located at higher altitude (1412m) in the montane forest. The stand differed from the stand at lower altitude in having more density and short statured and multi-trunk trees, the canopy of which hardly exceeded 20m. A total of 55 individuals belonging to 30 species was encountered in this profile. Though the canopy was composed of 8 species, it was largely dominated by *Helicia nilagirica*. Other species forming this layer were *Glochidion thomsonii, Ostodes paniculata, Castanopsis indica, Calophyllum polyanthum, Castanopsis armata*, *Elaeocarpus floribundus* and *Viburnum coriaceum.* No liana was recorded in this stand. The sub-canopy layer was not so distinct from the canopy layer though it could be differentiated from the latter by its species composition. There were 11 species in this layer. The lowermost stratum of undercanopy trees and shrubs was also composed of 11 species.

Fig. 5.4 c illustrates the vertical structure of a stand in the lowland forest ecosystem. In all, 34 individuals belonging to 22 species were encountered. The average canopy height was 25 to 30 m. This layer was composed of 10 species and 11 individuals. *Parkia roxburghii* and *Mastixia arborea* were the emergent trees. The lower layer was barely distinct from the upper layer. It was composed of 8 individuals belonging to 5 species. The lowermost layer was formed of 7 species and 15 individuals. *Trigonostemon semperflorense* was the dominant species of this layer.

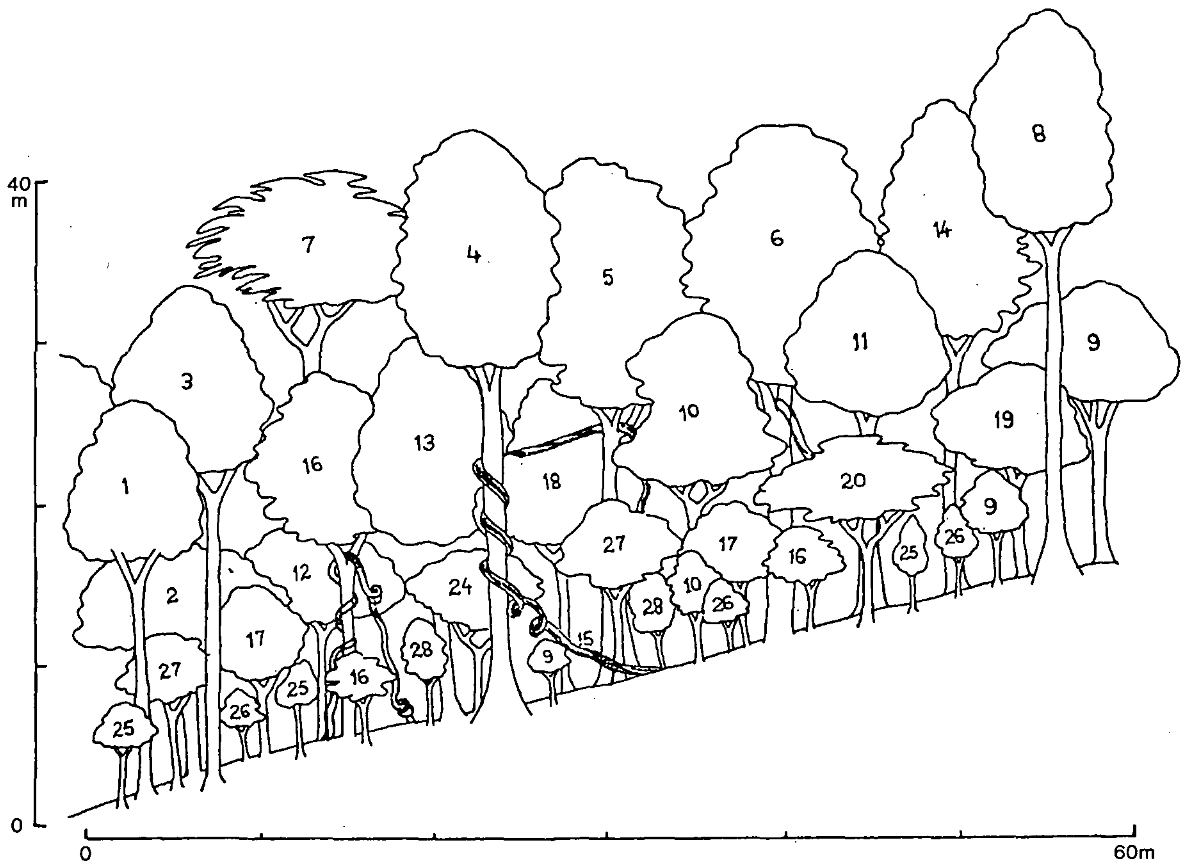


Fig. 5.4 a Profile diagram of a site (altitude 1250 m) in the montane forest.

1-*Dysoxylum gobara*, 2-*Phoebe lanceolata*, 3-*Mesua ferrea*, 4-*Syzygium grandis*, 5-*Calophyllum polyanthum*, 6-*Betula alnoides*, 7- *Celtis timorensis*, 8-*Gynocardia odorata*, 9-*Macropanax dispermus*, 10-*Litsea laeta*, 11-*Sarcosperma griffithii*, 12-*Drimycarpus racemosus*, 13-*Toona ciliata*, 14-*Aesculus assamica*, 15-*Tetrastigma rumicispermum*, 16-*Garcinia cowa*, 17-*Miliusa roxburghiana*, 18-*Ficus nervosa*, 19-*Litsea salicifolia*, 20-*Grewia disperma*, 21-*Saprosma ternatum*, 22-*Dendrocnide sinuate*, 23-*Neolitsea cassia*, 24-*Glycosmis arborea*, 25-*Capparis acutifolia*, 26-*Ardisia pedunculosa*, 27-*Lindera reticulata*, 28-*Clerodendrum wallichii*

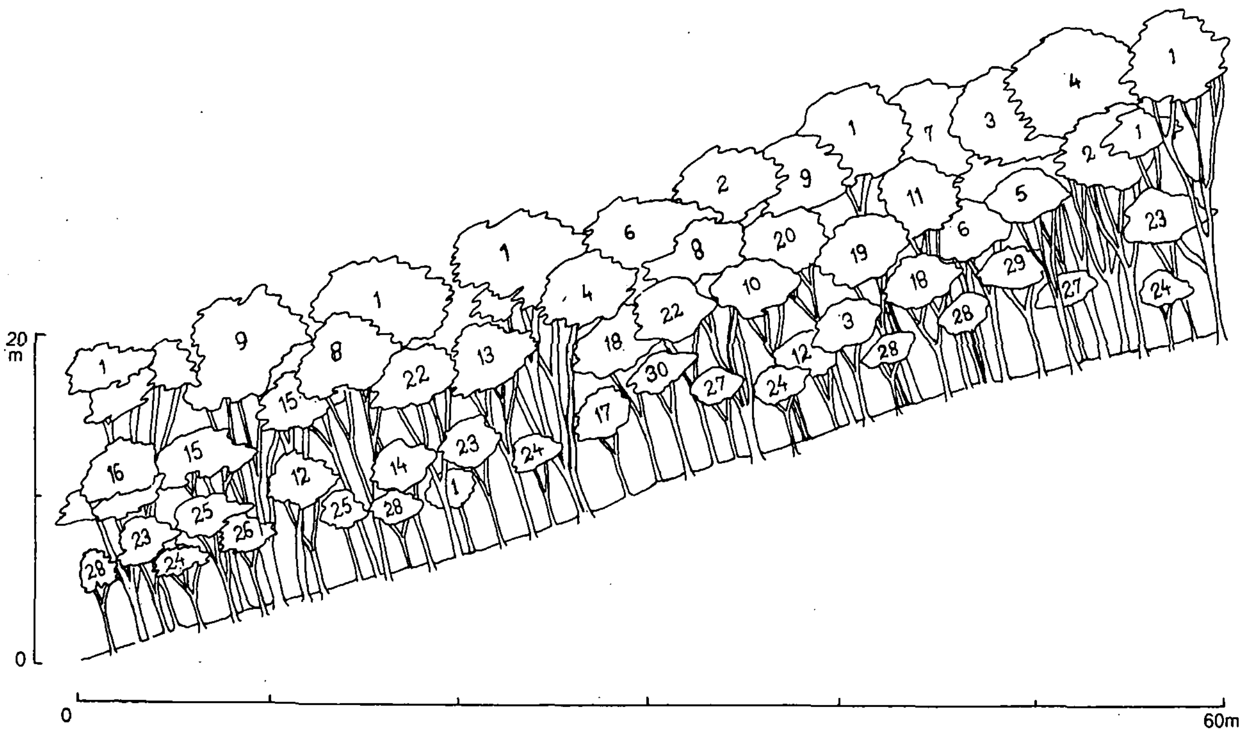


Fig. 5.4 b Profile diagram of a site (altitude 1412 m) in the montane forest.

1-*Helicia nilagirica*, 2-*Glochidion thomsonii*, 3-*Ostodes paniculata*, 4-*Castanopsis indica*, 5-*Gynocardia odorata*, 6-*Calophyllum polyanthum*, 7-*Castanopsis armata*, 8-*Elaeocarpus floribundus*, 9-*Viburnum coriaceum*, 10-*Persea gamblei*, 11-*Castanopsis tribuloides*, 12-*Neolitsea cassia*, 13-*Croton oblongus*, 14-*Cinnamomum tamala*, 15-*Itea chinensis*, 16-*Syzygium tetragonum*, 17-*Miliusa roxburghiana*, 18-*Eunonymus lawsonii*, 19-*Macropanax dispermum*, 20-*Litsea laeta*, 21-*Phoebe lanceolata*, 22-*Ilex odorata*, 23-*Glycosmis arborea*, 24-*Saprosma ternatum*, 25-*Lindera reticulate*, 26-*Psychotria symplocifolia*, 27-*Pittosporum podocarpum* Gagn., 28-*Ardisia pedunculosa*, 29-*Litsea lancifolia*, 30-*Premna latifolia*

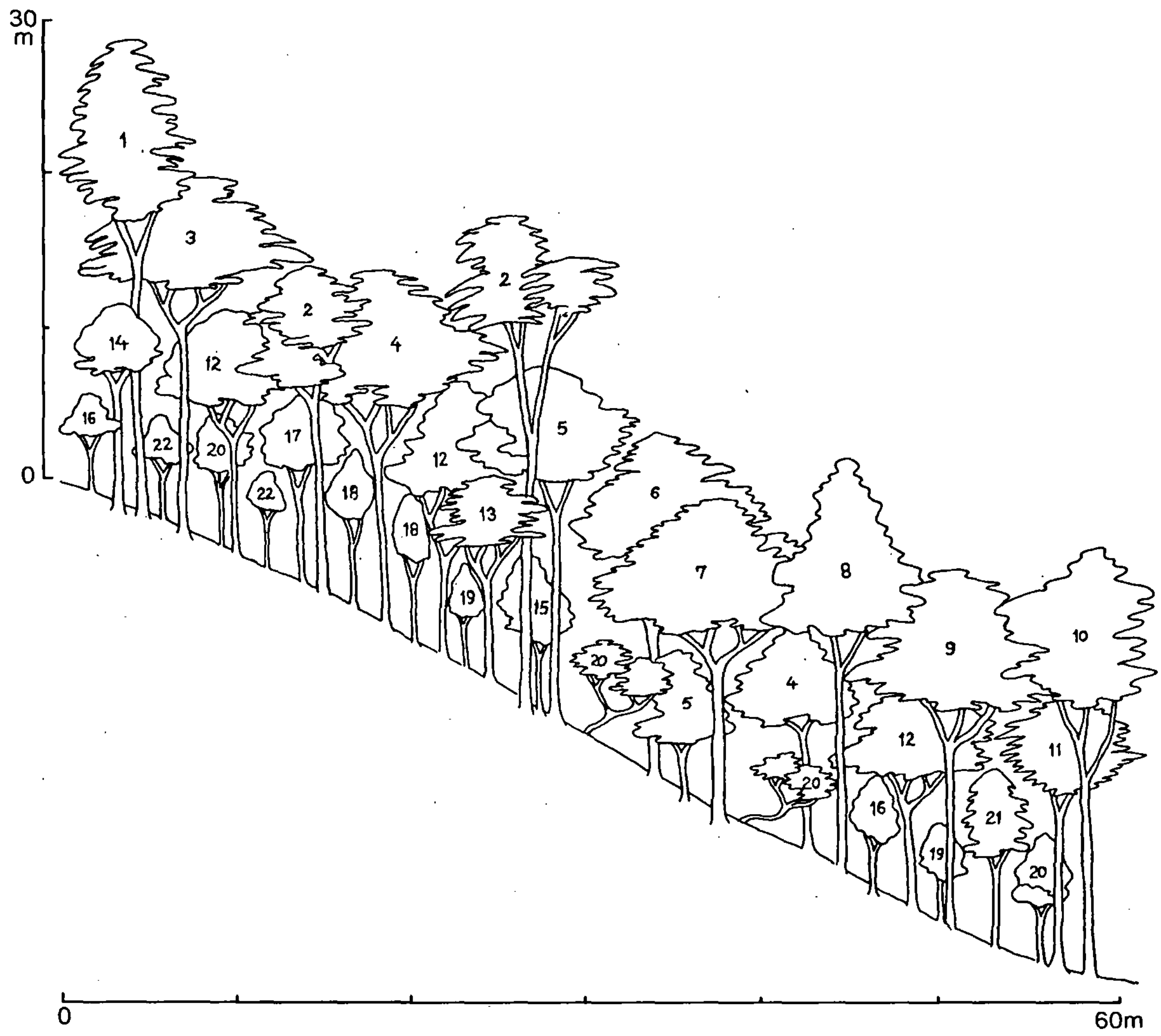


Fig. 5.4 c Profile diagram of the lowland forest.

1-*Mastixia arborea*, 2- *Parkia roxburghii*, 3- *Harpullia cupanoides*, 4-*Aquilaria agallocha*, 5-*Vitex peduncularis*, 6-*Syzygium kurzii*, 7-*Stereospermum chelonoides*, 8-*Mesua ferrea*, 9-*Sapium baccatum*, 10-*Shorea robusta*, 11-*Cleidion spiciflorum*, 12-*Cynometra polyandra*, 13-*Chaetocarpus castanocarpus*, 14-*Heteropanax fragrans*, 15-*Knema linifolia*, 16-*Maesa ramentacea*, 17-*Miliusa roxburghiana*, 18-*Syzygium malaccansis*, 19-*Tabernaemontana divaricata*, 20-*Trigonostemum semperflorus*, 21-*Turpinia pomifera*, 22-*Apania rubra*

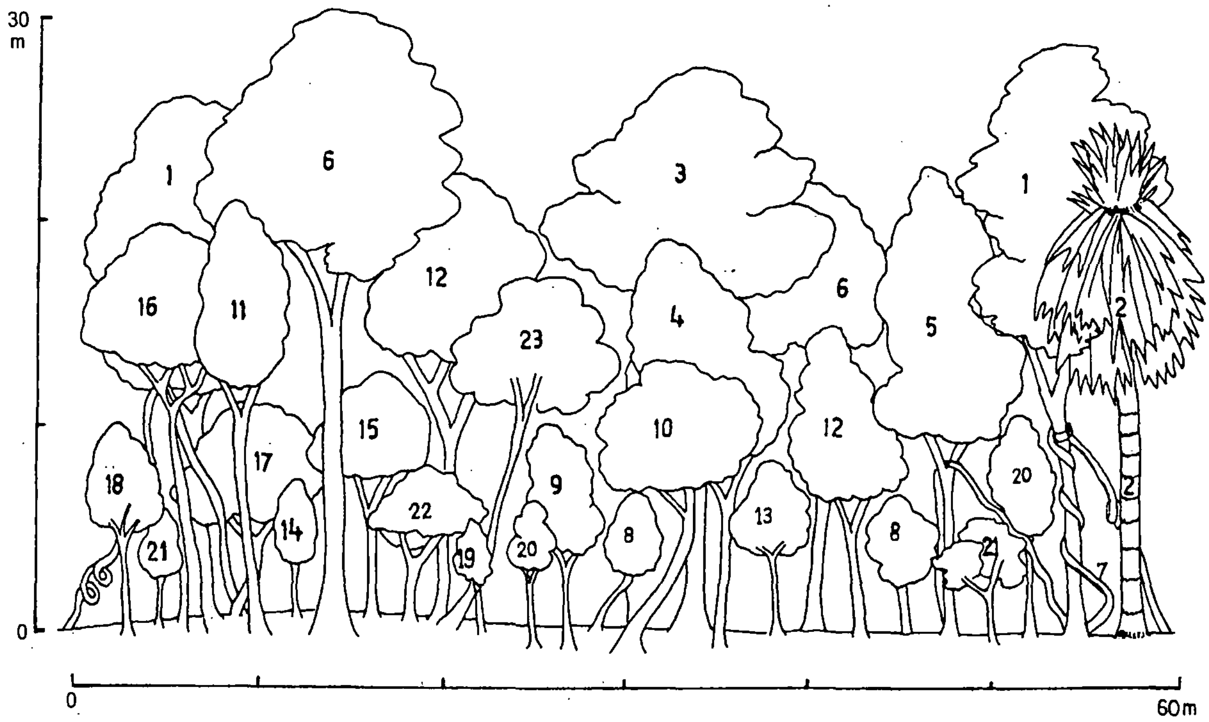


Fig. 5.4 d Profile diagram of the riverain forest.

1-*Calophyllum polyanthum*, 2-*Caryota urens*, 3-*Drimycarpus racemosus*, 4-*Dysoxylum gobara*, 5-*Ostodes paniculata*, 6-*Syzygium oblatum*, 7-*Fissistigma bicolor*, 8-*Callicarpa vesita*, 9-*Ficus nervosa* Heyne, 10-*Ficus subincisa*, 11-*Macaranga indica* Wt., 12-*Macropanax undulatus*, 13-*Micromelum integerrimum*, 14-*Neolitsea cassia*, 15-*Oreocnide integrifolia*, 16-*Prunus undulata*, 17-*Boehmeria macrophylla*, 18-*Taxus baccata*, 19-*Wendlandia tinctoria*, 20-*Knema linifolia*, 21-*Leea indica*, 22-*Millettia caudata*, 23- *Saurauia roxburghii*

Fig. 5.4 d shows the profile of a stand in the riverain forest, which depicts stratification of 29 individuals representing 23 species. The average canopy height was 25m and the canopy was not continuous. The sub-canopy layer formed a single undulating layer comprising of fourteen individuals belonging to 12 species. The emergent trees like, *Syzygium oblatum, Calophyllum polyanthum, and Drimycarpus racemosus* and lianas like, *Fissistigma bicolor* were also present in this layer. Fifteen trees and shrubs representing 11 species formed the under-canopy layer.

Life form spectrum

Life form spectrum of the three forests showed similar distribution pattern of the species in different life forms. Lianas and geophytes showed higher percentage of species in the riverain forest than in the montane and lowland forests. Phanerophytes constituted 63%, 67% and 56% in the montane, lowland and riverain forests respectively, while the therophytes were an inconspicuous component of the vegetation (Fig. 5.5).

Distribution of species under Raunkiaer's frequency classes

Majority (89-93%) of woody species including trees and lianas from all the undisturbed stands of the montane, lowland and riverain forests belonged to Raunkiaer's frequency class A, followed by a very small fraction belonging to class B (7-11%) and class C (0-2 %). Frequency class D and class E were totally absent in all the three forests (Fig. 5.6). *Gynocardia odorata, Saprosma ternatum, Glycosmis arborea* and *Dysoxylum gobara* from the montane forests, *Vitex peduncularis*, *Cynometra polyandra*, *Syzygium malaccense,* and *Garcinia cowa* from the lowland forests, and *Macropanax undulatus, Prunus undulata, Syzygium oblatum* and *Ficus nervosa* from the riverain forests are some of the most frequent tree species present in the classes B and C (Appendix II).

In case of shrubs, 90% to 100% species belonged to class A in all three stands. Thus, in the montane and lowland forest ecosystems last three classes (C, D and E) and in the riverain forest the last four classes (B, C, D and E) were totally absent.

Similarly, in case of herbs 100% species in the riverain forest ecosystem showed less than 20% frequency, while in the montane and lowland forest ecosystems the species were fairly distributed in the first three (i.e. classes A,B and C) and the first two frequency classes (classes A and B), respectively. *Pteris quadriaurita* was the most frequent species followed by *Elatostemma sikkimense* in the montane and the lowland forest ecosystems.

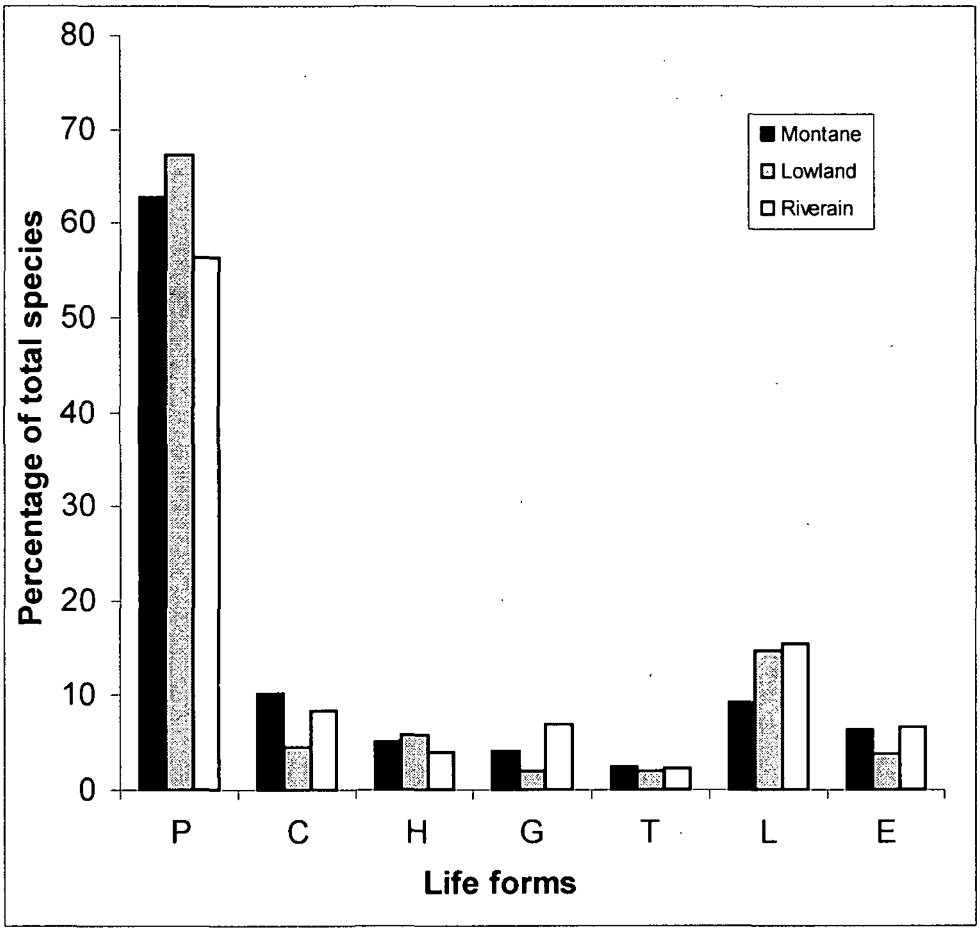


Fig. 5.5 **Life-form spectrum of the undisturbed montane, lowland and riverain forests of the Nokrek BR. (P- Phanerophytes, C- chamaephytes, H- Hemicryptophytes, G- Geophytes, T- Therophytes, L- Lianas, and E- Epiphytes).**

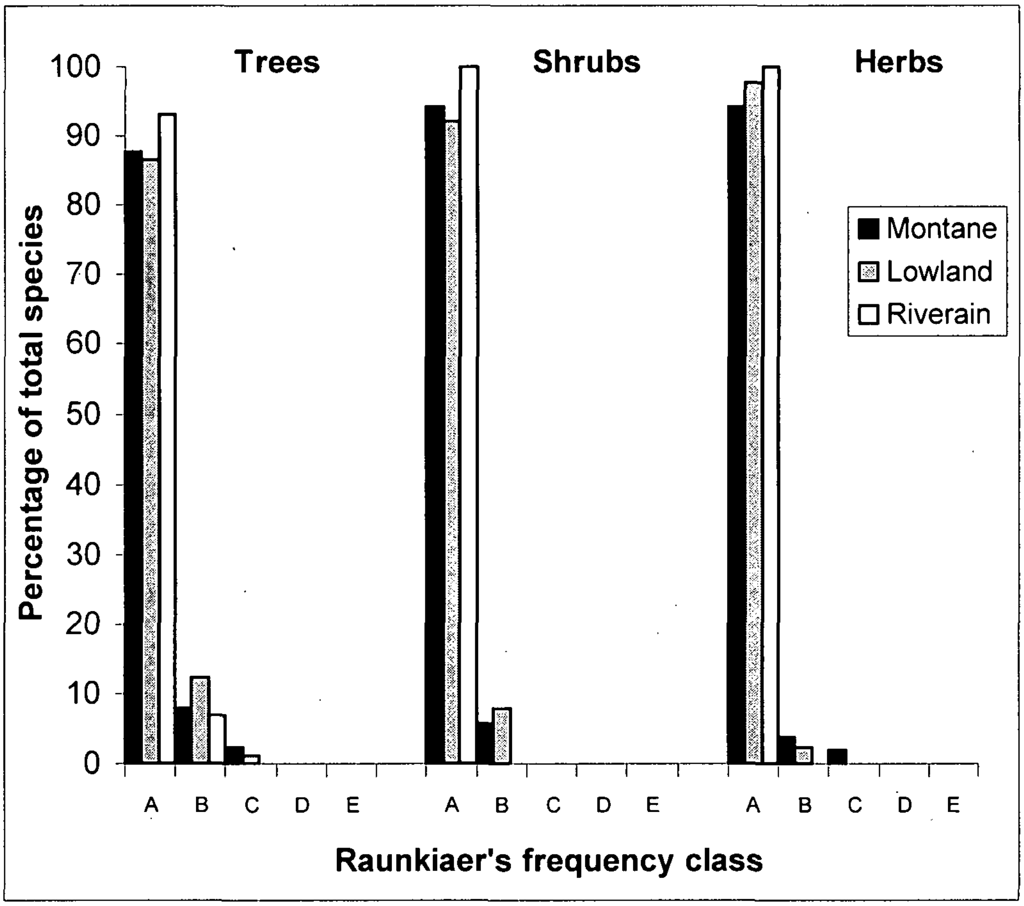


Fig. 5.6 **Distribution of tree, shrub and herb species in different frequency classes in the undisturbed montane, lowland and riverain forests in the Nokrek BR.**

Spatial distribution pattern

Majority of the tree species (87-93%) in the montane, lowland and riverain forests showed clumped or contiguous distribution. In the montane forest random distribution was shown by eight species and in the lowland forest by three species, whereas in the riverain forest 13% species showed random distribution. Only three species showed regular distribution in the lowland forest. However, no tree species showed regular distribution in the montane and riverain forests.

In the case of shrubs, all species in the montane forest showed clumped distribution while in the lowland forest two species (*Dracaena elliptica* and *D. angustifolia*) and in the riverain forest only one species (*Tabernaemontana divaricata*) showed random distribution. All the herb species in the three forest types showed clumped or contiguous distribution (Table 5.4).

Dominance

The three undisturbed forests showed altogether different patterns of dominance based on the IVI values of the tree, shrub and herb species (Appendix II). In the montane forests *Helicia nilagirica* (IVI 19.64) was the most dominant species and *Aphanamixis wallichii* and *Dysoxylum gobara* (IVI 15.73 and 13.47, respectively) were the co-dominant species. In the lowland forest *Vitex peduncularis* was the dominant tree species (IVI 19.49) followed by *Sapium baccatum* (IVI 14.23) and *Syzygium malaccense* (IVI 12.31), while the riverain community was dominated by *Caryota urens* (IVI 16.70), *Calophyllum polyanthum* (IVI 13.34) and *Macropanax undulatus* (IVI 12.25) (Appendix II).

Among the shrub species in the montane forest, *Rhynchotechum ellipticum* showed the highest values of IVI (IVI 24.60) followed by *Piper griffithii* (IVI 17.37), *Jasminum subtriplinerve* (IVI 13.76) and *Chasalia ophioxyloides* (IVI 13.76). In the lowland forest *Dracaena angustifolia* (IVI 25.91) and *Murraya koenigii* (IVI 14.06) were the dominant shrubs, while in the riverain forests the dominant shrub species were *Strobilanthus anisophyllus* (IVI 15.8), *Jasminum subtriplinerve* (IVI 15.3) and *Rhynchotechum vestitum* (IVI 12.74) (Appendix II).

The herbaceous component was dominated by *Pteris quadriaurita* (25.81), *Elatostemma sikkimense* (IVI 24.17), and *E. hookerianum* (IVI 14.36) in the montane forests, *Pteris quadriaurita* (IVI 30.37), *E. sikkimense* (IVI 12.75) and *Angiopteris evecta* (IVI 10.57) in the lowland forest, and *E. sikkimense* (IVI 35.34), *Tectaria polymorpha* (IVI 14.42) and *Abacopteris multilineata* (IVI 9.38) in the riverain forests (Appendix II).

However, the dominance- distribution curves for the tree, shrub and herb components of all three communities (Fig 5.7) showed lognormal distribution which is a characteristic of a complex, species-rich community (Whittaker 1975, Magurran 1988).

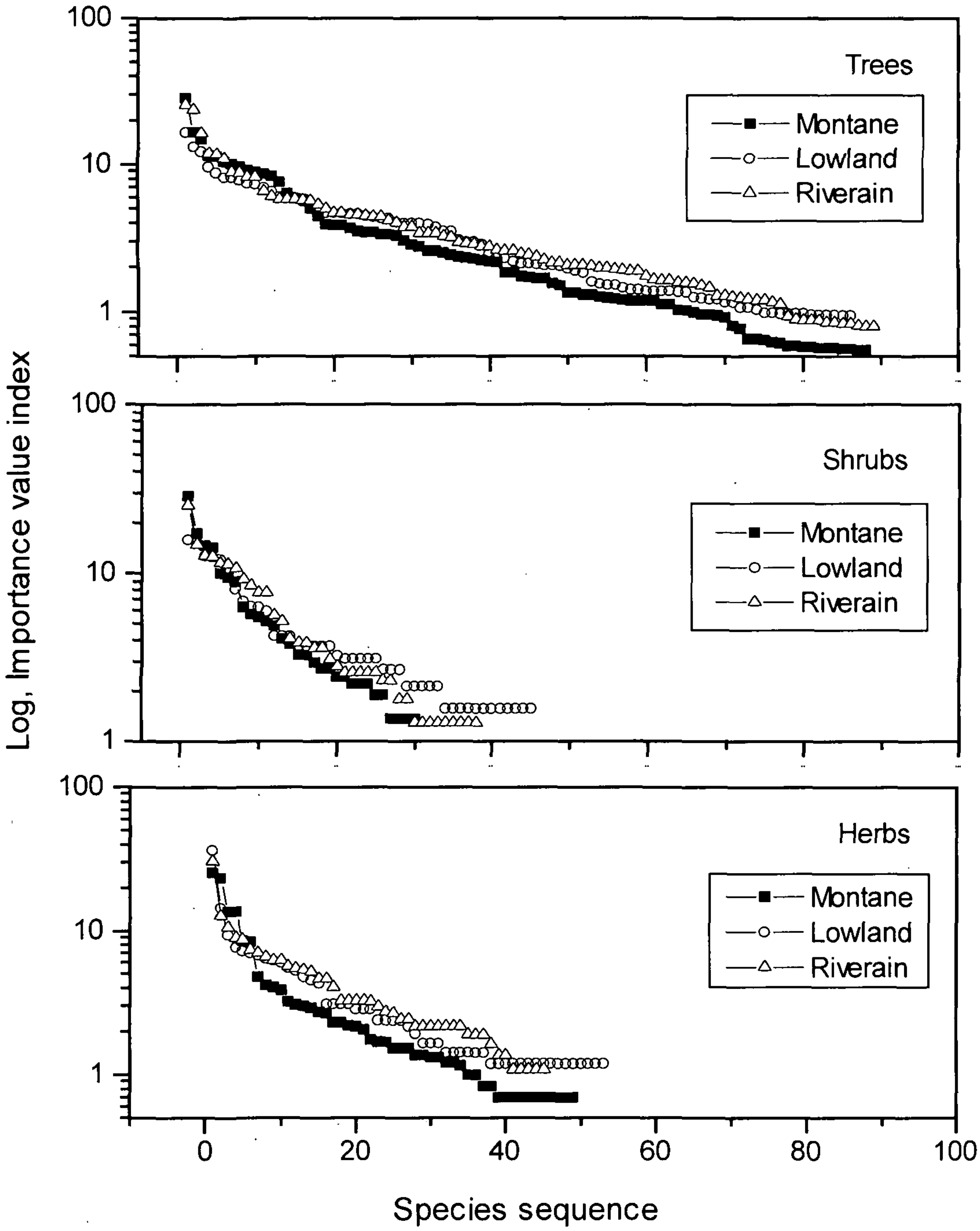


Fig 5.7 **Dominance-diversity curves for trees, shrubs and herbs in the undisturbed montane, lowland and riverain forests of the Nokrek BR.**

Density

The total stand density of woody species varied considerably in three forests. It was 2210 stems ha^{-1} in the montane forest and 1180 stems ha^{-1} in the riverain forest (Table 5.3). The species with highest density in montane forest were *Helicia nilagirica, Saprosma ternatum*, *Gynocardia odorata* and *Glycosmis arborea* (345, 175, 130 and 130 stems ha^{-1} respectively). *Vitex peduncularis* (100 stems ha^{-1}), *Aphania rubra* (90 stems ha^{-1}), *Garcinia cowa* (80 stems ha^{-1}) and *Syzygium malaccense* (80 stems ha^{-1}) were abundant in the lowland forest, and *Macropanax undulatus, Calophyllum polyanthum* and *Ostodes paniculata* (60, 45and 45 stems ha^{-1} respectively) were the abundant species in the riverain forest (Appendix II).

Density-distribution of the tree species in different girth classes (Fig. 5.8) revealed that the lowest girth class (5-15 cm) constituted 35% of the total stand density in the montane forest, 33 % in the lowland forest and 29% in the riverain forest. In all the three forests the percentage contribution to the total stand density decreased with the increasing girth class. However, the largest girth class (>95 cm) contributed more to the total stand density (12% in the montane forest, 9 % in the lowland forest and 8% in the riverain forest) compared to the percentage contribution by a few lower girth classes (Fig.5.8).

In case of shrubs, the total stand density was higher in the riverain forest (44500 stems ha^{-1}) than the montane forest (37250 stems ha^{-1}) and lowland forest

(43750 stems ha^{-1})(Table 5.3). The shrubs most abundant in the montane forest were *Rhynchotechum ellipticum*, *Piper griffithii*, *Chasalia ophioxyloides* and *Jasminum subtriplinerve* while in the lowland forest *Dracaena angustifolia*, *Murraya koenigii* and *Morinda angustifolia*, and in the riverain forests *Strobilanthus anisophyllus*, *Jasminum subtriplinerve* and *Rhynchotechum vestitum* showed high density (Appendix II).

Herb density was much lower in the lowland forest than the montane and riverain forests (Table 5.3). *Pteris quadriaurita* had the highest number of individuals in the montane forest, followed by *Elatostemma sikkimense* and *Globba clarkeii*. *P. quadriaurita* in the lowland forest and *E. sikkimense* in the riverain forest were the most abundant herb species (Appendix II).

Basal cover

Basal cover of the woody species also differed considerably in the three forests, 45.95 m^2ha^{-1} in the montane forest, 38.25 m^2ha^{-1} in the lowland forest and 28.15 m^2ha^{-1} in the riverain forests (Table 5.3).

In the montane forest ecosystem, species contributing largely to the total basal cover were *Sapium baccatum* (3.05 m^2ha^{-1}), *Helicia nilagirica* (2.24 m^2ha^{-1}), *Castanopsis indica* (2.98 m^2ha^{-1}), *Dysoxylum gobara* (2.60 m^2ha^{-1}), *Gynocardia odorata* (2.41 m^2ha^{-1}) and *Ostodes paniculata* (2.08 m^2ha^{-1}). In the lowland forest ecosystem *Sapium baccatum* (4.28 m^2ha^{-1}), *Calophyllum polyanthum* (3.48 m^2ha^{-1}), and *Vitex peduncularis* (2.83 m^2ha^{-1}) whereas, in the riverain forest ecosystem

Caryota urens (3.64 m^2 ha^{-1}), *Castanopsis purpurella* (1.93 m^2 ha^{-1}) and *Calophyllum polyanthum* (1.52m^2 ha^{-1}) were the major species that contributed to the basal cover.

The distribution of basal area in different girth classes revealed that in spite of showing the highest stand density, the lowermost girth class contributed the least to the total basal cover of the stand. The contribution to the basal cover increased gradually till the girth class 55-75 cm and then decreased back in the upper girth classes except the largest girth class (>95cm) where it contributed 55.5 %, 54.9 % and 54.4 % of the total basal cover in the montane, lowland and the riverain forests, respectively (Fig. 5.9).

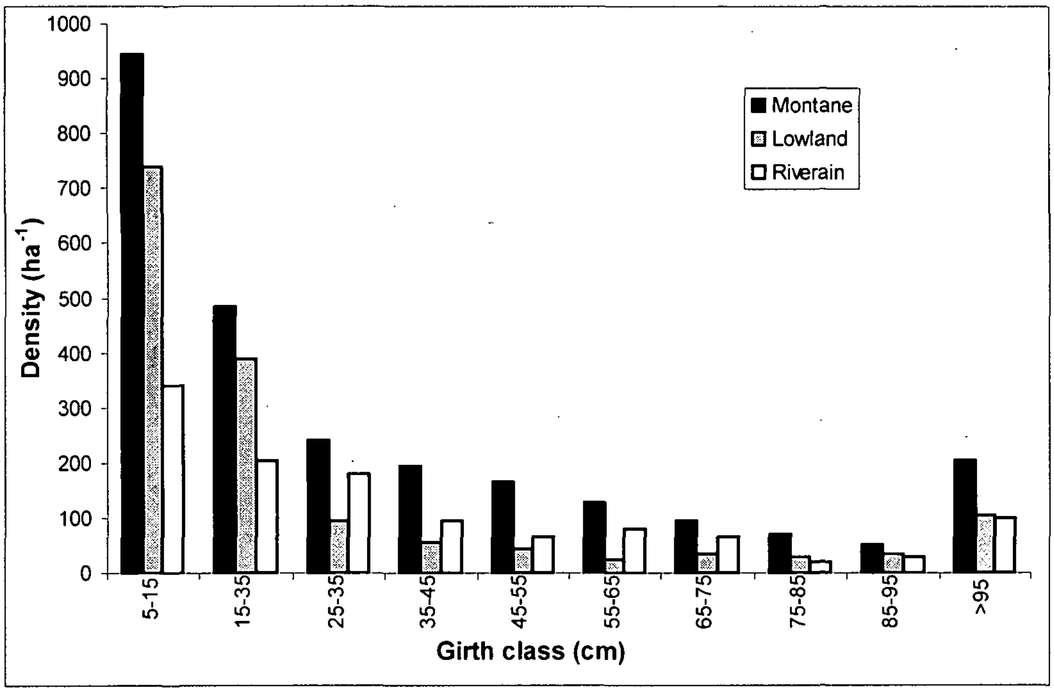


Fig. 5.8 **Density-diameter distribution of tree species in the undisturbed montane, lowland and riverain forests of the Nokrek BR.**

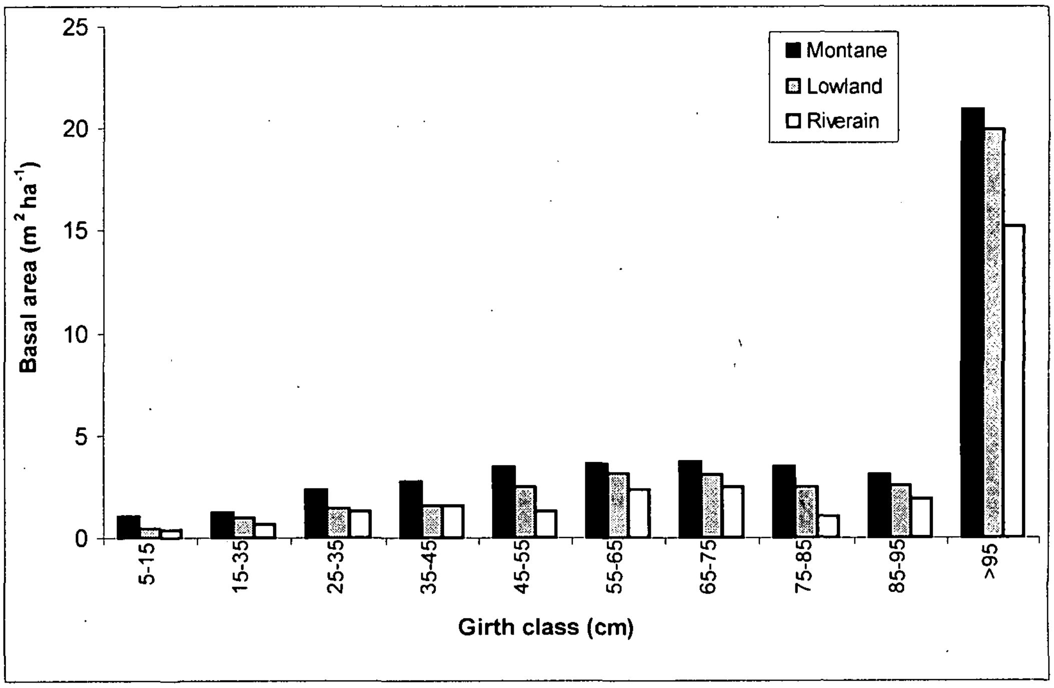


Fig. 5.9 **Distribution of basal area of tree species in different diameter classes in the undisturbed montane, lowland and riverain forests of the Nokrek BR.**

Ecological diversity

Different diversity indices worked out are given in table 5.5a. Trees and lianas showed high values for α-diversity, Shannon diversity index as well as Pielou evenness index, which indicates high diversity, and equitability of this component in all the three communities. This was also supported by the low values of Simpson dominance index. The herbs and the shrubs had lower values of diversity and higher values of dominance.

Among the three forest ecosystems, the riverain forest showed maximum α-diversity values for trees and herbs, while the lowland forest showed highest values for shrubs. However, the Shannon diversity index for trees and shrubs was highest in the riverain forest and for herbs in the lowland forest.

β-diversity showed highest values for the herbs followed by trees and shrubs (Table 5.5b).

Similarity

Sørensen index of qualitative similarity indicated the maximum similarity for the shrubs and minimum similarity for the herbs. However, the quantitative similarity between these forests worked out by Morisita- Horn index reveals that there is least similarity between the tree components of these forests (Table 5.6 and 5.7).

Table 5.5a Shannon diversity index, Pielou evenness index, Simpson dominance index and α- diversity of tree, shrub and herb species in the undisturbed montane, lowland and riverain forests of the Nokrek BR.

	Tree			Shrub			Herb		
	Montane forest	Lowland forest	Riverain forest	Montane forest	Lowland forest	Riverain forest	Montane forest	Lowland forest	Riverain forest
Shannon Diversity Index	3.798	4.104	4.188	3.130	3.268	3.420	3.169	3.280	3.030
Pielou Evenness Index	0.848	0.914	0.940	0.912	0.898	0.899	0.814	0.862	0.763
Simpson Dominance Index	0.040	0.024	0.019	0.056	0.053	0.071	0.070	0.059	0.107
α- diversity	14.09	15.51	15.74	6.41	7.76	6.30	8.34	7.61	8.79

Table 5.5b β- diversity of tree, shrub and herb species in the undisturbed montane, lowland and riverain forests of the Nokrek BR.

Trees	Montane forest	Lowland forest	Riverain forest
Montane forest	0	0.68	0.67
Lowland forest	-	0	0.85
Riverain forest	-	-	0
Shrubs	**Montane forest**	**Lowland forest**	**Riverain forest**
Montane forest	0	0.54	0.58
Lowland forest	-	0	0.73
Riverain forest	-	-	0
Herbs	**Montane forest**	**Lowland forest**	**Riverain forest**
Montane forest	0	0.36	0.75
Lowland forest	-	0	0.73
Riverain forest	-	-	0

Table 5.6 **Sørensen (qualitative) Index for tree, shrub and herb species showing similarity between the vegetation of the undisturbed montane, lowland and riverain forests of the Nokrek BR.**

Trees	Montane forest	Lowland forest	Riverain forest
Montane forest	1	31.63	33.33
Lowland forest	-	1	14.85
Riverain forest	-	-	1
Shrubs	**Montane forest**	**Lowland forest**	**Riverain forest**
Montane forest	1	46.83	42.11
Lowland forest	-	1	26.51
Riverain forest	-	-	1
Herbs	**Montane forest**	**Lowland forest**	**Riverain forest**
Montane forest	1	36.83	25.49
Lowland forest	-	1	26.53
Riverain forest	-	-	1

Table 5.7 Morisita-Horn (quantitative) Index for tree, shrub and herb species showing similarity between the vegetation of the undisturbed montane, lowland and riverain forests of the Nokrek BR.

Trees	Montane forest	Lowland forest	Riverain forest
Montane forest	1	0.11	0.16
Lowland forest	-	1	0.10
Riverain forest	-	-	1
Shrubs	**Montane forest**	**Lowland forest**	**Riverain forest**
Montane forest	1	0.28	0.47
Lowland forest	-	1	0.24
Riverain forest	-	-	1
Herbs	**Montane forest**	**Lowland forest**	**Riverain forest**
Montane forest	1	0.53	0.39
Lowland forest	-	1	0.25
Riverain forest	-	-	1

Population structure of dominant tree species

Population structure of a few dominant tree species in the undisturbed forest ecosystems was studied through distribution of individuals in different girth classes (Fig. 5.10 and 5.12)

In the montane forest, all the species except *Helicia nilagirica, Viburnum coriaceum* and *Ostodes paniculata* showed preponderance of individuals in the lowest girth class (5-15 cm girth class) (Fig. 5.10). *Gynocardia odorata* and *Ostodes paniculata* showed fluctuation in density distribution. *Garcinia cowa* and *Aesculus assamica* displayed a very poor representation of the upper girth classes and both species had more or less equal number of individuals. *Glochidion thomsonii, Dysoxylum gobara, Litsea elongata* showed similar patterns; there was decrease in population size in the upper girth classes and absence of individuals in intermediate girth classes. The undercanopy trees such as *Glycosmis arborea, Saprosma ternatum* and *Pittosporum podocarpum* in the montane forest showed sharp decrease in the number of individuals with increase in size of the girth classes.

The dominant tree species of the lowland forest also showed varied trend in the population behaviour (Fig 5.11). *Vitex peduncularis*, *Garcinia cowa*, *Maesa ramentacea* and *Aphania rubra* showed pyramidal population structure. *Calophyllum polyanthum*, *Cynometra poly*andr*a* and *Syzygium malaccense* also showed decline in the number of individuals in the upper girth classes and absence of individuals in the intermediate girth classes. The third group represented by *Aquilaria agallocha*, and *Syzygium syzygoides* showed irregular trend. *Sapium baccatum* was represented only by the old individuals.

In the riverain forest all selected species characteristically showed the absence of individuals in one or more girth classes (Fig 5.12). Only four out of twelve species viz., *Calophyllum polyanthum, Macropanax dispermus, Syzygium oblatum* and *Ficus nervosa* showed large number of young individuals in the lowest girth class, while the young individuals were absent in the case of *Caryota urens, Prunus undulatus* and *Drimycarpus racemosus*. In case of *Calophyllum polyanthum, Syzygium oblatum, Prunus undulata and Ficus nervosa* young individuals outnumbered the mature individuals, while *Caryota urens, Aphanamixis chittagonga* and *Drimycarpus racemosus* showed the reverse trend with poorly represented lower girth classes. However, some species such as *Macropanax dispermus, Ostodes paniculata, Oreocnide integrifolia, Macaranga denticulata* and *Sapium baccatum* did not follow any of these patterns and displayed irregular fluctuations in the population.

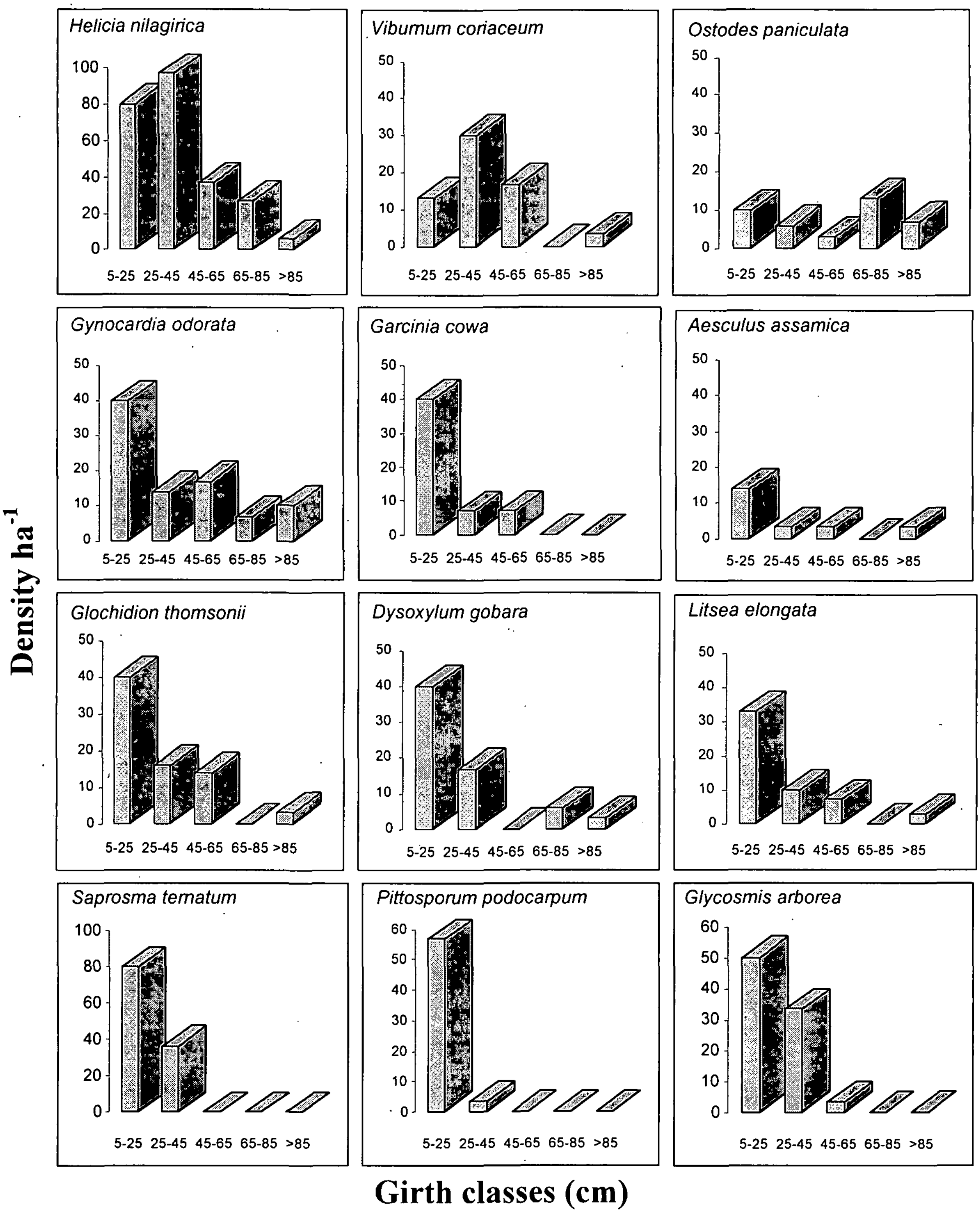


Fig.5.10 **Density-diameter distribution of some dominant tree species in the undisturbed montane forest in the Nokrek BR.**

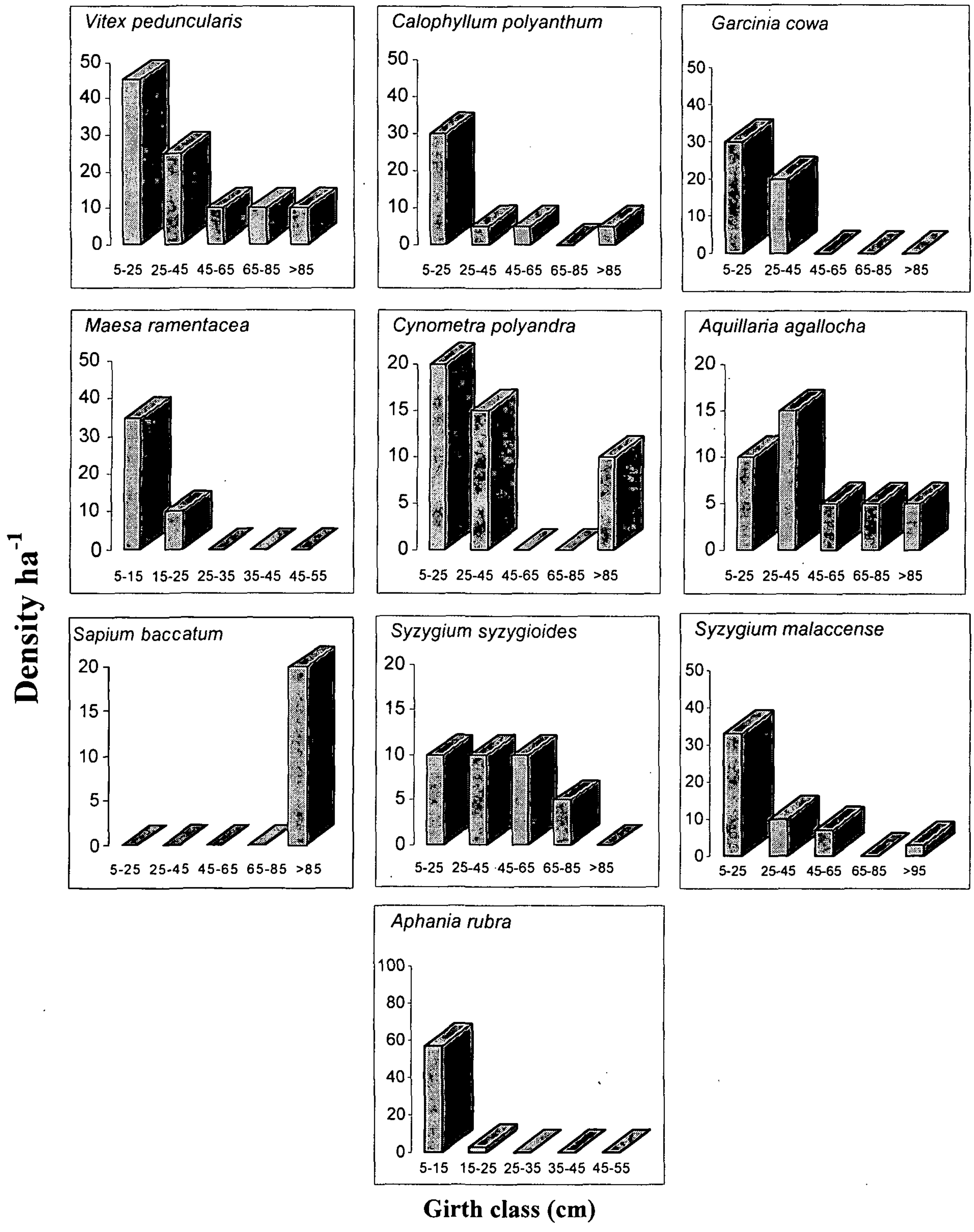


Fig. 5.11 Density-diameter distribution of some dominant tree species in the undisturbed lowland forest in the Nokrek BR.

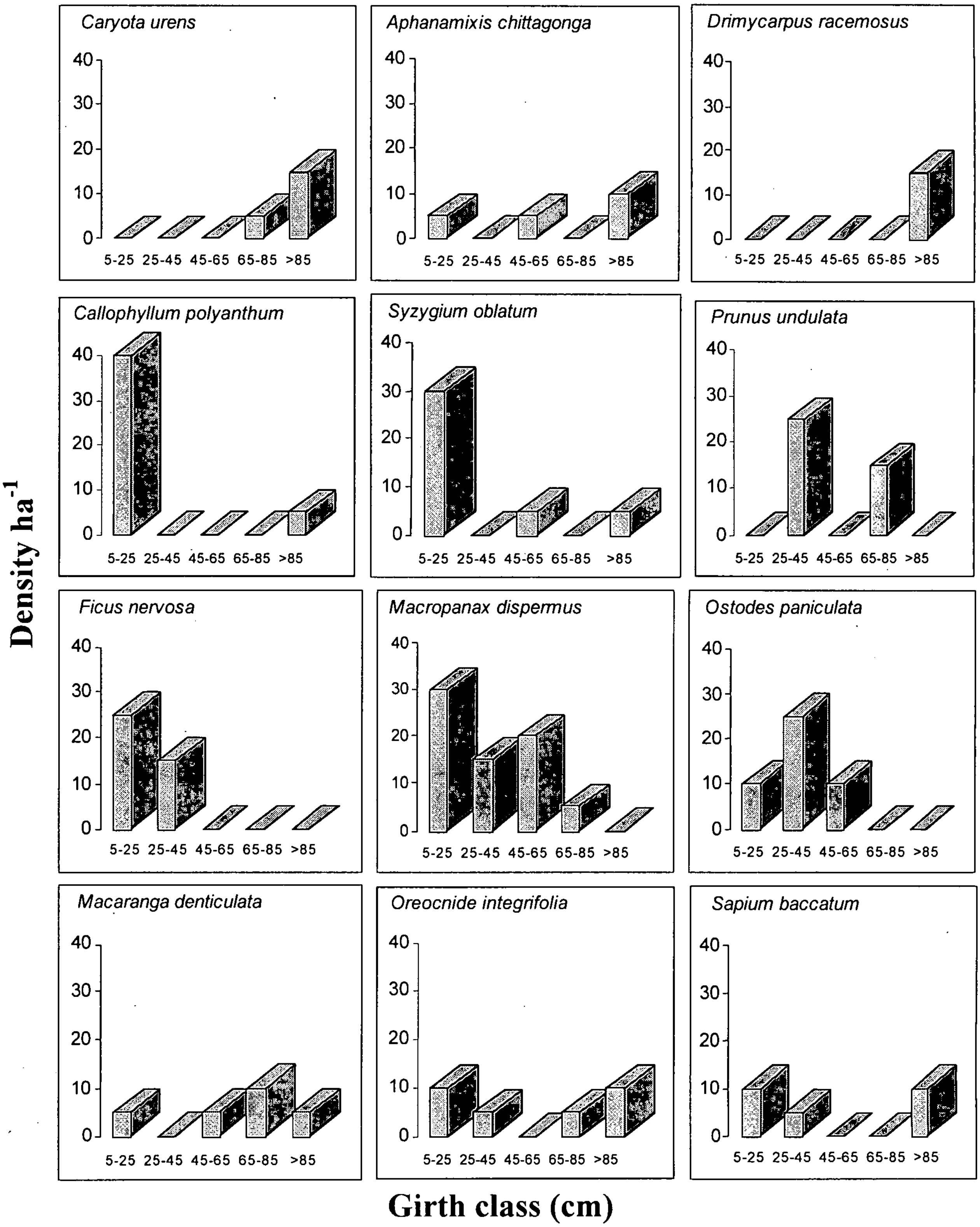


Fig.5.12 Density-diameter distribution of some dominant tree species in the undisturbed riverain forest in the Nokrek BR.

Seedling density

Table 5.8 gives an account of the seedling density recorded in the three forests. Seedlings of 40 species were recorded from the montane forest; seedlings of 37 species from the lowland forest and seedlings of 39 species were recorded from the riverain forests. The average seedling density per species was more or less same in all the three forests, (32- 34 seedlings 100 m^{-2}). However, the highest seedling density was found in case of *Caryota urens* in the riverain forest. Besides this, three more species (*Elaeocarpus floribundus*, *Persea duthiei* and *Beilschmiedia assamica*) out of the nine species having seedlings in all the three forests, showed more seedling density in the riverain forest than the other two forests. In the montane forest, *Calophyllum polyanthum* and in the lowland forest *Prunus jenlinsii* showed the highest seedling density. The species such as, *Premna barbata, Prunus cerasoides, Euonymus lawsonii, Ilex excelsa* and *Milletia caudata* showed very low seedling density.

Table 5.8 Tree seedling density (100m^{-2}) in the undisturbed montane, lowland and riverain forests in the Nokrek BR.

Species	Montane Forest	Lowland forest	Riverain Forest
Actephila excelsa	10	90	0
Actinodaphnae angustifolia	0	0	28
Actinodaphne obovata	0	0	28
Alangium chinense	0	0	25
Antidesma acidum	0	0	25

Antidesma diandrum	20	0	0
Aphanamixis chittagonga	35	0	0
Aporusa dioica	20	85	15
Baliospermum micranthum	33	0	0
Beilschmiedia assamica	13	0	15
Beilschmiedia roxburghii	0	120	23
Bischoffia javanica	0	0	40
Calophyllum polyanthum	240	140	120
Camellia caduca	32	0	0
Caryota urens	43	0	285
Celastrus paniculatus	40	0	0
Cinnamomum bejolghota	0	9	20
Cinnamomum tamala	0	57	18
Croton oblongus	40	33	0
Derris robusta	0	0	18
Drimycarpus racemosus	0	30	33
Elaeocarpus acuminatus	0	0	30
Elaeocarpus floribundus	43	0	45
Endospermum chinense	0	0	15
Erythroxylum kunthianum	10	0	0
Euonymus lawsonii	10	0	0
Eurya acuminata	8	0	0
Ficus elmeri	0	0	60
Ficus hispida	0	0	15
Ficus nervosa	0	0	15
Garcinia cowa	30	95	0
Gleditsia assamica	0	0	13
Glochidion thomsonii	25	15	0
Glochidion velutinum	0	15	60
Glycosmis arborea	70	0	0

Grewia disperma	0	0	45
Grewia microcos	0	0	13
Helicia nilagirica	18	0	0
Ilex excelsa	7	0	0
Ligustrum massalongianum	0	0	10
Lindera latifolia	7	0	0
Litsea monopetala	0	0	10
Litsea salicifolia	37	0	15
Maesa montana	7	0	0
Meliosma wallichii	60	0	0
Micromelum integerrimum	0	0	10
Miliusa roxburghiana	40	16	0
Millettia caudata	0	0	5
Neolitsea cassia	17	11	0
Olax dentata	5	8	0
Oreocnide integrifolia	22	0	0
Persea duthiei	12	25	15
Pittosporum podocarpum	15	0	0
Premna barbata	5	0	0
Prunus cerasoides	3	0	0
Prunus jenkinsii	0	240	0
Prunus undulata	42	85	15
Pterospermum lancaefolium	0	75	0
Quercus semiserrata	0	0	8
Randia cochinchinensis	3	9	0
Rhus javanica	0	0	90
Saprosma ternatum	50	0	0
Sarcosperma arboreum	50	40	0
Sarcosperma griffithii	0	0	8
Securinega virosa	0	0	30

Sterculia roxburghii	0	0	60
Symplocos racemosa	13	35	0
Syzygium cumini	108	50	0
Syzygium oblatum	42	0	15
Tarenna odorata	0	0	5
Viburnum coriaceum	13	0	0
Total	1298	1281	1295

Discussion

The undisturbed montane, lowland and riverain forests of the Nokrek Biosphere Reserve represent the flora of Manipur –Khasi province described by Takhtajan (1988), which exhibits saturation of eastern Asiatic floristic components and also shows strong ties with the florae of the eastern Himalaya, upper Burma and China. Geographic location as well as characteristic climatic conditions appear to be the major factors contributing to the floristic richness of the Nokrek BR.

Though a number of floristic and ecological studies have been carried out in the state as mentioned earlier in the review of literature, they are largely restricted to the sacred groves. During a floristic survey of 56 sacred groves 514 species have been reported by Tiwari *et al.* (1999). An ecological study by Jamir (2000) has reported 395 species of vascular plants from three sacred groves, while Upadhaya *et al.* (2003) reported 437 vascular species from three other sacred groves of Jaintia hills. In a floristic survey of Balphakram wild life sanctuary, 770 species have been listed by Kumar (1984), while Haridasan and Rao (1985-87) have described 1151 dicotyledonous forest species from the entire Meghalaya. In comparison to this, a total of 590 vascular species recorded from the Nokrek BR during the present study is worth noting. Dominance of angiosperms, richness of taxonomic families and presence of congeneric species are the characteristic features of tropical and sub-tropical moist forests as reported by many workers (Balakrishnan 1981, Kumar 1984, Haridasan and Rao 1985-87, Valencia *et al.* 1994, Ayyappan and Parthasarathy 1999, Jamir and Pandey 2002, Upadhaya *et al.* 2003). Concentration of tree, herb and epiphytic species depict the high heterogeneity of these forest ecosystems. Factors such as high humidity or seasonal drought are likely to influence abundance and diversity of epiphytes (Gentry and Dodson 1987) and terrestrial herbs (Wright 1992, Givnish 1995).

The available literature on the tree inventories of tropical forests is mostly based on the large spatial scale studies. In addition to this, there is a range of criteria and methodologies adopted for evaluation of the diversity, which makes direct comparison of the results of the present study with the earlier studies difficult. Table 5.9 gives the summary of a few studies based on small spatial scale in different tropical forests in the country and across the world.

This comparison helps in placing all the three undisturbed forests (i.e. the montane forest, lowland forest and riverain forest) of the Nokrek BR in the category of species-rich forests. In spite of many common species in tree, shrub

Table 5.9 Density, basal area, species richness and diversity indices of trees in different tropical forests of India and the world.

Site	Location (Latitude)	Altitude m a.s.l.	Area Ha^{-1}	Gbh/dbh threshold Cm	No. of species	Density ha^{-1}	Basal area m^2ha^{-1}	Diversity indices H'*	E*	D*	Source
Yanamono, Peru	$3^0$16'S	140	0.2	≥ 10 dbh	90	115	-	-	-	-	Gentry 1988
Mt. Kinabalu	605'N	1560	0.5	≥ 5 dbh	121	1730	-	4.18	0.88	-	Aiba and Kitayama 1999
Xishuangbanna	$21^0$09'-$22^0$33'N	800-1500	0.12	≥ 5 dbh	21	165	-	2.53	0.88	0.903	Cao and Zhang 1997
Xishuangbanna	$21^0$09'-$22^0$33'N	980	0.16	≥ 5 dbh	48	164	-	3.29	0.85	0.93	Cao and Zhang 1997
Sacred groves, Meghalaya	$25^0$26N	1200	0.8	≥ 5 dbh	135	1070	-	3.74-4.3	0.91-0.95	0.019-0.031	Jamir and Pandey 2003
Sacred grove, Meghalaya	$25^0$28'N	1350	0.5	≥ 5 dbh	82	1476	57.46	3.42	0.53	0.067	Upadhaya *et al.* 2003
Sacred grove, Meghalaya	$25^0$30'N	1300	0.5	≥ 5 dbh	80	938	71.44	3.55	0.56	0.052	Upadhaya *et al.* 2003
Dry evergreen forest, S. India	$12^0$11'N	-	0.2	≥ 20 gbh	-	280	11	0.83-2.43	-	-	Visalakshi 1995
Dry evergreen forest, S. India	$12^0$03' N	-	0.2	≥ 20 gbh	-	1130	36	1.47-1.59	-	-	Visalakshi 1995
Montane forest, NBR	25^0 20'-25^0 29'N	1050-1412	0.2	≥ 5 gbh	88	2595	45.95	3.80	0.85	0.04	Present study
Lowland forest, NBR	25^0 20'-25^0 29'N	319-750	0.2	≥ 5 gbh	89	1555	38.25	4.10	0.91	0.02	Present study
Riverain forest, NBR	25^0 20'-25^0 29'N	915-968	0.2	≥ 5 gbh	86	1180	28.15	4.19	0.94	0.02	Present study

H'- Shannon diversity index
E - Pielou evenness index
D - Simpson dominance index

and herb layers, these forests vary broadly in the vegetation characteristics and diversity. The low values of similarity indices and high β–diversity index reveal the high level of diversity across the habitats.

The lower girth classes include small trees as well as saplings of the large trees and so, greater number of species were present in these classes. Small girth classes having major contribution to the species richness is also a characteristic feature of ancient climax tropical forests (Whitmore 1970, Gentry 1982, Condit *et al.* 1996).

The density of tree species including lianas in the montane forest was found to be 2595, 1857, 1377 and 248 stems h^{-1} for the individuals having ≥ 5, 10, 15.5 (5cm dbh) and 30 cm gbh respectively. The undisturbed montane forest can be favourably compared with the forest in Mexico having 2976 individuals ha^{-1} (Bongers *et al.* 1988), forest in French Guyana having 1168 individuals ha^{-1} (Pelissier and Riera 1993) and forest in Amazonia with 1561 individuals (Valencia *et al.* 1994), but the tree density in this forest was much lower than the forest in Pasoh, Peninsular Malaysia having 6580 individuals ha^{-1} (Kochummen *et al.* 1990). When compared with forests of peninsular India, the montane forest of the Nokrek BR is denser than that of Uttar Kannada (869 ha^{-1}; Bhat *et al.* 2000) and Agumbe (1067 ha^{-1}; Srinivas and Parthasarathy 2000), while it falls well within the range of Anamalais (273 to 674 ha^{-1}; Ayyappan and Parthasarathy 2001). It was also comparable with the density values of the sacred groves of Meghalaya (1070, 1476 and 938 individuals ha^{-1}; Jamir and Pandey 2003, Upadhaya *et al.* 2003).

In the lowland forest, the tree species density values were 1555, 1243, 990and 198 individuals ha^{-1} for the individuals ≥ 5, 10, 15.7 and 30 cm gbh whereas in the riverain forest the corresponding density values were 1180, 1075, 815 and 110 individuals ha^{-1}. These two forests were less dense than most of the above-mentioned forests except for the Uttar Kannada and Agumbe of Peninsular India.

The basal cover of tree species was 45.95 m^2ha^{-1} in the montane forest, 38.25 m^2ha^{-1} in the lowland forest and 28.15 m^2 ha^{-1} in the riverain forest for the individuals with ≥ 5 cm gbh. The recalculated values of basal area for the individuals having ≥ 10, 15.7 and 30 cm gbh were 41.8, 41.24 and 39.19 m^2 ha^{-1} in the montane forest, 37.85, 36.11, and 34.98 m^2 ha^{-1} in the lowland forest, and 27.92, 27.57 and 26.45 m^2 ha^{-1} in the riverain forest, respectively. These values are moderate in comparison to the forests in Uttar Kannada and Agumbe (21 and 36.39 $m^2.ha^{-1}$ respectively for individuals of ≥10 cm gbh), Amazonia and French Guyana (29.1 and 37.94 respectively for individuals with ≥ 15.7 cm gbh), sacred groves of Meghalaya (57.46 and 71.44 m^2 ha^{-1} for individuals with ≥ 15.7 cm gbh) and Anamalais (36.47 $m^2.ha^{-1}$ for individuals with ≥ 30 cm gbh).

The Shannon and the evenness indices for all the undisturbed ecosystems show higher values, whereas Simpson index values are lower than the other stands mentioned in table 5.9. Many explanations for the diversity patterns have been proposed so far, which suggest that along with the main factors such as speciation, the geological history of the site, climate and precipitation as functions of latitudinal and altitudinal position (Gentry 1988a, 1992, Lieberman *et al.* 1985, Vázquez and Givnish 1998), and edaphic properties (Gentry 1988), a few other crucial factors such as competition (Huston 1979, 1980; Tilman 1982, Ashton 1989), and special and temporal micro-niche availability also influence the diversity (Tilman and Pacala 1993).

The dominance- distribution curve showing a lognormal distribution also supports that these forests are species-rich and heterogeneous communities (Whittaker 1972, Magurran 1988). Spatial distribution followed the general pattern of spatial dispersion (Greig-Smith 1983) which shows that a few species in nature are distributed in a regular way, while most of them are clumped or appear to be randomly distributed at some given observation scale. The presence of majority of clumped or contiguous species in these forest ecosystems also suggests that the present forests are highly heterogeneous and patchy which is a main characteristic feature of the tropical rain forests (Ashton 1969).

Richards (1996) has opined that high species content per unit area of the tropical forests is largely due to presence of the sinusiae. Whitmore (1975) has described 5 vertical strata in the tropical lowland evergreen rain forests of the Far East, which also include herbaceous layer. The profile diagrams of these undisturbed forest ecosystems, three layers including trees, lianas and shrubs overtopping the herbaceous layer, depict their structural complexity. The stratification in these forests allows to accommodate more species making the forest rich in species composition.

Biological spectrum of the three forest communities revealed that the phanerophytes, lianas and epiphytes surpassed their respective proportions in the normal spectrum given by Raunkiaer (1934), while the hemicryptophytes and therophytes were much below the normal proportion. Such biological spectra can be attributed to the humid climate (Meher-Homji 1964) of the Nokrek BR.

The population structure of the dominant species showed a reverse J-shaped density–diameter distribution curve, with preponderance of the individuals in the small girth classes, which revealed the mature stage of these forests and good regeneration. According to Condit *et al.* (1998), population health correlates with size distribution and healthy populations have steeper curves.

The population structure of the dominant species showed different patterns of growth. A few species such as, *Viburnum coriaceum* and *Ostodes paniculata* from the montane forest ecosystem and a majority of the lowland forest and riverain forest ecosystems showed poor regeneration. Several species having good number of saplings also showed poor recruitment in the lowland and riverain forests. The absence of individuals or smaller number of individuals in the intermediate girth classes may be explained by size-dependent growth-rate or higher size-specific mortality as suggested by Bongers *et al.* (1988).

CHAPTER VI

IMPACT OF HUMAN ACTIVITIES ON THE VEGETATION OF BUFFER ZONE

Introduction

The disturbed ecosystems in the buffer zone of the BR include, 1to12 year old successional communities on abandoned jhum fallows, bamboo groves, orange orchards and ecosystems affected by coal and limestone mining.

More than 300 sq. km area of the buffer zone of the BR is affected by shifting cultivation. The original vegetation of the BR has been converted into patches of secondary forests of different growing stages, due to shifting cultivation. Though the area affected by coal and limestone mining is much smaller compared to the area affected by shifting cultivation, mining activities have contributed substantially towards fragmentation of forests due to deposition of mine spoils and excavated minerals leading to altered habitat conditions and considerable loss of plant diversity.

In order to analyse the impact of various human activities on the vegetation of buffer zone, floristic composition, community characteristics and plant diversity have been studied in selected ecosystem types, viz. jhum fallows of 10 to 12 years age (J_{12}), 6 to 8 years age (J_6), 3 to 4 years age (J_3), and of one year age (J_1), bamboo groves (B), orange orchards (O), coal mine spoils (CM), and limestone mine spoils (LM). In the jhum fallows of 3-4 years, 6-8 years and 10-12 years age the trees, shrubs and herbs were all considered while carrying out the vegetation analysis. In case of one-year-old jhum fallows, bamboo groves and orange orchards, only herbaceous component was considered for vegetation analysis, whereas in mining-affected sites, which were devoid of tree species only shrub and herb components were studied in detail.

I. Communities on the jhum fallows, bamboo groves and orchards

Taxonomic diversity

A total of 356 vascular species including 334 angiosperms and 22 pteridophytes was recorded from the jhum fallows of different ages, bamboo groves and orchards. The number of species recorded per community increased with the age of the fallows (Table 6.1). Total number of genera was 261 of which 243 were angiospermic while 18 were pteridophytic. These 356 species representing 261 genera were distributed under 92 angiospermic and 13 pteridophytic families. Poaceae (31 species), Euphorbiaceae (20 species), Asteraceae (17 species) and Rubiaceae (16 species) were the dominant families in these communities. The first two families were dominant in all the communities. Asteraceae was the third dominant family in all the communities except in 10-12-yr old jhum fallows (J_{12}), where Lauraceae was the third dominant family instead of Asteraceae. *Ficus* (7 species), *Litsea* (7 species), *Rubus*, *Glochidion* and *Castanopsis* (5 species each) were the dominant genera found in these communities. Bamboo groves and orchards showed lower taxonomic diversity than the youngest jhum fallow (Table 6.1).

Table 6. 1 Taxonomic diversity of different communities of the buffer zone of Nokrek BR.

	J12	J6	J3	J1	B	O	Total
No. of species	225	148	141	98	94	62	356
No. of genera	174	120	121	88	89	59	261
No. of families	77	72	63	46	51	34	104

Species- area relationship

In the case of the pioneer communities on the younger jhum fallows, species-area curves for tree and shrub species indicated that the number of species reached the peak between 1700-2000 m^2, and in the case of herbs the number reached the plateau at about 35-40 m^2. However, in the older communities such as 10-12-yr old jhum fallows, shrub species did not reach the peak till 2000 m^2 area (Fig. 6.1). In Bamboo groves and orchards, herbaceous species showed the peak between 30-40 m^2.

Species richness

Species richness (species per 0.2 ha) of trees and shrubs increased with the age of the jhum fallows. However, herbaceous species-richness did not show any significant change with increase in the age of the communities on the jhum fallows (Table 6.2).

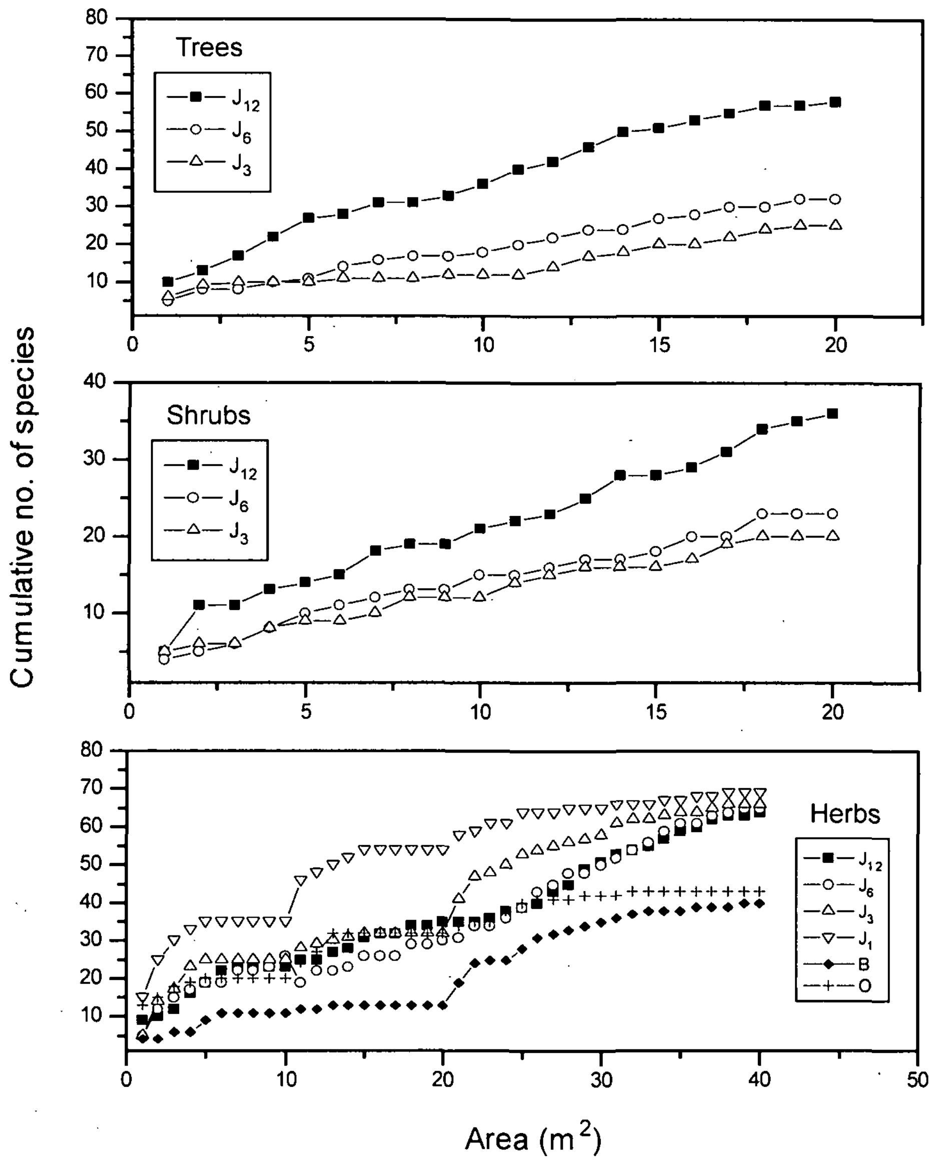


Fig. 6.1 Species-area curves for tree, shrub and herb species in plant communities on jhum fallows of different ages, bamboo groves and orchards in the buffer zone of the Nokrek BR (Area : x100 for trees and shrubs, and x 1 for herbs).

Number of tree species per plot (100 m^2) varied from 2 to10 in the young stands (J_3 and J_6) and from 7 to 14 species in the old stand (J_{12}) (Fig.

6.2). In the latter stand, 68 % of the plots had 10-15 species and no plot had less than 5 species. On the other hand, in the former stands, 63 to 73 % of the plots had 5-10 species and the rest of the plots had less than 5 species.

Tree species-richness was greater in the lower girth classes than in the higher girth classes in all the communities on the jhum fallows (Fig. 6.3).

Table 6.2 Species richness (measured per 0.2 ha in case of trees and shrubs, and per 40 m^2 in case of herbs) in different communities of the buffer zone of Nokrek BR.

Trees	**J_{12}**	**J_6**	**J_3**			
Species richness	58	32	25			
No. of genera	43	27	22			
No. of families	31	20	16			
Shrubs	**J_{12}**	**J_6**	**J_3**			
Species richness	36	23	20			
No. of genera	27	17	17			
No. of families	20	15	14			
Herbs	**J_{12}**	**J_6**	**J_3**	**J_1**	**B**	**O**
Species richness	64	65	66	69	40	43
No. of genera	59	59	60	62	28	27
No. of families	28	35	31	32	38	42

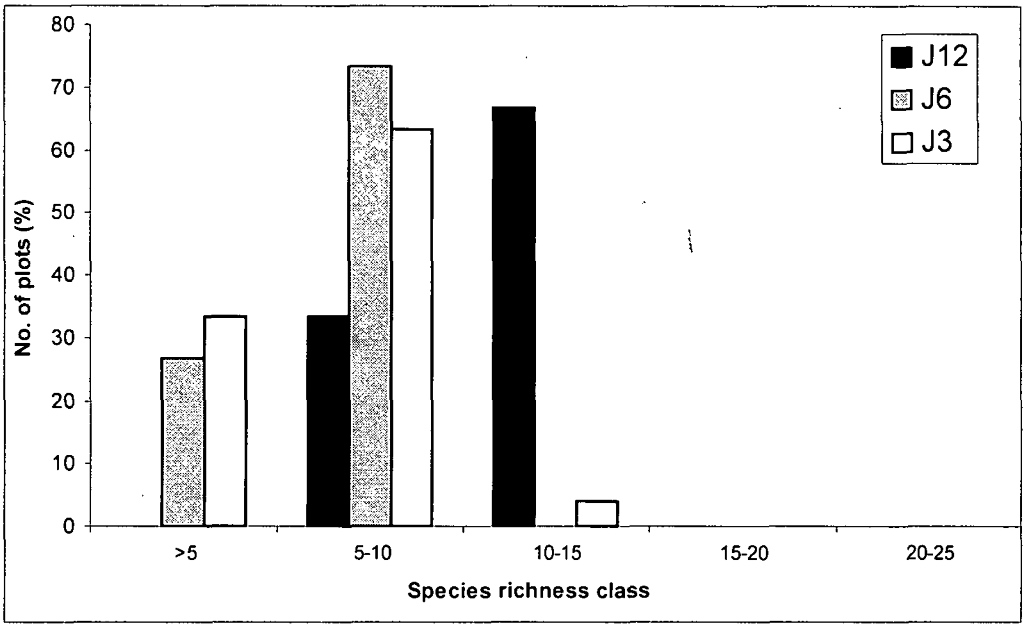


Fig. 6.2 Distribution of species richness (number of tree species per 100 m^2 plot) in the communities on jhum fallows of different ages in the buffer zone of the Nokrek BR.

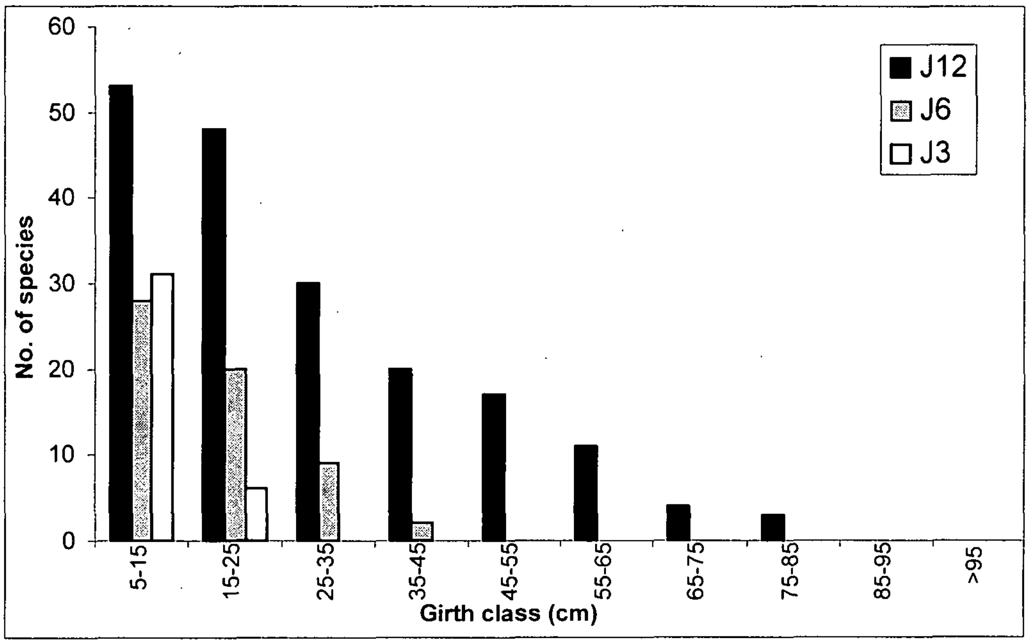


Fig. 6.3 Distribution of tree species richness in different girth classes in communities on jhum fallows of different ages in the buffer zone of the Nokrek BR.

Stratification

Profile diagrams of the communities on the jhum fallows of different ages helped in understanding the vertical stratification of the vegetation and the pattern of succession. Jhum fallows of 3-4 years age hardly showed any stratification. A total of 11 species was recorded from these stands, dominated by *Macaranga indica* saplings. Along with some other shrub species *M. indica* formed a more or less homogeneous stand with even canopy. The average height of the canopy was 3-3.5 m., although saplings of a few other tree species such as *Eurya acuminata*, *Callicarpa vestita* and *Bruinsmia polysperma* emerged above the canopy layer (Fig. 6.4a).

In the jhum fallows of 6-8 years age, the canopy attained 6-8 m height. In all 11 species were recorded from this stand. Here, the species were distributed in two strata; the canopy layer, which was composed of trees and the understorey, which was composed of shrubs and saplings of trees. In this stand too, canopy layer was dominated by *Macaranga indica* followed by *Callicarpa vestita* (Fig. 6.4b).

The mature fallows of 10-12 years age had three distinct strata. A total of 18 species was recorded from this stand. The top canopy layer had an average height of 15 m and was composed mostly of fast growing trees such as *Macaranga indica*, *Eurya acuminata*, *Callicarpa vestita*, and *Saurauia roxburghii.* The middle layer of the community was composed of such species as *Pittosporum podocarpum*, *Lindera reticulata* and *Saurauia nepaulensis*. The lowermost layer was composed of shrubs and saplings (Fig. 6.4c).

The orchards being the man-managed community had much simpler organisation consisting of even-aged trees, and showed no stratification (Fig. 6.4d).

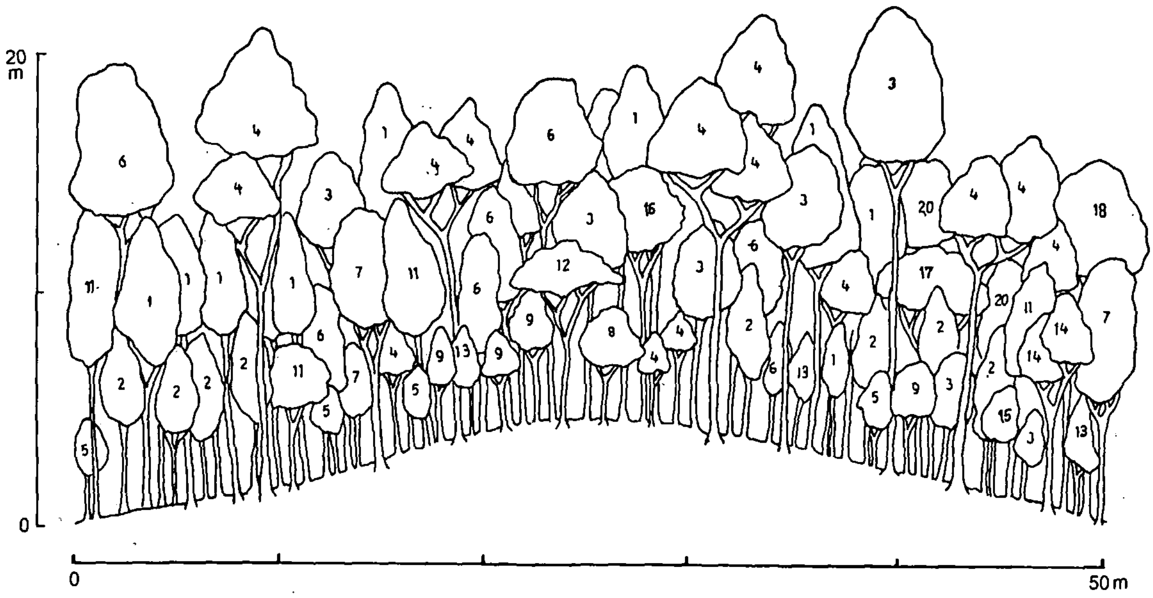


Fig. 6.4 a Profile diagram of a forest stand growing on a 10-12 yr old jhum fallow.

1-*Macaranga indica*, 2-*Saurauia punduana*, 3-*Eurya acuminata*, 4-*Saurauia roxburghii*, 5-*Pittosporum podocarpum*, 6-*Callicarpa vestita*, 7-*Symplocos hookeri*, 8-*Saurauia napaulensis*, 9-*Lindera reticulata*, 10-*Callicarpa arborea*, 11-*Ostodes paniculata*, 12-*Litsea lancifolia*, 13-*Phoebe lanceolata*, 14-*Gleditsia assamica*, 15-*Glochidion assamicum*, 16-*Castanopsis tribuloides*, 17-*Oreocnide integrifolia*, 18-*Schima wallichii*

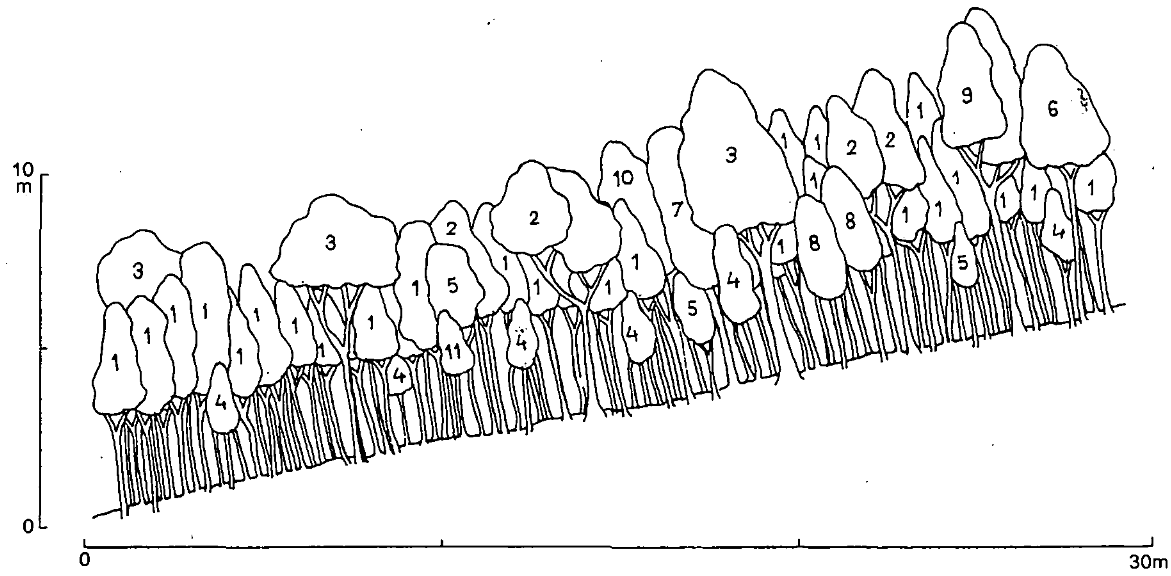


Fig. 6.4 b Profile diagram of a forest stand growing on a 6-8 yr old jhum fallow.

1-*Macaranga indica*, 2-*Saurauia punduana*, 3-*Callicarpa vestita*, 4-*Eurya acuminata*, 5-*Rhus javanica*, 6-*Securinega virosa*, 7-*Castanopsis tribuloides*, 8-*Pithecellobium heterophyllum*, 9-*Saurauia roxburghii*, 10-*Alangium chinense*, 11-*Miliusa roxburghiana*

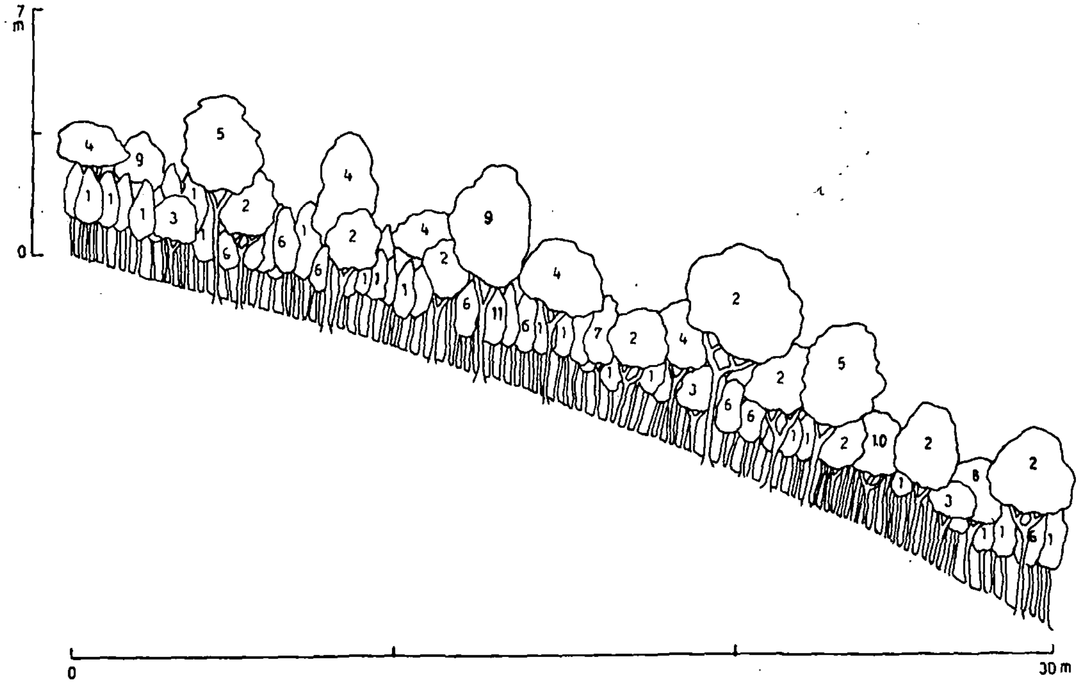


Fig. 6.4 c Profile diagram of a forest stand growing on a 3-4 yr old jhum fallow.

1-*Macaranga indica*, 2-*Eurya acuminata*, 3-*Saurauia punduana*, 4-*Callicarpa vestita*, 5-*Bruinsmia polysperma*, 6-*Maesa indica*, 7-*Skimmia laureola*, 8-*Rhus javanica*, 9-*Saurauia roxburghii*, 10-*Trema cannabina*, 11-*Citrus medica*

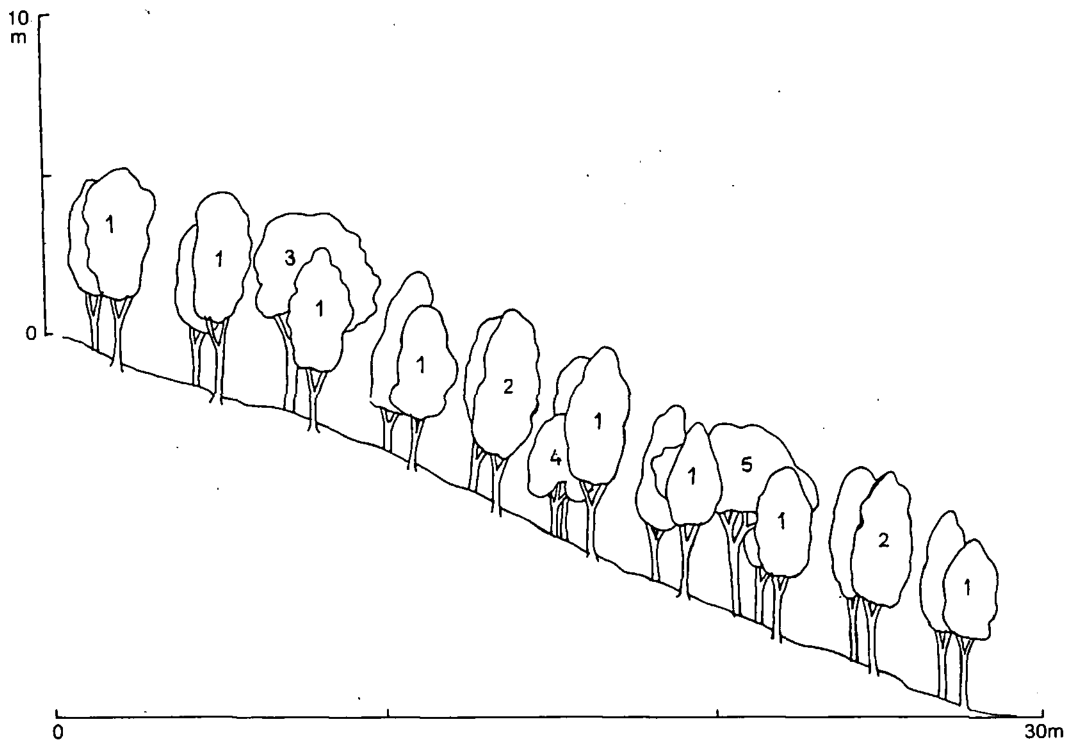


Fig. 6.4 d Profile diagram of an orchard.

1- *Citrus sinensis*, 2- *Citrus maxima*, 3- *Prunus persica*, 4- *Morus australis*, 5- *Glochidion lanceolarium*

Life form spectrum

The phanerophytes were dominant in the 10-12- yr. old jhum fallows, while chamaephytes and hemicryptophytes were abundant in the young jhum fallows (1 yr.-old) (Fig.6.5 A). There was a gradual decrease in the proportion of chamaephytes, hemicryptophytes and therophytes and increase in the proportion of lianas with the age of the fallows.

In the orchards the proportion of chamaephytes, hemicryptophytes, geophytes and therophytes was greater than in the bamboo groves (Fig 6.5 B). However, the proportion of phanerophytes and lianas was greater in the bamboo groves than in the orchards.

Distribution of species in the Raunkiaer's frequency classes

Frequency class A dominated in all the study sites suggesting that the communities on the jhum fallows are highly heterogeneous in nature (Fig. 6.6). Raunkiaer's normal frequency distribution (A> B>C D<E) was observed only in case of trees. *Macaranga indica, Eurya accuminata, Callicarpa vestita* were the most frequent species in all the jhum fallows. In addition to these, *Maesa ind*ica on the younger jhum fallows and *Saurauia roxburghii* on the 10-12 yr. old fallows were also frequently found.

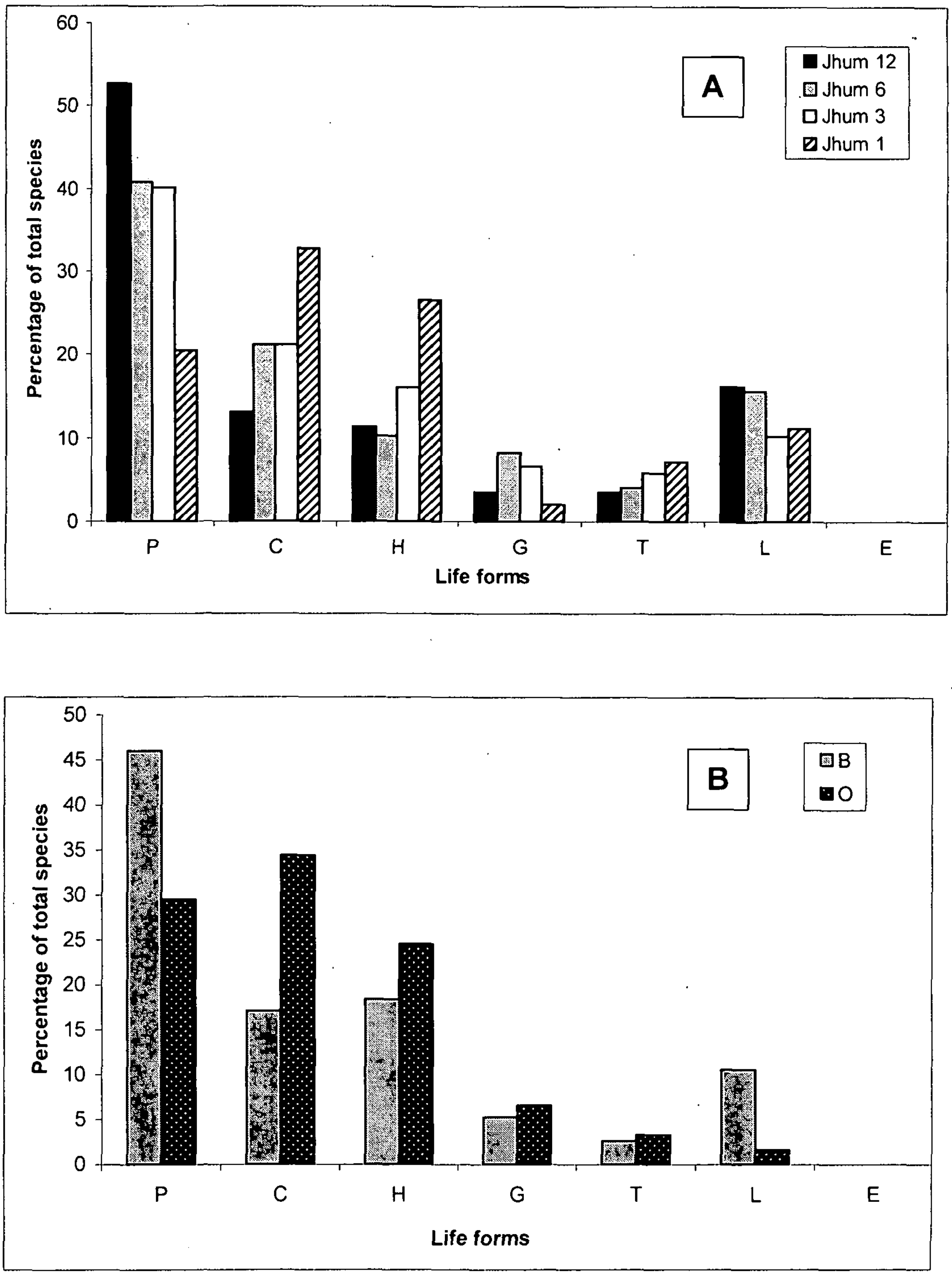


Fig. 6.5 Life form spectrum of (A) different communities on the jhum fallows of different ages, and (B) bamboo groves and orchards in the buffer zone of the Nokrek BR.

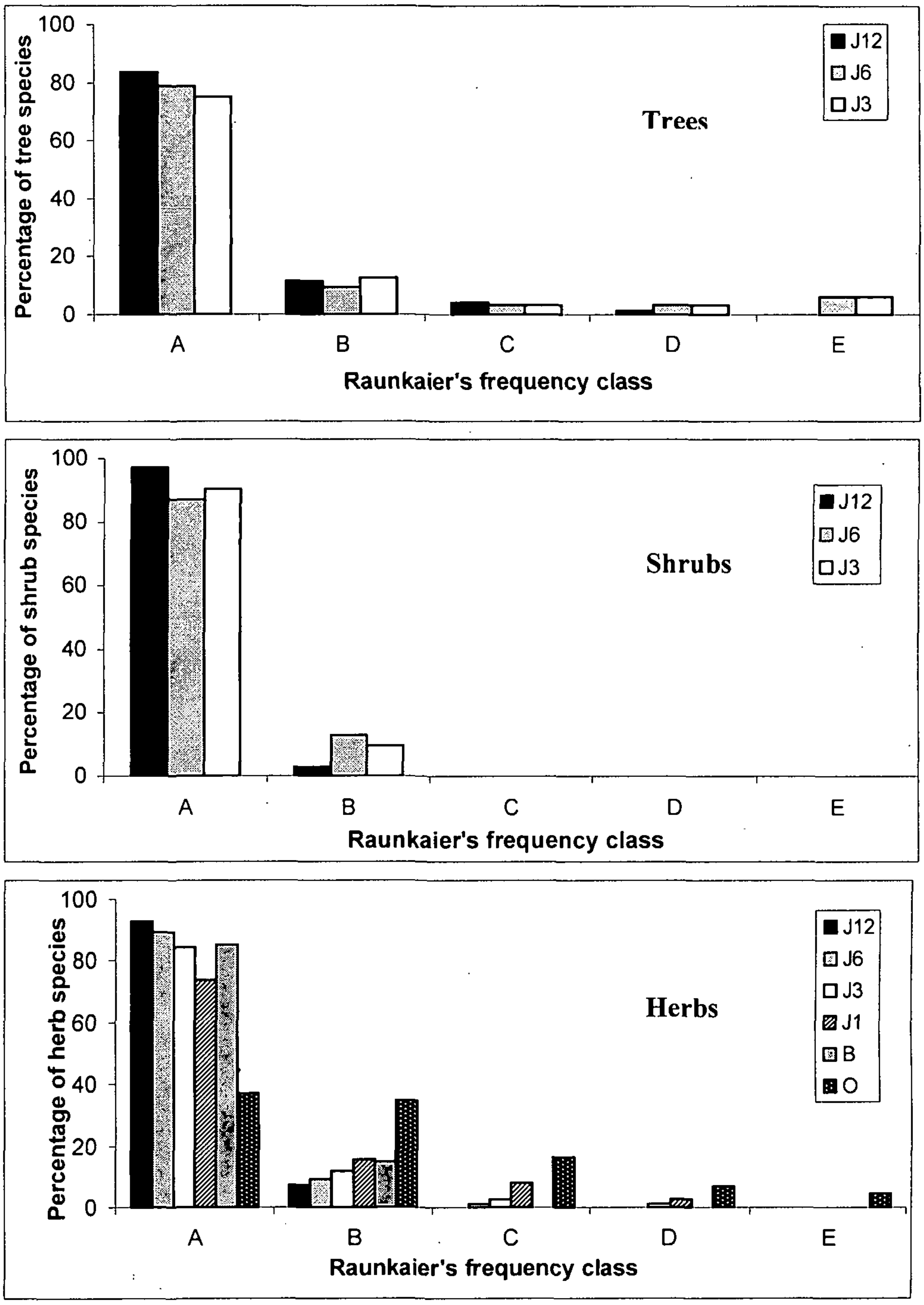


Fig. 6.6 **Distribution of tree, shrub and herb species in Raunkiaer's frequency classes, in the different communities of the buffer zone of the Nokrek BR.**

The shrubs were distributed in frequency classes A and B only. In case of the herbs, the proportion of species in class A increased with the age of jhum fallows.

The orchard was the only ecosystem in which the frequency class E was represented. The two species that showed high frequency value (>80 %) were *Ageratum conyzoides* and *Bidens pilosa.*

Spatial distribution pattern

On the jhum fallows, the contiguous distribution pattern was predominant (90-98%) among the constituent species. Regular distribution was rare and observed only in trees growing on the younger jhum fallows (Fig. 6.7). *Rhus javanica* in the 6 yr.–old fallows and *Callicarpa vestita* in the 3 yr.–old fallows showed somewhat regular distribution pattern.

Random distribution was shown by a few herbaceous species, like *Mikania micrantha* in one-year-old jhum fallows, *Piper mullesua* in Bamboo groves and *Phyllanthus urinaria* in the orchards.

Dominance

The dominance-diversity curves for trees followed a lognormal pattern in plant communities on jhum fallows. There was a gradual increase in equitability and a concomitant decrease in the dominance in the plant community with age of the fallows. The highly disturbed communities showed high dominance and low equitability thereby indicating that sites exposed to high degree of disturbance supported a community with few dominant species.

Where the disturbance was mild, community slowly changed from high dominance-low equitability to low dominance-high equitability during the course of recovery of jhum fallows.

The shrubs followed MacArthur's broken stick model, showing low equitability and high dominance. The herbs showed log normal distribution pattern of dominance (Fig 6.8). Table 6.3 gives an account of the dominant species of different communities in the buffer zone of the Nokrek BR.

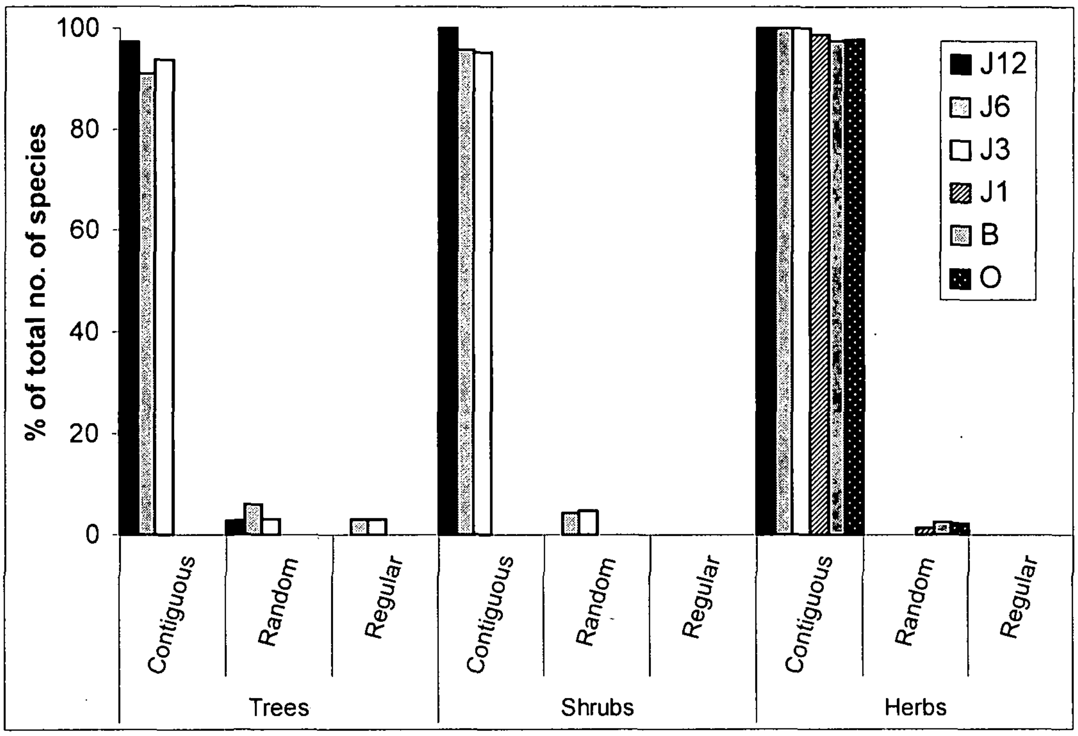


Fig. 6.7 Spatial distribution of the tree, shrub and herb species in the different communities in the buffer zone of the Nokrek BR.

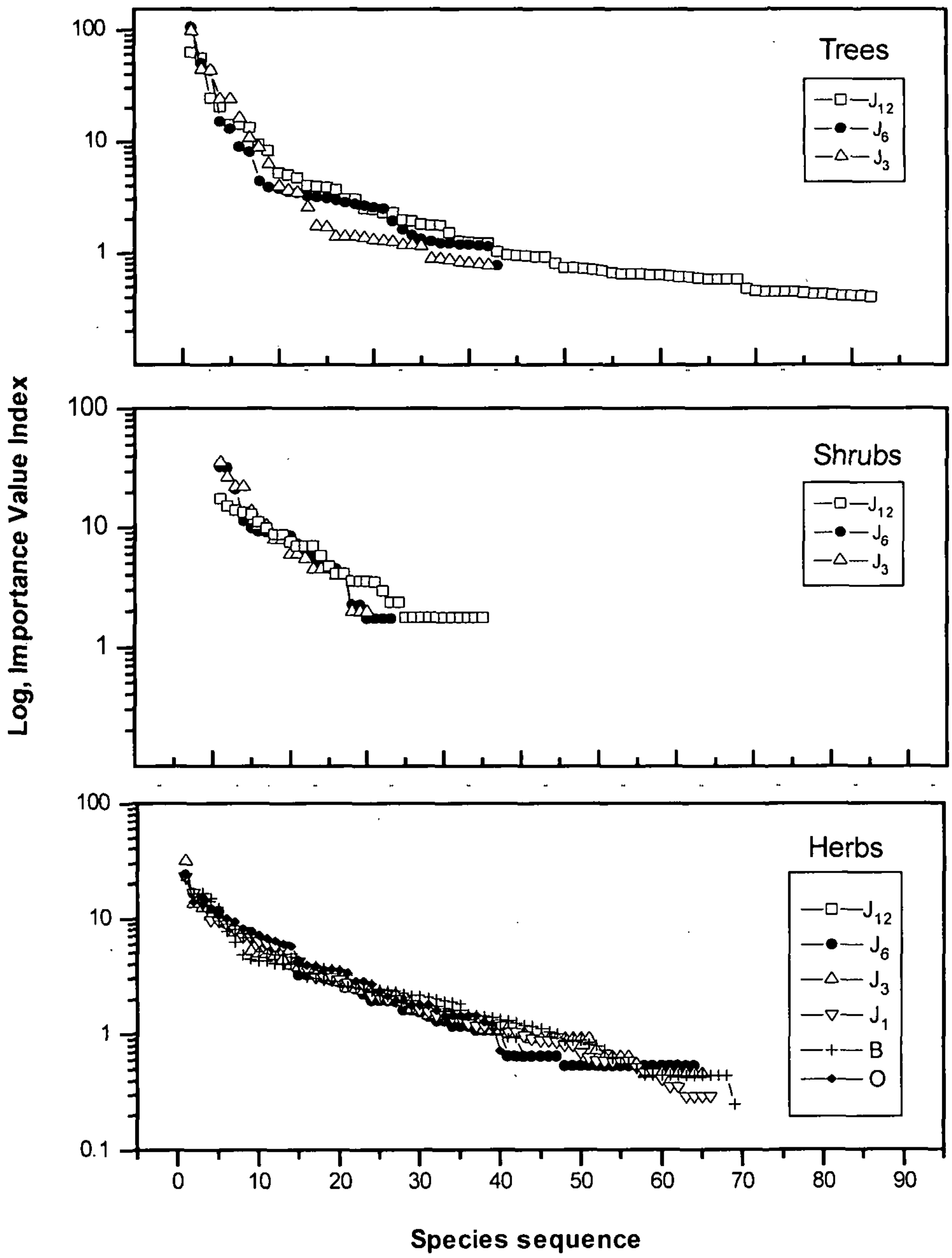


Fig. 6.8 **Dominance-diversity curves of tree, shrub and herb species in the different communities (J_{12}, J_6, J_3, J_1, B and O) of the buffer zone of the Nokrek BR.**

Density

The total stand density of tree species was recorded highest (9774 individuals ha^{-1}) in the 3- yr. old fallows (Table 6.4) and it decreased with increasing age of the jhum fallows. The tree species largely contributing to the stand density were *Macaranga indica*, *Eurya acuminata*, *Callicarpa vestita* and *Saurauia roxburghii* (Appendix III). The density- diameter distribution in different girth classes (Fig. 6.9) revealed that the density of tree species in the plant community decreased with increase in girth class.

The shrub density was similar in jhum fallows except in the 10-12 yr. old fallow. The density of the herbaceous species, similar to that of tree species, decreased with the increasing age of the jhum fallows. However, orchards showed the highest density of herbaceous species among all the communities. *Eupatorium adenophorum* was the dominant herb in all the fallows. *Panicum humidorum* and *Tectaria polymorpha* in the bamboo groves, *Ageratum conyzoides*, *Bidens pilosa* and *Peperomia pellucida* in the orchards had high population density (Appendix III).

Basal cover

The basal cover of the tree species increased with the age of the plant communities on jhum fallows (Table 6.4). In the pioneer community (3-4 yr. old fallows) young individuals (5-15 cm gbh) contributed maximum to the basal cover. In the plant community developing on 6-8 yr. old fallows, the individuals having 15-25 cm gbh along with younger plants (5-15 cm gbh) were main contributors, while in the old plant community in 10-12 yr. old fallows the plants of 15-25, 25-35, 35-45 cm gbh classes became more important than other classes (Fig. 6.10).

Macaranga indica, *Eurya acuminata* and *Callicarpa vestita* were the main contributors to the basal cover of the communities. The basal cover of *Macaranga indica* varied from 0.47 m^2ha^{-1} in J_3 to 4.55 m^2ha^{-1} in J_{12}. Similarly, basal cover of *Callicarpa vestita* varied from 0.25 to 1.8 m^2ha^{-1} and that of *Eurya acuminata*, from 0.23 to 3.2 m^2ha^{-1} in young (J_3) and older (J_{12}) jhum fallows, respectively.

Table 6.3 Dominant tree, shrub and herb species of different plant communities in the buffer zone of the Nokrek BR and their IVI values.

Trees		Shrubs		Herbs	
Dominant species	**IVI**	**Dominant species**	**IVI**	**Dominant species**	**IVI**
		J_{12}			
Macaranga indica	61.36	*Solanum myriacanthum*	17.50	*Eupatorium adenophorum*	23.56
Eurya acuminata	55.30	*Tabernaemontana divaricata*	15.21	*Eragrostis unioloides*	16.64
Callicarpa vestita	24.31	*Rhynchotechum ellipticum*	14.02	*Abacopteris multilineata*	14.59
		J_6			
Macaranga indica	103.21	*Thysanolaena maxima*	32.54	*Eupatorum adenophorum*	31.03
Eurya acuminata	50.13	*Clerodendrum viscosum*	32.01	*Ageratum conyzoides*	13.50
Callicarpa vestita	42.56	*Rubus khasianus*	21.04	*Pogostemon auricularis*	12.24
		J_3			
Macaranga indica	94.63	*Rubus khasianus*	34.88	*Eupatorum adenophorum*	22.89
Eurya acuminata	43.78	*Melastoma nepalensis*	26.56	*Bidens pilosa*	16.48
Callicarpa vestita	42.74	*Lantana camara* L.	22.14	*Borreria articularis*	13.28

		J_1			
-	-	-	-	*Eupatorium adenophorum*	23.57
-	-	-	-	*Ageratum conyzoides*	16.41
-	-	-	-	*Borreria articularis*	16.40
		B			
-	-	-	-	*Panicum humidorum*	23.51
-	-	-	-	*Piper mullesua*	13.88
-	-	-	-	*Tectaria polymorpha*	13.28
		O			
-	-	-	-	*Ageratum conyzoides*	21.44
-	-	-	-	*Bidens pilosa*	15.58
-	-	-	-	*Eupatorium adenophorum*	14.35

Table 6.4 Density and basal area of tree, shrub and herb species of different plant communities in the buffer zone of the Nokrek BR

Plant communities on different jhum fallows/ bamboo groves/ orchards	Trees		Shrubs	Herbs
	Density (ha^{-1})	Basal area ($m^2 ha^{-1}$)	Density (ha^{-1})	Density (ha^{-1})
J_{12}	5665	17.03	51833	2,09,500
J_6	7560	14.61	44833	2,79,500
J_3	10280	5.71	45000	4,49,000
J_1	-	-	-	8,40,500
B	-	-	-	1,46,000
O	-	-	-	10,41,750

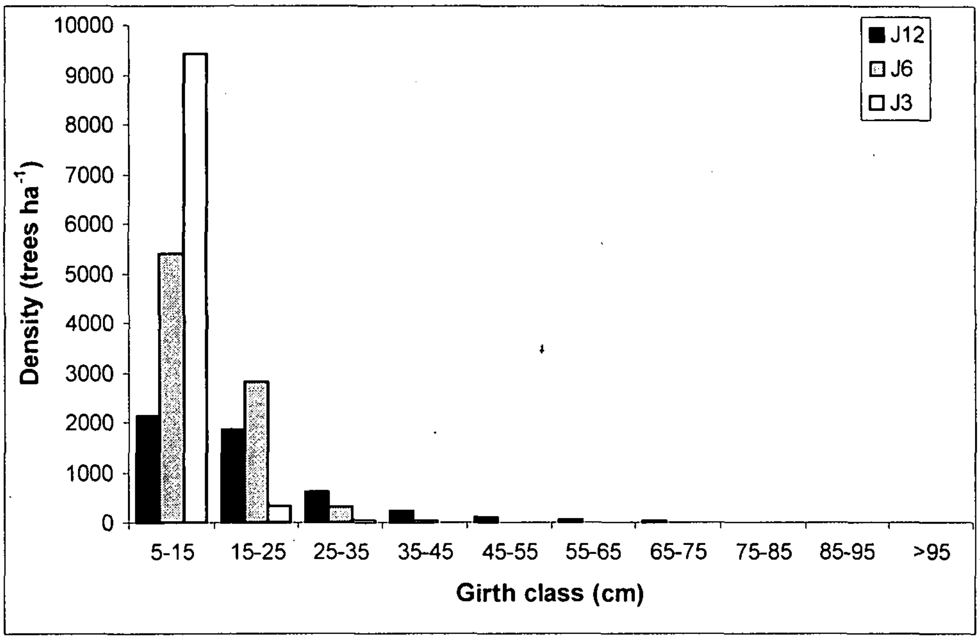


Fig. 6.9 Density–diameter distribution of tree species in the different communities on the jhum fallows of different ages in the buffer zone of the Nokrek BR.

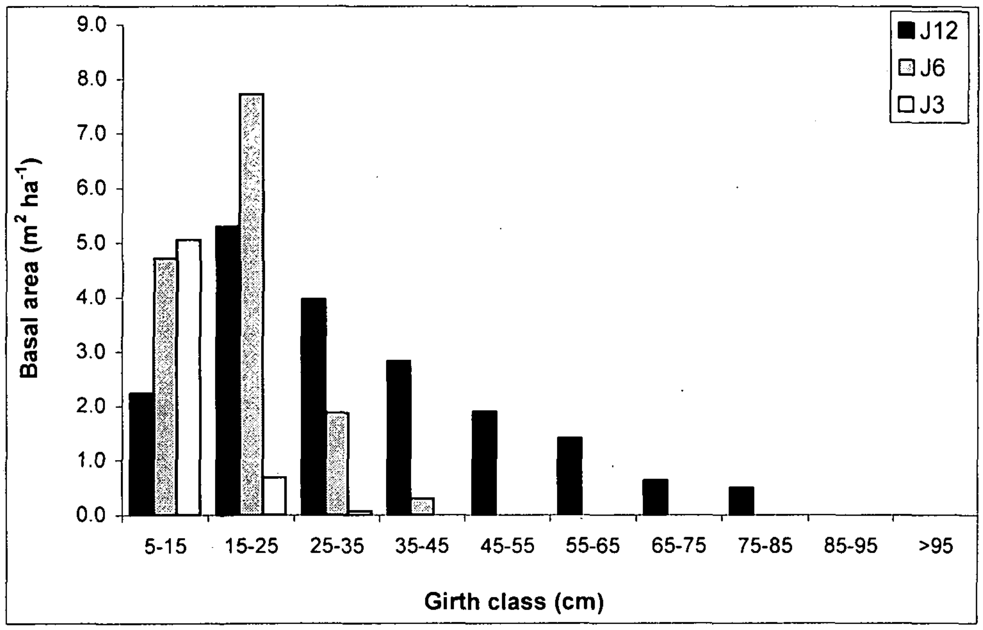


Fig. 6.10 Distribution of basal area of tree species in the different communities on the jhum fallows of different ages in the buffer zone of the Nokrek BR.

Ecological diversity

The α - diversity in the community increased with the age of the jhum fallows. Diversity of herbaceous species in the bamboo groves and orchards was lower than the younger jhum fallows (Table 6.5 a, b & c).

Tree β–diversity (Table 6.6 a, b and c) between different communities of buffer zone was higher than shrubs and herbs. The orchards were completely different than the other communities in terms of β–diversity of herbaceous species.

Similarity

The successional communities on the jhum fallows were dissimilar in species composition. Nevertheless, they showed greater similarity in shrubs and herbs than the trees (Table 6.7 a, b &c). The Morisita-Horn index of quantitative similarity was high between 6 yr and 3 yr-old stands (Table 6.8 a, b & c).

Population structure of dominant tree species

The population of all selected tree species in old jhum fallows showed a pyramidal structure indicating a marked decrease in the density of progressively aging individuals in the population (Fig. 6.11). The tree species in the fallows of younger ages were represented by saplings.

Table 6.5 a Diversity indices of tree species in different communities of the buffer zone of the Nokrek BR.

	J12	J6	J3
Shannon diversity index	2.43	1.97	1.88
Pielou evenness index	0.60	0.57	0.58
Simpson dominance index	0.17	0.27	0.24
α- diversity (S/logN)	8.25	5.39	4.00

Table 6.5 b Diversity indices of shrub species in different communities of the buffer zone of the Nokrek BR.

	J12	J6	J3
Shannon diversity index	3.14	2.58	2.48
Pielou evenness index	0.88	0.82	0.83
Simpson dominance index	0.06	0.12	0.11
α- diversity (S/logN)	6.80	4.39	3.76

Table 6.5 c Diversity indices of herb species in different communities of the buffer zone of the Nokrek BR.

	J12	J6	J3	J1	B	O
Shannon diversity index	3.14	3.19	3.38	3.16	3.13	3.14
Pielou evenness index	0.76	0.77	0.79	0.75	0.85	0.84
Simpson dominance index	0.07	0.08	0.06	0.08	0.07	0.06
α- diversity (S/logN)	9.51	9.25	8.81	8.50	6.28	5.16

Table 6.6 a β-diversity values for tree species between pairs of different communities of the buffer zone of the Nokrek BR.

	J12	J6	J3
J12	0	-	-
J6	0.64	0	-
J3	0.61	0.47	0

Table 6.6 b β-diversity values for shrub species between pairs of different communities of the buffer zone of the Nokrek BR.

	J12	J6	J3
J12	0	-	-
J6	0.34	0	-
J3	0.49	0.45	0

Table 6.6 c β-diversity values for herb species between pairs of different communities of the buffer zone of the Nokrek BR.

	J12	J6	J3	J1	B	O
J12	0	-	-	-	-	-
J6	0.36	0	-	-	-	-
J3	0.40	0.40	0	-	-	-
J1	0.46	0.40	0.41	0	-	-
B	0.58	0.64	0.64	0.74	0	-
O	0.61	0.59	0.52	0.57	0.78	0

Table 6.7 a Sørensen similarity index for tree species between pairs of different communities of the buffer zone of the Nokrek BR.

	J12	J6	J3
J12	1	-	-
J6	35.55	1	-
J3	38.55	52.63	1

Table 6.7 b Sørensen similarity index for shrub species between pairs of different communities of the buffer zone of the Nokrek BR.

	J12	J6	J3
J12	1	-	-
J6	65.52	1	-
J3	50.91	55.81	1

Table 6.7 c Sørensen similarity index for herb species between pairs of different communities of the buffer zone of the Nokrek BR.

	J12	J6	J3	J1	B	O
J12	1	-	-	-	-	-
J6	63.57	1	-	-	-	-
J3	60.00	59.54	1	-	-	-
J1	54.14	59.70	59.26	1	-	-
B	42.31	36.19	35.85	25.69	1	-
O	39.25	40.74	47.71	42.86	21.69	1

Table 6.8 a Morisita-Horn Index of quantitative similarity for tree species between pairs of different communities of the buffer zone of the Nokrek BR.

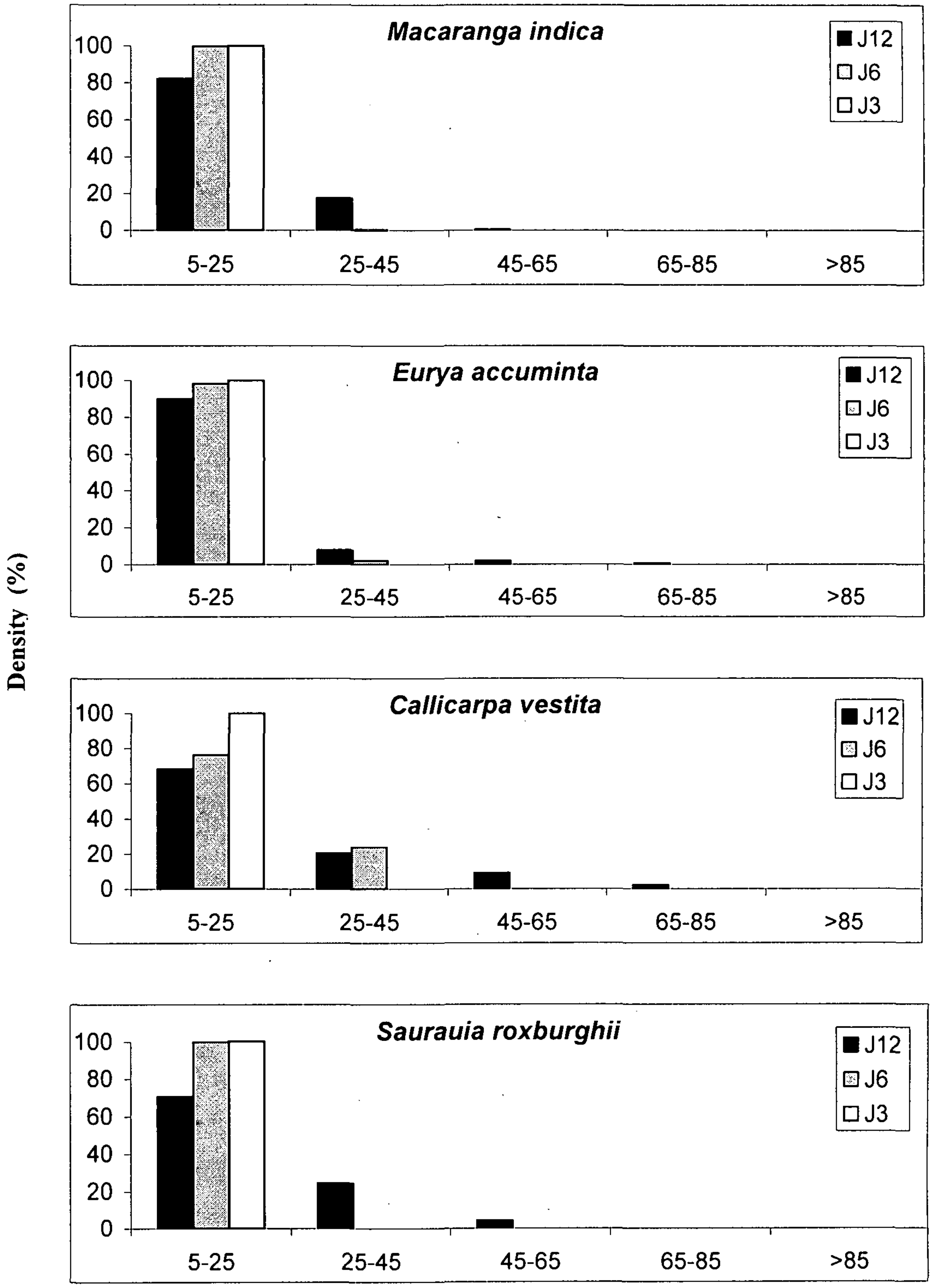
	J12	J6	J3
J12	1	-	-
J6	0.86	1	-
J3	0.82	0.97	1

Table 6.8 b Morisita-Horn Index of quantitative similarity for shrub species between pairs of different communities of the buffer zone of the Nokrek BR.

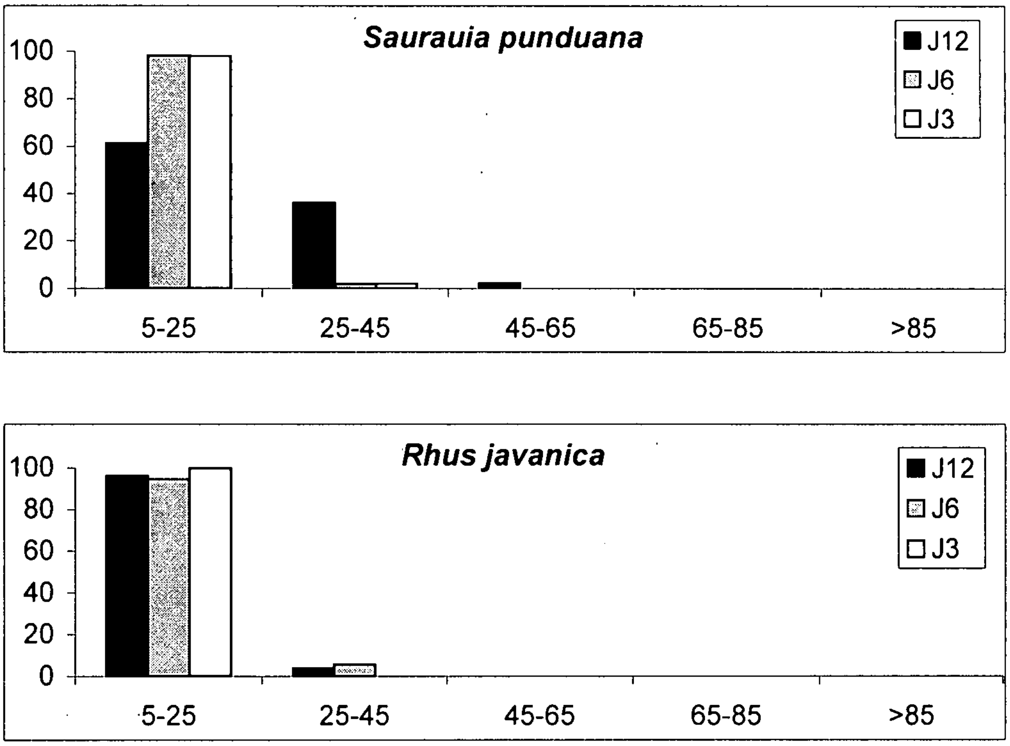
	J12	J6	J3
J12	1	-	-
J6	0.40	1	-
J3	0.39	0.30	1

Table 6.8 c Morisita-Horn Index of quantitative similarity for herb species between pairs of different communities of the buffer zone of the Nokrek BR.

	J12	J6	J3	J1	B	O
J12	1	-	-	-	-	-
J6	0.72	1	-	-	-	-
J3	0.63	0.81	1	-	-	-
J1	0.58	0.81	0.86	1	-	-
B	0.23	0.22	0.16	0.20	1	-
O	0.40	0.63	0.70	0.74	0.20	1


Density (%)
Macaranga indica
J12
J6
J3
100
80
60
40
20
0
5-25
25-45
45-65
65-85
>85
Eurya accuminta
J12
J6
J3
100
80
60
40
20
0
5-25
25-45
45-65
65-85
>85
Callicarpa vestita
J12
J6
J3
100
80
60
40
20
0
5-25
25-45
45-65
65-85
>85
Saurauia roxburghii
J12
J6
J3
100
80
60
40
20
0
5-25
25-45
45-65
65-85
>85

continued...



Girth class (cm)

Fig. 6.11 **Population structure of some dominant tree species in the communities on the jhum fallows of different ages in the buffer zone of the Nokrek BR.**

Tree Seedling density

The tree seedling density varied from 576 individuals $100m^{-2}$ in J_1 to 868 individuals $100m^{-2}$ in J_3 without showing any definite relationship with age of the community. The tree seedling density in the bamboo groves was 752 individuals $100m^{-2}$ and in orchards it was 80 individuals $100m^{-2}$ (Table 6.9).

Eurya acuminata, Maesa indica and *Saurauia nepaulensis* were the abundant species of J_{12}. *Securinega virosa, Rhus javanica* and *Maesa indica* were abundant in J_6. Seedlings of *Macaranga indica* were present in all the jhum fallows including J_1, however its seedling density was highest in J_3 (448 individuals $100m^{-2}$) and lowest in mature jhum fallows (36 individuals $100m^{-2}$). Besides *Macaranga indica, Eurya acuminata* and *Maesa indica* also had high seedling density (108 and 100 individuals $100m^{-2}$, respectively) in J_3.

In the bamboo groves seedlings of 16 tree species were recorded. Out of these tree species, *Ficus hirta* (172 individuals $100m^{-2}$) and *Pithecellobium heterophyllum* (112 individuals $100m^{-2}$) seedlings were more abundant. In the orchards, only *Alangium chinense* seedlings (80 individuals $100m^{-2}$) were recorded.

The seedlings of other dominant tree species such as *Glochidion sphaerogynum*, *Schima wallichii* and *Ficus subincisa* in J_{12}, *Saurauia roxburghii*, *Pithecellobium heterophyllum* and *Alangium chinense* in J_6, *Saurauia punduana*, *Skimmia laureola* and *Saurauia roxburghii* in J_3 were not recorded.

Table 6.9 Tree seedling density (no. $100m^{-2}$) in different communities of the buffer zone of the Nokrek BR.

Species	J12	J6	J3	J1	B	O
Eurya acuminata DC.	132	115	108	108	0	0
Maesa indica (Roxb.) Wall.	88	88	100	160	0	0
Saurauia nepaulensis DC.	72	0	0	0	0	0
Securinega virosa (Roxb. ex Willd.) Baill.	40	148	52	28	60	0
Symplocos racemosa Roxb.	28	0	0	0	0	0
Macaranga indica Wt.	36	96	448	188	0	0
Callicarpa vestita Roxb.	20	20	28	28	0	0
Picrasma javanica Bl.	20	0	0	0	0	0
Pittosporum podocarpum Gagn.	20	0	0	0	0	0
Saurauia roxburghii Wall.	20	0	0	52	0	0
Macaranga denticulata (Bl.) Muell.0Arg.	12	52	0	0	0	0
Croton oblogus Burm.f.	12	12	0	0	0	0
Ficus hirta Vahl.	12	12	0	0	172	0
Prunus cerasoides D. Don.	12	12	0	0	0	0
Ostodes paniculata Bl.	12	8	0	0	0	0
Erythroxylum kunthianum Kurz.	12	0	0	0	0	0

Euonymus lawsonii Clarke & Prain.	12	0	0	0	0	0
Saurauia punduana Wall.	12	0	0	0	0	0
Syzygium oblatum (Roxb.) Wall. ex Cowan & Cowan	12	0	0	0	0	0
Rhus javanica L.	8	28	12	0	0	0
Castanopsis indica A. DC.	8	40	0	0	0	0
Cinnamomum tamala (Spreng) Nees & Eberm.	8	12	0	0	0	0
Dysoxylum gobara(Buch.-Ham.) Merr.	8	0	28	0	0	0
Glochidion lanceolarium (Roxb.) Voigt.	8	0	12	0	0	0
Helicia nilagirica Bedd.	8	0	8	0	0	0
Litsea monopetala (Roxb.) Pers.	8	0	0	12	0	0
Litsea salicifolia (Nees) Hook.f.	8	0	0	0	40	0
Maesa montana DC.	8	0	0	0	20	0
Oreochnide integrifolia (Gaud.) Miq.	8	0	0	0	12	0
Caryota urens L.	0	32	0	0	0	0
Lindera reticulata Benth.	0	20	0	0	20	0
Melodinus monogynus Roxb.	0	20	0	0	0	0
Bauhinia variegata L.	0	12	0	0	0	0
Gleditsia assamica Bor.	0	12	0	0	0	0

Glochidion sphaerogynum Kurz.	0	12	0	0	0	0
Ilex excelsa (Wall.) Hook.f.	0	12	0	0	0	0
Alangium chinense (Lour.) Harms	0	8	0	0	32	80
Castanopsis tribuloides (Sm.) DC.	0	8	0	0	0	0
Bruinsmia polysperma (Cl.) Van Steenis	0	0	32	0	0	0
Ficus subincisa Buch.0Ham.ex J.E.Sm.	0	0	28	0	0	0
Glochidion thomsonii (Muell.0Arg.) Hook.f.	0	0	12	0	0	0
Pithecellobium heterophyllum (Roxb.) Haridasan & Rao	0	0	0	0	112	0
Antidesma acidum Retz.	0	0	0	0	60	0
Baliospermum calycinum Muell.0Arg.	0	0	0	0	40	0
Dillenia scabrella (D.Don) Roxb. ex Wall.	0	0	0	0	40	0
Meliosma wallichii Hook.f.	0	0	0	0	40	0
Lithocarpus elegans (Bl.) Soepadma	0	0	0	0	32	0
Schima wallichii (DC.) Korth.	0	0	0	0	32	0
Castanopsis purpurela (Miq.) Balakr.	0	0	0	0	20	0
Trevesia palmata (Roxb.) Vis.	0	0	0	0	20	0
Total	**664**	**779**	**868**	**576**	**752**	**80**

II. Communities on the mining sites

Floristic Composition

Altogether 19 species belonging to 14 families and 18 genera were recorded from the coalmine site. In case of lime stone mine spoils 36 species were recorded which belonged to 24 families and 35 genera. Asteraceae and Fabaceae were common on the lime stone minespoils while Poaceae on the coalmine spoils.

Species–area relationship

In both the mine spoil areas species –area curves for shrubs levelled off at around 500 m^2, whereas that for herbs between 20-40m^2 area.

Species richness

Tree, shrub and herb species richness per unit area decreased drastically from the unmined sites to the minespoil areas (Table 6.10).

Life form spectrum

On the coalmine and limestone mine spoils chamaephytes and geophytes were dominant and therophytes were absent (Fig. 6.13)

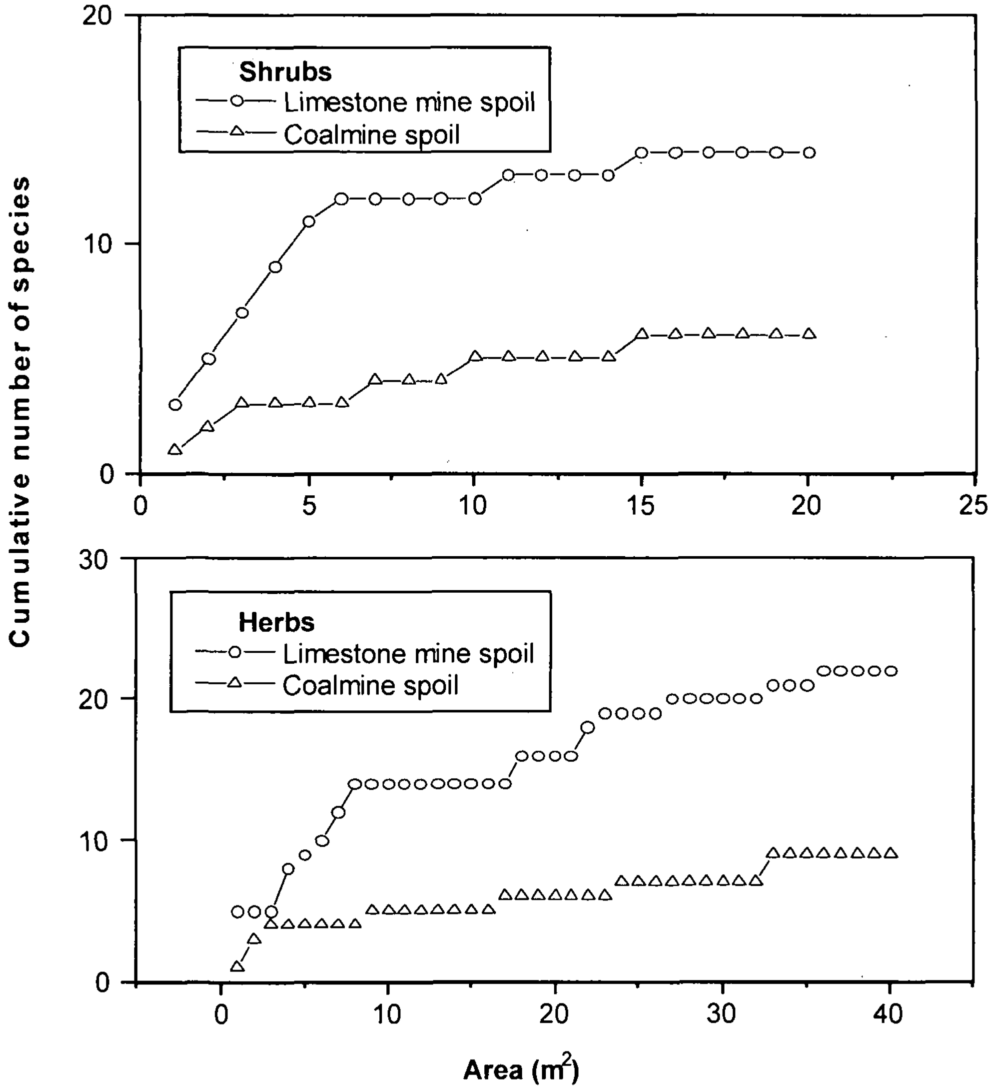


Fig. 6.12 **Species-area curves for tree, shrub and herb species in the communities at the mining sites in the buffer zone of the Nokrek BR (Area : X 100 for trees and shrubs and X 1 for herbs).**

Table 6.10 Species richness (measured as number of species per 0.2 ha in case of trees and shrubs and per 40 m^2 in case of herbs), density and basal area of trees, shrubs and herbs in communities at the mining sites in the buffer zone of the Nokrek BR.

	Limestone mine spoil		Coalmine spoil	
	Shrub	**Herbs**	**Shrub**	**Herbs**
Species richness	14	22	6	9
No. of genera	12	22	6	8
No. of families	11	17	5	7
Density (ha^{-1})	15500	86750	215	25250

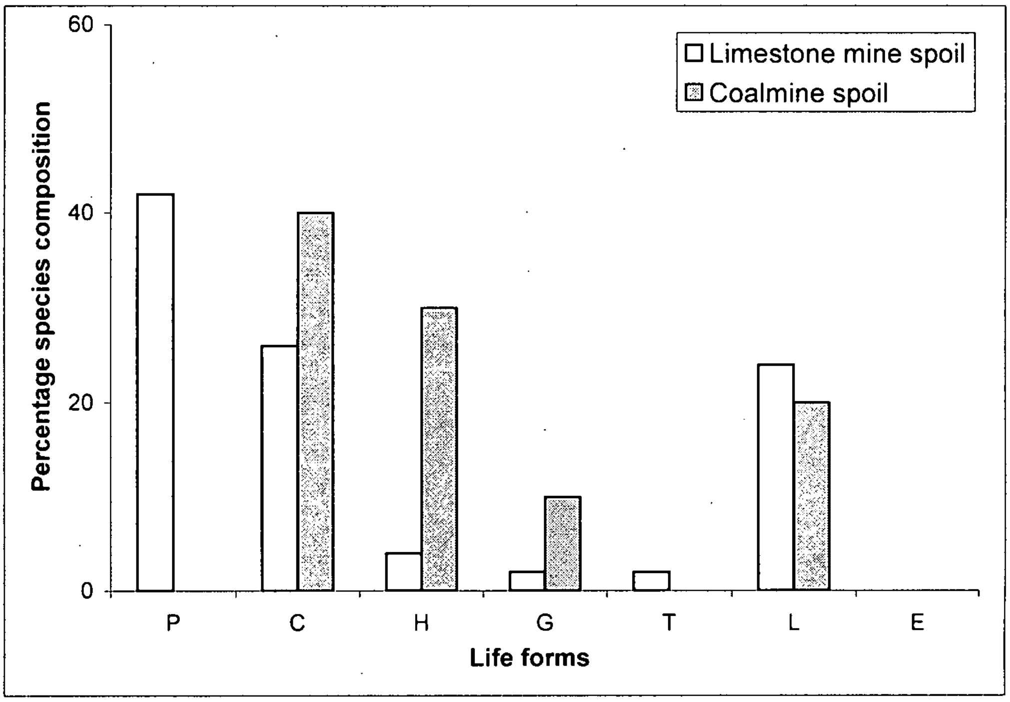


Fig. 6.13 Life form spectrum of different communities at the mining sites in the buffer zone of the Nokrek BR.

Distribution of species among the Raunkiaer's frequency classes

Frequency class A dominated in case of both herbs and shrubs at the limestone mine spoils suggesting heterogeneous nature of the community, whereas at the coalmine spoil site the shrub species were equally distributed in the frequency classes A and B (Fig. 6.14).

Spatial distribution

Majority of the shrubs (82-100 %) and herbs (64-82 %) were contiguously distributed at both the mine spoils. No regular distribution was observed (Fig. 6.15).

Dominance

The dominance-diversity curves for shrubs and herbs showed MacArthur's broken stick model of dominance distribution depicting low equitability and high dominance (Fig 6.16).

Density

Shrub species having maximum density at the limestone mine site were *Desmodium triquetrum* and *Cissampelos pareira,* whereas *Smilax aspera* was having the maximum number of individuals on the coalmine spoils (Appendix III).

Herbs, namely, *Paspalum* sp., *Ageratum conyzoides* and *Bidens pilosa* also had high density at limestone mine site. On the coalmine spoils *Pteris* sp. had the highest density (Appendix III).

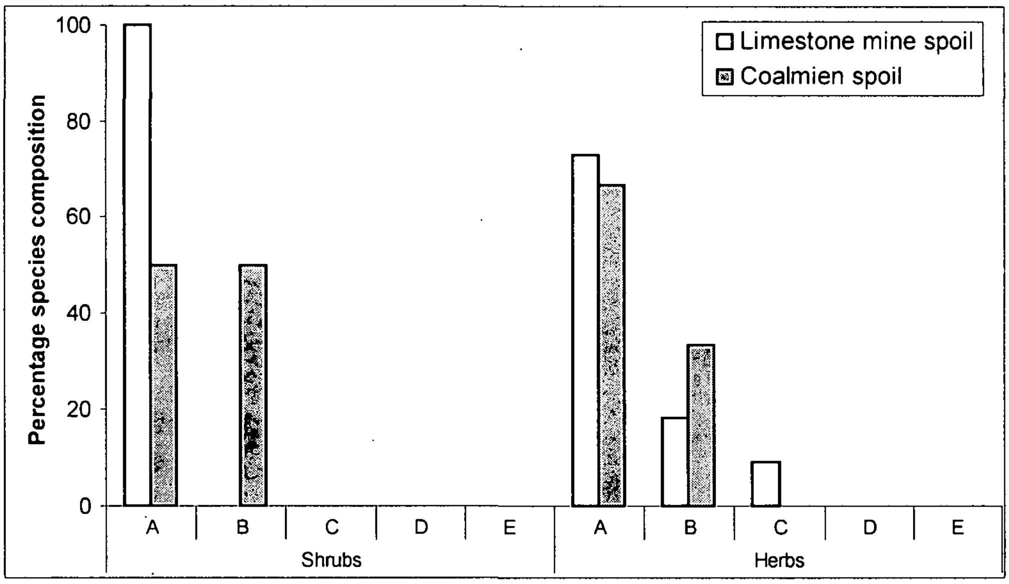


Fig. 6.14 **Distribution of shrub and herb species in the Raunkiaer's frequency classes, in the communities at the mining sites of the buffer zone of the Nokrek BR.**

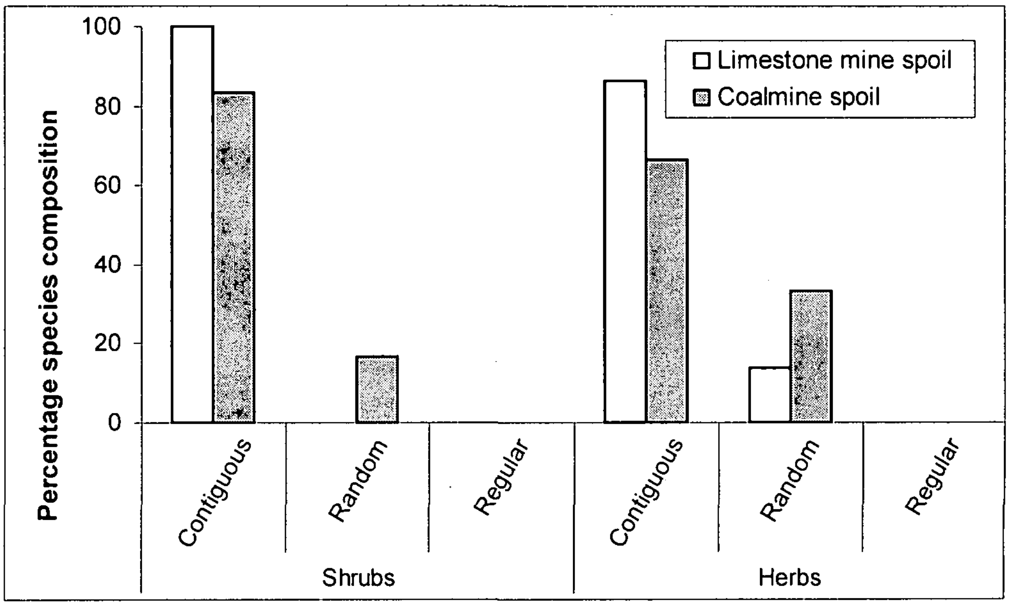


Fig 6.15 **Spatial distribution of the tree, shrub and herb species in the communities at the mining sites of the Nokrek BR.**

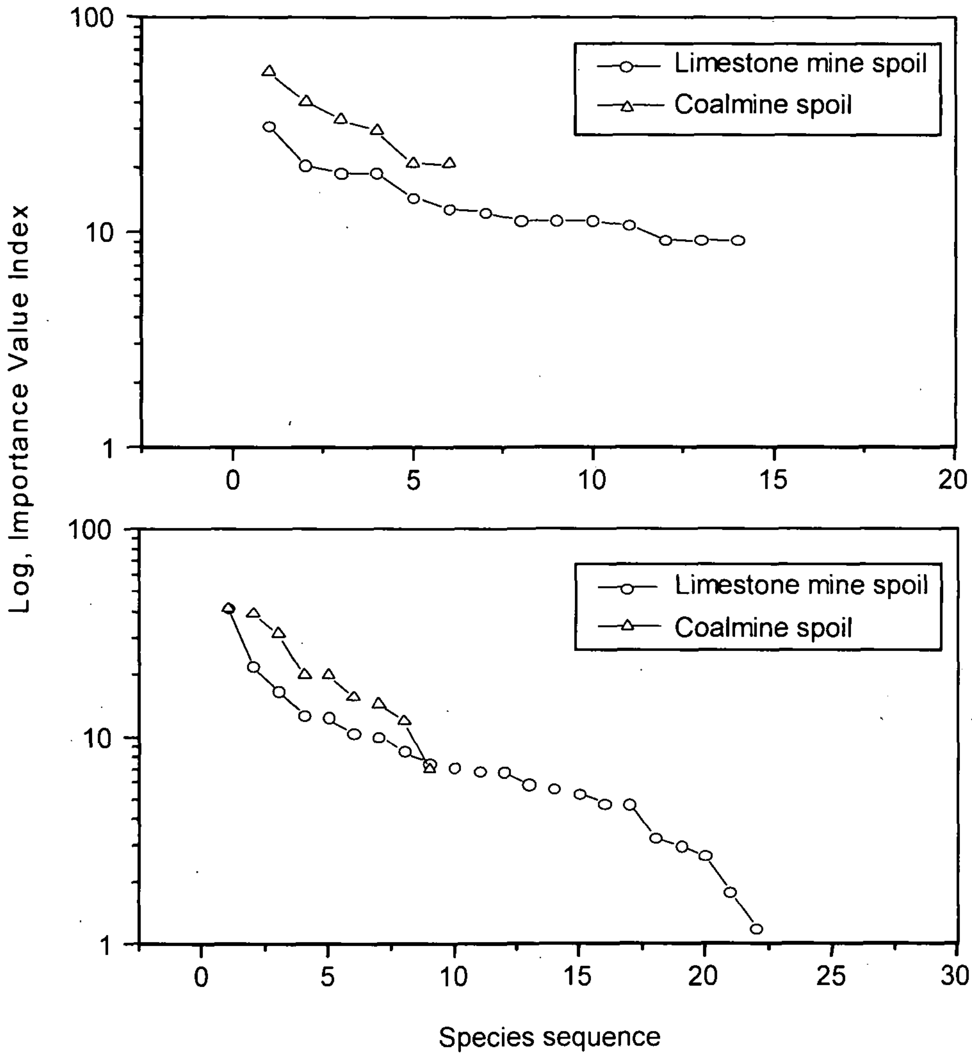


Fig. 6.16 Dominance- diversity curves of tree, shrub and herb species in the different communities at the mining sites in the buffer zone of the Nokrek BR

Ecological diversity

The Shannon diversity index, Pielou evenness index and Whittaker's diversity values for shrubs were higher in limestone mine areas than the coal mine areas. On both types of mining sites, the shrubs showed lower diversity than the herbs (Table 6.11).

Table 6.11 Diversity indices of shrub and herb species in different communities at mining sites in the buffer zone of the Nokrek BR.

	LM spoil		CM spoil	
	Shrub	**Herbs**	**Shrub**	**Herbs**
Shannon diversity index	2.57	2.57	1.68	2.04
Pielou evenness index	0.97	0.83	0.94	0.93
Simpson dominance index	0.08	0.13	0.21	0.15
α- diversity (S/logN)	3.39	3.76	1.60	1.95

Tree seedling density

Seedlings of a very few species were present on the limestone (5 species) as well as coalmine spoils (4 species). The seedling density varied from 304 individuals m^{-2} on the limestone mine spoils to 140 individuals m^{-2} on the coalmine spoils. Similarly, the average seedling density per species varied from 60.8 individuals m^{-2} on the limestone mine spoils to 35 individuals m^{-2} on the coalmine spoils. The maximum seedling density was shown by *Adina cordifolia* (120 individuals per m^2) on the limestone mine spoil and by *Vitex* *peduncularis* (80 individuals per m^2) on the coalmine spoils. These were the most dominant species of the respective communities.

Discussion

Plant communities on the jhum fallows in the buffer zone of the BR

The structure of secondary communities on the jhum fallows gradually became more complex with the age of the jhum fallows showing recovery from the human impact. The young jhum fallows, particularly those of one-year age, as well as orchards were colonized by herbs, mostly the weeds, and a few tree saplings and coppices of cut trees. The weeds such as *Eupatorium adenophorum* and *Ageratum conyzoides* were dominant in all the fallows. The emergence and increase in the dominance of these weed species have been attributed to the light and nutrient availability and reduced competition from the neighbouring plants following jhum cultivation (Bennet and Rao 1968, Kushwaha *et al.* 1983).

As the jhum fallows became older, they got covered with the even-aged stands of remarkably similar structure. The dominant species in these communities used the major fraction of available resources of the community leaving only a small fraction to be pre-empted by other species, as depicted by the dominance-diversity curves of these communities. These communities were predominantly composed of single fast growing secondary or pioneer species such as *Macaranga indica, Callicarpa vestita* or *Eurya accuminata.* However, these light demanding species, which cannot regenerate or grow under the shade, can live there for only one generation as argued by Richards (1996). The observed decline in the dominance and increase in the diversity in the older jhum fallows support this view.

The family dominance shifted from Asteraceae in one-year-old jhum fallow to Lauraceae in the 10-12 year old jhum fallow, which was also one of the dominant families in the undisturbed forests.

Increase in the number of strata in the vertical structure as well as increase in the proportion of phanerophytes with the age of these communities suggest the increasing structural complexity approaching the undisturbed forest vegetation. Decrease in the proportion of hemicryptophytes and therophytes with the age of these communities may be due to the lesser availability of light due to increasing canopy cover with the progress of succession (Meher-Homji 1964, Dagar and Balakrishna 1984, Dagar and Singh 1999).

van Gemerden *et al.* (2003) found that the basal area and plant density recovered in 5 years in logged areas and 50-60 years on the shifting cultivation sites, whereas the species richness recovery took 30-40 years after the shifting cultivation.

Population stability is the rare phenomenon in successional habitats, where a number of environmental factors change with community development (Kushwaha *et al.* 1983). The structure of successional communities developing on the jhum fallows showed drastic change due to various reasons. Removal of overstorey trees during jhum may favour germination and seedling establishment due to increased solar radiation on the forest floor and consequent increase in surface temperature and reduced competition from trees of the upper canopy (Koller 1972, Noble and Slatyer 1980, Oliver 1981, Barik *et al.* 1992). The high seedling population on the youngest jhum fallow could be due to suitable microsites created by tree felling and burning of the ground vegetation. The decrease in the seedling population with the age of jhum fallows can be ascribed to lack of threshold light for photosynthesis due to increasing canopy cover and a thick layer of litter on the soil surface which is likely to act as mechanical barrier for seedling emergence (Grime 1979). Thick litter layer may also influence survival of seedlings through producing allelochemics as reported by Khan *et al.* (1987).

Vegetation removal, burning, soil disturbance and weeding effectively destroy the seed bank eliminating possibilities for regeneration and resprouting of original forest species (Uhl *et al.* 1981, 1988). Wijdeven and Kuzee (2000) found forest recovery in pastures to be strongly limited by the availability of seeds. The species that are successful in reaching open pasture sites and are capable of avoiding seed and seedling predation were generally the pioneer species, and the same could be true even for the shifting cultivation sites.

Plant communities on the mining sites of the BR

Surface mining of coal causes massive damage to landscape and biological communities (Bradshaw and Chadwick 1980). The plant communities of the biosphere reserve that were disturbed by mining activity became very much impoverished in the species content. Chadwick (1973), Byrnes and Miller (1973) and Bradshaw (1983) showed that natural succession on the coalmine spoils was a slow process, attributable to the altered physico-chemical properties of soil. Delayed colonization of different minespoils has been reported by the workers such as Down (1974), Roberts *et al.* (1981) and Kimmerer (1984), which is attributed to lack of propagules capable of growing in such an environment. In the present study, however, the spoils were colonized within 2-3 years after abandonment. Such an early colonization was also reported by Game *et al.* (1982) in six coalmine sites in Missouri, USA, and Lygdoh *et al.* (1995) and Das Gupta (1999) in the coalmines of Jaintia Hills, Meghalaya, India.

Bradshaw and Chadwick (1980) working on the colliery spoils reported that the number of species colonizing the spoil was influenced by its pH. Decline in pH in mine spoils is one of the serious problems associated with coal mining activity. The low pH of the colliery spoils strongly affects the plant growth in various ways particularly by adversely influencing the availability of a large number of essential nutrients to plants colonizing these spoils. The main constraints in the recovery of these spoils are moisture stress, acute acidity and deficiency of organic matter and nutrients (Iverson and Wali 1992). Bradshaw and Chadwick (1988) found that acid-tolerant species were more successful in colonizing the mine spoils.

The unfavourable habitat conditions prevailing on the coalmine spoils in the Nokrek BR have made the recovery process in these areas extremely slow. The rhizome bearing species such as, *Pteris* sp. and *Globba clarkei* as well as the species having fibrous roots like *Axonopus compressus* and *Eragrostis* spp. are important colonizers on these spoils. Alvarez *et al.* (1974) reported prevalence of Asteraceae, Poaceae and Fabaceae on mine spoils. In the present study too, these families dominated the mine spoil areas. The perennials were more in number than the annuals in these areas indicating that the plant community developing on the minespoils are able to adapt to the prevailing stressed environmental conditions.

The dominance-distribution curves for the mined stands showed broken-stick series model (Poole 1974). This could be attributed to the lesser number of species occurring on these stands, which represented a stressed environment where conditions were not favourable for plant growth. Species diversity was extremely low on these stands, but the species that grow here appear to have developed tolerance that enabled them to grow in such an exacting environment.

The values of Shannon diversity index, evenness index and Simpson dominance index for coalmine spoils in the present study are well within the range reported by Lyngdoh (1995) and Das Gupta (1999).

Many plant species that were found in the undisturbed forests were absent from the jhum fallows as well as the mining sites. The slow colonization by the plants on these disturbed habitats following clear-cut logging and other disturbances has been attributed by many researchers to extreme microclimatic conditions that develop on the disturbed sites following anthropogenic activities, competition from early successional species, and low seed rain and slow growth rates of these species (Matlack 1994, Meier *et al.* 1995, McLachlan and Bazely 2001). Besides, allelopathic effects of some dominant weeds such as *Eupatorium adenophorum* and *E. riparium* (Tripathi *et al.* 1981, Rai and Tripathi 1984) may also hinder the germination and growth of *the* forest species. All these factors, in addition to highly physically and chemically altered soil conditions may explain the absence of a number forest species on the jhum fallows and the mine spoils.

CHAPTER VII

ENDEMIC, THREATENED AND MEDICINAL PLANTS, AND THEIR STATUS IN THE BIOSPHERE RESERVE

Introduction

The habitats are being altered and species are disappearing at rates never before witnessed on this planet (May 1990). Identification of species, communities or ecosystems that are likely to be strongly damaged by human activities forms an essential part of nature conservation (Nilsson and Grelsson 1995). The endemic and threatened species usually have specific ecological niches, edaphic gradients and vulnerable habitats. The Nokrek BR has several such species. Besides these species, there are many valuable medicinal plants which constitute important component of the flora of Nokrek BR, and they are being exploited at an increasing pace. An attempt has been made to analyse the status of endemic, threatened as well as medicinal plants of the Nokrek BR in this chapter.

Endemic and threatened plants

Endemism is the term applied to the taxa that are restricted to a particular geographical area or ecological region. Thus the concept of endemism is a relative one and the endemic status of a given texon can have varying biological significance depending on the size and location of the geographical area under consideration. Endemic species represent unique component of biodiversity. Rainfall, temperature, altitude and local topographic variables determine the endemism of the area. Most of the endemic species with a small geographic range end up as rare species and later, as threatened species unless their habitat is protected (Nayar 1996).

A threatened species refers to a species considered to fall within one of the categories of threat (extinct, endangered, vulnerable, rare and indeterminate) and in general terms can be considered as a species thought to be at a significant risk of extinction in the foreseeable future (IUCN 1994). These are the species that are rare, often genetically impoverished, of low fecundity, depending on patchy or unpredictable resources, extremely variable in population density, persecuted, or otherwise prone to extinction in the human-dominated landscapes (Terborgh and Winter 1980, Davis *et al.* 1986, Pimm *et al.* 1988, Noss 1990, WCMC 1992, Smith *et al.* 1993).

Endangered species include taxa whose numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction.

Vulnerable species are likely to move into the endangered category in the near future if the causal factors continue operating. The taxa included in this category are those whose most or all populations are decreasing because of over-exploitation, extensive destruction of habitat or other environmental disturbances, taxa whose populations have been seriously depleted and whose ultimate security is not yet assured, and taxa with populations that are still abundant but are under threat from serious adverse factors throughout their range.

A rare species is one that occurs in widely separated small populations so that inter-breeding between sub-populations is seriously reduced or restricted to a single population (Drury 1974). They may not at present be threatened but face a high risk of being so and are usually localized within restricted geographical area or habitat, or are thinly scattered over a more extensive range (IUCN 1994). One of the basic challenges involved in the conservation of rare species is that the group to be protected is heterogeneous comprising many causes and expressions of rarity (Rabinowitz 1981).

Flora of northeastern India is considerably rich with high level of endemism. Meghalaya alone has its 37 % (1236) species endemic and 2% (67) species fall under rare and threatened category (Khan *et al.* 1997). The entire Garo Hills area is considerably rich with high level of endemism. Its geological antiquity, taxonomic composition and its richness and peculiarity indicate that long before glacial times these mountains already constituted an important part of the area where the nucleus of the eastern Asiatic flora originated (Takhtajan 1988).

Endemic species

A list of species endemic to Meghalaya, northeastern region as well as to the eastern Himalayas, which are found in the BR, is given in the Table 7.1. The list includes 43 species belonging to 34 genera and 26 families. Lauraceae, Rutaceae and Gesneriaceae had the highest number of endemic species (3 species each). Out of the total recorded species, 13 species are endemic to the state of Meghalaya alone. Though 26 species (67% of the total endemic species recorded) are common or frequently found, 11 species have been recorded as rare whereas other 2 species, *Acer cappadocicum* and *Mastixia arborea* have been recorded as very rare species by the earlier workers (Haridasan and Rao 1985). Besides these, *Citrus latipes* (rare), *Fissistigma verrucosum* (rare), *Elaeocarpus acuminatus* (rare), *Adinandra griffithii* (vulnerable) are the species listed in the Red Data Book of the Indian Plants (Nayar and Sastry 1990).

An analysis of the distribution pattern of these recorded species in different synusiae revealed that *ca.* 40 % endemic species (17 species) were the trees followed by shrubs and scandent shrubs (11 species), herbs and epiphytes (9 species), and climbers and lianas (6 species).

Majority of these endemic species is found in the primary forests and hence, are found in the undisturbed core area of the Nokrek BR. A total of 27 species (69 %) were collected only from the core zone, and 5 species (8%) were collected exclusively from the buffer zone, whereas nine species were common to core and buffer zones. Moreover, majority of the species found in buffer zone is restricted to the riverain forests where the disturbance is least.

Table 7.1 List of endemic, rare and threatened species, and their status in the Nokrek BR

No.	Species	Family	Habit	M	L	R	J_{+2}	J_6	J_3	J_+	B	O	LM	CM	Status	G	H	*P*
1	*Acer cappadociccum* Gleditsch.	Aceraceae	T	+	-	-	-	-	-	-	-	-	-	-	E, VR	N	R	S
2	*Adinandra griffithii* Dyer	Theaceae	L	+	-	-	-	-	-	-	-	-	-	-	E, VU*	N	R	S
3	*Aeschynanthus parasitica* Cl.	Gesneriaceae	Ep	+	+	+	-	-	-	-	-	-	-	-	E, F	N	R	L
4	*Aeschynanthus sikkimensis* (Cl.) Stapf.	Gesneriaceae	Ep	+	+	-	-	-	-	-	-	-	-	-	E, R	N	R	S
5	*Aeschynanthus superba* Clarke	Gesneriaceae	Ep	+	+	+	-	-	-	-	-	-	-	-	E, F	N	R	S
6	*Ardisia griffithii* Clarke	Myrsinaceae	S	+	-	-	-	-	-	-	-	-	-	-	E, F	N	R	L
7	*Baliospermum micranthum* Muell.-Arg.	Euphorbiaceae	T	+	+	-	-	-	-	-	+	-	-	-	E, R	N	R	S
8	*Boehmeria macrophylla* D.Don	Urticaceae	S	+	+	+	-	-	-	-	-	-	-	-	E, F	N	R	L
9	*Boehmeria sidaefolia* Wedd.	Urticaceae	S	+	+	+	+	-	+	-	+	-	-	-	E, F	N	B	L
10	*Bulbophyllum griffithii* (Lindl.) Reich.	Orchidaceae	Ep	+	+	+	-	-	-	-	-	-	-	-	E, R	N	R	S
11	*Camellia caduca* Brandis	Theaceae	T	+	+	-	-	-	-	-	-	-	-	-	E, R	N	R	S
12	*Capparis acutifolia* Sw.	Capparidaceae	S	+	-	+	+	+	-	-	-	-	-	-	E, C	N	B	L
13	*Ceropegia longifolia* Wall.	Asclepiadaceae	Cl	-	-	-	+	-	-	-	-	-	-	-	E, F	N	R	S
14	*Citrus aurantium* Linn.	Rutaceae	S	+	-	-	-	-	+	-	-	-	-	-	E, R	N	B	S
15	*Citrus latipes* (Swingle) Tanaka	Rutaceae	T	+	-	-	-	-	-	-	-	-	-	-	E, R*	N	R	S
16	*Citrus medica* L.	Rutaceae	S	+	-	+	+	-	+	-	-	-	-	-	E, F	N	B	S
17	*Drimycarpus racemosus* (Roxb.) Hk.f.	Anacardiaceae	T	+	+	+	+	-	-	-	-	-	-	-	E, C	N	B	L
18	*Elaeagnus conferta* Roxb.	Elaeagnaceae	L	+	-	-	+	+	-	-	-	-	-	-	E, EN*	N	B	L
19	*Elaeocarpus acuminatus* Wall.ex Mast.	Elaeocarpaceae	T	+	-	+	-	-	-	-	-	-	-	-	E, R*	N	R	S
20	*Erythroxylum kunthianum* Wall. ex Kurz	Erythroxylaceae	T	+	-	-	+	-	-	-	-	-	-	-	E, F	N	R	S
21	*Euonymus lawsonii* Clarke & Prain	Celastraceae	T	+	-	+	+	-	-	-	-	-	-	-	E, F	N	B	L
22	*Fissistigma verrucosum* (Hook.f. & Th.)Merr.	Annonaceae	Sc	+	-	+	-	-	-	-	-	-	-	-	E, R*	N	R	S
23	*Garcinia cowa* Roxb. ex DC.	Clusiaceae	T	+	+	-	-	-	-	-	-	-	-	-	E, C	N	R	L
24	*Gleditsia assamica* Bor	Mimosaceae	T	-	-	+	+	+	-	-	-	-	-	-	E, C	N	B	L

25	*Glochidion thomsonii* Hk.f.	Euphorbiaceae	T	+	+	+	+	-	-	-	-	-	-	-	E, F	N	B	S
26	*Goniothalamus simonsii* Hk.f.&Th.	Annonaceae	T	+	+	+	-	-	-	-	-	-	-	-	E, F	N	R	S
27	*Impatiens laevigata Hook.f.*	Balsaminaceae	H	+	-	-	-	-	-	-	-	-	-	-	E, R	N	R	S
28	*Impatiens porrecta* Hook.f. & Th.	Balsaminaceae	H	+	-	-	-	-	-	-	-	-	-	-	E, R	N	R	L
29	*Lasianthus hookeri* Cl.ex Hk.f.	Rubiaceae	S	+	-	+	-	-	-	-	-	-	-	-	E, F	N	B	L
30	*Lindera latifolia* Hk.f.	Lauraceae	T	+	+	+	+	-	-	-	-	-	-	-	E, R	N	B	S
31	*Litsea elongata* (Nees) Hk.f.	Lauraceae	T	+	-	-	-	-	-	-	-	-	-	-	E, R	N	B	L
32	*Litsea laeta* Wall.ex Nees	Lauraceae	T	+	+	-	+	-	-	-	-	-	-	-	E, F	N	B	L
33	*Millettia caudata* (Benth.)Baker	Fabaceae	Sc	-	-	+	+	-	-	-	-	-	-	-	E, C	N	B	L
34	*Paramignya micrantha* Kurz.	Rutaceae	L	+	+	+	-	-	-	-	-	-	-	-	E, F	N	R	S
35	*Pavetta subcapitata* Hook.f.	Rubiaceae	S	-	-	+	-	-	-	-	-	-	-	-	E, C	N	R	S
36	*Phaius flavus* (Bl.) Lindl.	Orchidaceae	H	+	-	-	-	-	-	-	-	-	-	-	E, R	N	R	S
37	*Piper griffithii* C.DC.	Piperaceae	Cl	+	-	+	+	-	-	-	-	-	-	-	E, C	N	B	L
38	*Piper peepuloides* Roxb.	Piperaceae	Cl	+	-	+	-	-	-	-	-	-	-	-	E, VU	N	R	L
39	*Prunus jenkinsii* Hk.f.	Rosaceae	T	-	+	-	-	-	-	-	-	-	-	-	E, F	N	B	L
40	*Rhaphidophora calophyllum* Schott.	Araceae	Ep	+	+	+	-	-	-	-	-	-	-	-	E, C	N	R	L
41	*Rhaphidophora decursiva* (Roxb.) Schott.	Araceae	Ep	+	+	+	-	-	-	-	-	-	-	-	E, C	N	R	L
42	*Rubus khasianus* Cardot	Rosaceae	Sc	+	-	+	+	+	+	-	-	-	-	-	E, C	N	B	S
43	*Turpinia nepalensis* W.& A.	Staphylaceae	T	-	+	+	-	-	-	-	-	-	-	-	E, F	N	B	L
44	*Acer oblongum* Wall.	Aceraceae	T	+	-	-	-	-	-	-	-	-	-	-	R	W	B	S
45	*Actephila excelsa* (Dalz.) Muell.-Arg.	Euphorbiaceae	S	-	+	-	-	-	-	-	-	-	-	-	VR	W	R	L
46	*Aegynetia indica Linn.*	Orobanchaceae	H	+	-	-	-	-	-	-	+	-	-	-	F	W	R	L
47	*Agapetes veriagata* (Roxb.) D.Don	Vacciniaceae	Ep	+	+	+	-	-	-	-	-	-	-	-	F	W	R	L
48	*Anoectochillus roxburghii* (Wall.) Lindl.	Orchidaceae	H	+	-	-	-	-	-	-	-	-	-	-	R	W	R	S
49	*Aquilaria agallocha* Roxb.	Thymeleaceae	T	-	+	-	-	-	-	-	-	-	-	-	EN*	W	R	L
50	*Ardisia colorata* Roxb.	Myrsinaceae	S	-	+	-	-	-	-	-	-	-	-	-	VR	W	R	S
51	*Aristolochia cathcartii* Hk.f.	Aristolochiaceae	Cl	+	-	+	-	-	-	-	-	-	-	-	R	W	B	S

52	*Artocarpus gomezianus* Wall.ex Trecul.	Moraceae	T	-	+	+	-	-	-	-	-	-	-	-	R	W	B	S
53	*Balanophora dioica* L.	Balanophoraceae	H	+	-	-	-	-	-	-	-	-	-	-	R	W	R	L
54	*Begonia ovalifolia* DC.	Begoniaceae	H	+	+	-	-	-	-	-	-	-	-	-	R	W	R	S
55	*Begonia thomsonii* A. DC.	Begoniaceae	H	+	+	-	-	-	-	-	-	-	-	-	R	W	R	S
56	*Beilschmiedia assamica* Meissn.	Lauraceae	T	+	-	-	-	-	-	-	-	-	-	-	R	W	R	L
57	*Beutia minor* Buch.-Ham.ex Baker	Fabaceae	S	-	-	-	+	-	-	-	-	-	-	-	EN*	W	B	S
58	*Chirita oblongifolia* (Roxb.) SinClair	Gesneriaceae	Ep	+	-	-	-	-	-	-	-	-	-	-	R	W	R	S
59	*Clerodendrum hestatum* (Roxb.) Lindl.	Verbenaceae	S	-	+	+	-	-	-	-	-	-	-	-	VU	W	R	S
60	*Clerodendrum serratum* (L.) Spreng	Verbenaceae	S	-	-	+	+	+	-	-	-	-	-	-	VU*	W	B	S
61	*Croton oblongus* Burm. f.	Euphorbiaceae	T	+	+	+	+	+	-	-	-	-	-	-	R	W	B	S
62	*Cudrania fruticosa* (Roxb.) Kurz.	Moraceae	T	-	+	-	-	+	-	-	-	-	-	-	VR	W	B	S
63	*Dalhousiea bracteata* (Grah. Ex Roxb.) Wt.	Fabaceae	Cl	-	-	+	-	-	-	-	-	-	-	-	R	W	R	L
64	*Echinocarpus dasycarpus* Benth.	Elaeocarpaceae	T	-	-	+	-	-	-	-	-	-	-	-	R	W	B	S
65	*Euonymus fragidus* Wall.	Celastraceae	T	+	-	+	-	-	-	-	-	-	-	-	R	W	R	S
66	*Fagraea ceilanica* Thunb.	Loganiaceae	Ep	-	-	+	-	-	-	-	-	-	-	-	R	W	R	S
67	*Ficus consinna* Miq.	Moraceae	T	-	-	+	-	-	-	-	-	-	-	-	R	W	B	S
68	*Ficus subincisa* Buch.-Ham.ex J. E.Sm.	Moraceae	T	+	-	+	+	-	-	-	-	-	-	-	VR	W	B	S
69	*Ficus tinctoria* var. *parasitica*	Moraceae	Ep	-	-	+	-	-	-	-	-	-	-	-	R	W	R	S
70	*Gastrochilus acutifolius* (Lindl.)O. Ktze.	Orchidaceae	Ep	+	-	+	-	-	-	-	-	-	-	-	R	W	R	S
71	*Gloriosa superba* L.	Liliaceae	H	+	-	-	-	-	-	-	-	-	-	-	VR	W	R	S
72	*Gordonia excelsa* Bl.	Theaceae	T	-	-	+	-	-	-	-	-	-	-	-	VR	W	R	S
73	*Hedychium coronarium* Koen. ex Retz.	Zingiberaceae	H	+	+	+	-	-	-	-	-	-	-	-	EN*	W	R	S
74	*Helicia excelsa* Bl.	Proteaceae	T	+	-	-	-	-	-	-	-	-	-	-	R	W	B	S
75	*Hoya lobbii* Hook.f.	Asclepiadaceae	Ep	+	-	-	-	-	-	-	-	-	-	-	R	W	R	L
76	*Hoya parasitica* Wall.	AsClepiadaceae	Ep	+	+	+	-	-	-	-	-	-	-	-	R	W	R	S
77	*Impatiens chinensis* L.	Balsaminaceae	H	+	+	+	-	-	-	-	-	-	-	-	R	W	R	L
78	*Impatiens tripetala* DC.	Balsaminaceae	H	+	-	+	-	-	-	-	-	-	-	-	R	W	R	L

79	*Lasia spinosa* (L.) Thw.	Araceae	H	+	+	-	-	-	-	-	-	-	-	-	R	W	R	S
80	*Luisia teretifolia* Guad.	Orchidaceae	Ep	+	+	+	-	-	-	-	-	-	-	-	R	W	R	S
81	*Lysionotus serratus D.Don*	Gesneriaceae	Ep	+	+	+	-	-	-	-	-	-	-	-	R	W	R	S
82	*Mastixia arboria* Cl.	Cornaceae	T	-	+	-	-	-	-	-	-	-	-	-	VR	W	R	S
83	*Meliosma wallichii* Planch. ex Hk.f.	Sabiaceae	T	+	+	-	-	-	-	-	+	-	-	-	R	W	R	S
84	*Melodenus monogynus* Roxb.	Apocynaceae	L	+	-	+	+	+	-	-	-	-	-	-	R	W	B	S
85	*Ophioglossum pedunculosum* Desv.	Ophioglossaceae	H	+	-	-	-	-	-	-	-	-	-	-	R	W	R	S
86	*Oxyspora cernua* (Roxb.) Triana	Melastomataceae	Cl	-	+	-	+	-	-	-	-	-	-	-	R	W	R	S
87	*Paramichelia baillonii* (Pierre) Hu	Magnoliaceae	T	+	-	-	-	-	-	-	-	-	-	-	R*	W	R	S
88	*Peperomia pellucida* (L.) HBK.	Piperaceae	H	-	-	+	-	-	-	-	+	-	-	-	R	W	R	S
89	*Picrasma javanica* Bl.	Semaraubaceae	T	-	+	-	-	-	-	-	+	-	-	-	VU	W	B	S
90	*Podocarpus nerifilia* D.Don	Podocarpacaeae	T	+	-	-	-	-	-	-	-	-	-	-	R	W	R	S
91	*Polyalthia simiarum* (Hk.f. & Th.) Hk.f. & Th.	Annonaceae	T	+	+	+	-	-	-	-	-	-	-	-	R	W	B	S
92	*Psychotria symplocifolia* Kurz	Rubiaceae	S	+	-	-	-	-	-	-	-	-	-	-	VR	W	R	L
93	*Rauvolfia serpentina* (L.) Benth. ex Kurz.	Apocynaceae	S	-	-	+	-	-	-	-	-	-	-	-	EN*	W	B	S
94	*Sapindus rarak* DC.	Sapindaceae	T	+	+	+	-	-	-	-	-	-	-	-	R	W	B	S
95	*Schleichera trijuga* Wall.	Sapindaceae	T	+	+	-	-	-	-	-	-	-	-	-	R	W	R	L
96	*Syzygium grandis* (Wt.) Walp.	Myrtaceae	T	+	+	-	-	-	-	-	-	-	-	-	R*	W	R	L
97	*Taxus baccata* Linn.	Taxaceae	T	+	-	+	-	-	-	-	-	-	-	-	CR	W	R	S
98	*Trema cannabina* Lour.	Ulmaceae	T	-	-	-	+	-	+	-	-	-	-	-	VR	W	R	L
99	*Trigonostemon semperflorens* (Roxb.) Muell.-Arg.	Euphorbiaceae	S	-	+	-	-	-	-	-	-	-	-	-	R	W	R	L
	Total			72	44	52	22	8	5	-	6	-	-	-				

Habit: Cl- Climber, Ep- Epiphyte, H- herb, S- shrub, Sc- scandent, T- tree ; Status: E- Endemic, EN- Endangered, CR – Critically endangered, VU- Vulnerable, R-Rare, VR- VR, C- C, F- F; G- Geographical range, N- narrow, W-wide; H- Habitat specificity, R-restricted, B-broad; P-Population size, S-small, L-large;
* Status in India (Nayar and Sastry 1990)

Plates 18-21 Endemic and rare plant species encountered in the Nokrek BR.

Threatened species

Table 7.1 also gives the list of 55 species, which fall under different categories of the threatened species, of which 13 species are endemic in nature. Out of these species, *Beutia minor* (endangered), *Clerodendrum serratum* (vulnerable), *Hedychium coronarium* (endangered), *Paramichelia baillonii* (rare), *Rouvolfia serpentina* (endangered), *Syzygium grandis* (rare) are threatened in India, while other 44 species are rare and threatened in Meghalaya.

Rarity

To evaluate the types of rarity in the flora of Nokrek BR, all species were classified according to the geographic range (wide vs. narrow), habitat specificity and (broad vs. restricted) and population size (large vs. small). This 2 X 2 X 2 classification results into seven possible forms of rarity (and one form of commonness) (Rabinowitz 1981, Rabinowitz *et al.* 1986). The classification was carried out with the help of both, primary and secondary data collected from the local florae and relevant literature available.

A total of 99 species were recognized as rare species occurring within the Nokrek BR (Table 7.1). These contribute a significant part (13.94 %) of the flora of the BR (710 species). No single type of rarity appears to characterize the flora of Nokrek BR. However, the most important form was observed to be the narrow habitat specificity (65% species) followed by small population size (63% species) and small geographic range (43% species). Two types, one of narrow geographical range (endemics), restricted habitat specificity and small populations, and the other of wide geographical range (non-endemics), restricted habitat and small populations contributed the most (41%) to the rare flora of the BR (Fig. 7.1). The rare taxa with small populations outnumbered those with the large, dominant populations. The least form of rarity found in the BR was the taxa with narrow geographical range, broad habitat specificity and small populations. Rabinowitz *et al.* (1986) commented that the condition of having a narrow range, broad habitat and small populations was biologically unlikely.

The rare species were mostly concentrated in the undisturbed core zone (78%) followed by riverain forests (52%) of the buffer zone. In jhum fallows the number of rare species recorded increased with the age of the fallows (Table 7.1). No species was recorded in any of the one year-old jhum fallows, orchards and mine spoils.

To determine the most and the least abundant growth forms among the listed rare species, all the species were classified into five different growth forms or habits viz., 1- trees, 2 - shrubs including scandents, 3- lianas and 4- climbers and 5- herbs including epiphytes (Fig. 7.2). Trees ranked first (41% species). Herbs ranked second (30%), followed by shrubs (19%), climbers (6%) and lianas (4%).

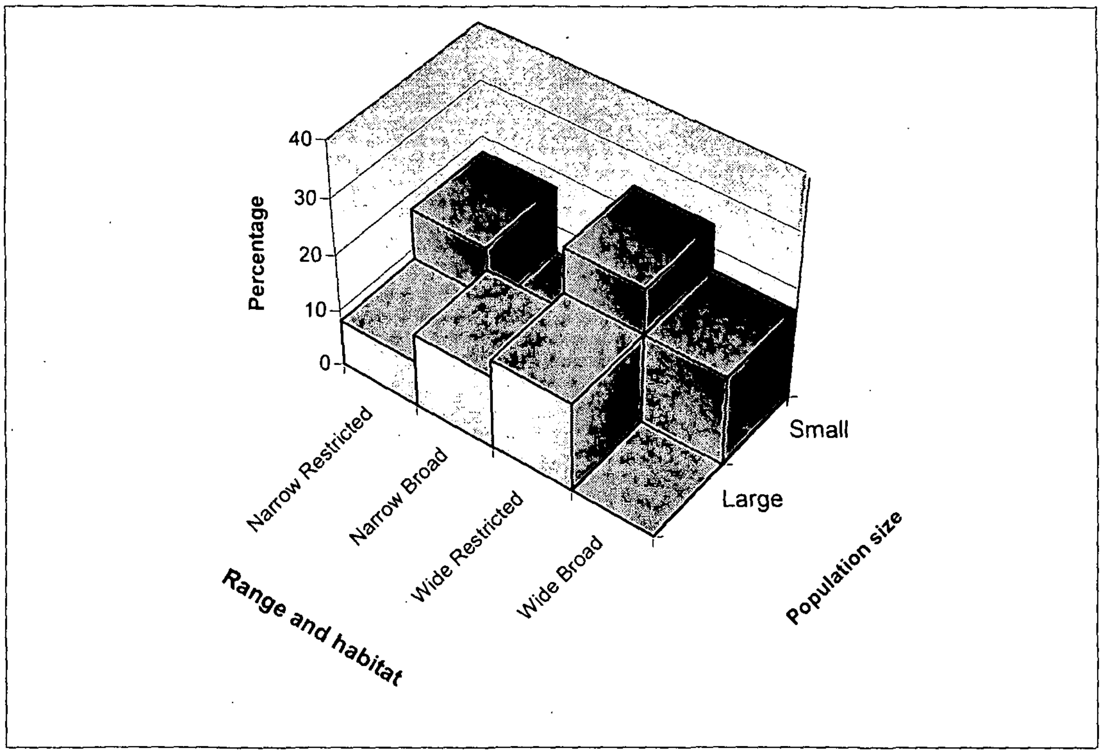


Fig. 7.1 Percentage of each of the seven forms of rarity in the Nokrek BR.

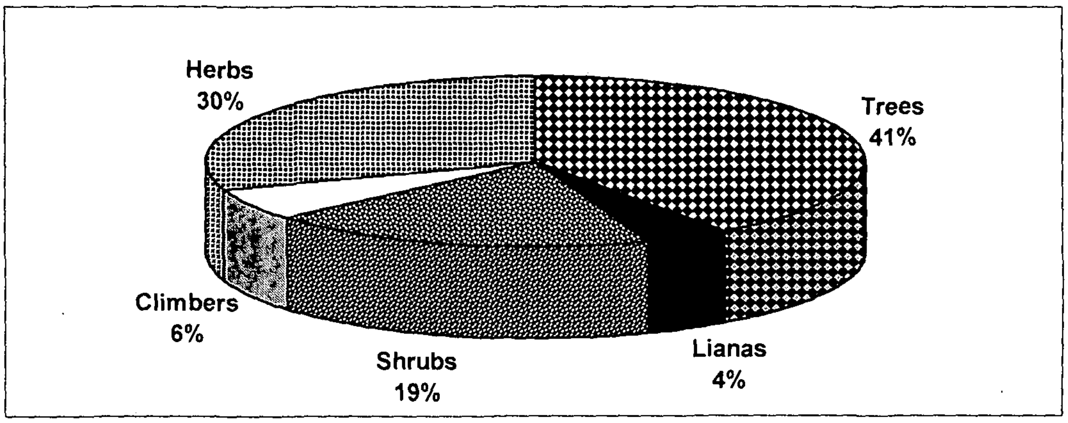


Fig 7.2 Percentage of the rare flora of the Nokrek BR in different growth forms.

Medicinal plants

The indigenous communities establish intimate relationship with the elements of biodiversity as they closely depend on it for their day-to-day life supplies and well-being. The species richness of plant diversity is determined to a great extent by the intensity of associations and dependence of the indigenous communities on that plant wealth. Respect for the indigenous knowledge and man-plant relationships help in conservation (Jain 2000). Alcorn (1984) emphasized that once a species gets known as a resource in any cultural group, the impact of this knowledge on expansion, distribution and threat to that species and even its extinction, plays a great role. The cultural relationships of humans with bioresources keep evolving and changing. Exploitation or protection of bioresources, which is usually also selective, influences the distribution, abundance and consequently availability, which in turn compels modification or substitution in man-plant (or man-animal) relationships. Political or socio-economic changes, advent of new style of living vocations as also exotic species also alter the interrelationships. With the penetration of modern civilization in most parts of the world occupied by the primitive societies and the consequent divorcement of the aboriginal people from dependence upon their vegetal environment for the necessities of life, there is a large disintegration of knowledge of plants and their properties (Maheshwari 1983).

High cultural and biological diversity of the northeastern region of India has led to the rich tradition of the ethnobiological knowledge including herbal medicines. In spite of the advent of modern medical facilities, majority of the local people are still dependent on the traditional herbal practices. The herbal medicinal practices of Garo people have been assessed by many workers to reveal the rich traditional knowledge as well as their dependency on plants (Rao 1981, Rao and Shanpru 1981, Rao 1989, Neogi *et al.* 1989).

A list of medicinal plants occurring in the Nokrek BR is given in Table 7.2 along with their local names, families, habit, source and medicinal uses. It includes medicinal plants used by the local traditional healers (based on the interviews of four traditional practitioners locally called *'Oza'*) as well as the plants, which are well known for their medicinal properties throughout the country (with the help of secondary sources). Thus, the list includes 102 species of locally used medicinal plants belonging to 90 genera and 61 families, which are used against 64 different ailments. In addition to the medicinal plants used by the local people, a list of 117 well known medicinal plants belonging to 106 genera and 61 families used against 150 different diseases is also included in the table. Six medicinal plants viz. *Bombax ceiba, Cinnamomum bejolghota, Inula cappa, Solanum kurzii, Tabernaemontana divaricata* are common to both the lists and so, a total of 213 species having medicinal properties were recorded from the Nokrek BR. The list includes five pteridophytes, one gymnosperm, 174 dicot and 33 monocot angiosperm species.

Many species growing as weeds viz., *Eupatorium* spp., *Ageratum conyzoides, Hedyotis scandens, Clerodendrum viscosum, Artimisia nilagirica,* *Hydrocotyle javanica, Innula cappa* are used by the people and are included in local medicines. Besides, many other species, which are strictly forest species such as, *Ardisia odontophylla*, *Begonia* spp., *Gloriosa superba*, *Goodiera procera and Hedychium coronarium* are also used commonly. In total 175 species were exclusively of wild origin, while 38 species were both wild as well as cultivated. The detailed analysis reveals that 77 % of the traditionally used medicinal plants are of wild origin, around 14 % species are collected from the wild as well as they are cultivated, whereas only 11 % species used are from exclusively cultivated sources. (Table 7.2)

Herbaceous species including climbers and epiphytes formed a major component of both, locally used medicinal plants as well as the well-known medicinal plants (Fig 7.3). The proportion of tree species included in the local medicinal systems was lesser than their proportion in the well-known medicinal plants.

Rare and threatened medicinal plants

Among the recorded medicinal plants of the BR, *Taxus baccata* is critically endangered, while *Gloriosa superba*, *Elaeagnus conferta, Butea minor*, *Rouvolfia serpentina* and *Hedychium coronarium* are endangered, and *Cinnamomum tamala*, *Clerodendrum serratum*, *Oroxylum indicum* and *Piper peepuloides* are vulnerable. *Oxyspora cernua* has been reported to be very rare in Meghalaya.

Table 7.3 **Diversity of medicinal plants in the Nokrek BR and their sources.**

	Species	Genus	Families	No. of ailments agaist which they are used
Traditionally used medicinal plants	102 (48)	90	61	64
Well-known medicinal plants	117 (55)	106	61	150
Source				
Wild	175 (82)	152	86	195
Cultivated	14 (7)	14	12	33
Both	24 (11)	23	21	53
Total	**213**	**182**	**92**	**172**

* Values in parentheses are the percentages of the total number of species

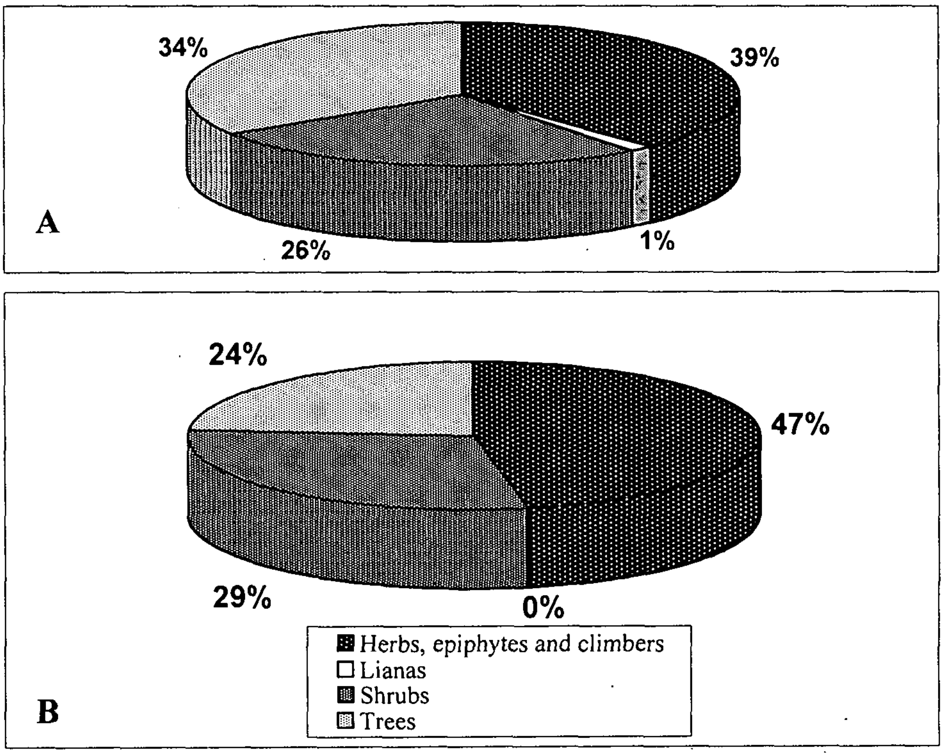


Fig 7.3 **Percentage distribution of the medicinal plants of the Nokrek BR among different growth forms: (A) all medicinal plants, (B) locally used medicinal plants.**

Table 7.2: Medicinal plants found in the Nokrek BR.

Locally used medicinal plants							
Sl. No	Name of the plant	Local name	Family	Habit [a]	Source [b]	Part(s) used [c]	Indications
1	*Acanthus leucostachyus* Wall.	Sam khatchi	Acanthaceae	H	W	L	Headache
2	*Adhatoda zeylanica* Medik.	Jakbi dalgapa	Acanthaceae	S	C	L	Bone fracture
3	*Ageratum conyzoides* Linn.	Sammok	Asteraceae	H	W	L	Cuts, wounds
4	*Alocasia sp.*	Gongmatra	Araceae	H	W/C	Bb	Dysentery
5	*Ardisia odontophylla* DC.	Beholisam	Myrsinaceae	S	W	L, B	Paralysis
6	*Ardisia sp.*	Bolsneng	Myrsinaceae	T	W	L	Weakness in children
7	*Aristolochia cathcartii* Hk.f.	Golbira	Aristolochiaceae	C	W	R	Cough
8	*Aristolochia tagala* Cham.	Chhisuk budu/ phenga	Aristolochiaceae	C	W	R	Vomiting, diarrhoea
9	*Artemisia nilagirica* (Cl.) Pamp.	-	Asteraceae	S	W	L	Headache
10	*Asplenium sp.*	Tekidagal	Aspleniaceae	H	W	L	Sprains
11	*Bauhinia macrostachya* Wall.	Bemegong	Caesalpiniaceae	Sc	C	L	Headache
12	*Bauhinia sp.*	Pathar chila	Caesalpiniaceae	T	W/ C	L	Cuts
13	*Bauhinia vahlii* W. & A.	Megong budu	Caesalpiniaceae	Sc	W/ C	R	Epilepsy
14	*Begonia palmata* D. Don	Achak	Begoniaceae	H	W	WP	Drug antidote
15	*Begonia thomsonii* A. DC.	Dawlik/ Khumchari	Begoniaceae	H	W	L, R	Labour pains, cuts, wounds
16	*Betula alnoides* Buch.-Ham. ex D. Don.	Gakkal	Betulaceae	T	W/ C	R, L	Gastric disorder, headache
17	*Bonnaya reptans* Spreng	-	Scrophulariaceae	H	W	WP	Nail infection
18	*Calamus errectus* Roxb.	Boldam	Arecaceae	H	W	R	Malaria, body ache
19	*Calamus floribundus* Griff.	Redop	Arecaceae	Sc	W/ C	R	Weakness
20	*Careya arborea* Roxb.	Gimbil	Baringtoniaceae	T	W/ C	B	Excess bleeding during delivery
21	*Caryota urens* Linn.		Arecaceae	T	W	Pith	Nail infection
22	*Castanopsis tribuloides* (Sm.) DC.	Chhaku	Fagaceae	T	W	L	Weakness
23	*Chirita oblongifolia* (Roxb.) Sinclair	Achhumiti sam	Gesneriaceae	H	W	L	Mental disorder
24	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet	-	Lauraceae	T	W	B, L, R	Abdomen pain
25	*Citrus aurantium* Linn.	Bimang narang	Rutaceae	S	W/ C	Fr	Multipurpose tonic
26	*Citrus medica* Linn.	Thimatchu	Rutaceae	S	W/ C	L, R, Fr	Scabies, stomach-ache
27	*Clausena excavate* Burn.	Samsueng/ Nolsing	Rutaceae	S	W	L	Headache, body ache, unconsciousness
28	*Clerodendrum hastatum* (Roxb.) Lindl.	Borphew	Verbenaceae	H	W	L	Children sickness
29	*Clerodendrum viscosum* Vent.	Sam makhi	Verbenaceae	S	W	L	Headache

30	*Commelina benghalensis* Linn.	Samkisol	Commelinaceae	H	W	L	Cuts, wounds
31	*Cordia dichotoma* Forst. f.	Boltiskeng	Boraginaceae	T	W/ C	B	Skin disease
32	*Crinum asiaticum* Linn.	-	Amarylidaceae	H	C	L	Bone fracture
33	*Cucumis sativus* Linn.	Samkachak/ kanchi sam	Cucurbitaceae	C	C	WP	Nail infection
34	*Curculigo orchioides* Gaertn.	Sam jatek	Hypoxidaceae	H	W	L	Cuts
35	*Cymbidium longifolium* D. Don	Samdumi	Orchidaceae	E	W	Bb	Infant headache
36	*Dalhousiea bracteata* (Grah. Ex Roxb.) Wt.	Duplok	Fabaceae	C	W	Fr	Stomach- ache, labour pains
37	*Datura stramonium* Linn.	Singapor	Solanaceae	S	C	Fr	Antidote on poison
38	*Desmos chinensis* Lour.	Gorchhok	Annonaceae	S	W	R	Gastric disorder
39	*Dischidia benghalensis* Coelb.	Samnakhet	Asclepiadaceae	C	W	L	Cuts, wounds
40	*Dryopteris sp.*	-	Adiantaceae	H	W	L	Bone fracture
41	*Eranthemum pulchellum* Andrews	Dojakpi	Acanthaceae	S	C	L	Bone fracture
42	*Ficus hirta* Vahl.	Chakhab	Moraceae	T	W	L	Ring-worm
43	*Fissistigma rubiginosa* (A. DC.) Merr.	Sam junma	Annonaceae	Sc	W	B, L	Burning sensation (skin)
44	*Garcinia cowa* Roxb.ex DC.	Rengran	Clusiaceae	T	W	B	Dysentery
45	*Garcinia tinctoria* (DC.) W. F. Wight	Aruwak	Clusiaceae	T	W		Digestive
46	*Gastrochilus acutifolius* (Lindl.)O. Ktze.	Samsoksu	Orchidaceae	E	W	L	High fever, headache
47	*Gomphostemma parviflorum* Wall.ex Benth.	Kimprang	Lamiaceae	S	W	L	Sprains
48	*Goniothalamus sesquipedalis* (Wall.) Hk. f. & Th	Haripanga	Annonaceae	T	W	B	Cuts, wounds
49	*Goniothalamus simonsii* Hk.f. & Th.*	Kitoksam	Annonaceae	T	W	Fr	Throat irritation
50	*Goodiera procera* (Ker.-Gawl) Hk.	Dejongma	Orchidaceae	H	W	Sap	Blood clot
51	*Hedychium coccineum* Buch.-Ham. ex Wal.	Sam riching	Zingiberaceae	H	W	Rh	Labour pain
52	*Hodgsonia macrocarpa* HK.f.	Thebe	Cucurbitaceae	C	W	L	Burns
53	*Hydrocotyle javanica* Thunb.	Manamuni	Apiaceae	H	W	L	Headache, bodyache
54	*Indigofera heterantha* Wall.	Chheng budu	Fabaceae	S	W	R	Urinary tract disorder
55	*Inula cappa* (Buch.-Ham. ex D. Don)DC.	Khimphrang	Asteraceae	S	W	L	Headache, cancer
56	*Jasminum subtriplinerve* Bl.	Khia wakal	Oleaceae	C	W	R	Vomitting, diarrhoea
57	*Litsea cubeba* (Lour.) Pers.	Jengjil	Lauraceae	T	W/ C	L, B	Headache
58	*Lobelia angulata* Forst.	Kensal	Lobeliaceae	H	W	WP	Cancer
59	*Macaranga indica* Wt.	Rimakatal	Euphorbiaceae	T	W	L	Severe headache
60	*Macropanax undulatus* (Wall. Ex G. Don) Seem.	-	Araliaceae	T	W	L	Headache
61	*Meliosma simplicifolia* (Roxb.) Walp.	Samnabat	Sabiaceae	S	W	L	Muscle pain

62	*Mitrephora tomentosa* Hk. F. & Th.	Bolsimpi	Annonaceae	T	W	B	Skin disease
63	*Moliniera capitulata* (Lour.)Herb.	Rikhokshi	Hypoxidaceae	H	W	Rh	Vomiting, fever
64	*Murraya koenigii* (Linn.) Spreng	Sam khatchi	Rutaceae	S	W	L	Vomiting, diarrhoea
65	*Mussaenda roxburgii* Hk.f.	-	Rubiaceae	S	W	WP	Cough, bronchitis, fever, inflammation, wounds, ulcers, leucoderma, jaundice
66	*Opuntia ficus-indica*	-	Cactaceae	S	C	Phylloclade	Bone fracture
67	*Oxyspora cernua* (Roxb.) Triana.	Dagal	Melastomataceae	C	W	L	Weakness
68	*Passiflora nepalensis* Wall.	Sam bima	Passifloraceae	C	W	L	Malaria, body ache
69	*Ophioglossum pedunculosum* Desv.	Rava-chhongapa	Ophioglossaceae	H	W	WP	Gum bleeding, nausea
70	*Peliosanthes bakeri* Hook f.	Rava-dalgapa	Liliaceae	H	W	L	Gum bleeding, nausea
71	*Piper peepuloides* Roxb.	Beholisam	Piperaceae	C	W	L, B	Paralysis
72	*Plantago erosa* Wall.	-	Plantaginaceae	H	W	L	Vomiting with traces of blood
73	*Polygonum molle* D.Don	-	Polygonaceae	H	W	L	Bone fracture
74	*Polygonum plebejum* Br.	-	Polygonaceae	H	W	L	Bone fracture
75	*Pothos scandens* Linn.	Durongru	Araceae	E	W	L	Headache
76	*Pteris sp.*	Sarak bolma	Pteridaceae	H	W	L	Cuts
77	*Rhincotechum ellipticum* A.DC.	Mebitchi	Gesneriaceae	S	W	L	Dog bite
78	*Rhus javanica* Linn.	Kitma	Anacardiaceae	T	W/ C	Fr, S, L	Diarrhoea
79	*Sanseviera zeylanica* Linn.	Sammogong	Agavaceae	H	C	L	Snake bite
80	*Sarcandra glabra* (Thunb.) Nakai	Jathok-gishung	Chloranthaceae	S	W	R, L	Epilepsy
81	*Scheffleria venulosa* (W. & A.) Harms	Dorengjasi	Araliaceae	T	W	St	Mentally retarded children
82	*Schima wallichii* (DC.) Korth.	Boldak	Theaceae	T	W/ C	St	Headache
83	*Scoparia dulcis* Linn.	Sampathar	Scrophulariaceae	H	W	L	Migraine
84	*Scutellaria discolor* Coelb.	Baksuchi/ Khalitchi	Lamiaceae	H	W	L	Vomiting, diarrhoea
85	*Smilax laceifolia* Roxb.	Durastheng	Smilacaceae	Sc	W	R	Dysentery
86	*Solanum erianthum* D.Don	Khimkha	Solanaceae	S	C	R	Stomach-ache
87	*Solanum kurzii* Br.	-	Solanaceae	S	W/ C	R	Stomach-ache
88	*Sonerila maculata* Roxb.	-	Melastomataceae	H	W	L	Headache
89	*Stephania hernandifolia* (Willd.) Waip.	Samtha	Menispermaceae	C	W	T	Stomach-ache
90	*Sterculia roxburghii* Wall.	Thegachu	Sterculiaceae	T	W	R	Stomach- ache
91	*Stereospermum chelonoides* (Linn. f.) *DC*	Bolsil	Bignoniaceae	T	W	L	Headache
92	*Strychnos wallichiana* Benth.	Dukhonkha	Loganiaceae	C	C	Fr, S	Skin diseases, helminthiasis
93	*Tabernaemontana divaricata* (Linn.) R.Br. ex Roem. & Schultes	-	Apocynaceae	S	W	R, Fl, latex	Paralysis, burning sensation, skin diseases & wounds

94	*Tacca integrifolia* Ker-Gawl.	Taccaceae	Taccaceae	H	W	Rh, L	Cuts and wounds
95	*Tainia sp.*	Dojaphung	Orchidaceae	H	W	WP	Labour pains
96	*Tapiria hirsuta* Hk.f.	Dachhengprup	Anacardiaceae	Sc	W	L	Poor eyesight
97	*Travesia palmata* Vis.	Chinatong	Araliaceae	T	W	L	Facial paralysis
98	*Vitis heyneana* Roem. & Schult.	Samkitup	Vitaceae	C	W	R	Piles
99	*Wallichia densiflora* Mart.	-	Arecaceae	S	W	L	Weakness
100	*Zanthoxylum rhetsa* (Roxb.)DC	Micheng	Rutaceae	T	W	L, S	Headache
101	*Zizyphus funiculosa* Ham.	Darichik	Rhamnaceae	S	W	L, B	Gynecological disorders

Well-known medicinal plants

Sl. No	Name of the plant	Family	Habit [a]	Source [b]	Part(s) used [c]	Indications
1	*Ageratum conyzoides* Linn.	Asteraceae	H	W	L, R	Cuts, wounds, boils
2	*Achyranthus aspera* L.	Amarantaceae	H	W	WP	Leprosy
3	*Aesculus assamica* Griff.*	Sapindaceae	T	W	L, R	Body swelling, diarrhoea, cholera, colic, chest trouble, headache, dropsy, chronic eye diseases, bowel disorder, beriberi
4	*Alpinia galanga* (Linn.) Willd.	Zingiberaceae	H	W	Rh	Arthritis, inflammations, cough, asthma, bronchitis, obesity, diabetes & fever
5	*Alstonia scholaris* (Linn.) R. Br.	Apocynaceae	T	W/C		Malaria, diarrhoea, dysentery, dyspepsia, leprosy, tumours, ulcers, asthma, cardiopathy & helminthiasis
6	*Aquilaria agallocha* Roxb.	Thymelaeaceae	T	W	Wood	Ear, nose & eye diseases
7	*Bambusa arundinacea* Ait.	Poaceae	T	W	R	Inflamed joints, haematemesis
8	*Bixa orellana* Linn.	Bixaceae	T	W/C	R, B, S	Fevers, gonorrhoea, mosquito repellent, dysentery
9	*Boehmeria macrophylla* Horn. *	Urticaceae	S	W	L	Eczema
10	*Boerhaavia diffusa* Linn.	Nyctaginaceae	H	W	WP	Inflammations, scabies, jaundice, anemia, constipation
11	*Bombax ceiba* Linn.	Bombacaceae	T	W	R, B, L, Fr, S	Dysentery, influenza, chronic inflammations & ulceration of the bladder & kidney, gonorrhoea & restoration of skin colour
12	*Butea minor* (Lam.) Taub.*	Fabaceae	Sc	W	R	Poisonous bites of animals
13	*Butea monosperma* (Lam.) Taub.	Fabaceae	T	W	S & Fl	Diarrhoea, haemorrhoids, skin disorders, leprosy, swellings, fever, arthritis, bone fractures & efficacious in birth control
14	*Callicarpa arborea* Roxb.	Verbenaceae	T	W	Fl & Fr	Rheumatoid arthritis, burning sensation, dyspepsia, dysentery, haemorrhages, poisonous bites, skin diseases, vomiting, fever & general weakness
15	*Cannabis sativa* Linn.	Cannabinaceae	S	W	L, In, B & S	Diarrhoea, haematorrhoea, carminative & anti- inflammatory
16	*Celastrus paniculatus* Willd.	Celastraceae	T	W	B, L & S	Antidote on opium poisoning, expectorant, appetiser, on itching & skin diseases, paralysis, asthma, leucoderma, beri-beri & sores
17	*Centella asiatica* (Linn.) Urban	Apiaceae	H	W	WP	Insomnia, asthma, bronchitis, hiccough, leprosy & fever

18	*Cinnamomum tamala* (Buch.-Ham.) Nees.	Lauraceae	T	W/C	L	Inflammations, helminthiasis, dyspepsia & ophthalmia
19	*Cissampelos pariera* Linn.	Menispermaceae	C	W	R	Fever, diarrhoea, internal inflammations
20	*Clerodendrum serratum* (Linn.) Moon.	Verbenaceae	S	W	R & L	Dyspepsia, helminthiasis, cough, asthma, bronchitis, hiccough, tumours, tuberculosis, dropsy, leucoderma, leprosy & fevers
21	*Costus speciosus* (Koenig) Smith	Zingiberaceae	H	W	Rh	Anthelmintic, expectorant, in burning sensations, skin diseases, fever, asthma, bronchitis, inflammations & anaemia
22	*Cyclea peltata* (Lam.) Hook.f. & Thoms.	Menispermaceae	C	W	R, L	Cough, bronchitis, diarrhoea, dysentery, dropsy, fever, leprosy, ulcers, wounds, vomiting, dandruff, burning sensation of eyes
23	*Cynodon dactylon* (Linn.) Pers.	Poaceae	H	W	WP	Burning sensation, haemorrhages, wounds, conjunctivitis, leprosy, skin diseases, vomiting, dysentery, diarrhoea, abortion
24	*Dendrobium moschatum* Sw.	Orchidaceae	E	W	L	Ear pain
25	*Desmodium triquetrum* (Linn.) DC.	Fabaceae	S	W	WP	Cough, bronchitis, wounds, abscess, sores, dysentery, burning sensations
26	*Dioscorea bulbifera* Linn.	Dioscoriaceae	C	W	Tb	Sores, syphilis, dysentery, diarrhoea, piles
27	*Drymeria cordata* (Linn.) Willd.ex R.& S.	Caryophyllaceae	H	W	WP	Burns, snake-bite
28	*Drynaria quercifolia* (Linn.) J. Smith	Polypodiaceae	H	W	Rh	Typhoid, dyspepsia, diarrhoea, foul ulcers, and migraine
29	*Duabanga grandiflora* (Roxb. ex DC.) Walp.	Soneratiaceae	T	W/C	St, B	Anticancer, spasmog.
30	*Eclipta prostrata* (Linn.) Linn.	Asteraceae	H	W	WP	Skin diseases, wounds, elephantiasis, helminthiasis, fever, jaundice, leprosy, and for blackening and strengthening hair, gums
31	*Elaeagnus conferta* Roxb.*	Elaeagnaceae	S	W/C	AP	Spasmog.
32	*Elephantopus scaber* Linn.	Asteraceae	H	W	R, L, Fl	Fevers, diarrhoea, bronchitis, haemorrhoids, skin diseases,
33	*Entada purseatha* DC.	Mimosaceae	L	W	S	Glandular swellings
34	*Erythrina stricta* Roxb.	Fabaceae	T	W	Fl	Tonic
35	*Eupatorium adenophorum* Sch.-Bip.	Asteraceae	H	W	L	Swellings, intermittent fevers
36	*Eupatorium odoratum* Linn.	Asteraceae	H	W	AP, L	Spasmol., cuts, wounds
37	*Eurya acuminata* DC.	Theaceae	T	W	L, Fr	Stomachic
38	*Ficus hispida* Linn.f.	Moraceae	T	W	B, Fr	Ulcers, leucoderma, jaundice, anaemia, haemorrhoids, epistaxis, inflammations, fever
39	*Ficus semicordata* Buch.-Ham. ex Sm.	Moraceae	T	W	Fr	Spasmog.
40	*Ficus sub-incisa* Buch.-Ham. ex Sm.	Moraceae	T	W	AP	Spasmog.
41	*Flacourtia jangomas* Rausch.	Flacourtiaceae	T	W	B, L, Fr	Odontalgia, diarrhoea, haemorrhoids, rheumatism, nausea, skin disease, diabetes, jaundice, tumours.
42	*Flemingia macrophylla* (Willd.) Prain	Fabaceae	S	W	St	Spleen complaints, smallpox, fistula, cholera, dysentery, blindness
43	*Garcinia morella* (Gaertn.) Desr.	Clusiaceae	T	W	St	Dropsy, ulcers, blood pressure, pimples, boils, wounds, arthritis
44	*Gloriosa superba* Linn.*	Liliaceae	H	W	T	Labour pains, leprosy, piles, colic, boils, intestinal worms, gonorrhoea
45	*Glycosmis arborea* (Roxb.) DC.	Rutaceae	S	W	WP	Inflammations, rheumatism, jaundice, anaemia, fever,

						hepatopathy, skin diseases, fever, helminthiasis, wounds, cough, bronchitis
46	*Grewia disperma* Rottb.	Tiliaceae	T	W	B, Fr	Burning sensation, cough, skin diseases, ulcers, wounds, seminal weakness
47	*Gynocordia odorata* Br.	Flacaurtiaceae	T	W	S	Leprosy & other skin diseases
48	*Hedychium coronarium* Koen. ex Retz.	Zingiberaceae	H	W	Fl, R	Foetid nostrils
49	*Hibiscus sabdariffa* L.	Malvaceae	S	C	Fr	Bilious excretion
50	*Hiptage benghalensis* (Linn.)Kurth	Malpighiaceae	L	W	B, L, Fl	Burning sensation, wounds, skin, diseases, ulcers, leprosy, rheumatism, hyperdipsia, cough, asthma
51	*Holarrhena antidysenterica* (Linn.) Wall.	Apocynaceae	S	W	B, S, L	Amoebic dysentery, diarrhoea, asthma, hepatopathy, rheumatism, malaria, vomiting, skin diseases, bronchitis, boils, ulcers
52	*Houttuynia cordata* Thunb.	Saururaceae	H	W	WP	Antimicrobial, diuretic, antitumour
53	*Inula cappa* (Buch.-Ham. ex D. Don)DC.	Asteraceae	S	W	L	Headache, cancer
54	*Jasminum dispermum* Wall.	Oleaceae	Sc	W	AP	Anticancer, diuretic
55	*Knema linifolia* (Roxb.) Warb.	Myristicaceae	T	W	L	Dysentery
56	*Kylinga monocephala* Roltb.	Cyperaceae	H	W	R	Fever
57	*Lagerstroemia parvifolia* Roxb.	Lythraceae	T	W	B	Wounds
58	*Lantana camara* Linn.	Verbenaceae	S	W	WP	Malaria, epilepsy, dysentery, odontalgia, cuts, wounds, ulcers, swellings, fever, fistula, pustules, tumours, rheumatism
59	*Lasia spinosa* (Linn.) Thw.	Araceae	H	W	R, Fr, L	Colic, rheumatism, intestinal diseases, affections of throat, piles, stomach ache
60	*Leea indica* (Burm.f.) Merr.	Leeaceae	S	W	R, L	Diarrhoea, dysentery, colic, ulcers, skin diseases, vertigo
61	*Litsea lancifolia* (Roxb.ex Nees) Hk.f.	Lauraceae	T	W	B	Sprains, wounds
62	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	T	W	B,R	Diarrhoea, pains, bruises, contusions
63	*Litsea sebifera* Pers.	Lauraceae	T	W	B	Diarrhoea, bruises
64	*Maesa montana* DC	Lauraceae	S	W	L	Eye infection
65	*Maesa indica* Willd.	Lauraceae	S	W	Fr	Anthelmintic
66	*Mallotus philippensis* (Lam.) Muell.-Arg.	Euphorbiaceae	T	W	Glandular hairs on the fruit	Constipation, wounds, ulcers, cough, renal and vesicle calculi, poisonous affections, scabies, ring worm, herpes, haemorrhages
67	*Melastoma malabathricum* L.	Melastomataceae	S	W	B,R	Diarrhoea, dysentery, leucorrhoea, wounds, skin diseases
68	*Melia azadirach* Linn.	Meliaceae	T	W/C	R, L, S, Fl	Sciatica, cephalalgia, leprosy, leucoderma, wounds, ulcers, diabetes, fevers, helminthiasis, cough, asthma
69	*Mentha piperata* Linn.	Lamiaceae	H	W	L	Ulcers, wounds, cuts, helminthiasis, vomiting, skin diseases, cough, asthma, bronchitis
70	*Mesua ferrea* Linn.	Clusiaceae	T	W/C	Fl, S oil	Asthma, cough, leprosy, scabies, vomiting, dysentery, ulcers,

						impotency, fever
71	*Morus alba* Linn.	Moraceae	T	W/C	R, L, Fr	Scabies, smallpox, diarrhoea, hepatopathy, splenopathy
72	*Mussaenda roxburgii* Hk.f.	Rubiaceae	S	W	WP	Cough, bronchitis, fever, inflammation, wounds, ulcers, leucoderma, jaundice
73	*Neolitsea cassia* Bl.	Lauraceae	T	W	B	Diarrhoea, fever, flatulence, spasmodic affections, nausea, vomiting, urine haemorrhage
74	*Nicotiana tabacum* Linn.	Solanaceae	S	C	L	Dental caries, tubercular glands, hernia, inflammations, helminthiasis, bronchitis, scabies, tumours.
75	*Ophiorrhisa mungos* Linn.	Acanthaceae	S	W	R	Wounds, ulcers, helminthiasis, snake poison, poisonous wounds, leprosy, cancer, hydrophobia
76	*Oreocnide integrifolia* (Gaud.) Miq.	Urticaceae	T	W	R	Rashes, skin infection
77	*Oroxylon indicum* (Linn.) Benth. ex. Kurth	Bignoniaceae	T	W/C	R, L, Fr, S	Inflammations, dropsy, sprains, cough, asthma, bronchitis, dysentery, vomiting, leucoderma, rhumatoid arthritis, fever
78	*Oxalis corniculata* Linn.	Oxalidaceae	H	W	WP	Liver tonic, anaemia, fever, diarrhoea, scurvy, corns, warts, toxicity, cardiopathy
79	*Paedaria foetida* Linn.	Rubiaceae	C	W	WP	Rheumatism, colic, spasm, gout
80	*Pandanus odoratissimus* Linn. f.	Pandanaceae	S	W	R, L, Fl, bract	Skin diseases, leprosy, fever, diabetes, tumors, smallpox, syphilis, insomnia
81	*Paramignya micrantha* Kurth.	Rutaceae	Sc	W	R	Diuretic
82	*Persea gamblei* (King ex HK.f.) Kosterm.	Lauraceae	T	W		Muscular pains
83	*Phyllanthus emblica* Linn.	Euphorbiaceae	T	C	R B, B, L, Fr	Gonorrhoea, jaundice, peptic ulcer, conjunctivitis, dysentery, leprosy, anaemia, grayness of hair
84	*Piper betel* Linn.	Piperaceae	C	C	WP	Fever, alcoholism, impotency, rheumatism, leprosy, cough
85	*Piper mullesua* D.Don	Piperaceae	C	W	R	Asthma, bronchitis, dyspepsia
86	*Pouzolzia hirta* Hassk.	Urticaceae	H	W	R	Hair tonic
87	*Premna latifolia* Roxb.	Verbenaceae	Sc	W	L	Dropsy
88	*Prunus cerasoides* D. Don.	Rosaceae	T	W/C	Heart wood	Sprains, wounds, ulcers, leprosy, skin discoloration, vomiting, hallucinations, fever
89	*Rauvolfia serpentina* (Linn.) Benth. ex Kurth	Apocynaceae	S	W	R, L	Hypertension, fever, wounds, insomnia, epilepsy, giddiness, uterine contraction, removing opacity of cornea
90	*Rhyncostylis retusa* (Linn.) Bl.	Orchidaceae	E	W/C		Emollients
91	*Rubia cordifolia* Linn.	Rubiaceae	C	W	R	Diarrhoea, dysentery, leprosy, skin diseases, diabetes, discolouration of skin, jaundice, pectoral diseases
92	*Rubus ellipticus* Sm.	Rosaceae	Sc	W	Fr, R	Dysentery
93	*Rubus rugosus* Sm.	Rosaceae	Sc	W	Fr	Body swellings
94	*Sapindus mukorossi* Gaertn.	Sapindaceae	T	W	Fr, S	Excessive salivation, epilepsy, dental problem
95	*Saprosma ternatum* (Wall. ex Roxb.) Hk.f.	Rubiaceae	S	W	L	Flatulence, stomach ache

96	*Saraca asoca* (Roxb.) D. Willd.	Caesalpiniaceae	T	W/C	B	Uterine affections (menorrhagia)
97	*Saurauia nepaulensis* DC.	Saurauiaceae	T	W	B	Splinters
98	*Schleichera trijuga* Willd.	Saurauiaceae	T	W	B	Hair growth promoter
99	*Scirpus sp.*	Cyperacea	H	W	WP	Diarrhoea, vomiting
100	*Selaginella sp.*	Selaginaceae	H	W	WP	Coughs, prolapse of rectum, bleeding piles, gravel, amenorrhoea, fever, backache
101	*Shorea robusta* Gaertn.f,	Dipterocarpaceae	T	W	Resin	Fumigation for disinfection, plasters & ointments
102	*Sida rhombifolia* Linn.	Malvaceae	S	W	R, St	Dermatopathy, diarrhoea, tuberculosis, leucorrhoea, burning sensation & dipsia
103	*Solanum kurzii* Br.	Solanaceae	S	W/ C	R	Stomach-ache
104	*Spondias pinnata* (Linn.f.) Kurth	Anacardiaceae	T	W	R, L, B, Fr	Dysentery, diarrhoea, vomiting, muscular rheumatism, otalgia, bilious dyspepsia & general debility
105	*Syzygium cumini* (Linn.) Skeels	Myrtaceae	T	W	B, L, Fr	Diabetes, stomatalgia, fever, strengthening teeth & gums, vomiting, diarrhoea, pharyngitis, splenopathy & ringworm
106	*Tabernaemontana divaricata* (Linn.) R.Br. ex Roem. & Schultes	Apocynaceae	S	W	R, Fl, latex	Odontalgia, opacity of the cornea, paralysis, arthralgia, melalgia, burning sensation, dermatopathy & wounds
107	*Taxus baccata* Linn.	Taxaceae	T	W	L	Asthma, bronchitis, vesical catarrh, cancer
108	*Terminallia belerica* (Gaertn.) Roxb.	Combretaceae	T	W	S	Affections of throat & chest
109	*Thysanolaena maxima* (Roxb.) O. Ktze.	Poaceae	H	W	R	Cooling & cleaning eyes, mouthwash during fever
110	*Toddalia asiatica* (Linn.) Lamk.	Rutaceae	L	W	R, L, Fl, Fr	Odontalgia, paralysis, malaria, dyspepsia, colic, flatulence, diarrhoea, cough, bronchitis, nausea, wounds, ulcers, epilepsy, gonorrhoea & external applications in wasp-stings
111	*Toona ciliata* Roem.	Meliaceae	T	W	B, Fl	Chronic infantile dysentery, cough, bronchitis, intermittent fevers, leprosy, dermatopathy, ulcers & in menstrual disorders
112	*Trema orientalis* Bl.	Ulmaceae	T	W	R,B,L	Diarrhoea, blood in urine, epilepsy, muscular pains
113	*Triumfetta rhomboidea* Jacq.	Tiliaceae	H	W	Fr	Demulcents
114	*Vitex peduncularis* Linn.	Verbenaceae	T	W	WP	Arthritis, inflammation, dysentery, uropathy, wounds, ulcers, bronchitis, malaria, leprosy, cholera
115	*Wendlandia tinctoria* DC.	Rubiaceae	T	W	B	Cholera
116	*Zingiber officinale* Rosc.	Zingiberaceae	H	C	Rh	Dropsy, cephalalgia, cough, bronchitis, cholera, nausea, vomiting, elephantiasis
117	*Zizyphus rugosa* Lamk.	Rhamnaceae	T	W	B	Diarrhoea

[a]: T= trees; S= shrubs; Sc= scandent shrubs; C= climbers; H= herbs; E= epiphytes

[b]: W= wild; C= cultivated

[c]: WP= whole plant; St= stem; AP= Apical portion, L= leaves; B=bark; R= roots; Bb= Bulb, T= Tuber, Rh= rhizome; In= Inflorescence; Fl= flowers; Fr= fruits; S= seeds

* Rare and threatened medicinal plants

Sources: Dymok *et al.* 1890, Rao 1981, Bentley and Trimen 1983, Neogi *et al.* 1989, Kirtikar and Basu 1933, Warrier *et al.* 1993, Rao and Shanpru 1981

GENERAL DISCUSSION

The impact of human activities on species diversity is an issue that has attracted the interest of ecologists from both theoretical as well as applied perspectives (Stapanian *et al.* 1997a). Clements (1936) viewed disturbance as a negative force that destroys climax assemblages and brings instability in the system, while Paine (1966), Huston (1979) and Lubchenco (1978) considered it as a positive force that might increase species diversity in the community by preventing competitive exclusion. Species richness has been correlated with natural disturbance by several authors (Grub 1977, Connell 1978, Grime 1979, Huston 1979, Armesto and Pickett 1985). Connell proposed that tree species diversity in the rain forests would be greatest where disturbances are moderate in intensity and frequency. Similarly, Collins *et al.* (1995) argued that species richness should be highest at intermediate disturbance level when conditions favour the competitive species as well as the disturbance-tolerant species.

The present study was undertaken to analyse various factors causing disturbance in the Nokrek Biosphere Reserve of Meghalaya and to assess the impact of such disturbances on the plant diversity and forest community characteristics of the BR. Shifting cultivation and mining activities were found to be the main causes of disturbance in the Nokrek BR, and each has differential effects on the structure and the subsequent development of vegetation in the BR.

As many as eleven ecosystem types were identified within the BR, covering both, core as well as buffer zone. Three types of undisturbed forest ecosystems, viz., montane, lowland and riverain forest ecosystems were considered as control sites for assessing the impact of disturbance on various community parameters.

The undisturbed montane, lowland and riverain forests of the Nokrek BR represent the flora of Manipur–Khasi province described by Takhtajan (1988), which exhibits saturation of eastern Asiatic components and also shows strong ties with the florae of the eastern Himalaya, upper Burma and China. Available species are the product of the bio-geographical influences and evolutionary process (Meher-Homji 1989) as well as the site and landscape histories. Rainfall pattern and temperature regimes strongly influence the floristic composition, phenology and community architecture of tropical forests, which are further modified by edaphic, orographic, biotic and historical influences (UNESCO/ UNEP/ FAO 1978, Richards 1996). Geographic location as well as the favourable climatic conditions appear to be the most important factors contributing to the floristic richness of the Nokrek BR.

Though a number of floristic and ecological studies have been carried out in the state of Meghalaya, they are largely restricted to the sacred groves. During a floristic survey of 56 sacred groves, 514 species have been reported by Tiwari *et al.* (1999). An ecological study by Jamir and Pandey (2003) have reported 395 species of vascular plants from three sacred groves of Jaintia Hills, while Upadhaya *et al.* (2003) reported 437 vascular species from three other sacred groves of Jaintia hills. In a floristic survey of Balphakram wild life sanctuary, 770 species have been listed by Kumar (1984), while Haridasan and Rao (1985-87) have described 1151 dicotyledonous forest species from the entire state. In comparison to these, 590 vascular species were recorded from the Nokrek BR During the present study, a total of 710 species belonging to 465 genera and 140 families was recorded from the different ecosystems in the BR. This included 678 angiosperms, 3 gymnosperms and 29 pteridophytes. Out of these 710 species, the undisturbed forests had 590 species, of which 392 species were recorded from the montane forests of the core zone alone. Dominance of angiosperms and presence of congeneric species are two important characteristic features of tropical and sub-tropical moist forests (Balakrishnan 1981, Kumar 1984, Haridasan and Rao 1985-87, Valencia *et al.* 1994, Jamir and Pandey 2003, Upadhaya *et al.* 2003). The forests in core and buffer zones of the BR had high angiospermic diversity and contained at least 129 genera (33% of the total genera recorded) with congeneric species. The high concentration of tree, herb and epiphytic species depicts the high heterogeneity of these forest ecosystems. Fifty five species were exclusively present in the montane forest of the core zone. Some of the tree species such as *Acer cappadocicum*, *A. oblongum*, *Paramichelia balonii*, *Citrus latipes* and *Psychotria symplocifolia*, shrubs like *Dendrocnide sinuate*, *Ardisia pedunculosa*, *A. odontophylla* and *A. griffithii*, and herbs such as *Zingiber chrysanthemum*, *Balanophora dioica*, *Impatience porrecta* and *Chirita oblngifolia* are taxonomically very important. The dominant families in the tropics are Rubiaceae, Euphorbiaceae, Annonaceae, Moraceae and Myrtaceae. The undisturbed forests of the Nokrek BR also contained large number of Rubiaceae and Euphorbiaceae members.

All the three undisturbed forests, i.e. montane, lowland and riverain forests had very high species richness and they differed considerably in their species composition, community structure and physiognomy. The taxonomic diversity in terms of number of species, genera and families declined from the montane forest to lowland forest and it was the least in the riverain forest. The species-area curves for these forests, however, did not reach the plateau indicating that more area needs to be sampled for recording all the species present in these forests. Among the disturbed ecosystems taxonomic diversity was least at the sites affected by mining while the jhum fallow communities showed increasing taxonomic diversity with the age (Fig. 8.1). The riverain forests were found to be the richest in the shrub and herbaceous species richness.

Species, genera and family richness for trees and shrubs, decreased from the undisturbed to disturbed ecosystems and their number were the lowest on the coalmine spoils (Fig. 8.2a-c and 8.3a-c). On the other hand, herbaceous species richness was maximum on the youngest jhum fallow, and it decreased with increasing age of the jhum fallows (Fig. 8.4a-c). The complexity of the secondary forest communities on the jhum fallows increased with the increase in age of the jhum fallows depicting natural recovery following the disturbance. These secondary forest communities on the jhum fallows constituted the dominant communities in the buffer zone of the Nokrek BR, and were largely composed of fast growing tree species such as *Macaranga indica*, *Callicarpa vestita* and *Eurya accuminata.* These are light demanding pioneer species, which cannot regenerate or grow under the shade and thus remain dominant for only one generation (Richards 1996). The decline in the dominance and increase in the plant diversity with the increasing age of the jhum fallows supports this view.

The species richness in the forest communities has been correlated with various edaphic characters by several workers (Hall and Swaine 1976, Huston 1980). Hall and Swaine (1976) inversely related the total exchangeable bases in soil with species richness in a number of forest ecosystems in Ghana. Huston (1980) demonstrated a negative correlation between available soil nutrients (except magnesium, manganese and nitrogen) and species richness in the forests of Costa Rica. On the other hand, Proctor *et al.* (1983) found no correlation between soil nutrient levels and species richness. In the present study, the nutrient build-up in the soil on the jhum fallows during their recovery is largely dependent upon the age of the fallow. The nutrient built-up in the soil was found to be closely associated with the increase in the species richness and vegetational complexity of the jhum fallows. The changes in the lifeform composition during fallow recovery process have significant impact on the soil characteristics, particularly the soil nutrient contents (Aweto 1981).

Chadwick (1973), Byrnes and Miller (1973) and Bradshaw (1983) showed that natural succession on the coalmine spoils was a slow process, attributable to the altered physico-chemical properties of the soil. The main constraints in the recovery of these spoils are moisture stress, acute acidity and deficiency of organic matter and nutrients (Iverson and Wali 1992). Bradshaw and Chadwick (1988) found that acid-tolerant species were more successful in colonizing the mine spoils.

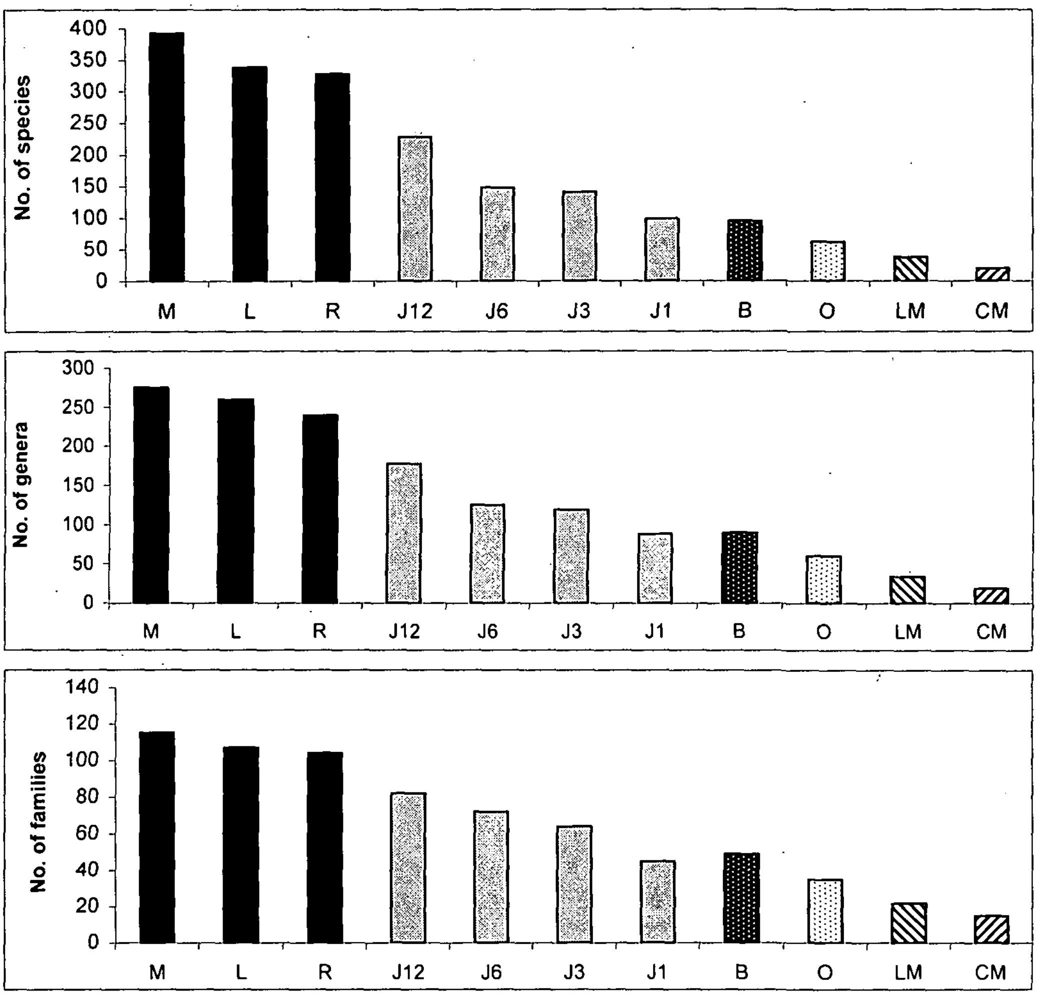


Fig 8.1 Taxonomic diversity in terms of number of species genera and families encountered in the different ecosystems of the Nokrek BR.

The unfavourable habitat conditions prevailing on the coalmine spoils in the Nokrek BR have made the recovery process in these areas extremely slow. The rhizome bearing species such as, *Pteris* sp. and *Globba clarkei* as well as the species having fibrous roots like *Axonopus compressus* and *Eragrostis* spp. are important colonizers on these spoils. Alvarez *et al.* (1974) reported prevalence of Asteraceae, Poaceae and Fabaceae on mine spoils. In the present study too, these families dominated the mine spoil areas. The perennials were more in number than the annuals in these areas indicating that the plant community has been able to adopt to the prevailing stressed environments.

The surface mining of coal in the Nokrek BR has been causing massive damage to landscape and biological communities. Plant communities, which appear naturally, are disturbed by mining activity, and the habitat becomes impoverished presenting a very rigorous condition for plant growth. Bradshaw and Chadwick (1980) working on the colliery spoils also reported that the number of species colonizing on the minespoil was influenced by its pH. Decline in pH in mine spoils is one of the serious problems associated with coal mining activity. Lowering of pH strongly affects the plant growth in various ways including the availability of a large number of essential nutrients in the soil.

Richards (1996) opined that high species content per unit area of the tropical forests is largely due to the presence of several synusiae. Whitmore (1975) described 5 vertical strata in the tropical lowland evergreen rain forests of the Far East. The profile diagrams of these forest ecosystems depict their structural complexity. The stratification in these forests allows the growth of more diverse species making the forest species rich.

Biological spectrum as described for the three undisturbed forest communities viz. montane, lowland and riverain, revealed that the phanerophytes, lianas and epiphytes surpassed their respective proportions in which they are represented in the normal spectrum of Raunkiaer (1934), while the hemicryptophytes and therophytes were much below the normal proportion. Such a biological spectrum has been attributed to the humid climate by Meher-Homji (1964). Thus, it is only logical that the undisturbed forests of the Nokrek BR are characterised by this type of biological spectrum.

The vertical structure of communities on the fallows of different ages depicted the gradual increase in the phanerophytes and elimination of therophytes as well as hemicryptophytes with time. Absence of complexity in the vertical structure of the jhum fallows is due to the dearth of the megaphanerophytes (Aweto 1981).

The plant communities on the man-impacted ecosystems such as 1-yr old jhum fallows and coalmine spoils showed least similarity with that of the undisturbed ecosystems in terms of qualitative as well as quantitative characteristics of the vegetation (Table 8.5 and 8.6). With the passage of time, however, the communities on the jhum fallows showed an increasing similarity in species composition as well as abundance with the undisturbed ecosystems (Table 8.1-8.6). During the recovery process, the declining dominance of the pioneer species and increasing diversity of primary species with the increasing age of the fallows seemed to have contributed to such similarity.

Table 8.1 Sorensen Index showing qualitative similarity between tree component of different ecosystems in the Nokrek BR.

	M	L	R	J_{12}	J_6	J_3
M	100.00	-	-	-	-	-
L	31.63	100.00	-	-	-	-
R	33.33	14.85	100.00	-	-	-
J_{12}	31.50	8.16	27.77	100.00	-	-
J_6	16.66	3.30	22.03	35.55	100.00	-
J_3	10.61	0.00	18.01	38.55	52.63	100.00

Table 8.2 Morisita- Horn Index showing quantitative similarity between tree component of different ecosystems in the Nokrek BR.

	M	L	R	J_{12}	J_6	J_3
M	1.00	-	-	-	-	-
L	0.11	1.00	-	-	-	-
R	0.16	0.10	1.00	-	-	-
J_{12}	0.01	0.00	0.08	1.00	-	-
J_6	0.01	0.00	0.08	0.86	1.00	-
J_3	0.00	0.00	0.03	0.82	0.97	1.00

Table 8.3 Sorensen Index showing qualitative similarity between shrub component of different ecosystems in the Nokrek BR.

	M	L	R	J_{12}	J_6	J_3	LM	CM
M	100.00	-	-	-	-	-	-	-
L	46.38	100.00	-	-	-	-	-	-
R	42.11	26.51	100.00	-	-	-	-	-
J_{12}	21.21	21.92	40.00	100.00	-	-	-	-
J_6	11.11	13.11	35.29	65.52	100.00	-	-	-
J_3	7.84	10.34	21.54	50.91	55.81	100.00	-	-
LM	4.44	11.54	6.78	24.49	21.62	11.76	100.00	-
CM	0.00	27.27	7.84	5.00	6.90	0.00	10.00	100.00

Table 8.4 Morisita- Horn Index showing quantitative similarity between shrub component of different ecosystems in the Nokrek BR.

	M	L	R	J_{12}	J_6	J_3	LM	CM
M	1.00	-	-	-	-	-	-	-
L	0.28	1.00	-	-	-	-	-	-
R	0.47	0.24	1.00	-	-	-	-	-
J_{12}	0.30	0.07	0.24	1.00	-	-	-	-
J_6	0.06	0.14	0.16	0.40	1.00	-	-	-
J_3	0.10	0.04	0.16	0.39	0.30	1.00	-	-
LM	0.03	0.09	0.03	0.14	0.14	0.01	1.00	-
CM	0.06	0.41	0.07	0.01	0.05	0.00	0.11	1.00

Table 8.5 Sorensen Index showing qualitative similarity between shrub component of different ecosystems in the Nokrek BR.

	M	L	R	J12	J6	J3	J1	B	O	LM	CM
M	100.00	-	-	-	-	-	-	-	-	-	-
L	63.83	100.00	-	-	-	-	-	-	-	-	-
R	25.49	26.53	100.00	-	-	-	-	-	-	-	-
J_{12}	30.01	31.19	23.93	100.00	-	-	-	-	-	-	-
J_6	22.81	30.91	21.73	63.57	100.00	-	-	-	-	-	-
J_3	17.39	19.82	20.17	60.00	59.54	100.00	-	-	-	-	-
J_1	13.56	21.05	13.11	54.14	59.70	59.26	100.00	-	-	-	-
B	26.97	30.59	19.35	42.31	36.19	35.85	25.69	100.00	-	-	-
O	8.70	6.82	22.92	39.25	40.74	47.71	42.86	21.69	100.00	-	-
LM	5.63	8.96	5.35	18.60	18.39	15.91	13.19	16.13	18.46	100.00	-
CM	3.45	11.11	6.45	13.70	16.22	13.33	7.69	8.16	11.54	6.45	100.00

Table 8.6 Morisita- Horn Index showing quantitative similarity between herb component of different ecosystems in the Nokrek BR.

	M	L	R	J12	J6	J3	J1	B	O	LM	CM
M	1.00	-	-	-	-	-	-	-	-	-	-
L	0.53	1.00	-	-	-	-	-	-	-	-	-
R	0.39	0.25	1.00	-	-	-	-	-	-	-	-
J_{12}	0.07	0.17	0.23	1.00	-	-	-	-	-	-	-
J_6	0.04	0.08	0.09	0.72	1.00	-	-	-	-	-	-
J_3	0.05	0.09	0.09	0.63	0.81	1.00	-	-	-	-	-
J_1	0.03	0.04	0.07	0.58	0.81	0.86	1.00	-	-	-	-
B	0.15	0.22	0.24	0.23	0.22	0.16	0.20	1.00	-	-	-
O	0.00	0.00	0.06	0.40	0.63	0.70	0.74	0.20	1.00	-	-
LM	0.01	0.02	0.00	0.01	0.12	0.14	0.19	0.04	0.27	1.00	-
CM	0.07	0.04	0.03	0.07	0.04	0.10	0.09	0.03	0.03	0.03	1.00

The undisturbed forests represented the mosaics of high and low species diversity patches. This seems to be the result of the combined effect of non-extreme stable environmental conditions and gap phase dynamics within the forests (Whittaker 1972). The majority of the species of the forest ecosystems exhibited clumped or contiguous distribution pattern suggesting the highly heterogeneous and patchy character of the forests. Clumping of individuals of the same species may be due to opportunity or chance of colonization/ establishment and it is also often related to the dispersal mechanism of the species (Poore 1968, Ashton 1969, Hubbell 1979).

The Shannon's, Pielou's and Simpson's species diversity indices values obtained in the present study are comparable with the studies of Jamir 2000, Tripathi *et al.* 2001, Upadhaya *et al.* 2003 who conducted studies in other tropical/ subtropical forests of Meghalaya. Several explanations have been put forward for the variation in diversity patterns. Speciation, geological history of the site, climate, precipitation, latitudinal and altitudinal position (Gentry 1988a, 1992, Lieberman *et al.* 1996, Vázquez and Givinish 1998) and edaphic properties (Gentry 1988) have been considered as crucial factors for determining the species diversity of a particular community. Biological factors such as competition (Huston 1979, 1980, Tilman 1982, Ashton 1989), and spatial and temporal micro-niche availability also influence the diversity (Tilman and Pacala 1993).

Drastic reduction in diversity values was observed with increasing disturbance in the ecosystems (Fig. 8.2 f-i, 8.3 e-h, 8.4 e-h). The Shannon diversity index and the Pielou evenness index for all the undisturbed ecosystems showed higher values than the disturbed ecosystems. However, Simpson index was lower in the undisturbed forests than the disturbed forest stands.

High β- diversity (Table 8.7-8.9) values indicate the high diversity across the different ecosystems of the BR. It ranged between 0.47and 1 for trees, 0.34 and 1 for shrubs, and 0.36 and 0.97 for herbs. Higher β- diversity values for herbs could be due to the presence of a large number of habitat-specialist herbs in the BR.

The undisturbed forest ecosystems of the Nokrek BR are comparable with several other rain forests of the tropics in terms of density and basal cover (Chapter V). The montane forest had highest tree density as well as basal cover, among the undisturbed forests (Fig. 8.2d,e). On the other hand, the highest tree density of young jhum fallows was due to the dominance of saplings (5-15 cm gbh) (Fig. 8.2d), having minimal basal area (Fig. 8.2e).

Shrub and herb densities decreased with the age of the fallows and were the least in the undisturbed forests (8.3d, 8.4d).

The dominance-distribution curves showing a lognormal distribution also depict that these forests are species-rich and heterogeneous communities (Whitmore 1970, Magurran 1988). This suggests that in these forest stands there was more or less an even allocation of resources among the species.

The curves for the trees on the jhum fallows as well as herbs in the mined areas showed broken-stick series model (Poole 1974). This could be attributed to the lesser number of species occurring on these stands. The decrease in number on jhum fallows and on the mining sites depicts the stressed environment on these sites where conditions are not favourable for plant growth. Although the species diversity was low in these stands, the species that grow here appear to have developed tolerance that has enabled them to grow in such an environment. The works of Lyngdoh (1995) and Das Gupta (1999) support the present findings.

The population structure of the dominant species in the undisturbed forests showed a reverse J-shaped density–diameter distribution curve, with preponderance of the individuals in the small girth classes, which revealed the mature stage of these forests, low rate of recruitment of seedlings and saplings, and relatively low seedling mortality. According to Condit *et al.* (1998), population health correlates with size distribution and healthy populations have steeper curves. Such expanding and typical population structure has also been reported from Brazilian Amazon (Campbell *et al.* 1992), Costa Rica (Nadkarni *et al.* 1995) and the Eastern Ghats, India (Kadavul and Parthasarathy 1999a,b).

Many dominant species in the undisturbed as well as disturbed communities on the jhum fallows did not have seedling populations. The factors such as specific germination requirements, microsite characteristics (Harper 1977), predation, litter thickness (Collins and Good 1987, Tripathi and Khan 1990), structural and successional status of the vegetation (Crawley and Long 1995) are said to be responsible for the abundance and performance of individuals within a population through regulating their germination and seedling establishment. The complete absence of individuals or presence of smaller number of individuals in the intermediate girth classes may be explained on the basis of size-dependent growth rate or higher size-specific mortality as advocated by Bongers *et al.* (1988).

The development of secondary vegetation on different disturbed sites differed greatly from each other depending on the previous history of the site as well as on local climatic and edaphic conditions. Colonization of the shade-tolerant species at initial stages of seedling succession is of great importance in determining the species composition of the community at later stages of succession. According to Richards (1996), the sustained viability of the shifting agricultural systems depends on the balance between short periods of cultivation in small plots, surrounded by primary or successional forest, and sufficient period of woody fallow.

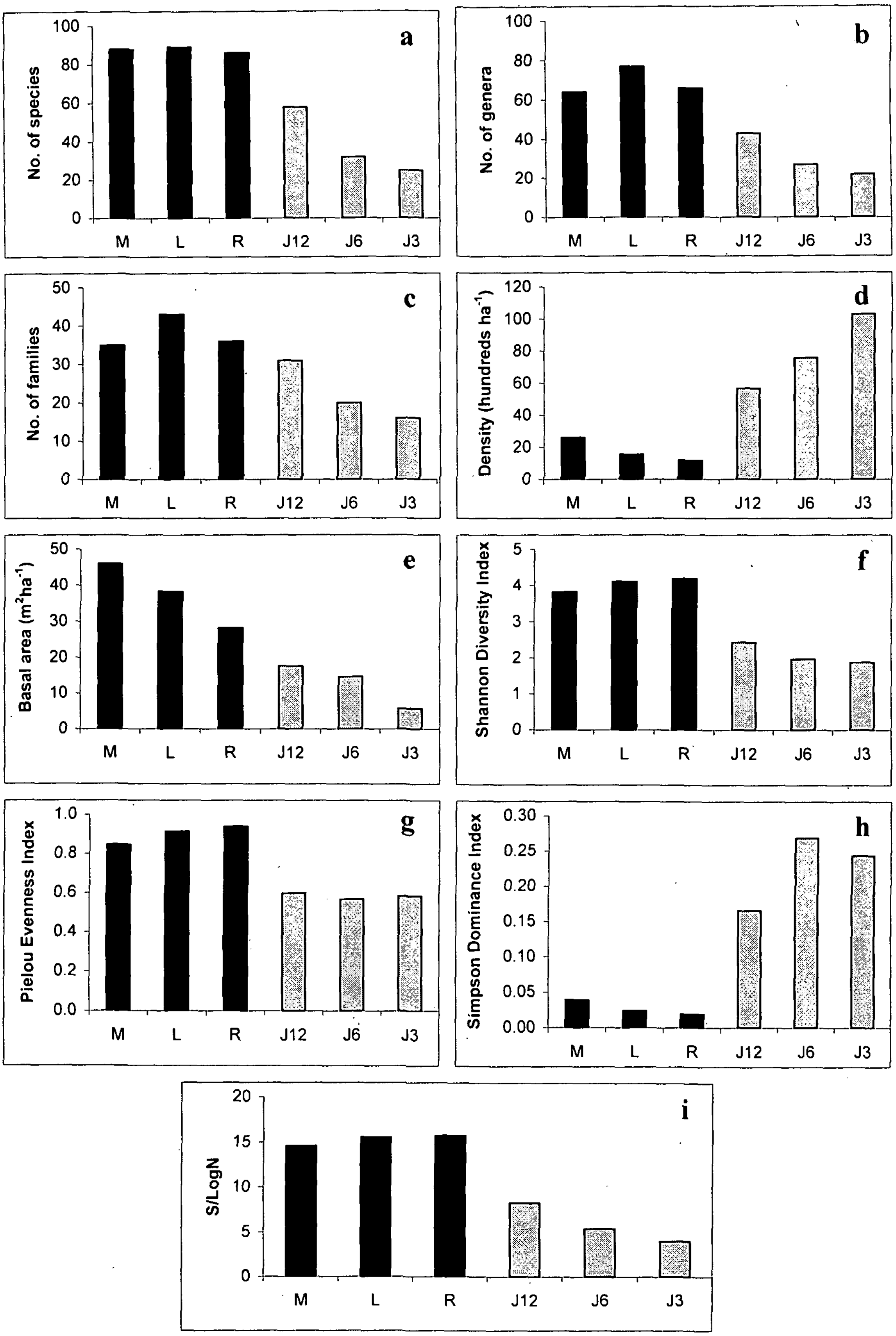


Fig. 8.2 Different community characteristics of trees in undisturbed and disturbed ecosystems of the Nokrek BR.

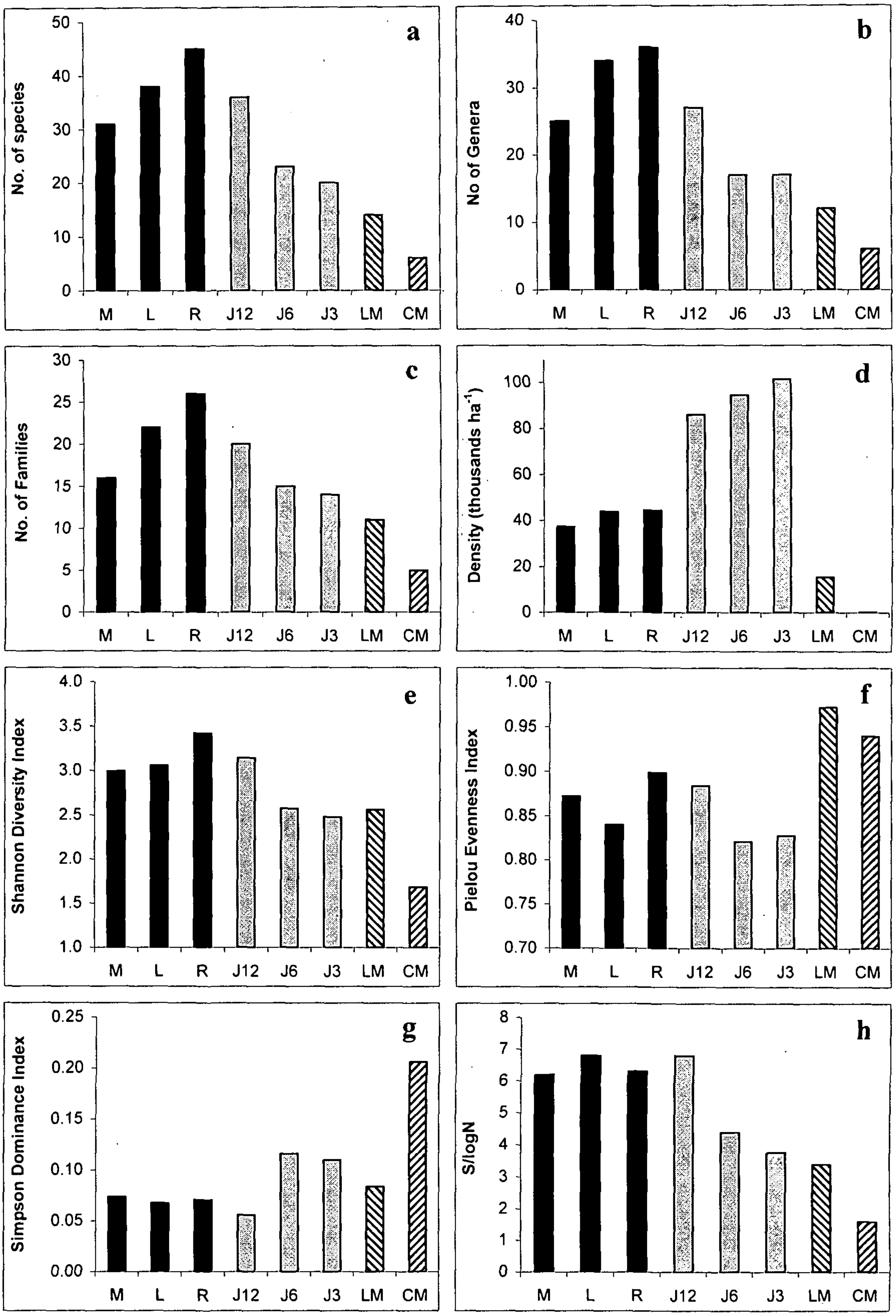


Fig. 8.3 Different community characteristics of shrubs in undisturbed and disturbed ecosystems of the Nokrek BR.

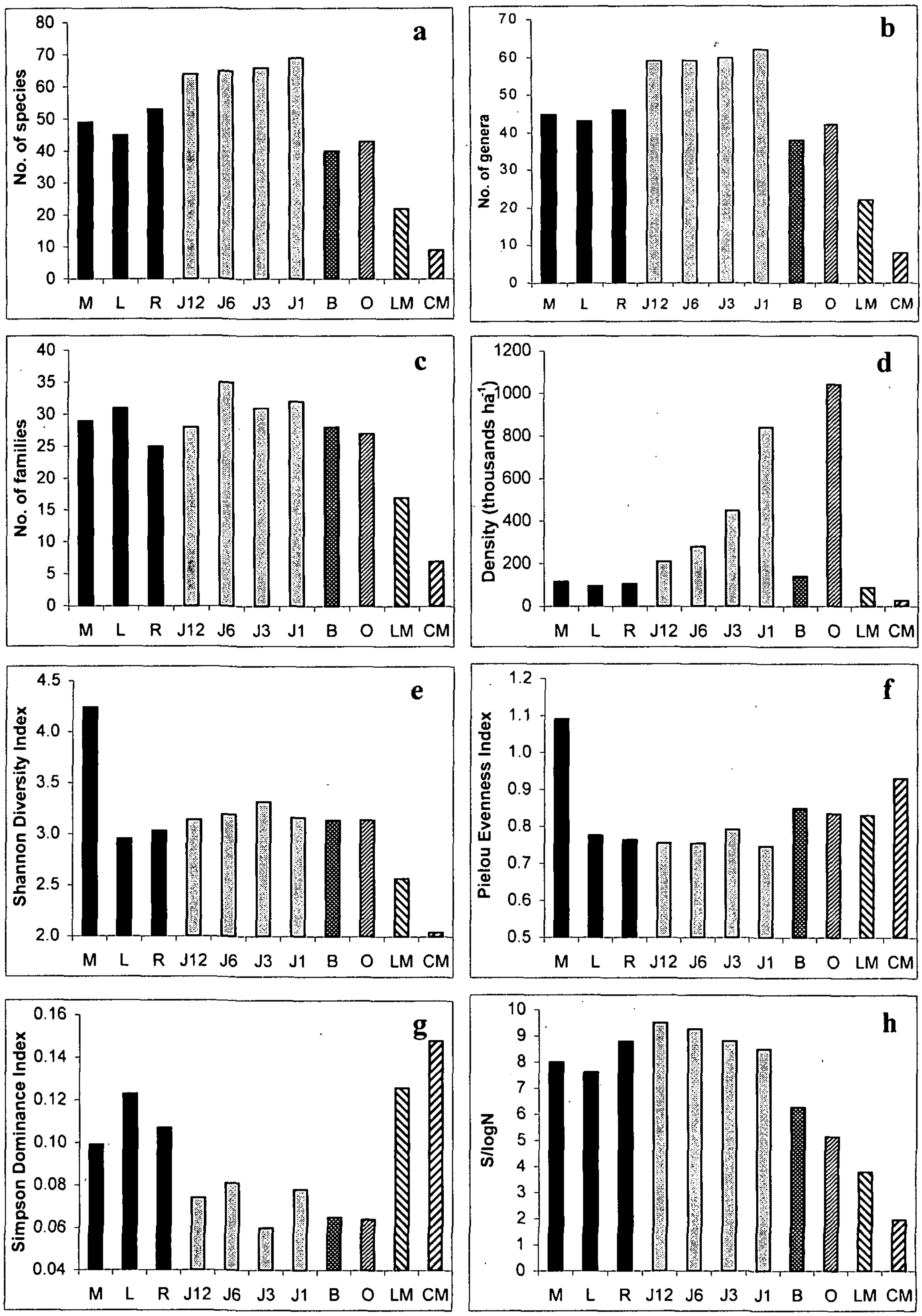


Fig. 8.4 Different community characteristics of herbs in undisturbed and disturbed ecosystems of the Nokrek BR.

Table 8.7 β- diversity of trees in the different ecosystems of the Nokrek BR.

	M	L	R	J_{12}	J_6	J_3
M	0.00	-	-	-	-	-
L	0.68	0.00	-	-	-	-
R	0.67	0.85	0.00	-	-	-
J_{12}	0.69	0.92	0.72	0.00	-	-
J_6	0.83	0.97	0.78	0.64	0.00	-
J_3	0.89	1.00	0.82	0.61	0.47	0.00

Table 8.8 β- diversity of shrubs in the different ecosystems of the Nokrek BR.

	M	L	R	J_{12}	J_6	J_3	LM	CM
M	0.00	-	-	-	-	-	-	-
L	0.54	0.00	-	-	-	-	-	-
R	0.58	0.73	0.00	-	-	-	-	-
J_{12}	0.79	0.78	0.60	0.00	-	-	-	-
J_6	0.89	0.87	0.65	0.34	0.00	-	-	-
J_3	0.92	0.90	0.78	0.49	0.44	0.00	-	-
LM	0.96	0.88	0.93	0.76	0.78	0.88	0.00	-
CM	1.00	0.73	0.92	0.95	0.93	1.00	0.90	0.00

Table 8.9 β- diversity of herbs in the different ecosystems of the Nokrek BR.

	M	L	R	J12	J6	J3	J1	B	O	LM	CM
M	0.00	-	-	-	-	-	-	-	-	-	-
L	0.36	0.00	-	-	-	-	-	-	-	-	-
R	0.75	0.73	0.00	-	-	-	-	-	-	-	-
J_{12}	0.70	0.69	0.76	0.00	-	-	-	-	-	-	-
J_6	0.77	0.69	0.97	0.36	0.00	-	-	-	-	-	-
J_3	0.83	0.80	0.80	0.40	0.40	0.00	-	-	-	-	-
J_1	0.86	0.79	0.87	0.46	0.40	0.41	0.00	-	-	-	-
B	0.73	0.69	0.81	0.58	0.64	0.64	0.74	0.00	-	-	-
O	0.91	0.93	0.77	0.61	0.59	0.52	0.57	0.78	0.00	-	-
LM	0.94	0.91	0.95	0.81	0.82	0.84	0.87	0.84	0.82	0.00	-
CM	0.97	0.89	0.94	0.86	0.84	0.87	0.92	0.92	0.88	0.94	0.00

The species recorded from the Nokrek BR were categorized into common and rare species. In total, 99 species out of 710 were rare which included 43 endemic and 15 threatened species. Maximum number of the endemic and rare species was recorded from the montane forest of core zone of the BR, and their number gradually decreased in the successional communities (Table 8.10). No such species was recorded in 1 yr old fallows, orchards or mine spoils. Secondary forest taxa are more widely distributed than those of primary forest taxa. Primary taxa are narrowly localized and are found in disjunct areas (Richards 1996). In Trinidad, Greig-Smith (1952) found a smaller percentage of endemics in the secondary and degraded forests than in the undisturbed forests.

The species with narrow habitat specificity contributed maximum (65%) to the rare flora of the BR. The unprotected lowland and riverain forests contained 45% and 53% of the total rare species, respectively. This rare flora is likely to be threatened if the habitat destruction continues in the adjacent areas.

The Nokrek biosphere reserve is also very rich in medicinal plant wealth. In total, 213 plant species of medicinal value were recorded and out of these, 177 are used locally. Only a very few of them are cultivated by the local people to meet their requirement and most of them are collected from the wild. This could lead to the disappearance of the over-exploited medicinal plants whose populations are not large enough to sustain the anthropogenic pressure.

Table 8.10 Ecosystem-wise distribution of endemic and rare species of the Nokrek BR.

Ecosystems	Endemic species	Rare species
Montane forest	38	72
Lowland forest	29	44
Riverain forest	25	52
10-12 yr old jhum fallow	15	22
6-8 yr old jhum fallow	4	8
3-4 yr old jhum fallow	4	5
Bamboo grove	2	6

Considering the floral richness of the Nokrek BR and the presence of high percentage of the endemic and threatened categories of species in its flora, immediate steps are required to be taken to check the human disturbance in the BR. The devastating effect of mining of coal and limestone in certain parts of the BR is causing depletion of biodiversity and the rampant jhum cultivation in the buffer zone of the BR is causing large-scale deforestation and other associated problems. There is a strong need to develop a comprehensive management plan for the Nokrek BR, which may ensure the rehabilitation of plant species affected by mining activity and jhum cultivation. The mined areas need to be reclaimed for *in situ* conservation of rare species, which otherwise may fail to establish elsewhere. The jhum cultivation, in any case, needs to be regulated.

The core zone, which is home to numerous medicinal and taxonomically important plants, needs to be fully protected. The overexploitation of medicinal plants must be regulated and the cultivation of the most widely used medicinal plants should be encouraged. The cultivation/ plantation of the selected and important medicinal plants by the people living in the buffer zone would go a long way in conserving their populations in the wild and in improving the socio-economic condition of the people. Unless corrective/ preventive measures are taken, the rich floral diversity of the Nokrek BR will not be able to withstand the anthropogenic pressure and in course of time the rich forest vegetation may be converted into small fragments of degraded forest patches.

SUMMARY

The present study was conducted during 2000-2003 in the Nokrek Biosphere Reserve, situated in the southeastern part of Meghalaya covering parts of East, West and South Garo Hills. The biosphere reserve covers a total area of 820 km^2 of which 47.48 km^2 area has been strictly protected as the core zone of the BR. The rest of the area surrounding the core zone is the buffer zone, where the inhabitants of the villages located within the BR carry out different land use practices for their subsistence. The activities include shifting cultivation, orchards and tea plantations, settled agriculture, and coal and limestone mining. The present study was carried out in the core as well as buffer zones of the Nokrek BR to evaluate the biodiversity in different ecosystems of the BR and to determine the impact of human activities on the plant diversity. The study was carried out with the following specific objectives:

1. Inventorying the plant diversity of different ecosystems found in the Nokrek biosphere reserve
2. Assessing the impact of human activities on plant diversity of the Biosphere Reserve
3. Identification of biodiversity-rich vegetation patches containing endemic, rare, endangered and medicinal plant species.

To achieve the above objectives, eleven ecosystem types were identified within the BR, covering both, core as well as buffer zone. The identified and

characterized ecosystems were broadly categorized into undisturbed and disturbed ecosystems. The undisturbed ecosystems included sub-tropical evergreen (montane) forest, tropical evergreen (lowland) forest, tropical semi-evergreen forest, tropical moist deciduous forest and riverain forest. Three of these forest ecosystems, viz. montane, lowland and riverain forest ecosystems were considered as control sites for assessing the impact of disturbance on various community parameters and were studied in detail. Human impacted ecosystem types were grouped into three categories: (i) the ecosystems with successional communities (as the jhum fallows and bamboo groves), (ii) man-managed ecosystems (as orchards, tea gardens and settled agricultural fields), and (iii) man-damaged ecosystems (as on mining sites).

The Nokrek Biosphere Reserve is extremely rich in plant diversity. Besides the well-protected core zone of the BR covered by the dense subtropical evergreen (montane) forest, the vegetation represented by tropical evergreen (lowland) forests and riverain forests in the buffer zone are also rich in plant diversity, although these forests are threatened by the human activities operating in the adjacent areas. The undisturbed montane, lowland and riverain forests of the Nokrek BR exhibit saturation of eastern Asiatic components and show strong ties with the florae of the eastern Himalaya, upper Burma and China. In total, 710 plant species belonging to 465 genera and 140 families were recorded from different ecosystems of the BR. This included 678 angiosperms, 3 gymnosperms and 29 pteridophytes. The undisturbed forest ecosystems had 590 species, of which 392 species were recorded from the montane forests of the core zone alone. Fifty five species were exclusively present in the montane forest of the core zone. Some of the taxonomically important species include trees such as *Acer cappadocicum*, *A. oblongum*, *Paramichelia balonii*, *Citrus latipes* and *Psychotria symplocifolia*, shrubs like *Dendrocnide sinuata*, *Ardisia pedunculosa*, *A. odontophylla* and *A. griffithii*, and herbs such as *Zingiber chrysanthemum*, *Balanophora dioica*, *Impatience porrecta* and *Chirita oblngifolia*.

The number of species recorded in different ecosystem types was reduced from 392 in the undisturbed montane forest to 98 in the 1 yr. old community on jhum fallows and it was reduced further to 20 on the coalmine sites. Similarly, the species richness (per 0.2 ha) in case of trees and shrubs also declined from the undisturbed to disturbed communities and was the least on the mining sites. Tree species, genus and family richness decreased by 28, 34 and 46 %, respectively on the youngest jhum fallows, which recovered up to 66, 67 and 89 %, respectively in the 10-12 year old jhum fallows. The primary species were largely replaced by pioneer and secondary species on the jhum fallows. The plant diversity was lowest on the young jhum fallows, which were highly dominated by a few pioneer species like *Macaranga indica*, *Eurya acuminata* and *Callicarpa vestita*. The plant diversity increased with the age of the jhum fallows, and with the increase in plant diversity, the dominance gradually decreased. However, even after 10-12 years of secondary succession on the jhum fallows, only 66% of the total species content could be recovered.

The shrub species, genus and family richness increased with the successional development of communities on the jhum fallows. The 10-12 yr. old jhum fallows were richer in shrub species than the undisturbed forests. The shrub richness declined as the succession on jhum fallows progressed. In the case of herbaceous species, the species richness on the youngest jhum fallows was 1.5 fold greater than the undisturbed forests, which gradually decreased with the increase in age of the jhum fallows.

Plant communities on the mine spoils had the lowest species richness, lowest diversity and highest dominance values for shrub as well as herb components, unlike the successional communities on jhum fallows, which showed emergence of high number of species instantly after the first year of disturbance (i.e. cutting and burning). Mining activities brought about 10-20 fold decrease in species richness of the community. The adverse soil conditions could be the cause of lowest species richness and diversity even after a recovery period of 2-3 years on the coalmine as well as limestone mine spoils.

The species diversity (Shannon diversity index and Whittaker's α–diversity index) was the highest in the riverain forest, followed by lowland and montane forest. The plant diversity decreased in the seral communities on the jhum fallows and on the mining sites, where it was the lowest. The species dominance followed a reverse trend. High β- diversity (Table 8.7-8.9) values indicate the high diversity across the different ecosystems of the BR. It ranged between 0.47and 1 for trees, 0.34 and 1 for shrubs, and 0.36 and 0.97 for herbs.

The tree species richness was drastically reduced due to anthropogenic disturbances. The shrub and herb species richness showed a significant increase with increasing disturbance. The successional communities on jhum fallows, bamboo groves, orchards as well as mine spoils contained a large number of weed species. A number of rare/ important species, such as *Dendrocnide sinuata*, *Ardisia pedunculosa*, *A. odontophylla*, *A. griffithii*, *Naravelia zeylanica*, *Hoya lanceolata*, *Zingiber chrysanthemum*, *Balanophora dioica*, *Impatiens chinensis*, *Impatience porrecta*, *Tacca integrifolia*, *Luisia teretifolia* and *Chirita oblngifolia* disappeared as a result of disturbance.

Biological spectrum of the undisturbed forest communities was phanerophytic. The phanerophytes, lianas and epiphytes surpassed their respective proportions in which they are represented in the normal spectrum of Raunkiaer, while the hemicryptophytes and therophytes were much below the normal proportion. The plant communities on the young jhum fallows and coalmine spoils showed a life form spectrum, which was dominated by chamaephytes.

Majority (89-93%) of woody species from all the undisturbed forests belonged to Raunkiaer's frequency class A, suggesting the highly heterogeneous nature of these forests. Raunkiaer's normal frequency distribution was observed only in the case of trees. In the case of successional communities on the jhum fallows too, the majority (90-98 %) of the tree species exhibited less than 20% frequency.

Majority of the tree species (87-93%) in the undisturbed forests exhibited clumped or contiguous distribution pattern. On the jhum fallows also, the contiguous distribution pattern was predominant (90-98%) among the constituent tree species.

The buffer zone ecosystems exhibited low equitability or high dominance in contrast to the undisturbed sites, where high equitability or low dominance was observed. With the increasing disturbance, equitability was reduced.

Among the undisturbed forests, the montane forest had the highest tree density (2595 individuals ha^{-1}). The density in seral communities on the jhum fallows, decreased from the youngest to the older jhum fallows. The density was two fold higher on the 10 –12 yr. old fallows than the undisturbed forests, due to the abundance of saplings. The mature tree (individuals ≥ 25 cm gbh) density, however, showed the substantial reduction on the jhum fallows. Correspondingly, the tree basal cover also decreased drastically from the undisturbed to the disturbed ecosystems. The herb density was highest in the orchards and one yr. old fallow, and it decreased in the older fallows.

Population structure of the trees based on the density-diameter values in the undisturbed forests revealed that these forests have attained the mature stage and showed good regeneration. The communities in the undisturbed forests as well as jhum fallows showed growing population. The seedling density decreased with the increasing disturbance.

The Nokrek BR harbours a number of endemic, rare and threatened plant species. A total of 99 such species were recorded of which 43 were endemic and 15 belonged to the threatened category. The species with narrow habitat specificity contributed maximum (65%) to the rare flora of the BR. The unprotected lowland and riverain forests contained 45% and 53% of the total rare species, respectively. This rare flora is likely to be threatened if the habitat destruction continues in the adjacent areas.

The BR is also a storehouse of several medicinally important plants, including locally used less-known species as well as well-known medicinal plant species. In all 213 medicinal plants were recorded, out of which 102 species are used locally. Only 23 % of these species are cultivated, while the rest are collected from the wild. Thus, the medicinal plants growing in the BR are subjected to considerable anthropogenic pressure.

Considering the floral richness of the Nokrek BR and concentration of the endemic and threatened species in its flora, immediate steps are required to be taken to check the human disturbance in the BR. The present conservation strategies of Nokrek BR are confined to a small portion of existing primary vegetation, by demarcating the core zone, which largely represents the subtropical evergreen forest. However, the vegetation of entire BR is highly patchy and heterogeneous. Owing to such patchiness of the entire landscape of the BR, there is a strong need to develop a comprehensive management plan, which may ensure to protect such high plant diversity spread across different habitats. Unless preventive as well as remedial measures are taken, the rich floral diversity of the Nokrek BR will not be able to withstand the anthropogenic pressure and in course of time, the rich forest vegetation may be converted into small fragments of degraded forest patches.

The present study uses the qualitative as well as quantitative approach to assess the plant diversity of natural, semi-natural and artificial ecosystems of the Nokrek BR. The data generated on various aspects such as comparison of structural and compositional diversity, population structure of dominant species of these undisturbed and disturbed ecosystems provide the baseline information for developing suitable conservation strategies.

List of the plant species inventoried in the undisturbed montane (M), lowland (L) and riverain (R) forests of the buffer zone of the Nokrek BR.

I. Trees

Sl. No.	Name of species	Family	M	L	R
1	*Actinodaphnae angustifolia* Nees	Lauraceae	+	+	+
2	*Acer cappadociccum* Gleditsch.	Aceraceae	+	-	-
3	*Acer oblongum* Wall.	Aceraceae	+	-	-
4	*Achronychia pedunculata* (Linn.)Miq.	Rutaceae	-	+	-
5	*Actinodaphnae obovata* (Nees) Bl.	Lauraceae	-	-	+
6	*Aesculus assamica* Griff.	Sapindaceae	+	-	+
7	*Aglaia edulis* A. Gray	Meliaceae	+	+	-
8	*Alangium chinense* (Lour.)Harms	Cornaceae	+	-	+
9	*Albizia mollis* Boiv.	Mimosaceae	-	-	+
10	*Albizia procera* (Roxb.)Benth.	Mimosaceae	-	+	-
11	*Albizia lebbeck* (Linn.) Benth.	Mimosaceae	-	+	-
12	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	-	+	-
13	*Antidesma acidum* Retz.	Euphorbiaceae	+	-	+
14	*Antidesma bunius* (Linn.) Spreng.	Euphorbiaceae	+	-	-
15	*Antidesma nigricans* Tul.	Euphorbiaceae	-	+	-
16	*Aphanamixis chittagonga* (Miq.) Haridasan et Rao	Meliaceae	+	-	-
17	*Aphanamixis wallichii* (King) Haridasan et Rao	Meliaceae	+	-	-
18	*Aporusa dioica* (Roxb.) Muell.-Arg.	Euphorbiaceae	-	+	+
19	*Aquilaria agallocha* Roxb.	Thymeleaceae	+	+	-
20	*Artocarpus gomezianus* Wall.ex Trecul.	Moraceae	-	+	+
21	*Baliospermum micranthum* Muell.-Arg.	Euphorbiaceae	+	+	-
22	*Beilschmiedia assamica* Meissn.	Lauraceae	+	-	-
23	*Beilschmiedia roxburghiana* Nees	Lauraceae	+	+	+
24	*Betula alnoides* Buch. -Ham. ex D. Don	Betulaceae	+	+	-
25	*Bridelia retusa* (L.) Spreng.	Euphorbiaceae	+	+	-
26	*Callicarpa vestita* Wall. ex Cl.	Verbenaceae	+	-	+
27	*Callicarpa arborea* Roxb.	Verbenaceae	+	-	+
28	*Callophyllum polyanthum* Choisy.	Clusiaceae	+	+	+
29	*Camellia caduca* Brandis	Theaceae	+	-	-
30	*Camellia caudata* Wall.	Theaceae	+	+	-
31	*Canthium angustifolium* Roxb.	Rubiaceae	-	+	-
32	*Canthium dicoccum* (Gaert.) T.&T.	Rubiaceae	-	+	-
33	*Carallia brachiata* (Lour.)Merr.	Rhizophoraceae	-	+	-
34	*Careya arborea* Roxb.	Baringtoniaceae	+	+	+
35	*Caryota urens* L.	Arecaceae	+	+	+
36	*Casearia kurzii* Cl.	Flacourtiaceae	+	+	+
37	*Castanopsis armata* Spach.	Fagaceae	+	-	+
38	*Castanopsis indica* A. DC.	Fagaceae	+	-	+
39	*Castanopsis kurzii* (Hance)S.N.Biswas	Fagaceae	+	-	+
40	*Castanopsis purpurella* (Miq.) Balak	Fagaceae	+	+	+
41	*Castanopsis tribuloides* (Sm.) DC.	Fagaceae	+	-	+
42	*Celastrus paniculatus* Willd.	Celastraceae	+	+	-
43	*Chaetocarpus castanocarpus* (Roxb.) Thw.	Meliaceae	-	+	-

44	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet.	Lauraceae	+	+	-
45	*Cinnamomum pauciflorum* Nees	Lauraceae	-	+	-
46	*Cinnamomum tamala* Fr.Nees	Lauraceae	+	+	+
47	*Citrus latipes* (Swingle) Tanaka	Rutaceae	+	-	-
48	*Clausena excavata* Burn.	Rutaceae	+	+	-
49	*Cleidion spiciflorum* (Burm.) Merr.	Euphorbiaceae	+	+	+
50	*Coffea* sp.	Rubiaceae	-	+	-
51	*Croton oblongus* Burm. f.	Euphorbiaceae	+	+	+
52	*Crypteronia paniculata* Bl.	Crypteroniaceae	+	+	+
53	*Cudrania fruticosa* (Roxb.) Kurz.	Moraceae	-	+	-
54	*Cynometra polyandra* Roxb.	Caesalpiniaceae	+	+	-
55	*Derris robusta* (Roxb.ex DC.) Benth.	Fabaceae	-	-	+
56	*Dillenia pentagyna* Roxb.	Dilleniaceae	-	+	-
57	*Diospyros kaki* Thunb.	Ebenaceae	+	-	-
58	*Diospyros variegata* Kurz	Ebenaceae	-	+	-
59	*Drimycarpus racemosus* (Roxb.) Hk.f.	Anacardiaceae	+	+	+
60	*Drypetes assamica* (Hk.f.)Pax et Hoffm.	Euphorbiaceae	+	+	-
61	*Duabunga grandiflora* (Roxb. ex DC.) Walp.	Soneraceaceae	+	+	-
62	*Dysoxylum gobara* (Buch.-Ham.) Merr.	Meliaceae	+	+	+
63	*Echinocarpus dasycarpus* Benth.	Elaeocarpaceae	-	-	+
64	*Elaeocarpus acuminatus* Wall.ex Mast.	Elaeocarpaceae	+	-	+
65	*Elaeocarpus aristatus* Roxb.	Elaeocarpaceae	+	-	+
66	*Elaeocarpus floribundus* Bl.	Elaeocarpaceae	+	-	+
67	*Elaeocarpus lancifolius* Roxb.	Elaeocarpaceae	+	-	+
68	*Elaeocarpus rugosus* Roxb.	Elaeocarpaceae	+	+	-
69	*Elaeocarpus tectorius* (Lour.) Poir.	Elaeocarpaceae	+	-	-
70	*Endospermum chinense* Benth.	Euphorbiaceae	-	+	+
71	*Engelhardtia spicata* Leschn.ex Bl.	Juglandaceae	+	-	-
72	*Eryobotrya bengalensis* Hk.f.	Rosaceae	+	-	+
73	*Erythroxylum kunthianum* Wall. ex Kurz	Erythroxylaceae	+	-	-
74	*Euodia* sp.	Rutaceae	+	-	-
75	*Euonymus fragidus* Wall.	Celastraceae	+	-	+
76	*Euonymus lawsonii* Clarke & Prain	Celastraceae	+	-	+
77	*Eurya acuminata* DC.	Theaceae	+	-	+
78	*Ficus altissima* Bl.	Moraceae	-	+	+
79	*Ficus consinna* Miq.	Moraceae	-	-	+
80	*Ficus elmeri* Merr.	Moraceae	+	+	-
81	*Ficus hirta* Vahl.	Moraceae	+	-	+
82	*Ficus hispida* Linn.f.	Moraceae	-	-	+
83	*Ficus nervosa* Heyne ex Roth	Moraceae	+	-	-
84	*Ficus prostrata* Wall.	Moraceae	-	-	+
85	*Ficus semicordata* J.E.Sm.	Moraceae	+	-	+
86	*Ficus subincisa* Buch.-Ham.ex J. E.Sm.	Moraceae	+	-	+
87	*Garcinia cowa* Roxb. ex DC.	Clusiaceae	+	+	-
88	*Garcinia lancifolia* (G.Don) Roxb.	Clusiaceae	+	-	-
89	*Garcinia morella* (Gaertn.) Desr.	Clusiaceae	+	-	+
90	*Garcinia pedunculata* G. Don	Clusiaceae	+	+	+
91	*Garcinia tinctoria* (DC.)W.F.Wight	Clusiaceae	+	+	+
92	*Gleditsia assamica* Bor	Mimosaceae	+	-	+
93	*Glochidion assamicum* Hk.f.	Euphorbiaceae	+	-	+
94	*Glochidion lanceolarium* (Roxb.) Voigt.	Euphorbiaceae	+	-	+
95	*Glochidion thomsonii* Hk.f.	Euphorbiaceae	+	+	+
96	*Glochidion velutinum* Wt.	Euphorbiaceae	+	-	+

97	*Goniothalamus sesquipedalis* (Wall.) Hk. f. & Th	Annonaceae	+	+	+
98	*Goniothalamus simonsii* Hk.f.&Th.	Annonaceae	+	+	+
99	*Gordonia excelsa* Bl.	Theaceae	-	-	+
100	*Grewia disperma* Roth	Tiliaceae	+	-	+
101	*Grewia microcos* L.	Tiliaceae	+	-	+
102	*Gynocardia odorata* R.Br.	Flacourtiaceae	+	-	+
103	*Harpulia cupanoides* Roxb.	Sapindaceae	-	+	-
104	*Helicia excelsa* Bl.	Proteaceae	+	-	-
105	*Helicia nilagirica* Bedd.	Proteaceae	+	-	-
106	*Heritiera macrophylla* Kurz	Sterculiaceae	-	+	-
107	*Heteropanax fragrans* (D.Don) Seem	Araliaceae	+	+	-
108	*Holarrhena antidysenterica* (Roth) A.DC.	Apocynaceae	-	+	+
109	*Hydnocarpus kurzii* Warb.	Flacourtiaceae	-	+	+
110	*Hymenodiction flaccidum* Wall.	Rubiaceae	+	+	-
111	*Hyptianthera stricta* (Willd.) W. & A.	Rubiaceae	-	+	-
112	*Ilex excelsa* (Wall.) Hk.f.	Aquifoliaceae	+	+	-
113	*Ilex odorata* Buch.-Ham. ex D. Don.	Aquifoliaceae	+	-	-
114	*Ilex umbellulata* (Wall.) Loes.	Aquifoliaceae	+	-	-
115	*Itea chinensis* Hk.f.	Iteaceae	+	-	-
116	*Ixora* sp.	Rubiaceae	+	+	-
117	*Ixora undulata* Roxb.	Rubiaceae	+	+	-
118	*Kayea floribunda* Wall.	Clusiaceae	+	-	-
119	*Knema angustifolia* (Roxb.) Warb.	Myristicaceae	-	+	-
120	*Knema linifolia* (Roxb.) Warb.	Myristicaceae	+	+	+
121	*Lagerstroemia parviflora* Roxb.	Lythraceae	-	+	+
122	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	-	+	-
123	*Lepisanthes erecta* (Thw.) Leenhouts	Sapindaceae	+	-	-
124	*Ligustrum massalongianum* Vis.	Oleaceae	-	-	+
125	*Lindera latifolia* Hk.f.	Lauraceae	+	+	+
126	*Lindera pulcherrima* (Nees)Benth.	Lauraceae	+	-	+
127	*Lindera reticulata* Benth.	Lauraceae	+	-	+
128	*Lithocarpus elegans* (Bl.) Hatus ex Soep	Fagaceae	+	-	+
129	*Litsea angustifolia* Wall.	Lauraceae	+	-	+
130	*Litsea cubeba (Laur.) Pers.*	Lauraceae	+	-	-
131	*Litsea elongata* (Nees) Hk.f.	Lauraceae	+	-	-
132	*Litsea laeta* Wall.ex Nees	Lauraceae	+	+	+
133	*Litsea lancifolia* (Roxb.ex Nees) Wall.ex Hk.f.	Lauraceae	+	-	-
134	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	+	-	+
135	*Litsea salicifolia* (Roxb.ex Nees) Hook.f.	Lauraceae	+	+	+
136	*Litsea* sp.	Lauraceae	-	+	-
137	*Macaranga denticulata* Muell.-Arg.	Euphorbiaceae	+	-	+
138	*Macaranga indica* Wt.	Euphorbiaceae	+	-	+
139	*Macropanax dispermus* (Bl.) O. Ktz.	Araliaceae	+	+	+
140	*Macropanax undulatus* (Wall.ex G. Don) Seem	Araliaceae	+	-	+
141	*Maesa indica* (Roxb.) Wall.	Myrsinaceae	+	-	+
142	*Maesa montana* DC.	Myrsinaceae	+	-	+
143	*Mallotus philippensis* (Lam.) Muell.-Arg.	Euphorbiaceae	+	+	-
144	*Mallotus roxburghianus* Muel.-Arg.	Euphorbiaceae	+	+	-
145	*Mastixia arboria* Cl.	Cornaceae	-	+	-
146	*Meliosma pinnata* (Roxb.) Walp.	Sabiaceae	-	-	+
147	*Meliosma wallichii* Planch. ex Hk.f.	Sabiaceae	+	+	-
148	*Melocanna bambusoides* Trin.	Poaceae	-	+	-
149	*Mesua ferrea* Linn.	Clusiaceae	+	+	+

150	*Meyna laxiflora* Robyns	Rubiaceae	-	+	-
151	*Michelia oblonga* Wall.ex Hk.f.	Magnoliaceae	-	+	+
152	*Micromelum integerrimum* (Roxb.) Wt. & Arn.	Rutaceae	-	+	+
153	*Microtropis discolor (Wall.) Arn.*	Celastraceae	+	+	+
154	*Miliusa roxburghiana* (Wall.) Hk.f.	Annonaceae	+	+	-
155	*Murraya paniculata* (Linn.) Jack.	Rutaceae	+	-	-
156	*Mycetia longifolia* (Wall.) O. Ktz.	Rubiaceae	-	+	+
157	*Myrioneuron nutans* Kurz.	Rubiaceae	+	-	-
158	*Neocinnamomum caudatum* (Wall.ex Nees) Merr.	Lauraceae	+	+	-
159	*Neolitsea cassia* (Linn.) Koster.	Lauraceae	+	+	-
160	*Neolitsea umbrosa* (Nees) Gamble	Lauraceae	+	+	-
161	*Olea dentata* Wt.ex Dc.	Oleaceae	+	+	-
162	*Oreocnide integrifolia* (Gaud.) Miq.	Urticaceae	+	-	+
163	*Ostodes paniculata* Bl.	Euphorbiaceae	+	-	+
164	*Pandanus odoraratissima* Linn.f.	Pandanaceae	+	-	-
165	*Paramichelia baillonii* (Pierre) Hu	Magnoliaceae	+	-	-
166	*Parapentapanax subcordatum* (G.Don) Hutch.	Araliaceae	+	-	-
167	*Persea duthiei* (Hk.f.)Koestern	Lauraceae	+	+	+
168	*Persea gamblei* (King ex Hk.f.) Koster.	Lauraceae	+	+	-
169	*Persea petiolaris* (Hk.f.) Deb	Lauraceae	-	+	-
170	*Persea villosa* (Roxb.) Koster.	Lauraceae	+	-	-
171	*Phoebe lanceolata* (Nees) Nees	Lauraceae	+	-	+
172	*Photonia notoniana Wt.& Arn.*	Rosaceae	+	-	-
173	*Picrasma javanica* Bl.	Semaraubaceae	-	+	-
174	*Pittosporum podocarpum* Gagn.	Pittosporaceae	+	-	-
175	*Podocarpus nerifilia* D.Don	Podocarpacaeae	+	-	-
176	*Polyalthia jenkinsii* Benth. & Hk.f.	Annonaceae	+	+	+
177	*Polyalthia simiarum* (Hk.f. & Th.) Hk.f. & Th.	Annonaceae	+	+	+
178	*Premna barbata* Schauer.	Verbenaceae	+	-	-
179	*Premna latifolia* Roxb.	Verbenaceae	+	-	-
180	*Premna milleflora* Cl.	Verbenaceae	-	+	-
181	*Prismatomeris tetrandra* (Roxb.) K. Schum.	Rubiaceae	+	+	-
182	*Prunus cerasoides* D.Don	Rosaceae	+	-	-
183	*Prunus jenkinsii* Hk.f.	Rosaceae	-	+	-
184	*Prunus nepaulensis*(Ser.) Steud.	Rosaceae	+	-	-
185	*Prunus undulata* Buch.-Ham. ex D. Don.	Rosaceae	+	+	+
186	*Pterospermum acerifolium* Willd.	Sterculiaceae	-	+	-
187	*Pterospermum lancifolium* DC.	Sterculiaceae	+	+	-
188	*Pygeum montanum* Hk.f.	Rosaceae	-	-	+
189	*Quercus glauca* Thunb.	Fabaceae	+	+	-
190	*Quercus semiserrata* Roxb.	Fagaceae	-	+	+
191	*Randia cochinchinensis (Lour.) Merr.*	Sapindaceae	+	+	-
192	*Randia longiflora* Lamk.	Rubiaceae	-	+	-
193	*Rhus javanica* Linn.	Anacardiaceae	-	-	+
194	*Sapindus danura* Voigt.	Sapindaceae	-	+	-
195	*Sapindus mukorossi* Gaertn.	Sapindaceae	+	+	-
196	*Sapindus rarak* DC.	Sapindaceae	+	+	+
197	*Sapium baccatum* Roxb.	Euphorbiaceae	+	+	+
198	*Saprosma ternatum* Hk.f.	Rubiaceae	+	-	+
199	*Saraca asoca* (Roxb.) D. Willd.	Caesalpiniaceae	-	+	+
200	*Sarcosperma arboreum* Cl.	Sapotaceae	+	+	+
201	*Sarcosperma griffithii* Cl.	Sapotaceae	+	+	+

202	*Saurauia macrotricha* Kurz ex Dyer.	Saurauiaceae	-	-	+
203	*Saurauia napaulensis* DC.	Saurauiaceae	+	-	-
204	*Saurauia roxburghii* Wall.	Saurauiaceae	+	+	+
205	*Schima waliichii* (DC.) Korth.	Theaceae	+	-	+
206	*Schleichera trijuga* Wall.	Sapindaceae	+	+	-
207	*Securinega virosa* (Roxb.ex Willd.) Baill.	Euphorbiaceae	+	-	+
208	*Shorea robusta* Gaertn f.	Dipterocarpaceae	-	+	-
209	*Spondias axillaris* Roxb.	Anacardiaceae	+	+	+
210	*Sterculia alata* Roxb.	Sterculiaceae	-	+	+
211	*Sterculia hamiltonii* (O.Ktz.) Adelb	Sterculiaceae	+	+	-
212	*Sterculia roxburghii* Wall.	Sterculiaceae	+	-	+
213	*Stereospermum chelonoides* (L.f.) DC.	Bignoniaceae	-	+	-
214	*Strychnos wallichiana* Benth.	Loganiaceae	-	+	+
215	*Symplocos hookeri* Clarke	Symplocaceae	+	+	-
216	*Symplocos javanica* (Bl.) Kurz	Symplocaceae	-	+	+
217	*Symplocos racemosa* Roxb.	Symplocaceae	+	+	-
218	*Syzygium balsameum* (Wt.) Wall.ex AM. & SM. Cowan	Myrtaceae	-	-	+
219	*Syzygium cumini* (Linn.) Skeels	Myrtaceae	+	+	-
220	*Syzygium diospyrifolium* (Wall. ex Duthie) S.N. Mitra	Myrtaceae	-	+	-
221	*Syzygium grandis* (Wt.) Walp.	Myrtaceae	+	+	-
222	*Syzygium kurzii* (Duthie) Balak.	Myrtaceae	-	+	-
223	*Syzygium malaccansis* Linn.	Myrtaceae	-	+	-
224	*Syzygium oblatum* (Roxb.) Wall.ex Cowan &Cowan	Myrtaceae	+	-	+
225	*Syzygium ramosissimum* (Wall.ex Duthie) Balak.	Myrtaceae	+	-	+
226	*Syzygium syzygioides* (Miq.) Merr. & Perr.	Myrtaceae	+	+	-
227	*Syzygium tetragonum* (Wt.) Kurz.	Myrtaceae	+	-	-
228	*Talauma hodgsonii* Hk.f. & Th.	Magnoliaceae	-	+	+
229	*Taxus baccata* Linn.	Taxaceae	+	-	+
230	*Terminalia chebula* Retz.	Combretaceae	-	+	+
231	*Terminallia belerica* (Gaertn.) Roxb.	Combretaceae	-	+	+
232	*Toona ciliata* Roem.	Meliaceae	+	+	-
233	*Trema orientalis* (Linn.) Bl.	Ulmaceae	-	-	+
234	*Trevesia palmata* (Roxb.) Vis.	Araliaceae	+	-	-
235	*Trewia nudiflora* Linn.	Euphorbiaceae	+	+	-
236	*Turpinia nepalensis* W.& A.	Staphylaceae	+	+	+
237	*Turpinia pomifera* (Roxb.) DC.	Staphylaceae	+	+	+
238	*Vernonia volkameriifolia* DC.	Asteraceae	+	-	-
239	*Viburnum colebrookianum* Wall. ex DC.	Caprifoliaceae	-	+	-
240	*Viburnum coriaceum* Bl.	Caprifoliaceae	+	-	-
241	*Vitex glabrata* R. Br.	Verbenaceae	-	+	-
242	*Vitex peduncularis* Wall.ex Sch.	Verbenaceae	-	+	-
243	*Vitex quinata* (Lour.) F.N.William	Verbenaceae	-	+	-
244	*Walsura robusta* Roxb.	Sapindaceae	-	+	+
245	*Xerospermum glabratum* (Kurz) Radlk.	Sapindaceae	+	+	-
246	*Xylosma longifolium* Clos.	Flacourtiaceae	+	+	+
247	*Zanthoxylum rhetsa* (Roxb.) DC.	Rutaceae	+	+	-
248	*Zizyphus oenoplia* (Linn.) Mill.	Rhamnaceae	-	-	+

II. Shrubs

1	*Achyranthus aspera* L.	Amarantaceae	+	+	+
2	*Actephila excelsa* (Dalz.) Muell.-Arg.	Euphorbiaceae	-	+	-
3	*Alchornea tiliaefolia* Muell.-Arg.	Euphorbiaceae	-	+	-
4	*Allophyllus distachys* (DC.) Radlk.	Sapindaceae	+	+	+
5	*Aphania rubra* (Roxb.) Radlk.	Sapindaceae	-	+	-
6	*Ardisia griffithii* Clarke	Myrsinaceae	+	-	-
7	*Ardisia colorata* Roxb.	Myrsinaceae	-	+	-
8	*Ardisia crispa* (Thunb.) DC.	Myrsinaceae	-	+	-
9	*Ardisia odontophylla* DC.	Myrcinaceae	+	-	-
10	*Ardisia pedunculosa* Wall.	Myrsinaceae	+	-	-
11	*Ardisia virens* Kurz	Myrsinaceae	-	+	-
12	*Artemisia nilagirica* (Cl.) Pamp.	Asteraceae	+	-	+
13	*Bischofia javanica* Bl.	Bischofiaceae	-	+	+
14	*Boehmeria glomerulifera* Miq.	Urticaceae	+	+	-
15	*Boehmeria macrophylla* D.Don	Urticaceae	+	+	+
16	*Boehmeria platyphylla* D.Don	Urticaceae	-	+	-
17	*Boehmeria sidaefolia* Wedd.	Urticaceae	+	+	+
18	*Calamus floribundus* Griff.	Arecaceae	+	+	+
19	*Calicarpa rubella* Lindl.	Verbenaceae	+	-	+
20	*Capparis acutifolia* Sw.	Capparidaceae	+	-	+
21	*Chasalia ophioxyloides* (Wall.) Craib.	Rubiaceae	+	+	+
22	*Citrus aurantium* Linn.	Rutaceae	+	-	-
23	*Citrus medica* L.	Rutaceae	+	-	+
24	*Clerodendrum hestatum* (Roxb.) Lindl.	Verbenaceae	-	+	+
25	*Clerodendrum serratum* (L.) Spreng	Verbenaceae	-	-	+
26	*Clerodendrum viscosum* Vent.	Verbenaceae	+	-	-
27	*Clerodendrum wallichii* Merr.	Verbenaceae	+	-	+
28	*Dendroicnide sinuata* (Bl.) Chew.	Urticaceae	+	-	-
29	*Desmodium multiflorum* DC.	Fabaceae	-	-	+
30	*Desmodium sequax* Wall.	Fabaceae	-	-	+
31	*Desmodium triquatrum* (L.) DC.	Fabaceae	-	-	+
32	*Difflugossa colorata* (Nees) Bremk.	Acanthaceae	-	+	-
33	*Dillenia scabrella* (D.Don) Roxb. ex Wall.	Dillenaceae	-	+	-
34	*Dracaena angustifolia* Roxb	Dracaenaceae	+	+	+
35	*Dracaena elliptica* Thunb.	Dracaenaceae	+	+	+
36	*Ficus abelii* Miq.	Moraceae	-	-	+
37	*Flemingia macrophylla* (Willd.) Prain	Fabaceae	+	-	+
38	*Glycosmis arborea* (Roxb.) DC.	Rutaceae	+	-	+
39	*Goldfussia echinata* (Nees.) Haridasan et Rao	Acanthaceae	-	+	+
40	*Gomphostemma parviflorum* Benth.	Lamiaceae	+	-	-
41	*Grewia hirsuta* Vahl.	Tiliaceae	-	+	-
42	*Gymnostachyum venustum* (Nees) T.And.	Acanthaceae	-	-	+
43	*Inula cappa* (Buch.-Ham.ex D.Don) DC.	Asteraceae	+	-	+
44	*Justicia vasculosa* (Nees) T.And.	Acanthaceae	-	-	+
45	*Lantana camara* L.	Verbenaceae	-	-	+
46	*Lasianthus hookeri* Cl.ex Hk.f.	Rubiaceae	+	-	+
47	*Lasianthus lucidus* Bl.	Rubiaceae	+	-	-
48	*Leea crispa* L.	Leeaceae	+	+	+
49	*Leea edgeworthii* Santapau	Leeaceae	+	-	+
50	*Leea indica* (Burm.f.) Merr.	Leeaceae	+	-	+

51	*Leea robusta* Roxb.	Leeaceae	+	-	+
52	*Maesa ramentacea* Wall.	Myrsinaceae	-	+	-
53	*Melastoma malabathricum* L.	Melastomaceae	+	-	+
54	*Melastoma nepalensis* Lodd.	Melastomataceae	+	-	+
55	*Morinda angustifolia* Roxb.	Rubiaceae	+	+	-
56	*Munronia pinnata* (Wall.) Harms.	Meliaceae	+	+	-
57	*Murraya koenigii* (L.) Spreng	Rutaceae	+	+	+
58	*Mussaenda glabra* Vahl.	Rubiaceae	+	+	-
59	*Mussaenda roxburghii* Hk.f.	Rubiaceae	+	-	+
60	*Ophiopogon parviflorus* (Hook.f.) Hara	Liliaceae	+	+	+
61	*Ophiorrhyza mungos* L.	Rubiaceae	+	-	+
62	*Osbekia nutans* Triana	Melastomataceae	-	+	-
63	*Pavetta subcapitata* Hook.f.	Rubiaceae	-	-	+
64	*Phlogacanthus curviflorus* Nees	Acanthaceae	-	-	+
65	*Phyllanthus roeperianus* Muell.-Arg.	Euphorbiaceae	-	-	+
66	*Pinanga gracilis* (Roxb.) Bl.	Arecaceae	+	+	-
67	*Piper mullesua* D. Don	Piperaceae	+	+	+
68	*Poikilospermum suaveolens* (Bl.) Merr.	Moraceae	-	+	+
69	*Polysolenia wallichii* Hoo.f.	Rubiaceae	+	-	-
70	*Psychotria adenophylla* Wall.	Rubiaceae	-	+	-
71	*Psychotria calocarpa* Kurz.	Rubiaceae	+	+	-
72	*Psychotria denticulata* Wall.	Rubiaceae	-	+	+
73	*Psychotria symplocifolia* Kurz	Rubiaceae	+	-	-
74	*Rauvolfia serpentina* (L.) Benth. ex Kurz.	Apocynaceae	+	-	-
75	*Rhynchotechum ellipticum* (Dietr.) A.DC.	Gesneriaceae	+	-	+
76	*Rhynchotechum vestitum* Clarke	Gesneriaceae	+	-	+
77	*Sarcandra glabra* (Thunb.) Nakai	Chloranthaceae	+	+	+
78	*Sarcochlamys pulcherrima* Gaud.	Urticaceae	-	-	+
79	*Sarcopyramis nepalensis* Wall.	Melastomataceae	-	-	+
80	*Sauropus androgynus* (L.) Merr.	Euphorbiaceae	-	+	-
81	*Sida rhombifolea* L.	Malvaceae	+	-	+
82	*Solanum kurthii* Br.	Solanaceae	+	-	+
83	*Solanum myriacanthum* Dunal.	Solanaceae	+	-	-
84	*Staurogyne argentea* Wall.	Acanthaceae	+	+	-
85	*Strobilanthus agrestis* Clarke	Acanthaceae	+	-	-
86	*Strobilanthus anisophyllus* T. Anders	Acanthaceae	+	-	+
87	*Strobilanthus decirrens* T.And.	Acanthaceae	-	+	+
88	*Strobilanthus scaber* Nees	Acanthaceae	+	-	-
89	*Tabernaemontana divaricata* (L.) R. Br.	Apocynaceae	+	+	+
90	*Tarenna odorata* (Roxb.) Robins.	Rubiaceae	-	+	+
91	*Thysanolaena maxima* (Roxb.) O. Ktze	Poaceae	-	+	+
92	*Trigonostemon semperflorens* (Roxb.) Muell.-Arg.	Euphorbiaceae	-	+	-
93	*Triumfetta rhomboidea* Jacq.	Tiliaceae	+	-	+
94	*Urena lobata* L.	Malvaceae	+	+	+
95	*Vernonia subsessilis* DC.	Asteraceae	-	-	+
96	*Wallichia densiflora* Mart.	Arecaceae	+	+	-
97	*Wendlandia tinctoria* (Roxb.) DC.	Rubiaceae	-	-	+
98	*Wendlandia wallichii* W. & A.	Rubiaceae	-	-	+
99	*Ziziphus rugosa* Lamk.	Rhamnaceae	-	+	+
100	*Zizyphus apetala* Hook.f.	Rhamnaceae	-	+	+

IV. Scandent shrubs and lianas

1	*Acacia pruinesens* Kurz.	Mimosaceae	-	+	-
2	*Acacia rugata* (Lam.) Voigt.	Mimosaceae	-	+	-
3	*Amblyanthus glandulosus* (Roxb.) DC.	Myrsinacae	+	+	-
4	*Calamus errectus* Roxb.	Arecaceae	+	+	-
5	*Calamus leptospadix* Griff.	Arecaceae	+	+	+
6	*Celtis timorensis* Spanogh.	Ulmaceae	-	+	-
7	*Connarus paniculatus* Roxb.	Connaraceae	-	+	-
8	*Dalbergia pinnata* (Lour.) Prain	Fabaceae	-	+	-
9	*Dalbergia rimosa* Roxb.	Fabaceae	-	+	-
10	*Desmos chinensis* Lour.	Anonceae	+	+	-
11	*Embelia* sp.	Myrsinaceae	-	+	-
12	*Erythropalum scandens* Bl.	Olacaceae	-	-	+
13	*Fissistigma bicolor* (Roxb.) Merr.	Annonaceae	+	-	+
14	*Fissistigma verrucosum* (Hook.f. & Th.)Merr.	Annonaceae	+	-	+
15	*Flacourtia jangomas* (Lour.) Raeusch.	Flacourtiaceae	+	+	+
16	*Friesodielsia forniculata* (Roxb.) Das	Annonaceae	+	+	-
17	*Jasminum dispermum* Wall.	Oleaceae	+	-	+
18	*Jasminum lanceolaria* Roxb.	Oleaceae	+	-	+
19	*Jasminum subtriplinerve* Bl.	Oleaceae	+	+	+
20	*Millettia caudata* (Benth.)Baker	Fabaceae	-	-	+
21	*Millettia cineria* Benth.	Fabaceae	-	+	-
22	*Mitrephora tomentosa* Hk.f.	Annonaceae	+	+	-
23	*Pyrularia edulis* A.DC.	Santalaceae	-	-	+
24	*Rourea caudata* Planch.	Connaraceae	-	+	+
25	*Rourea minor* (Gaertn.) Leenh.	Connaraceae	-	+	-
26	*Rubus ellipticus* Smith	Rosaceae	+	-	+
27	*Rubus hexagynus* Roxb.	Rosaceae	-	-	+
28	*Rubus khasianus* Cardot	Rosaceae	+	-	+
29	*Rubus lucens* Focke.	Rosaceae	-	-	+
30	*Rubus rugosus* Sm	Rosaceae	-	-	+
31	*Schefflera venulosa* (W.&A.)Harms	Araliaceae	+	+	+
32	*Smilax aspera* L.	Smilacaceae	-	+	-
33	*Smilax lanceifolia* Roxb.	Smilacaceae	+	+	+
34	*Smilax myrtillus* DC.	Smilacaceae	+	+	+
35	*Smilax quadrata* DC.	Smilacaceae	+	-	-
36	*Stixis suaveolens* (Roxb.) Baill.	Capparidaceae	-	+	+
37	*Tapiria hirsuta* Hk.f.	Anacardiaceae	-	-	+
38	*Toddalia asiatica* (L.) Lamk.	Rutaceae	+	-	+
39	*Adinandra griffithii* Dyer	Theaceae	+	-	-
40	*Aspidopterys elliptica* A.Juss.	Malpighiaceae	-	+	-
41	*Aspidopterys indica* (Willd.) Hochr.	Malpighiaceae	-	+	+
42	*Cayratia pedata* (Lour.) Gagnep.	Vitaceae	-	+	-
43	*Elaeagnus conferta* Roxb.	Elaeagnaceae	+	-	-
44	*Entada purseatha* DC.	Fabaceae	+	+	+
45	*Gnetum montanum* Mg.f.	Gnetaceae	+	+	-
46	*Hiptage benghalensis* (Linn.)Kurth	Malpighiaceae	+	-	-
47	*Melodenus monogynus* Roxb.	Apocynaceae	+	-	+
48	*Paramignya micrantha* Kurz.	Rutaceae	+	+	+
49	*Sphenodesma involucrata* (Presl.) Robin.	Verbenaceae	+	+	-
50	*Tetrastigma rumicispermum* (Laws) Planch.	Vitaceae	+	+	+

51	*Tetrastigma serrulatum* (Roxb.) Planch.	Vitaceae	+	+	-

V. Climbers

1	*Argyreia roxburghii* Choisy	Convolvulaceae	-	+	-
2	*Aristolochia cathcartii* Hk.f.	Aristolochiaceae	+	-	+
3	*Aristolochia tagala* Cham.	Aristolochiacaea	-	+	+
4	*Cayratia japonica* (Thumb.) Gagnep.	Vitaceae	+	+	+
5	*Cissampelos pareira* L.	Menispermaceae	+	+	+
6	*Cissus discolor* Bl.	Vitaceae	+	+	-
7	*Cissus repanda* Vahl.	Vitaceae	-	+	-
8	*Cyclea peltata* (Lam.) Hook.f. & Thoms.	Menispermaceae	+	-	+
9	*Dalhousiea bracteata* (Grah. Ex Roxb.) Wt.	Fabaceae	-	-	+
10	*Dioscorea bulbifera* L.	Dioscoriaceae	-	+	+
11	*Dioscorea hispida* Dennst.	Dioscoreaceae	-	+	+
12	*Gloriosa superba* Linn.	Liliaceae	+	-	-
13	*Hedyotes glabra* (Roxb.) Miq.	Rubiaceae	-	+	-
14	*Heterostemma alatum* Wt.	Asclepiadaceae	+	+	-
15	*Hodgsonia macrocarpa* HK.f.	Cucurbitaceae	+	-	+
16	*Holboellia latifolia* Wall.	Lardizabalaceae	+	+	-
17	*Indigofera atropurpurea* Hornem.	Fabaceae	-	+	-
18	*Lygodium wallichiana*	Lygodiaceae	-	+	-
19	*Naravelia zeylanica* DC.	Ranunculaceae	+	+	+
20	*Oxyspora cernua* (Roxb.) Triana	Melastomataceae	-	+	-
21	*Oxyspora vagans* (Roxb.) Wall.	Melastomaceae	+	-	+
22	*Paedaria foetida* Linn.	Rubiaceae	+	-	+
23	*Paederia scandens* (Lour.) Merr.	Rubiaceae	+	-	+
24	*Panicum humidorum* Buch.-Ham. ex Hook.	Poaceae	-	-	+
25	*Passiflora nepalensis* Wall.	Passifloraceae	-	-	+
26	*Pegia nitida*Colebr.	Anacardiaceae	+	-	+
27	*Pericampylos glaucus* (Lamk.) Merr.	Menispermaceae	-	+	-
28	*Piper griffithii* C.DC.	Piperaceae	+	-	+
29	*Piper peepuloides* Roxb.	Piperaceae	+	-	+
30	*Piper thomsonii* (C. DC.) Hook.f.	Piperaceae	+	+	-
31	*Rubia cordifolia* Linn.	Rubiaceae	+	+	-
32	*Sabia lanceolata* Colebr.	Sabiaceae	+	+	-
33	*Sabia leptandra* Hook.f.	Sabiaceae	-	+	+
34	*Stephania japonica* (Thunb.) Miers.	Menispermaceae	+	-	+
35	*Thladiantha calcarata* C.B.Clarke	Cucurbitaceae	-	-	+
36	*Vitis heyneana* Roem. & Schult.	Vitaceae	+	+	-

VI. Epiphytes

1	*Aeschynanthus parasitica* Cl.	Gesneriaceae	+	+	+
2	*Aeschynanthus sikkimensis* (Cl.) Stapf.	Gesneriaceae	+	+	-
3	*Aeschynanthus superba* Clarke	Gesneriaceae	+	+	+
4	*Agapetes veriagata* (Roxb.) D.Don	Vacciniaceae	+	+	+
5	*Asplenium* sp.	Aspleniaceae	+	+	+
6	*Bulbophyllum griffithii* (Lindl.) Reich.	Orchidaceae	+	+	+
7	*Chirita oblongifolia* (Roxb.) Sinclair	Gesneriaceae	+	-	-

8	*Cymbidium longifolium* D. Don	Orchidaceae	+	+	+
9	*Dendrobium bicameratum* Lindl.	Orchidaceae	+	-	-
10	*Dendrobium eriaeflorum* Griff.	Orchidaceae	+	-	-
11	*Dendrobium moschatum* Sw.	Orchidaceae	+	+	+
12	*Drynaria* sp.	Polypodiaceae	+	-	+
13	*Dschidia nummularia* R.Br.	Asclepiadaceae	+	+	+
14	*Eria stricta* Lindl.	Orchidaceae	+	+	+
15	*Fagraea ceilanica* Thunb.	Loganiaceae	-	-	+
16	*Ficus tinctoria* var. *parasitica*	Moraceae	-	-	+
17	*Gastrochilus acutifolius* (Lindl.)O. Ktze.	Orchidaceae	+	-	+
18	*Hoya lanceolata* Wall.ex D.Don	Asclepiadaceae	+	+	+
19	*Hoya lobbii* Hook.f.	Asclepiadaceae	+	-	-
20	*Hoya parasitica* Wall.	Asclepiadaceae	+	+	+
21	*Luisia teretifolia* Guad.	Orchidaceae	+	+	+
22	*Lycopodium cernuum* Linn.	Lycopodiaceae	+	+	+
23	*Lygodium* sp.	Lygodiaceae	+	-	+
24	*Lysionotus serratus D.Don*	Gesneriaceae	+	+	+
25	*Nervilia aragoana* Gaud.	Orchidaceae	-	-	+
26	*Pothos scandens* L.	Araceae	+	+	+
27	*Remusatia vivipara* (Lodd.) Schott.	Araceae	+	+	+
28	*Rhaphidophora calophyllum* Schott.	Araceae	+	+	+
29	*Rhaphidophora decursiva* (Roxb.) Schott.	Araceae	+	+	+
30	*Rhyncostylis retusa* (Linn.) Bl.	Orchidaceae	-	-	+
31	*Taxillus assamica* Dans.ex A.Das	Loranthaceae	+	+	-

VII. Herbs

1	*Abacopteris multilineata*	Aspidiaceae	+	+	+
2	*Acanthus leucostachys* Nees	Acanthaceae	-	+	-
3	*Achyrospermum wallichianum* (Benth.) Hook.f.	Gesneriaceae	+	+	-
4	*Adiantum phillipense* L.	Adiantaceae	+	+	+
5	*Aegynetia indica Linn.*	Orobanchaceae	+	-	-
6	*Ageratum conizoides* L.	Asteraceae	+	-	+
7	*Alocasia fornicata* (Roxb.) Schott	Araceae	-	+	+
8	*Alopecurus myosuroides* Huds.	Poaceae	-	+	-
9	*Alpinia allughas* (Retz.) Rose	Zingiberaceae	+	+	+
10	*Ammomum aromaticum* Roxb.	Zyngiberaceae	+	+	-
11	*Angiopteris evecta* (Forst.) Hoffen.	Marathiaceae	+	+	+
12	*Anoectochillus roxburghii* (Wall.) Lindl.	Orchidaceae	+	-	-
13	*Arachinoides aristata* (Frost.f.) Tindle	Aspidiaceae	+	+	-
14	*Arisaema tortuosum* (Wall.) Schott.	Araceae	+	+	+
15	*Arthromeris wallichiana*	Aspidiaceae	+	+	-
16	*Arundinaria* sp.	Poaceae	-	+	-
17	*Asplenium japonicum*	Aspleniaceae	+	+	-
18	*Athyrium* sp.	Aspidiaceae	+	-	-
19	*Balanophora dioica* L.	Balanophoraceae	+	-	-
20	*Begonia ovalifolia* DC.	Begoniaceae	+	+	-
21	*Begonia palmata* L.	Begoniaceae	-	+	+
22	*Begonia thomsonii* A. DC.	Begoniaceae	+	+	-
23	*Blumea riparia* (Bl.)DC.	Asteraceae	-	-	+
24	*Bonnaya reptans* Spreng	Scrophulariaceae	+	-	+

25	*Briza maxima* L.	Poaceae	-	+	-
26	*Calanhe masuca* (D.Don) Lindl.	Orchidaceae	+	+	-
27	*Calanthe* sp.	Orchidaceae	+	-	-
28	*Carex filicina* Nees	Cyperaceae	+	+	+
29	*Carex nubigena* D.Don	Cyperaceae	-	+	+
30	*Centella asiatica* (L.) Urban	Apiaceae	+	-	+
31	*Centrotheca lappacea* (L.) Desv.	Poaceae	-	-	+
32	*Colocasia esculenta* (L.) Schott.	Araceae	+	-	+
33	*Commelina appendiculata* Clarke	Commelianaceae	+	+	+
34	*Commelina benghalensis* L.	Commelinaceae	+	+	+
35	*Costus speciosus* L.	Liliaceae	+	-	+
36	*Curculigo orchioides* Gaertn.	Hypoxidaceae	+	-	+
37	*Curcuma montana* Rosc.	Zingiberaceae	+	+	+
38	*Cycloceros parasiticus* (L.) Farwelt	Thalypteridaceae	+	-	+
39	*Cyclosorus sagittifolius* (Bl.) Copel	Thalypteridaceae	+	-	+
40	*Cynodon dactylon* (L.) Pers.	Poaceae	+	-	+
41	*Cyperus kyllingia* Endl.	Cyperaceae	-	-	+
42	*Cyrtococcum oxyphyllum* (Steud.)Stapf.	Poaceae	-	-	+
43	*Davalia trichomanoides* Bl.	Davaliaceae	+	+	-
44	*Disporum calcarata* D.Don	Liliaceae	+	-	+
45	*Drymaria cordata* (L.) Roem. & Schult.	Caryophyllaceae	+	-	+
46	*Drynaria quercifolia* (Wall.) Copel	Polypodiaceae	+	+	+
47	*Dryopteris* sp.	Adiantaceae	+	+	+
48	*Elatostemma hookerianum* Wedd.	Urticaceae	+	-	+
49	*Elatostemma sessile* Forst.	Urticaceae	-	+	-
50	*Elatostemma sikkimense* Clarke	Urticaceae	+	+	+
51	*Elephantopus scaber* inn.	Asteraceae	+	+	-
52	*Elsholtzia blanda* (Benth.) Benth.	Lamiaceae	-	+	+
53	*Eragrostis artovirens* (Desf.) Trin ex Steud.	Poaceae	-	+	-
54	*Eragrostis unioloides* (Retz.) Steud.	Poaceae	-	+	-
55	*Eupatorium adedophorum* Spreng	Asteraceae	+	-	+
56	*Eupatorium odoratum* L.	Asteraceae	+	+	+
57	*Globa clarkei* Backer	Zingiberaceae	+	+	+
58	*Goniophlebium argutum* Wall.	Polypodiaceae	-	+	+
59	*Goniophlebium* sp.	Polypodiaceae	-	-	+
60	*Goodyera procera* (Ker.) Hook.	Orchidaceae	+	+	-
61	*Hedychium coccinium* Smith	Zyngiberaceae	+	+	+
62	*Hedychium coronarium* Koen. ex Retz	Zingiberaceae	+	+	+
63	*Hedychium gracile* Roxb.	Zingiberaceae	+	+	-
64	*Houttoynia cordata* Thunb.	Saururaceae	-	-	+
65	*Hydrocotyl japonica*Thunb.	Apiaceae	+	-	+
66	*Impatiens chinensis* L.	Balsaminaceae	+	+	+
67	*Impatiens laevigata* Hook.f.	Balsaminaceae	-	-	+
68	*Impatiens porrecta* Hook.f. & Th.	Balsaminaceae	+	-	-
69	*Impatiens tripetala* DC.	Balsaminaceae	+	-	+
70	*Ischaemum barbatum* Retz.	Poaceae	-	+	+
71	*Kylinga monocephala* Roltb.	Cyperceae	+	-	+
72	*Lasia spinosa* (L.) Thw.	Araceae	-	+	-
73	*Lindenbergia muraria* (Roxb.) Bruhl.	Scrophulariaceae	-	+	-
74	*Lindernia elata* (Benth.) Wettst.	Scrophulariaceae	-	+	-
75	*Lindernia nummularifolia* (D.Don) Wettst.	Scrophulariaceae	-	+	-
76	*Lobelia angulata* Forst.	Lobeliaceae	+	-	-
77	*Lycopodium clavatum*	Lycopodiaceae	-	+	-

78	*Molineria capitulata* (Lour.) Herb.	Liliaceae	+	+	+
79	*Murdannia nudiflora* (L.) Brenan.	Commelinaceae	-	+	-
80	*Onichium japonica*	Pteridaceae	-	+	-
81	*Ophioglossum pedunculosum* Desv.	Ophioglossaceae	+	-	-
82	*Oxalis corniculata* L.	Oxalidaceae	+	-	+
83	*Paraleptochillus decurrens* (Blum.) Copel.	Polypodiaceae	+	-	-
84	*Peliosanthes backerii* Clarke	Liliaceae	+	+	+
85	*Peperomia pellucida* (L.) HBK.	Piperaceae	-	-	+
86	*Phaius flavus* (Bl.) Lindl.	Orchidaceae	+	-	-
87	*Phaius* sp.	Orchidaceae	-	-	+
88	*Pholidota imbricata* Hook.	Orchidaceae	+	+	-
89	*Phrynium placentarium* (Lour.) Merr.	Marantaceae	+	+	+
90	*Pilea umbrosa* Wedd.	Urticaceae	+	+	+
91	*Plantago erosa* Wall.	Plantaginaceae	+	-	+
92	*Plectranthus japonicus* (Burm.f.) Koidz.	Lamiaceae	+	+	-
93	*Pogonatherum crinitum* (Thunb.) Kunth.	Poaceae	-	-	+
94	*Pogostemon auricularis* (L.) Hassk.	Lamiaceae	-	+	-
95	*Pogostemon brachystachys* Benth.	Poaceae	+	+	-
96	*Polygonum capitatum* D. Don	Polygonaceae	-	+	-
97	*Polygonum chinense* L.	Polygonaceae	+	+	+
98	*Polygonum molle* D.Don	Polygonaceae	+	-	+
99	*Polygonum plebejum* Br.	Polygonaceae	-	-	+
100	*Polygonum viscosum* D. Don	Polygonaceae	-	+	-
101	*Polystichum aculeatum* L.	Aspidiaceae	+	+	+
102	*Polyura geminata* Hook.f.	Rubiaceae	+	+	+
103	*Pouzolzia hirta* (Bl.) Hassk.	Urticaceae	+	+	+
104	*Pseudostachyum polymorphum* Munro.	Poaceae	-	+	-
105	*Pteris quadriaurita* (retz.) Copel	Pteridaceae	+	-	+
106	*Pteris* sp.	Pteridaceae	+	+	+
107	*Salomonia cantoniensis* Lour.	Polygalaceae	-	+	-
108	*Scirpus sp.*	Cyperacea	+	-	+
109	*Scoparia dulsis* L.	Scrophulariaceae	+	+	+
110	*Scutellaria discolor* Benth.	Lamiaceae	+	+	-
111	*Selaginella* sp.1	Selaginellaceae	+	+	+
112	*Selaginella* sp.2	Selaginellaceae	-	+	-
113	*Senecio wightii* DC. Clarkei	Asteraceae	-	-	+
114	*Sonerila maculata* Roxb.	Melastomataceae	+	-	-
115	*Spiradiclis bifida* Kurz.	Rubiaceae	+	-	-
116	*Stemona tuberosa* Lour.	Stemonaceae	-	+	-
117	*Tacca integrifolia* Ker-Gawl.	Taccaceae	+	+	+
118	*Tainia sp.*	Orchidaceae	-	+	+
119	*Tectaria polymorpha* (Wall.) Copel.	Aspidiaceae	+	+	+
120	*Teucrium quadrifarium* Buch.-Ham.	Lamiaceae	+	+	-
121	*Torenia diffusa* D. Don.	Scrophulariaceae	-	+	-
122	*Tupistra nutans* Wall.	Liliaceae	-	+	+
123	*Viola sikkimensis* W. Becker	Violaceae	+	-	-
124	*Zingiber chrysanthum* Rosc.	Zingiberaceae	+	-	-

A. Density (ha^{-1}), frequency (%), basal area (m^2/ ha^{-1}) and Importance Value Index of the tree species of the montane forest.

Name of the plant species	Family	Density	Frequency	Basal area	IVI
Acer oblongum Wall.	Aceraceae	10	10	0.10	1.33
Actinodaphne angustifolia Nees	Lauraceae	5	5	0.10	0.78
Adinandra griffithii Dyer	Theaceae	5	5	0.02	0.59
Aesculus assamica Griff.	Sapindaceae	35	25	0.30	3.79
Allophylus distachys (DC.) Radlk.	Sapindaceae	5	5	0.31	1.22
Antidesma bunius (Linn.) Spreng.	Euphorbiaceae	5	5	0.01	0.57
Aphanamixis chittagonga (Miq.) Haridasan et Rao	Meliaceae	50	20	0.58	4.63
Aphanamixis wallichii (King) Haridasan et Rao	Meliaceae	35	15	2.09	15.73
Beilshmiedia roxburghiana Nees	Lauraceae	10	10	0.22	1.57
Betula alnoides Buch.-Ham ex D.Don	Betulaceae	5	5	0.20	0.98
Calophyllum polyanthum Choisy	Clusiaceae	35	25	0.19	3.56
Camellia caudata Wall.	Theaceae	25	15	0.60	3.35
Casearia kurzii Cl.	Flacaurtiaceae	5	5	0.01	0.57
Castanopsis armata Spach.	Fagaceae	25	15	0.03	2.11
Castanopsis indica A.D.C.	Fagaceae	20	20	2.98	8.71
Castanopsis purpurella (Miq.) Balak	Fagaceae	15	15	0.05	1.76
Castanopsis tribuloides (Sm.) DC.	Fagaceae	30	15	2.07	6.76
Cinnamomum bejolghota (Buch.-Ham.) Sweet.	Lauraceae	15	15	0.19	2.07
Cinnamomum tamala Fr.Nees	Lauraceae	5	5	0.12	0.81
Citrus latipes (Swingle) Tanaka	Rutaceae	15	5	0.61	2.26
Croton oblongus Burm. f.	Euphorbiaceae	15	10	0.50	2.39
Diospyros kaki Thunb.	Ebenaceae	15	10	0.04	1.38
Drimycarpus racemosus (Roxb.) Hk.f.	Anacardiaceae	30	10	0.55	3.07
Drypetes assamica (Hk.f.)Pax et Hoffm.	Euphorbiaceae	5	5	0.02	1.59
Dysoxylum gobara (Buch.-Ham.) Merr.	Meliacee	100	55	2.60	13.47
Elaeocarpus floribundus Bl.	Elaeocarpaceae	20	20	0.41	3.10
Elaeocarpus rugosus Roxb.	Elaeocarpaceae	10	10	0.05	1.20
Eunonymus lawsonii Cl & Pr.	Celastraceae	5	5	0.53	1.70
Ficus elmeri Merr.	Moraceae	5	5	0.21	1.00
Ficus nervosa Heyne ex Roth	Moraceae	5	5	0.22	1.03
Garcinia cowa Roxb. ex DC.	Clusiaceae	80	30	0.79	6.97
Garcinia lancifolia (G.Don) Roxb.	Clusiaceae	10	10	0.12	1.35
Garcinia pedunculata G. Don	Clusiaceae	20	10	0.18	1.89
Garcinia tinctoria (DC.) W.F. Wt.	Cluciaceae	5	5	0.04	1.63
Glochidion assamica Hk.f.	Euphorbiaceae	15	10	0.01	1.31
Glochidion thomsonii Hk.f.	Euphorbiaceae	110	45	1.23	10.16
Glycosmis arborea (Roxb.) DC.	Rutaceae	130	60	0.75	10.95
Grewia disperma Roth	Tiliaceae	25	20	2.04	2.48
Gynocardia odorata R. Br.	Flacurtiaceae	130	60	1.41	12.39
Helicia excelsa Bl.	Proteaceae	5	5	0.05	0.67
Helicia nilagirica Bedd.	Proteaceae	345	50	2.24	19.64
Ilex excelsa (Wall.) Hk.f.	Aquifoliaceae	5	5	0.30	1.21
Ilex odorata Buch.-Ham. ex D. Don.	Aquifoliaceae	15	15	0.10	1.86
Itea chinensis Hk.f.	Iteaceae	10	10	0.02	1.14
Lasianthus hookeri Cl. ex Hk.f.	Rubiaceae	5	5	0.18	0.95
Lasianthus lucidus Bl.	Rubiaceae	10	5	0.01	0.77
Lindera latifolia Hk.f.	Lauraceae	10	10	0.44	2.06

Lindera reticulata Benth.	Lauraceae	30	20	0.10	2.81
Litsea elongata (Nees) Hk.f.	Lauraceae	55	40	1.78	13.25
Litsea laeta Wall. ex Nees	Lauraceae	70	35	0.46	6.21
Litsea lancifolia (Roxb. ex Nees) Wall. ex Hk.f.	Lauraceae	30	25	0.06	3.07
Litsea salicifolia (Roxb. ex Nees) Hk.f.	Lauraceae	30	20	0.38	3.42
Macropanax dispermum (Bl.) O. Ktz.	Araliaceae	25	25	0.02	2.79
Macropanax undulatus (Wall. ex G. Don) Seem	Araliaceae	10	10	0.02	1.14
Meliosma wallichii Planch. ex Hk.f.	Sabiaceae	5	5	0.04	0.63
Mesua ferrea Linn.	Clusiaceae	50	30	0.07	4.22
Micromelum integerrimum (Roxb.) Wt. & Arn.	Rutaceae	15	10	0.01	2.32
Microtropis discolor (Wall.) Arn.	Celastraceae	15	10	0.17	1.67
Miliusa roxburghiana (Wall.) Hk.f. & Th.	Anonaceae	35	30	0.39	4.34
Morinda angustifolia Roxb.	Rubiaceae	25	10	0.02	1.72
Neolitsea cassia (Linn.) Koster.	Lauraceae	60	25	0.40	4.98
Neolitsea umbrosa (Nees) Gamble	Lauraceae	5	5	0.02	0.60
Oriocnide integrifolia (Gaud.) Miq.	Urticaceae	5	5	0.05	0.66
Ostodes paniculata Bl.	Ephorbiaceae	45	30	2.08	8.43
Paramichelia baillonii (Pierre) Hu	Magnoliaceae	5	5	0.05	0.65
Persea duthiei (King ex Hk.f.) Koster.	Lauraceae	5	5	0.24	1.08
Phoebe lanceolata (Nees) Nees	Lauraceae	40	25	0.12	3.58
Pittosporum podocarpum Gagn.	Pittosporaceae	50	30	2.00	8.44
Premna latifolia Roxb.	Verbenaceae	15	15	0.03	1.71
Psychotria symplocifolia Kurz	Rubiaceae	20	20	0.10	2.43
Randia cochinchinensis (Lour.) Merr.	Rubiaceae	5	5	0.01	0.57
Sapium baccatum Roxb.	Euphorbiaceae	40	25	3.05	3.44
Saprosma ternatum Hk. f.	Rubiaceae	175	60	0.21	11.52
Sarcosperma arboreum Cl.	Sapotaceae	20	20	0.20	2.64
Sarcosperma griffithii Cl.	Sapotaceae	25	20	0.60	3.70
Saurauia roxburghii Wall.	Saurauiaceae	10	5	0.01	0.77
Sterculia hamiltonii (O.Ktz.) Adelb	Sterculiaceae	5	5	0.00	0.55
Syzygium cumini (Linn.) Skeels	Myrtaceae	5	5	0.01	0.57
Syzygium grandis (Wt.) Walp.	Myrtaceae	10	10	0.65	2.52
Syzygium ramosissimum (Wall.ex Duthie) Balak.	Myrtaceae	5	5	0.05	0.66
Syzygium tetragonum (Wt.) Kurz.	Myrtaceae	5	5	0.22	1.03
Toona ciliata Roem.	Meliaceae	5	5	0.00	0.55
Trevesia palmata (Roxb.) Vis.	Araliaceae	5	5	0.00	0.55
Turpinia pomifera (Roxb.) D.C.	Staphylaceae	10	10	0.02	3.15
Viburnum coriaceum Bl.	Caprifoliaceae	95	35	0.32	6.87
Liana					
Fissistigma verucosum (Hk.f. & Th.) Merr.	Annonaceae	5	5	0.18	0.95
Friesodielsia forniculata (Roxb.) Das	Annonaceae	5	5	0.26	1.11
Tetrastigma rumicispermum (Laws) Planch.	Vitaceae	10	10	0.52	8.16
Total		**2580**		**45.74**	**300.00**

B. Density (ha^{-1}), frequency (%), basal area (m^2/ ha^{-1}) and Importance Value Index of the tree species of the lowland forest.

Name of the plant species	Family	Density	Frequency	Basal area	IVI
Achronychia pedunculata (Linn.)Miq.	Rutaceae	30	15	0.10	3.51
Actephila excelsa (Dalz.) Muell.-Arg.	Euphorbiaceae	15	15	0.10	2.54
Actinodaphnae angustifolia Nees	Lauraceae	20	15	0.38	3.59
Aglaia edulis A. Gray	Meliaceae	10	10	0.56	2.99
Albizzia lebbeck (Linn.) Benth.	Mimosaceae	10	10	0.24	2.13
Antidesma nigricans Tul.	Euphorbiaceae	5	5	0.03	0.83
Aphania rubra (Roxb.) Radlk.	Meliaceae	90	30	0.18	8.87
Aporusa dioica (Roxb.) Muell.-Arg.	Euphorbiaceae	25	20	0.04	3.45
Aquilaria agallocha Roxb.	Thymeleaceae	40	25	1.42	8.47
Beilshmiedia roxburghiana Nees	Lauraceae	10	10	0.05	1.65
Bridelia retusa (Linn.) Spreng	Euphorbiaceae	10	5	0.79	3.15
Calophyllum polyanthum Choisy	Clusiaceae	20	15	3.48	11.69
Camellia caudata Wall.	Theaceae	10	5	0.21	1.63
Canthium dicoccum (Gaert.) T.&T.	Rubiaceae	5	5	0.31	1.56
Carallia brachiata (Lour.)Merr.	Rhizophoraceae	25	20	0.22	3.91
Careya arborea Roxb.	Baringtoniaceae	15	10	0.05	1.96
Casearia kurzii Cl.	Flacaurtiaceae	5	5	0.21	1.30
Celtis timorensis Spanogh.	Ulmaceae	20	10	0.38	3.14
Chaetocarpus castanocarpus (Roxb.) Thw.	Meliaceae	10	10	0.39	2.52
Cinnamomum bejolghota (Buch.-Ham.) Sweet.	Lauraceae	10	15	0.05	2.09
Cinnamomum tamala Fr.Nees	Lauraceae	10	10	0.03	1.60
Cudrania fruticosa Wt.ex Kurz	Moraceae	5	5	0.09	1.00
Cynometra polyandra Roxb.	Caesalpiniaceae	45	45	2.00	12.03
Dalbergia rimosa Roxb.	Fabaceae	5	5	0.02	0.81
Dillenia pentagyna Roxb.	Dilleniaceae	15	10	0.11	2.11
Diospyros variegata Kurz	Ebenaceae	15	15	0.07	2.46
Drypetes assamica (Hk.f.)Pax et Hoffm.	Euphorbiaceae	5	5	0.50	2.06
Duabunga grandiflora (Roxb. ex DC.) Walp.	Soneraceaceae	5	5	0.55	2.19
Elaeocarpus robustus Roxb.	Elaeocarpaceae	15	15	0.20	2.79
Elaeocarpus rugosus Roxb.	Elaeocarpaceae	10	10	0.05	1.65
Ficus elmeri Merr.	*Moraceae*	10	10	0.40	2.56
Garcinia cowa Roxb. ex DC.	Clusiaceae	80	35	0.30	8.98
Garcinia tinctoria (DC.)W.F.Wight	Clusiaceae	5	5	0.24	1.39
Harpulia cupanoides Roxb.	Sapindaceae	20	20	0.41	4.11
Heritiera macrophylla Kurz	Sterculiaceae	20	15	0.32	3.42
Heteropanax fragrans (D.Don) Seem	Araliaceae	5	5	0.04	0.85
Hymenodictyon flaccidum Wall.	Rubiaceae	10	10	0.46	2.72
Hyptianthera stricta (Willd.) W.&A.	Rubiaceae	10	10	0.10	1.77
Itea chinensis Hk.f.	Iteaceae	5	5	0.05	0.88
Kayea floribunda Wall.	Clusiaceae	10	10	0.53	2.89
Knema linifolia (Roxb.) Warb.	Myristicaceae	35	25	0.19	4.93
Lagerstroemia parviflora Roxb.	Lythraceae	25	15	0.10	3.18
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	5	5	1.10	3.64
Litsea salicifolia (Roxb. ex Nees) Hk.f.	Lauraceae	30	25	0.17	4.56
Macropanax dispermum (Bl.) O. Ktz.	Araliaceae	5	5	0.22	1.33
Maesa ramentacea Wall.	Myrsinaceae	40	35	0.04	5.72
Mallotus roxburghianus Muell.-Arg.	Euphorbiaceae	5	5	0.05	0.89
Mastixia arboria Cl.	Cornaceae	15	10	0.40	2.89
Meliosma wallichii Planch. ex Hk.f.	Sabiaceae	5	5	0.04	0.86
Mesua ferrea Linn.	Clusiaceae	25	20	0.29	4.09
Meyna laxiflora Robyns	Rubiaceae	5	5	0.18	1.24

Micromelum integerrimum (Roxb.) Wt. & Arn.	Rutaceae	15	10	0.02	1.90
Microtropis discolor (Wall.) Arn.	Celastraceae	15	10	0.02	1.89
Mitrephora tomentosa Hk.f.	Anonaceae	10	5	0.03	1.16
Neolitsea cassia (Linn.) Koster.	Lauraceae	35	25	0.06	4.59
Neolitsea umbrosa (Nees) Gamble	Lauraceae	10	10	0.02	1.56
Olea dentata Wall. ex DC.	Oleaceae	5	5	0.05	0.88
Paramichelia baillonii (Pierre) Hu	Magnoliaceae	5	5	0.22	1.33
Persea duthiei (King ex Hk.f.) Koster.	Lauraceae	5	5	0.30	1.54
Persea petiolaris (Hk.f.) Deb	Lauraceae	10	25	1.23	6.03
Polyalthia simiarum (Hk.f. & Th.) Hk.f. & Th.	Anonceae	10	5	0.02	1.14
Premna milleflora Cl.	Verbenaceae	20	10	0.06	2.30
Prunus jenkinsii Hk.f.	Rosaceae	20	15	0.07	2.77
Pterospermum lancifolium DC.	Sterculiaceae	30	20	0.32	4.52
Randia cochinchinensis (Lour.) Merr.	Sapindaceae	15	15	0.20	2.78
Sapium baccatum Roxb.	Euphorbiaceae	20	20	4.28	14.23
Schleichera trijuga Wall.	Sapindaceae	5	5	0.01	0.78
Shorea robusta Gaertn f.	Dipterocarpaceae	35	25	0.44	5.57
Spondias axillaris Roxb.	Anacardiaceae	5	5	2.07	6.17
Stereospermum chelonoides (Linn.f.) DC.	Bignoniaceae	15	15	0.50	3.59
Symplocos racemosa Roxb.	Symplocaceae	5	5	0.19	1.26
Syzygium cumini Linn.	Myrtaceae	35	25	0.26	5.10
Syzygium diospyrifolium (Wall. ex Duthie) S.N. Mitra	Myrtaceae	10	10	0.09	1.76
Syzygium grandis (Wt.) Walp.	Myrtaceae	5	5	0.58	2.27
Syzygium kurzii (Duthie) Balak.	Myrtaceae	10	10	0.10	1.77
Syzygium malaccense (L.) Merril & Perry	Myrtaceae	80	40	1.41	12.31
Syzygium syzygioides (Miq.) Merr. & Perr.	Myrtaceae	45	15	1.71	8.66
Talauma hodgsonii Hk.f. & Th.	Magnoliaceae	15	15	1.24	5.50
Trevesia palmata (Roxb.) Vis.	Araliaceae	5	5	0.03	0.83
Trewia nudiflora Linn.	Euphorbiaceae	5	5	0.18	1.24
Viburnum colebrookianum Wall. ex DC.	Caprifoliaceae	10	5	0.09	1.32
Vitex peduncularis Wall.ex Sch.	Verbenaceae	100	65	2.83	19.49
Vitex quinata (Lour.) F.N.William	Verbenaceae	10	10	0.88	3.82
Xerospermum glabratum (Kurz) Radlk.	Sapindaceae	5	5	0.02	0.81
Xylosma longifolium Clos.	Flacaurtiaceae	5	5	0.02	0.81
Zanthoxylum rhetsa (Roxb.) DC.	Rutaceae	5	5	0.10	1.03
Liana					
Gnetum scandens Roxb.	Gnetaceae	5	5	0.01	0.79
Entada purseatha DC.	Fabaceae	15	10	0.07	2.01
Friesodielsia forniculata (Roxb.) Das	Anonaceae	15	10	0.05	1.97
Total		**1555**		**38.25**	**300.00**

C. **Density (ha^{-1}), frequency (%), basal area (m^2/ ha^{-1}) and Importance Value Index of the tree species of the riverain forest.**

Name of the plant species	Family	Density	Frequency	Basal area	IVI
Actinodaphnae obovata (Nees) Bl.	Lauraceae	20	20	0.26	4.68
Aesculus assamica Griff.	Sapindaceae	5	5	0.06	1.17
Aphanamixis chittagonga (Miq.) Haridasan et Rao	Meliaceae	20	20	1.15	7.86
Artocarpus gomezianus Wall.ex Trecul.	Moraceae	5	5	0.17	1.53
Beilshmiedia assamica Meissn.	Lauraceae	10	5	0.06	1.57
Boehmeria macrophylla D.Don	Urticaceae	15	10	0.57	4.32
Bridelia retusa (Linn.) Spreng	Euphorbiaceae	10	10	0.17	2.49
Callicarpa vestita Wall. ex Cl.	Verbenaceae	25	20	0.07	4.45
Callophyllum polyanthum Choisy.	Clusiaceae	45	40	1.52	13.34
Caryota urens Linn.	Arecaceae	20	20	3.64	16.70
Casearia kurzii Cl.	Flacaurtiaceae	5	5	0.60	3.08
Castanopsis armata Spach.	Fagaceae	20	20	0.61	5.94
Castanopsis purpurella (Miq.) Balak.	Fagaceae	10	5	1.93	8.21
Castanopsis tribuloides (Sm.) DC.	Fagaceae	10	10	0.09	2.19
Cleidion spiciflorum (Burm.) Merr.	Euphorbiaceae	25	20	0.14	4.68
Crypteronia paniculata Bl.	Crypteroniaceae	20	15	0.21	3.98
Drimycarpus racemosus (Roxb.) Hk.f.	Anacardiaceae	15	15	1.31	7.48
Dysoxylum gobara (Buch.-Ham.) Merr.	Meliaceae	25	20	0.21	4.93
Echinocarpus dasycarpus Benth.	Elaeocarpaceae	5	5	0.01	0.97
Elaeocarpus aristatus Roxb.	Elaeocarpaceae	10	10	0.32	3.01
Elaeocarpus lancifolius Roxb.	Elaeocarpaceae	5	5	0.14	1.45
Elaeocarpus tectoris (Lour.) Poir.	Elaeocarpaceae	5	5	0.33	2.13
Eryobotrya bengalensis Hk.f.	Rosaceae	5	5	0.08	1.22
Euonymus lawsonii Cl. & Pr.	Celastraceae	10	5	0.06	1.57
Ficus altissima Bl.	Moraceae	10	5	0.02	1.45
Ficus elmeri Merr.	Moraceae	5	5	0.09	1.25
Ficus hispida Linn.f.	Moraceae	10	10	0.06	2.09
Ficus nervosa Heyne ex Roth.	Moraceae	40	30	0.24	7.36
Ficus prostrata Wall.	Moraceae	15	10	0.58	4.36
Ficus subincisa Buch.-Ham.ex J. E. Sm.	Moraceae	5	5	0.04	1.08
Flacourtia jangomas (Lour.) Raeusch.	Flacourtiaceae	5	5	0.32	2.07
Garcinia cowa Roxb.ex DC.	Clusiaceae	5	5	0.01	0.96
Garcinia lancifolia (G. Don) Roxb.	Clusiaceae	25	20	0.12	4.62
Glochidion lanceolarium (Roxb.) Voigt.	Euphorbiaceae	10	10	0.79	4.69
Goniothalamus simonsii Hk.f.&Th.	Anonaceae	10	10	0.05	2.07
Gordonia excelsa Bl	Theaceae	10	10	0.07	2.13
Hydnocarpus kurzii Warb.	Flacaurtiaceae	5	5	0.13	1.41
Knema linifolia (Roxb.) Warb.	Myristicaceae	20	15	0.22	4.03
Lasianthus hookeri Cl.ex Hk.f.	Rubiaceae	5	5	0.01	0.98
Leea edgeworthii Santapau	Leeaceae	15	10	0.02	2.37
Leea indica (Burm.f.) Merr.	Leeaceae	20	20	0.05	3.93
Leea robusta Roxb.	Leeaceae	5	5	0.02	1.00
Lithocarpus elegans (Bl.) Hatus ex Soep.	Fagaceae	15	15	0.19	3.50
Litsea angustifolia Wall.	Lauraceae	5	5	0.01	0.97
Litsea elongata (Nees) Hk.f.	Lauraceae	5	5	0.02	1.00
Macaranga denticulata Muell.-Arg.	Euphorbiaceae	25	20	1.14	8.23
Macaranga indica Wt.	Euphorbiaceae	20	15	0.55	5.21
Macropanax undulatus (Wall. ex G. Don) Seem	Araliaceae	60	40	0.85	12.25
Maesa indica (Roxb.) Wall.	Myrcinaceae	15	15	0.02	2.90
Meliosma pinnata (Roxb.) Walp.	Sabiaceae	10	5	0.01	1.40
Mesua ferrea Linn.	Clusiaceae	5	5	0.06	1.14

Michelia oblonga Wall.ex Hk.f.	Magnoliaceae	5	5	1.44	6.05
Micromelum integerrimum (Roxb.) Wt. & Arn.	Rutaceae	25	20	0.06	4.41
Miliusa roxburghiana (Wall.) Hk.f. & Th.	Anonaceae	5	5	0.01	0.96
Millettia caudata (Benth.)Baker	Fabaceae	10	5	0.01	1.40
Neolitsea cassia (Linn.) Koster.	Lauraceae	10	5	0.00	1.38
Oreocnide integrifolia (Gaud.) Miq.	Urticaceae	30	20	0.54	6.53
Ostodes paniculata Bl.	Euphorbiaceae	45	15	0.47	7.05
Polyalthia jenkinsii Benth. & Hk.f.	Anonaceae	5	5	0.12	1.35
Polyalthia simiarum (Hk.f. & Th.) Hk.f. & Th.	Anonaceae	15	15	0.50	4.59
Prunus undulata Buch.-Ham.ex D. Don	Rosaceae	40	30	0.87	9.58
Pygeum montanum Hk.f.	Rosaceae	20	15	0.21	4.00
Pyrularia edulis A.DC.	Santalaceae	5	5	0.09	1.25
Rhus javanica Linn.	Anacardiaceae	10	10	0.06	2.11
Sapindus rarak DC.	Sapindaceae	10	10	0.05	2.06
Sapium baccatum Roxb.	Euphorbiaceae	25	20	0.52	6.04
Saprosma ternatum Hk.f.	Rubiaceae	5	5	0.01	0.97
Sarcochlamys pulcherrima Gaud.	Urticaceae	15	15	0.05	3.02
Sarcosperma arboreum Cl.	Sapotaceae	5	5	0.01	0.98
Saurauia macrotricha Kurz ex Dyer.	Saurauiaceae	5	5	0.06	1.16
Saurauia roxburghii Wall.	Saurauiaceae	20	15	0.08	3.52
Schefflera venulosa (W.&A.)Harms	Araliaceae	10	5	0.07	1.62
Spondias axillaris Roxb.	Anacardiaceae	5	5	0.39	2.33
Symplocos javanica (Bl.) Kurz	Symplocaceae	5	5	0.08	1.22
Syzygium balsameum (Wt.) Wall. ex AM. & SM.	Myrtaceae	5	5	0.26	1.85
Syzygium oblatum (Roxb.) Wall.ex Cowan & Cowan	Myrtaceae	40	30	0.63	8.74
Syzygium ramosissimum (Wall.ex Duthie) Balak.	Myrtaceae	5	5	0.17	1.54
Talauma hodgsonii Hk.f. & Th.	Magnoliaceae	15	10	0.92	5.58
Taxus baccata Linn.	Taxaceae	5	5	0.04	1.07
Terminalia chebula Retz.	Combretaceae	5	5	0.13	1.42
Turpinia pomifera (Roxb.) DC.	Staphylaceae	15	15	0.27	3.77
Walsura robusta Roxb.	Sapindaceae	10	10	0.61	4.04
Wendlandia tinctoria (Roxb.) DC.	Rubiaceae	5	5	0.01	0.98
Wendlandia wallichii W. & A.	Rubiaceae	10	10	0.02	1.97
Ziziphus rugosa Lamk.	Rhamnaceae	5	5	0.03	1.04
Liana					
Fissistigma bicolor (Roxb.) Merr.	Anonaceae	5	5	0.01	0.98
Total		**1180**		**28.15**	**300.00**

D Density (ha^{-1}), frequency (%) and Importance Value Index of the shrub species of the montane forest.

Plant species	Family	Density	Frequency	IVI
Amblyanthus glandulosus (Roxb.) DC.	Myrsinacae	500	5	2.03
Ardisia odontophylla DC.	Myrcinaceae	1500	10	4.85
Ardisia pedunculosa Wall.	Myrsinaceae	2500	10	6.44
Boehmeria sidaefolia Wedd.	Urticaceae	2000	10	5.64
Calamus leptospadix Griff.	Arecaceae	500	5	2.03
Chasalia ophioxyloides (Wall.) Craib	Rubiaceae	4000	30	13.76
Dendroicnide sinuata (Bl.) Chew.	Urticaceae	500	5	2.03
Dracaena angustifolia Roxb.	Dracaenaceae	3500	10	8.02
Dracaena elliptica	Agavaceae	1500	15	6.08
Gomphostema parviflorum Benth.	Lamiaceae	500	5	2.03
Jasminum dispermum Wall.	Oleaceae	2000	20	8.11
Jasminum lanceolaria Roxb.	Oleaceae	1500	10	4.85
Jasminum subtriplinerve Bl.	Oleaceae	4000	30	13.76
Leea crispa Linn.	Leeaceae	3000	15	8.47
Munronia pinnata (Wall.) Harms	Meliaceae	1000	5	2.82
Mussaenda glabra Vahl.	Rubiaceae	1000	10	4.06
Mussaenda roxburghii Hook.f.	Rubiaceae	500	5	2.03
Ophiorrhiza mungos L.	Rubiaceae	500	5	2.03
Paederia scandens (Lour.) Merr.	Rubiaceae	500	5	2.03
Piper griffithii C. DC.	Piperaceae	5500	35	17.37
Piper mullesua D.Don	Piperaceae	1500	10	4.85
Piper thomsonii (C. DC.) Hook.f.	Piperaceae	1000	5	2.82
Plectranthus japonicus (Burm.f.) Koidz.	Lamiaceae	500	5	2.03
Pogostemon brachystachys Benth.	Poaceae	1500	10	4.85
Rhynchotechum elliptecum (Wall. ex DFN Dietr.) A. DC.	Gesneriaceae	8500	45	24.60
Sabia lanceolata Colebr.	Sabiaceae	1500	10	4.85
Sarcandra glabra (Thunb.) Nakai	Cloranthaceae	3500	25	11.73
Smilax lanceolaria Roxb.	Smilacaceae	2000	10	5.64
Staurogyne argentea Wall.	Acanthaceae	3500	25	11.73
Strobilanthus scaber Nees	Acanthaceae	2000	10	5.64
Teucrium quadrifarium Buch.-Ham.	Lamiaceae	1000	5	2.82
Total		**63000**		**200.00**

E. **Density (ha^{-1}), frequency (%) and Importance Value Index of the shrub species of the lowland forest.**

Plant species	Family	Density	Frequency	IVI
Acacia pruinesens Kurz.	Mimosaceae	1000	10	3.69
Amblyanthus glandulosus (Roxb.) DC.	Myrsinacae	500	5	1.85
Ardisia colorata Roxb.	Myrsinaceae	500	5	1.85
Ardisia crispa (Thunb.) DC.	Myrsinaceae	3500	25	10.72
Boehmeria sidaefolia Wedd.	Urticaceae	500	5	1.85
Calamus leptospadix Griff.	Arecaceae	500	5	1.85
Canthium angustifolium Roxb.	Rubiaceae	500	5	1.85
Chasalia ophioxyloides (Wall.) Craib	Rubiaceae	1000	10	3.69
Cissampelos pareira L.	Menispermaceae	500	5	1.85
Clerodendrum hestatum (Roxb.) Lindl.	Verbenaceae	1500	15	5.54
Coffea sp.	Rubiaceae	1000	5	2.59
Dracaena angustifolia Roxb	Dracaenaceae	10000	50	25.91
Dracaena elliptica Thunb.	Poaceae	3000	30	11.07
Grewia hirsuta Vahl.	Tiliaceae	1000	5	2.59
Leea crispa L.	Leeaceae	500	5	1.85
Melocanna bambusoides Trin.	Dracaenaceae	3500	25	10.72
Millettia cineria Benth.	Fabaceae	1500	5	3.34
Morinda angustifolia Roxb.	Rubiaceae	4000	25	11.46
Munronia pinnata (Wall.) Harms.	Meliaceae	2000	15	6.28
Murraya koenigii (L.) Spreng	Rutaceae	5000	30	14.06
Mussaenda glabra Vahl.	Rubiaceae	500	5	1.85
Myrioneuron nutans Kurz.	Rubiaceae	1000	5	2.59
Piper thomsonii (C. DC.) Hook.f.	Piperaceae	1500	5	3.34
Pogostemon brachystachys Benth.	Lamiaceae	1000	5	2.59
Pseudostachyum polymorphum Munro.	Poaceae	3000	15	7.77
Psychotria adenophyllum Wall.	Rubiaceae	1000	10	3.69
Psychotria calocarpa Kurz.	Rubiaceae	500	5	1.85
Randia longiflora Lamk.	Rubiaceae	1500	15	5.54
Sabia lanceolata Colebr.	Sabiaceae	2000	10	5.18
Sarcandra glabra (Thunb.) Nakai	Chloranthaceae	500	5	1.85
Sauropus androgynus (L.) Merr.	Euphorbiaceae	500	5	1.85
Smilax aspera L.	Smilacaceae	2500	20	8.13
Smilax lanceifolia Roxb.	Smilacaceae	500	5	1.85
Staurogyne argentea Wall.	Acanthaceae	1500	5	3.34
Tabernaemontana divaricata (L.) R. Br.	Apocynaceae	1500	15	5.54
Teucrium quadrifarium Buch.-Ham.	Lamiaceae	500	5	1.85
Thysanolaena maxima (Roxb.) O. Ktze.	Poaceae	3000	20	8.87
Trigonostemon semperflorens (Roxb.) Muell.-Arg.	Euphorbiaceae	3000	15	7.77
Total		**67000**		**200.00**

F. Density (ha^{-1}), frequency (%) and Importance Value Index of the shrub species of the riverain forest.

Plant species	Family	Density	Frequency	IVI
Aristolochia cathcartii Hk.f.	Aristolochiaceae	500	3	2.12
Boehmeria sidaefolia Wedd.	Urticaceae	1250	10	6.81
Calamus leptospadix Griff.	Arecaceae	250	3	1.56
Calicarpa rubella Lindl.	Verbenaceae	500	3	2.12
Capparis acutifolia Sw.	Capparidaceae	250	3	1.56
Chasalia ophioxyloides (Wall.) Craib.	Rubiaceae	1000	5	4.25
Clerodendrum hastatum (Roxb.)Lindle	Verbenaceae	250	3	1.56
Clerodendrum wallichii Merr.	Verbenaceae	500	3	2.12
Desmodium multiflorum DC.	Fabaceae	1500	8	6.37
Desmodium sequax Wall.	Fabaceae	750	5	3.69
Dracaena augustifolia Roxb.	Dracaenaceae	2500	13	10.62
Dracaena elliptica Thunb.	Dracaenaceae	500	3	2.12
Ficus abelii Miq.	Moraceae	1000	5	4.25
Flemingia macrophylla (Willd.) Prain.	Fabaceae	750	5	3.69
Goldfussia echinata (Nees) Haridasan et Rao	Acanthaceae	250	3	1.56
Jasminum dispermum Wall.	Oleaceae	1000	3	3.25
Jasminum lanceolarium Roxb.	Oleaceae	250	3	1.56
Jasminum subtriplinerve Bl.	Oleaceae	3250	20	15.30
Leea crispa L.	Leeaceae	500	5	3.12
Melastoma nepalensis Lodd.	Melastomataceae	250	3	1.56
Melodinus monogynus Roxb.	Apocynaceae	500	5	3.12
Mussaenda roxburghii Hk.f.	Rubiaceae	1000	5	4.25
Mycetia longifolia (Wall.) O. Ktz.	Rubiaceae	500	3	2.12
Paederia scandens L.	Rubiaceae	750	3	2.69
Pavetta subcapitata Hook.f.	Rubiaceae	750	3	2.69
Phylanthus roeperianus Muell.-Arg.	Euphorbiaceae	750	5	3.69
Piper griffithii C. DC.	Piperaceae	500	5	3.12
Piper mullesua D.Don	Piperaceae	2750	15	12.18
Psychotria denticulata Wall.	Rubiaceae	250	3	1.56
Rhaphidophora calophyllum Schott.	Araceae	250	3	1.56
Rhaphidophora decursiva (Roxb.) Schott.	Araceae	500	5	3.12
Rhynchotechum ellipticum (Wall.ex DFN Dietr.) A. DC.	Gesneriaceae	2250	8	8.06
Rhynchotechum vestitum Clarke	Gesneriaceae	3000	15	12.74
Rubus hexagynus Roxb.	Rosaceae	250	3	1.56
Rubus khasianus Cardot	Rubiaceae	750	3	2.69
Sarcandra glabra (Thunb.)Nakai	Chloranthaceae	1750	5	5.93
Smilax lanceifolia Roxb.	Smilacaceae	250	3	1.56
Smilax myrtillus DC.	Smilacaceae	750	5	3.69
Staphania japonica (thunb.) Miers.	Menispermaceae	750	5	3.69
Strobilanthus anisophyllus T. Anders	Acanthaceae	5250	10	15.80
Tabernaemontana divaricata (L.)R.Br.	Apocynaceae	2000	20	12.49
Thladiantha calcarata C.B.Clarke	Cucurbitaceae	500	5	3.12
Thysanolaena maxima (Roxb.)O.Ketz.	Poaceae	1000	10	6.25
Toddalia asiatica (L.) Lamk.	Rutaceae	250	3	1.56
Urena lobata L.	Malvaceae	250	3	1.56
Total		**44500**		**200.00**

G. **Density (ha^{-1}), frequency (%) and Importance Value Index of the herb species of the montane forest.**

Plant species	Family	Density	Frequency	IVI
Adiantum sp.	Adiantaceae	750	3	1.53
Aeginetia indica Linn.	Orobancaceae	250	3	0.96
Amomum aromatichum Roxb.	Zyngiberaceae	1250	5	2.77
Anoectochillus roxburghii (Wall.) Lindl.	Orchidaceae	250	3	0.96
Arachnioides aristata (Frost.t.) Tind.	Aspidiaceae	750	8	2.89
Arthromeris wallichiana	Aspidiaceae	1750	8	4.01
Asplenium japonicum	Aspleniaceae	1000	3	1.81
Asplenium sp.	Aspleniaceae	1000	5	2.49
Athyrium sp.	Aspidiaceae	250	3	0.96
Balanophora dioica L.	Balanophoraceae	3500	5	5.30
Begonia ovalifolia DC.	Begoniaceae	500	3	1.24
Canscora deccussata Roem.	Gentianaceae	750	5	2.21
Carex filicina Nees.	Cyperaceae	2250	8	4.58
Cayretia japonica (Thunb.) Gagneb.	Vitaceae	750	8	2.89
Cissus discolor Bl.	Vitaceae	1250	10	4.13
Colocasia esculenta Linn.	Araceae	1250	5	2.77
Commelina benghalensis L.	Comelinaceae	250	3	0.96
Costus spaciosus Linn.	Liliaceae	1500	10	4.41
Davalia trichomanoides Bl.	Davaliaceae	2750	10	5.82
Disporum calcaratum D.Don	Liliaceae	250	3	0.96
Drynaria sp.	Polypodiaceae	250	3	0.96
Elatostemma hookerianum Wedd.	Urticaceae	5500	30	14.36
Elatostemma sikkimense Clarke	Urticaceae	13000	35	24.17
Elsholtzia blanda (Benth.) Benth.	Lamiaceae	250	3	0.96
Globa clarkei Baker	Zingiberaceae	8000	28	16.50
Gloriosa superba Linn.	Liliaceae	250	3	0.96
Goodyera procera (Ker.) Hook.	Orchidaceae	750	5	2.21
Hedychium coccineum Smith	Zingiberaceae	750	5	2.21
Hedychium gracile Roxb.	Zingiberaceae	250	3	0.96
Heterostemma alatum Wt.	Apocynaceae	250	3	0.96
Hydrocotyl javanica Thunb.	Apiaceae	1750	5	3.33
Impatiens porrecta Hook.f. & Th.	Balsaminaceae	6500	18	12.09
Impatiens tripetala DC.	Balsaminaceae	2000	10	4.97
Lygodium sp.	Lycopodiaceae	500	5	1.92
Molineria capitulata (Lour.) Herb.	Hypoxidaceae	500	3	1.24
Naravelia zeylanica DC.	Ranunculaceae	250	3	0.96
Ophiopogon parviflorus (Hook.f.) Hara	Liliaceae	1000	8	3.17
Pauzolzia hirta (Bl.) Hassk.	Urticaceae	250	3	0.96
Peliosanthes bakerii Clarke	Liliaceae	2750	18	7.86
Phrynium placentarium (Lour.) Merr.	Marantaceae	1000	8	3.17
Pogostemon brachystachys Benth.	Poaceae	750	3	1.53
Polygonum chinense L.	Polygonaceae	500	3	1.24
Polystichum aculeatum	Aspidiaceae	250	3	0.96
Polyura geminata Hook.f.	Rubiaceae	1500	8	3.73
Pteris quadriaurita Retz.	Pteridaceae	13250	40	25.81
Scutellaria discolor Colebr.	Lamiaceae	1250	3	2.09
Tectaria polymorpha (Wall.) Copel.	Aspidiaceae	250	3	0.96
Viola sikkimensis W. Becker	Violaceae	2000	5	3.61
Zingiber chrysanthum Rosc.	Zingiberaceae	1000	5	2.49
Total		**88750**		**200.00**

H. Density (ha^{-1}), frequency (%) and Importance Value Index of the herb species of the lowland forest.

Plant species	Family	Density	Frequency	IVI
Acanthus leucostachys Nees	Acanthaceae	1000	3	1.90
Adiantum sp.	Adiantaceae	750	3	1.63
Alopecurus myosuroides Huds.	Poaceae	1500	8	4.08
Amomum aromatichum Roxb.	Zyngiberaceae	1000	5	2.72
Angiopteris evecta (Forst.) Hoffen.	Marathiaceae	6000	13	10.57
Arachnioides aristata (Frost.t.) Tind.	Aspidiaceae	750	8	3.27
Arisaema tortuosum (Wall.)Schott.	Araceae	750	8	3.27
Asplenium japonicum	Aspleniaceae	3500	8	6.23
Athyrium sp.	Aspidiaceae	1750	3	2.71
Begonia ovalifolia DC.	Begoniaceae	500	3	1.36
Begonia palmata L.	Begoniaceae	1750	10	5.17
Calanthe masuca (D.Don) Lindl.	Orchidaceae	250	3	1.09
Canscora deccussata Roem.	Gentianaceae	2000	8	4.62
Carex filicina Nees.	Cyperaceae	4500	8	7.31
Cayretia japonica (Thunb.) Gagneb.	Vitaceae	5250	10	8.94
Cissus discolor Bl.	Vitaceae	2250	13	6.52
Commelina benghalensis L.	Comelinaceae	2250	3	3.25
Curcuma montana Rosc.	Zingiberaceae	500	5	2.18
Davalia trichomanoides Bl.	Davaliaceae	2000	10	5.44
Dioscorea bulbifera L.	Dioscoreaceae	250	3	1.09
Dioscorea hispida Dennst.	Dioscoriaceae	500	5	2.18
Elatostema sessile Forst.	Urticaceae	2000	8	4.62
Elatostemma sikkimensis Clarke	Urticaceae	6500	18	12.75
Elephantopus scaber inn.	Asteraceae	2750	10	6.24
Elsholtzia blanda (Benth.) Benth.	Lamiaceae	250	3	1.09
Eragrostis unioloides (Retz.) Steud.	Poaceae	5000	10	8.67
Globba clarkei Backer	Zingiberaceae	1250	5	2.99
Goodyera procera (Ker.) Hook.	Orchidaceae	750	5	2.45
Hedychium coccineum Smith	Zingiberaceae	500	5	2.18
Hydrocotyl javanica Thunb.	Apiaceae	3000	8	5.69
Lindernia nummularifolia (D.Don) Wettst.	Scrophulariaceae	500	5	2.18
Lygodium sp.	Lycopodiaceae	500	5	2.18
Molineria capitulata (Lour.) Herb.	Hypoxidaceae	500	5	2.18
Naravelia zeylanica DC.	Ranunculaceae	250	3	1.09
Ophiopogon parviflorus (Hook.f.) Hara	Liliaceae	250	3	1.09
Peliosanthes backerii Clarke	Liliaceae	1000	3	1.90
Pericampylos glaucus (Lamk.) Merr.	Menispermaceae	500	5	2.18
Phrynium placentarium (Lour.) Merr.	Marantaceae	1500	5	3.26
Piper mullesua D.Don	Piperaceae	500	3	1.36
Polygonum chinense L.	Polygonaceae	750	5	2.45
Polyura geminata Hook.f.	Rubiaceae	3500	5	5.41
Pteris quadriaurita Retz.	Pteridaceae	16000	40	30.37
Scutellaria discolor Colebr.	Lamiaceae	1000	3	1.90
Tectaria polymorpha (Wall.) Copel.	Aspidiaceae	3500	10	7.05
Zingiber chrysanthum Rosc.	Zingiberaceae	1500	5	3.26
Total		**92750**		**200.00**

I. Density (ha^{-1}), frequency (%) and Importance Value Index of the herb species of the riverain forest.

Plant species	Family	Density	Frequency	IVI
Abacopteris multilineata	Aspidiaceae	2750	18	9.38
Achyranthus aspera Linn.	Amarantaceae	500	3	1.44
Adiantum sp.	Adiantaceae	750	3	1.68
Ageratum conizoides L.	Asteraceae	250	3	1.20
Alocasia fornicata (Roxb.) Schott.	Araceae	250	3	1.20
Alpinia allughas (Retz.) Rose	Zingiberaceae	1000	5	2.88
Angiopteris evecta (Frost.)Hoffen	Maratiaceae	1750	8	4.57
Arisaema tortuosum (Wall.)Schott.	Araceae	250	3	1.20
Aristolochia tagala Cham.	Aristolochiaceae	1250	5	3.13
Begonia palmata D.Don	Begoniaceae	250	3	1.20
Blumea riparia (Bl.)DC.	Asteraceae	500	3	1.44
Carex nubigena D.Don	Cyperaceae	250	3	1.20
Centrotheca lappacea (L.) Desv.	Poaceae	2250	3	3.13
Colocasia esculenta (L.) Schott.	Araceae	3750	5	5.53
Cyclosorus parasiticus (L.) Trawelt.	Aspidiaceae	250	3	1.20
Cyclosorus sagittifolius (Bl.) Copel	Aspidiaceae	500	5	2.40
Cyrtococcum oxyphyllum (Steud.)Stapf.	Poaceae	250	3	1.20
Elatostema hookerianum Wedd.	Urticaceae	2000	8	4.81
Elatostema sikkimense Clarke	Urticaceae	28750	20	35.34
Eupatorium adenophorum Spreng	Asteraceae	1500	3	2.40
Globba clarkei Baker	Zingiberaceae	4500	8	7.21
Goniophlebium argutum Wall.	Polypodiaceae	500	3	1.44
Goniophlebium sp.	Polypodiaceae	1250	3	2.16
Hedychium coccinium Sm.	Zingiberaceae	2750	10	6.49
Houttuynia cordata Thunb.	Saururaceae	500	5	2.40
Impatiens chinensis L.	Balsaminaceae	3750	5	5.53
Impatiens laevigata Hook.f.	Balsaminaceae	2250	3	3.13
Impatiens tripetala DC.	Balsaminaceae	1000	5	2.88
Ischaemum barbatum Retz.	Poaceae	250	3	1.20
Justicia vasculosa (Nees) T.And.	Acanthaceae	1000	5	2.88
Moliniera capitulata (Laur.)Herb.	Hy[poxidaceae	1250	5	3.13
Nervilia aragoana Gaud.	Orchidaceae	250	3	1.20
Paleosanthes bakeri Hook.f.	Liliaceae	1500	8	4.33
Panicum humidorum Buch.-Ham.ex Hooker	Poaceae	5250	5	6.97
Passiflora nepalensis Wall.	Passiflorceae	500	5	2.40
Pavetta subcapitata Hook.f.	Rubiaceae	750	3	1.68
Peperomia pellucida (L.)H.B.K.	Piperaceae	500	3	1.44
Phaius sp.	Orchidaceae	250	3	1.20
Phrynium placentarium (Lour.) Merr.	Amarantaceae	1250	13	6.01
Pilea umbrosa Wedd.	Urticaceae	250	3	1.20
Pogonatherum crinitum (Thunb.) Kunth.	Poaceae	250	3	1.20
Polystichum aculeatum L.	Aspidiaceae	750	3	1.68
Polyura geminata Hook.f.	Rubiaceae	4000	8	6.73
Pothos scandens L.	Araceae	500	3	1.20
Pozaulzia hirta (Bl.)Hassk.	Urticaceae	5000	3	1.44
Pteris quadriaurita Retz.	Pteridaceae	250	8	7.69
Pteris sp.	Pteridaceae	500	3	1.20
Remusatia vivipara (Lodd.) Schott.	Araceae	250	3	1.44
Selaginella sp.	Selaginellaceae	1000	3	1.20
Senecio wightii DC. Clarkei	Asteraceae	2500	3	1.92
Tacca laevis Roxb.	Taccaceae	9000	8	5.29
Tectaria polymorpha (wall.) Copel.	Aspidiaceae	250	15	14.42
Tupistra nutans Wall.	Liliaceae	1250	5	3.13
Total		**104000**		**200.00**

A. **Density (ha^{-1}), frequency (%), basal area (m^2/ ha^{-1}) and Importance Value Index of the tree species of 10-12 yr. old jhum fallow.**

Name of the plant species	Family	Density	Frequency	Basal area	IVI
Albizia procera (Roxb.)Benth.	Mimosaceae	5	5	0.01	0.63
Betula alnoides Buch.-Ham.ex D.Don	Betulaceae	5	5	0.01	0.61
Bischofia javanica Bl.	Euphorbiaceae	10	5	0.05	0.92
Callicarpa arborea Roxb.	Verbenaceae	35	20	0.09	3.03
Callicarpa vestita Wall. ex. Cl.	Verbenaceae	355	75	1.86	24.31
Castanopsis armata Spach.	Fagaceae	5	5	0.02	0.65
Castanopsis indica A. DC.	Fagaceae	20	15	0.38	4.03
Castanopsis tribuloides (Sm.) DC.	Fagaceae	10	5	0.06	1.01
Cleidion spiciflorum (Burm.) Merr.	Euphorbiaceae	5	5	0.00	0.58
Dalbergia rimosa Roxb.	Fabaceae	15	15	0.01	1.74
Diospyros variegata Kurz.	Ebenaceae	5	5	0.01	0.60
Dysoxylum gobara (Buch.-Ham.) Merr.	Meliaceae	20	15	0.03	1.93
Erythrina stricta Roxb.	Fabaceae	10	5	0.02	0.74
Eurya acuminata DC.	Theaceae	1625	80	3.24	55.30
Ficus elmeri Merr.	Moraceae	10	10	0.01	1.20
Ficus hirta Vahl.	Moraceae	10	10	0.01	1.21
Ficus hispida Linn.f.	Moraceae	5	5	0.06	0.91
Ficus nervosa Heyne ex Roth	Moraceae	5	5	0.01	0.64
Gleditsia assamica Bor	Mimosaceae	15	15	0.01	1.74
Glochidion assamicum Hk.f.	Euphorbiaceae	20	10	0.04	1.51
Glochidion sphaerogynum Kurz	Euphorbiaceae	315	50	0.63	14.03
Glochidion thomsonii Hk.f.	Euphorbiaceae	5	5	0.12	1.25
Grewia disperma Roth	Tiliaceae	15	10	0.01	1.26
Gynocardia odorata R.Br.	Flacaurtiaceae	10	5	0.01	0.72
Helicia robusta Wall.ex Benn.	Proteaceae	140	50	0.18	8.27
Heteropanax fragrans (D.Don)Seem	Araliaceae	15	10	0.18	2.27
Holarrhena antidysenterica (Roth) A.DC.	Apocynaceae	5	5	0.00	0.58
Hyptianthera stricta (Willd.) W. & A.	Rubiaceae	5	5	0.00	0.58
Lindera latifolia Hk.f.	Lauraceae	5	5	0.01	0.63
Lindera reticulata Benth.	Lauraceae	35	20	0.19	3.66
Litsea laeta Wall.ex Nees	Lauraceae	15	15	0.02	1.80
Litsea lancifolia (Roxb.ex Nees) Wall.ex Hk.f.	Lauraceae	20	20	0.03	2.41
Litsea monopetala (Roxb.) Pers.	Lauraceae	5	5	0.01	0.59
Litsea sebifera Pers.	Lauraceae	5	5	0.04	0.80
Macaranga indica Wt.	Euphorbiaceae	1475	90	4.55	61.36
Macropanax undulatus (Wall.ex G. Don) Seem	Araliaceae	5	5	0.03	0.73
Maesa indica (Roxb.) Wall.	Myrsinaceae	40	30	0.04	3.81
Millettia caudata (Benth.)Baker	Fabaceae	5	5	0.02	0.65
Oreocnide integrifolia (Gaud.) Miq.	Urticaceae	5	5	0.02	0.69
Ostodes paniculata Bl.	Euphorbiaceae	15	15	0.23	3.05
Phoebe lanceolata (Nees) Nees	Lauraceae	15	15	0.05	1.97
Pittosporum podocarpum Gagn.	Pittosporaceae	60	25	0.08	3.93
Pterospermum acerifolium Willd.	Sterculiaceae	10	5	0.01	0.71
Rhus javanica Linn.	Anacardiaceae	205	40	0.33	9.35
Saprosma ternatum Hk.f.	Rubiaceae	5	5	0.00	0.58
Saurauia macrotricha Kurz ex Dyer.	Saurauiaceae	15	10	0.19	2.30
Saurauia napaulensis DC.	Saurauiaceae	65	15	0.35	4.63

Saurauia punduana Wall.	Saurauiaceae	220	45	0.85	13.13
Saurauia roxburghii Wall.	Saurauiaceae	265	70	1.51	20.20
Schima waliichii (DC.) Korth.	Theaceae	265	55	0.70	14.01
Sterculia roxburghii Wall.	Sterculiaceae	5	5	0.02	0.66
Stereospermum chelonoides (Linn.f.) DC.	Bignoniaceae	20	5	0.02	0.93
Stixis suaveolens (Roxb.) Baill.	Capparidaceae	5	5	0.07	0.95
Symplocos hookeri Clarke	Symplocaceae	95	15	0.36	5.21
Syzygium oblatum (Roxb.) Wall.ex Cowan &Cowan	Myrtaceae	60	30	0.17	4.93
Toona ciliata Roem.	Meliaceae	5	5	0.06	0.93
Trema cannabina Lour.	Ulmaceae	15	20	0.05	2.48
Turpinia pomifera (Roxb.) DC.	Sapindaceae	5	5	0.01	0.62
Total		**5665**		**17.03**	**300.00**

B. Density (ha^{-1}), frequency (%), basal area (m^2/ha^{-1}) and Importance Value Index of the tree species of 6-8 yr. old jhum fallow.

Name of the plant species	Family	Density	Frequency	Basal area	IVI
Alangium chinense (Lour.)Harms	Cornaceae	60	10	0.11	3.21
Bauhinia variegata Linn.	Caesalpineaceae	20	5	0.02	1.20
Beilshmiedia brandisii Hk.f.	Lauraceae	60	15	0.08	3.87
Bruinsmia polysperma (Cl.) Van Steenis	Styracaceae	40	10	0.10	2.85
Callicarpa vestita Wall. ex. Cl.	Verbenaceae	780	80	2.76	42.56
*Castanopsis tribuloides (*Sm.) DC.	Fagaceae	40	5	0.26	3.11
Combretum roxburghii Spreng	Combretaceae	20	5	0.02	1.20
Engelhardtia spicata Leschn.ex Bl.	Juglandaceae	20	5	0.01	1.19
Eurya acuminata DC.	*Theaceae*	1460	90	2.31	50.13
Ficus elmeri Merr.	*Moraceae*	40	10	0.13	3.12
Ficus nervosa Heyne ex Roth	Moraceae	40	10	0.11	2.96
Gleditsia assamica Bor.	Mimosaceae	60	15	0.03	3.47
Glochidion lanceolarium (Roxb.) Voigt.	Euphorbiaceae	20	5	0.08	1.61
Glochidion velutinum Wt.	Euphorbiaceae	20	5	0.01	1.16
Lindera reticulata Benth.	Lauraceae	40	5	0.17	2.54
Litsea sebifera Pers.	Lauraceae	40	5	0.01	1.45
Macaranga denticulata Muell.-Arg.	Euphorbiaceae	20	5	0.03	1.28
Macaranga indica Wt.	Euphorbiaceae	3520	100	5.84	103.21
Macropanax dispermus (Bl.) O. Ktz.	Araliaceae	20	5	0.01	1.13
Maesa indica (Roxb.) Wall.	*Myrsinaceae*	60	10	0.04	2.73
Miliusa roxburghiana (Wall.) Hk.f.	Anonaceae	60	15	0.03	3.48
Ostodes paniculata Bl.	Euphorbiaceae	60	5	0.04	1.90
Pithecellobium heterophyllum (Roxb.) Haridasan et Rao	Mimosaceae	60	15	0.16	4.40
Pittosporum podocarpum Gagn.	Pittosporaceae	60	10	0.00	2.49
Prunus cerasoides D.Don	Rosaceae	60	15	0.07	3.77
Rhus acuminata DC.	Anacardiaceae	60	10	0.03	2.67
Rhus javanica Linn.	*Anacardiaceae*	300	50	0.40	15.05
Sarcosperma arboreum Cl.	Sapotaceae	20	5	0.01	1.19
Saurauia punduana Wall.	*Saurauiaceae*	100	15	1.32	12.83
Saurauia roxburghii Wall.	*Saurauiaceae*	200	25	0.17	8.01
Schima wallichii (DC.) Korth.	Theacae	20	5	0.03	1.33
Securinega virosa (Roxb.ex Willd.) Baill.	*Euphorbiaceae*	180	30	0.22	8.89
Total		**7560**		**14.61**	**300.00**

C. **Density (ha^{-1}), frequency (%), basal area (m^2/ ha^{-1}) and Importance Value Index of the tree species of 3-4 yr. old jhum fallow.**

Name of the plant species	Family	Density	Frequency	Basal area	IVI
Albizia chinensis (Osb.) Merr.	Mimosaceae	60	15	0.02	3.61
Bohmeria platyphylla D.Don	Urticaceae	20	5	0.01	1.30
Bruinsmia polysperma (Cl.) Van Steenis	Styracaceae	440	35	0.32	16.13
Callicarpa vestita Wall. ex. Cl.	Verbenaceae	980	95	0.99	43.78
Castanopsis tribuloides (Sm.) DC.	Fagaceae	20	5	0.01	1.27
Elaeagnus conferta Roxb.	Elaeagnaceae	20	5	0.02	1.39
Eurya acuminata DC.	Theaceae	1540	65	0.93	42.74
Ficus subincisa Buch.-Ham.ex J. E.Sm.	Moraceae	20	5	0.00	1.16
Glochidion assamicum Hk.f.	Euphorbiaceae	60	15	0.01	3.47
Glochidion lanceolarium (Roxb.)Voigt.	Euphorbiaceae	40	10	0.38	8.79
Glochidion thomsonii Hk.f.	Euphorbiaceae	20	5	0.01	1.17
Lindera reticulata Benth.	Lauraceae	20	5	0.00	1.15
Lithocarpus elegans (Bl.) Hatus ex Soep	Fagaceae	20	5	0.01	1.23
Litsea monopetala (Roxb.) Pers.	Lauraceae	40	5	0.02	1.69
Macaranga indica Wt.	Verbenaceae	4640	95	1.86	94.63
Maesa indica (Roxb.) Wall.	Myrsinaceae	880	55	0.30	23.47
Ostodes paniculata Bl.	Euphorbiaceae	20	5	0.02	1.39
Pittosporum podocarpum Gagn.	Pittosporaceae	20	5	0.02	1.37
Rhus javanica Linn.	Anacardiaceae	240	35	0.12	10.72
Saurauia punduana Wall.	Saurauiaceae	800	45	0.46	23.79
Saurauia roxburghii Wall.	Saurauiaceae	140	10	0.05	3.94
Schima wallichii (DC) Korth.	Theaceae	20	5	0.04	1.72
Securinega virosa (Roxb.ex Willd.) Baill.	Euphorbiaceae	40	10	0.02	2.52
Skimmia laureola (DC.) Sieb & Zucc ex Walp.	Rutaceae	160	20	0.06	6.22
Trema cannabina Lour.	Ulmaceae	20	5	0.02	1.35
Total		**10280**		**5.71**	**300.00**

D. Density (ha^{-1}), frequency (%) and Importance Value Index of the shrub species of 10-12 yr. old jhum fallow.

Plant species	Family	Density	Frequency	IVI
Acacia rugata (Lamk.) Voigt.	Mimosaceae	301	5	1.76
Callicarpa rubella Lindl.	Verbenaceae	603	10	3.52
Cayratia pedata (Lour.) Gagnep.	Vitaceae	301	5	1.76
Chasalia ophioxyloides (Wall.) Craib.	Rubiaceae	603	5	2.34
Cissampelos pareira Linn.	Vitaceae	301	5	1.76
Citrus medica L.	Rutaceae	1808	10	5.84
Clerodendrum serratum (L.) Spreng.	Verbenaceae	2712	10	7.59
Clerodendrum viscosum Vent.	Verbenaceae	2411	35	12.89
Dalburgia pinnata (Lour.) Prain.	Solanaceae	3315	10	8.75
Desmodium sequax Wall.	Fabaceae	301	5	1.76
Desmodium triquetrum (L.) DC.	Fabaceae	1808	15	7.02
Flemingia macrophylla (Willd.) Prain.	Fabaceae	301	10	2.93
Goldfussia echinata (Nees.) Haridasan et Rao	Acanthaceae	301	5	1.76
Inula cappa (D. Don) DC.	Asteraceae	301	5	1.76
Jasminum dispermum Wall.	Oleaceae	3315	10	8.75
Leea crispa L.	Leeaceae	603	5	2.34
Leea indica (Burm.f.) Merr.	Leeaceae	2712	25	11.11
Melodenus monogynus Roxb.	Apocynaceae	904	10	4.10
Munronia pinnata (Wall.) Harms.	Meliaceae	301	5	1.76
Mussaenda roxburghii Hook.f.	Rubiaceae	1808	15	7.02
Orthosiphon incurvus Benth.	Lamiaceae	603	10	3.52
Osbekia nutans Triana	Melastomataceae	301	5	1.76
Oxyspora cernua (Roxb.) Triana	Melastomataceae	301	5	1.76
Piper griffithii C.DC.	Piperaceae	603	10	3.52
Rhynchotechum ellipticum (Wall. ex DFN Dietr.) A. DC.	Fabaceae	4219	25	14.02
Rubus ellipticus Smith	Rosaceae	904	10	4.10
Rubus hexagynus Roxb.	Rosaceae	301	5	1.76
Rubus khasianus Cardot.	Rosaceae	2712	35	13.47
Rubus rugosus Smith	Rosaceae	2109	25	9.95
Smilax aspera L.	Smilacaceae	301	5	1.76
Smilax lanceifolia Roxb.	Smilacaceaea	1808	15	7.02
Smilax quadrata DC.	Smilacaceae	1205	5	3.50
Solanum myriacanthum Dunal.	Gesneriaceae	6630	20	17.50
Tabernaemontana divaricata (L.) R. Br.	Apocynaceae	3616	35	15.21
Thysanolaena maxima (Roxb.) O.Ktze.	Poaceae	1205	10	4.68
Total		**51833**		**200.00**

E. Density (ha^{-1}), frequency (%) and Importance Value Index of the shrub species of 6-8 yr. old jhum fallow.

Plant species	Family	Density	Frequency	IVI
Acacia rugata (Lam.) Voigt.	Mimosaceae	250	5	1.73
Callicarpa rubella Lindl.	Verbenaceae	1750	15	7.32
Cayratia pedata (Lour.) Gagnep.	Vitaceae	250	5	1.73
Clerodendrum serratum (L.) Spreng	Verbenaceae	1250	25	8.67
Clerodendrum viscosum Vent.	Verbenaceae	10000	45	32.01
Cudrania fruticosa (Roxb.) Kurz.	Moraceae	250	5	1.73
Desmodium sequax Wall.	Fabaceae	750	10	4.00
Desmodium triquetrum (L.) DC.	Fabaceae	3000	15	9.96
Flemingia macrophylla (Willd.) Prain	Fabaceae	500	5	2.26
Jasminum dispermum Wall.	Oleaceae	250	5	1.73
Leea crispa L.	Leeaceae	1750	20	8.52
Leea edgeworthii Santapau	Leeaceae	2000	30	11.46
Melastoma nepalensis Lodd.	Melastomataceae	1250	25	8.67
Mussaenda roxburghii Hook.f.	Rubiaceae	1500	25	9.20
Rhynchotechum ellipticum (Dietr.) A.DC.	Gesneriaceae	1000	10	4.53
Rhynchothechum vestitum Clarke	Gesneriaceae	1000	10	4.53
Rubus ellipticus Smith	Rosaceae	1250	10	5.06
Rubus khasianus Cardot	Rosaceae	4250	50	21.04
Smilax aspera L.	Smilacaceae	1250	15	6.26
Smilax quadrata DC.	Smilacaceae	500	5	2.26
Solanum myriacanthum Dunal	Solanaceae	1000	15	5.73
Tabernaemontana divaricata (L.) R. Br.	Apocynaceae	2000	20	9.05
Thysanolaena maxima (Roxb.) O. Ktze.	Poaceae	10250	45	32.54
Total		**47250**		**200.00**

F. **Density (ha^{-1}), frequency (%) and Importance Value Index of the shrub species of 3-4 yr. old jhum fallow.**

Plant species	Family	Density	Frequency	IVI
Citrus medica L.	Rutaceae	750	10	4.42
Clerodendrum serratum (L.) Spreng	Verbenaceae	250	5	1.96
Clerodendrum viscosum Vent.	Verbenaceae	750	10	4.42
Inula cappa (Buch.-Ham.ex D.Don) DC.	Asteraceae	2500	10	7.87
Lantana camara L.	Verbenaceae	8250	20	22.14
Leea crispa L.	Leeaceae	500	10	3.93
Melastoma nepalensis Lodd.	Melastomaceae	9000	30	26.56
Mussaenda roxburghii Hk.f.	Rubiaceae	750	15	5.89
Orthosiphon incurvus Benth.	Lamiaceae	750	15	5.89
Plectranthus ternifolius D. Don.	Lamiaceae	3000	15	10.32
Rhynchotechum ellipticum (Dietr.) A.DC.	Gesneriaceae	3000	15	10.32
Rubus ellipticus Smith	Rosaceae	1000	20	7.85
Rubus khasianus Cardot	Rosaceae	8000	65	34.88
Rubus rugosus Sm	Rosaceae	250	5	1.96
Smilax quadrata DC.	Smilacaceae	1250	10	5.40
Smithia ciliata Royle	Fabaceae	250	5	1.96
Solanum myriacanthum Dunal.	Solanaceae	3250	25	13.76
Strobilanthus lanceolata Bl.	Acanthaceae	1250	5	3.93
Tabernaemontana divaricata (L.) R. Br.	Apocynaceae	5250	40	22.11
Thysanolaena maxima (Roxb.) O. Ktze	Poaceae	750	10	4.42
Total		**50750**		**200.00**

G. Density (ha^{-1}), frequency (%) and Importance Value Index of the shrub species of limestone mine spoil.

Plant species	Family	Density	Frequency	IVI
Acasia pennata (L.) Willd.	Mimosaceae	1000	8	12.83
Argyreia roxburghii Choisy	Convolvulaceae	750	5	9.09
Cissampelos pareira L.	Menispermaceae	1500	13	20.32
Desmodium sequax Wall.	Fabaceae	1000	5	10.71
Desmodium triquetrum (L.)DC.	Fabaceae	2500	18	31.02
*Dracaena elliptica*Thunb.	Dracaenaceae	1250	5	12.32
Indigofera atropurpurea Hornem.	Fabaceae	1250	13	18.70
Polygonum chinense Linn.	Polygonaceae	750	8	11.22
Rauvolfia serpentina (L.) Benth. ex Kurz.	Apocynaceae	1250	8	14.45
*Rubus ellipticus*Sm.	Rosaceae	750	8	11.22
*Rubus rugosus*Sm.	Rosaceae	750	8	11.22
Smilax aspera L.	Smilacaceae	750	5	9.09
*Vernonia scandens*DC.	Asteraceae	750	5	9.09
Ziziphus oenoplia (Linn.) Mill.	Rhamnaceae	1250	13	18.70
Total		**15500**		**200.00**

H. Density (ha^{-1}), frequency (%) and Importance Value Index of the shrub species of coalmine spoil.

Plant species	Family	Density	Frequency	IVI
Clerodendrum hestatum (Roxb.) Lindl.	Verbenaceae	20	15	20.84
Dracaena angustifolia Roxb.	Dracaenaceae	30	20	29.34
Morinda angustifolia Roxb.	Rubiaceae	30	25	33.18
Sauropus androgynus (L.) Merr.	Euphorbiaceae	20	15	20.84
Smilax aspera L.	Smilacaceae	70	30	55.64
Trigonostemon semperflorens (Roxb.) Muell.-Arg.	Euphorbiaceae	45	25	40.16
Total		**215**		**200.00**

I. Density (ha^{-1}), frequency (%) and Importance Value Index of the herb species of 10-12 yr. old jhum fallow.

Name of the plant species	Family	Density	Frequency	IVI
Abacopteris multilineata	Aspidiaceae	24500	18	14.59
Ageratum conyzoides L.	Asteraceae	250	3	0.53
Anotis calycina Hook.f.	Rubiaceae	2000	13	3.02
Argyreia capitata (Vahl) Arn.ex Choisy	Convolvulaceae	2500	13	3.26
Axonopus compressus (Sw.) P.Beauv.	Poaceae	1500	8	1.96
Bidens pilosa L.	Asteraceae	3750	25	5.92
Blumea balsamifera (L.) DC.	Asteraceae	2250	5	1.90
Boehmeria sidaefolia Wedd.	Urticaceae	1500	8	1.96
Borreria articularis (L.f.) F.N.Williams	Rubiaceae	9250	28	8.96
Carex filicina Nees	Cyperaceae	6250	23	6.70
Cayratia japonica (Thunb.) Gagnep.	Vitaceae	2250	18	3.97
Centella asiatica (L.) Urban	Apiaceae	500	5	1.07
Cissus discolor Bl.	Vitaceae	750	8	1.60
Commelina appendiculata Clarke.	Commelinaceae	1250	5	1.42
Costus speciosus L.	Liliaceae	500	3	0.65
Cyclosorus sagittifolius (Bl.) Copel	Thalypteridaceae	250	3	0.53
Digitaria setigera Roth.	Poaceae	8750	23	7.90
Dioscorea bulbifera L.	Dioscoriaceae	1500	15	3.20
Dioscorea hispida Dennst.	Dioscoreaceae	750	8	1.60
Disporum calcaratum D. Don.	Liliaceae	250	3	0.53
Elatostemma sikkimense Clarke.	Urticaceae	6750	8	4.46
Eragrostis japonica (Thunb.) Trin.	Poaceae	250	3	0.53
Eragrostis unioloides (Retz.) Steud.	Poaceae	22750	35	16.64
Eupatorium adedophorum Spreng	Asteraceae	35500	40	23.56
Eupatorium odoratum L.	Asteraceae	1750	13	2.90
Exacum tetragonum Roxb.	Gentianaceae	250	3	0.53
Globa clarkei Backer	Zingiberaceae	1000	5	1.30
Glychenium sp.	Glycheniaceae	250	3	0.53
Gomphostemma parviflorum Benth.	Lamiaceae	1500	5	1.54
Hedyotes scandens D.Don	Rubiaceae	500	5	1.07
Heterostemma alatum Wt.	Asclepiadaceae	500	3	0.65
Hydrocotyle javanica Thunb.	Apiaceae	750	5	1.18
Lobelia angulata Frost.	Lobeliaceae	250	3	0.53
Mikania micrantha HBK.	Asteraceae	4500	33	7.52
Molineria capitulata (Lour.) Herb.	Liliaceae	1000	5	1.30
Murdannia nudiflora (L.) Brenan.	Commelinaceae	500	3	0.65
Ophiopogon parviflorus (Hook.f.) Hara	Liliaceae	500	3	0.65
Paederia scandens (Lour.) Merr.	Rubiaceae	500	5	1.07

Panicum humidorum Buch.-Ham. ex Hook.f.	Poaceae	13000	33	11.58
Paspalum conjugatum Berg.	Poaceae	16750	23	11.71
Phragmites karka (Retz.) Steud.	Poaceae	4250	3	2.44
Phylanthus urinaria L.	Euphorbiaceae	5250	30	7.46
Pilea umbrosa Wedd.	Urticaceae	1500	8	1.96
Piper mullesua D. Don	Piperaceae	2750	8	2.55
Plectranthus japonicus (Burm.f.) Koidz.	Lamiaceae	500	3	0.65
Poa annua L.	Poaceae	500	3	0.65
Pogostemon auricularis (L.) Hassk.	Lamiaceae	250	3	0.53
Polygonum capitatum L.	Polygonaceae	500	3	0.65
Polygonum chinense L.	Polygonaceae	250	3	0.53
Polygonum viscosum D. Don	Polygonaceae	250	3	0.53
Polystichum aculeatum L.	Aspidiaceae	250	3	0.53
Polyura geminata Hook.f.	Rubiaceae	750	5	1.18
Pouzolzia hirta (Bl.) Hassk.	Urticaceae	250	3	0.53
Pteris quadriaurita Retz.	Pteridaceae	2000	8	2.19
Scutellaria discolor Colebr.	Lamiaceae	250	3	0.53
Setaria palmifolia (Koen.) Stapf.	Poaceae	1500	13	2.78
Shuteria vestita W.& A.	Fabaceae	250	3	0.53
Sida rhombifolia L.	Malvaceae	750	5	1.18
Smithia Ciliata Royle	Fabaceae	250	3	0.53
Sonerila maculata Roxb.	Melastomataceae	250	3	0.53
Stephania japonica (Thunb.) Miers.	Menispermaceae	500	5	1.07
Tectaria polymorpha (Wall.) Copel.	Aspidiaceae	3250	10	3.20
Tetrastigma serrulatum (Roxb.) Planch.	Vitaceae	250	3	0.53
Urena lobata L.	Malvaceae	3750	23	5.51
Total		**209500**		**200.00**

J. **Density (ha^{-1}), frequenPcy (%) and Importance Value Index of the herb species of 6-8 yr. old jhum fallow.**

Name of the plant species	Family	Density	Frequency	IVI
Abacopteris multilineata	Aspidiaceae	6000	18	4.70
Adiantum sp.	Adiantaceae	2000	3	1.08
Ageratum conizoides L.	Asteraceae	26500	28	13.50
Anotis calicina Hook.f.	Rubiaceae	2750	13	2.81
Argyreia capitata (Vahl.) Choisy	Convolvulaceae	500	5	0.91
Artemisia nilagirica (Clarke) Pamp.	Asteraceae	500	3	0.54
Bidens pilosa L.	Asteraceae	7500	15	4.87
Blumea alata (D. Don.) DC.	Asteraceae	500	5	0.91
Blumea balsamifera (L.) DC.	Asteraceae	250	3	0.45
Borreria articularis (L.f.) F.N.Williams	Rubiaceae	11750	23	7.49
Carex filicina Nees	Cyperaceae	11000	25	7.59
Cayratia japonica (Thumb.) Gagnep.	Vitaceae	4500	23	4.89
Commelina appendiculata Clarke	Commelianaceae	500	5	0.91
Costus speciosus L.	Liliaceae	750	3	0.63
Curculigo orchioides Gaertn.	Hypoxidaceae	1250	10	1.91
Cyclosorus sagittifolius (Bl.) Copel	Thalypteridaceae	750	3	0.63
Digitaria setigera Roth.	Poaceae	750	8	1.36
Dioscorea bulbifera L.	Dioscoriaceae	1250	13	2.27
Dioscorea hispida Dennst.	Dioscoriaceae	1000	8	1.45
Elsholtzia blanda (Benth.) Benth.	Lamiaceae	500	5	0.91
Eragrostis unioloides (Retz.) Steud.	Poaceae	1500	5	1.27
Eupatorium adenophorum Spreng	Asteraceae	62250	60	31.03
Eupatorium odoratum L.	Asteraceae	3000	18	3.63
Globba clarhei Backer	Zingiberaceae	750	3	0.63
Glychenia wallichii	Glycheniaceae	750	5	1.00
Hedyotes scandens D. Don	Rubiaceae	500	5	0.91
Houttoynia cordata Thunb.	Piperaceae	2000	5	1.45
Hydrocotyl javanica Thunb.	Apiaceae	3000	8	2.17
Inula cappa (D. Don.) DC.	Asteraceae	3500	13	3.08
Justicia procumbens L.	Acanthaceae	250	3	0.45
Lindenbergia muraria (Roxb.) Bruhl.	Scrophulariaceae	1750	13	2.45
Lindernia nummularifolia (D.Don) Wettst.	Scrophulariaceae	1000	8	1.45
Lobelia angulata Forst.	Lobeliaceae	500	5	0.91
Lygodium sp.	Lygodiaceae	250	3	0.45
Mikania micrantha HBK.	Asteraceae	8750	40	8.97
Munronia pinnata (Wall.) Harms	Meliaceae	250	3	0.45
Murdannia nudiflora (L.) Brenan.	Commelinaceae	3000	13	2.90
Ophioglossum sp.	Ophioglossaceae	500	5	0.91

Oxalis corniculata L.	Oxalidaceae	750	5	1.00
Paederia scandens (Lour.) Merr.	Rubiaceae	1000	5	1.09
Panicum auritum Presl ex Nees	Poaceae	750	5	1.00
Panicum humidorum Buch.-Ham. ex Hook.	Poaceae	14750	30	9.66
Paspalum conjugatum Berg.	Poaceae	17000	30	10.46
Peliosanthes bakerii Hook.f.	Liliaceae	1500	3	0.90
Phylanthus urinaria L.	Euphorbiaceae	4250	25	5.17
Pilea umbrosa Wedd.	Urticaceae	3750	13	3.17
Piper mullesua D. Don.	Piperaceae	2250	20	3.72
Plectranthus japonicus (Burm.f.) Koidz.	Lamiaceae	250	3	0.45
Poa annua L.	Poaceae	1500	5	1.27
Pogonatherus critinum (Thunb.) Kunth.	Poaceae	1500	8	1.63
Pogostemon auricularis (L.) Hassk.	Lamiaceae	23000	28	12.24
Polygonum capitatum D. Don.	Polygonaceae	2000	5	1.45
Polygonum chinense L.	Polygonaceae	250	3	0.45
Polyura geminata Hook.f.	Rubiaceae	750	3	0.63
Pteris quadriaurita Retz.	Pteridaceae	1500	13	2.36
Scoparia dulsis L.	Scrophulariaceae	2000	3	1.08
Selaginella sp.	Sellaginellaceae	4250	5	2.25
Setaria palmifolia (Koen.) Stapf	Poaceae	5750	13	3.88
Smithia ciliata Royle	Fabaceae	250	3	0.45
Staphania japonica (Thunb.) Miers.	Menispermaceae	250	3	0.45
Tectaria polymorpha (Wall.) Copel	Aspidiaceae	3750	8	2.44
Torenia diffusa D.Don	Scrophulariaceae	2000	10	2.18
Triumpfetta rhomboidea Jacq.	Tiliaceae	1000	3	0.72
Urena lobata L.	Malvaceae	7000	13	4.33
Vernonia scandens L.	Asteraceae	2500	5	1.62
Total		**279500**		**200.00**

K. Density (ha^{-1}), frequency (%) and Importance Value Index of the herb species of 3-4 yr. old jhum fallow.

Name of the plant species	Family	Density	Frequency	IVI
Abacopteris multilineata	Aspidiaceae	500	5	0.58
Ageratum conyzoides L.	Asteraceae	25000	40	9.32
Anotis calycina Hook.f.	Rubiaceae	3750	20	2.71
Artemisia nilagirica (Clarke) Pamp.	Asteraceae	1000	3	0.46
Arundina graminifolia (D.Don) Hochr.	Orchidaceae	750	8	0.87
Asplenium japonicum	Aspleniaceae	3750	10	1.77
Axonopus compressus (Sw.) P.Beauv.	Poaceae	16000	33	6.62
Bidens pilosa L.	Asteraceae	39250	83	16.49
Blumea balsamifera (L.) DC.	Asteraceae	2000	13	1.62
Boehmeria sidaefolia Wedd.	Urticaceae	4750	20	2.94
Borreria articularis (L.f.) F.N. Williams	Rubiaceae	37500	53	13.28
Briza maxima L.	Poaceae	2250	5	0.97
Carex filicina Nees	Cyperaceae	25250	43	9.61
Cayratia pedata (Lour.) Gagnep.	Vitaceae	1000	10	1.16
Centella asiatica L.	Apiaceae	500	3	0.35
Commelina appendiculata Clarke	Commelinaceae	3250	15	2.13
Costus speciosus L.	Liliaceae	500	3	0.35
Cyperus cyperoides (L.) O. Ktze	Cyperaceae	2750	10	1.55
Davalia trichomanoides Bl.	Davaliaceae	1500	5	0.80
Desmodium sequax Wall.	Fabaceae	8250	25	4.18
Desmodium triquatrum (L.) DC.	Fabaceae	750	8	0.87
Digitaria setigera Roth.	Poaceae	2500	5	1.03
Dioscorea bulbifera L.	Dioscoreaceae	2000	5	0.91
Dioscorea hispida Dennst.	Dioscoreaceae	3000	25	3.02
Drymaria cordata (L.) Roem. & Schult.	Caryophyllaceae	750	3	0.40
Elatostemma sikkimense Clarke	Urticaceae	2500	5	1.03
Eragrostis artovirens (Desf.) Trin.ex Steud.	Poaceae	7500	10	2.61
Eupatorium adenophorum Spreng	Asteraceae	72250	73	22.90
Eupatorium odoratum L.	Asteraceae	5250	20	3.05
Exacum tetragonum Roxb.	Gentianaceae	1000	5	0.69
Globba clarkei Backer	Zingiberaceae	500	5	0.58
Glychenium sp.	Glycheniaceae	500	5	0.58
Hedyotes scandens D.Don	Rubiaceae	1000	10	1.16
Houttuynia cordata Thunb.	Saururaceae	5000	10	2.05
Hydrocotyle javanica Thunb.	Umbelliferae	3750	20	2.71
Lindernia murraria (Roxb.) Brahl.	Scrophulariaceae	2000	10	1.38
Lobelia angulata Forst.	Lobeliaceae	2250	10	1.44
Mikania micrantha HBK.	Asteraceae	15250	58	8.80

Ophiopogon parviflorus (Hook.f.) Hara	Liliaceae	250	3	0.29
Oxalis corniculata L.	Oxalidaceae	5750	35	4.57
Paederia Scandens L.	Rubiaceae	500	5	0.58
Panicum auritum Presl ex Nees	Poaceae	17000	20	5.66
Panicum humidorum Buch.-Ham. ex Hooker	Poaceae	5250	20	3.05
Paspalum conjugatum Berg.	Poaceae	19250	20	6.17
Phyllanthus urinaria L.	Euphorbiaceae	7000	23	3.67
Plantago erosa Wall.	Plantaginaceae	1250	10	1.22
Plectranthus japonicus (Burm.f.) Koidz.	Lamiaceae	2250	10	1.44
Poa annua L.	Poaceae	16000	25	5.91
Pogonatherum crinitum (Thunb.) Kunth.	Poaceae	1750	5	0.86
Pogostemon auricularis (L.) Hassk.	Lamiaceae	1000	3	0.46
Polygonum capitatum D. Don.	Polygonaceae	3250	13	1.90
Pouzolzia hirta (Bl.) Hassk.	Urticaceae	250	3	0.29
Pteris quadriaurita (Ritz.) Copel	Pteridaceae	2000	10	1.38
Rungia parviflora Nees	Asteraceae	250	3	0.29
Selaginella sp.	Selaginellaceae	20750	23	6.73
Setaria palmifolia (Koen.) Stapf.	Poaceae	2500	15	1.97
Sida rhombifolia L.	Malvaceae	1500	5	0.80
Spiradiclis bifida Kurz.	Rubiaceae	1000	10	1.16
Tectaria polymorpha (Wall.) Copel	Aspidiaceae	11750	33	5.67
Torenia diffusa D. Don.	Scrophulariaceae	500	5	0.58
Triumfetta pilosa Roth	Sterculiaceae	250	3	0.29
Triumfetta rhomboidea Jacq.	Tiliaceae	2500	15	1.97
Triumfetta tomentosa Bojer.	Tiliaceae	1250	3	0.51
Urena lobata L.	Malvaceae	14000	50	7.81
Vernonia scandens DC.	Asteraceae	1000	10	1.16
Vetiveria zizanioides (L.) Nash	Poaceae	1750	3	0.62
Total		**449000**		**200.00**

L. Density (ha^{-1}), frequency (%) and Importance Value Index of the herb species of 1- yr. old jhum fallow.

Name of the plant species	Family	Density	Frequency	IVI
Ageratum conyzoides L.	Asteraceae	90000	75	16.41
Angiopteris evecta (Frost.) Hoffm.	Marathiaceae	3000	10	1.12
Anoectochillus roxburghii (Wall.) Lindl.	Orchidaceae	500	5	0.44
Axonopus compressus (SW) P.Beauv.	Poaceae	1000	10	0.88
Bidens pilosa L.	Asteraceae	86750	60	14.88
Blumea balsamifera (L.) DC.	Asteraceae	2000	5	0.62
Blumea densiflora DC.	Asteraceae	1500	5	0.56
Borreria articularis (L.f.) F.N. Williams	Rubiaceae	104250	53	16.40
Briza maxima L.	Poaceae	7000	13	1.78
Carex filicina Nees	Cyperaceae	15750	28	3.97
Centella asiatica (L.) Urban.	Umbelliferae	11000	35	3.97
Commelina appendiculata Clarke.	Commelinaceae	4000	15	1.62
Cynodon dactylon (L.) Pers.	Poaceae	12500	18	2.82
Davalia trichomanoides Bl..	Davaliaceae	3500	13	1.37
Desmodium gyrans DC.	Fabaceae	9500	25	3.03
Dioscorea hispida Dennst.	Dioscoreaceae	500	5	0.44
Eragrostis coarctata Stapf.ex Hook.f.	Poaceae	5000	15	1.74
Eragrostis japonica (Thunb.) Trin.	Poaceae	1000	5	0.50
Eragrostis unioloides (Retz.) Steud.	Poaceae	3000	5	0.74
Eupatorium adenophorum Spreng	Asteraceae	147000	80	23.57
Eupatorium odoratum L.	Asteraceae	2000	10	1.00
Euphorbia hirta L.	Euphorbiaceae	500	5	0.44
Exacum tetragonum Roxb.	Gentianaceae	2500	10	1.06
Glychenia sp.	Glycheniaceae	2500	15	1.44
Gnaphalium affine D. Don.	Asteraceae	500	5	0.44
Hedyotes scandens D.Don	Rubiaceae	1500	15	1.32
Hibiscus sabdariffa L.	Malvaceae	1000	10	0.88
Hydrocotyle javanica Thunb.	Umbeliferae	8750	20	2.56
Ipomoea batatas (Linn.) Lamk.	Solanaceae	4500	15	1.68
Justicia procumbens L.	Acanthaceae	5500	15	1.80
Lindenbergia muraria (Roxb.) Bruhl.	Scrophulariaceae	2000	13	1.19
Lindernia elata (Benth.) Wettst.	Scrophulariaceae	500	10	0.82
Lindernia nummularifolia (D.Don)Wettst.	Scrophulariaceae	11500	10	2.13
Lobelia angulata Forst.	Lobeliaceae	19750	33	4.82
Lygodium wallichii	Lycopodiaceae	500	5	0.44
Mikania micrantha HBK.	Asteraceae	7500	43	4.12
Murdannia nudiflora (L.) Brenan.	Commelinaceae	4500	10	1.30
Onichium japonica	Pteridaceae	3500	5	0.80

Ophioglossum sp.	Ophioglossaceae	5500	10	1.41
Ophiopogon parviflorus (Hook.f.) Hara	Liliaceae	1500	5	0.56
Oxalis corniculata L.	Oxalidaceae	30250	55	7.78
Oxystelma esculentum Br.	Asclepiadaceae	500	5	0.44
Paederia scandens (Lour.) Merr.	Rubiaceae	1000	10	0.88
Panicum auritum Presl.ex Nees	Poaceae	500	5	0.44
Panicum humidorum Buch.-Ham.ex Hook.f.	Poaceae	48500	50	9.57
Paspalum conjugatum Berg.	Poaceae	16750	30	4.27
Paspalum orbiculare Forst.	Poaceae	500	5	0.44
Peliosanthes bakerii Hook.f.	Liliaceae	9500	10	1.89
Phyllanthus urinaria L.	Euphorbiaceae	10500	40	4.29
Piper mullesua D.Don	Piperaceae	500	5	0.44
Plantago erosa Wall.	Plantaginaceae	12000	40	4.47
Plectranthus ternifolius D. Don.	Lamiaceae	4000	13	1.43
Poa annua L.	Poaceae	16000	20	3.42
Pogonatherum crinitum (Thunb.) Kunth.	Poaceae	7000	20	2.35
Pogostemon auricularis (L.) Hassk.	Lamiaceae	3500	10	1.18
Polygonum capitatum D. Don.	Polygonaceae	2500	13	1.25
Pouzolzia hirta (Bl.) Hassk.	Urticaceae	7000	28	2.92
Pteris quadriaurita (retz.) Copel	Pteridaceae	5000	25	2.50
Scoparia dulsis L.	Scrophulariaceae	10250	25	3.12
Scutellaria discolor Colebr.	Lamiaceae	500	5	0.44
Selaginella sp.1	Selaginellaceae	9000	20	2.59
Setaria palmifolia (Koen.) Stapf.	Poaceae	4000	15	1.62
Sida rhombifolea L.	Malvaceae	500	5	0.44
Smithia ciliata Royle	Asteraceae	4500	18	1.87
Torenia diffusa D. Don.	Scrophulariaceae	5500	15	1.80
Triumfetta rhomboidea Jacq.	Tiliaceae	7750	20	2.44
Urena lobata L.	Malvaceae	5500	20	2.18
Vernonia scandens DC.	Asteraceae	22250	48	6.26
Vigna vexillata (L.) A.Rich	Fabaceae	500	3	0.25
Total		**804500**		**200.00**

M. Density (ha^{-1}), frequency (%) and Importance Value Index of the herb species of bamboo grove.

Name of the plant species	Family	Density	Frequency	IVI
Adiantum sp.	Adiantaceae	1500	5	2.12
Aeginetia indica L.	Orobanchaceae	1250	5	1.95
Ageratum conyzoides L.	Asteraceae	4000	5	3.83
Ammomum aromaticum Roxb.	Zingiberaceae	1000	10	2.87
Arisaema tortuosum (Wall.) Schott.	Araceae	1000	5	1.78
Asplenium sp.	Aspleniaceae	1500	8	2.67
Atylosia scarabaeoides (L.) Benth.	Fabaceae	1000	10	2.87
Axonpus compressus (Sw.) P. Beauv.	Poaceae	5500	10	5.95
Bidens pilosa L.	Asteraceae	500	5	1.44
Boehmeria sidaefolia Wedd.	Urticaceae	500	5	1.44
Cayratia japonica (Thunb.) Gagnep.	Vitaceae	6000	30	10.67
Commelina appendiculata Clarke.	Commelinaceae	1000	5	1.78
Costus speciosus L.	Liliaceae	4000	20	7.11
Dichanthium parviflorum (R.Br.) de Wet & Harlan	Poaceae	2000	10	3.56
Dioscorea bulbifera L.	Dioscoreaceae	250	5	1.26
Dioscorea hispida Dennst.	Dioscoreaceae	250	3	0.72
Disporum calcarata D.Don	Liliaceae	1500	15	4.31
Globba clarkei Backer	Zingiberaceae	5000	15	6.70
Glychenia sp.	Glycheniaceae	3500	15	5.68
Gomphostemma parviflorum Benth.	Lamiaceae	1750	10	3.38
Hackelochloa porifera (Hack.) Rhind	Poaceae	10250	23	11.94
Houttuynia cordata Thunb.	Saururaceae	5250	13	6.33
Lygodium sp.	Lycopodiaceae	500	5	1.44
Panicum humidorum Hook.f.	Poaceae	24750	30	23.51
Panisetum sp.	Poaceae	12250	8	10.03
Paspalum conjugatum Berg.	Poaceae	1750	5	2.29
Paspalum polystachyon (L.) Schult.	Poaceae	6250	18	8.11
Pericampylos glaucus (Lamk.) Merr.	Menispermaceae	2750	8	3.52
Phyllanthus urinaria L.	Euphorbiaceae	1000	5	1.78
Pilea umbrosa Wedd.	Urticaceae	500	5	1.44
Piper mullesua D. Don	Piperaceae	7500	40	13.88
Polypodium sp.	Polypodiaceae	1250	5	1.95
Pteris quadriaurita Retz.	Pteridaceae	5500	25	9.23
Scutellaria discolor Benth.	Lamiaceae	1000	3	1.23
Sida rhombifolia L.	Malvaceae	2000	10	3.56
Spiranthes sinensis (Pers.) Ames	Orchidaceae	750	5	1.61
Tectaria polymorpha (Wall.) Copel.	Aspidiaceae	13000	20	13.28
Trichosanthes sp.	Cucurbitaceae	2500	10	3.90
Triumfetta tomentosa Bojer.	Tiliaceae	500	5	1.44
Urena lobata L.	Malvaceae	3750	23	7.49
Total		**146000**		**200.00**

N. Density (ha^{-1}), frequency (%) and Importance Value Index of the herb species of orchard.

Name of the plant species	Family	Density	Frequency	IVI
Abacopteris multiliniata	Aspidiaceae	10750	23	2.70
Achyranthus aspera L.	Amarantaceae	20750	23	3.66
Ageratum conyzoides L.	Asteraceae	153750	90	21.44
Anotis calycina Hook.f.	Rubiaceae	4250	23	2.08
Axonopus compressus (Sw.) P. Beauv.	Poaceae	21750	25	3.94
Bidens pilosa L.	Asteraceae	98500	83	15.58
Blumea balsamifera (L.) DC.	Asteraceae	17000	43	4.79
Borreria articularis (L.f.) F.N. Williams	Rubiaceae	51500	55	9.02
Centella asiatica (L.) Urban.	Umbelliferae	8000	28	2.81
Clerodendrum viscosum Vent.	Verbenaceae	3500	15	1.45
Colocasia esculenta (L.) Schott.	Araceae	2000	10	0.93
Commelina appendiculata Clarke	Commelinaceae	15750	33	3.92
Cyperus kyllingia Endl.	Cyperaceae	10750	15	2.15
Dactyloctenium aegyptium (L.) Willd.	Poaceae	24750	30	4.60
Desmodium gyrans DC.	Lamiaceae	8250	23	2.46
Digitaria setigera Roth.	Poaceae	13500	33	3.71
Drymaria cordata (L.) Roem. & Schult.	Caryophyllaceae	17250	43	4.81
Drynaria sp.	Polypodiaceae	6250	18	1.90
Eclipta alba L.	Asteraceae	3000	5	0.66
Eupatorium adenophorum Spreng	Asteraceae	91500	75	14.35
Eupatorium odoratum L.	Asteraceae	4000	10	1.13
Euphorbia hirta L.	Euphorbiaceae	12750	28	3.26
Fimbristylis sp.	Cyperaceae	11500	23	2.77
Gnaphalium affine D. Don.	Asteraceae	7000	20	2.16
Houttoynia cordata Thunb.	Saururaceae	28000	30	4.91
Hydrocotyle japonica Thunb.	Apiaceae	5250	13	1.43
Justicia procumbens L.	Acanthaceae	35000	10	4.10
Lantana canmara L.	Lamiaceae	3500	23	2.01
Lobelia angulata Forst.	Lobeliaceae	11000	18	2.35
Mikania micrantha HBK.	Asteraceae	28750	55	6.84
Molineria capitulata (Lour.) Herb.	Hypoxidaceae	2000	10	0.93
Oxalis corniculata L.	Oxalidaceae	17500	48	5.20
Panicum humidorum Buch.-Ham.ex Hooker	Poaceae	38500	43	6.85
Paspalum conjugatum Berg.	Poaceae	44500	50	7.98
Peliosanthes bakerii Hook.f.	Liliaceae	3750	20	1.84
Peperomia pellucida (L.) HBK.	Piperaceae	95750	65	14.01
Phyllanthus urinaria L.	Euphorbiaceae	3750	28	2.40
Plantago erosa Wall.	Plantaginaceae	10250	35	3.58
Polygonum capitatum D. Don	Polygonaceae	7750	20	2.23
Pteris sp.	Pteridaceae	6000	13	1.50
Rangia parviflora Nees	Acanthaceae	5000	20	1.96
Selaginella sp.	Selaginellaceae	75750	70	12.47
Sida rhombifolia L.	Malvaceae	1750	13	1.10
Total		**1041750**		**200.00**

O. Density (ha^{-1}), frequency (%) and Importance Value Index of the herb species of limestone mine spoil.

Name of the plant species	Family	Density	Frequency	IVI
Abutilon indicum (L.) Sweet	Malvaceae	2250	18	6.81
Ageratum conyzoides L.	Asteraceae	9000	48	21.82
Argyreia capitata (Vahl.) Choisy	Companulaceae	2000	20	7.12
Bidens pilosa L.	Asteraceae	6500	38	16.53
Biophytum petersianum Klotz.	Oxalidaceae	3750	18	8.54
Boerhaavia diffusa L.	Nyctaginaceae	750	8	2.67
Cassia tora L.	Caesalpiniaceae	1750	15	5.63
Cisus discolor Bl.	Vitaceae	1500	13	4.74
Commelina benghalensis L.	Commelinaceae	5000	18	9.98
Costus speciosus L.	Liliaceae	500	5	1.78
Cyclea peltata Hk.f. & Th.	Menispermaceae	1500	15	5.34
Dioscorea bulbifera L.	Dioscoreaceae	1250	8	3.25
Erigeron pusillus Nutt.	Asteraceae	5250	28	12.68
Eupatorium odoratum Spreng.	Asteraceae	3750	25	10.35
Euphorbia hirta L.	Euphorbiaceae	5000	28	12.39
Mimosa pudica L.	Mimosaceae	2750	15	6.78
Paspalum sp.	Poaceae	26000	48	41.42
Peperomia pellucida (L.) HBK.	Piperaceae	2500	8	4.69
Phyllanthus urinaria L.	Euphorbiaceae	2000	15	5.92
Shuteria vestita W.& A.	Fabaceae	1000	8	2.96
Triumfetta rhoboidifolia	Tiliaceae	500	3	1.18
Vitis heyneana Roem. & Schult.	Vitaceae	2250	20	7.41
Total		**86750**		**200.00**

P. Density (ha^{-1}), frequency (%) and Importance Value Index of the herb species of coalmine spoil.

Name of the plant species	Family	Density	Frequency	IVI
Axonopus compressus (S.W.) Beauw.	Poaceae	5750	28	39.190
Borreria articularis (L.f.) F.N. Williams	Rubiaceae	1500	10	11.911
Dioscorea hispida Dennst.	Dioscoriaceae	2000	20	19.861
Eragrostis artovirens Link.	Poaceae	4500	23	31.255
Eragrostis unioloides (Retz.) Steud.	Poaceae	1000	5	6.945
Eupatorium odoratum L.	Asteraceae	2000	13	15.383
Globa clarkei Backer	Zingiberaceae	2000	20	19.861
Lindernia nummularifolia (D.Don) Wettst.	Scrophulariaceae	1750	13	14.393
Pteris sp.	Ptridaceae	4750	38	41.200
Total		**25250**		**200.00**

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