

The present book deals work completed over more than a decade on characterizing conditions of tropical forests in the Garo Hills of western Meghalaya State of North East India. This is essentially a compilation and compendium of findings presented in an Ph.D. work of Ashish Kumar and in related studies including analyses of forest fragmentation, Land use pattern, Forest classification, community analysis. and botanical diversity of the region. The work has led to innovations in use of remote sensing information and tools and to suggestions for designing a protected area network for conservation planning in the region A companion volume will present findings on, and implications for, wildlife conservation of the region.

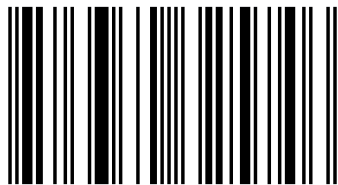


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Tropical Forests and Fragmentation

A case of South Garo Hills, Meghalaya, North East India



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TROPICAL FORESTS AND FRAGMENTATION
A case of South Garo Hills, Meghalaya, North East India¹

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¹ This book is based on the work done for a long term (1996-2012) research and application project entitled, 'Management of Forests in India for Biological Diversity and Forest Productivity - A New Perspective' by the Wildlife Institute of India, an autonomous institute of the Ministry of Environment, Forest and Climate Change, Government of India, in collaboration with the USDA Forest Service and the State Forest Department, Meghalaya.

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PREFACE AND ACKNOWLEDGMENTS

This volume summarizes work completed over more than a decade on characterizing conditions of tropical forests in the Garo Hills of western Meghalaya State of North East India. This is essentially a compilation and compendium of findings presented in an Ph.D. Thesis of Ashish Kumar and in related studies including analyses of forest fragmentation (Kumar et al. 2000, 2008), forest management (Kumar et al. 2002), impacts of *Jhum* (shifting cultivation) (Kumar et al. 2006), and botanical diversity (Kumar et al. 2006) of the region. The work has led to innovations in use of remote sensing information and tools (Kumar et al. 2012) and to suggestions for designing a protected area network for conservation planning in the region (Kumar et al. 2010). A companion volume will present findings on, and implications for, wildlife conservation of the region.

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1. INTRODUCTION

1.1 Background

The tropical forests are the most ancient, diverse and ecologically complex land communities (Lewin 1986), which covers only 7% of the earth surface, but sustain more than half of the planet's life forms (Myers 1984) and support the considerable portion of overall biodiversity. Laurance & Bierregaard (1997) broadly designated tropical forest nations into three categories: (1) nations that already have experienced a drastic loss of forest cover, (2) nations that have moderate amounts of tropical forest cover remaining, but are experiencing rapid forest conversion, and (3) nations in which tropical forests are being rapidly modified but which still retain large tracts of intact forest. In general, India belongs to the first category, but at least some states of the north-eastern Indian region belong to the second and third categories, however, the most of the forests in northeast India are under the tremendous pressure of exploitation due to unplanned traditional forestry practices especially the widespread use of slash and burn shifting cultivation (locally known as *jhumming*), wherein native people clear and burn the old forest growth over a piece of land to get fertile land for raising agricultural crops for one or two years and then move on to clear fresh forest land. The state of Meghalaya is not an exception and experiencing the heavy loss of old forest growth annually due to the practice of *jhumming*. As per the reports of North Eastern Council during 1979, a total of 4116 km² was placed under *jhumming*, of which 760 km² of land was used at one point of time every year by 68 000 *jhummia* families (DSWC 1995) within the state.

The *Garo Hills*, situated in Western Meghalaya, represent a remnant of the ancient plateau of the pre-Cambrian peninsular shield (Momin, 1984). This plateau separates watersheds of the Surma valley of Bangladesh to the south and Bramhaputra valley to the north. The most salient topographic features of the *Garo Hills* include the Tura range and the Simsang valley. The Tura range runs west to east, extending from Tura town to Siju, a distance of about 50 km. Nokrek peak (1500 m), on Tura range, is the highest peak of the *Garo Hills*. The *Kailash Hills*, locally known as *Chutmang* (1023 m) is the highest peak of Balpakram National Park, the largest and most important protected area of the Meghalaya.

This park includes Balpakaram plateau, which is regarded as the ‘home of the spirits of the dead’ and considered as the most sacred place by the *Garos*. The South *Garo Hills* district including the Balpakaram and the adjoining Nokrek Biosphere Reserve and National Park in the south of *Garo hills* represent the specific study area, which is prominently inhabited by the native *Garo* tribes.

The *Garo* tribes constitute the major ethnic community in the *Garo Hills*. The ancestors of the present *Garo* tribes reached the northeast India during Neolithic period (5000 B.C.) from their original homeland in China (Sharma, 1984). After the initial settlements in the region, the *Garos* spread over the whole *Garo Hills* range, which subsequently developed as settlements or villages, locally known as ‘*Akings*’. The Neolithic people, living in semi-permanent settlements, were food producers and gatherers, and practised slash and burn shifting cultivation, locally known as ‘*Jhum*’ (Sharma, 1984 and Jha 1997).

1.2 Key conservation issues and concerns

In *Garo Hills*, the state government manages only 7% of land as protected areas and reserved forests, while rest of the 93% land is under non-government ownership and largely inhabited by native tribes. Much of their community forests is heavily used for *Jhumming*, in which forest vegetation is slashed and burned on site for cultivating agricultural crops (Momin, 1984). Following are a few major challenges identified during the present study, which inhibit the successful conservation of native biodiversity and sustainable resource use by human society over the long term in *Garo Hills*.

- The majority of the land base in the *Garo Hills* is non-government and subjected to unsustainable resource use patterns.
- Use of village and clan land for *Jhum* is determined by village headmen, locally known as *Nokmas*, and by traditional family use, usually without broader planning for conservation of forest and wildlife resources.
- Widespread use of *Jhum* on an increasingly shorter cycle by which the *Garo* people are consuming more old forest land annually.

- Inadequate basic infrastructure including road network needing development for transportation of goods outside the region.
- Isolation of the native *Garo* people from major benefits of economy and trade.
- Long and porous international border with Bangladesh with a gaping problem of illegal export of forest resources across the border.
- Ongoing insurgency and presence of military and police forces.
- A potential decline in interest in traditional agricultural practices.
- Increase in social unrest, especially among the young men.

Collectively, these challenges pose significant hurdles to biodiversity conservation, which may otherwise entail successfully redirecting land allocations, guiding agricultural practices (especially regarding reducing impacts of *jhum*, and potentially increasing use of permanent agricultural plots to complement and offset the shifting cultivation), diversifying the economic base for the villages, protecting culturally and ecologically important sites, reducing social unrest, and providing a promising future of long-term economic and cultural development and sustainable use of forests and their resources for people of the region. We do not intend to solve all these problems, but aimed at studying and understanding the problems rationally to provide a sound scientific basis for building a comprehensive solution. The present study, therefore, succeeded in providing major advances in information and use of technology as a basis for such solutions by providing specific information based on the extent of land uses and its impact on the old forest growth at landscape level using remote sensing and Geographical Information System and then describing the characteristics features of various forest communities for the status of dominant tree species.

1.3 Stressors to native biodiversity

The major stressor to native forest biodiversity in *Garo* Hills is the increasing anthropogenic conversion of mature and primary forests to *jhum* land. Probably no one stressor than *jhum* has had a more extensive influence on the loss of old

forest habitat and associated wildlife, both plants and animals, and on the loss of soil fertility and an increase in soil erosion. Awasthi (1999) noted that several issues impede conservation of plant diversity there, including extraction of plants for local use, commercial exploitation of medicinal and ornamental plants, the effect of eroding traditions on the lack of protection of sacred groves, development activities, shifting agriculture (*jhum*), problems of forest management, and mining. Awasthi (1999) also identified the need for additional floristic studies and inter-institutional linkages to aid successful conservation.

Other direct stressors affecting the wildlife and their habitats in *Garo Hills* include, the hunting and poaching of animals for consumption as food and trade; excessive and illegal extraction of some forest products of importance to native wildlife; mining for coal and limestone around protected areas, road construction; excessive fishing; excessive collection of non-timber forest products; and lack of infrastructure developments. These stressors are acting in concert with the *jhum* cultivation to cause even greater local threats to some wildlife. Stressors to wildlife habitat also affect plant species, plant diversity, and diversity of vegetation communities. These too are part of the concern for overall biodiversity conservation (Rao & Haridasan 1981, Murti 1986, Khan *et al.* 1997).

1.4 Present study: gaps and rationale

Little work has been done to evaluate the plant communities of the *Garo Hills*, except a few floristic assessments and surveys (Kumar & Rao 1985; Haridasan & Rao 1988; and Khan *et al.* 1997). Specifically, we examined the species diversity and phytosociological indicators of tree species in primary and secondary forests of the *Garo Hills*. Trees are the principal plants of terrestrial ecosystem and dominate over all other life forms. They are the robust indicators of disturbances at the landscape level and thus, are most suitable for long-term studies and monitoring landscape changes. Trees represent all forest strata from ground vegetation to top canopy and perform important functions in the ecosystem by controlling light penetration and rainwater trapping. Also, they are important renewable resources and used by wildlife and human beings in several ways.

Tree species were examined in various growth stages representing distinct successional stages of native forests to evaluate their status and colonisation pattern during different seral stages. Understanding such patterns would help in identifying adequate silvicultural treatments for managing specific tree populations in these forests with a consideration to native wildlife and human society inhabiting such *Jhum* influenced tropical forest conditions in the Garo Hills. Modern wildlife conservation requires the understanding of the patterns and processes of vegetation changes (Morrison *et al.*, 2006). We used secondary information from existing literature and the indigenous knowledge of native tribes to better understand and describe the wildlife and cultural uses of selected tree species which could be further referred as Key Ecological Functions (KEFs) and Key Cultural Functions (KCFs), respectively. KEFs refer to the principal roles performed by a species in its ecosystem and the KCFs refer to the principal set of cultural roles performed by a species in the culture and society of native societies (Morrison *et al.* 2006).

Describing the matrix of primary and secondary forests in terms of standard forest types following classification scheme by Champion & Seth (1968) would help to link non-spatial attributes of the landscape with the spatial ones. The distinct forest types in the Garo Hills were identified from these primary and secondary forests. Earlier mapping work (Sudhakar & Singh 1993; Kumar & Singh 1997; Roy & Tomar 2001; and Talukdar 2004) in the Garo Hills have identified broad forest types at varying scales (1:50 000 to 1:250 000) at geographical coverages of landscapes. At the start of this work, there were no overall finer scale maps of the area (including maps of land use land cover, vegetation and *Jhum* locations) except for some general vegetation mapping of Meghalaya at 1:250 000 scale (Sudhakar & Singh 1993). With the help of remote sensing satellite data, we prepared a land use and land cover map of the larger landscape (2459 km²) comprising South Garo Hills district and adjoining Nokrek National Park and Biosphere Reserve.

Relatively larger patches of virgin primary forests are the characteristic features of the landscape; however, age-old practice of *Jhum* over centuries in the region has created secondary forests. The secondary forest patches all over the landscape may serve as a good indicator of rapidly increasing anthropogenic

pressures and resultant forest fragmentation of the old forest growth in any forest area. The ‘fragmentation’ is a key research area for developing sustainable forestry and considered as key biodiversity indicator nowadays (Kupfer *et al.* 2004) and has been researched extensively on different aspects including plants, animals, land use and others during past two decades (Crim *et al.* 2002). Present study performed further analysis of land use land cover, which helped in identifying the levels of fragmentation and available core areas in the interiors of relatively larger patches of old forest growth in the area, crucial for wildlife conservation in the face of biotic disturbance.

1.5 Conservation significance of present study

Such landscape level mapping and analysis, when integrated with distribution patterns of wildlife species provide useful information for developing specific guidelines and management strategies for conservation planning of specific wildlife species. Such studies are lacking in the *Garo Hills* except for a preliminary analysis of elephant habitat relationship using elephant densities, old forest growth and fragmentation levels for South *Garo Hills* district (Marcot *et al.* 2002).

The elephant and tigers are the flagship and umbrella species of the region and the successful conservation of these species would help entail the conservation of entire ecosystem including associated plant and animal species of conservation significance. The landscape approach is very important for such wide-ranging animal species, which require larger areas with extensive forest cover patches with adequate connectivity. The present study took examples from the landscape scale assessment of elephant habitat relationship (Marcot *et al.* 2002) and identified the potential migratory route for the subpopulations of elephants, tigers (and prey base) and other species across several isolated wildlife habitats. This could be a multi-species approach towards effective wildlife management and conservation in the region.

These corridors help maintain the connectivity by linking several elements of protected area network. At present, the elements of protected area network in *Garo Hills* include the national parks, wildlife sanctuaries, biosphere reserve

(lately designated by extending a national park), and reserved forests, which comprised 15% of the landscape. The protected areas (and up to some extent the reserved forests also) can be characterised as areas of source populations for several wildlife species, particularly elephants in the present case. The source populations have the higher rate of recruitment compared to that of mortality among wildlife species, so that these populations disperse in the surrounding unprotected forest areas, which consequently help counterbalance the negative pulls within sink populations with low recruitment and high mortality rates, provided the wildlife habitats and potential corridors between protected and unprotected areas managed with adequate strategic planning. We devised a framework (to be presented in the next volume) for strengthening existing protected area network to help enhance the conservation status of land in the *Garó Hills*.

1.6 Scope, goal and objectives

Overall findings and recommendations generated through present study could be replicated for other landscapes in tropics and extrapolated at the regional level, for example, Meghalaya and entire northeast India, for broader scale conservation planning. Like *Garó Hills*, the tropical landscapes in the rest of northeast India and adjoining countries from Indo-Malayan and Indo-Chinese biogeographic realms are known to harbour rich biodiversity. Societies inhabiting these forests share more or less similar ethnic identities and socio-cultural values. The prevailing conservation issues, challenges and consequent stressors in geographically distinct localities across this region resembles very similar to those in the *Garó Hills*.

The major goal of the present study is to perform an ecological assessment of tropical forests at stand and landscape levels to provide knowledge, tools and indicators to evaluate specific diversity patterns and related ecological processes happening in these tropical forest conditions; and monitoring landscape changes for managing forest and wildlife resources of *Jhum* influenced *Garó Hills*. The study presented in this volume focused on the following objectives:

- to analyse landscape characteristics with special reference to forest fragmentation to evaluate the critical wildlife habitats; and
- to assess diversity patterns and successional changes among tree communities in various forest land use categories.

The ecological assessment of study area was done at broader scale for landscape level assessment and finer scale for stand level assessment to achieve the objective one and two, respectively. The former one involves mapping and analysis of various land use land cover; standard forest types including evergreen and deciduous forest types; existing protected area network in the region; and distribution pattern of the elephant population in relation with broad vegetation categories, which are representing the specific wildlife habitats. For stand (or field) level assessment, the distribution and diversity patterns of tree species were examined in distinct forest types and broad vegetation types including several growth forms of primary and secondary forests, which were situated in the areas exposed to varying degree of disturbances. These areas included the protected areas (free from any kind of anthropogenic pressure), reserved forest (subjected to the silvicultural treatments by Working Plan Division of State Forest Department till 1990, and optimal resource use activities by local tribes), and unprotected and unmanaged community land (used heavily for *jhumming* and Non-Timber Forest Product (NTFP) collection by native *Garo* tribes).

2. LADSCAPE: AREA, FOREST AND WILDLIFE

2.1 Introduction

The term 'landscape' in this volume denotes area encompassing entire South *Garó* Hills district and adjoining Tura Ridge area in the East and West *Garó* Hills districts. This landscape is a part of the *Garó* Hills representing the western-most hill ranges of Meghalaya state in northeast India. There are four out of five protected areas of state situated within the landscape, which offers excellent prospects of conserving native forest and associated biodiversity of the region. These protected areas sustain considerable portion of biological and cultural elements of ecological significance. The majority of land in these protected areas and surrounding unprotected areas are characterised by extremely rugged terrain, undulating hill ranges with deep gorges and several rivers/streams flowing across the north-south gradient.

2.2 Area size, location and drainage pattern

The landscape consists of South *Garó* Hills district (1850 km²) and adjoining Nokrek National Park along with the and surrounding community land, which collectively comprised 2459 km² in the southwest corner of the *Garó* Hills (**Fig. 2.1**).

It belongs to biogeographic zone (province) 9B, *i.e.*, North-East -- North-East Hills, and falls within 90° 07'- 91° E longitude and 25° 02'- 25° 32' N latitude (Rodgers & Panwar 1988), bordering Bangladesh at the southern boundary. The altitudinal range varies from about 50 m to 1500 m above MSL.

The *Garó* Hills receive rainfall from the north-eastern monsoon in winter and from the south-eastern monsoon in summer. As per the records of state's agricultural department based at *Garó* Hills, the mean minimum and mean maximum temperatures were 12.3°C and 32.5°C for the months of January and April, respectively. The mean maximum temperature was 25°C in winters

(November to January) to 32°C in summers (April to June), however, the mean minimum temperature was 10°C in winters (Kumar & Singh, 1997). The total average annual rainfall was 3362 mm with an average of 114 rainy days. The landscape is hot and humid compared to rest of the state due to relatively lower altitude and closer proximity to the world's highest rainfall areas including Cherrapunjee (Sohra) and Mawsynram at about 150 km in the east. June has consistently been the wettest month averaging 21.3 rainy days (Kumar & Rao, 1985). During winters, this area receives very rare rainfalls and remains comparatively drier during December to February.

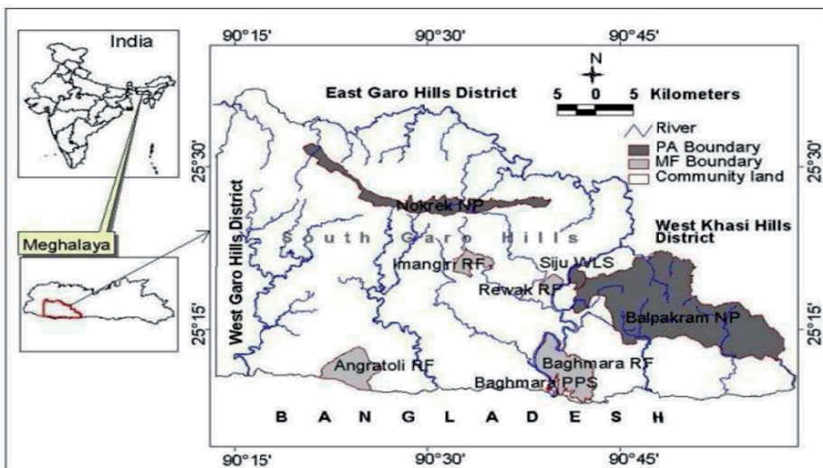


Fig. 2.1: Study area map with a geographical location within India and Meghalaya. Used with the permission of Current Science. (PA = Protected Areas, NP = National Park, WLS = Wildlife Sanctuary, MF = Managed Forests, RF = Reserved Forests and PPS = Pitcher Plant Sanctuary)

The drainage system of the Garo Hills is divided directly by the central upland zone, which divides rivers flowing south to the Surma valley of Bangladesh, from rivers flowing north to the Brahmaputra valley of Assam. The rivers in the Garo Hills are generally not navigable in large boats, but the *Simsang*, *Ganol*, *Bugi* or *Bugoi*, and *Dareng* or *Nitai* rivers are used for local navigation within the Garo Hills. Other important rivers of the Garo Hills include the *Nareng*, *Rongdik*, *Chibe*, *Rongdi*, *Rongkol*, *Mahadeo*, *Maheshkola*, *Kanai*, *Nawa* and *Lengta*. The river *Simsang* is the major river, flowing south through

the centre of the landscape. It originates in the Tura range near the Nokrek Peak and flows east then south and emerges on the plains of Pargana Susang of the Mymensing district in Bangladesh. It passes through the villages of *Simsanggiri*, *Rongrenggiri*, *William Nagar*, *Nangalbibra*, *Do'bak Kol*, *Rongbinggiri*, *Siju*, and *Rewak*, and the Baghmara town. Important tributaries of the Simsang are the Rongkoi, Rompa, Ringdi, Rongdik, Chibok, and so on. The upper course of this river is not navigable due to several cataracts and boulders. The lower course, however, has many deep pools and falls, namely *Mrik*, *Matma*, *Kon'chru Suk*, *Warisik*, *Bobra* and *Goka*. This river is important for the transportation of goods, including smuggling of timber and other forest produce to Bangladesh in the monsoon when it is extremely difficult for the government to monitor and halt such activities and catch the culprits.

2.3 Initiatives on forest and biodiversity conservation

During the British period, the government acquired 263 km² of the land for reserved forests during 1883-88 and initiated systematic forest management in 1887. Some of the reserved forests were leased to contractors. M.C. Jacob prepared the first detailed working plan covering all reserved forests of the Garo Hills in 1940-41. He prescribed five working circles, based on the commercial value and silvicultural characteristics of the forests. M.M. Islam prepared the second detailed plan (1956-57) for all reserved forests, after detailed stock mapping and ground inventory, and constituted four working circles. The latest working plan for managing the reserved forests of Garo Hills by F. Suchiang (1975-76) was in operation until 1990 and following six working circles were constituted in that plan.

- Sal Selection working circles (12.90 km²);
- Sal Conversion working circles (21.71 km²);
- Plantation working circles except for Siju (91.71 km²);
- Bamboo working circles (20.77 km²);
- Protection working circles (4.79 km²); and

- Ghugra (*Schima wallichii*) overlapping working circles (Overlapping all reserves).

The sal area of Angratoli and other reserved forests of the East and West Garo Hills districts were allotted to Sal Conversion working circles with the objective of attaining maximum sustained yield. The Ghugra overlapping working circles focused on *Schima wallichii* associated with sal, to be worked through the selection system. The Taungya working circles was allotted to areas under plantations and all the known areas of reserved forests suitable for plantations. Sal improvement working circle was allotted to the Rewak, Emangiri, Baghmara, Angratoli and Siju reserved forests in addition to some other reserved forests of the Garo Hills with the objective of improving the condition and composition of sal by silvicultural operations, and allowing sustained supply of timber. All miscellaneous forests of various reserved forests were allotted to the Miscellaneous working circles with the objective of maximising the sustained yield and replacing existing poor stock by valuable species. The British government has raised the forest plantations from time to time and established the 'taungya' plantation in the Garo Hills during 1905 and 1906 over 60 km² of *Shorea robusta*, *Tectona grandis* and other commercially important tree species. Later, in 1986-90 the State Forest Department of Meghalaya raised extensive social forestry plantations of *Shorea robusta*, *Tectona grandis* and *Gmelina arborea* covering about 51 km².

Shuching's Working Plan also started the process of conservation and wildlife protection in the Garo Hills, as illustrated in these two objectives of the plan, which state i) to protect, in perpetuity, the precipitous slopes and catchment areas of the rivers with a view to conserving soil and moisture, and ii) without disregard to the principles of scientific forestry to conserve and improve the status of wildlife in these forests. The Meghalaya state government initiated wildlife management and protection measures in 1977 by setting up state's first wildlife division and then Siju Wildlife Sanctuary (SWS), which is followed by establishment of protected areas namely Baghamara Pitcher Plant Sanctuary (BPPS), Balpakram National Park (BNP), and Nokrek National Park (NNP). The State Forest Department embarked on eco-development activities in 1985 around BNP and NNP, covering 101 and 33 villages, respectively (Table 2.1).

Table 2.1 Historical account of landscape use pattern in the study area

Priority objective	Activity/Task	Govt. official	Purpose
Forest Management	Working Plan (1941-51)	M.C. Jacob, DFO	Commercial mainly timber production
	Working Plan (1956-57)	M.M. Islam, DFO	
	Working (1975-90)	F. Suchiang, DFO	
Wildlife Management	Wildlife Division, Meghalaya (1977)	SFD, Meghalaya	Wildlife Protection and Management planning
	Siju WLS (1979)	SFD, Meghalaya	
	Wildlife Circle (1982)	SFD, Meghalaya	
	Balpakram & Nokrek NP (1986)	SFD, Meghalaya	
	Wildlife Division, Baghmara (1987)	SFD, Meghalaya	
Biodiversity Conservation	Preliminary Management Plan	J. Datta, DFO	Biodiversity Conservation and land use planning
	Management Plan	S.N. Sangma, ACF	
	Eco-development and sustainable development	Eco-development Society of Meghalaya	Covering 134 villages around protected areas

Source: Compiled from the working plans and other sources from State Forest Department (SFD, 1995)

2.4 Land stewardship and land tenure system

The land tenure system and land holding pattern in the *Garo* hills quite different from other parts of the country, since the majority of land base belongs to the native community. The old forest growths occur in three main land-use classes, i) protected areas, which include national parks and wildlife sanctuaries; ii) managed forests, which are designated as no-harvest reserved forests in the

state; and iii) privately-owned *Garo* community land. The primary forests are mainly confined to protected areas, but, there are a few intact patches of primary forests over community land in the interior hills. The secondary forests are confined mainly to the community lands and some newly acquired protected areas.

2.4.1 Protected areas

The four protected areas were notified either by acquiring community-owned forest land from tribals, for example, Balpakram National Park (BNP), or designating the existing reserved forests, for example, Siju Wildlife Sanctuary (SWS). BNP was created in 1986 by acquiring 220 km² of land (notified), followed by the addition of another 133 km² of land (SFD, 1985). The Nokrek National Park (NNP) was also constituted with the BNP during 1985 by acquiring 47 km² land over the Nokrek ridge. Later, the government acquired pieces of land around the national park and declared Nokrek Biosphere Reserve to be 80 km² of land over the ridge top, which encompasses the 47 km² of NNP. The SWS (5 km²), managed since 1883 as a reserved forest, was constituted wildlife sanctuary in 1979. The Baghmara Pitcher Plant Sanctuary (BPPS) was created in 1984, in middle of the Baghmara town, to conserve the endemic Pitcher plant (*Nepenthes khasiana*) population. Most of these protected areas have primary forests, while certain areas where *Jhum* was practised contain secondary forests.

2.4.1 Reserved forests

The four reserved forests, namely Baghamara (44.29 km²), Rewak (6.48 km²), Emangiri (8.29 km²), and Angratoli Reserved Forests (30.11 km²) were created at the turn of the twentieth century and since then they are managed by the State Forest Department. Secondary forests do not occur in these reserved forests since no *Jhum* has been practised here for a long time. A few plantations of *Shorea robusta* and *Tectona grandis*, however, have been raised in reserved forests during the 1930s. The state government after, attaining statehood as Meghalaya in 1972, has raised small scale plantations of cashew nut and rubber

inside the reserved forests as well as outside the notified forest areas in community land.

2.4.3 Community land

Most of the remaining 85% area, other than protected areas and reserved forests, is managed by the Garo Hills District Council (GDC), while the actual control at village level remains in the hands of the *Nokma* or village community head. Most members of the rural population depend upon the *Jhumming* for their livelihood. *Jhumming* is an integral part of their traditional lifestyle. Each *Aking* (village or group of small villages) has its own land for *Jhumming*, which is distributed among families by the *Nokma*. In the case of any social or legal dispute, the *Nokma*'s decision is final and bound on the villagers. In the past, when population pressure was comparatively low, *Jhumias* (*Jhumming* families) used to return to an old *Jhum* site after a gap of twenty to thirty years but, nowadays, the *Jhum* cycle is reduced to just two to three years or even less. Increasing incidence of *Jhum* and shortening of *Jhum* cycle are the main factors responsible for the loss of forest cover and a significant reduction in agricultural output (Ramakrishnan 1985 and 1992; Ramakrishnan & Toky 1983; Mishra & Ramakrishnan 1982; and Kushwaha & Kuntz 1993).

In recent times, some settled agriculture has been established, especially in valleys where water is available for irrigation, and plantations have been raised. In the flat valleys, the local *Garo* people permanently cultivate sweet potato, gram, vegetables, and other seasonal crops. People also have bagans (gardens) near their homes to raise plants and cash crops including orange, cashew nut, pineapple, gol/kali mirch (black pepper), mango, and other fruits. The local offices of the Social Forestry Division and the Department of Soil and Water Conservation of Meghalaya have developed plantations of economic species along roadsides and on community land within the study area.

Apart from having a complex mosaic of current and abandoned *Jhum* fields, secondary forests, plantations, and settlements, this area still has many patches of undisturbed primary forests, valuable wildlife corridors, water catchments, special and unique habitats, which are important from a biodiversity

conservation point of view. Current trends in land use practices, however, will lead to irreparable loss of otherwise renewable natural resources, such as productive soils, further loss of primary and old secondary forests, and of biodiversity associated with the old forests of the community land.

2.5 Tropical forests and tree species

At first glance, the tropical forests of *Garo Hills* resembled a mosaic of primary and secondary forests, however, no attempt has ever been made to define them as primary and secondary forests and describe their species composition, richness and diversity. The State Forest Department of Meghalaya and other research studies (Kumar & Rao, 1985; Haridasan & Rao, 1988; Khan *et al.*, 1997; and Awasthi, 1999) identified these forests as a matrix of evergreen and deciduous forest types. Though, Kumar & Rao (1995) mentioned the existence of secondary forests in Balpakram area and listed *Callicarpa arborea*, *Glochidion lanceolaria*, *Careya arborea*, *Phyllanthus emblica*, *Holarrhaena antidysentrica*, *Micromelon integrefolium*, *Lagerstroemia parvifloram*, *Macaranga denticulata*, and *Syzygium* spp. as prominent secondary forest species, however, no quantitative analysis of diversity pattern and species distribution and dynamics of tree species in these forests was ever done. The present study provided a detailed account of species richness and diversity in primary and secondary forests of the landscape.

In a natural forests, the matrix of evergreen and deciduous forests is so intermingled that makes the field identification of distinct evergreen, semi-evergreen and deciduous forest types a difficult task and in most of the tropical forest conditions like *Garo Hills*, it may not be feasible to differentiate evergreen with semi-evergreen and semi-evergreen with deciduous forest types very accurately. Also, understanding the primary and secondary forests especially in terms of species composition and diversity of dominant life forms like tree species would help describe the forest stand dynamics. Kumar & Rao (1985) reported that secondary forests of Balpakram area in South *Garo Hills* were inferior in species richness and diversity of the flora. But they are of immense use and possess high conservation values as several studies in the tropical countries reported the importance of secondary forests and their uses by

the wildlife and society (Budowski, 1965 and De Jong *et al.*, 2001). Present study quantified the successional changes among selected tree species providing critical services to native wildlife and human society. To identify the potential uses of tree species, a list of 150 tree species generated during the initial phase of this study was used to conduct focus group interviews for their cultural importance.

2.6 Forest classification

For valid comparison with other studies, it would be necessary to understand those primary and secondary forests as per the standard classification scheme practised in India for managing forests and mapping landscapes, *i.e.*, the revised classification scheme of forest types by Champion & Seth (1968). It would help in identifying crucial habitats for existing wildlife and correlating the species distribution and other variables for understanding their relations with habitat and developing management strategies for protecting the wildlife species of conservation significance. The State Forest Department of Meghalaya (SFD, 1995) categorised the *Garo* hills forests into seven categories, including sal forests (alluvial sal and foothill and plateau sal), mixed deciduous forests, evergreen forests, bamboo forests, grasslands, very moist sal bearing forests, and eastern Himalayan moist deciduous forests.

First ever landscape level mapping to classify land and land cover in the region was done by Sudhakar & Singh (1993), who provided a map of Meghalaya including *Garo* Hills districts at 1: 250 000 scale and identified tropical semi-evergreen, moist deciduous and dry deciduous forest types. Later, Roy & Tomar (2001) and Talukdar (2004) did mapping at the same scale and refined this classification to identify evergreen, semi-evergreen and deciduous forest types among old forest growths. Kumar & Singh (1997), however, performed finer scale mapping (1:50 000) of a portion of landscape covering 447 km² of Balpakram National Park and surrounding community land area in South *Garo* Hills district to identify the similar forest types. Kumar and Rao (1985) surveyed the Balpakram area and suggested three distinct forest types as tropical moist evergreen, semi-evergreen and moist deciduous forests based on the classification scheme suggested by Holdridge *et al.* (1971). Broadly, all available literature

categorised the old forest growth in *Garó Hills* as evergreen, semi-evergreen and deciduous forest types following the standard (revised) classification scheme by Champion & Seth (1968).

2.6.1 Tropical moist evergreen forests (TMEFs)

TMEFs usually occur in high rainfall areas, mainly confined at the ridge top, valley bottom, deep gorges and moderate to steep slopes in the Tura range and Balpakram areas of the *Garó Hills*. These forests are relatively less disturbed and support luxuriant growth of diverse tropical vegetation under warm and humid conditions. The common species in top canopy of these forests included *Acrocarpus fraxinifolius*, *Castanopsis indica*, *Cynometra polyandra*, *Diospyros gobara*, *D. stricata*, *Dysoxylum binectariferum*, *D. kurzii*, *Elaeocarpus floribundus*, *Kayea floribunda*, *Engelhardia spicata*, *Walsura robusta*, *Mesua ferra*, *Parkia roxburghii*, *Pterospermum acerifolium*, *Sapium baccatum*, *Ferniana colorata* and *Schima wallichii*. The middle canopy was composed of *Aquilaria agallocha*, *Antidesma acuminata*, *Garcinia cowa*, *Saraca asoca*, *Sterculia roxburghii* and *Syzygium* spp. The lower canopy comprised smaller trees such as *Ficus* spp., *Leea umbraculia*, *Saprosma ternata*, *Dracaena spicata*, *Ixora* spp., and *Miliosa roxburghiana*. Deciduous species such as *Hibiscus macrophyllus* and *Tetrameles nudiflora* were also found in forest openings and gaps (Kumar & Rao 1985, and Simon 1996).

2.6.2 Tropical semi-evergreen forests (TSEFs)

These forests showed the dominance of evergreen species in top canopy such as *Castanopsis* spp., *Mesua ferrea*, *Lithocarpus elegans*, *Pterospermum lancaefolium*, *Acrocarpus fraxinifolius*, *Albizia* spp., *Careya arborea*, *Terminalia* spp., *Sterculia* spp., *Lagerstroemia parviflora*, *Stereospermum chelonoides*. In the middle canopy, common tree species were *Crateva nurvala*, *Maesa rementacea*, *Rhus javanica*, *Phoebe lanceolata*, *Styrax serrulatum*, *Ligustrum robustum*, *Capparis* spp. and *Calliandra umbrosa* (Kumar & Rao 1985, and Simon 1996).

2.6.3 Tropical moist deciduous forests (TMDFs)

These are the sub-climax type and are occur in community land at the gentle slopes. In most cases, these are the man-made forests and subjected to frequent anthropogenic conversion to the *jhum* land. These disturbed forests were characterised by tree species like *Bauhinia purpurea*, *Callicarpa arborea*, *Phyllanthus emblica*, *Grewia microcos*, *Kydia calycina*, *Macaranga denticulata* and other fast growing species. Other tree species in these forests were *Albizia lebbeck*, *A. lucida*, *Dillenia pentagyna*, *Elaeocarpus floribundus*, *Erythrina stricata*, *Glochidion* spp., *Gmelina arborea*, *Holarrhaena antidysentrica*, *Lagerstroemia* spp., *Ochna integerrima*, *Salmalia malabarica*, *Schima wallichii*, *Sterculia villosa*, *Terminalia bellerica*, *Vitex glabra*, and *V. peduncularis*. The second story comprised *Aporosa dioica*, *Bredelia retusa*, *Croton joufra*, *C. roxburghii*, *Grewia microcos*, *Glochidion lanceolarium*, *Mallotus philippinensis*, *Rhus javanica*, and other species (Kumar & Rao 1985, and Simon 1996).

2.7 Wildlife

The zoological explorations have been recorded the 85 mammal species from Garo Hills forests (ZSI 1995), which accounts for more than 60% of the mammalian diversity of the state of Meghalaya. Like mammals, other invertebrate fauna were also represented well from these forests (Fig. 2.2). The rodents and chiropters (bats) contribute about 45% of all mammal species, and many of them have adopted to cavernicolous (adapted to cave), of which 5 were reported from Siju cave by Kemp & Chopra (1924).

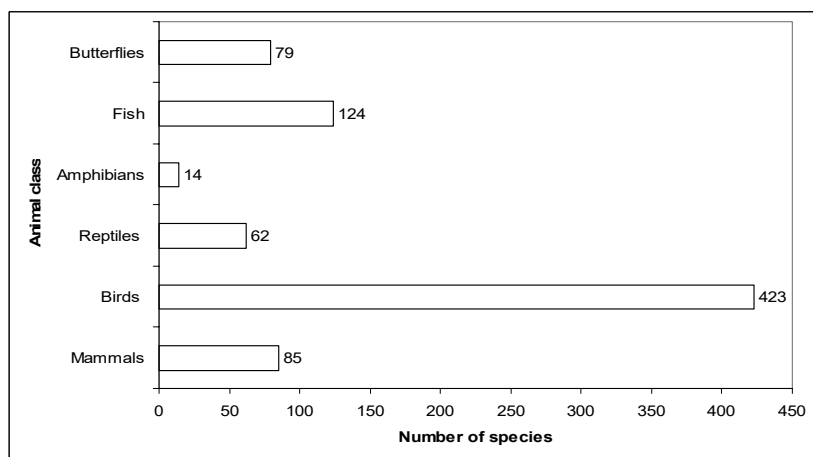


Fig. 2.2 Vertebrate fauna in *Garo Hills* (Sources: ZSI, 1995 for mammal and fish; and Ghosh, 1984 for others)

Earlier studies and surveys have been conducted to record the faunal species inhabiting these forests (Kemp & Chopra 1924, Pillai & Yazdani 1977, Ghosh & Biswas 1977, Ghosh 1984, Kumar & Rao 1985, Pillai & Murhy 1989, Alfred & Sati 1990, Marak 1998, SFD 1981, 1993, and 1995), but no ecological study has ever been conducted to understand the wild fauna of the *Garo Hills* in relation with their habitats except for a study by Kumar & Rao (1985), which mentioned the preliminary level of association of selected mammal species with the broad vegetation categories reported in the Balpakram National Park area. Further after a long gap of more than 15 years Kumar *et al.* (2002), Mathur *et al.* (2002) and Marcot *et al.* (2002) provided the landscape level analyses on wildlife habitat relations in the region. Important Wild animal species of landscape includes tiger (*Panthera tigris*), leopard (*Panthera pardus*), clouded leopard (*Neofelis nebulosa*), leopard cat (*Felis bengalensis*), jungle cat (*Felis Temmincki*), mithun (*Bibos spp.*), wild buffalo (*Bubalus bubali*), wild dog or dhole (*Cuon alpinus*) and others. Of all such species, the Asian elephant is the most important species of the *Garo Hills* region. The elephant is an integral part of the *Garos* life and well represented in their folklores.

In India, elephant attains one of its highest densities in the *Garo Hills* area, which lately has been designated an ‘Elephant Reserve’ under the Project Elephant of the

Government of India. The Balpakram and Nokrek areas have been recognised as the most important elephant bearing areas of the region (SFD, 1995) and act as areas of 'Source Populations' of the elephants. The landscape may also serve as the source population area, since it holds the greatest densities of an elephant compared to other hilly and plain regions of adjoining East/West *Garo Hills* districts, East Khasi Hills, Assam and Bangladesh.

The species specific or community-based ecological studies on the wildlife habitat relationship are lacking in the *Garo Hills* except for a preliminary analysis of elephant habitat relationship using elephant densities, old forest growth and fragmentation levels for South *Garo Hills* district (Marcot *et al.*, 2002). The elephant is a flagship and umbrella species of the region and conserving this species would entail the conservation of entire ecosystem including associated plant and animal species of conservation significance. Williams & Johnsingh (1996) conducted a few short term elephant surveys and identified potential wildlife (especially for elephants) habitat corridors over community land in the South *Garo Hills*. The three habitat corridors, linking Balpakram National Park-Rewak Reserved Forests-Emangiri Reserved Forests-Nokrek National Park, provide migratory routes to elephant populations towards Brahmaputra plains in North (Assam) and Surma plains in South (Bangladesh). Kumar *et al.* (2002) and Marcot *et al.* (2002 and) provided a quantitative analysis of elephant-habitat-relationship for this landscape and precisely mapped the corridors and analysed the influences of increasing anthropogenic factors (settlements, road network and other developments) over landscape.

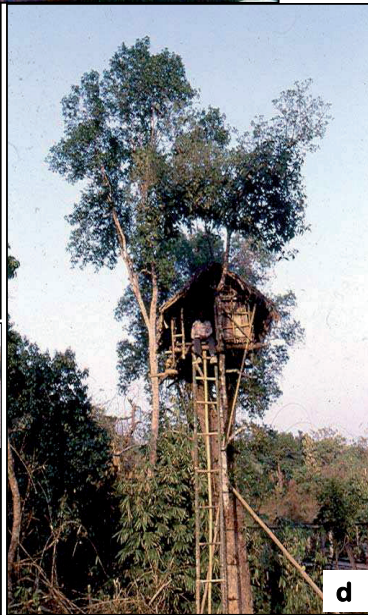
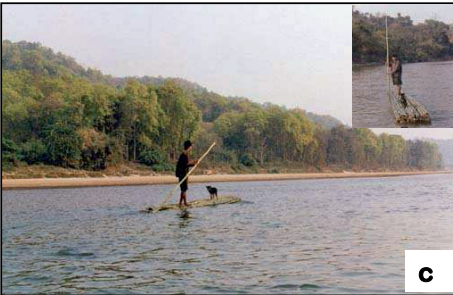
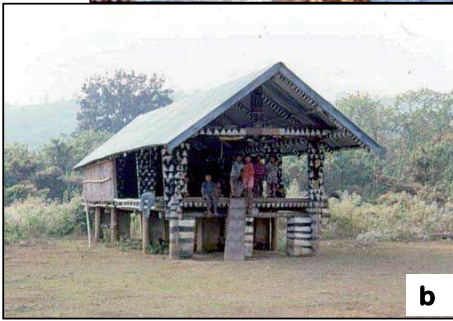


Photo Plate 1: Garos and glimpses of their life style

a. A Garo couple in their drawing room, these traditional houses are made up of wood and bamboos; **b.** *Nokpante* - the bachelors' dormitory, used by youths for community gatherings and entertainment; females are not allowed to enter; **c.** A Garo boy using bamboos for rafting. He will sell these bamboos in the market and go back by road-. **d.** A hut made on a tall tree (25-30 m high above the ground) for watching their *jhum* crops from wildlife species.

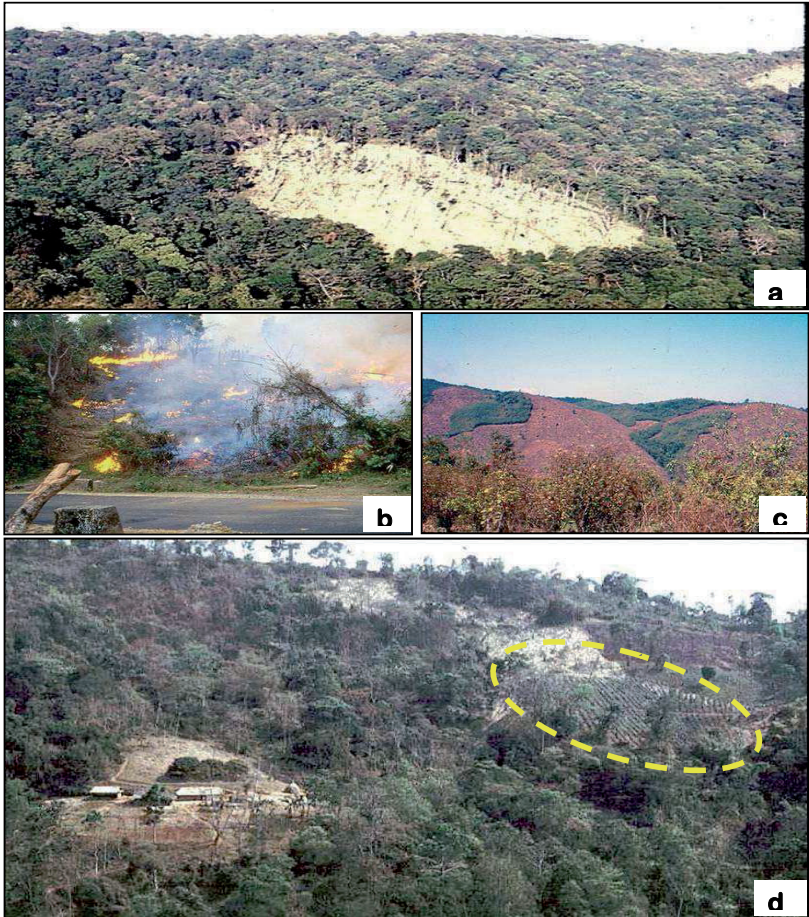


Photo Plate 2: Shifting Cultivation (*jhumming*): forests are cleared and burnt for agriculture

a. A recently cleared patch of old primary forest growth adjacent to the boundaries of Balpakram National Park (area 220 km² as notified at the time of initiation of the study in 1996), the largest one in the state of Meghalaya; **b.** Fire is used to remove debris, which consequently enhances the nutrient status of organic soil around Balpakram National Park; **c.** Most adversely affected landscape by *jhum* near Nokrek National Park. **d.** The typical *Garo* set up for a family (now seen in the interior hills only); note the use of contour agriculture, which could be a better alternative of the *jhumming* (Photograph by Dr Bruce G. Marcot).

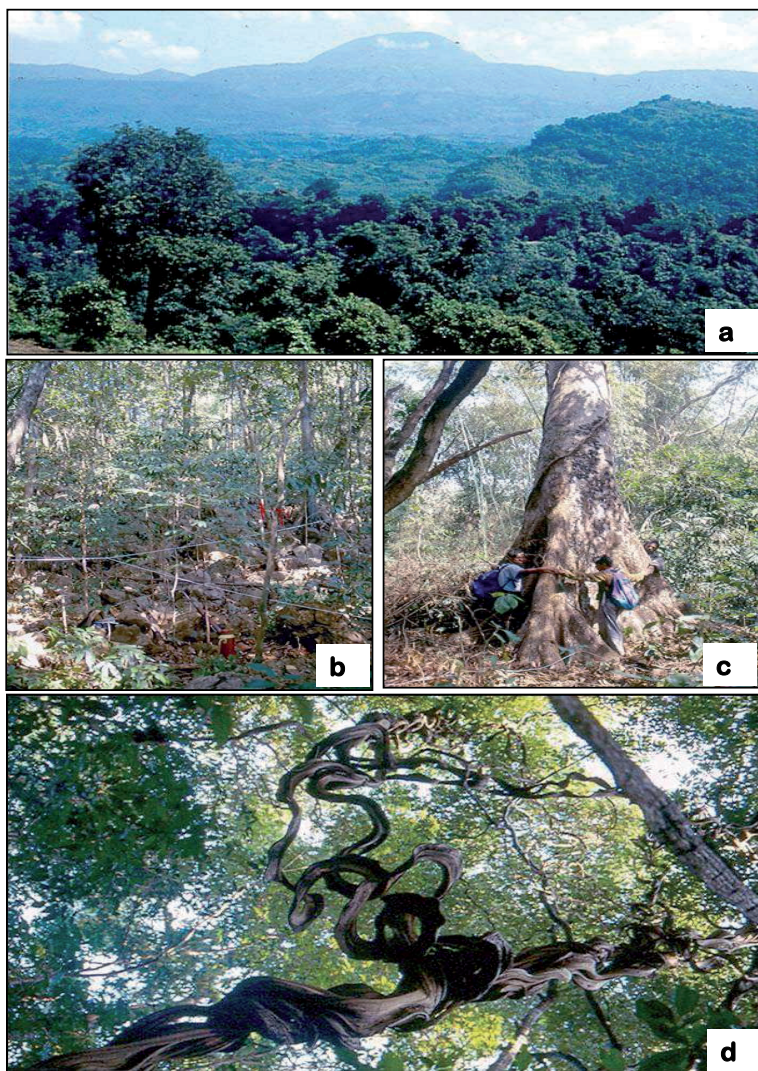


Photo Plate 3: The tropical forests and a few characteristic features

a. A long stretch of primary forest growth around Balpakram National Park, note the highest peak of area; **b.** Field data collection using stratified random sampling and standard field techniques; **c.** Big buttressed trees are the characteristic features of these forests; **d.** Woody climbers (*Entada pursaetha*) are very common in the dense primary forest growth.

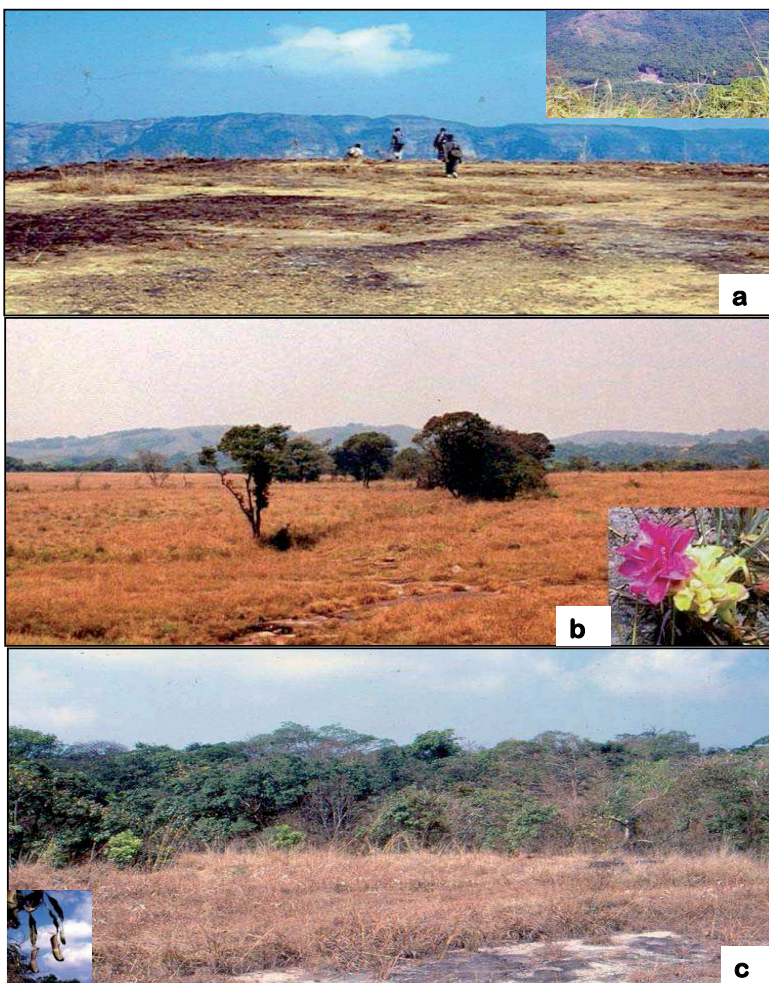


Photo Plate 4: Balpakram plateau, the most sacred place to *Garo* people

a. The view of Balpakram plateau across the mini Canyon, a deep gorge at River Mahadeo (inset), note the remains of burnt grassland during the dry season, which makes an important habitat for several wildlife species; **b.** Balpakram plateau with the growth of a few stunted tree species (*Litsea* spp. and others), and a beautiful plant of zingiberaceae family- *Curcuma* spp. (inset); **c.** Shola type vegetation growth around plateau; adjoining steep slopes form excellent habitats for Pitcher plant (*Nepenthes khasiana*) inset.



Photo Plate 5: Pitcher plant, habitat and protected area

- a. Development of township at the bank of river Simsang (the major river of *Garo Hills*) adjacent to the boundaries of Baghmara Reserved Forests – a view from Baghmara Pitcher Plant Sanctuary, inset photograph of Pitcher plant from these forests;
- b. A pitcher plant (Photograph taken by Sh. Ajai Saxena at Balpakram plateau);
- c. Pitcher plant along Simsang river at the boundary of Baghmara Reserved Forests;
- d. Pitcher plant habitat along river bank across the Baghmara town.

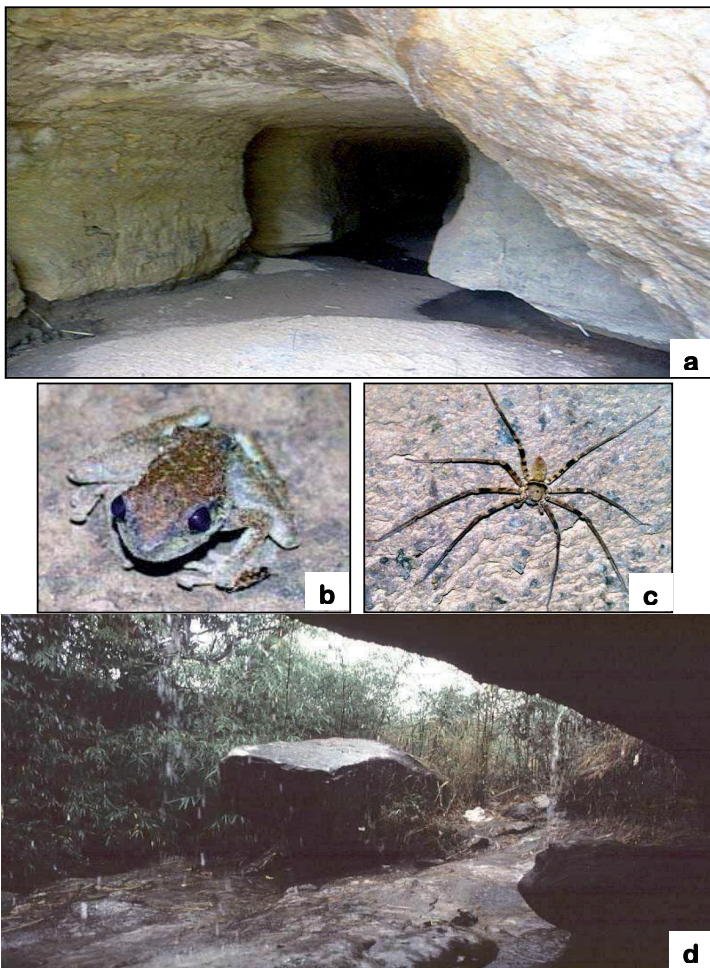


Photo Plate 6: Caves are the unique habitats for several wildlife species

a. Famous Siju cave adjacent to the Siju Wildlife Sanctuary near river Simsang;
b. A frog species (*Amolops* spp.) adopted for cavernicolous lifestyle; **c.** A cavernicolous spider; **d.** Sacred cave of the witches in a rainstorm on Balpakram plateau (photograph by Dr Bruce G. Marcot).

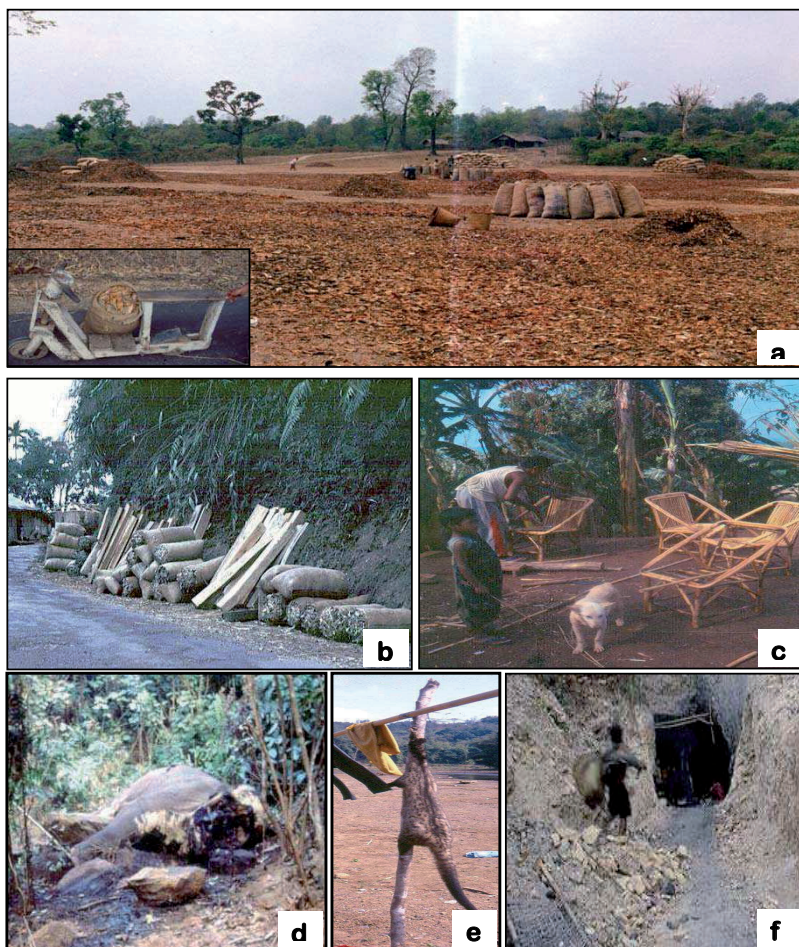


Photo Plate 7: A few examples of threats to the native biodiversity

a. Mass extraction of the bark of *Persia villosa* (locally known as *Nameaga*) and *Litsea sebifera* (*boldukaki*) towards the southern boundary of Nokrek Biosphere Reserve and National Park note a wooden bi-cycle (local made) to carry the collected bark to the middle man or contractor, mainly young boys use it; **b.** The lumbers and non-timber forest products in the adjacent Khasi Hills; **c.** Cane is extensively used for commercial purposes; **d.** Poaching is the major threat to the native wildlife, a killed elephant near Rongra range during 1998-99, face removed by poachers for tusk; **e.** This skin of small Indian civet is being dried along with clothes in a village adjacent to the Baghmara Reserved Forests; **f.** The initiation of coal mining around Siju Wildlife Sanctuary at upper Siju area.

3. LAND USE AND FOREST FRAGMENTATION

3.1 Introduction

The concept of 'Landscape Ecology' is widely used all over the world to evaluate the land characteristics. The land characteristics directly influence various ecosystem processes, such as the species distribution, population dynamics and community structure of several life forms in an ecosystem. The landscape characteristics can be expressed as a function of patch mosaic and their spatial arrangement over the landscape (McGarigal & Marks, 1994). The patch mosaics in Garo Hills included several landscape elements representing distinct forest types and land uses. Like other tropics in the world, the landscapes in Garo Hills too supports luxuriant old forest growth, which provides habitats to a variety of life forms including wildlife species (Kumar *et al.*, 2002). For successful conservation efforts, it is vital to know the landscape structure, which directly affects several functions of the landscape, for example, the role of various forest types or habitats or other landforms under the influence of unplanned land use activities, in deciding the abundance and distribution pattern of the native wildlife communities and human societies. The mapping of existing land use and land cover including distinct old forest cover for understanding their extent and magnitude is the first step towards designing specific landscape-scale conservation strategies for sensible land use planning and management of natural forest and wildlife resources.

The 'land cover' corresponds to the physical condition of the ground surface (for example, forest, grassland, human settlements and others), while 'land use' reflects human activities over certain land covers (such as the use of the land for specific purposes by native society, for example, industrial, residential, agricultural fields and other activities). The land cover in the Garo Hills can be categorised as old forest growth, non-forest vegetation (mainly bamboo growth), and man-induced land cover (or land use) classes. Generally land cover does not coincide with land use and a land use class may compose of several land covers (Lillesand & Kiefer 1994). Most of the work for mapping land use land cover and vegetation in Meghalaya was carried out at 1: 250 000 scale (Sudhakar & Singh, 1993; Kumar & Singh, 1997, Roy & Tomar 2000, 2001; and Talukdar, 2004),

however, for the first time, FSI (2001) performed the classification of forest cover at 1:50 000 scale and classified the old forest growth as 'dense' and 'open' forests, which collectively constituted the 70% land of the Meghalaya. Additionally, landscape characteristics and forest fragmentation of Meghalaya state have been quantified at much broader scale for larger geographical coverage (Roy & Tomar 2001, and Talukdar 2004). Roy & Tomar (2001) reported 69% of land in Meghalaya under forest cover during 1980, which was reduced to 63% during 1995. Likewise, the forest cover in *Garó Hills* constituted 78 % of the total land area (FSI, 2001), while rest of the 22% land was used by native society for several kinds of land uses including residential and agricultural (settled and shifting) purposes.

We focused on evaluating the land use pattern by quantifying the landscape structure (composition and configuration) and identifying the fragmentation in the old forest growth due to traditional land use by native society. The spatial arrangement of distinctive forest and non-forest patches help quantify spatial patterns of the landscape for measuring the fragmentation. The process of forest fragmentation was an outcome of prolonged practice of unplanned forestry activities, such as *jhumming* and other associated developmental activities including road construction and mining. The developmental activities were comparatively slower in the region and absolute urban environment nowhere existed at the landscape. Like other parts of the *Garó Hills*, the use of land for residential and agricultural purposes was prominent in the landscape. Baghmara, the headquarter of South *Garó Hills* district is developing fast as township across the river Simsang and resembles semi-urban (or semi-rural) conditions, while rest of the landscape represented the rural environment. The old forest growth occupied a major portion of landscape and extensively used by the variety of wild animals.

3.2 Methods

The technologies, viz., Remote Sensing (RS) and Geographic Information System (GIS) provide the effective tools for evaluating land use land cover classes (Lillesand and Kiefer 1994). Specific land cover classes, which were used by native societies of *Garó Hills*, were delineated as land uses in the present study.

All work related to digitisation of boundaries, land cover mapping and further GIS analysis was done using ArcInfo (version 8.0.2), ERDAS Imagine (version 8.7), and ArcView (version 3.1). Further analysis of spatial patterns was done to evaluate the characteristics of the landscape using Bio_CAP, a GIS-based software with the customised package of selected landscape indices, developed by the Indian Institute of Remote Sensing (IIRS), Dehra Dun. Other landscape indices for describing the spatial patterns in present study were computed using concepts from FRAGSTATS, a GIS-based programme to quantify landscape structure, which offers a comprehensive choice of landscape metrics (McGarigal & Marks, 1994). Further information on land uses was supplemented through secondary sources, which was used to discuss the findings from this study.

3.2.1 Determining landscape boundaries and spatial scales

The boundaries were demarcated by following ecological features of the landscape either taken from the Survey of India (SoI) toposheets or remotely sensed satellite data. The eastern boundary was mapped by following river Maheshkola, which separates the landscape from hills of adjoining West Khasi Hills district of Meghalaya. The northern boundary was drawn by demarcating river Simsang, which joins Tura-Williamnagar road along Tura hill ranges running towards western corner of the landscape. The western boundary was identified as Tura-Dalu Road, which goes parallel to the river Bogai (locally known as Bugi), which originates from the southern side of Nokrek mountain and runs through Dalu village and enters into Mymensingh district in Bangladesh. The SoI toposheets were not available for the southern portion of the landscape (along with the international border between India and Bangladesh) due to security reasons, so the southern boundary of the landscape was delineated through visual interpretation of southern hill ranges of Garo Hills from the satellite data.

The maps of protected areas and reserved forests were available in very crude prepared at varying scales ranging from 1:10 000 to 1:250 000 scales by different individuals from divisions of State Forest Department of Meghalaya, which were brought at the homogenous 1:50 000 scale for present study to maintain uniformity in the mapping and analysis efforts. Finally, all the boundary maps

were integrated into the single theme to obtain a base map of the landscape (**Fig. 2.1**), which was used for further analysis and ecological interpretation of the results. Furthermore, the concentration or distribution pattern of elephant population was mapped within officially designated elephant census zones, which was earlier prepared by the State Forest Department of Meghalaya in the field and later digitised at 1:50 000 scale in GIS domain for present study.

3.2.2 Mapping land use and land cover of landscape

The classification and mapping were done by digital image processing to a scene from satellite IRS-1 D LISS III (row 110 and path 54) with a spatial resolution of 23.5 m for delineating land use the land cover of the landscape. The scene was acquired for the relatively cloud free season during February 1999. The standard techniques described by Lillesand & Kiefer (1994) were used to generate the final output.

The raw image data contain some inherent systematic errors, such as radiometric, geometric, and atmospheric errors due to limitations in the sensing of signal digitisation or data recording or transmission process. The pre-processing operations involved the image rectification and restoration in improving the quality of image by removing unwanted and distracting elements from an image data. Further, the ‘feature extraction’ was done to reduce the dimensionality of the data, which helped in isolating the most useful components of data for further study while discarding the less useful or useless aspects of data. The ‘feature extraction’ here, does not refer to the geographical features visible on the image but rather ‘statistical’ characteristics of image data like a combination of band values that carry information concerning systematic variation within the scene. The specific spectral band combinations used for classification in the present study include 3, 2, and 1 in LISS III. Then, the image was enhanced using contrast stretching or ratio based techniques to facilitate the discrimination while matching the ground control point with natural features of image data. Finally, the boundary map was overlaid on the scene to extract the specific study area, *i.e.*, landscape.

Image classification was done using unsupervised and then supervised classification techniques. The unsupervised classification provided an image with 50 distinct spectral classes, which more or less represented the natural features of a landscape. The field photographs of this image were taken to the field and verified using certain ground control points. Some of the ground control points easily identifiable on image display were used as training areas to perform the supervised classification, while rest of them were used to evaluate the classification accuracy of major land use land cover classes. These training areas provided a numerical description of spatial attributes of each class and merging more similar spectral classes into more meaningful and identifiable land use land cover classes. A total of nine land use land cover themes were identified through supervised classification using Gaussian Maximum Likelihood Classifier, which determined the variance and covariance of each theme providing the probability function. Some of the pixels falling in complete shadow areas remained unclassified and depicted as a shadow in the present study. Following ten land cover classes were identified and delineated in the present study.

- Evergreen as ‘Tropical Moist Evergreen Forest (TMEF)’;
- Semi-evergreen as ‘Tropical Semi-Evergreen Forest (TSEF)’;
- Deciduous (including sal growth) as ‘Tropical Moist Deciduous Forest (TMDF)’;
- Bamboo (including young secondary forests below 6 years of age) as ‘Bamboo/Young SF’;
- *Shola* type forests along with associated grasslands at Balpakram plateau as ‘Plateau grasslands and *Shola* type’;
- Settlement, abandoned *jhum*, scrub/shrubs and fallow/barren land as ‘Habitation/Abandoned *jhum*’;
- Agricultural fields in valley plains along with associated sandy riverbanks as ‘Agriculture/sand’;
- Areas under current *jhum* along with seasonal grasslands in plains as ‘Shifting cultivation’;
- Water-bodies especially rivers as visible through digital data; and

- The areas overshadowed by the cloud covers or high hills with steep slopes over deep gorges as 'Shadow'.

This process helped in smoothening of output land use the land cover image to reduce the noise, which occurred mainly due to inherent spectral variability encountered by a classifier when applied on a pixel-by-pixel basis. The odd pixels either single or in a pair within the particular class were considered as the noise of classified data. For this purpose, a 3 x 3-pixel majority filter was applied on the output from the automatic classifier to remove noise and improve the overall classification accuracy. In order to prevent pixels from being converted to very dissimilar classes, each class was filtered separately. The resultant polygon attribute table of the finally classified map was used to analyse the patch characteristics of the landscape to evaluate and quantify the landscape characteristics.

Classification accuracy assessment could not be done very correctly for finer land use and forest cover classes, however, the broad land uses (combined three land use categories) and old forest growth (combined three forest types) were assessed for the level of accuracy. The major problems associated with accuracy assessment could be attributed with the extreme remoteness of several localities and in most cases, the dense forest cover did not allow the connectivity of Geographical Positioning Systems (GPS). Anyhow, land cover information from a total of 80 ground control points were collected with the help of toposheets and verified with the finally classified image with land use land cover map of the landscape.

3.2.3 Landscape spatial indices as measures of fragmentation

Spatial pattern analyses using standard landscape indices was done for quantifying landscape patterns and process of fragmentation. Over the years, more than 60 spatial indices have been developed to quantify landscape patterns and fragmentation (McGarigal & Marks 1994; and Dale & Pearson 1997), however, a set of few simple measurement indices very well describe the spatial patterns with the help of a land cover or wildlife habitat map (Dale & Pearson, 1997). Present study computed some of the simple spatial indices representing an area of wildlife

habitat patches (depicted by land cover classes), the frequency distribution of patch sizes, edges, core areas, and various levels of forest fragmentation. These indices are indicative measures of the fragmentation for quantifying different characteristics, facilitating the comparison with other studies or long-term monitoring of landscape at temporal scale. All of these indices, either independently or in combination could be used for comparing various segments of landscape, for example, among protected areas, reserved forests and community land; or between overall land uses and forest cover; or within several land uses or forest cover; or between two protected areas, such as Balpakram and Nokrek National Parks; or other combinations of subsets of larger landscape, to be determined with consideration to the focal target of proposed management activities.

3.2.3.1 Patch indices

Area and number of patches provide valuable information about the extent of various types of wildlife habitats for most landscape-level analyses. The ecological characteristics of a landscape are likely to be governed by the characteristics of the largest patch (Dale & Pearson, 1997). The percent area of the largest patch provided an index of habitat fragmentation (Pearson *et al.*, 1996) and landscapes with higher largest patch index the highly fragmented habitat conditions, while lower values indicated the good connectivity among wildlife habitat patches. The frequency distribution of patch size also reflects the connectivity of fragmentation of wildlife habitats, *i.e.*, whether it is aggregated into a few large patches or distributed among many small patches (Dale & Pearson, 1997). The following spatial indices (McGarigal & Marks, 1994) at patch, class and landscape levels were used for describing the landscape composition and configuration for evaluating the process of forest fragmentation in the present study.

- Total area of patches $\geq 0.01 \text{ km}^2$;
- Percent of total landscape area;
- Largest patch index (%) with respect to area of all patches (2459 km^2), since it reflect the influence of the largest patch over landscape;
- Number of patches;
- Patch density (no./ km^2);

- Mean patch size (km^2);
- Patch size Standard Deviation - PSSD (km^2); and
- Patch size Coefficient of Variation - PSCV (%).

3.2.3.2 *Edge indices*

Some other landscape indices, which were computed during the present study, included the measures of edges between two different cover types (or wildlife habitats). The edges are very important for specialist wildlife species for examples several primates, rodents and other species, which are benefited by a higher concentration of food plants within ecotonal areas. The biotic and abiotic factors especially microclimatic conditions change dramatically near forest edges (Kapos, 1989; Williams-Linera, 1990; Laurance, 1991; Kapos *et al.*, 1997; Turton & Freiburger, 1997, and Didham, 1997), which signify the potential importance of edge effects. Usually, the larger patches contain more species and form better habitats for native wildlife species by providing more cover and space, however, the patches with elongated shape with higher edge-to-area ratio, which experience extensive edge effects from surrounding land cover, may better serve as dispersal corridors, if juxtaposed adequately for linking the larger and intact forest patches in a landscape mosaic. Following edge indices were computed during present study based on the McGarigal & Marks (1994).

- Total edge length (km);
- Edge density (km/km^2);
- Largest edge length (km);
- Mean edge length (km);
- Edge length Standard Deviation (km) – ELSD (km); and
- Edge length Coefficient of Variation - ELCV (%).

These edge indices could be used in determining the shape indices, another measure of landscape composition and configuration. The shape of the patch also plays an important role (Patton, 1975; Covich, 1976; Marcot & Meretsky, 1983; Forman & Godron, 1986) in determining the effective area for potential wildlife use, depending on the species of wildlife and its sensitivity to edge conditions. But, such measures did not quantify the actual availability of quality habitats for larger wildlife species especially larger mammals like elephants or tigers or Indian bison, which require larger intact forest tracts with the more undisturbed area

within the old forest growth. Earlier, the perimeter (or edge) length-to-area ratios (p/a ratios: Forman & Godron, 1986) were used to quantify the edge effect in the forest fragments, which could influence the habitat quality and consequent species distribution in the area. This particular index tells whether the patch is compact (squarish or circular) or elongated (rectangular or cylindrical) in shape, however, this does not very well quantify the availability of specific habitat area for wildlife species especially the interior specialist species. The p/a ratio has been superseded by the Core Area Model of Laurance & Yensen (1991), which relies on quantifying the edge penetration distance in order to calculate the unaffected core area in a fragment of any given size or shape.

3.2.4 Core area model

The core areas were delineated for all old forest patches including TMEF, TSEF, and TMDF in order to get an idea of the interior unaffected area, which could be a potential habitat for forest interior wildlife species. The core area is defined as the area within a patch beyond some specified edge distance or buffer width (Fig. 3.1). The core area has been found to be a much better predictor of habitat quality than patch area for forest interior specialist wildlife species (Temple 1986).

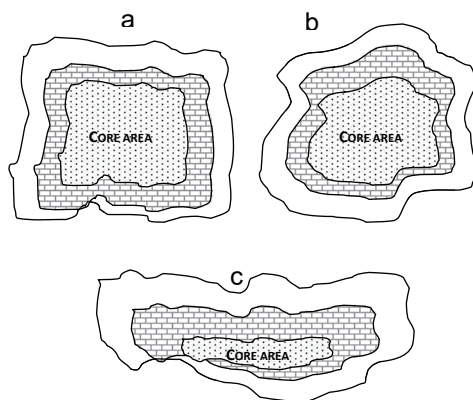


Fig. 3.1 The core area effect due to varying shapes at the specified edge distances of 250 m and 500 m: (a) square, (b) circular and (c) rectangular patches.

Studies on edge effects revealed that edges have significant influence up to 250 m inside of a forest patch, which may have direct or indirect effects on most life forms of an ecosystem and it should be doubled while considering for wildlife management purposes (Laurance & Bierregaard 1997). Hence, the core areas were measured at edge distances of 250 m and 500 m among all the forest patches considering the views of various studies for assessing edge effects and microhabitat conditions at the varying interior edge distances, referred above. Unlike patch area, core area is affected by patch shape. Thus, while a patch may be large enough to support a given species, it still may not contain enough suitable core area to support the species.

3.2.5 Forest fragmentation

Fragmentation is the tendency of land cover in breaking down to smaller patches (Forman, 1995; and Frohn, 1998). The fragmentation can be defined as ‘the number of forest and non-forest patches per unit area’, and can be measured as the density of all types of patches (Romme, 1982; Roy & Tomar, 2001). Landscape analysis programme (LAP) in Bio_CAP using Borland C++ provided a good measure of forest fragmentation in which iteration of involving convolution of a specific size moved over a spatial data for deriving the number of patches under forest and non-forest categories. First, the land cover map was reclassified in two classes, *i.e.* forest and non-forest cover to quantify the levels of forest fragmentation, subsequently a window of 250 m x 250 m was convolved with the forest/non-forest map to derive the number of forest patches within the window. The iteration was repeated by moving the window through the entire forest/non-forest map. The outputs of GIS analysis were provided in the form of normalised data of the patches per cell in the range of 0 to 10 (**Table 3.1**) and a fragmentation image depicting specific locations of various levels of forest fragmentation.

Table 3.1 Fragmentation values using Bio_CAP

Fragmentation value	# Pixels (Millions)
2	495920.50
3	466651.25
5	222004.50
6	56329.50
8	9388.25
9	1656.75
10	530.16
200	104375.25

3.3 Results

The land cover classes, which could be delineated separately in given mapping efforts at available coarse resolution of satellite data (23.5 m) included the TMEF, TSEF, and TMDF, Bamboo growth & Young secondary forests up to 6 years old, *Shola* type forests along with associated grasslands at Balpakram plateau, Habitation/abandoned *jhum*, Agriculture/sand, Shifting cultivation/ grasslands and Waterbodies especially rivers as visible through digital data (**Fig. 3.2**).

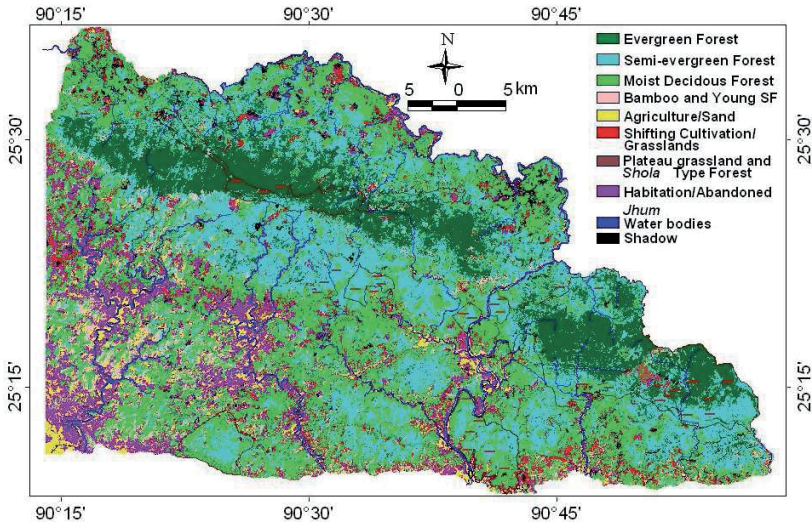


Fig. 3.2 Land use land cover map of Landscape

Six of these nine land cover classes including various land uses and forest type were grouped into two broad categories, *i.e.*, i) land uses, including land area under habitation, permanent agriculture and *jhumming*; and ii) old forest growth including TMEF, TSEF, and TMDF. The classification accuracy for these two broad categories was 100% except the intermingled growth of Bamboo and grassland patches within the old forest growth, which contributed a low proportions as revealed by the land use and land cover map of landscape generated during present study (Fig. 3.2).

3.3.1 Patch characteristics

The analysis of patch statistics derived from the polygon attribute table of finally classified land use the land cover map provided the basis for making the quantitative description of landscape composition and configuration. All patches with minimum 0.01 km² or 1 ha area were considered for further analysis in order to avoid the pseudo-representation of a large number of small sized patches, most of which had been arisen due to an error in data processing and misclassification

of certain patches of landscape elements (**Appendix 1** for detailed patch statistics).

The landscape was mosaic of 227 977 patches and constituted 2459 km² land, however, the majority of the land base, *i.e.*, 84% of the total landscape was confined to 20 914 big size patches (patches with ≥ 0.01 km² or 1 ha area). The mean patch size ($\pm$ standard deviation) was 0.10 ± 1.23 km² with mean edge length ($\pm$ standard deviation) for all patches was 3 ± 18 km. The overall patch and edge densities of the landscape were 10 patches per/km² and 28 km/km², respectively. The largest patch occupied nearly 5% of entire landscape area and represented by the old forest growth, specifically, the TSEF. The majority of these patches represented the smaller patch size classes, for example, 90% of all patches were smaller to 0.1 km² or 10 ha area, which all together constituted 84% area of selected patches (≥ 0.01 km² or 1 ha area). There were only 201 such patches with at least 1 ha (0.01 km²) area, which comprised the 55% area of the landscape (**Fig. 3.3**).

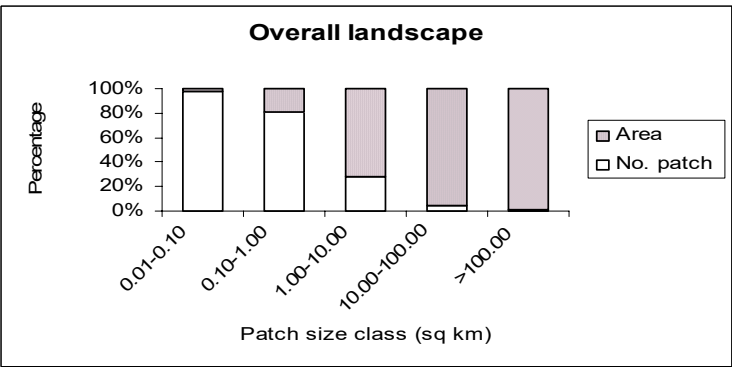


Fig. 3.3: Proportion of landscape area under various patch size classes

3.3.2 Land use

All land use patterns were observed for 7435 patches, which collectively comprised 17% of total landscape area (**Appendix 1**). The mean patch size ($\pm$ standard deviation) was 0.05 ± 0.25 km² with mean edge length ($\pm$ standard deviation) of 2 ± 6 km. The overall patch and edge densities of the landscape

were 21 patches/km² and 37 km/km², respectively. The largest patch occupied nearly 4% of entire landscape area and represented by the inhabited area in the south-west of landscape. Like patch characteristics of landscape, the majority of patches were observed for smaller size classes, 98% of all patches were smaller than 0.1 km² or 10 ha area, which all together constituted only 49% of total landscape area. The biggest 20 patches, each covering minimum of 1 km² area constituted 20% area of the landscape (Fig. 3.4).

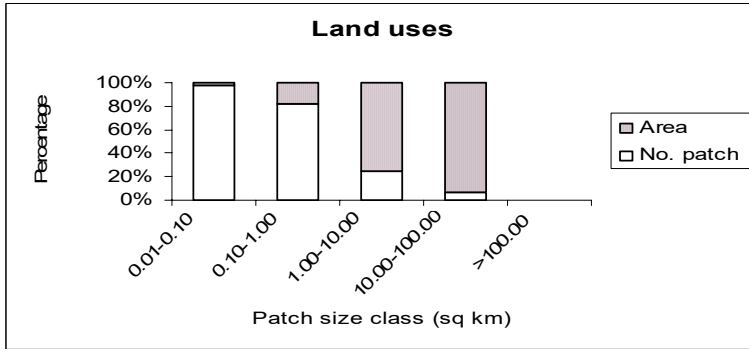


Fig. 3.4 Proportional area of all land uses under various patch size classes

The habitation, settled agriculture and *jhumming* were observed for 9%, 4% and 4% area of landscape, with the largest patch indices of 0.52, 0.17 and 0.04, respectively (Appendix 1). The mean patch sizes ($\pm$ standard deviation) were 0.06 ± 0.38 , 0.06 ± 0.16 , and 0.03 ± 0.04 km² with mean edge length ($\pm$ standard deviation) of 2.22 ± 9.69 , 1.66 ± 2.23 , and 1.32 ± 1.26 km, respectively. The overall patch and edge densities of the landscape were 16, 17 and 33 patches/km², respectively.

3.3.2.1 Habitation/abandoned jhum

The habitations in the form of small to medium sized settlements of several clans of Garo people occupied about 10% of the landscape and largely inhabited by 712 *Akings* (or villages). These *Akings* belong to the four Community Development Blocks (CDBs) of Garo Hills with a crude population density of 45 persons/km². Rongra CDB with a crude density of 25 persons/km² is the least human CDB,

mainly because a large portion of this block was protected as BNP during the mid 1980s. Chokpot CDB has the maximum number of villages, which indicates the higher level of forest fragmentation in this particular block. Altogether, 107,167 persons were living in the landscape (DSE, 1995) and most of them depend on agriculture production and practise the permanent cultivation in valley plain areas and *jhum* cultivation in hilly areas (**Table 3.2**).

Table 3.2 Human population and settlements in the study area

Community Block	Development	Area (km ²)	Inhabited Villages	Population	Density (Person/km ²)
Chokpot		612	337	29464	48
Baghmara		651	145	33255	51
Rongra		587	102	14345	25
Samanda		547	128	30094	55
Total		2397	712	107167	45

Source: Directorate of Economics and Statistics (DSE, 1995)

3.3.2.2 Permanent agriculture

A small portion occupying only 4% of the landscape was used for cultivating paddy and other crops through settled or permanent agriculture, most of which was confined in the valley plains or lower hills at gentle slopes around habitation. The major crops include paddy, maize, jute, cotton, ginger and mustard. Subsidiary crops are millet, pulse, potato, sesamum, chilly, turmeric, tobacco, tapioca, sweet potato and soya bean. Vegetables include pumpkin, gourd, cucumber, brinjal, onion, peas, carrot, melon, radish, turnip, garlic, beans, cabbage, cauliflower, tomato and others. Fruits include the papaya, pineapple, orange, jackfruit, *litchi*, mango, pears cashew nut, banana and areca nut. Most agricultural crops are subjected to a variety of air- and soil-borne pathogens as well as pests. Major pests of these crops are wild animals. Herds of elephants occasionally visit the crop fields and cause considerable damage to the crops. Wild pigs, sambar, rodents and other herbivores also harm the agricultural crops. Animal husbandry is being practised at a smaller scale in the form of poultry,

piggeries. Since the cattle rearing is not very popular in the area, so the livestock grazing is limited and restricted to a very small portion of community lands, which is mainly confined to areas around the habitation areas only.

3.3.2.3 Shifting cultivation

The land under shifting cultivation was much higher compared to settled agriculture and occupied about 7 % of landscape area. One-third of total families were engaged in practising *jhum* agriculture (DSWC, 1995) and covering 47 km² of land area at a time (for one cycle of *jhum*), which is about 2 % of the landscape (**Table 3.3**). The land consumption per family for *jhumming* varied from 0.28 ha (for Rongra CDB) to 0.80 ha (for Chokpot CDB) of land.

Table 3.3 Families engaged in *Jhumming*

Community Development Block (CDB)	Total no. of <i>Jhumia</i> families	<i>Jhum</i> area (ha/family)	Total area under <i>Jhumming</i> (km ²)	Total Households
Chokpot	2991	0.80	24	5519
Baghmara	763	0.70	5	6175
Rongra	989	0.28	3	2698
Samanda	1960	0.75	15	5782
Total	6703	0.70	47	20174

Source: Directorate of Soil and Water Conservation (DSWC, 1995)

3.3.3 Forest cover

In the case of forest cover classes, a total of 8921 patches were recorded, which constituted 75% of total landscape area (**Appendix 1**). The mean patch size ($\pm$ standard deviation) was 0.17 ± 1.86 km² with mean edge length ($\pm$ standard deviation) of 4 ± 27 km. The overall patch and edge densities of the landscape were 6 patches/km² and 24 km/km², respectively. The largest patch among all

forest cover classes occupied nearly 7% of entire landscape area with the largest patch index of 4.12 and represented by the TSEF patch situated over community land in the Tura Ridge area. The majority of patches under forest cover were observed for smaller size classes, 98% of all patches were smaller to 0.1 km² or 10 ha area, which all together constituted only 33% of total landscape area. The number of patches with minimum 1 km² was comparatively much higher compared to land uses with 174 patches covering 42% area of the landscape (Fig. 3.5).

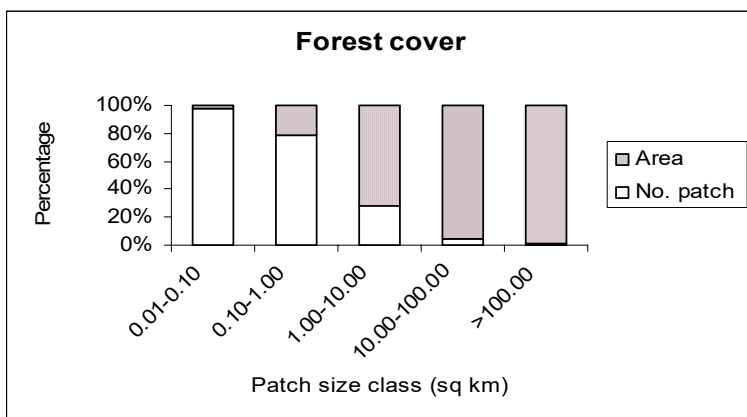


Fig. 3.5 Proportional area of old forest growth under various patch size classes

The distinct forest types identified during present study correspond to the standard forest types based on the revised classification scheme by Champion & Seth (1968). These forest types include TMEF, TSEF and TMDF, which all together constitute 68% of the landscape. The TMEF represented the old primary forest growth and occupied about 14% of the landscape. The TSEF growth mostly buffered the TMEF and occupied 26% of the landscape. Most forest growth within TSEF supported primary forest vegetation except in some area where the edges coincide with the areas under anthropogenic influences especially historic *jhum* activities, which contain the old secondary forest growth usually 30 years of age or older. The TMDF (29% of landscape) usually associated with the forest growth at fringes of human settlements or habitations and other land use subjected to frequent anthropogenic disturbances. Such forests usually had the semblance with the mature secondary forest growth (15 to 30 years old). This particular

forest type was found very closely associated with sal growth within reserved forests and community land. Among protected areas, the Siju Wildlife Sanctuary exceptionally had the extensive growth of sal forests in the core of sanctuary because it was a reserved forest prior to 1979 and subjected to the regular silvicultural treatments by State Forest Department of Meghalaya under ‘Sal Selection Working Circle’.

3.3.4 Core areas

The core area analysis revealed 2236 patches as specific core areas within old forest growth, covering an area of 561 km² of forested land, assuming a 250 m edge distance, which decreased to 644 patches with a total area of 291 km² when the edge distance was doubled (**Table 3.5**). At an edge distance of 250 m, nearly 92% of the patches (below 0.1 km² or 10 ha) were found with less than 5 percent of the available core area, while 5 patches in larger sized categories (>10 km²) constituted 78% of core area (**Table 3.5** and **Fig. 3.6**). In the case of 500 m edge distance, 80% of smaller sized patches (<0.1 km²) contributed less than 4% of available core area; however, the four larger patches (>10 km²) contributed 73% of the total core area (**Table 3.4** and **Fig. 3.7**).

Table 3.4 Distribution of core areas of forest patches at various edge distances

Size Class	No. of core areas	Area (km ²)	% Area	No. of core areas	Area (km ²)	% Area
	core area at 250 m edge distance			core area at 500 m edge distance		
<1 ha	1430	4	1	285	2	1
1-5 ha	494	11	2	165	4	1
>5-10 ha	126	9	2	63	4	2
>10-50 ha	134	29	5	103	21	7
>50-100 ha	28	21	4	11	7	2
1-5 km ²	16	31	6	10	19	7
>5-10 km ²	3	20	3	3	21	7
>10-50 km ²	3	41	7	2	56	19
>50 km ²	2	395	70	2	157	54
Total	2236	561		644	291	

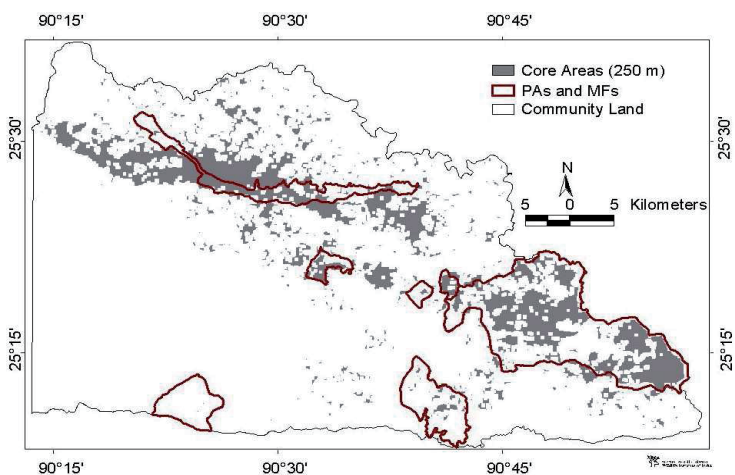


Fig. 3.6 Core areas at specified distance of 250 m

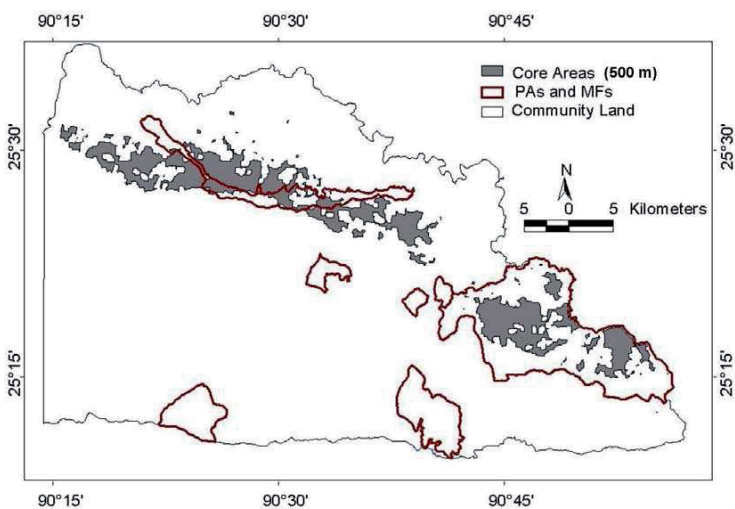


Fig. 3.7 Core areas at specified distance of 500 m

3.3.5 Fragmentation

The output image from Bio_CAP analysis suggested eight fragmentation categories, referred to the fragmentation value (**Table 3.6**). The count gives the number of pixels under particular fragmentation value. These fragmentation values were then re-classed into four categories by combining 2 and 3 as 1; 5 and 6 as 2; 8, 9 and 10 as 3 and the 200 as 4. The re-classed fragmentation values of 1, 2 and 3 were identified as areas under low, medium and high levels of forest fragmentation areas, whereas 4 represented the non-forest land (**Fig. 3.8**).

The majority of old forest growth was intact or subjected to a very low level of fragmentation, which accounted for 71% area of the landscape. Only 1% of the landscape was under medium high fragmentation, while medium fragmentation was observed over 21% of the landscape. Fragmentation analysis revealed that 8% of the landscape was devoid of any forested patch within the windows of specified size (250 m x 250 m) convolved over forest and non-forest map (**Table 3.5** and **Fig. 3.8**).

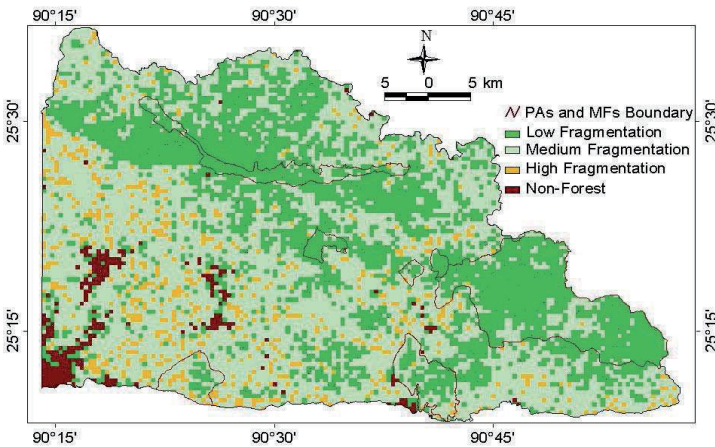


Fig. 3.8 The map showing various levels of forest fragmentation

Table 3.5 The levels of forest fragmentation over landscape

Fragmentation value	Re-classed value	Fragmentation level	Area (km ²)	
2	1	Low	898	1742
3			845	
5	2	Medium	402	504
6			102	
8	3	High	17	21
9			3	
10			<1	
200	4	Non-forest	189	189

3.4 Discussion

The land use and a land cover map generated during present study could not differentiate all land use categories distinctively but grouped them into three broad categories depicting area used by native *Garo* people for habitation, permanent agriculture and *jhumming*. Also, these land uses were intermingled with surrounding degraded forest growth, scrub areas and grasslands. All patches covering minimum of 1 ha areas were used for further analysis of landscape conditions, which revealed that various land use activities were confined to only 17% area of landscape compared to 75% area under intact forest cover, while rest of the land was covered by non-forest cover, which was unoccupied by the human activities.

Total bamboo growth along with young secondary forest growth occurred on 5% of land area. The extensive patches of bamboo growth and the young secondary forests up to six years constituted the majority of the non-forest cover of the landscape, which provided important habitats for several wild species and valuable services to the human society. The grasslands along with adjoining *Shola* type vegetation at Balpakram plateau constituted very small portion (0.1%

of landscape) of Balpakram National Park, which provided habitat to Indian Bison or Gaur, Malayan giant squirrel, grass owl and several other species.

Some localities at Nokrek ridge and within the gorges of Balpakram area covering 3% of the landscape could not be identified for any of above-mentioned land cover classes either due to the presence of persistent cloud cover or deep gorges or some other landforms and were referred as a shadow in the present study. The majority of such lands were represented by the steep slopes, which were overshadowed by adjoining higher hills and provided a range of unique habitats of geomorphic origin, such as a cave, talus and cliffs providing habitats for specialist wildlife species, for example, serow, rodents, reptiles, amphibians and other sundry invertebrates. Such areas act as indicators of specific microenvironment facilitating the formation of specific microhabitats for specialist wild species, for example, citrus at the Tura ridge and serow in the deep gorges formed by the major rivers, especially Mahadeo in Balpakram area.

The analysis of patch characteristics revealed that there were 201 patches each with minimum one km² of the area. Lower mean patch size and edge length of land use patches compared to those of forest cover patches suggested that fragmentation in the area is setting at its initial stages and the landscape still holds larger tracts of old forest cover. The higher patch and edge densities confirmed the findings revealed by mean patch sizes and edge lengths referred above.

The largest patch index was very high for forest patches measuring 4.12 compared to 0.53 for land use patches, which indicated that specific landscape characteristics were largely governed by the forest patches instead of land use patches, which had the least influence over the landscape. The coefficient of variations (for patch size and edge length) would be useful for comparing various subsets (or segments) of landscape (specific protected area or reserved forest, for example, Balpakram or Nokrek National Parks) with similar standard deviations (for patch size and edge length) with highly varying mean patch sizes. These spatial indices (**Appendix 1**) were presented along with other indices and could be used to compare various segments of landscape as per the need of management options.

The land in *Garo Hills* was chiefly used for residential and agricultural purposes by society. The residential areas were very closely associated with the horticultural gardens and other green vegetation around houses. This made the discrimination of settlements from adjoining degraded scrub areas difficult through remotely sensed data at 23.5 m resolution. The most areas around settlements were extensively used for *jhumming* till recent past, hence the degraded scrub areas were concentrated around villages or settlements. For agricultural purposes, all culturable land is being used either for settled permanent agriculture or *jhumming*. These permanent agricultural fields could not be differentiated with sandy river banks in valley plains due to the spectral similarity of satellite data. Likewise, the *jhum* fields or shifting cultivation areas were classified with the seasonal grasslands, which were growing parallel to the *jhum* fields in adjoining areas.

Baghmara and Rongra CDBs collectively accounted for 8 km² land under *jhumming*. These areas could be projected as model areas to determine the appropriate land allocation to the native *jhumia* families for *jhumming* purpose. Long-term monitoring plots could be set up to observe various forest and wildlife communities for predictive modelling within these CDBs. The land use land cover map and other spatial analysis of landscape would help identify the locations, which could be opened or closed for *jhumming* after a careful examination by ecologists, managers and planners. Some of such localities could be set up as demonstration areas to initiate some pilot projects for regulating the practice of *jhum* with adequate land allocation guidelines as a practical approach towards broad scale conservation planning of landscape and its biodiversity.

Finer resolution satellite data could not very precisely delineate the specific land use activities, however, the mapping efforts at 23.5 m x 23.5 m pixel resolution during present study could be used to locate specific sites for implementing land management activities, such as proposing further land acquisition by state government or allocating land for guiding *jhum* regulations to help protect the potentially viable forest patches, for example, all patches bearing large enough core area within unprotected community land. Several forest patches around existing protected areas and Baghmara, Angratoli Reserved Forests are the best examples of such area, which have been providing promising habitats to the hoolock gibbons, which gradually disappeared during past couple of decades and

become locally extinct from these areas. The spatial analysis revealed a total of 2236 patches with a total core area of 561 km² at the edge distance of 250 m, which decreased to 644 numbers and 291 km² when edge distance doubled. The management may think to adopt some of such sites for implementing restoration programmes for specific wildlife habitats.

The forest cover of landscape formed matrix of patches of young to old primary forests and younger secondary forests, which were developed over decades as results of prolonged practice of *jhum* over the landscape. The impact of *jhum* can be described by identifying the levels of forest fragmentation and the distribution over the landscape. Fortunately, 71% of landscape area accounted for low fragmentation level, while most of the medium or high fragmentation areas concentrated in the south-west corner of the landscape. This portion lies on the flat land in the south of Nokrek ridge and quite away from the Balpakram area, both having the important protected areas in the region. This particular piece of land belongs to the Chokpot block, which was represented by the highest village density among all four blocks of the landscape. The majority of *jhum* patches were recorded from this block with a total of 26% area supporting 46% *jhumia* families of the landscape. The other blocks seem to have moderate land use activities and the least affected by the fragmentation, where low to moderate levels of fragmentation was reported. The *jhum* regulation guidelines would help to keep the situation under control in these low fragmented community developmental blocks sustaining protected areas and reserved forests of the landscape.

4. FOREST COMMUNITY ANALYSIS

4.1 Introduction

For effective conservation planning of the precious forest and wildlife resources of *Garo Hills*, planners and managers essentially need to know the undergoing vegetation patterns and processes occurring within various forest communities at stand level or finer scale. This would help in describing the old forest growth and distribution of species for stand level assessments for promoting the decision-makings at specific levels. The prevalence of rather destructive land use practices is the major cause of the destruction of natural forest wealth in the *Garo Hills*. For example, *jhumming*, the most widely used traditional practice in the *Garo Hills*, which is being practised at large scale and faster pace than ever; and by which native population is consuming more forest growth annually and forming patches of secondary forest growth. These secondary forests wherever get the opportunity to grow, provided a variety of habitats with a specific composition of several plant species as food and cover, which supported the wide array of wild fauna inhabiting the tropical forest conditions in the *Garo Hills*.

We focused on the assessment of forest structure, distinctive forest types, species composition and the successional changes, all reflected by the most dominant life form of landscape, *i.e.*, tree species. As stated earlier in this volume, the trees are the robust indicator of changes at the landscape level and act as a tool for long-term monitoring of the status of native biodiversity in any forest ecosystem, thus selected to represent various communities of the old forest growth in the present study. The chapters one and two provided the useful insights on the utility of various tree species for native wildlife and cultural societies. Many studies have described vegetation characteristics and the diversity of other tropical forests of India and other parts of the world in terms of tree species (Singh *et al.* 1984; Parthasarathy 1986; Parthasarathy *et al.* 1992; Rai & Procter 1986; Jha & Singh 1990; Visalakshi 1995; Ganesh *et al.* 1996; Sundarapandian & Swamy 2000; Thorington *et al.* 1982; Hubbell & Foster 1983; Campell *et al.* 1986, 1992; Itow 1986; Ho *et al.* 1987; Procter *et al.* 1988; Swan 1988; Heaney & Procter 1990; Jaffre & Veillon 1990; Mosango 1991; and many

others), however, Meghalaya has remained largely unstudied except for a few landscape level assessments (Khan *et al.* 1997; Roy & Tomar 2001; Kumar *et al.* 2002; and Talukdar 2004) and a few surveys for describing the floristic of vascular plant species (Kanjilal *et al.* 1934-40; Rao & Haridasan 1981; Haridasan & Rao 1985; Kumar & Rao, 1985; Awasthi, 1999; and Tiwari *et al.*, 1999).

4.2 Methods

Most studies, as referred above, have described the evergreen, semi-evergreen and deciduous forests from several tropical regions of the India and world, however, these three forest types were not at all distinctive in actual field conditions, where the old forest growth existed as a mosaic of various forest growths either varying in terms of structural age classes or specific species composition due to other climatic or edaphic factors, for example, altitude. In most cases, it was extremely difficult to discriminate the semi-evergreen forest growth with its evergreen or deciduous counterparts, however, the patches of primary or secondary forest growth forms and age-old plantations of sal or *Shorea robusta* (>60 years old) constituted the entire old forest growth of the landscape and such patches were clearly identifiable in the field conditions. Thus, the present chapter discusses these old forests as growth forms of the forests (*i.e.*, primary or secondary forests) instead of various forest types (*i.e.*, evergreen or deciduous), which will be discussed in the subsequent chapter as typical forest types at the landscape level.

The primary field data and secondary information were used to evaluate tree species diversity and successional changes across several old forest growth forms of landscape. Several opportunistic surveys and stratified sampling were employed to collect the primary field data on tree species from various old forest communities. The species were confirmed with the records from herbaria of the Botanical Survey of India, Shillong, and the Wildlife Institute of India (WII), Dehradun. The leaves, twigs, and, where available, flowers or fruits of unidentified tree species were collected and referred to the herbarium section of WII, Dehradun for species identification. Their conservation status and potential habitats were gleaned from secondary sources including several publications (Kumar *et al.*, 2002; Rao & Haridasan 1981; Haridasan & Rao 1985; Kumar &

Rao 1985; Awasthi 1999; Nengminza 1996; Tiwari *et al.* 1999; and Kanjilal *et al.* 1934-40) and unpublished records with local NGOs, individuals, the State Forest Department, and other government agencies.

4.2.1 Field sampling design

The old forest growth including primary and secondary forests was surveyed along existing footpaths and elephant travel lanes using belt transects suggested for such conditions. In tropical forest conditions, usually the number of species is very high and obviously, a bigger sample with more area would be a better representative for widely distributed objects like tree species. Sykes & Horrills (1977) suggested using one ha plots to collect samples for tree species in the Indian tropical forests for monitoring the tree species of tropical Indian Tiger Reserves, which often laden with the dense growth of older trees. Preferably the square shaped plots with the dimensions of 100 m x 100 m should be laid down for sampling purpose, but, in most tropics, the extremely rugged and undulating terrain often does not offer the opportunity of laying down such a large sample inside forested tracts. In such cases, it was advised to lay down the rectangular plots or belt-transect covering one ha area, which may vary according to field conditions.

For present study, a total of 35 belt-transects (1000 m x 10 m, thus 1 ha each) were surveyed for various growth forms of primary and secondary forests, of which 17, 11 and 7 were in protected areas, reserved forests and community land, respectively (**Appendix 2**). Attempts were made to collect at least 3 sample plots from various formations of primary and secondary forests for acquiring representative sampling from a particular forest formation. The forest formations of primary forests represented by the forest growths at different elevations, corresponding to the spatial succession across the altitudinal gradient, while secondary forest formations were represented by the forest growths of varying age classes corresponding to the secondary succession across the temporal gradient.

The primary forests, secondary forest and sal plantations were the major identifiable growth forms of the native tropical forests and represented by the 21,

10 and 4 belt-transects among samples (**Table 4.1**). The ages of sample secondary forests were verified with the *Nokma* or village headmen or any other senior local resident of that particular *Akhing* land. The local names and girths of all those trees with ≥ 30 cm girth at breast height (gbh) were recorded.

Table 4.1 The distribution of samples among various identifiable growths of native forests. Used with the permission of Current Science.

Forest type	Primary Forests	Secondary Forests	Sal plantations	Total
Land stewardship				
Protected areas	12	5	-	17
Reserved forests	8	-	3	11
Community lands	1	5	1	7
Total	21	10	4	35

4.2.2 Stratification of forest growth

The primary forests were further categorised into three forest formations based on elevation: PF low ($n = 8$ belt transects) at <400 m elevation, PF mid ($n = 9$) at 400-800 m elevation, and PF high ($n = 4$ belt transects) at >800 m elevation, while all secondary forests were categorised into three broad classes, which were considered representing distinct successional stages based on age (years since stand-replacing disturbance, principally *jhum*): SF1 fifteen years or younger usually up to 6 years old ($n = 3$), SF2 between fifteen and thirty years ($n = 4$), and SF3 older than 30 years ($n = 3$). Studies in the *jhum* influenced the landscape of northeast Indian forests suggested that only after 30 years or so does any semblance of the older native forest regime tend to begin to reappear (DSWC 1995). Budowski (1965) analysed several characteristics of distinct successional stages of secondary forests and defined the five to fifteen years old secondary forest growths as early seral (successional) stages. The age classes suggested in the present study to stratify secondary forests have clearly different habitat values to different wildlife species. These age classes of young to old secondary forests were chosen to represent the distinctive

successional stages and observe the noticeable changes among tree communities, which otherwise occur gradually within tree communities of the landscape. The present study does not claim that these three classes are the standard age classes for observing the successional changes, however, it grouped the secondary forest samples in these three categories to describe the temporal changes among various tree communities.

4.2.3 Phytosociological analysis

The old forest growth was evaluated to describe the vegetation characteristics following standard formulae to describe the community structure of old forest growth (Misra, 1968). These vegetation characteristics can be expressed as a function of certain analytical characters, such as frequency, density, abundance, dominance and other characters for the target group of species. The frequency of tree species was expressed as the ratio of a number of sampling unit (belt-transect in the present study) of occurrence and total no. of sampling units. The frequency distribution indicated the structural heterogeneity of various forest growths in the study area. The percent frequency was computed and all tree species were grouped into five frequency classes (FC), *i.e.*, 1-20% (FC 1), 21-40% (FC 2), 41-60% (FC 3) and 61-80% (FC 4) and 81-100% (FC 5) as per Raunkiaer's law of frequency (Misra 1968).

The density and abundance represent the numeric strength of species in the community (Misra 1968). The density along with frequency help understand the distribution pattern of the species while abundance represents the number of individuals per unit area. The density was expressed as the no. of trees (stems) per belt-transect while the abundance as a number of individuals per belt-transect of occurrence. The ratio of abundance to frequency is a relative measure of the degree of contagiousness of the distribution of any species in a stand (Misra, 1968). High frequency with low abundance indicated the regular distribution of particular species.

Basal area refers to the ground actually penetrated by stems and represents the dominance and nature of the community (Misra 1968). The basal area was measured using gbh assuming the cylindrical shape of stems. The species

importance values (SIV) of tree species were computed as per Misra (1968), who used the term "importance value index" or IVI for the same. The SIV represented the cumulative influence of relative dominance (percentage basal area of a species), relative density (percentage individuals of a species), and relative frequency (percentage of occurrences of a species) of a tree species.

4.2.4 Similarity measures

The Jacard's (JI), Sørenson's (SI) and Czekanowski's indices (CI) were computed to measure the similarity among various old forest growths. The Jacard's and Sørenson's indices were based on the presence or absence of species shared between samples of vegetation and species unique to each sample. CI is similar to SI except that it considers the abundance of the species (Hmaier, 2002).

4.2.5 Species diversity and rarefaction analysis

The statistical software STATECOL was used to compute species richness (Menhinick index), diversity (Shannon-Wiener diversity index) and evenness (modified Hill's ratio) for various forest growths. The abundance of tree species was used to compute the above-mentioned diversity indices in various vegetation categories and forest formations (Ludwig and Reynolds, 1988). Since the correct application of these diversity measures are controversial for making valid comparison among two communities, which were sampled for different sample sizes, therefore, the species diversity pattern of tree species in primary and secondary forests along with several forest formations and successional stages was done using the rarefaction analysis, which produced a graph by plotting the expected number of species against the number of individuals drawn from a population to standardise the sample size for valid comparison amongst stands (Hurlbert, 1971; and James & Rathban 1981).

4.2.6 Test of the significance

The primary and secondary forests were compared using the t-test for equality of means when equal variances were not assumed to reject the first null hypothesis, which states, “*There is no difference between the tree diversity values of primary and secondary forests*”. The variables were no. of species, tree density, basal area, species richness (Menhinik index), species diversity (Shannon Index) and species evenness (Modified Hill’s ratio) for comparing these primary and secondary forests. The same variables were used to perform the analysis of variance (ANOVA) for comparing the identified formations of primary forests and successional stages of secondary forests, and testing hypothesis, which states, “*there is no difference among tree diversity values of the successional stages of primary and secondary forests*”.

4.2.7 Tree species versus successional changes

The successional changes were quantified across the age gradient among three seral stages of secondary forests represented by SF1, SF2 and SF3 along with the mature primary forests and identified four groups, each containing the top five tree species, based on following criteria:

- Species with the highest SIV representing the most important species in primary forests providing an idea of the invasion of the climax species during the course of time as a secondary forests converts into a primary forest;
- Species with the highest SIV representing the most important species in secondary forests;
- Important species providing food to the native wildlife; and
- Important species providing timber and other non-timber forest products to the native community.

Three species were common between groups 1 and 2 so the seven species were considered to discuss the quantitative changes among identified seral stages. The species included *Polyalthia simiarum*, *Schima wallichii*, *Castanopsis*

purpurella, *Syzygium cumini*, *Grewia microcos*, *Shorea robusta*, and *Macaranga denticulata*. The groups 3 and 4 were considered separately by plotting the SIVs of select species among various age classes or successional stages (**Table 4.2**).

Table 4.2 Identified groups of tree species selected for discussing the quantitative changes among various successional stages of tropical forests. Used with the permission of Current Science.

Group of tree species	Criteria of selecting species	Top five species
Group 1	Species with the highest SIV in primary forests	<i>Polyalthia simiarum</i> , <i>Schima wallichii</i> , <i>Castanopsis purpurella</i> , <i>Syzygium cumini</i> , and <i>Grewia microcos</i>
Group 2	Species with the highest SIV in secondary forests	<i>Schima wallichii</i> , <i>Castanopsis purpurella</i> , <i>Shorea robusta</i> , <i>Macaranga denticulata</i> , and <i>Grewia microcos</i>
Group 3	Species providing food for wildlife	<i>Grewia microcos</i> , <i>Artocarpus chaplasha</i> , <i>Syzygium cumini</i> , <i>Lepisanthes rubiginosa</i> , and <i>Artocarpus gomezianus</i>
Group 4	Species providing timber and other non-timber forest products to the native community	<i>Dillenia pentagyna</i> , <i>Terminalia citrina</i> , <i>Artocarpus chaplasha</i> , <i>Callicarpa arborea</i> , and <i>Careya arborea</i>

4.3 Results

The inventory of tree species revealed 411 tree species (71 families and 224 genera), of which majority of species (44% of all reported) were common, while 73 and 44 of them were reported as frequent and rare in the literature (**Appendix 3**). The broad habitats of various tree species as reported in the literature included the evergreen forests, moist deciduous forest, bamboo growth, cultivation areas, mixed evergreen forests, mixed deciduous forests, sal

forests, shady area, open areas, edges, secondary forests, dry sandy areas, road cuttings, rocky areas, dry areas, streamlets, plantations, *jhum*, and river banks (Appendix 3).

Through systematic sampling, a total of 29 884 trees were enumerated, which were identified for 165 different tree species (153 specifically identified to species level) among 54 families in primary, secondary, and Sal forests. The ten most frequent species across all vegetation types combined were *Castanopsis purpurella* (present in 33 belt-transects), *Syzygium cumini* (33), *Dillenia pentagyna* (32), *Sapium baccatum* (32), *Grewia microcos* (31), *Aporosa dioica* (30), *Litsea monopelata* (30), *Schima wallichii* (30), *Persea villosa* (29) and *Stereospermum chelonoides* (29). *Adina cordifolia*, *Anacardium occidentale*, *Bauhinia* spp., *Dysoxylum alliarium*, and *Lepisanthes rubiginosa* were the least frequent tree species, each occurring in only one belt-transect. The 10 most important tree species (listed in decreasing order of SIV) among all vegetation types were *Shorea robusta*, *Schima wallichii*, *Castanopsis purpurella*, *Polyalthia simiarum*, *Syzygium cumini*, *Grewia microcos*, *Aporosa dioica*, *Dillenia pentagyna*, *Drimycarpus racemosus* and *Eurya acuminata*. The ten most important tree species (listed in decreasing order of SIV values) in each vegetation type were:

PF: *Polyalthia simiarum*, *Schima wallichii*, *Castanopsis purpurella*, *Syzygium cumini*, *Grewia microcos*, *Drimycarpus racemosus*, *Dillenia pentagyna*, *Cynometra polyandra*, *Aphanamixis polystachya*, and *Walsura tubulata*;

SF: *Schima wallichii*, *Castanopsis purpurella*, *Shorea robusta*, *Macaranga denticulata*, *Grewia microcos*, *Syzygium cumini*, *Aporosa dioica*, *Eurya acuminata*, *Dillenia pentagyna*, and *Callicarpa arborea*; and

Sal plantations: *Shorea robusta*, *Glycosmis arborea*, *Schima wallichii*, *Artocarpus chaplasha*, *Syzygium cumini*, *Aporosa dioica*, *Vitex peduncularis*, *Sapium baccatum*, *Litsea monopelata*, and *Castanopsis purpurella*.

4.3.1 Community structure

The distribution pattern of frequency classes and the abundance to a frequency ratio of tree species represent the community structure patterns. Analysis of

Raunkier's frequency classes revealed that most of the tree species had a low frequency (**Fig. 4.1**) as would be expected in typical species-abundance distributions. The three vegetation types were not significantly different in frequency class distributions (likelihood ratio Chi-square = 13.32, df = 12, p = 0.35), although secondary forests had a somewhat higher proportion of species (63%) in low frequencies classes (FC1 and FC2) than did primary forests (57%). The low contagion, *i.e.*, low abundance and high frequency of a species indicated a regular or even spatial distribution, whereas the reverse indicated a clumped distribution.

The ten species with the most regular distributions in each vegetation type, listed in increasing order of abundance: frequency ratio, were:

PF: *Artocarpus gomezians*, *Artocarpus* spp., *Oroxylum indicum*, *Macaranga indica*, *Moringa oleifera*, *Alstonia scholaris*, *Rhus acuminata*, *Duabanga grandiflora*, *Albizia chinensis*, and *Ficus nervosa*;

SF: *Artocarpus gomezians*, *Garcinia tinctoria*, *Gmelina arborea*, *Pterygota alata*, *Mesua ferrea*, *Mallotus roxburghianus*, *Oroxylum indicum*, *Litsea sebifera*, *Rhus acuminata*, and *Saraca asoca*; and

Sal plantations: *Persea villosa*, *Schefflera* spp., *Vitex glabrata*, *Drimycarpus racemosus*, *Betula alnoides*, *Ficus gibbosa*, *Toona ciliata*, *Albizia chinensis*, *Careya arborea*, and *Emblica officinalis*.

The ten species with the most clumped distributions in each vegetation type, listed in decreasing order of abundance : frequency ratio, were:

PF: *Tectona grandis*, *Casearia glomerata*, *Boehmeria hamiltoniana*, *Ilex embelioides*, *Syzygium* spp., *Cinnamomum tamala*, *Castanopsis* spp., *Syzygium balsameum*, *Saurauia nepaulensis*, and *Shorea robusta*;

SF: *Castanopsis* spp., *Boehmeria hamiltoniana*, *Viburnum colebrookianum*, *Saurauia nepaulensis*, *Shorea robusta*, *Calophyllum polyanthum*, *Syzygium operculatum*, *Acronychia pedunculata*, *Lagerstroemia speciosa*, and *Schima wallichii*; and

Sal plantations: *Shorea robusta*, *Glycosmis arborea*, *Ficus infectoria*, *Actinodaphne augustifolia*, *Callicarpa arborea*, *Schima wallichii*, *Albizia odoratissima*, *Aporosa dioica*, *Salmalia malabarica*, and *Eurya acuminata*.

PF, SF, and sal plantations had 162, 132 and 87 tree species and 54, 53 and 37 tree families, respectively. Plots of rarefaction analysis (**Fig. 4.2**) revealed that, for a given sample effort, PF had significantly more tree species than did SF. Number of observed tree species (**Fig. 4.3**) and Menhinick's species richness (**Fig. 4.4**) both differed significantly among the three vegetation types (**Table 4.3**), being greatest in PF. In terms of presence and abundance of tree species, PF was most similar to SF, and sal plantations were least similar to both PF and SF (**Fig. 4.5a**). Neither mean tree density nor basal area differed significantly among the three vegetation types (**Table 4.3** and **Fig. 4.3**). However, Shannon-Wiener diversity and Hill evenness both varied significantly among the vegetation types (**Table 4.3**), being lowest in sal plantations (**Fig. 4.4**). Shannon-Wiener diversity was also significantly greater in PF than SF ($t = 2.99$, $df = 22$, $p = 0.007$; **Fig. 4.4**).

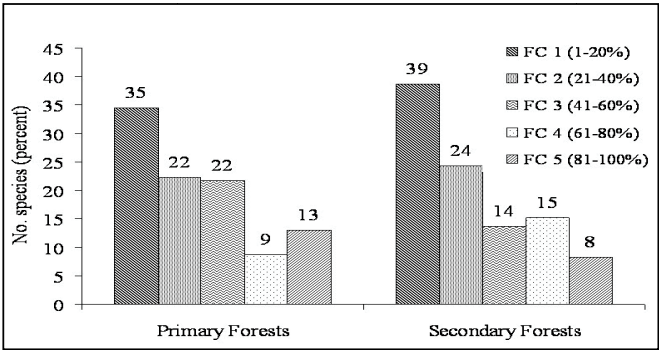


Fig. 4.1 Raunkiaer's Frequency Classes (FC) of tree species in primary forests. ($n = 21$ belt-transects) and secondary forests ($n = 10$). Used with the permission of Current Science.

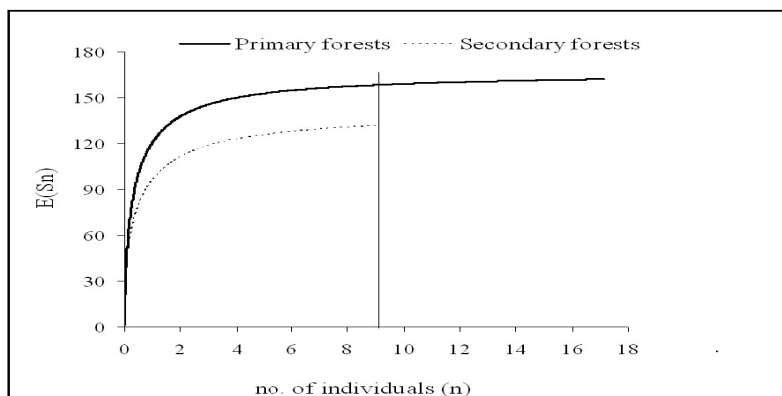


Fig. 4.2 Rarefaction curves for comparing tree species richness in PF (top curve; n= 21 belt-transects) and in SF (bottom curve; n= 10). $E(Sn)$ = expected number of tree species. Used with the permission of Current Science.

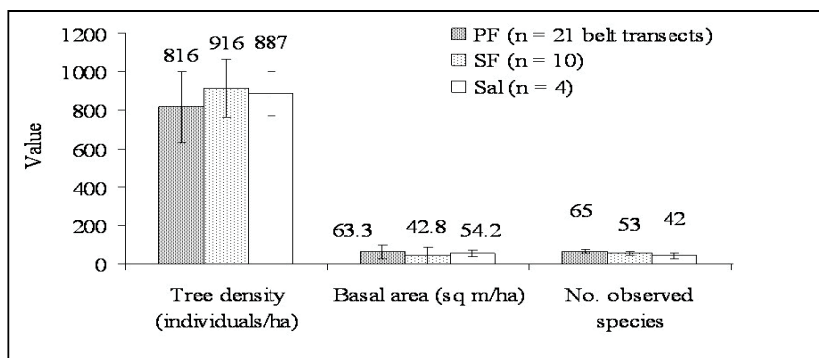


Fig. 4.3 Tree density and basal area in the three main vegetation types (error bars denote standard deviation); Primary forests (n= 21 belt-transects), secondary forests (n=10) and Sal (n=4). Used with the permission of Current Science.

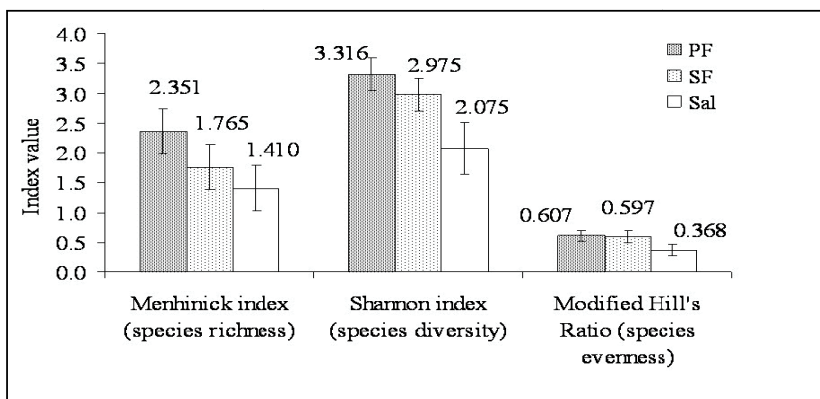


Fig. 4.4 Indices of richness (Menhinick), diversity (Shannon-Wiener), and evenness (Hill) of the three main vegetation types (error bars denote standard deviation); Primary forests (n= 21 belt-transects), secondary forests (n=10) and Sal (n=4). Used with the permission of Current Science.

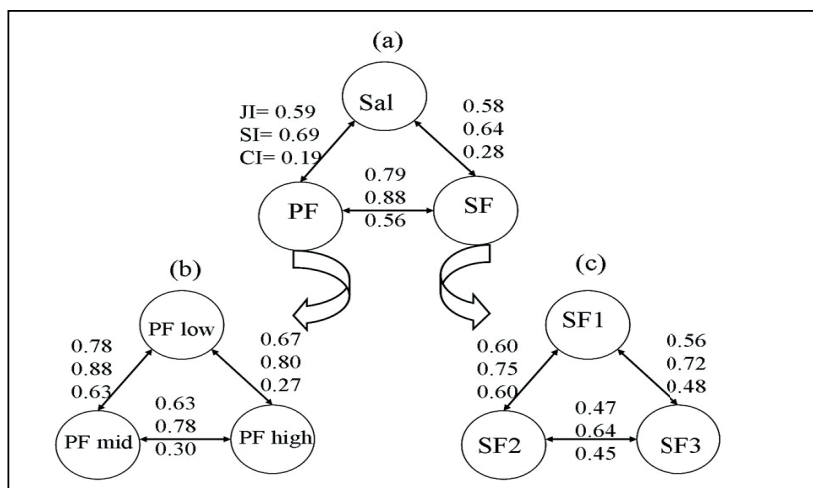


Fig. 4.5 Jacard's (JI), Sørensen's (SI), and Czekanowski's (CI) indices of similarity measured among: (a) three broad vegetation types of primary forest (n=21 belt-transects), secondary forest (n=10), and sal plantations (n=4); (b) three formations of PF; PF low (n=9), PFmid (n=8), PF high (n=4) and (c) three successional stages of SF; SF1 (n=3), SF2 (n=4) and SF3 (n=3). Used with the permission of Current Science.

Table 4.3 Statistical comparisons of tree parameters among 3 vegetation types, 3 primary forest formations, and 3 secondary forest successional stages. All tests used analysis of variance and $df = 2$. Used with the permission of Current Science.

Vegetation types		
	F	p
No. observed species	10.463	<0.0005 **
Tree density	1.230	0.306
Basal area	1.120	0.339
Menhinick richness index	9.574	0.001 **
Shannon-Wiener diversity index	23.956	<0.0005 **
Modified Hill's evenness index	9.898	<0.0005 **
Primary forest formations		
	F	p
No. observed species	1.458	0.259
Tree density	4.344	0.029 *
Basal area	14.635	<0.0005 **
Menhinick richness index	3.425	0.055 +
Shannon-Wiener diversity index	0.775	0.475
Modified Hill's evenness index	1.035	0.376
Secondary forest successional stages		
	F	p
No. observed species	2.634	0.140
Tree density	1.170	0.364
Basal area	7.089	0.021 *
Menhinick richness index	5.877	0.032 *
Shannon-Wiener diversity index	1.665	0.256
Modified Hill's evenness index	0.579	0.585

+ $P < 0.10$; * $P < 0.05$; and ** $P < 0.01$

Vegetation types: primary forest; secondary forest; sal plantation;

Primary forest formations: PF high, PF mid, PF low;

Secondary forest successional stages: SF1, SF2, SF3 (see text for descriptions).

Sample sizes of numbers of 1-ha belt-transects were 4, 9, 8 in PF high, PF mid, PF low; 3, 4, 3 in SF1, SF2, SF3; and 4 in sal plantation, respectively.

4.3.2 Primary forest formations

Primary forests were confined to the interior hills of Balpakram National Park and Nokrek Biosphere Reserve and National Park, around deep gorges of Simsang and Mahadeo Rivers, and in the surroundings of thinly populated habitation at higher elevations. The three primary forest formations were:

PF low: Low elevation primary forest patches were less humid, sometimes including a few deciduous tree species. The ten most important tree species in PF low formation, listed in decreasing order of SIV, were *Tectona grandis*, *Castanopsis purpurella*, *Canarium strictum*, *Polyalthia simiarum*, *Drimycarpus racemosus*, *Grewia microcos*, *Dillenia pentagyna*, *Tetrameles nudiflora*, *Schima wallichii*, and *Shorea robusta*.

PF mid: Mid-elevation PF supported vast tracts of dense forest cover, the major portion of which occurred in limestone areas. The ten most important tree species in PF mid formation were *Polyalthia simiarum*, *Walsura tubulata*, *Schima wallichii*, *Syzygium cumini*, *Cynometra polyandra*, *Grewia microcos*, *Shorea robusta*, *Drimycarpus racemosus*, *Castanopsis purpurella*, and *Sapium baccatum*.

PF high: High elevation PF occurred near Nokrek and Tura peak areas and in the high reaches of Chutmang (or Kailash) hills near Balpakram. This formation was characterized by a very humid microclimate. The ten most important tree species in PF high formation were *Aphanamixis polystachya*, *Syzygium operculatum*, *Castanopsis* spp., *Schima wallichii*, *Diospyros variegata*, *Castanopsis purpurella*, *Parapentapanax subcordatum*, *Garcinia cowa*, *Eurya acuminata*, and *Dillenia pentagyna*.

Number of observed species did not vary significantly across the three primary forest formations (Table 4.3 and Fig. 4.6), although Menhinick richness index was marginally lower in PF2 than in PF1 or PF3 (Table 4.3 and Fig. 4.7). The rarefaction analysis suggested that PF low was on average the most tree-diverse

followed by PF high and PF mid (**Fig. 4.8**). The three primary forest formations were fairly similar in terms of the presence of tree species, and when considering abundance, PF low and PF mid were far more similar than either was to PF high (**Fig. 4.5b**).

Tree density was significantly lowest in PF low, and basal area was significantly greatest in PF high (**Table 4.3** and **Fig. 4.6**). Tree species diversity and evenness did not differ significantly among three primary forest formations (**Table 4.3** and **Fig. 4.7**).

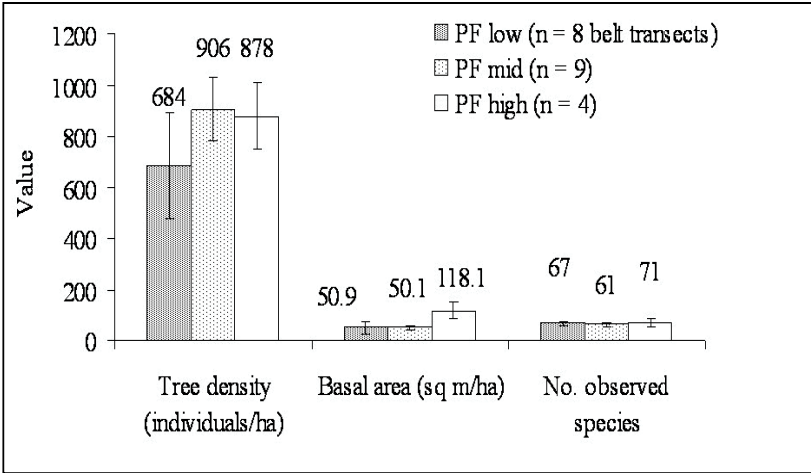


Fig. 4.6 Tree density and basal area in three primary forest formations (error bars denote standard deviation); PF low (n=9 belt-transects), PFmid (n=8) and PF high (n=4). Used with the permission of Current Science.

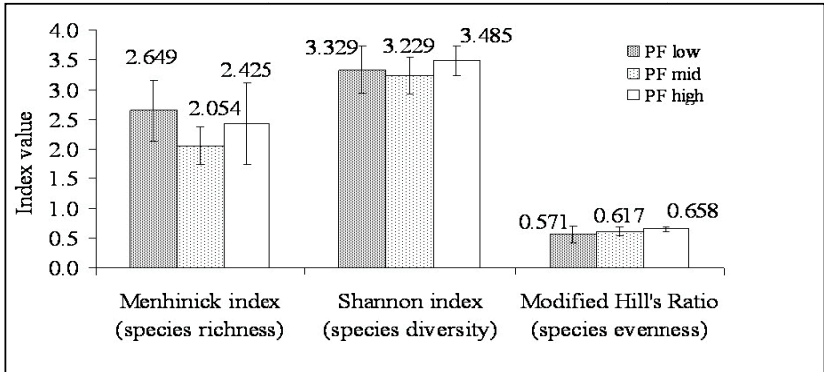


Fig. 4.7 Indices of richness (Menhinick), diversity (Shannon-Wiener), and evenness (Hill) of primary forest formations (error bars denote standard deviation). PF low (n=9 belt-transects), PFmid (n=8) and PF high (n=4) . Used with the permission of Current Science.

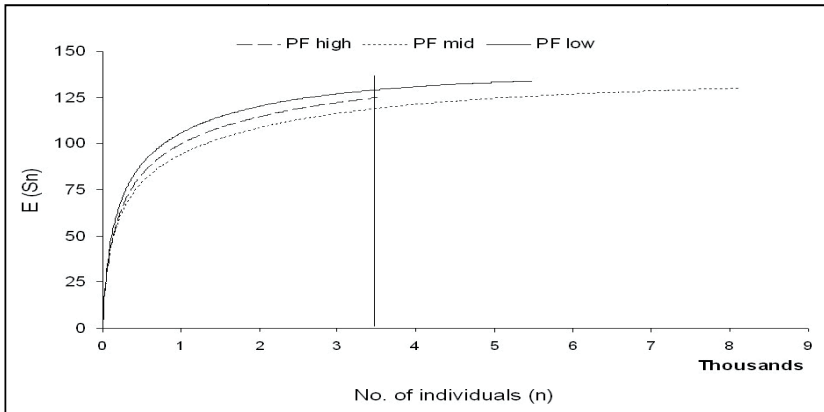


Fig. 4.8 Rarefaction curves standardising the number of samples for comparing species richness in three primary forest formations: PF high (n=4 belt-transects; middle curve), PF mid (n=9; bottom curve) and PF low (n=8; top curve). Used with the permission of Current Science.

4.3.3 Secondary forest successional stages

In the three SF successional stages, the ten most important tree species, in decreasing order of importance, were:

SF1: *Schima wallichii*, *Macaranga denticulata*, *Castanopsis purpurella*, *Syzygium cumini*, *Albizia odoratissima*, *Stereospermum chelonoides*, *Eurya acuminata*, *Persea villosa*, *Aporusa dioica*, and *Callicarpa arborea*.

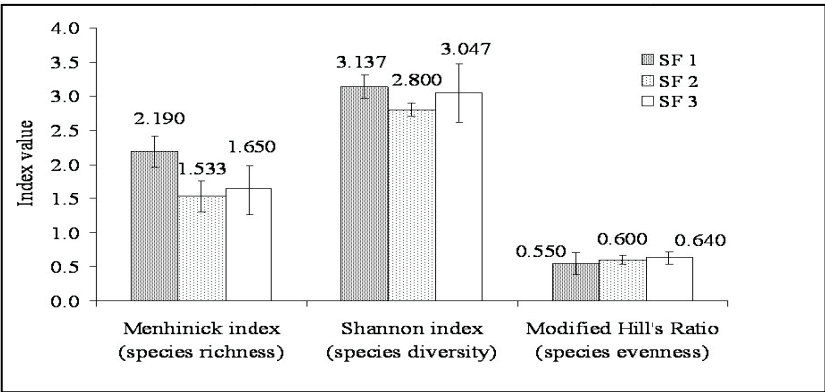
SF2: *Grewia microcos*, *Schima wallichii*, *Aporusa dioica*, *Macaranga denticulata*, *Castanopsis purpurella*, *Syzygium cumini*, *Terminalia bellirica*, *Shorea robusta*, *Holarrhena antidysenterica*, and *Callicarpa arborea*.

SF3: *Schima wallichii*, *Castanopsis purpurella*, *Shorea robusta*, *Eurya acuminata*, *Diospyros variegata*, *Dillenia pentagyna*, *Betula alnoides*, *Syzygium operculatum*, *Calophyllum polyanthum*, and *Castanopsis* spp.

Number of observed species did not vary significantly across the three secondary forest successional stages (**Table 4.3** and **Fig. 4.9**), although Menhinick richness index was significantly higher in SF1 than in SF2 or SF3 (**Table 4.3** and **Fig. 4.10**). The rarefaction analysis suggested that SF2 was consistently fewer species rich than SF1 or SF3 (**Fig. 4.11**). The three secondary forest successional stages were fairly similar in terms of presence tree species, and when considering abundance, SF1 and SF2 were more similar than either was to SF3 (**Fig. 5c**).

Tree density did not differ significantly among the three secondary forest successional stages, although basal area did, being far greater in SF3 than in SF1 and SF2 (**Table 4.3** and **Fig. 4.9**). Tree species diversity and evenness did not differ significantly among the three primary forest formations (**Table 4.3** and **Fig. 4.10**). Shannon-Wiener diversity and Hill's evenness did not vary significantly across the three secondary forest successional stages (**Table 4.3** and **Fig. 4.10**).

Fig. 4.9 Tree density and basal area in three successional stages of secondary forest (SF) (errors



bars denote standard deviation); SF1 (n = 3 belt-transects), SF2 (n= 4) and SF3 (n=3). Used with the permission of Current Science.

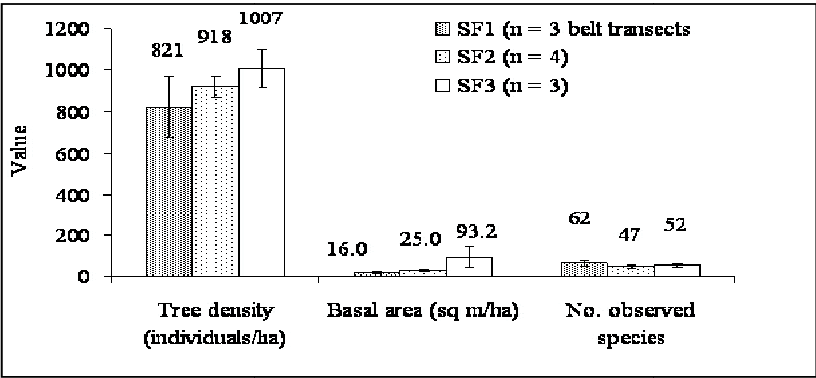


Fig. 4.10 Indices of richness (Menhinick), diversity (Shannon-Wiener), and evenness (Hill) of the three successional stages of secondary forest (SF) (error bars denote standard deviation); SF1 (n = 3 belt-transects), SF2 (n= 4) and SF3 (n=3). Used with the permission of Current Science.

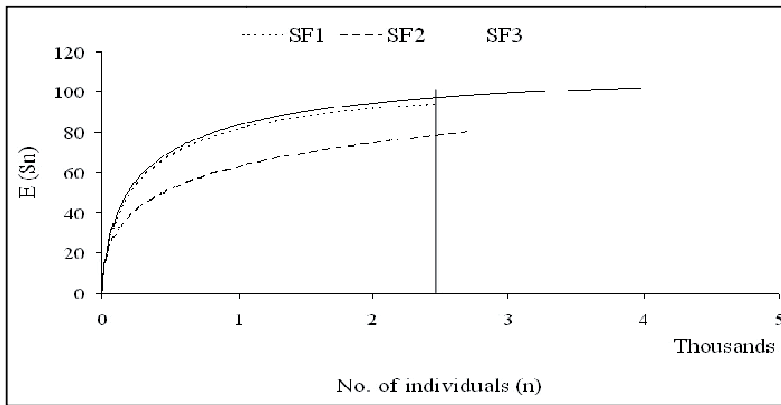


Fig. 4.11 Rarefaction curves standardising the number of samples for comparing species richness in three successional stages of secondary forest (SF). SF 1 ($n = 3$; middle curve), SF 2 ($n = 4$; bottom curve) and SF 3 ($n = 3$; top curve). Used with the permission of Current Science.

4.3.4 Successional changes

4.3.4.1 Group 1: Species with highest SIV

The top five tree species of primary forest, listed in decreasing order of overall importance values, were *Polyalthia simiarum*, *Schima wallichii*, *Castanopsis purpurella*, *Syzygium cumini*, and *Grewia microcos*. *P. simiarum* occurred occasionally in secondary forests and increased sharply in primary forest (Fig. 4.12). *S. cumini* contributed significantly in SF1 and SF2, followed by a general decline in SF3 and primary forest. The other three tree species showed higher levels in some formation of secondary forest than in primary forest. The findings confirm the fact that *S. cumini* is a secondary forest species.

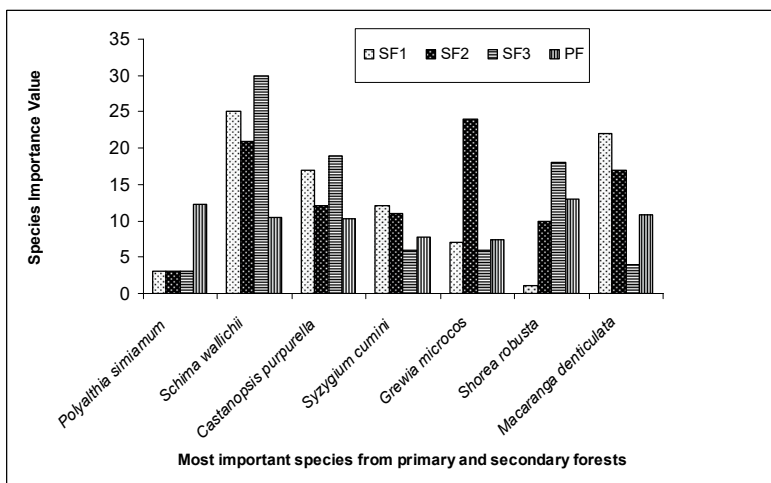


Fig. 4.12 Changing species composition of top 5 secondary forest tree species from primary and secondary forests amongst various seral stages representing temporal succession; SF1 (n=3 belt-transects), SF2 (n=4), SF3 (n=3), and PF (n=21). Used with the permission of Current Science.

The five most important tree species of secondary forests, among all three successional stages of secondary forest listed in decreasing order were *Schima wallichii*, *Castanopsis purpurella*, *Shorea robusta*, *Macaranga denticulata*, and *Grewia microcos*. These species changed their relative importance among the three secondary forest age classes and primary forest, as a function of forest age. *Schima wallichii*, *Castanopsis purpurella* and *Macaranga denticulata* colonised first among woody species on barren land following *jhum* (slash, burn, planting, and harvesting of crop plants).

Schima wallichii has the greatest importance in nearly all secondary and primary forest formations. In contrast, *Grewia microcos* increased very sharply between SF1 and SF2, and then declined through primary forest stages. *Castanopsis purpurella* showed less variation between secondary and primary forests. *Macaranga denticulata* was abundant in SF1, SF2 and declined thereafter. *Shorea robusta* was nearly absent in SF1 but increased thereafter, reaching maximum value in SF3 although still present in primary forest.

4.3.4.2 Group 2: Species providing food for wildlife

G. Microcos is the species which most animals in the study area used (Kumar *et al.*, 2002). This species did not show the extreme importance in SF1 but a significant increase in middle aged secondary forest, then again reduced drastically in old secondary and primary forests, still contributed significantly compared to other food species in this group. *S. cumini* showed the maximum importance in SF1 and SF2 and then sharply declined in SF3 and primary forest. These findings reveal that the middle-aged secondary forest is extremely useful for providing wildlife food and the shortened *jhum* cycle may reduce the availability of such forests causing native wildlife to lack food (Fig. 4.13).

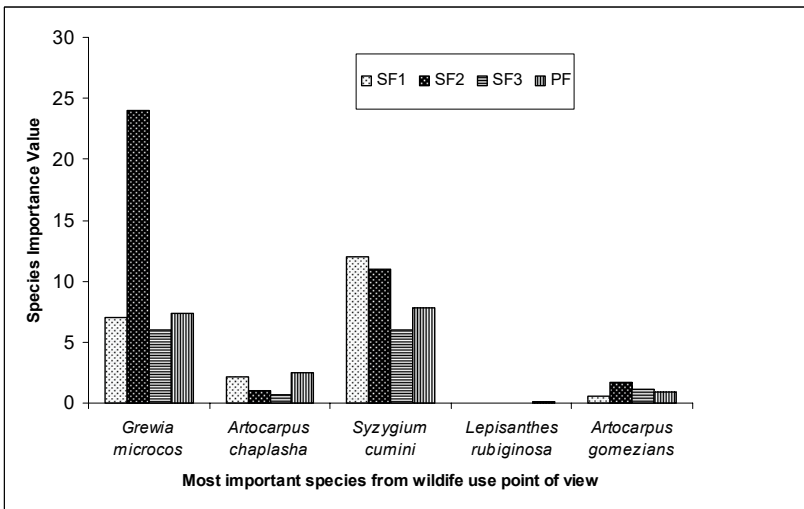


Fig. 4.13 Changing species composition of top five tree species as important for native wildlife; SF1 (n=3 belt-transects), SF2 (n=4), SF3 (n=3), and PF (n=21). Used with the permission of Current Science.

4.3.4.3 Group 3: Species providing timber and NTFP

Dillenia pentagyna showed little importance in SF1 and SF2, then a slight increase towards maturity, but did not contribute significantly in either category. *Callicarpa arborea* showed more importance in SF1 and SF2, but decreased significantly in SF3 and primary forest. *Careya arborea* and *A. chaplasha* showed the least in all seral stages (Fig. 4.14).

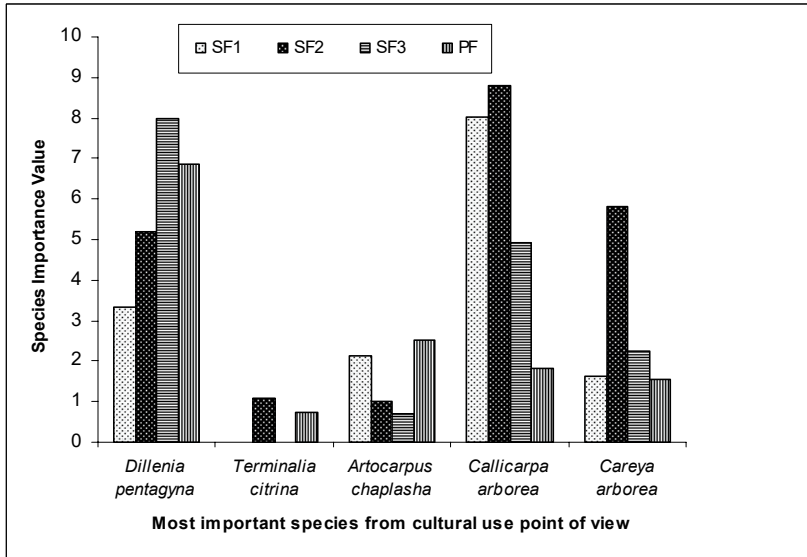


Fig. 4.14 Changing species composition of five tree species as important for native society; SF1 (n=3 belt-transects), SF2 (n=4), SF3 (n=3), and PF (n=21). Used with the permission of Current Science.

4.3.5 Comparison with other tropical forests

Ranges of tree density among the 3 vegetation types from the present study (417-1111 individuals/ha of trees >30 cm gbh) are within the ranges of estimates from a variety of other studies of tropical evergreen forest within India (294-1173 individuals/ha; **Table 4.4**). In general, tree density varies by forest community types, forest age classes, tree species and size class, site

history, site conditions, and other factors. Studies in tropical forests outside India also reveal a wide range of densities of trees >30 cm gbh, ranging from 98 trees/ha in Panamanian equatorial insular forest (Itow 1986) to 1720 trees/ha in the Amazonian tropical rain forest (Campbell *et al.* 1992) (**Table 4.4**). The tree density of landscape compared well with that reported from other tropical forests. The basal area recorded in this study ranged 12-162 m²/ha, the upper value being far greater than the highest value of 107 m²/ha in any tropical forests of the world (Parthasarathy *et al.* 1986). The high annual precipitation rate and equable tropical climate of the study area may have contributed to the high tree basal area, which was observed.

Table 4.4 Vegetation (tree species) characteristics of various forest communities in the tropics of India and other countries (- = not reported). Used with the permission of Current Science.

Forest type	Location	Plot size (ha)	Girth studied (cm)	Density (no./ha)	Basal area (m ² /ha)	Source
TROPICAL FORESTS IN INDIA						
Evergreen forest	Silent Valley, Kerala	-	≥ 31.5	620-709	29-103	Singh <i>et al.</i> (1984)
Tropical forest: Scrub jungle to wet evergreen forest	Kalakad RF, Western Ghats	0.2	>20	320-1260	18-107	Parthasarathy (1986)
Tropical wet evergreen forest	Kalakad RF, Western Ghats	1.0	>30	574-915	55-94	Parthasarathy <i>et al.</i> (1992)
Evergreen forests	Karnataka	0.44	-	466-1386	33-48	Rai & Procter (1986)
Dry tropical forest	Vidhyan region	-	>30	294-559	7-23	Jha & Singh (1990)
Dry Evergreen Forest	Marakkanam RF Coromandel coast	0.3	≥20	280	11	Visalakshi (1995)

Forest type	Location	Plot size (ha)	Girth studied (cm)	Density (no./ha)	Basal area (m ² /ha)	Source
Dry evergreen forest	Puthupet Sacred Grove Coromandel coast	0.2	≥20	1130	36	Vishalakshi (1995)
Tropical wet evergreen forests	Kakachi, Kalakad-Mundanthurai Tiger Reserve, W. Ghats	0.50	>30	315- 418	54-84	Ganesh <i>et al.</i> (1996)
Tropical wet evergreen forests	Kodayar, Western Ghats, India	0.5	> 30	352- 1173	28-81	Sundarapandian and Swamy (2000)
PF	South Garo Hills and adjoining Nokrek area, Garo Hills	1.0	>30	417 - 1023	29 - 162	Present study
SF	-do-	1.0	>30	620 - 1111	12 - 151	-do-
Sal plantations	-do-	1.0	>30	724 - 980	39 - 74	-do-
<i>TROPICAL FORESTS IN OTHER COUNTRIES</i>						
Tropical rain forests	Barro Colorado Island, Panama	5	60.0	171	-	Thorington <i>et al.</i> (1982)
Tropical rain forests	Barro Colorado Island, Panama	50	>62.8	152	-	Hubbell & Foster (1983)
Tropical rain forests	Amazonia	3	31.4	1420	28-68	Campbell <i>et al.</i> (1986)
Equatorial insular forests	Eastern Caroline Island, Panama	50	>31.4	98-114	17	Itow (1986)

Forest type	Location	Plot size (ha)	Girth studied (cm)	Density (no./ha)	Basal area (m ² /ha)	Source
Tropical rain forests	Jengka Reserve, Malaysia	11	91	104	23	Ho <i>et al.</i> (1987)
Tropical rain forest	Gunung Silam, Malaysia	0.04	31.4	513-1596	23-46	Procter <i>et al.</i> (1988)
Tropical moist forest	Singapore	0.4	>6.3	604	-	Swan (1988)
Tropical rain forests	Valcan Barva, Costa Rica	6	>31.4	391-617	-	Heaney & Procter (1990)
Slope forests	New Caledonia	2.8	>31.4	1533	49	Jaffre & Veillon (1990)
Alluvium forests	New Caledonia	2.6	31.4	1183	47	Jaffre & Veillon (1990)
Equatorial forests	Kongo Island, Zaire	-	-	440-553	10-45	Mosango (1991)
Tropical rain forests	Amazonia	3	>31.4	1720	78	Campbell <i>et al.</i> (1992)

The Shannon-Wiener values for species diversity in the present study were 4.27, 3.78 and 2.47 for primary, secondary and sal plantations, respectively, which are quite high compared to 2.20-2.65 for the tropical forests of Kodayar in the Western Ghats of southern India (Sundrapandian & Swamy 2000). More comparable values were reported from Silent Valley, Kerala, with diversity index values of 4.15, 4.08 and 3.52 in riparian, mesic upland and less-mesic upland communities, respectively (Singh *et al.* 1984). Diversity values in tropical forests of Kalakad Reserved Forests in the Western Ghats (Parthasarathy *et al.* 1982) were reported as 3.31 and 3.69, and in tropical forests of Barro Colorado Island in Panama (Knight 1975) as 4.8.

It is inappropriate to draw quantitative comparisons among these studies, however, because of significant differences in sample size, plot size and dimensions, choice of standard gbh by researchers, environmental conditions, and other site factors mentioned above. Still, it is useful to rank-order tropical forests by tree species richness, density, basal area, and diversity. In so doing, tropical forests from the present study rank as some of the most diverse and dense in the world.

4.6 Discussion

The practice of *jhumming* in the Garo Hills has become deleterious during last few decades, when surplus tribal population started approaching previous *jhum* fields frequently at shorter *jhum* cycles (fallow period between two subsequent clear-felling operations over same forest patch), which truncated the old forest growth in the region and created several formations of secondary forests, representing the successional stages of native forest growth. A study on *jhum* effects over old forest growth in the Indonesian tropical forests revealed the significant decline in tree species density and diversity due to prolonged practice of *jhumming* during a period of 200 years (with 10 prior *jhum* cycles) in the Bornean rainforests (Lawrence 2004). Fortunately, the landscape still holds considerable old secondary forest growths, sometimes up to 60 years old (personal communication with the owner of particular *jhum* land within the landscape). One hectare of such area was sampled in present study suggested that particular forest patch resembled more or less primary forests from the adjoining protected area, *i.e.*, Nokrek National Park.

A database of all plant species of Meghalaya mentioned the presence of total 830 tree species in Meghalaya including Garo, Khasi, and Jaintia Hills (Khan *et al.* 1997), of which 305 and 58 species were reported from low (0-750 m) and mid (750-1500 m) elevations, respectively. The Garo Hills area is represented within this altitudinal range and included the majority of old tropical forest cover of the state. The present study extended the existing databases on tree species, since it reported a total of 411 tree species from a relatively smaller landscape covering only one tenth of the geographical area of Meghalaya state. Available literature on the conservation status of tree species was very scanty

except for a few attempts made by some plant taxonomists (Haridasan & Rao 1988 and others) or some government and non-government agencies. There were only 44 tree species, which were mentioned as rare one in the literature, however, the databases of World Conservation Union (IUCN) and World Conservation Monitoring Centre (WCMC) did not have any of such species in their records. The present study would help update the extensive databases on tree species.

The potential species with poor representation in samples need the proper attention of plant biologists for ascertaining their conservation status and key functions. Some of the example species (in the increasing order of SIV) included *Disoxylum hamiltonii*, *Aristolochia tagala*, *Lapisanthus rubiginosa*, *Dillenia indica*, *Derris robusta*, *Pithecellobium monodelphum*, *Garuga pinnata*, *Bredelia tomentosa*, *Albizia stipulata*, *Adina cordifolia*, *Cassia fistula*, *Bauhinia malabarica*, *Hodgsonia macrocarpa*, *Ficus lamponga*, *Pithecellobium monadelphum* and *Citrus* spp.

Mapping concentration areas (showing map locations of spatial distribution of select tree species over landscape) and further studies on the key ecological and cultural functions of such species would help in determining the actual thrust areas for managing associated and dependant populations of selective wildlife species within South Garo Hills. The forest managers can make use of such information in day-to-day management from wildlife as well as cultural point of view. Apart from qualitative characteristics, the quantitative characters related with the density, dominance and diversity very well act as indicators of changes among various vegetation categories and their formations, which could be further interpreted as the distinct wildlife habitats.

The frequency distribution of tree species suggested that most tree species had low frequency as would be expected in typical species-abundance distributions, however, three main vegetation types including primary, secondary forests and sal formations were not significantly different in frequency class distributions, although, the secondary forests had higher proportion of species in the lowest frequency class, which indicated that SF was more heterogeneous compared to primary forests or sal plantations. This suggested that old forest growth in the

study area was a mosaic of intermingled vegetation classes, which did not vary much in terms of species-abundance distribution.

Tree species like *Artocarpus gomezians*, *Oroxylum indicum*, and *Rhus accuminata* had shown the most regular distribution (low abundance and high frequency) among both primary and secondary forests. Other species with regular distribution in given sample efforts included the *Macaranga indica*, *Moringa oleifera*, *Alstonia scholaris*, *Duabanga grandiflora*, *Albizia chinensis*, and *Ficus nervosa* among primary forest and the *Garcinia tinctoria*, *Gmelina arborea*, *Pterygota alata*, *Mesua ferrea*, *Mallotus roxburghianus*, *Litsea sebifera* and *Saraca asoca* among secondary forest samples.

The species like *Shorea robusta*, *Boehmerea hamiltoniana*, *Saurauia nepaulensis* had shown the most clumped distribution (high abundance and low frequency) in both primary and secondary forest samples. The study of the distribution pattern of several tree species would be of prime importance in deciding the management options for specific host populations of native wildlife, which otherwise may face the danger of local extinction due to frequent removal of old forest conditions in the *Garo Hills*.

Both of these forest growth forms, *i.e.*, primary and secondary forests had shown closer affinity with each other compared to that of sal plantations and most of the sal plantations represented a different set of the specific composition of trees. The three primary forest formations including PF high, PF mid and PF low were fairly similar when evaluated using presence and absence of tree species, but closer affinity was observed on the basis of abundance of tree species, however, three secondary forest formations (or successional stages) were quite similar to each other and shown closer affinity among themselves in both conditions. Tree density and basal areas were higher in primary forests, but they did not significantly different from secondary forests and sal plantations as occurred among PF formations, which revealed significantly lowest tree density in PL low and the significantly highest basal area in PF high. Among secondary forest formations or various successional stages, tree density did not differ significantly, although basal area did, being far greater in SF3 than in SF1 and SF2.

The numbers of observed tree species and associated diversity measures including species richness, diversity and evenness varied significantly among the broad vegetation types compared to several primary or secondary forest formations, for which only Menhinick index of species richness accounted for significant differences. The rarefaction analysis was a much better predictor to describe the differences among various forest communities (above discussed broad vegetation types and formations within) by equalising the sample sizes across all forest communities.

It suggests that primary forest always remained more tree diverse compared to secondary forests. Among primary forests, lower elevation formations were more tree diverse compared to primary forests at mid or high altitude, while old secondary forests (SF3) were more tree diverse among identified successional stages. The younger secondary forest growths (SF1) were more tree diverse compared to middle-aged secondary forests (SF2), which suggested the higher colonisation rate among tree species in the early successional stages. Though these findings revealed that secondary forests were less tree-diverse, however, one should not undermine the valuable services they are providing to the wildlife as well as human beings. There is a need for understanding the 'underlying causes' of SF formations and their subsequent dynamics, and how those underlying causes can be influenced by proper management of secondary forests and sustainable use their resources (De Jong *et al.* 2001).

For *jhumming* purposes, the *Garos* prefer the land earlier occupied by dense primary forests for getting maximum benefits of natural organic manures. As they abandon the land after growing and harvesting agricultural crops for 2 - 3 years, the pioneer plant species occupy the bare land, which included a very dense and impenetrable growth of stem of a few species during first few years.

The light-loving climbers (Convolvulaceae, Cucurbitaceae and Dioscoreaceae) grow like a blanket over the young secondary growth. Under the thick blanket, the young branches die due to lack of light and create the gaps in place of dense cover. The accumulated litter transformed into humus during the course of time giving the way to other species. If undisturbed, the succession proceeds: young

forest gives the way to the old secondary forest (Jacobs, 1981). Due to the long life of trees, the changes take place gradually, which are difficult to observe without very concrete and long term efforts.

Early successional stages occur between five to fifteen years old *jhum* fallows (Budowski 1965) with a few no. of woody species usually less than 10, which may go up to 50 in late successional stages, though present study revealed far more species, *i.e.*, 94 in early successional stages and 102 in old secondary forests.

The present study provided the first use of tree importance index (SIV) to quantify successional changes of secondary forests. Zhang and Cao (1995) described the secondary tropical forests of south-west China using importance values, in which they combined the effects of tree abundance and dominance on individual plots. The present study compared the SIV (denoting the combined effects of abundance, density and basal areas) of selected tree species within identified successional stages (age classes) of secondary forests. Forest succession following any disturbance, such as *jhum*, is reflected by secondary changes among tree communities, the major structural component of the vegetation (Misra, 1968) and present study quantified such changes for select species having important ecological and cultural values. One of the major food items, *Lepisanthes rubiginosa*, did not exist in SF and showed almost negligible importance in PF. Likewise, *Artocarpus chaplasha* and *A. gomezianus* showed very little importance. Tree species such as *L. rubiginosa*, *A. chaplasha*, *A. gomezianus*, *C. arborea*, which showed very little importance, need to be studied for their silviculture to work out how to make abundant populations.

This would be providing an idea for arresting desired successional stages for the benefits of wildlife and human beings. One of the important applications of these findings could be used for rationalising the ecologically sound fallow period with longer *jhum* cycle. This would help to implement adequate silvicultural treatment to the stands as per the needs of native wildlife and society.

Further, silviculture of these primary forest tree species coupled with analysis of various forest formations of primary forest, successional stages of secondary forest and response by individual tree species would provide information useful in recovering primary forest following clearing and developing a scientific foundation for forest management and biodiversity conservation. It would recommend a better form of regulated *jhum* to ensure that at least some patches and elements of primary forest could be restored and retained throughout the region to reduce the impact of forest fragmentation, which frequent *jhumming* is posing over the landscape.

5. FOREST CLASSIFICATION

5.1 Introduction

The wildlife managers very often confronted with finding ways to manage hundreds of species simultaneously, and in most cases, those species may not respond in a similar manner to environment gradient and management actions. The same would happen with the information on old forest growth described in terms of tree species in various forest communities (such as primary and secondary forests along with several formations and successional stages) generated during present study and provided in the previous chapter. All of those species could be aggregated into a manageable number of groups for management purposes. All forest growth forms of landscape need to be evaluated more rationally on scientific basis using standard statistical process. Among multivariate analysis techniques, the cluster analysis is one of the best ways to aggregate a large number of entities (species or sites) into fewer ones (McGarigal *et al.* 2000). The tree abundance data collected during present study and presented in an earlier chapter was further used to classify the old forest growth into more conventional classes, *i.e.* standard forest types based on the revised classification scheme suggested by Champion & Seth (1968).

This chapter uses the information on spatial characteristics of landscape generated through the land cover map to describe the extent of specific forest types and non-spatial vegetation characteristics of primary and secondary forests. This exercise would help in linking the information presented in previous chapters on landscape and stand level assessments and rationalising the overall findings for making valid comparison with other studies on the classification of the old forest growth in other tropics of India or elsewhere by discriminating these forests on the basis of specific composition of forest communities including TMEF, TSEF and TMDF, which could be further used in several ways for wildlife management, such as establishing the species-specific wildlife habitat relationship, for which examples of elephant habitat relationships will be discussed in the concluding chapter of the thesis.

5.2 Methods

The detailed methods for mapping land cover including standard forest types and field data collection for tree species have already been described in the sections 3.2 and 4.2 of preceding chapters. This chapter, however, describes the patch characteristics (spatial indices) and vegetation characteristics (phytosociological indicators) of TMEF, TSEF and TMDF using the same analysis presented in chapter three and four, respectively. These three forest types were identified from various primary and secondary forest growths using cluster classification technique by grouping the numerous and variable tree species into few classes of similar species combination, which occurred in similar habitat conditions. The abundance of tree species was used to classify various primary and secondary forest growths. The sampling efforts during present study were quantified on the basis of Probability Proportion to the Size (PPS).

5.2.1 Sampling intensity

For landscape level assessments, the ideal sampling intensity for collecting tree data should aim to cover at least 0.01% area of particular forest types (IIRS, 2002). The TMDF, TSEF and TMDF constituted the 353 km², 624 km², and 703 km² area. The representative area sampled from TMEF, TMMF, and TMDF accounted for 9, 11 and 15 ha area, respectively (**Table 5.1**).

Table 5.1 The distribution of samples among forest types versus land stewardships

Forest type Land stewardship	Tropical Moist Evergreen Forests	Tropical Semi- evergreen Forests	Tropical Moist Deciduous Forests (inclusive of sal)	Total
Protected areas	8	5	4	17
Reserved forests	-	2	9	11
Community lands	1	4	2	7
Total	9	11	15	35

5.2.2 Classifying forests using spatial attributes

The land use land cover map generated during present study was used to classify and evaluate the old forest growth into various forest types as indicated in chapter 3. Present chapter described the detailed spatial indices (as mentioned in chapter 3) were used to describe the landscape level characteristics of old forest growth comparing TMEF, TSEF and TMDF.

5.2.3 Classifying forests using non-spatial attributes

Systematic classification puts the distinct plant communities into a comprehensive system (Ludwig and Reynolds 1988), which is applicable to a limited geographical area. Clustering strategies, which are hierarchical, agglomerative and polythetic are the most commonly used by the ecologists. This classification procedure provides minimum loss of predictive accuracy in hierarchical clustering. Minimum variance technique, also known as Ward's method, is one of the best ways to classify ecological communities and most commonly used by the ecologists (Ludwig & Reynolds, 1988).

The cluster analysis generated a dendrogram (**Appendix 4**) providing hierarchically nested groups or clusters representing distinct forest communities, which were named for various forest types and formations, which were represented by the sub-clusters. The further phytosociological analysis was done to evaluate the vegetation characteristics of tree species in various forest types, *i.e.*, TMEF, TSEF, and TMDF including their forest formations. The analysis of variance (ANOVA) was done for comparing three forest types and their formations on the basis of six variables including number of species, tree density per ha, basal area per ha, species richness (Menhinick index), species diversity (Shannon index), and species evenness (modified Hill's ratio) as done for broad vegetation types and various formations of primary and secondary forests in previous chapter.

5.3 Results

Three distinct forest types, which were identified as forest types based on standard (revised) classification scheme by Champion and Seth (1968) included the TMEF, TSEF, and TMDF, which all together comprised 68% of total landscape area. The analysis of larger patches (with area 1 ha or above) of these three forest types occupied 16%, 28% and 30% of all bigger patches (area 1 ha) of the landscape. **Table 5.2** below provides the detailed spatial indices computed for the present study.

Table 5.2 The select spatial indices revealing patch characteristics of various patches of forest types of landscape

Spatial indices	Tropical Moist Evergreen Forests	Tropical Semi-evergreen Forests	Tropical Moist Deciduous Forests
Total area of patches $\geq 0.01 \text{ km}^2$	339.48	583.57	630.36
% of total landscape area	16.40	28.18	30.44
Largest patch index (%)	0.46	4.12	1.65

Spatial indices	Tropical Moist Evergreen Forests	Tropical Semi- evergreen Forests	Tropical Moist Deciduous Forests
No. of patches	1006	3081	4834
Patch density (no./ km ²)	2.96	5.28	7.67
Mean patch size (km ²)	0.34	0.19	0.13
Patch size Standard Deviation - PSSD (km ²)	3.73	2.06	0.90
Patch size Coefficient of Variation - PSCV (%)	1104.52	1085.19	688.05
Total edge (km)	4120.45	13193.05	19956.26
Edge density (km/ km ²)	12.14	4.28	31.66
Largest edge (km)	538.58	1545.48	941.41
Mean edge length (km)	0.54	4.28	4.13
Edge length Standard Deviation (km)	31.71	32.64	22.17
Edge length Coefficient of Variation (%)	5922.12	762.16	537.08

These forest types were identified through cluster analysis using an abundance of tree species, which clumped all sampled data (35 belt-transects, as described in chapter four) into three broad clusters or groups (**Fig. 5.1**).

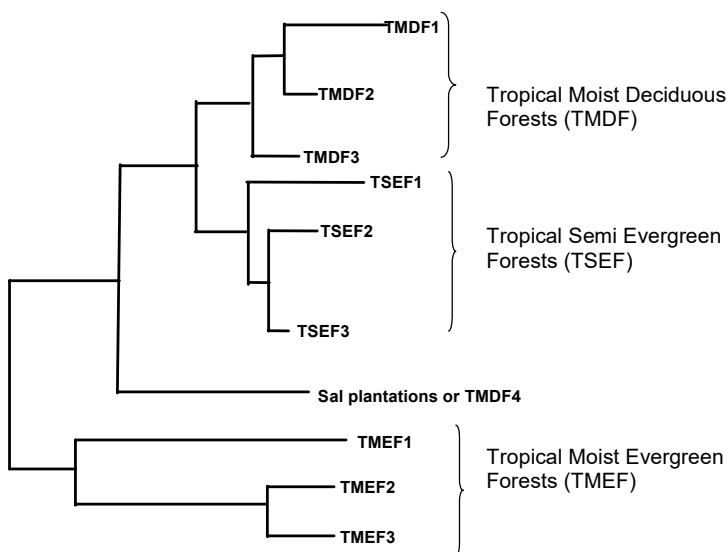


Fig. 5.1 The specific forest types as identified through hierarchical cluster classification using Ward's method on tree abundance data.

As mentioned in the previous chapter, a total of 165 tree species were identified from 29844 trees sampled from 35 one-ha belt transects and the number of tree species ranged from 26 to 87 species per ha. The mean tree density ($\pm$ standard deviation) and mean basal area ($\pm$ standard deviation) were 853 ± 173 trees/ha and 56 ± 36 m²/ha, respectively. The species richness, diversity and evenness varied from 0.97 – 3.26, 1.72 – 3.72, and 0.25 – 0.71, respectively. None of the six variables including number of species ($F=0.06$, $df=2$, and $p>0.05$), tree density per ha ($F=0.90$, $df=2$, and $p>0.05$), basal area per ha ($F=2.19$, $df=2$, and $p>0.05$), species richness ($F=0.69$, $df=2$, and $p>0.05$), species diversity ($F=0.47$, $df=2$, and $p>0.05$), and species evenness ($F=0.62$, $df=2$, and $p>0.05$) used for ANOVA varied significantly among TMEF, TSEF and TMDF (**Table 5.3**).

Table 5.3 Summary statistics for three forest types.

Vegetation characteristics	Tropical Moist Evergreen Forests (n = 9 belt transects)	Tropical Semi-evergreen Forests (n = 11)	Tropical Moist Deciduous Forests (n = 15)
No. of species	132 (51 – 70)	131 (37 – 87)	129 (26 – 55)
No. of trees	7076	9572	13196
Total basal area (m ²)	696	552	727
Mean tree density (± SD)	786 ± 268	870 ± 163	880 ± 92
Mean basal area (m ² /ha) (± SD)	77 ± 42	50 ± 47	49 ± 14
Species richness (Menhinick index)	1.55 – 3.22	1.24 – 3.26	0.97 – 2.87
Species diversity (Shannon index)	2.64 – 3.60	2.40 – 3.72	1.72 – 3.61
Species evenness (modified Hill's ratio)	0.50 – 0.71	0.25 – 0.70	0.29 – 0.70

5.3.1 Tropical moist evergreen forests (TMEF)

A total of 1006 patches (with $\geq 0.01 \text{ km}^2$ area) of TMEF were recorded, which constituted 16% of total area of bigger sized patches of the landscape. The mean patch size ($\pm$ standard deviation) was $0.34 \pm 3.73 \text{ km}^2$ while mean edge length ($\pm$ standard deviation) for all patches was $0.54 \pm 32 \text{ km}$. The overall patch and edge densities of TMEF were 3 patches/ km^2 and 12 km/km^2 , respectively (**Table 5.2**). The 10 most important species (in decreasing order of SIV) were *Polyalthia simiarum*, *Walsura tubularis*, *Syzygium operculatum*, *Castonopsis purpurella*, *Castonopsis* spp., *Diospyros variegata*, *Mesua ferrea*, *Canarium strictum*, *Aphanamixis polystachya*, and *Michelia champaca* (see **Appendix 4** for detailed phytosociological characteristics).

The TMEF can be categorised into three forest formations, which were names as TMEF1, TMEF2 and TMEF3. The number of species ($F=2.87$, $df=2$ and $p>0.5$) and basal area per ha ($F=18.14$, $df=2$ and $p>0.05$) did not vary

significantly among three formations of TMEF, however, tree density ($F=4.42$, $df=2$ and $p<<0.05$), species richness ($F=17.30$, $df=2$ and $p<0.05$), species diversity ($F=6.35$, $df=2$ and $p<0.05$) and species evenness ($F=6.50$, $df=2$ and $p<0.05$) did (**Table 5.4**). Tree density was recorded for the highest value in TMEF2, while species richness and diversity were highest in TMEF1 and species evenness in TMEF3 (**Table 5.4**).

Table 5.4 Summary statistics for three formations of TMEF

Vegetation characteristics	TMEF1 (n = 3 belt transects)	TMEF2 (n = 3)	TMEF3 (n = 3)
No. of species	60 – 70	51 – 66	51 – 59
No. of trees	1364	2866	2846
Total basal area (m ²)	210.7	133.0	352.2
Mean tree density ($\pm$ SD)	455 $\pm$ 36	955 $\pm$ 180	949 $\pm$ 86
Mean basal area (m ² /ha) ($\pm$ SD)	70 $\pm$ 40	44 $\pm$ 5	117 $\pm$ 34
Species richness (Menhinick index)	2.94 – 3.22	1.55 – 2.41	1.64 – 2.02
Species diversity (Shannon index)	3.44 – 3.60	2.64 – 3.29	3.17 – 3.28
Species evenness (modified Hill's ratio)	0.55 – 0.70	0.50 – 0.58	0.66 – 0.71

The ten most important tree species of three TMEF formations were as follows:

TMEF1: *Polyalthia simiarum*, *Canarium strictum*, *Tetrameles nudiflora*, *Michelia champaca*, *Drimycarpus racemosus*, *Cynometra polyandra*, *Sapium baccatum*, *Walsura tubularis*, *Walsura arborea*, and *Pterospermum lancifolium*;

TMEF2: *Polyalthia simiarum*, *Walsura tubularis*, *Mesua ferrea*, *Michelia champaca*, *Pterospermum lancifolium*, *ynometra polyandra*, *Drimycarpus racemosus*, *Syzygium cuminni*, *Canarium strictum*, and *Betula alnoides*; and

TMEF3: *Syzygium operculatum*, *Diospyros variegata*, *Castonopsis spp.*, *Castonopsis purpurella*, *Aphanamixis polystachya*, *Calophyllum*

polyanthum, *Casearia graveolens*, *Boehmeria* spp., *Garcinia kydea*, and *Betula alnoides*.

5.3.2 Tropical semi-evergreen forests (TSEF)

A total of 3081 patches (with $\geq 0.01 \text{ km}^2$ area) of TSEF were recorded, which constituted 28% of total area of bigger sized patches of landscape. The mean patch size ($\pm$ standard deviation) was $0.19 \pm 2.06 \text{ km}^2$ with mean edge length ($\pm$ standard deviation) for all patches was $4.28 \pm 33 \text{ km}$. The overall patch and edge densities of TMEF were 5 patches/ km^2 and 4 km/km^2 , respectively (**Table 5.2**). The 10 most important tree species (in decreasing order of SIV) from TSEF included *Schima wallichii*, *Castonopsis purpurella*, *Shorea robusta*, *Macaranga denticulata*, *Dillenia pentagyna*, *Syzygium cumini*, *Tectona grandis*, *Grewia microcos*, *Aporosa dioica*, and *Eurya accuminata* (see **Appendix 6** for detailed phytosociological characteristics).

The TSEF can be categorised into three formations, which were named as TMEF1, TMEF2 and TMEF3. The number of tree species ($F=2.60$, $df=2$ and $p>0.05$), tree density ($F=0.09$, $df=2$ and $p>0.05$), basal area ($F=1.12$, $df=2$ and $p>0.05$), species richness ($F=1.28$, $df=2$ and $p>0.05$) and evenness ($F=3.62$, $df=2$ and $p>0.05$) did not vary significantly among three TSEF formations. Only species diversity ($F=5.16$, $df=2$ and $p<0.05$) varied significantly with highest values in TSEF1 (**Table 5.5**).

Table 5.5 Summary statistics for three formations of TSEFs

Vegetation characteristics	TSEF1 (n = 4 belt transects)	TSEF2 (n = 3)	TSEF3 (n = 4)
No. of species	50 – 87	49 – 56	37 – 66
No. of trees	3601	2535	3436
Total basal area (m^2)	309	80	163
Mean tree density ($\pm$ SD)	900 ± 163	845 ± 195	859 ± 187

Mean basal area (m ² /ha) (± SD)	77 ± 71	27 ± 13	41 ± 26
Species richness (Menhinick index)	1.70 – 3.26	1.71 – 1.98	1.24 – 2.50
Species diversity (Shannon index)	2.90 – 3.72	2.86 – 3.17	2.40 – 3.13
Species evenness (modified Hill's ratio)	0.60 – 0.70	0.51 – 0.63	0.25 – 0.62

The ten most important tree species of three TSEF formations were as follows;

TSEF1: *Schima wallichii*, *Aphanamixis polystachya*, *Castonopsis* spp., *Syzygium cuminni*, *Eurya accuminata*, *Grewia microcos*, *Dillenia pentagyna*, *Macaranga denticulata*, *Polyalthia simiarum*, and *Aporusa dioica*;

TSEF2: *Schima wallichii*, *Castonopsis purpurella*, *Aporusa dioica*, *Syzygium cuminni*, *Grewia microcos*, *Terminalia balerica*, *Eurya accuminata*, *Oriocnoide integrefolia*, *Glochidion velutinum*, and *Sapium baccatum*; and

TSEF3: *Shorea robusta*, *Schima wallichii*, *Tectona grandis*, *Macaranga denticulata*, *Dillenia pentagyna*, *Castonopsis purpurella*, *Lagerstroemia parviflora*, *Grewia microcos*, *Albizia odoratissima*, and *Vitex peduncularis*.

5.3.3 Tropical moist deciduous forests (TMDF)

A total of 4834 patches (with ≥ 0.01 km² area) of TMDF were recorded, which constituted 30% of total area of bigger sized patches of the landscape (**Table 5.2**). The mean patch size ($\pm$ standard deviation) was 0.13 ± 0.90 km² with mean edge length ($\pm$ standard deviation) for all patches was 4.13 ± 22 km. The overall patch and edge densities of TMEF were 8 patches/km² and 32 km/km², respectively (**Table 5.2**). The 10 most important tree species (in decreasing order of SIV) were *Shorea robusta*, *Schima wallichii*, *Grewia microcos*, *Castonopsis purpurella*, *Syzygium cuminni*, *Aporusa dioica*, *Dillenia*

pentagyna, *Sapium baccatum*, *Cynometra polyandra*, and *Vitex peduncularis* (see **Appendix 7** for detailed phytosociological characteristics).

The cluster analysis provided three distinct formations of TMDF, which were named as TMDF1, TMDF2 and TMDF3. The sal plantations made the fourth formations of TMDF, which was analysed along with three TMDF formations. Except basal area ($F=0.51$, $df=3$ and $p>0.05$), all variables including number of species ($F=3.40$, $df=3$ and $p<0.05$), tree density ($F=3.85$, $df=3$ and $p<0.05$), species richness ($F=3.79$, $df=3$ and $p<0.05$), species diversity ($F=15.92$, $df=3$ and $p<<0.05$) and species evenness ($F=18.85.40$, $df=3$ and $p<<0.05$) varied significantly among all four TMDF formations (**Table 5.6**). The TMDF2 have shown the highest values for a number of species, species diversity and richness, while TMDF1 showed the highest values of tree density and species evenness.

Table 5.6 Summary statistics for four formations of TMDF including sal plantations as TMDF4

Vegetation characteristics	TMDF1 (n = 3 belt transects)	TMDF2 (n = 4)	TMDF3 (n = 4)	TMDF4 (n = 4)
No. of species	59 – 67	46 – 84	57 – 74	26 – 55
No. of trees	2906	3598	3145	3547
Total basal area (m ²)	157	177	177	217
Mean tree density ($\pm$ SD)	969 $\pm$ 33	900 $\pm$ 67	786 $\pm$ 29	887 $\pm$ 115
Mean basal area (m ² /ha) ($\pm$ SD)	52 $\pm$ 3	44 $\pm$ 16	44 $\pm$ 15	54 $\pm$ 17
Species richness (Menhinick index)	1.86 – 2.16	1.48 – 2.82	2.01 – 2.70	0.97 – 1.84
Species diversity (Shannon index)	3.40 – 3.54	2.76 – 3.61	3.19 – 3.56	1.72 – 2.60
Species evenness (modified Hill's ratio)	0.66 – 0.70	0.58 – 0.65	0.55 – 0.68	0.29 – 0.51

The ten most important tree species of three TMDF formations were as follows;

TMDF1: *Schima wallichii*, *Shorea robusta*, *Syzygium cuminni*, *Castonopsis purpurella*, *Lagerstroemia parviflora*, *Grewia microcos*, *Eurya accuminata*, *Sapium baccatum*, *Aporusa dioica*, and *Polyalthia simiarum*;

TMDF2: *Grewia microcos*, *Shorea robusta*, *Aporusa dioica*, *Schima wallichii*, *Dillenia pentagyna*, *Syzygium cuminni*, *Holarrhena antidysentrica*, *Vitex peduncularis*, *Croton joufera*, and *Castonopsis purpurella*; and

TMDF3: *Castonopsis purpurella*, *Cynometra polyandra*, *Diospyros variegata*, *Syzygium cuminni*, *Grewia microcos*, *Sapium baccatum*, *Drimycarpus racemosus*, *Tetrameles nudiflora*, *Canarium strictum*, and *Dillenia pentagyna*;

TMDF4: *Shorea robusta*, *Glycosmis arborea*, *Schima wallichii*, *Artocarpus chaplasha*, *Syzygium cuminni*, *Aporusa dioica*, *Vitex peduncularis*, *Sapium baccatum*, *Litsea monopelata*, and *Castonopsis purpurella*.

5.4 Discussion

The challenge is to establish linkages between these forest communities with the standard forest types identified through landscape level mapping, without which it would not be possible to make valid comparison with other studies on the classification of forest cover of Meghalaya (Sudhakar & Singh 1993; Kumar & Singh 1997; Roy & Tomar 2000, 2001; and Talukdar 2004). All these studies classified old forest cover into three distinct phenological units of the old forest growth including TMEF, TSEF and TMDF. However, these three forest types were not at all distinctive in actual field conditions, where the old forest growth existed as a mosaic of primary and secondary forest growths. Over the decades, the natural forests have been modified periodically through the practice of

jhumming and other unplanned forestry practices. This resulted in the overlap of species among several (distinct) naturally occurring forest types, which has made it very difficult to clearly distinguish semi-evergreen and deciduous forest types from each other. In fact, most Indian literature on the classification of old forest growth used this classification scheme by following the standard (revised) forest classification scheme suggested by Champion & Seth (1968), who divided all Indian forests into sixteen main forest types to be further specified into subtypes on the basis of local climatic and edaphic factors.

The assessment of old forest growth as described in chapter four is of utmost importance to the forest managers in day-to-day management activities in actual field conditions in the *Garo Hills*, however, it may not be used successfully for comparing these forests with other forests of the tropics in India and other countries, since most studies aimed at describing phonological units of forest growth forms, which more or less corresponds to the standard forest types based on the revised classification scheme suggested by the Champion and Seth (1968). In order to make valid comparison and better understanding of forest cover in relation with the landscape attributes, the old forest growth, which was observed as mosaic of primary and secondary forest patches was described as standard forest types and named as TMEF, TSEF and TMDF along with their characteristic sub-types (formations) referred above in this chapter.

The fact that these three forest types were not at all distinctive in typical field conditions, was supported by the results of ANOVA, which revealed that none of the vegetation characteristics (out of six variables used in ANOVA) had shown significant difference among three forest types, *i.e.*, TMEF, TSEF and TMDF. However, various formations of three forest types had shown a significant difference for one or more variables, since these formations represented the specific growth forms of primary and secondary forests, for example, TMEF1, TMEF2 and TMEF3 represented the PF low, PF mid and PF high, respectively. The TMEF and TSEF could be better considered as a single unit and named as Tropical Moist Mixed Forests (TMMF), which was evident through the results of cluster classification performed using tree abundance data.

The spatial analysis of larger patches ($\geq 0.01 \text{ km}^2$ or 1 ha) revealed that TMEF, TSEF and TMDF occupied 16%, 28% and 30% area of the landscape (patches with $\geq 0.01 \text{ km}^2$ or 1 ha area). The higher mean patch size and lower mean edge length of TMEF suggested that this particular forest type were more intact and least affected by the fragmentation compared to TSEF and TMDF, which was evident by the lower values for the patch and edge densities. The TMDF had shown the least mean patch size and highest patch density, which pointed out towards highly fragmented conditions of this particular forest type (*i.e.*, TMDF).

The TMEF patches were mainly confined to the Nokrek and Balpakram areas in the relatively undisturbed forest. Most of the time such areas remained out of reach of society, hence could not be used for *jhumming* by the native society. The TSEF mainly buffered the TMEF and sometimes represented by very old *jhum*, wherever their edges coincides with human settlements. A large belt of TSEF occurred in the south of Nokrek ridge, which spread between Imangiri village to the rewak village across river Simsang near Siju village. The TSEF areas formed the upper catchments Nareng, Bugi and Dareng rivers, while a few patches of TSEF in the central and southern portion of the landscape formed the middle and lower catchments of river Simsang. The TMDF patches formed the mosaic of a large number of smaller sized patches, which are scattered all over the landscape in a matrix with the TSEF, land uses (habitation and agriculture) and non-forest vegetative patches. In the majority of cases, those represented the man-made forest types, which included the very old sal plantations.

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Analysis results of patches covering 0.01 sq km (1 ha) area or above

Spatial indices	Land stewardship			
	Landscape			
Total area of patches $\geq 0.01 \text{ km}^2$	2070.58			
% of total landscape area	100.00			
Largest patch index (%)	4.12			
No. of patches	20914.00			
Patch density (no./ km^2)	10.10			
Mean patch size (km^2)	0.10			
Patch size Standard Deviation - PSSD (km^2)	1.23			
Patch size Coefficient of Variation - PSCV (%)	1239.08			
Total edge (km)	57061.49			
Edge density (km/km^2)	27.56			
Largest edge (km)	1545.48			
Mean edge length (km)	2.73			
Edge length Standard Deviation (km)	18.30			
Edge length Coefficient of Variation (%)	670.76			
	Overall land cover			
	Land uses	Forest cover	Bamboo	Cloud cover
Total area of patches $\geq 0.01 \text{ km}^2$	352.55	1553.40	101.29	57.99
% of total landscape area	17.03	75.02	4.89	2.80
Largest patch index (%)	0.53	4.12	0.58	0.07
No. of patches	7435	8921	2821	1629
Patch density (no./ km^2)	21.09	5.74	27.85	28.09
Mean patch size (km^2)	0.05	0.17	0.04	0.04
Patch size Standard Deviation - PSSD (km^2)	0.25	1.86	0.07	0.07
Patch size Coefficient of Variation - PSCV (%)	523	1069	198	184
Total edge (km)	12901	37270	4588	2121

Edge density (km/ km ²)	36.59	23.99	45.29	36.57
Largest edge (km)	303.62	1545.48	37.41	38.92
Mean edge length (km)	1.74	4.18	1.63	1.30
Edge length Standard Deviation (km)	6.21	27.34	2.16	1.54
Edge length Coefficient of Variation (%)	357.68	654.39	133.02	118.07
	Land use			
	Habitation	Permanent agriculture	Shifting agriculture	
Total area of patches ≥ 0.01 km ²	187.88	76.44	88.51	
% of total landscape area	9.07	3.69	4.27	
Largest patch index (%)	0.53	0.17	0.04	
No. of patches	2912	1293	3256	
Patch density (no./ km ²)	15.50	16.92	36.78	
Mean patch size (km ²)	0.06	0.06	0.03	
Patch size Standard Deviation - PSSD (km ²)	0.38	0.16	0.04	
Patch size Coefficient of Variation - PSCV (%)	588.20	262.29	139.09	
Total edge (km)	6478.37	2145.26	4293.02	
Edge density (km/ km ²)	34.48	28.07	48.50	
Largest edge (km)	303.62	42.35	25.76	
Mean edge length (km)	2.22	1.66	1.32	
Edge length Standard Deviation (km)	9.69	2.23	1.26	
Edge length Coefficient of Variation (%)	435.73	134.12	95.45	

Forest Formations at stand level within sample plots
(35 one ha belt transects)

Plot code	Description of plot	Forest formation
BNP10	Chutmang Hills in BNP, 10-12 km from Siju WLS. Primary forest at 800-900 m altitude	<i>Schima wallichii</i> - <i>Polyalthia simiarum</i> - <i>Aphanamixis polystachya</i>
BNP9	Young secondary forests in BNP near village Rongsu, about 7-8 km from Siju WLS	<i>Schima wallichii</i> - <i>Castonopsis purpurella</i> - <i>Callicarpa arborea</i>
BNPBASE1	Old Primary forest in Mahadeo gorge in BNP mainly riverine and semi-evergreen forest	<i>Michelia champaca</i> - <i>Kaeya floribunda</i> - <i>Grewia microcos</i>
BNPBASE2	Old Primary forest in the Mahadeo gorge in BNP mainly riverine and semi-evergreen forest	<i>Tetrameles nudiflora</i> - <i>Polyalthia simiarum</i> - <i>Canarium strictum</i>
BNPBASE3	Old Primary forest in the Mahadeo gorge in BNP mainly riverine and semi-evergreen forest	<i>Polyalthia simiarum</i> - <i>Canarium strictum</i> - <i>Drimycarpus racemosus</i>
BNPPFA	Primary forest in the limestone area of BNP sometimes touches the edges with old secondary forest of deciduous nature	<i>Polyalthia simiarum</i> - <i>Michelia champaca</i> - <i>Walsura tubularis</i>
BNPPFB	Primary forest in the limestone area of BNP sometimes touches the edges with old secondary forest of deciduous nature	<i>Walsura tubularis</i> - <i>Polyalthia simiarum</i> - <i>Mesua ferrea</i>
BNPPFC	Primary forest in the limestone area of BNP sometimes touches the edges with old secondary forest of deciduous nature	<i>Polyalthia simiarum</i> - <i>Walsura tubularis</i> - <i>Mesua ferrea</i>
BNPSF1	Secondary forest in BNP, below 10 years	<i>Castonopsis purpurella</i> - <i>Schima wallichii</i> - <i>Syzygium cumini</i>
BNPSF2A	Secondary forest in BNP, 10-20 years	<i>Schima wallichii</i> - <i>Macaranga denticulate</i> - <i>Syzygium cumini</i>

Plot code	Description of plot	Forest formation
BNPSF2B	Secondary forest in BNP, 10-20 years	<i>Macaranga denticulate</i> - <i>Albizia odoratissima</i> - <i>Bignonia</i> spp.
BNPSF3A	Secondary forest in BNP, 20-30 years	<i>Grewia microcos</i> - <i>Aporusa</i> <i>dioica</i> - <i>Castonopsis</i> <i>purpurella</i>
BNPSF3B	Secondary forest in BNP, 20-30 years	<i>Grewia microcos</i> - <i>Aporusa</i> <i>dioica</i> - <i>Terminalia balerica</i>
BRFN5	Natural Forest at moist places in Baghmara Reserved forests surrounded by old Sal forest	<i>Castonopsis purpurella</i> - <i>Grewia microcos</i> - <i>Cynometra</i> <i>polyandra</i>
BRFN6	Natural Forest at moist places in Baghmara Reserved forests surrounded by old Sal forest	<i>Schima wallichii</i> - <i>Aporusa</i> <i>dioica</i> - <i>Castonopsis</i> <i>purpurella</i>
BRFN7	Natural Forest at moist places in Baghmara Reserved forests surrounded by old Sal forest	<i>Castonopsis purpurella</i> - <i>Dillenia pentagyna</i> - <i>Celtis</i> <i>tetranda</i>
BRFPL1	Sal Forest in alluvial soil and lower part of hills near simsang river in Baghmara Reserved forests (Locally known as Sal Plantation)	<i>Shorea robusta</i> - <i>Artocarpus</i> <i>chaplasha</i> - <i>Aporusa dioica</i>
BRFPL8	Sal Forest in alluvial soil and lower part of hills near simsang river in Baghmara Reserved forests (Locally known as Sal Plantation)	<i>Shorea robusta</i> - <i>Schima</i> <i>wallichii</i> - <i>Aporusa dioica</i>
BRFPL9	Sal Forest in alluvial soil and lower part of hills near simsang river in Baghmara Reserved forests (Locally known as Sal Plantation)	<i>Shorea robusta</i> - <i>Glycosmis</i> <i>arborea</i> - <i>Tectona grandis</i>
ERF1	Old forest in side Emangiri Reserved Forest	<i>Schima wallichii</i> - <i>Shorea</i> <i>robusta</i> - <i>Syzygium cuminni</i>

Plot code	Description of plot	Forest formation
ERF2	Old forest in side Emangiri Reserved Forest	<i>Schima wallichii</i> - <i>Lagerstroemia parviflora</i> - <i>Grewia microcos</i>
ERF3	Old forest in side Emangiri Reserved Forest	<i>Cynometra polyandra</i> - <i>Castonopsis purpurella</i> - <i>Sapium baccatum</i>
IVR1	Village reserve forest in the surrounding areas Emangiri Reserved Forest	<i>Shorea robusta</i> - <i>Schima wallichii</i> - <i>Dillenia pentagyna</i>
IVR2	Village reserve forest in the surrounding areas Emangiri Reserved Forest	<i>Schima wallichii</i> - <i>Sapium baccatum</i> - <i>Syzygium cumini</i>
IVR3	Village reserve forest in the surrounding areas Emangiri Reserved Forest	<i>Schima wallichii</i> - <i>Castonopsis purpurella</i> - <i>Shorea robusta</i>
IVR4	Village reserve forest in the surrounding areas Emangiri Reserved Forest	<i>Schima wallichii</i> - <i>Macaranga denticulate</i> - <i>Shorea robusta</i>
NNP1	Old, moist Primary forest at Nokrek ridge near Nokrek peak in Nokrek National Park	<i>Syzygium operculatum</i> - <i>Aphanamixis polystachya</i> - <i>Castonopsis</i> spp.
NNP3	60 years old secondary forest (Looks like Primary forest), at neighbouring hills of Nokrek hills Outside Nokrek National Park	<i>Diospyros variegata</i> - <i>Castonopsis purpurella</i> - <i>Calophyllum polyanthum</i>
NNP4	Old, moist Primary forest at Nokrek ridge near Nokrek Peak inside Nokrek National Park	<i>Diospyros variegata</i> - <i>Castonopsis</i> spp.- <i>Castonopsis purpurella</i>
NNPTURAP E	Old, moist Primary forest at Tura Peak inside Tura reserve at the western most corner of Tura ridge, a very important catchment area.	<i>Castonopsis</i> spp.- <i>Schima wallichii</i> - <i>Aphanamixis polystachya</i>
RRF1	Old forest in Rewak reserved forest nearby rivers	<i>Shorea robusta</i> - <i>Dillenia pentagyna</i> - <i>Lagerstroemia parviflora</i>
RRF2	Old forest in Rewak reserved forest nearby rivers	<i>Tectona grandis</i> - <i>Shorea robusta</i> - <i>Tetrameles nudiflora</i>

Plot code	Description of plot	Forest formation
SWS1	Semi-evergreen forest in Siju WLS	<i>Schima wallichii</i> - <i>Grewia microcos</i> - <i>Persia villosa</i>
SWS2	Semi-evergreen forest with the higher proportion of deciduous trees near lake in Siju WLS	<i>Diospyros variegata</i> - <i>Tetrameles nudiflora</i> - <i>Cynometra polyandra</i>
SWS3	Semi-evergreen forest in Siju WLS	<i>Shorea robusta</i> - <i>Aporosa dioica</i> - <i>Grewia microcos</i>

Tree species in study area

c = Common, f = frequent, r = rare, PF = Primary forests, SF = Secondary Forests, ev = Evergreen Forests, dd = Moist deciduous forest, bmb = Bamboo growth, cult = Cultivation, mixed ev = Mixed evergreen forests, Mixeddd = mixed deciduous forests, rb = river bank and blank = not known.

Scientific name	Family	Conservation status	Habitat
<i>Alangium salvifolium</i>	Alangiaceae		
<i>Anacardium occidentale</i> Linn.	Anacardiaceae	c	cult
<i>Drimycarpus racemosus</i> (Roxb.) Hk. f.	Anacardiaceae	o	ev
<i>Lannea coromandelica</i> (Houtt.) Merr.	Anacardiaceae	c	dd, SF, open
<i>Mangifera indica</i> Linn.	Anacardiaceae	o	cult
<i>Mangifera sylvatica</i> Roxb.	Anacardiaceae		ev
<i>Rhus acuminata</i> DC.	Anacardiaceae	f	open, edge
<i>Rhus javanica</i> Linn.	Anacardiaceae		SF, open, edge
<i>Semecarpus anacardium</i> Linn. f.	Anacardiaceae	c	dd, SF
<i>Spondias axillaris</i> Roxb.	Anacardiaceae	f	ev, mixdd
<i>Spondias pinnata</i> (Linn. f.) Kurz.	Anacardiaceae	c	dd
<i>Alphonsea ventricosa</i> Hk. f.	Annonaceae		
<i>Milium roxburghiana</i> (Wall.) Hk. f.	Annonaceae	c	ev
<i>Milium tomentosa</i> (Roxb.) Sinclair	Annonaceae		
<i>Milium velutina</i> Hk. f.	Annonaceae	r	Sal
<i>Mitrephora tomentosa</i> Hk. f. & Th.	Annonaceae		dd

Scientific name	Family	Conservation status	Habitat
<i>Polyalthia jenkinsii</i> Benth. & Hk. f.	Annonaceae	c	ev
<i>Polyalthia simiamum</i> (Hk. f. & Th.) Hk. f. & Th.	Annonaceae	r	ev
<i>Alstonia scholaris</i> (Linn.) R. Br.	Apocynaceae	f	dd, SF, edge
<i>Holarrhena antidysenterica</i> (Roth) A. DC.	Apocynaceae	c	SF, dry sandy
<i>Plumeria rubra</i> Linn.	Apocynaceae		cult
<i>Thevetia peruviana</i> (Pers.) K. Schum.	Apocynaceae	c	SF, dd
<i>Wrightia arborea</i> (Dennst.) Mabberley	Apocynaceae		cult
<i>Ilex embelioides</i> Hk. f.	Aquifoliaceae	r	
<i>Ilex excelsa</i> (Wall.) Hk. f.	Aquifoliaceae	c	ev
<i>Ilex fragilis</i> Hk. f.	Aquifoliaceae	r	
<i>Ilex umbellulata</i> (Wall.) Loes.	Aquifoliaceae	c	
<i>Areca catechu</i> Willd.	Araceae		
<i>Aralia thomsonii</i> Seem	Araliaceae		PF, road cutting
<i>Brassiopsis glomerulata</i> (Bl.) Regel	Araliaceae	f	ev
<i>Heteropanax fragrans</i> (D. Don) Seem	Araliaceae		ev, disturbed
<i>Macropanax dispermus</i> (Bl.) O. Ktz.	Araliaceae		broadleaved
<i>Macropanax undulatus</i> (Wall ex G. Don) Seem	Araliaceae	c	ev
<i>Merillioanax japonicum</i> Seem	Araliaceae		
<i>Parapentapanax subcordatum</i> (G. Don) Hutch.	Araliaceae	c	rocky
<i>Schefflera hypoleuca</i> (Kurz.) Harms	Araliaceae	c	

Scientific name	Family	Conservation status	Habitat
<i>Schefflera wallichiana</i> (W. & A.) Harms	Araliaceae	c	ev
<i>Trevesia palmata</i> (Roxb.) Vis.	Araliaceae		ev, streamlets
<i>Caryota urens</i> Linn.	Arecaceae	f	
<i>Licuala peltata</i> Roxb.	Arecaceae		
<i>Phoenix humilis</i> Royle	Arecaceae		
<i>Pinanga gracilis</i> Bl.	Arecaceae		
<i>Vernonia arborea</i> Buch.-Ham.	Asteraceae	r	open
<i>Vernonia volkameriifolia</i> DC.	Asteraceae	f	Dry areas
<i>Averrhoa carambola</i> Linn.	Averrhoaceae		sandy,cult, wild
<i>Careya arborea</i> Roxb.	Barringtoniaceae	c	mixev
<i>Betula alnoides</i> Buch.-Ham. ex D. Don	Betulaceae	c	higher elevation
<i>Jacaranda mimosifolia</i> D. Don	Bignoniaceae	c	cult
<i>Oroxylum indicum</i> (Linn.) Vent.	Bignoniaceae	c	dd
<i>Radermachera gigantea</i> (Bl.) Miq.	Bignoniaceae	r	
<i>Stereospermum chelonoides</i> (Linn. f.) DC.	Bignoniaceae	c	ev, dd
<i>Bischofia javanica</i> Bl.	Bischofiaceae	c	ev,mixev
<i>Salmalia malabarica</i> (DC.) Schott. & Endlicher	Bombacaceae	c	SecF
<i>Cordia dichotoma</i> Forst. f.	Boraginaceae	r	dd
<i>Cordia fragrantissima</i> Kurz.	Boraginaceae	r	ev

Scientific name	Family	Conservation status	Habitat
<i>Cordia grandis</i> Roxb.	Boraginaceae	f	rb
<i>Bursera serrata</i> Colebr.	Burseraceae	c	ev, mixed
<i>Canarium strictum</i> Roxb.	Burseraceae	r	edge, ev, rb
<i>Garuga pinnata</i> Roxb.	Burseraceae	c	dd, open
<i>Acrocarpus fraxinifolius</i> Arn. ex Wt.	Caesalpiniaceae	f	dd
<i>Bauhinia malabarica</i> Roxb.	Caesalpiniaceae		
<i>Bauhinia purpurea</i> Linn.	Caesalpiniaceae	c	dd, SF, edge
<i>Bauhinia retusa</i> Ham.	Caesalpiniaceae		
<i>Bauhinia variegata</i> Linn.	Caesalpiniaceae	f	dd
<i>Cassia fistula</i> Linn.	Caesalpiniaceae	c	plantation, wild
<i>Cynometra polyandra</i> Roxb.	Caesalpiniaceae	c	ev
<i>Delonix regia</i> (Boj.) Rafim.	Caesalpiniaceae		cult
<i>Saraca asoca</i> (Roxb.) de Wilde	Caesalpiniaceae	r	ev, rb, cult
<i>Crataeva nurvala</i> Buch.-Ham.	Capparidaceae	r	ev
<i>Crataeva religiosa</i> Forst.	Capparidaceae		
<i>Viburnum colebrookianum</i> Wall. ex DC.	Caprifoliaceae	c	
<i>Calophyllum polyanthum</i> Choisy	Clusiaceae		PF
<i>Garcinia acuminata</i> Planch. & Triana	Clusiaceae	c	ev
<i>Garcinia anomala</i> Planch. & Triana	Clusiaceae		
<i>Garcinia cowa</i> Roxb. ex DC.	Clusiaceae	c	Mixed ev

Scientific name	Family	Conservation status	Habitat
<i>Garcinia lancifolia</i> (G.Don) Roxb.	Clusiaceae		ev
<i>Garcinia morella</i> Desr.	Clusiaceae		ev
<i>Garcinia paniculata</i> (G.Don) Roxb.	Clusiaceae		ev
<i>Garcinia tinctoria</i> (DC.) W. F. Wight	Clusiaceae	c	ev
<i>Garcinia xanthochymus</i> Hk. f.	Clusiaceae	c	
<i>Kayea floribunda</i> Wall.	Clusiaceae	c	ev
<i>Mesua ferrea</i> Linn.	Clusiaceae		ev
<i>Microtropis discolor</i> (Wall.) Arn.	Clusiaceae	f	ev
<i>Terminalia bellirica</i> (Gaertn.) Roxb.	Combretaceae	c	ev, dd
<i>Terminalia chebula</i> Retz.	Combretaceae	f	
<i>Terminalia citrina</i> (Gaertn.) Flem.	Combretaceae	c	
<i>Terminalia myriocarpa</i> Heurck & Muell.-Arg.	Combretaceae	c	ev
<i>Crypteronia paniculata</i> Bl.	Crypteroniaceae		
<i>Dillenia indica</i> Linn.	Dilleniaceae	c	ev, rb
<i>Dillenia pentagyna</i> Roxb.	Dilleniaceae	c	dd
<i>Dillenia scabrella</i> (D. Don) Roxb. ex Wall.	Dilleniaceae		dd
<i>Shorea robusta</i> Gaertn.	Dipterocarpaceae	c	dd
<i>Vatica lanceaefolia</i> Bl.	Dipterocarpaceae	c	dd, rb
<i>Diospyros kaki</i> Thumb.	Ebenaceae	f	open
<i>Diospyros lancifolia</i> Roxb.	Ebenaceae	c	ev, rb

Scientific name	Family	Conservation status	Habitat
<i>Diospyros malabarica</i> (Desr.) Kostel	Ebenaceae	f	
<i>Diospyros montana</i> Roxb.	Ebenaceae	f	SF, PF, edge
<i>Diospyros toposia</i> Ham.	Ebenaceae	f	PF, ev
<i>Diospyros variegata</i> Kurz	Ebenaceae	c	ev, open
<i>Ehretia acuminata</i> R. Br.	Ehretiaceae	c	ev, open
<i>Echinocarpus assamicus</i> Benth.	Elaeocarpaceae	c	rb
<i>Elaeocarpus aristatus</i> Roxb.	Elaeocarpaceae		
<i>Elaeocarpus floribundus</i> Bl.	Elaeocarpaceae		
<i>Elaeocarpus lancifolius</i> Roxb.	Elaeocarpaceae	c	
<i>Elaeocarpus rugosus</i> Roxb.	Elaeocarpaceae	c	
<i>Elaeocarpus varuna</i> Ham. ex Mast.	Elaeocarpaceae	c	Ev, dd
<i>Alchornea tiliacifolia</i> Muell.-Arg.	Euphorbiaceae	c	Mixed sal
<i>Antidesma bunius</i> (Linn.) Spreng.	Euphorbiaceae	c	
<i>Antidesma nigricans</i> Tul.	Euphorbiaceae	f	bmb
<i>Aporusa aurea</i> Hk. f.	Euphorbiaceae	f	dd, bmb
<i>Aporusa dioica</i> (Roxb.) Muell.-Arg.	Euphorbiaceae	c	dd, mixedd
<i>Aporusa oblonga</i> Muell.-Arg.	Euphorbiaceae	c	dd
<i>Aporusa wallichii</i> Hk. f.	Euphorbiaceae	f	
<i>Baccaurea ramiflora</i> Lour.	Euphorbiaceae		cult
<i>Bridelia monoica</i> (Lour.) Mess	Euphorbiaceae	c	dd

Scientific name	Family	Conservation status	Habitat
<i>Bridelia retusa</i> (Linn.) Spreng	Euphorbiaceae	c	sal, mixedd
<i>Chaetocarpus castanocarpus</i> (Roxb.) Thw.	Euphorbiaceae	c	sandy rb
<i>Cleidion spiciflorum</i> (Burm.) Merr.	Euphorbiaceae	c	ev
<i>Cleistanthus chartaceus</i> Muell.-Arg.	Euphorbiaceae	f	
<i>Croton joufera</i> Roxb.	Euphorbiaceae	c	dd, sal
<i>Croton roxburghii</i> Balak.	Euphorbiaceae	c	dd
<i>Drypetes lancifolia</i> (Hk. f.) Pax et Hoffm.	Euphorbiaceae	r	
<i>Emblica officinalis</i> Gaertn.	Euphorbiaceae	c	SF,dd
<i>Glochidion acuminatum</i> Muell.-Arg.	Euphorbiaceae	f	
<i>Glochidion hirsutum</i> Muell.-Arg.	Euphorbiaceae	f	sal
<i>Glochidion sphaerogynum</i> Kurz	Euphorbiaceae	c	SF,edge
<i>Glochidion velutinum</i> Wt.	Euphorbiaceae	c	SF
<i>Hevea brasiliensis</i> Muell.-Arg.	Euphorbiaceae		plt
<i>Macaranga denticulata</i> Muell.-Arg.	Euphorbiaceae	c	SF, <i>jhum</i>
<i>Macaranga indica</i> Wt.	Euphorbiaceae	f	ev
<i>Mallotus albus</i> Muell.-Arg.	Euphorbiaceae	c	Mixed ev
<i>Mallotus leucocarpus</i> (Kurz) A. Shaw	Euphorbiaceae	f	ev
<i>Mallotus philippinensis</i> (Lam.) Muell.-Arg.	Euphorbiaceae	o	dd
<i>Mallotus roxburghianus</i> Muell.-Arg.	Euphorbiaceae		
<i>Mallotus tetracoccus</i> (Roxb.) Kurz.	Euphorbiaceae	c	ev, mixed ev

Scientific name	Family	Conservation status	Habitat
<i>Ostodes paniculata</i> Bl.	Euphorbiaceae	c	ev
<i>Sapium baccatum</i> Roxb.	Euphorbiaceae	c	ev
<i>Sapium eugeniaefolium</i> Ham. ex Hk. f.	Euphorbiaceae		ev
<i>Trewia nudiflora</i> Linn.	Euphorbiaceae	c	dd, rb
<i>Butea monosperma</i> (Lamk.) Ktz.	Fabaceae	r	dd, SF, open
<i>Dalbergia stipulacea</i> Roxb.	Fabaceae	c	sal
<i>Derris robusta</i> (Roxb. ex DC.) Benth.	Fabaceae	c	ev, dd
<i>Erythrina stricta</i> Roxb.	Fabaceae	c	dd
<i>Erythrina suberosa</i> Roxb.	Fabaceae		
<i>Milletia picsidia</i> Wt.	Fabaceae	c	
<i>Castanopsis armata</i> Spach.	Fagaceae	c	ev, edges
<i>Castanopsis indica</i> A. DC.	Fagaceae	c	ev
<i>Castanopsis kurzii</i> (Hance) Biswas	Fagaceae		
<i>Castanopsis purpurella</i> (Miq.) Balak.	Fagaceae	c	ev, stream
<i>Castanopsis tribuloides</i> (Sm.) DC.	Fagaceae	c	ev, stream
<i>Lithocarpus elegans</i> (Bl.) Hatus ex Soep.	Fagaceae	c	lower elevation
<i>Casearia glomerata</i> Roxb.	Flacourtiaceae		Mixed ev
<i>Casearia kurzii</i> Cl.	Flacourtiaceae	f	ev
<i>Casearia zeylanica</i> (Gaert.) Thw.	Flacourtiaceae		
<i>Gynocardia odorata</i> R. Br.	Flacourtiaceae	c	ev,mixed ev

Scientific name	Family	Conservation status	Habitat
<i>Homalium bhamoense</i> Cubit et Sm.	Flacourtiaceae	r	lower elevation
<i>Homalium schlichii</i> Kurz	Flacourtiaceae	r	
<i>Xylosma controversum</i> Clos.	Flacourtiaceae		SF
<i>Xylosma longifolium</i> Clos.	Flacourtiaceae		
<i>Exbucklandia populnea</i> (R. Br. ex Griff)	Hamamelidaceae	c	
<i>Engelhardtia roxburghiana</i> Wall.	Juglandaceae	r	lower elevation
<i>Engelhardtia spicata</i> Leschn. ex Bl.	Juglandaceae		
<i>Engelhardtia spicata</i> var. <i>colebrookeana</i> (Wall.) Kds. & Val. Bijdr.	Juglandaceae	c	
<i>Engelhardtia spicata</i> var. <i>spicata</i>	Juglandaceae		
<i>Actinodaphne augustifolia</i> Nees	Lauraceae	c	
<i>Actinodaphne obovata</i> (Nees) Bl.	Lauraceae	c	Moist, shady, ev
<i>Beilshmedia fagifolia</i> Nees	Lauraceae	r	ev
<i>Beilshmedia roxburghiana</i> Nees	Lauraceae	c	Stream bank
<i>Cinnamomum bejolghota</i> (Buch.-Ham.) Sweet.	Lauraceae	c	ev, mixedd
<i>Cinnamomum glanduliferum</i> (Wall.) Meissn.	Lauraceae	c	
<i>Cinnamomum glaucescens</i> (Nees) Meissn.	Lauraceae	c	
<i>Cinnamomum tamala</i> Fr. Nees	Lauraceae	c	SF, cult,
<i>Cryptocarya amygdalina</i> Nees	Lauraceae	c	sal

Scientific name	Family	Conservation status	Habitat
<i>Cryptocarya andersonii</i> King ex Hk. f.	Lauraceae	r	
<i>Lindera melastomacea</i> Benth.	Lauraceae	c	
<i>Lindera nacusua</i> (D. Don) Merr.	Lauraceae	f	
<i>Lindera pulcherrima</i> (Nees) Benth.	Lauraceae	c	
<i>Litsea cubeba</i> (Lour.) Pers.	Lauraceae	c	SF
<i>Litsea glutinosa</i>	Lauraceae		
<i>Litsea lancifolia</i> (Roxb. ex Nees) Wall. ex Hk. f.	Lauraceae	f	ev
<i>Litsea meissneri</i> Hk. f.	Lauraceae	f	ev
<i>Litsea monopelata</i> (Roxb.) Pers.	Lauraceae	f	plt
<i>Litsea salicifolia</i> (Roxb. ex Nees) Hk. f.	Lauraceae	c	
<i>Litsea sebifera</i> Pers.	Lauraceae	c	ev
<i>Litsea tomentosa</i> Nees	Lauraceae		
<i>Neocinnamomum caudatum</i> (Wall. ex Nees) Merr.	Lauraceae	f	
<i>Neolitsea umbrosa</i> (Nees) Gamble	Lauraceae		
<i>Persea odoratissima</i> (Nees) Koster.	Lauraceae	c	
<i>Persea petiolaris</i> (Hk. f.) Deb.	Lauraceae	f	
<i>Persea villosa</i> (Roxb.) Koster.	Lauraceae	c	ev,SF,mixeddd
<i>Phoebe attenuata</i> (Nees) Nees	Lauraceae	c	ev
<i>Phoebe cooperiana</i> U. N. Kanjilal	Lauraceae	r	dd
<i>Phoebe goalparensis</i>	Lauraceae		

Scientific name	Family	Conservation status	Habitat
<i>Phoebe lanceolata</i> (Nees) Nees	Lauraceae	c	ev,rb
<i>Phoebe paniculata</i> Nees	Lauraceae	r	
<i>Leea compactiflora</i> Kurz	Leeaceae	c	ev
<i>Leea edgeworthii</i> Sant.	Leeaceae	c	dd, mixed ev
<i>Leea indica</i> (Burm. f.) Merr.	Leeaceae	c	dd, SF, edge
<i>Fagraea ceilanica</i> Thumb.	Loganiaceae	r	dd
<i>Lagerstroemia parviflora</i> Roxb.	Lythraceae	c	dd, mixeddd
<i>Lagerstroemia speciosa</i> (Linn.) Pers.	Lythraceae	c	rb, edge, cult
<i>Magnolia pterocarpa</i> Roxb.	Magnoliaceae	c	ev
<i>Manglietia insignis</i> (Wall.) Bl.	Magnoliaceae	c	ev
<i>Michelia champaca</i> Linn.	Magnoliaceae	c	ev
<i>Michelia doltsopa</i> DC.	Magnoliaceae	c	ev
<i>Michelia oblonga</i> Wall. ex Hk. f.	Magnoliaceae	c	ev
<i>Talauma hodgsonii</i> Hk. f. & Th.	Magnoliaceae		
<i>Hibiscus macrophyllus</i> Roxb. ex Hornem.	Malvaceae		ev dd
<i>Kydia calycina</i> Roxb.	Malvaceae	c	
<i>Memecylon cerasiforme</i> Kurz	Melastomataceae	f	stream
<i>Aglaia edulis</i> A. Gray	Meliaceae	c	ev
<i>Aphanamixis polystachya</i> (Wall.) Parker	Meliaceae	c	ev
<i>Aphanamixis wallichii</i> (King.) Haridasan & Rao	Meliaceae	c	ev

Scientific name	Family	Conservation status	Habitat
<i>Chikrassia tabularis</i> Anbr. Juss.	Meliaceae		ev
<i>Chisocheton paniculatus</i> (Roxb.) Hiern.	Meliaceae	c	ev, dd
<i>Dysoxylum alliarium</i> (Ham.) Balak.	Meliaceae		
<i>Dysoxylum binectariferum</i> Hk. f. et. Bedd.	Meliaceae	c	
<i>Dysoxylum gobara</i> (Buch.-Ham.) Merr.	Meliaceae	c	ev
<i>Melia azedarach</i> Linn.	Meliaceae		cultiv
<i>Toona ciliata</i> Roem.	Meliaceae	c	dd, mixedd
<i>Walsura robusta</i> Roxb.	Meliaceae	c	ev, edge
<i>Walsura tubulata</i> Hiern	Meliaceae	r	
<i>Acacia auriculiformis</i> A. Cuno. ex Benth.	Mimosaceae		
<i>Albizia chinensis</i> (Osb.) Merr.	Mimosaceae		
<i>Albizia lebbek</i> (Linn.) Benth.	Mimosaceae	f	dd, open
<i>Albizia lucidior</i> (Steud.) Neilson ex Hara	Mimosaceae	c	ev,dd,rb
<i>Albizia mollis</i> Boiv.	Mimosaceae	c	
<i>Albizia odoratissima</i> (Linn. f.) Benth.	Mimosaceae	c	dd
<i>Albizia procera</i> (Roxb.) Benth.	Mimosaceae	c	dd, SF, open
<i>Calliandra umbrosa</i> (Wall.) Benth.	Mimosaceae	c	SF
<i>Parkia roxburghii</i> G. Don	Mimosaceae	r	dd, mixed ev
<i>Pithecellobium heterophyllum</i> (Roxb.) Haridasan & Rao	Mimosaceae	c	dd, SF

Scientific name	Family	Conservation status	Habitat
<i>Pithecellobium monadelphum</i> (Roxb.) Koster.	Mimosaceae	f	ev, edge
<i>Artocarpus chaplasha</i> Roxb.	Moraceae		
<i>Artocarpus gomezians</i> spp. <i>Gomezianus</i> Wall. ex Trecul	Moraceae		
<i>Artocarpus gomezianus</i> spp. <i>zeylanicus</i> Wall. ex Trecul	Moraceae	r	dd
<i>Artocarpus heterophyllus</i> Lamk.	Moraceae	o	cult, wild
<i>Broussonetia papyrifera</i> Vent	Moraceae	r	cult
<i>Ficus altissima</i> Bl.	Moraceae	r	open area
<i>Ficus benghalensis</i> Linn.	Moraceae	f	bmb, others
<i>Ficus benjamina</i> Linn.	Moraceae	r	cult
<i>Ficus cyrtophylla</i> Wall. ex Miq.	Moraceae	c	ev
<i>Ficus drupacea</i> Thumb.	Moraceae	f	ev
<i>Ficus elastica</i> Roxb. ex Hornem.	Moraceae	f	ev, rb
<i>Ficus fistulosa</i> Reinwdt.	Moraceae	f	dd, rb
<i>Ficus gibbosa</i> Bl.	Moraceae	f	
<i>Ficus glaberrima</i> Bl.	Moraceae	f	dd
<i>Ficus heterophylla</i> Linn. f.	Moraceae	f	rb
<i>Ficus hirta</i> Vahl	Moraceae	c	stream, bmb
<i>Ficus hispida</i> Linn. f.	Moraceae	c	stream
<i>Ficus infectoria</i> Roxb.	Moraceae	f	

Scientific name	Family	Conservation status	Habitat
<i>Ficus ischnopoda</i> Miq.	Moraceae	c	river, rocky area
<i>Ficus lamponga</i> Miq.	Moraceae	f	dd, mixedd
<i>Ficus neriifolia</i> J. E. Sm. Var. <i>Trilepis</i> (King) Corn.	Moraceae	c	subtropical
<i>Ficus nervosa</i> Heyne ex Roth	Moraceae	c	ev
<i>Ficus oligodon</i> Miq.	Moraceae	r	sev
<i>Ficus religiosa</i> Linn.	Moraceae	o	planted
<i>Ficus rumphii</i> Bl.	Moraceae	f	lower elevation
<i>Ficus semicordata</i>	Moraceae		
<i>Morus australis</i> Poir.	Moraceae		cult, wild
<i>Morus macroura</i> Miq.	Moraceae	c	dd, mix, cult
<i>Streblus asper</i> Lour.	Moraceae	r	dry
<i>Streblus zeylanicus</i> Kurz	Moraceae		
<i>Moringa oleifera</i> Lamk.	Moringaceae	c	cultiv, wild
<i>Ardisia colorata</i> Roxb.	Myrsinaceae	r	ev
<i>Ardisia floribunda</i> Wall.	Myrsinaceae	f	rb, edge
<i>Ardisia paniculata</i> Roxb.	Myrsinaceae	o	dd, mixed ev
<i>Ardisia virens</i> Kurz	Myrsinaceae	f	ev, stream
<i>Maesa indica</i> (Roxb.) Wall.	Myrsinaceae	c	shady
<i>Maesa ramentacea</i> Wall.	Myrsinaceae	c	SF, edge

Scientific name	Family	Conservation status	Habitat
<i>Cleistocalyx operculatus</i> (Roxb.) Merr. & Perr.	Myrtaceae	c	dd, mixev
<i>Eucalyptus tereticornis</i> Sm.	Myrtaceae		cult
<i>Psidium guajava</i> Linn.	Myrtaceae		cult
<i>Syzygium balsameum</i> (Wt.) Wall. ex AM. & SM. Cowan	Myrtaceae	f	edge, rb
<i>Syzygium cumini</i> (Linn.) Skeels	Myrtaceae	c	
<i>Syzygium formosum</i> (Wall.) Mas.	Myrtaceae	f	ev,
<i>Syzygium grandis</i> (Wt.) Wala.	Myrtaceae	r	
<i>Syzygium kurzii</i> (Duthie) Balak.	Myrtaceae	c	ev, sev
<i>Syzygium operculatum</i> (Roxb.) Wall	Myrtaceae		
<i>Syzygium polypetalum</i> (Wall. ex Wt.) Merr. & Perr.	Myrtaceae	f	rb
<i>Syzygium praecoxum</i> (Roxb.) Haridasan & Rao	Myrtaceae	c	dd, mixedd
<i>Syzygium ramosissimum</i> (Wall. ex Duthie) Balak.	Myrtaceae	c	ev
<i>Syzygium sizigioides</i> (Miq.) Merr. & Perr.	Myrtaceae	c	
<i>Syzygium tetragonum</i> (Wt.) Kurz	Myrtaceae	c	
<i>Ochna integerrima</i> (Lour.) Merr.	Ochnaceae	r	
<i>Chionanthus macrophylla</i> Bl.	Oleaceae	c	ev
<i>Ligustrum indicum</i> (Lour.) Merr.	Oleaceae	f	ev, edge
<i>Ligustrum robustum</i> (Roxb.) Bl.	Oleaceae	c	
<i>Olea dentata</i> Wall. ex DC.	Oleaceae	c	ev, mixed ev

Scientific name	Family	Conservation status	Habitat
<i>Olea dioica</i> Roxb.	Oleaceae	f	ev
<i>Pandanus foetidus</i> Roxb.	Pandanaceae		
<i>Pandanus odoratissimus</i> (Lamk.) Linn.	Pandanaceae		
<i>Pittosporum nepaulense</i> (DC.) Rehr. & Wils.	Pittosporaceae	c	
<i>Podocarpus latifolia</i> Wall.	Podocarpaceae		
<i>Podocarpus neerifolia</i> D. Don	Podocarpaceae		
<i>Xanthophyllum flavescens</i> Roxb.	Polygalaceae	r	ev
<i>Grevillea robusta</i> A. Cunn.	Proteaceae		cult
<i>Helicia excelsa</i> Bl.	Proteaceae	r	
<i>Helicia nilagirica</i> Bedd.	Proteaceae		
<i>Helicia robusta</i> Wall ex Benn.	Proteaceae	f	
<i>Rhamnus nepalensis</i> (Wall.) Laws.	Rhamnaceae		SF,open
<i>Zizyphus rugosa</i> Lamk.	Rhamnaceae	c	open
<i>Carallia brachiata</i> (Lour.) Merr.	Rhizophoraceae	c	ev, rb, edge
<i>Eriobotrya bengalensis</i> Hk. f.	Rosaceae	f	ev
<i>Anthocephalus chinensis</i> (Lam.) A. Rich. ex Walp.	Rubiaceae	c	
<i>Canthium dicoccum</i> (Gaert.) T. & T.	Rubiaceae	f	ev
<i>Canthium glabrum</i> Bl.	Rubiaceae	r	dd
<i>Catunaregam spinosa</i> (Thumb.) Tiruv	Rubiaceae		
<i>Catunaregam uliginosa</i> (Retz.) Siv.	Rubiaceae		

Scientific name	Family	Conservation status	Habitat
<i>Cinchona ledgeriana</i> Moons. ex Trim.	Rubiaceae		cult
<i>Gardenia campanulata</i> Roxb.	Rubiaceae	r	
<i>Haldina cordifolia</i>	Rubiaceae	r	
<i>Hymenodictyon flaccidum</i> Wall.	Rubiaceae	f	ev, mixedd
<i>Hymenodictyon excelsum</i> Wall.	Rubiaceae	f	
<i>Hyptianthera stricta</i> (Willd.) W. & A.	Rubiaceae	c	ev
<i>Ixora undulata</i> Roxb.	Rubiaceae	c	
<i>Mitragyna rotundifolia</i> (Roxb.) O. Ktz.	Rubiaceae	f	
<i>Nauclea griffithii</i> Hav.	Rubiaceae	f	ev
<i>Pavetta indica</i> Linn.	Rubiaceae	c	ev
<i>Prismatomeris tetrandra</i> (Roxb.) K. Schum.	Rubiaceae	c	ev
<i>Randia griffithii</i> Hk. f.	Rubiaceae	o	edge
<i>Randia wallichii</i> Hk. f.	Rubiaceae	f	ev
<i>Saprosma ternatum</i> Hk. f.	Rubiaceae	c	ev, dd, bmb
<i>Tarenna asiatica</i> (Linn.) Sant. & Merch.	Rubiaceae	f	
<i>Tricalysis singularis</i> K. Schum.	Rubiaceae	c	mixedd
<i>Wendlandia glabrata</i> DC.	Rubiaceae	f	
<i>Wendlandia grandis</i> Cowan	Rubiaceae	c	ev, SF
<i>Wendlandia paniculata</i> DC.	Rubiaceae	f	gorges
<i>Wendlandia tinctoria</i> (Roxb.) DC.	Rubiaceae	c	SF, edge

Scientific name	Family	Conservation status	Habitat
<i>Xeromphis spinosa</i> (Thunb.) Keay	Rubiaceae	f	SF, edge
<i>Acronychia pedunculata</i> (Linn.) Miq.	Rutaceae		
<i>Aegle marmelos</i> (Linn.) Correa	Rutaceae	r	cultiv
<i>Atalantia monophylla</i> Corr.	Rutaceae		
<i>Citrus medica</i> Linn.	Rutaceae		
<i>Evodia glabrifolia</i> Champ.	Rutaceae		
<i>Glycosmis arborea</i> (Roxb.) DC.	Rutaceae		
<i>Glycosmis cymosa</i> (Kurz.) Narayanswamy	Rutaceae		
<i>Micromelem integerrimum</i> (Roxb.) Wt. & Arn.	Rutaceae		
<i>Murraya paniculata</i> (Linn.) Jack.	Rutaceae		
<i>Zanthoxylum hamiltonianum</i> Wall.	Rutaceae		
<i>Zanthoxylum rhetsa</i> (Roxb.) DC.	Rutaceae		ev,
<i>Meliosma arnottiana</i> (Wt.) Walp	Sabiaceae	r	
<i>Meliosma simplicifolia</i> (Roxb.) Walp	Sabiaceae	c	ev, SF
<i>Aesculus assamica</i> Griff.	Sapindaceae	c	dd, rb
<i>Aphania rubra</i> (Roxb.) Radlk.	Sapindaceae		Mixed ev
<i>Dimocarpus longan</i> Lour.	Sapindaceae		
<i>Lepisanthes rubiginosa</i> (Roxb.) Leenh.	Sapindaceae	o	
<i>Palaquium polyanthum</i> (Wall. ex DC.) Engl.	Sapotaceae	r	
<i>Sarcosperma arboreum</i> Cl.	Sapotaceae	c	ev,

Scientific name	Family	Conservation status	Habitat
<i>Saurauia cerea</i> Griff. ex Dyer.	Saurauiaceae		
<i>Saurauia nepaulensis</i> DC.	Saurauiaceae		SF, edge
<i>Saurauia panduana</i> Wall.	Saurauiaceae		
<i>Saurauia roxburghii</i> Wall.	Saurauiaceae		edge, dsiturbed
<i>Ailanthus excelsa</i> Roxb.	Simaroubaceae		Pltd
<i>Ailanthus integrifolia</i> Lamk.	Simaroubaceae		ev
<i>Picrasma javanica</i> Bl.	Simaroubaceae	c	ev
<i>Duabanga grandiflora</i> (Roxb. ex DC.) Walp.	Sonneratiaceae	c	rb
<i>Turpinia nepalensis</i> Wall. ex W. & A.	Staphyliaceae	f	ev
<i>Turpinia pomifera</i> (Roxb.) DC.	Staphyliaceae	c	
<i>Firmiana colorata</i> (Roxb.) R. Br.	Sterculiaceae	c	dd
<i>Heritiera acuminata</i> Wall.	Sterculiaceae		
<i>Pterospermum acerifolium</i> Willd.	Sterculiaceae	c	dd
<i>Pterospermum lancifolium</i> DC.	Sterculiaceae		ev dd
<i>Pterygota alata</i> (Roxb.) R. Br.	Sterculiaceae	r	
<i>Sterculia colorata</i> Roxb.	Sterculiaceae		
<i>Sterculia hamiltonii</i> (O. Kt.) Adelb.	Sterculiaceae		ev
<i>Sterculia villosa</i> Roxb.	Sterculiaceae	c	dd
<i>Styrax serrulatum</i> Roxb.	Styracaceae	c	SF, edge
<i>Symplocos javanica</i> (Bl.) Kurz	Symplocaceae	f	ev, rb

Scientific name	Family	Conservation status	Habitat
<i>Symplocos laurina</i> (Retz.) Wall. ex Rehd. & Wils.	Symplocaceae	c	ev, dd, edge
<i>Symplocos lucida</i> (Thumb.) S. & Z.	Symplocaceae	c	PF
<i>Symplocos racemosa</i> Roxb.	Symplocaceae	c	ev, edge
<i>Symplocos sumuntia</i> Buch.-Ham. ex D. Don	Symplocaceae	f	dd, sal
<i>Cephalotaxus griffithii</i> Hk. f.	Taxaceae		
<i>Tetrameles nudiflora</i> R. Br.	Tetramelaceae		open,dd
<i>Eurya acuminata</i> DC.	Theaceae	c	ev dd
<i>Schima khasiana</i> Dyer.	Theaceae		
<i>Schima wallichii</i> (DC) Korth.	Theaceae		
<i>Aquilaria malaccensis</i> Lamk.	Thymeliaceae	f	ev
<i>Grewia disperma</i> Roth.	Tiliaceae	c	ev
<i>Grewia elastica</i> Royle	Tiliaceae	c	dd
<i>Grewia microcos</i> Linn.	Tiliaceae	c	dd
<i>Grewia multiflora</i> Juss.	Tiliaceae		
<i>Celtis tetranda</i> Roxb.	Ulmaceae	f	dd
<i>Celtis timorensis</i> Spanogh.	Ulmaceae	c	ev
<i>Holoptelea integrifolia</i> (Roxb.) Planch.	Ulmaceae	r	
<i>Trema orientalis</i> (Linn.) Bl.	Ulmaceae	f	open,edge
<i>Ulmus lanceifolia</i> Roxb.	Ulmaceae	r	
<i>Boehmeria hamiltoniana</i> Wedd.	Urticaceae		waterfall-

Scientific name	Family	Conservation status	Habitat
			courses
<i>Boehmeria macrophylla</i> D. Don	Urticaceae		
<i>Debregeasia longifolia</i> (Burm. f.) Wedd.	Urticaceae	c	ev, edges
<i>Debregeasia wallichiana</i> (Wedd.) Wedd.	Urticaceae	f	ev
<i>Oreocnide frutescens</i> (Thunb.) Miq.	Urticaceae	c	higher elevation
<i>Oreocnide integrifolia</i> (Gaud.) Miq.	Urticaceae	c	lower elevation
<i>Sarcochlamys pulcherrima</i> Gaud.	Urticaceae	c	ev
<i>Callicarpa arborea</i> Roxb.	Verbenaceae	c	SF, dd
<i>Callicarpa vestita</i> Wall. ex Cl.	Verbenaceae	o	SF
<i>Gmelina arborea</i> Roxb.	Verbenaceae	c	dd, SF
<i>Premna barbata</i> Wall. ex Sch.	Verbenaceae	f	
<i>Premna bengalensis</i> Cl.	Verbenaceae	f	dd, stream
<i>Premna bracteata</i> Wall. ex Cl.	Verbenaceae	r	ev
<i>Premna latifolia</i> Roxb.	Verbenaceae	c	ev, dd
<i>Premna mucronata</i> Roxb.	Verbenaceae	c	dd, ev
<i>Premna racemosa</i> Wall. ex Sch.	Verbenaceae		ev
<i>Tectona grandis</i> Linn. f.	Verbenaceae		pltd
<i>Vitex altissima</i> Linn. f.	Verbenaceae	f	dd
<i>Vitex glabrata</i> R. Br.	Verbenaceae	c	dd, open
<i>Vitex negundo</i> Linn.	Verbenaceae	f	cult

Scientific name	Family	Conservation status	Habitat
<i>Vitex peduncularis</i> Wall. ex Sch.	Verbenaceae	c	dd, SF
<i>Vitex pinnata</i> Linn.	Verbenaceae	c	dd, mixedd

The agglomeration of sampling units (belt-transects) represented by a dendrogram from Cluster classification using Ward's method on tree abundance data (see appendix 4.1 for details of sample plots)

C A S E		0	5	10	15	20	25
Label	Num	+-----+-----+-----+-----+					
1 ERF1	20	-++					
2 IVR3	25	-+ +-----+					
3 ERF2	21	---+		I			
4 RRF1	31	-----++ +-----					
5 SWS3	35	-----+ ++		I I			
6 SWS1	33	-----+ +-----		I			
7 BNPSF3B	13	-----+		+-----			
8 BRFN5	14	-----+		I I			
9 BRFN7	16	-----+-----		I		I 1. Semi-evergreen Forests	
10 ERF3	22	-----+ +-----			I		
11 SWS2	34	-----+			+-----		
12 BNP10	1	-----+-----+		I		I	
13 NNPTURAP	30	-----+		I I		I	
14 BNPSF2A	10	-----+-----		I I		I	
15 BNPSF3A	12	-----+ +-----+ +-----				I	
16 BNPSF1	9	-----++ I		I I		I	
17 BRFN6	15	-----+ ++		I I		I	
18 BNP9	2	-----+		++		+-----+	
19 IVR1	23	-----+-----		I		I	I
20 IVR4	26	-----+ ++		I		I	I
21 BNPSF2B	11	-----+ ++				I	I
22 RRF2	32	-----+				I	I
23 BRFPL1	17	---++				I	I
24 BRFPL8	18	---+ +-----				I	I
25 IVR2	24	-----+ +-----					I
26 BRFPL9	19	-----+				2. Moist Deciduous Forest	I
27 NNP1	27	-+-----					I
28 NNP4	29	-+ +-----					I
29 NNP3	28	-----+				I	I
30 ENPPFB	7	---+-----					+-----+
31 ENPPFC	8	---+ +-----				I	
32 ENPPFA	6	-----+		+-----			
33 ENPBASE1	3	-----+		I 3. Moist Evergreen Forest			
34 ENPBASE2	4	-----+-----					
35 ENPBASE3	5	-----+					

**The phyto-sociological characteristics of tree species in
Tropical Moist Evergreen Forests**

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Polyalthia simiarum</i>	105.50	70.33	66.67	1.10	8.85	6.77	16.72
<i>Walsura tubularis</i>	103.83	69.22	66.67	1.10	8.71	2.87	12.68
<i>Syzygium operculatum</i>	43.88	39.00	88.89	1.47	4.91	5.78	12.16
<i>Castonopsis purpurella</i>	34.50	30.67	88.89	1.47	3.86	5.15	10.48
<i>Castonopsis sp.</i>	49.40	27.44	55.56	0.92	3.45	4.21	8.58
<i>Diospyros variegata</i>	87.67	29.22	33.33	0.55	3.68	4.12	8.35
<i>Mesua ferrea</i>	54.00	36.00	66.67	1.10	4.53	1.60	7.23
<i>Canarium strictum</i>	16.00	12.44	77.78	1.28	1.57	4.32	7.17
<i>Aphanamixis polystachya</i>	24.13	21.44	88.89	1.47	2.70	2.90	7.07
<i>Michelia champaca</i>	32.17	21.44	66.67	1.10	2.70	2.98	6.78
<i>Drimycarpus racemosus</i>	14.63	13.00	88.89	1.47	1.64	2.88	5.99
<i>Tetrameles nudiflora</i>	20.00	13.33	66.67	1.10	1.68	2.81	5.59
<i>Calophyllum polyanthum</i>	34.50	15.33	44.44	0.73	1.93	2.84	5.50
<i>Eurya accuminata</i>	17.57	13.67	77.78	1.28	1.72	2.07	5.07
<i>Betula alnoides</i>	15.71	12.22	77.78	1.28	1.54	2.22	5.04
<i>Cynometra polyandra</i>	13.50	12.00	88.89	1.47	1.51	2.03	5.00
<i>Sapium baccatum</i>	11.78	11.78	100.00	1.65	1.48	1.58	4.71
<i>Garcinia kydea</i>	17.71	13.78	77.78	1.28	1.73	1.62	4.64

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Pterospermum lancifolium</i>	37.20	20.67	55.56	0.92	2.60	1.11	4.62
<i>Casearia graveolens</i>	44.33	14.78	33.33	0.55	1.86	1.65	4.06
<i>Boehmeria sp.</i>	29.67	9.89	33.33	0.55	1.24	2.23	4.02
<i>Cinnamomum bejolghota</i>	10.50	9.33	88.89	1.47	1.17	1.10	3.74
<i>Acronychia pedunculata</i>	12.71	9.89	77.78	1.28	1.24	1.09	3.61
<i>Viburnum colebrookianum</i>	21.75	9.67	44.44	0.73	1.22	1.44	3.39
<i>Syzygium cuminni</i>	13.00	10.11	77.78	1.28	1.27	0.79	3.35
<i>Kaeya floribunda</i>	5.63	5.00	88.89	1.47	0.63	1.09	3.18
<i>Duabunga grandiflora</i>	5.11	5.11	100.00	1.65	0.64	0.85	3.15
<i>Actinodaphne obovata</i>	11.00	7.33	66.67	1.10	0.92	1.08	3.11
<i>Parapentapanax subcordatum</i>	24.33	8.11	33.33	0.55	1.02	1.48	3.05
<i>Elaeocarpus aristatus</i>	10.50	7.00	66.67	1.10	0.88	1.01	2.99
<i>Micromelum integerrimum</i>	7.13	6.33	88.89	1.47	0.80	0.65	2.91
<i>Trewia nudiflora</i>	13.00	8.67	66.67	1.10	1.09	0.64	2.83
<i>Persia villosa</i>	5.75	5.11	88.89	1.47	0.64	0.62	2.73
<i>Saurauia nepaulensis</i>	20.00	6.67	33.33	0.55	0.84	1.31	2.70
<i>Chukresia sp.</i>	20.33	6.78	33.33	0.55	0.85	1.22	2.63
<i>Croton joufera</i>	8.86	6.89	77.78	1.28	0.87	0.37	2.52
<i>Dillenia pentagyna</i>	6.14	4.78	77.78	1.28	0.60	0.63	2.51
<i>Aesculus assamica</i>	13.50	6.00	44.44	0.73	0.76	0.77	2.25
<i>Aporosa dioica</i>	10.33	6.89	66.67	1.10	0.87	0.26	2.23
<i>Ficus semicordata</i>	7.40	4.11	55.56	0.92	0.52	0.76	2.20

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Walsura arborea</i>	10.50	4.67	44.44	0.73	0.59	0.87	2.19
<i>Flacourtia jangomas</i>	11.25	5.00	44.44	0.73	0.63	0.82	2.18
<i>Grewia microcos</i>	13.40	7.44	55.56	0.92	0.94	0.30	2.16
<i>Schima wallichii</i>	7.50	5.00	66.67	1.10	0.63	0.41	2.14
<i>Macaranga denticulata</i>	14.40	8.00	55.56	0.92	1.01	0.19	2.11
<i>Ailanthus integrifolia</i>	7.80	4.33	55.56	0.92	0.55	0.63	2.09
<i>Knema linifolia</i>	3.86	3.00	77.78	1.28	0.38	0.40	2.07
<i>Korol</i>	8.17	5.44	66.67	1.10	0.69	0.26	2.05
<i>Ligustrum roburm</i>	4.00	2.22	55.56	0.92	0.28	0.65	1.85
<i>Saraca indica</i>	15.25	6.78	44.44	0.73	0.85	0.18	1.77
<i>Litsea monopelata</i>	2.29	1.78	77.78	1.28	0.22	0.25	1.76
<i>Diospyros malabarica</i>	5.40	3.00	55.56	0.92	0.38	0.45	1.74
<i>Bignonia sp.</i>	3.40	1.89	55.56	0.92	0.24	0.59	1.74
<i>Carralia sp.</i>	4.80	2.67	55.56	0.92	0.34	0.48	1.74
<i>Syzygium balsameum</i>	12.33	4.11	33.33	0.55	0.52	0.66	1.73
<i>Pterospermum acerifolium</i>	7.75	3.44	44.44	0.73	0.43	0.55	1.72
<i>Ulmus lancefolia</i>	10.33	3.44	33.33	0.55	0.43	0.68	1.67
<i>Oriocnoide integrefolia</i>	5.80	3.22	55.56	0.92	0.41	0.33	1.65
<i>Ilex embedioides</i>	17.00	5.67	33.33	0.55	0.71	0.14	1.40
<i>Glochidion velutinum</i>	3.80	2.11	55.56	0.92	0.27	0.21	1.39
<i>Hibiscus macrophyllus</i>	5.00	2.78	55.56	0.92	0.35	0.12	1.39
<i>Ficus subulata</i>	2.80	1.56	55.56	0.92	0.20	0.26	1.38

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Mallotus sp.</i>	2.80	1.56	55.56	0.92	0.20	0.25	1.36
<i>Artocarpus chaplasha</i>	4.25	1.89	44.44	0.73	0.24	0.36	1.34
<i>Glochidion sphenogynum</i>	4.20	2.33	55.56	0.92	0.29	0.12	1.33
<i>Sapium eugeniaefolium</i>	2.40	1.33	55.56	0.92	0.17	0.23	1.32
<i>Ostodes paniculata</i>	9.67	3.22	33.33	0.55	0.41	0.36	1.32
<i>Callicarpa arborea</i>	7.25	3.22	44.44	0.73	0.41	0.12	1.26
<i>Palaquium polyanthum</i>	13.00	2.89	22.22	0.37	0.36	0.53	1.26
<i>Rhus accuminata</i>	1.80	1.00	55.56	0.92	0.13	0.15	1.20
<i>Sterculia villosa</i>	2.33	0.78	33.33	0.55	0.10	0.50	1.15
<i>Ilex umbellulata</i>	2.75	1.22	44.44	0.73	0.15	0.22	1.11
<i>Garcinia lancifolia</i>	2.50	1.11	44.44	0.73	0.14	0.23	1.11
<i>Albizia chinensis</i>	1.40	0.78	55.56	0.92	0.10	0.09	1.10
<i>Phoebe sp.</i>	1.40	0.78	55.56	0.92	0.10	0.05	1.07
<i>Croton caudatus</i>	2.00	0.89	44.44	0.73	0.11	0.22	1.07
<i>Podocarpus neerifolia</i>	6.00	1.33	22.22	0.37	0.17	0.47	1.01
<i>Kydia calycina</i>	2.50	1.11	44.44	0.73	0.14	0.13	1.01
<i>Mallotus tetracoccus</i>	4.67	1.56	33.33	0.55	0.20	0.23	0.98
<i>Morinda augustifolia</i>	2.25	1.00	44.44	0.73	0.13	0.12	0.98
<i>Actinodaphne augustifolium</i>	6.67	2.22	33.33	0.55	0.28	0.13	0.96
<i>Mangifera sylvatica</i>	2.33	0.78	33.33	0.55	0.10	0.28	0.93
<i>Bombax ceiba</i>	3.00	1.00	33.33	0.55	0.13	0.24	0.92
<i>Ficus foveolata</i>	1.75	0.78	44.44	0.73	0.10	0.08	0.92

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Holarrhena antidysentrica</i>	1.50	0.67	44.44	0.73	0.08	0.10	0.91
<i>Artocarpus sp.</i>	1.50	0.67	44.44	0.73	0.08	0.04	0.86
<i>Garcinia tinctoria</i>	1.00	0.44	44.44	0.73	0.06	0.06	0.85
<i>Sterculia colorata</i>	1.00	0.33	33.33	0.55	0.04	0.22	0.81
<i>Schefflera venulosa</i>	8.50	1.89	22.22	0.37	0.24	0.17	0.77
<i>Gmelina arborea</i>	4.00	0.89	22.22	0.37	0.11	0.29	0.77
<i>Lannea grandis</i>	2.33	0.78	33.33	0.55	0.10	0.08	0.73
<i>Terminalia citrina</i>	4.00	0.89	22.22	0.37	0.11	0.25	0.72
<i>Macaranga indica</i>	1.00	0.33	33.33	0.55	0.04	0.12	0.72
<i>Dalbergia peniculata</i>	5.50	1.22	22.22	0.37	0.15	0.18	0.70
<i>Pithecellobium monadelphum</i>	6.50	1.44	22.22	0.37	0.18	0.15	0.70
<i>Elaeocarpus rugosus</i>	10.00	2.22	22.22	0.37	0.28	0.05	0.69
<i>Cinnamomum glaucescens</i>	3.50	0.78	22.22	0.37	0.10	0.21	0.68
<i>Lagerstroemia speciosa</i>	2.00	0.44	22.22	0.37	0.06	0.24	0.66
<i>Aquilaria agallocha</i>	1.33	0.44	33.33	0.55	0.06	0.04	0.65
<i>Trema orientalis</i>	1.67	0.56	33.33	0.55	0.07	0.02	0.64
<i>Bredelia retusa</i>	1.00	0.33	33.33	0.55	0.04	0.04	0.64
<i>Bauhinia stipularis</i>	4.50	1.00	22.22	0.37	0.13	0.11	0.61
<i>syzygium sp.</i>	4.00	0.89	22.22	0.37	0.11	0.13	0.61
<i>Lithocarpus elegans</i>	3.50	0.78	22.22	0.37	0.10	0.09	0.55
<i>Grewia sp.</i>	1.50	0.33	22.22	0.37	0.04	0.14	0.55
<i>Rhus succedanea</i>	4.50	1.00	22.22	0.37	0.13	0.05	0.54

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Toona ciliata</i>	3.00	0.67	22.22	0.37	0.08	0.07	0.52
<i>Wendlandia excelsa</i>	2.00	0.44	22.22	0.37	0.06	0.08	0.50
<i>Vitex peduncularis</i>	2.00	0.44	22.22	0.37	0.06	0.06	0.49
<i>Albizia stipulata</i>	2.00	0.44	22.22	0.37	0.06	0.06	0.49
<i>Ilex sp.</i>	3.00	0.67	22.22	0.37	0.08	0.03	0.49
<i>Celtis tetranda</i>	2.00	0.44	22.22	0.37	0.06	0.05	0.48
<i>Maesa sermentosa</i>	16.00	1.78	11.11	0.18	0.22	0.06	0.46
<i>Pithecellobium heterophyllum</i>	3.00	0.67	22.22	0.37	0.08	0.01	0.46
<i>Artocarpus gomezianus</i>	1.50	0.33	22.22	0.37	0.04	0.05	0.46
<i>Pterigota alata</i>	1.50	0.33	22.22	0.37	0.04	0.04	0.45
<i>Vitex glabrata</i>	1.50	0.33	22.22	0.37	0.04	0.03	0.44
<i>Drimycarpus sp.</i>	1.50	0.33	22.22	0.37	0.04	0.03	0.44
<i>Pithecellobium monodephum</i>	1.00	0.22	22.22	0.37	0.03	0.04	0.43
<i>Gynocardia odorata</i>	1.50	0.33	22.22	0.37	0.04	0.01	0.42
<i>Oroxylum indicum</i>	7.00	0.78	11.11	0.18	0.10	0.14	0.42
<i>Randia uliginosa</i>	6.00	0.67	11.11	0.18	0.08	0.15	0.41
<i>Alstonia scholaris</i>	1.00	0.22	22.22	0.37	0.03	0.02	0.41
<i>Neocinnamomum caudatum</i>	1.00	0.22	22.22	0.37	0.03	0.02	0.41
<i>Cinnamomum tamala</i>	7.00	0.78	11.11	0.18	0.10	0.12	0.40
<i>Castonopsis indiaca</i>	7.00	0.78	11.11	0.18	0.10	0.04	0.32
<i>Ficus sp.</i>	1.00	0.11	11.11	0.18	0.01	0.10	0.30
<i>Ardisia sp.</i>	5.00	0.56	11.11	0.18	0.07	0.05	0.30

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Terminalia balerica</i>	1.00	0.11	11.11	0.18	0.01	0.10	0.29
<i>Polyalthia sp.</i>	3.00	0.33	11.11	0.18	0.04	0.05	0.28
<i>Erythrina stricta</i>	4.00	0.44	11.11	0.18	0.06	0.03	0.27
<i>Lansea coromandelica</i>	1.00	0.11	11.11	0.18	0.01	0.07	0.27
<i>Careya arborea</i>	3.00	0.33	11.11	0.18	0.04	0.04	0.26
<i>Albizia lebbek</i>	1.00	0.11	11.11	0.18	0.01	0.04	0.24
<i>Lapisanthus rubiginosa</i>	2.00	0.22	11.11	0.18	0.03	0.02	0.23
<i>Heteropanax fragrans</i>	2.00	0.22	11.11	0.18	0.03	0.02	0.23
<i>Ficus hispida</i>	2.00	0.22	11.11	0.18	0.03	0.01	0.22
<i>Firmiana colorata</i>	1.00	0.11	11.11	0.18	0.01	0.03	0.22
<i>Glycosmis arborea</i>	1.00	0.11	11.11	0.18	0.01	0.02	0.22
<i>Bredelia tomentosa</i>	1.00	0.11	11.11	0.18	0.01	0.02	0.22
<i>Garuga pinnata</i>	1.00	0.11	11.11	0.18	0.01	0.02	0.21
<i>Anthocephalus chinensis</i>	1.00	0.11	11.11	0.18	0.01	0.01	0.21
<i>Alangium chinense</i>	1.00	0.11	11.11	0.18	0.01	0.01	0.21
<i>Abrus precatorius</i>	1.00	0.11	11.11	0.18	0.01	0.01	0.20
<i>Litsea sebifera</i>	1.00	0.11	11.11	0.18	0.01	0.00	0.20

**The phyto-sociological characteristics of tree species in
Tropical Semi-evergreen Forests**

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Schima wallichii</i>	113.55	113.55	100.00	1.63	13.02	14.60	29.26
<i>Castonopsis purpurella</i>	53.09	53.09	100.00	1.63	6.09	4.66	12.37
<i>Shorea robusta</i>	81.50	44.45	54.55	0.89	5.10	5.68	11.67
<i>Macaranga denticulata</i>	64.50	58.64	90.91	1.48	6.72	1.97	10.18
<i>Dillenia pentagyna</i>	23.73	23.73	100.00	1.63	2.72	4.71	9.06
<i>Syzygium cuminni</i>	36.00	36.00	100.00	1.63	4.13	3.09	8.85
<i>Tectona grandis</i>	369.00	33.55	9.09	0.15	3.85	4.71	8.70
<i>Grewia microcos</i>	39.36	39.36	100.00	1.63	4.51	1.71	7.85
<i>Aporosa dioica</i>	37.73	37.73	100.00	1.63	4.33	1.19	7.15
<i>Eurya accuminata</i>	25.82	25.82	100.00	1.63	2.96	2.08	6.67
<i>Aphanamixis polystachya</i>	36.50	13.27	36.36	0.59	1.52	3.76	5.88
<i>Ilex umbellulata</i>	21.40	19.45	90.91	1.48	2.23	2.06	5.77
<i>Callicarpa arborea</i>	33.56	27.45	81.82	1.33	3.15	1.27	5.76
<i>Polyalthia simiarum</i>	9.82	9.82	100.00	1.63	1.13	2.77	5.52
<i>Bignonia sp.</i>	16.67	13.64	81.82	1.33	1.56	2.31	5.21
<i>Castonopsis sp.</i>	37.50	6.82	18.18	0.30	0.78	3.79	4.87
<i>Persia villosa</i>	19.70	17.91	90.91	1.48	2.05	0.81	4.35
<i>Vitex peduncularis</i>	12.55	12.55	100.00	1.63	1.44	1.04	4.11
<i>Lagerstroemia parviflora</i>	18.88	13.73	72.73	1.19	1.57	1.14	3.90

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Terminalia balerica</i>	13.60	12.36	90.91	1.48	1.42	0.85	3.75
<i>Sapium baccatum</i>	8.70	7.91	90.91	1.48	0.91	1.34	3.73
<i>Litsea monopelata</i>	7.91	7.91	100.00	1.63	0.91	1.06	3.60
<i>Oriocnoide integrefolia</i>	15.10	13.73	90.91	1.48	1.57	0.52	3.57
<i>Glochidion spharogynum</i>	16.38	11.91	72.73	1.19	1.37	0.69	3.24
<i>Garcinia kydea</i>	9.88	7.18	72.73	1.19	0.82	1.10	3.11
<i>Mangifera sylvatica</i>	7.00	4.45	63.64	1.04	0.51	1.41	2.95
<i>Glochidion velutinum</i>	17.17	9.36	54.55	0.89	1.07	0.98	2.95
<i>Artocarpus chaplasha</i>	6.63	4.82	72.73	1.19	0.55	0.96	2.70
<i>Michelia champaca</i>	18.00	3.27	18.18	0.30	0.38	2.03	2.70
<i>Micromelum integerrimum</i>	4.14	2.64	63.64	1.04	0.30	1.29	2.63
<i>Syzygium operculatum</i>	12.00	3.27	27.27	0.44	0.38	1.80	2.62
<i>Holarrhena antidysentrica</i>	7.10	6.45	90.91	1.48	0.74	0.24	2.47
<i>Elaeocarpus rugosus</i>	8.88	6.45	72.73	1.19	0.74	0.45	2.37
<i>Bauhinia stipularis</i>	10.25	7.45	72.73	1.19	0.85	0.29	2.33
<i>Albizia odoratissima</i>	12.60	5.73	45.45	0.74	0.66	0.91	2.31
<i>Careya arborea</i>	11.43	7.27	63.64	1.04	0.83	0.43	2.30
<i>Cynometra polyandra</i>	4.25	3.09	72.73	1.19	0.35	0.76	2.30
<i>Diospyros variegata</i>	16.33	4.45	27.27	0.44	0.51	1.34	2.30
<i>Actinodaphne obovata</i>	9.20	4.18	45.45	0.74	0.48	0.88	2.10
<i>Drimycarpus racemosus</i>	4.63	3.36	72.73	1.19	0.39	0.52	2.09
<i>Bombax ceiba</i>	4.43	2.82	63.64	1.04	0.32	0.69	2.05

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Duabunga grandiflora</i>	7.00	3.82	54.55	0.89	0.44	0.72	2.04
<i>Litsea sebifera</i>	4.44	3.64	81.82	1.33	0.42	0.23	1.98
<i>Trema orientalis</i>	9.20	4.18	45.45	0.74	0.48	0.74	1.96
<i>Croton joufera</i>	6.00	4.36	72.73	1.19	0.50	0.27	1.95
<i>Maesa sermentosa</i>	18.40	8.36	45.45	0.74	0.96	0.22	1.92
<i>Tetrameles nudiflora</i>	6.60	3.00	45.45	0.74	0.34	0.80	1.89
<i>Betula alnoides</i>	2.38	1.73	72.73	1.19	0.20	0.42	1.80
<i>Ficus subulata</i>	3.13	2.27	72.73	1.19	0.26	0.27	1.72
<i>Lannea grandis</i>	4.00	2.55	63.64	1.04	0.29	0.34	1.67
<i>Garcinia tinctoria</i>	2.67	1.45	54.55	0.89	0.17	0.56	1.61
<i>Actinodaphne augustifolium</i>	5.33	2.91	54.55	0.89	0.33	0.36	1.58
<i>Pterospermum lancifolium</i>	5.57	3.55	63.64	1.04	0.41	0.11	1.55
<i>Emblica officinalis</i>	8.33	4.55	54.55	0.89	0.52	0.14	1.55
<i>Parapentapanax subcordatum</i>	15.67	4.27	27.27	0.44	0.49	0.60	1.53
<i>Gmelina arborea</i>	3.50	1.91	54.55	0.89	0.22	0.38	1.49
<i>Hibiscus macrophyllus</i>	7.00	3.82	54.55	0.89	0.44	0.16	1.48
<i>Kaeya floribunda</i>	3.43	2.18	63.64	1.04	0.25	0.13	1.42
<i>Canarium strictum</i>	5.17	2.82	54.55	0.89	0.32	0.21	1.42
<i>Kydia calycina</i>	5.40	2.45	45.45	0.74	0.28	0.37	1.39
<i>Mesua ferrea</i>	2.17	1.18	54.55	0.89	0.14	0.35	1.37
<i>Pterigota alata</i>	3.67	2.00	54.55	0.89	0.23	0.17	1.29

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Grewia sp.</i>	9.67	2.64	27.27	0.44	0.30	0.54	1.29
<i>Erythrina stricta</i>	3.33	1.82	54.55	0.89	0.21	0.17	1.26
<i>Rhus accuminata</i>	2.80	1.27	45.45	0.74	0.15	0.36	1.25
<i>Albizia lebbek</i>	3.50	1.91	54.55	0.89	0.22	0.14	1.25
<i>Elaeocarpus aristatus</i>	8.50	3.09	36.36	0.59	0.35	0.30	1.25
<i>Pterospermum acerifolium</i>	2.67	1.45	54.55	0.89	0.17	0.18	1.23
<i>Albizia chinensis</i>	3.40	1.55	45.45	0.74	0.18	0.31	1.23
<i>Bursera serrata</i>	2.33	1.27	54.55	0.89	0.15	0.16	1.20
<i>Macaranga indica</i>	11.75	4.27	36.36	0.59	0.49	0.11	1.19
<i>Carralia sp.</i>	5.00	1.36	27.27	0.44	0.16	0.47	1.07
<i>Oroxylum indicum</i>	1.50	0.82	54.55	0.89	0.09	0.07	1.05
<i>Acronychia pedunculata</i>	8.50	1.55	18.18	0.30	0.18	0.56	1.03
<i>Cinnamomum bejolghota</i>	9.67	2.64	27.27	0.44	0.30	0.28	1.03
<i>Cinnamomum glaucescens</i>	5.50	1.00	18.18	0.30	0.11	0.60	1.01
<i>Syzygium balsameum</i>	13.50	2.45	18.18	0.30	0.28	0.42	1.00
<i>Mallotus roxbughianus</i>	2.50	0.91	36.36	0.59	0.10	0.28	0.97
<i>Mallotus sp.</i>	6.50	2.36	36.36	0.59	0.27	0.10	0.97
<i>Sterculia villosa</i>	2.80	1.27	45.45	0.74	0.15	0.07	0.96
<i>Alstonia scholaris</i>	2.20	1.00	45.45	0.74	0.11	0.04	0.90
<i>Artocarpus gomezianus</i>	1.40	0.64	45.45	0.74	0.07	0.07	0.89
<i>Toona ciliata</i>	3.50	1.27	36.36	0.59	0.15	0.14	0.88
<i>Castonopsis indiaca</i>	1.40	0.64	45.45	0.74	0.07	0.06	0.87

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Ilex sp.</i>	3.75	1.36	36.36	0.59	0.16	0.10	0.85
<i>Bredelia retusa</i>	3.75	1.36	36.36	0.59	0.16	0.10	0.85
<i>Ficus foveolata</i>	2.33	0.64	27.27	0.44	0.07	0.30	0.82
<i>Celtis tetrandia</i>	4.33	1.18	27.27	0.44	0.14	0.17	0.75
<i>Cinnamomum tamala</i>	2.75	1.00	36.36	0.59	0.11	0.02	0.73
<i>Polaquim polyanthum</i>	1.67	0.45	27.27	0.44	0.05	0.19	0.68
<i>Ligustrum robustum</i>	2.33	0.64	27.27	0.44	0.07	0.16	0.68
<i>Morinda augustifolia</i>	1.50	0.55	36.36	0.59	0.06	0.01	0.67
<i>Drimycarpus sp.</i>	4.00	1.09	27.27	0.44	0.13	0.08	0.65
<i>Knema linifolia</i>	2.00	0.36	18.18	0.30	0.04	0.27	0.61
<i>Lagerstroemia speciosa</i>	4.50	0.82	18.18	0.30	0.09	0.21	0.60
<i>Ficus hispida</i>	2.33	0.64	27.27	0.44	0.07	0.08	0.59
<i>Abrus precatorius</i>	3.67	1.00	27.27	0.44	0.11	0.02	0.58
<i>Randia uliginosa</i>	2.50	0.45	18.18	0.30	0.05	0.22	0.57
<i>Pithecellobium heterophyllum</i>	3.00	0.82	27.27	0.44	0.09	0.03	0.57
<i>Trewia nudiflora</i>	2.00	0.55	27.27	0.44	0.06	0.04	0.55
<i>Alangium chinense</i>	8.50	1.55	18.18	0.30	0.18	0.06	0.54
<i>Schefflera venulosa</i>	2.33	0.64	27.27	0.44	0.07	0.02	0.54
<i>Lannea coromandelica</i>	1.67	0.45	27.27	0.44	0.05	0.04	0.54
<i>Heteropanax fragrans</i>	2.00	0.55	27.27	0.44	0.06	0.03	0.53
<i>Ailanthus integrifolia</i>	1.33	0.36	27.27	0.44	0.04	0.05	0.53

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Emblica sp.</i>	2.00	0.55	27.27	0.44	0.06	0.02	0.53
<i>Artocarpus sp.</i>	1.67	0.45	27.27	0.44	0.05	0.02	0.52
<i>Ardisia sp.</i>	1.67	0.45	27.27	0.44	0.05	0.01	0.51
<i>Terminalia citrina</i>	1.00	0.18	18.18	0.30	0.02	0.14	0.45
<i>Xylosma longifolium</i>	6.50	1.18	18.18	0.30	0.14	0.02	0.45
<i>Phoebe sp.</i>	3.00	0.55	18.18	0.30	0.06	0.09	0.45
<i>Ficus lamponga</i>	4.00	0.73	18.18	0.30	0.08	0.02	0.40
<i>Garcinia lancifolia</i>	3.50	0.64	18.18	0.30	0.07	0.01	0.38
<i>Neocinnamomum caudatum</i>	9.00	0.82	9.09	0.15	0.09	0.13	0.37
<i>Calophyllum polyanthum</i>	1.00	0.18	18.18	0.30	0.02	0.05	0.37
<i>Hodgsonia macrocarpa</i>	1.00	0.18	18.18	0.30	0.02	0.04	0.36
<i>Walsura tubularis</i>	1.50	0.27	18.18	0.30	0.03	0.02	0.35
<i>Saraca indica</i>	2.00	0.36	18.18	0.30	0.04	0.01	0.35
<i>Polyalthia sp.</i>	1.50	0.27	18.18	0.30	0.03	0.01	0.34
<i>Ficus infectoria</i>	1.50	0.27	18.18	0.30	0.03	0.01	0.34
<i>Vitex glabrata</i>	1.50	0.27	18.18	0.30	0.03	0.01	0.34
<i>Dillenia indica</i>	1.50	0.27	18.18	0.30	0.03	0.01	0.34
<i>Cassia fistula</i>	1.00	0.18	18.18	0.30	0.02	0.01	0.33
<i>Gynocardia odorata</i>	1.00	0.18	18.18	0.30	0.02	0.01	0.33
<i>Glycosmis arborea</i>	5.00	0.45	9.09	0.15	0.05	0.10	0.30
<i>Ostodes paniculata</i>	3.00	0.27	9.09	0.15	0.03	0.03	0.21
<i>Bredelia tomentosa</i>	1.00	0.09	9.09	0.15	0.01	0.04	0.20

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Chukresia sp.</i>	1.00	0.09	9.09	0.15	0.01	0.03	0.19
<i>Viburnum colebrookianum</i>	1.00	0.09	9.09	0.15	0.01	0.03	0.19
<i>Wendlandia excelsa</i>	2.00	0.18	9.09	0.15	0.02	0.02	0.18
<i>Aristolochia tagala</i>	2.00	0.18	9.09	0.15	0.02	0.01	0.18
<i>Ficus heterophylla</i>	2.00	0.18	9.09	0.15	0.02	0.01	0.17
<i>Disoxylum hamiltonii</i>	2.00	0.18	9.09	0.15	0.02	0.00	0.17
<i>Sterculia colorata</i>	2.00	0.18	9.09	0.15	0.02	0.00	0.17
<i>Flacourtia jangomas</i>	1.00	0.09	9.09	0.15	0.01	0.01	0.17
<i>Aesculus assamica</i>	1.00	0.09	9.09	0.15	0.01	0.01	0.16
<i>Kotdoi</i>	1.00	0.09	9.09	0.15	0.01	0.01	0.16
<i>Anacardium occidentale</i>	1.00	0.09	9.09	0.15	0.01	0.00	0.16
<i>Aporosa sp.</i>	1.00	0.09	9.09	0.15	0.01	0.00	0.16
<i>Citrus sp.</i>	1.00	0.09	9.09	0.15	0.01	0.00	0.16
<i>Aquilaria agallocha</i>	1.00	0.09	9.09	0.15	0.01	0.00	0.16
<i>Rhus succedanea</i>	1.00	0.09	9.09	0.15	0.01	0.00	0.16
<i>Bischoffia javanica</i>	1.00	0.09	9.09	0.15	0.01	0.00	0.16

**The phyto-sociological characteristics of tree species in
Tropical Mpoist Deciduous Forests**

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Shorea robusta</i>	200.45	147.00	73.33	1.24	16.58	20.40	38.21
<i>Schima wallichii</i>	49.54	42.93	86.67	1.47	4.84	6.89	13.19
<i>Grewia microcos</i>	56.80	56.80	100.00	1.69	6.41	3.12	11.22
<i>Castonopsis purpurella</i>	39.43	36.80	93.33	1.58	4.15	4.96	10.69
<i>Syzygium cumini</i>	35.20	35.20	100.00	1.69	3.97	4.90	10.56
<i>Aporosa dioica</i>	50.08	43.40	86.67	1.47	4.89	2.13	8.49
<i>Dillenia pentagyna</i>	21.57	20.13	93.33	1.58	2.27	3.24	7.09
<i>Sapium baccatum</i>	20.00	17.33	86.67	1.47	1.95	3.15	6.57
<i>Cynometra polyandra</i>	22.42	17.93	80.00	1.35	2.02	2.81	6.19
<i>Vitex peduncularis</i>	17.33	17.33	100.00	1.69	1.95	2.15	5.80
<i>Polyalthia simiarum</i>	25.69	22.27	86.67	1.47	2.51	1.62	5.60
<i>Canarium strictum</i>	16.86	15.73	93.33	1.58	1.77	2.01	5.37
<i>Glycosmis arborea</i>	56.75	15.13	26.67	0.45	1.71	2.96	5.12
<i>Diospyros variegata</i>	32.22	19.33	60.00	1.01	2.18	1.44	4.63
<i>Lagerstroemia parviflora</i>	30.11	18.07	60.00	1.01	2.04	1.56	4.62
<i>Holarrhena antidysentrica</i>	22.25	17.80	80.00	1.35	2.01	0.96	4.32
<i>Litsea monopelata</i>	14.83	11.87	80.00	1.35	1.34	1.61	4.30
<i>Artocarpus chaplasha</i>	11.22	6.73	60.00	1.01	0.76	2.41	4.18
<i>Eurya accuminata</i>	24.60	16.40	66.67	1.13	1.85	1.02	4.00

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Terminalia balerica</i>	11.92	9.53	80.00	1.35	1.08	1.38	3.81
<i>Croton joufera</i>	16.38	14.20	86.67	1.47	1.60	0.72	3.78
<i>Ilex sp.</i>	12.43	11.60	93.33	1.58	1.31	0.73	3.62
<i>Lanea grandis</i>	7.93	7.40	93.33	1.58	0.83	1.17	3.58
<i>Drimycarpus sp.</i>	15.55	11.40	73.33	1.24	1.29	1.05	3.58
<i>Bignonia sp.</i>	7.47	7.47	100.00	1.69	0.84	1.04	3.57
<i>Glochidion velutinum</i>	13.08	11.33	86.67	1.47	1.28	0.80	3.54
<i>Kydia calycina</i>	10.54	9.13	86.67	1.47	1.03	0.72	3.22
<i>Drimycarpus racemosus</i>	19.11	11.47	60.00	1.01	1.29	0.86	3.17
<i>Persia villosa</i>	15.09	11.07	73.33	1.24	1.25	0.59	3.07
<i>Ilex umbellulata</i>	8.36	7.80	93.33	1.58	0.88	0.55	3.01
<i>Kaeya floribunda</i>	7.67	6.13	80.00	1.35	0.69	0.65	2.70
<i>Tetrameles nudiflora</i>	13.50	5.40	40.00	0.68	0.61	1.36	2.65
<i>Bursera serrata</i>	8.92	7.13	80.00	1.35	0.80	0.47	2.63
<i>Careya arborea</i>	8.58	6.87	80.00	1.35	0.77	0.50	2.63
<i>Ficus subulata</i>	4.50	3.60	80.00	1.35	0.41	0.83	2.59
<i>Elaeocarpus aristatus</i>	8.55	6.27	73.33	1.24	0.71	0.46	2.41
<i>Betula alnoides</i>	3.92	3.40	86.67	1.47	0.38	0.45	2.30
<i>Trewia nudiflora</i>	6.90	4.60	66.67	1.13	0.52	0.57	2.22
<i>Vitex pinnata</i>	9.00	3.60	40.00	0.68	0.41	1.11	2.19
<i>Bauhinia stipularis</i>	9.56	5.73	60.00	1.01	0.65	0.48	2.14
<i>Callicarpa arborea</i>	15.57	7.27	46.67	0.79	0.82	0.41	2.02

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Actinodaphne obovata</i>	8.00	5.33	66.67	1.13	0.60	0.29	2.02
<i>Mallotus sp.</i>	10.75	5.73	53.33	0.90	0.65	0.39	1.93
<i>Aphanamixis polystachya</i>	6.75	3.60	53.33	0.90	0.41	0.56	1.87
<i>Micromelum integerrimum</i>	8.50	4.53	53.33	0.90	0.51	0.42	1.83
<i>Polaquim polyanthum</i>	24.75	6.60	26.67	0.45	0.74	0.62	1.81
<i>Elaeocarpus rugosus</i>	5.00	3.00	60.00	1.01	0.34	0.37	1.72
<i>Macaranga denticulata</i>	7.00	3.73	53.33	0.90	0.42	0.26	1.58
<i>Albizia lebbek</i>	5.25	2.80	53.33	0.90	0.32	0.35	1.57
<i>Bredelia retusa</i>	4.33	2.60	60.00	1.01	0.29	0.22	1.53
<i>Pterospermum lancifolium</i>	9.57	4.47	46.67	0.79	0.50	0.20	1.50
<i>Bombax ceiba</i>	4.00	1.87	46.67	0.79	0.21	0.47	1.47
<i>Walsura tubularis</i>	6.14	2.87	46.67	0.79	0.32	0.35	1.46
<i>Mesua ferrea</i>	5.25	2.80	53.33	0.90	0.32	0.20	1.41
<i>Artocarpus gomezianus</i>	1.50	1.00	66.67	1.13	0.11	0.11	1.35
<i>Pterospermum acerifolium</i>	5.71	2.67	46.67	0.79	0.30	0.25	1.34
<i>Saraca indica</i>	14.60	4.87	33.33	0.56	0.55	0.19	1.30
<i>Celtis tetranda</i>	8.40	2.80	33.33	0.56	0.32	0.42	1.30
<i>Albizia odoratissima</i>	8.40	2.80	33.33	0.56	0.32	0.40	1.28
<i>Tamarindus indica</i>	12.20	4.07	33.33	0.56	0.46	0.26	1.28
<i>Tectona grandis</i>	10.33	2.07	20.00	0.34	0.23	0.70	1.28
<i>Actinodaphne augustifolium</i>	8.00	3.20	40.00	0.68	0.36	0.23	1.27
<i>Oroxylum indicum</i>	1.78	1.07	60.00	1.01	0.12	0.12	1.25

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Ailanthus integrifolia</i>	1.88	1.00	53.33	0.90	0.11	0.21	1.23
<i>Sterculia villosa</i>	18.75	5.00	26.67	0.45	0.56	0.20	1.22
<i>Litsea sebifera</i>	2.38	1.27	53.33	0.90	0.14	0.13	1.17
<i>Albizia chinensis</i>	3.71	1.73	46.67	0.79	0.20	0.16	1.15
<i>Duabunga grandiflora</i>	2.43	1.13	46.67	0.79	0.13	0.19	1.11
<i>Morinda augustifolia</i>	2.86	1.33	46.67	0.79	0.15	0.16	1.10
<i>Randia uliginosa</i>	4.50	1.80	40.00	0.68	0.20	0.21	1.09
<i>Emblica officinalis</i>	3.43	1.60	46.67	0.79	0.18	0.10	1.07
<i>Gmelina arborea</i>	3.50	1.40	40.00	0.68	0.16	0.22	1.05
<i>Artocarpus sp.</i>	2.43	1.13	46.67	0.79	0.13	0.13	1.04
<i>Glochidion spharogynum</i>	4.33	1.73	40.00	0.68	0.20	0.14	1.01
<i>Ficus sp.</i>	2.33	0.47	20.00	0.34	0.05	0.61	1.00
<i>Bischoffia javanica</i>	4.00	1.60	40.00	0.68	0.18	0.15	1.00
<i>Vitex glabrata</i>	7.75	2.07	26.67	0.45	0.23	0.32	1.00
<i>Firmiana colorata</i>	1.83	0.73	40.00	0.68	0.08	0.24	1.00
<i>Toona ciliata</i>	3.00	1.20	40.00	0.68	0.14	0.17	0.98
<i>Cinnamomum bejolghota</i>	6.80	2.27	33.33	0.56	0.26	0.15	0.97
<i>Rhus accuminata</i>	2.00	0.80	40.00	0.68	0.09	0.08	0.84
<i>Ficus infectoria</i>	21.50	2.87	13.33	0.23	0.32	0.29	0.84
<i>Garcinia kydea</i>	1.17	0.47	40.00	0.68	0.05	0.04	0.77
<i>Ilex embedioides</i>	63.00	4.20	6.67	0.11	0.47	0.13	0.72
<i>Michelia champaca</i>	8.00	1.60	20.00	0.34	0.18	0.19	0.71

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Hibiscus macrophyllus</i>	2.40	0.80	33.33	0.56	0.09	0.04	0.70
<i>Lannea coromandelica</i>	1.60	0.53	33.33	0.56	0.06	0.06	0.69
<i>Lagerstroemia speciosa</i>	54.00	3.60	6.67	0.11	0.41	0.15	0.67
<i>Grewia sp.</i>	3.75	1.00	26.67	0.45	0.11	0.10	0.66
<i>Premna latifolia</i>	3.75	1.00	26.67	0.45	0.11	0.09	0.66
<i>Ochna integerrima</i>	2.75	0.73	26.67	0.45	0.08	0.07	0.60
<i>Ligustrum robustum</i>	2.00	0.53	26.67	0.45	0.06	0.09	0.60
<i>Oriocnide integrifolia</i>	3.00	0.80	26.67	0.45	0.09	0.05	0.59
<i>Alstonia scholaris</i>	2.25	0.60	26.67	0.45	0.07	0.06	0.58
<i>Schefflera venulosa</i>	1.50	0.40	26.67	0.45	0.05	0.04	0.54
<i>Castanopsis indica</i>	2.00	0.40	20.00	0.34	0.05	0.15	0.53
<i>Meliosma simplicifolia</i>	4.33	0.87	20.00	0.34	0.10	0.09	0.52
<i>Mangifera sylvatica</i>	1.50	0.40	26.67	0.45	0.05	0.02	0.51
<i>Trema orientalis</i>	1.00	0.27	26.67	0.45	0.03	0.01	0.49
<i>Diospyros malabarica</i>	2.67	0.53	20.00	0.34	0.06	0.06	0.46
<i>Mallotus roxburghianus</i>	4.33	0.87	20.00	0.34	0.10	0.02	0.45
<i>Terminalia citrina</i>	2.67	0.53	20.00	0.34	0.06	0.04	0.44
<i>Xylocarpus longifolium</i>	3.00	0.60	20.00	0.34	0.07	0.01	0.42
<i>Pterigota alata</i>	1.67	0.33	20.00	0.34	0.04	0.04	0.42
<i>Carralia sp.</i>	1.67	0.33	20.00	0.34	0.04	0.03	0.41
<i>Bauhinia malabarica</i>	2.00	0.40	20.00	0.34	0.05	0.02	0.41
<i>Aporosa sp.</i>	2.00	0.40	20.00	0.34	0.05	0.02	0.41

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Erythrina stricta</i>	1.33	0.27	20.00	0.34	0.03	0.03	0.40
<i>Garcinia lancifolia</i>	1.67	0.33	20.00	0.34	0.04	0.02	0.40
<i>Flacourtia jangomas</i>	2.00	0.40	20.00	0.34	0.05	0.01	0.39
<i>Anthocephalus chinensis</i>	4.50	0.60	13.33	0.23	0.07	0.10	0.39
<i>Maesa sermentosa</i>	1.33	0.27	20.00	0.34	0.03	0.02	0.39
<i>Ficus heterophylla</i>	1.67	0.33	20.00	0.34	0.04	0.01	0.39
<i>Ficus foveolata</i>	1.00	0.20	20.00	0.34	0.02	0.02	0.38
<i>Adina cordifolia</i>	9.00	0.60	6.67	0.11	0.07	0.17	0.35
<i>Sterculia colorata</i>	4.50	0.60	13.33	0.23	0.07	0.03	0.33
<i>Cinnamomum glaucescens</i>	3.00	0.40	13.33	0.23	0.05	0.05	0.32
<i>Walsura arborea</i>	2.00	0.27	13.33	0.23	0.03	0.05	0.30
<i>Calophyllum polyanthum</i>	3.00	0.40	13.33	0.23	0.05	0.02	0.29
<i>Pithecellobium heterophyllum</i>	3.50	0.47	13.33	0.23	0.05	0.01	0.29
<i>Derris robusta</i>	1.50	0.20	13.33	0.23	0.02	0.03	0.28
<i>Gynocardia odorata</i>	1.00	0.13	13.33	0.23	0.02	0.03	0.28
<i>Mallotus tetracoccus</i>	11.00	0.73	6.67	0.11	0.08	0.08	0.27
<i>Korol</i>	1.00	0.13	13.33	0.23	0.02	0.02	0.26
<i>Polyalthia sp.</i>	1.00	0.13	13.33	0.23	0.02	0.01	0.25
<i>Aesculus assamica</i>	1.00	0.13	13.33	0.23	0.02	0.00	0.25
<i>Heteropanax fragrans</i>	5.00	0.33	6.67	0.11	0.04	0.03	0.18
<i>Aquilaria agallocha</i>	4.00	0.27	6.67	0.11	0.03	0.01	0.16

Species	Abundance	Density	% frequency	Rel. frequency	Rel. density	Rel. dominance	Species Importance value
<i>Garuga pinnata</i>	2.00	0.13	6.67	0.11	0.02	0.02	0.15
<i>Hodgsonia macrocarpa</i>	3.00	0.20	6.67	0.11	0.02	0.01	0.14
<i>Sapium eugeniaefolium</i>	1.00	0.07	6.67	0.11	0.01	0.02	0.14
<i>Cassia fistula</i>	2.00	0.13	6.67	0.11	0.02	0.01	0.13
<i>Bauhinia sp.</i>	1.00	0.07	6.67	0.11	0.01	0.01	0.13
<i>Abrus precatorius</i>	1.00	0.07	6.67	0.11	0.01	0.01	0.13
<i>Syzygium operculatum</i>	1.00	0.07	6.67	0.11	0.01	0.00	0.12
<i>Ficus lamponga</i>	1.00	0.07	6.67	0.11	0.01	0.00	0.12
<i>Wendlandia excelsa</i>	1.00	0.07	6.67	0.11	0.01	0.00	0.12
<i>Lithocarpus elegans</i>	1.00	0.07	6.67	0.11	0.01	0.00	0.12
<i>Citrus sp.</i>	1.00	0.07	6.67	0.11	0.01	0.00	0.12
<i>Phoebe sp.</i>	1.00	0.07	6.67	0.11	0.01	0.00	0.12
<i>Macaranga indica</i>	1.00	0.07	6.67	0.11	0.01	0.00	0.12

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