DRAFT

ASSESSMENT OF TREE DIVERSITY, SUCCESSIONAL CHANGES AND FOREST FRAGMENTATION IN *JHUM* INFLUENCED FOREST ECOSYSTEM OF SOUTH GARO HILLS, MEGHALAYA

A THESIS SUBMITTED FOR AWARD OF THE DEGREE

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FORWARD

Kali with sword and severed demon head.
Garjia Temple, Kosi River, near Corbett Tiger Reserve. Photo by Bruce Marcot.

In Hindu mysticism, Mother Kali is often portrayed as wielding a sword and holding the severed head of a demon. However, such superficial imagery can be more deeply interpreted as the sword representing knowledge, and the head representing the severing of ignorance and thus the dawning of understanding. So too, does the science presented in this Thesis serve as Kali's sword, providing the light of knowledge and destroying ignorance.

However, the sword of science is double-edged. On one side, it cuts out ignorance, just as this Thesis provides, to date, the definitive scientific statement of vegetation, wildlife, and forest ecology of Garo Hills.

But on the other side, the sword of science can also cut, unintended, into those resources that are the most precious. With scientific knowledge, people can more easily locate and exploit those forest resources having greatest value, and thereby only degrade the environment further.

Thus, the two-edged Kali sword of science must be wielded with not just knowledge but also wisdom, if people and their natural environment are to be both provided over the long term. This Thesis provides a superb scientific basis by which scarce or declining plants, animals, and forest resources of Garo Hills can be conserved for future generations. And in my own collaboration with Ashish Kumar, I have come to respect and expect not only his scientific expertise but also his desire to help wield his scientific findings with humility, reverence and wisdom for the benefit of both the people and the natural environment of Garo Hills.

- Bruce G. Marcot, Ph.D.
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SUMMARY

The findings presented in this thesis are the outcome of a long term research project entitled 'Management of Forests in India for Biological Diversity and Forest Productivity - A New Perspective (1996 – 2002)'. The intensive study area is a part of the Garo Hills situated in the western Meghalaya of the northeast India. The landscape (2459 km^2) is a mosaic of protected areas (PAs), managed forests (MFs) and intervening private/community land. The major goal of present study is to provide knowledge, tools, and indicators for monitoring, and potential management guidelines for conserving native biological diversity of study area. The objectives of present study are (i) to assess diversity patterns and successional changes among tree communities, (ii) to analyse landscape characteristics in particular fragmentation, classify tropical forests and prioritise wildlife areas, (iii) to discuss the native wild fauna and develop information base for modelling wildlife habitat relationships, and (iv) to assess the socioeconomics of native tribes, and evaluate the impact on existing protected areas of the region.

The land in study area can be grouped into three broad categories based on legal status: (1) protected areas (PAs) including a biosphere reserve, two national parks and two wildlife sanctuaries; (2) managed forests (MFs) including four reserved forests (RFs); and (3) community or privately owned land. PAs and RFs cover 372 km^2 (15% of the study area) and are under the control of the state government, whereas the remaining 85% of the study area belongs to tribal councils and individuals (termed "community land" in the present study). Community lands are being used for agriculture, plantations, settlement and other non-forest landuses. The Meghalaya state government initiated wildlife management in the state first time by declaring the Siju Wildlife Sanctuary (SWS) in 1979, followed by the Baghamara Pitcher Plant Sanctuary (BPPS) in 1984 and then Balpakram National Park (BNP) and the Nokrek National Park (NNP) in 1985. At the same time the government embarked on eco-development activities around BNP and NNP, covering 134 villages for sustainable development. The existing protected area network (PAN) offers prospects of conserving the existing old-forest biodiversity of the region, and improving the overall conservation of wildlife and forests through sensible landuse planning.

Present investigation used the stratified random sampling to collect tree data by surveying along existing footpaths and elephant travel lanes using belt transects (1000 m x 10 m, thus 1 ha each). I established 35 belt transects of which 21, 10 and 4 were in PF, SF and sal forests, respectively and recorded the local names and girths of all those trees with ≥ 30 cm girth at breast height. I stratified the PF into three forest formations including PF low (below 400 m elevation), PF mid (400 – 800 m elevation) and PF high (above 800 m elevation) based on elevation and SF into three successional stages including SF1 (15 years old or younger), SF2 (15 – 30 years old), and SF3 (more than 30 years old) based on age (years since stand-replacing disturbance, principally *jhum*) for present study. A total of 411 tree species and their conservation status and potential habitats were recorded from all surveys in study area. The 10 most important tree species (listed in decreasing order of 'species importance value SIV') among all vegetation conditions and forest formations combined were *Shorea robusta, Schima wallichii, Castanopsis purpurella, Polyalthia simiarum, Syzygium cumini, Grewia microcos, Aporusa dioica, Dillenia pentagyna, Drimycarpus racemosus* and *Eurya acuminata.*

The average tree density was greatest in SF and lowest in PF, whereas basal area was highest in primary forest and lowest in secondary forest. Tree species richness and diversity were highest in primary forest and lowest in sal forest, and evenness was highest in secondary forest and lowest in sal forest. Tree species richness was slightly greater in SF1, but not significantly so over three SF formations, although richness of SF1 was significantly greater than SF2, indicating an initial flush of many tree species following *jhum* in SF1, followed by a decrease in SF2 and then a subsequent increase in SF3 as new tree species recover or re-invade. Rarefaction analysis suggested that SF3 are the most tree–diverse, followed by SF1 and SF2, respectively.

The present study compared the SIV (including the combined effects of abundance, density and basal areas) among three groups of tree species within identified successional stages (age classes) of secondary forests. The findings revealed that the middle aged SF are extremely useful for providing wildlife food and the shortened *jhum* cycle may reduce the availability of such forests causing native wildlife to lack food. This would help forest managers and planners to use the correct strategies to arrest the succession at the right stage and to regulate the *jhum* for the maximum benefit of the native wildlife and humans.

The present study mapped the landuse landcover, analysed the forest fragmentation, and classified old native forests to evaluate the landscape characteristics. It identified the critical wildlife habitats including remaining core areas and potential wildlife habitat corridors. Furthermore the study assessed PF and SF at landscape level and classified the tropical forests (using cluster analysis) as 'tropical moist evergreen forest (TMEF)', 'tropical semi-evergreen forests (TSEF)', and tropical moist deciduous forests (TMDF)', which altogether constituting 68 % of the landscape. TMDF covered an area of 703 km^2 (29 % of entire landscape), TSEF covered 624 km^2 (25 %), and TMEF covered 353 km^2 (fourteen percent). The most of the forest cover occurred outside the boundaries of legally managed government controlled land, which accounts for about 80 % of the total forest cover or 1680 km^2. A total of 1062 plant species belonging to 154 families and 578 genera have been recorded from these forests through opportune survey. Euphorbiaceae (33 species), Lauraceae (31), Moraceae (30) and Rubiaceae (26) are the families found with more than 25 species.

The results also suggested that 1742 km^2 (71%) of the study area had forest cover with low fragmentation, and 525 km^2 had moderate or high fragmentation. In many places, this community-owned forest cover formed contiguous forest tracts with low fragmentation. The re-classed fragmentation image was used to delineate seven major corridors that provide links between most PAs and MFs. The total area of these seven corridors was 274 km^2, of which 253 km^2 (92 %) was in the forest cover.

The Zoological Survey of India, Shillong is one of the major sources of intensive inventories of the faunal resources of the Garo Hills. The Garo Hills contain a rich diversity of fauna with 859 vertebrate species recorded or suspected, which is a significant share of the total of 958 animal species in Meghalaya. (ZSI, 1995). The avifauna in the Garo Hills contribute about 60% of all the vertebrate species found there, followed by fish, mammals, reptiles, and amphibians. Much information and research on the ecology of animals, however, is lacking in the Garo Hills. The present study summarized the surveys and population estimates of tiger, elephant and hollock gibbon done by the state forest department or other agencies/individauals, and rates of elephant mortality reported by the wildlife divisions of the Garo Hills.

The present study provided the information database for wildlife-habitat relationship in four components, including mammal-habitat relationships, elephant-habitat relationships, mammal-tree relationships, and bird-habitat relationships. The study used the selected species for developing such information base. Local villagers and field staff were interviewed as sources of information on mammal-habitat relationships. Information on elephant-habitat relationships included data on elephant densities, population trends, and numbers of elephants, as correlated with the topographic, landscape, vegetation and anthropogenic variables of Garo Hills. The analyses suggested that higher elephant densities occurred in elephant census zones with at least four percent of the landscape in deciduous forest cover; less than thirty percent in current *jhum* and abandoned *jhum*; less than five percent in current *jhum* alone; less than twenty percent in high forest patchiness (caused by *jhum*); and village density less than about 0.4 / km^2. These values can be used as testable management hypotheses for guiding conservation or restoration of habitat conditions for elephant conservation in the Garo Hills.

Information on mammal species' use of tree species and tree parts suggestsed that *Grewia microcos, Artocarpus chama, Syzygium cumini, Lapisanthus rubiginosa, Artocarpus gomezianus, Ficus semicordata* and *Lannea grandis* are the most used tree species. *Grewia microcos* is the common food source for all fifteen mammalian species that this study specifically evaluated. Macaques (rhesus, Assamese, pig-tailed and stump-tailed macaques), slow loris, serow and deer (sambar and barking deer) had a wide range of food use for tree species by consuming various body parts of 28, 27, 25 and 25 tree species, respectively. Squirrels, hoolock and capped langur had the next most diverse use of trees, feeding on 21, 20 and 20 tree species, respectively. *Grewia microcos, Artocarpus chaplasha, Syzygium cumini, Lapisanthus rubiginosa, Artocarpus gomezianus, Ficus semicordata* and *Lannea grandis* are the tree species used by most number of the fifteen mammal species assessed.

Information on bird-habitat relationships included a list of 184 bird species observed in the Garo Hills, with habitat relationships shown for 110 of these species of which a total of 51 species used primary forest habitat and other habitats. Out of the 36 bird species recorded from the Balpakram plateau, ten species were not seen anywhere else in the Garo Hills. An additional bird species observed in the BNP area that was not included in their list was the large niltava (*Niltava grandis*), seen in the secondary forest. Additionally, the fairy bluebird in the secondary forest, and the large-billed (Jungle) crow (*Corvus macrorhynchos*), white-bellied yuhina (*Yuhina zantholeuca*), peacock pheasant, kalij pheasant (*Lophura leucomelanos*), and pale-capped (Purple Wood) pigeon (*Columba punicea*) on the slopes of Balpakram Plateau were also observed.

Once very wild and violent, the Garos have become better educated and their social status has improved. The Garo community is well-structured and Garo families average five to eight members, of which two to six are working members. They still practice *jhum* or slash-and-burn, shifting cultivation for their sustenance in rural areas in the absence of alternate agricultural methods. Excessive use of *jhum* agriculture, with increasingly short fallow periods, is one of the major causes of the degredation of the native old forests in the Garo Hills. As per a report (1995) of Directorate of Soil Conservation Department, Government of Meghalaya, on an average 10,432 ha area of landscape is *jhummed* every year, however, the annual soil and vegetation loss from *jhumming* for one ha land equalled around Rs. 12,200 only (see chapter 2 section 2.12 and appendix 2.1 for detail). The present study identified the links between current landuse patterns including resource dependency of local Garo populations, and impacts on protected areas (PAs) of the region.

The zone of influence (ZI) or buffer was evaluated around existing protected areas (PAs), including national parks and reserved forests, to determine forest resources available for local people, the degree of pressure on existing PAs and the potential for further conservation of old native forests of the region. Two ZIs were assessed based on 2 km and 5 km distances from PA boundaries. In both sizes of ZI, especially in the 2-km ZI, the proportions of agricultural, *jhum* and scrubland were very low, which indicated that anthropogenic pressures on native forests was not very high inside ZI.

The 28 wild food plants used by Garos are provided with their local names, important characters and parts used. The seasonal patterns in the collection of NTFP from the forests of community land have also been discussed, based on questionnaire surveys of households. A total of 108 tree species was found to be used by local people as food (33 tree species), medicine (20), timber (54), fuelwood (98), or boat construction material (43). The total monthly expenditure incurred on food by an average Garo rural family was 74 % in the hills region and 73 % in the plains region of Garo Hills. The high percentage of expenditure on essential items such as clothing, housing, and education indicated a low standard of living in the average rural family. As regards the forest management practices inside the community owned areas, the main emphasis had been on the strict protection of the Village Community Reserves in the midst of *jhum* areas. Such examples exist near Nokrek, Balpakram, Baghmara and Emangiri area and could provide the basis for further forest conservation.

Eco-development Society of Meghalaya brought about 134 villages around Balpakram and Nokrek National Parks were under several eco-developmental programmes during 1985. The important schemes taken up by the Community Development Block (CDB) aims at improving the agriculture, communication, animal husbandry and veterinary, health and sanitation, education and social welfare, industries and co-operation. The CDB also administered all the normal rural works and other rural development programmes such as the Integrated Rural Development Programme (IRDP), and the National Rural Employment Programme (NREP). Collectively, these programmes influence the health, welfare, and economy of the local communities of the Garo Hills, and are important vehicles by which future resource use by Garo peoples should be guided.

Finally, this thesis suggested a few recommended applications of findings for regulating *jhum* for adequate conservation planning of landscape, protected area network, and wildlife habitats for managing the tropical forest ecosystem at landscape level.

CHAPTER 1

INTRODUCTION

1.1 Background and origin

This thesis is the outcome of a long term (seven years) Wildlife Institute of India (WII) - United States Forest Service (USFS) collaborative project entitled 'Management of Forests in India for Biological Diversity and Forest Productivity - A New Perspective (1996 – 2002)'. The project chiefly demonstrated how to achieve integration of concerns in India for biological diversity, forest based products and their sustained flow in support of technological, economic and social benefits to urban and rural lifestyles. It addressed ecological assessment across relatively undisturbed ecosystems with forestry interventions under various resource use systems, which support subsistence and related market-based economies. The study used modern ecological concepts as framework to develop guidelines for managers providing pointers to achieving synergy between ecology and forest based economy bringing their significant aspects into a managerial training system to improve manager's capabilities.

Four sites in four bio-geographic locations, the Anaimalai Conservation Area (ACA) in South India; the Satpura Conservation Area (SCA) in Central India; the Terai Conservation Area (TCA) in Eastern/Northern India on the India-Nepal border, and the Garo Hills Conservation Area (GCA) in Northeast India on the India-Bangladesh border comprising some 15,500 km^2 of forested tract were chosen for the project work (**Fig. 1.1**). The selected sites represent a variety of biogeographic patterns, forestry practices, wild plant and animal communities, ethnic human societies, their forest based cultures, economics and traditions, besides the range of administrative realities. The present study assesses aims and objectives at the GCA field site, which is a mosaic of protected areas (PAs), managed forests (MFs) and intervening private/community land over a landscape of 2459 km^2 in Northeast India.

1.2 Conservation issues and concerns

India ranks sixth among the twelve mega biodiverse countries of the world (Maslekar, 2000) with total forest cover over 675,583 km^2 of land (FSI, 2001), which is about 21% of the total geographical area of the country (**Fig. 1.2**). The Indian subcontinent is home to about 46,000 species of plants and some 81,000 species of vertebrate and invertebrate animals (Sarat Babu and Arora, 1999). It owns two out of the sixteen most important biodiversity hot spots of the world, namely Eastern Himalaya and Western Ghats. Northeast India and the Eastern Himalayan region are unique, forming a transitional zone between the Indian, the Indo-Malayan and the Indo-Chinese bio-geographical zones, as well as being the meeting point of the Himalayan region with peninsular India (Takhtajan, 1988). The region harbours about 8000 species of flowering plants, including several representatives of primitive or ancient angiosperms (Takhtajan, 1988).

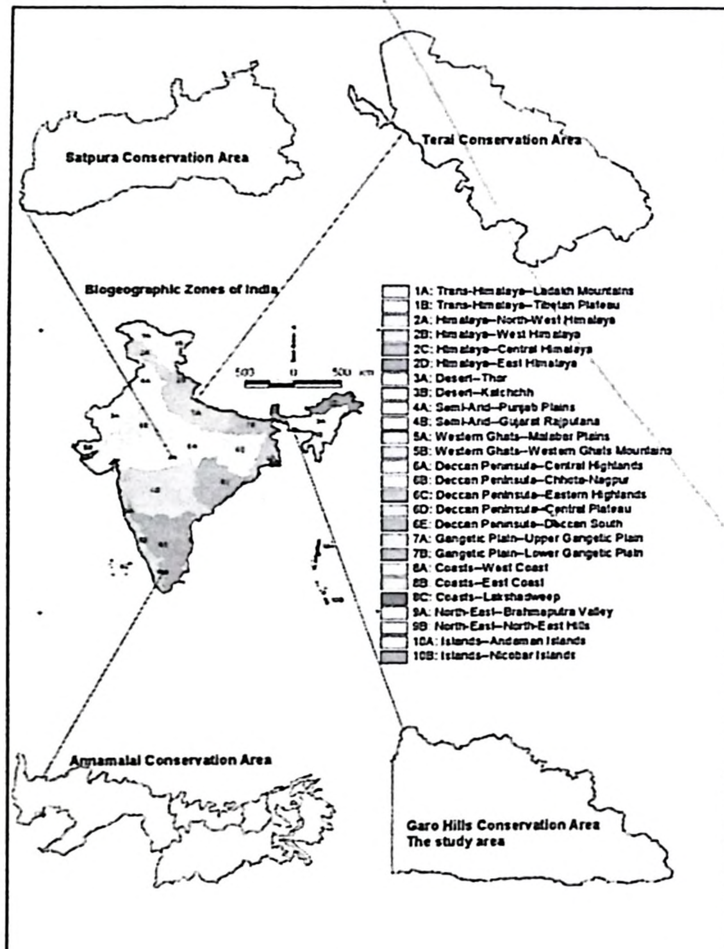


Fig. 1.1: Four study sites of WII-USFS project

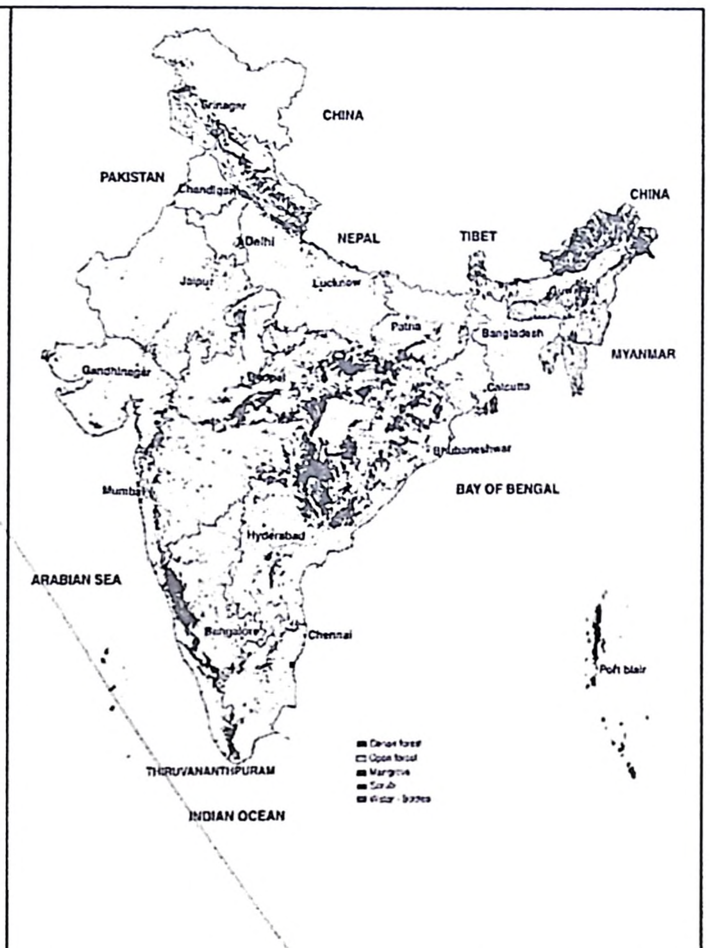
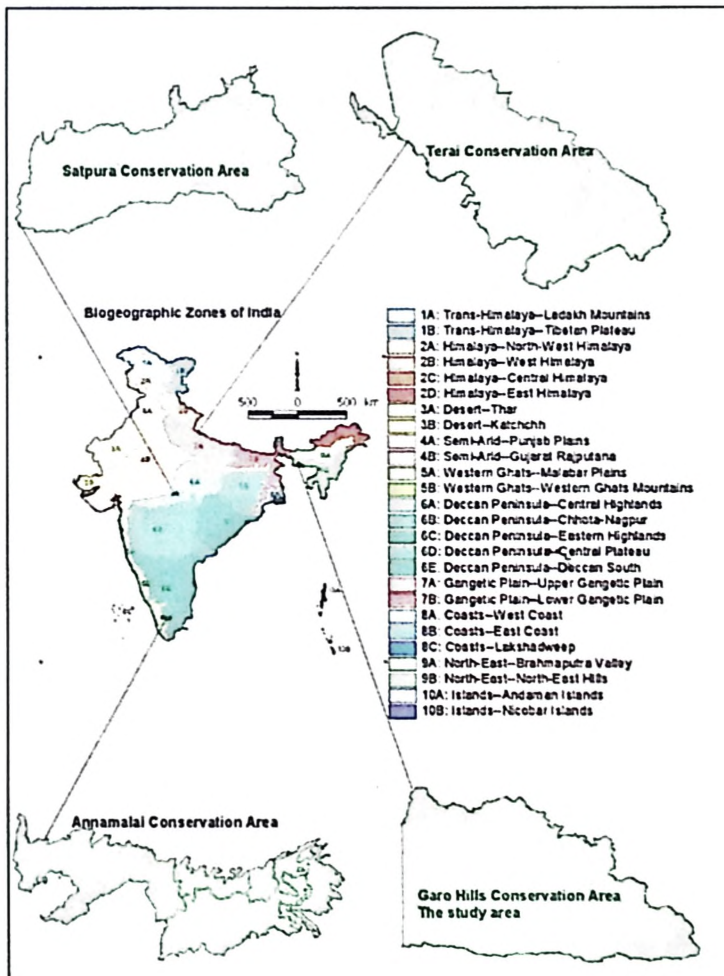


Fig. 1.2: Forest cover of India (source: FSI, 1999)

Northeast India encompasses seven states and popularly known as the '*seven sisters*'. It occupies about 7.76% of total geographical area of country (225,083 km^2). The forest cover of the seven states is 166,173 km^2, which is about 25% of the forest cover of India (FSI, 2001). These forests can be broadly categorised into tropical evergreen, semi-evergreen and temperate forests (Champion & Seth 1968). The forest cover of the hill states of northeast India, however, namely Arunachal Pradesh, Manipur, Meghalaya, Mizoram and Nagaland is under tremendous pressure from exploitation, and the recent assessments showed a loss of about 2972 km^2 of forest cover between 1999 and 2001 (FSI, 2001). Shifting cultivation is the age-old practice of raising crops to about 46,000 species of plants and some 81,000 species of vertebrate and invertebrate animals (Sarat Babu and Arora, 1999). It owns two out of the sixteen most important biodiversity hot spots of the world, namely Eastern Himalaya and Western Ghats. Northeast India and the Eastern Himalayan region are unique, forming a transitional zone between the Indian, the Indo-Malayan and the Indo-Chinese bio-geographical zones, as well as being the meeting point of the Himalayan region with peninsular India (Takhtajan, 1988). The region harbours about 8000 species of flowering plants, including several representatives of primitive or ancient angiosperms (Takhtajan, 1988).



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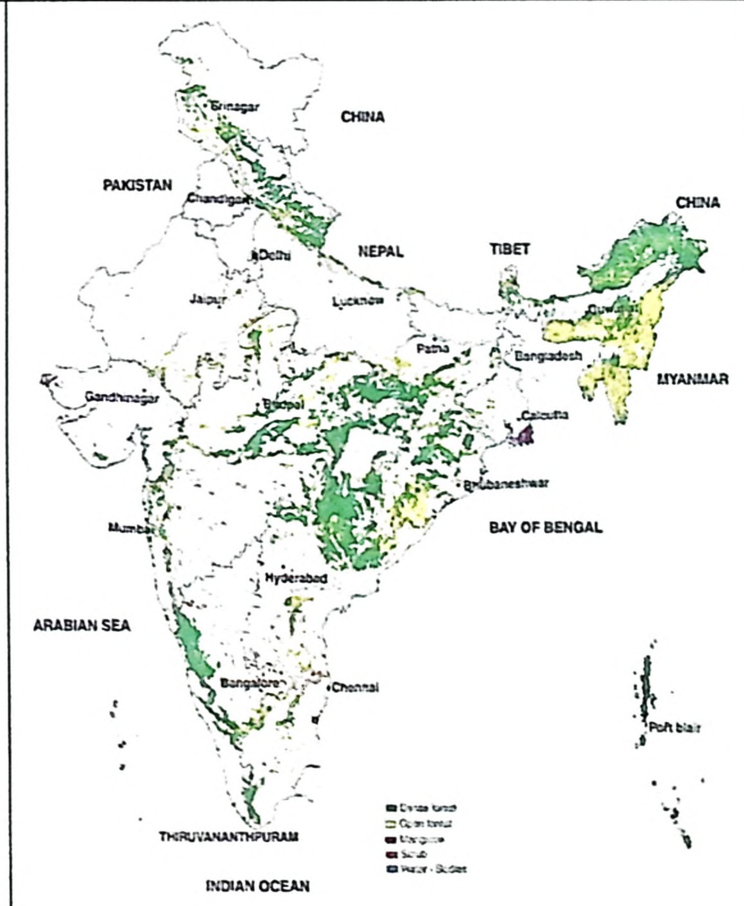

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Northeast India encompasses seven states and popularly known as the '*seven sisters*'. It occupies about 7.76% of total geographical area of country (225,083 km^2). The forest cover of the seven states is 166,173 km^2, which is about 25% of the forest cover of India (FSI, 2001). These forests can be broadly categorised into tropical evergreen, semi-evergreen and temperate forests (Champion & Seth 1968). The forest cover of the hill states of northeast India, however, namely Arunachal Pradesh, Manipur, Meghalaya, Mizoram and Nagaland is under tremendous pressure from exploitation, and the recent assessments showed a loss of about 2972 km^2 of forest cover between 1999 and 2001 (FSI, 2001). Shifting cultivation is the age-old practice of raising crops by clearing and burning a forest patch. The field is abandoned after a few years as soil productivity decreases and a fresh forest area is cleared. Apart from shifting cultivation, large-scale timber harvesting has been carried out during the last few decades. Various pulp industries, as well as native communities harvest bamboo forest, a seral community, for commercial purposes as well as for local use (Ramakrishnan, 1985; Ramakrishnan & Toky, 1983).

1.3 Study gaps

Studies have been undertaken earlier in northeast India and elsewhere on the shifting cultivation or *jhum*, impact on the environment (flora and fauna) and socio-economics (Momin, 1984; Murti, 1986; Ramakrishnan, 1992; William & Johnsingh, 1996; Burling, 1997; Jha, 1997; Khan *et* al., 1997; and Awasthi, 1999). Limited use has been made of satellite and GIS techniques to assess the extent and impact of *jhum* on the ecosystem and landscape (Kumar *et al.*, 2002; and Roy & Tomar, 2001). But, so far, detailed studies on the impact of *jhum* on the overall biodiversity values have not been done. Similarly, an assessment of biodiversity values and the impact of various landuse practices on a larger landscape combined with effective conservation in the form of PAs have not been carried out in northeast India.

1.4 Present study

An outcome of this study is the identification of critical unprotected primary and old secondary forest areas, which if managed properly, will help in maintaining an effective protected area network (PAN) in the South Garo Hills and result in long-term biodiversity conservation at landscape level. The spatial and non-spatial databases comprising of vegetation and landscape attributes will help planners and forest managers ask more relevant questions about correct landuse planning, appropriate use of forest resources and improvement of conservation by protecting critical landscape components and developing an effective network of protected areas in the western Meghalaya. This may serve as model for other northeast Indian states, since all of these seven states possess more or less similar biological, social and ecological values.

The present study focused specifically on the tree species diversity; secondary changes among tree communities representing ecological succession; wildlife habitat relationships for select taxa; landscape composition and structure including existing landuse patterns, evaluating forest fragmentation and core areas for identifying critical wildlife habitats and potential wildlife corridors; and the management implications for conserving biological diversity in the region. The study also discussed the socio-economic conditions of native Garo tribes through literature review and collecting primary data using open- and close-ended questionnaire surveys in selected villages around protected areas.

1.5 Rationale

Shifting cultivation or *jhumming* is the major cause of fragmentation and habitat loss, which consequently, during the course of time lead the formation of secondary forests. During this process of succession, each stand passes through several seral stages, which makes distinct wildlife habitats with the diverse plant species as wildlife food and cover. Also, the 'fragmentation' was prominantly highlighted in literature during mid 1990s (Crim *et* al., 2002) and still getting keen attention of ecologists worldwide. Nowadays, it is considered as key indicator of biodiversity (Kupfer *et al.*, 2004), hence, I focused on ascertaining the fragmentation the forests of Garo Hills.

As a matter of fact, modern wildlife conservation requires the understanding of the patterns and processes of vegetation changes (Morrison, 1998), so I studied the successional changes in present study. Trees are the principal plants in forest ecosystem and are dominant over much of the land surface for thousand of years (Misra, 1968). Therefore, I studied tree species for investigating the secondary forest dynamics, which represented distinct successional wildlife habitats in tropical forests. Following are a few important factors for selecting trees as indicator of landscape level patterns and changes in present study. Trees are

- robust indicator of disturbance at landscape level,
- representative of all forest strata from ground vegetation to top canopy,
- dominant amongst all life forms,
- controlling factor for light penetration and rain water trapping,
- important renewable resource, and
- suitable for long term studies and monitoring.

1.6 Scope and goal of study

The present research study assesses tree diversity over a much larger area and the efficacy of present conservation efforts from an ecological and biological point of view. Also, this thesis explores the existing PAN for its conservation status, biodiversity values, and possibilities of increasing the conservation area network to enhance the conservation status of landscape. The major goal of present study was to provide knowledge, tools, and indicators for monitoring, and potential management guidelines for biological diversity conservation, in the study area. As the study proceeded, I (in consultation with the supervisor and co-supervisors) decided to improve the objectives and increase the extent of the study area (see **appendix 1.1** for originally proposed study aera and objectives) from 1030 km^2 to 2459 km^2, which is the identified landscape for the parent WII-USFS project (1996 - 2002). I reworded the first hypothesis to make it more focussed and testable. Objectives two and three proposed in synopsis were not so different and based on similar themes so I merged them and added two new objectives to enhance the ecological significance of present research. The classification of native forests is critical in evaluating the wildlife habitats, since distinct forest types provide unique wildlife habitats, so I added that fact here with second objective. Hence, the present thesis focused on following hypotheses and objectives.

1.7 Hypotheses

a. there is no difference between the tree diversity of primary and secondary forests

b. there is no difference among the tree diversity of three distinct successional stages of secondary forests and forest formations of primary forests

1.8 Objectives

(i) to assess diversity patterns and successional changes among tree communities in various forest landuse categories

(ii) to analyse landscape characteristics in particular fragmentation and classify tropical forests to evaluate critical wildlife habitats; develop databases based on the above information to identify and prioritise wildlife areas for targeting conservation and management efforts

(ii) to discuss the native wild fauna and develop information base for modelling wildlife habitat relationships for select wildlife species

(iv) to assess the socioeconomics of native tribes, identify the links between current landuse patterns versus local resource dependency, and evaluate the impact on existing protected areas of the region

1.9 Organisation of the thesis

The thesis is organised in seven chapters, a summary and eleven appendices to answer multiple questions posed by above mentioned objectives. Chapter one provides the background and origin of the thesis; a brief introduction with the rationale of this research in northeast India; and original as well as revised hypotheses and objectives. Chapter two describes the study area on a broader scale, that is, a landscape scale. It provides a brief description of the landscape, including a historical account of the people and their society, area size, boundaries, important physiographic features; general as well as forest administration; forest and wildlife management; biodiversity conservation and sustainable development initiatives taken by state government; and the conservation significance of the landscape. Chapter three holds extract from the analysis of data on tree species representing the community structure of the *jhum*-influenced tropical forest ecosystem. Chapter four discusses the tropical forests and landuse landcover over the landscape. It identifies the status of forest fragmentation in tropical forest conditions, which helps identify and model the critical but unprotected wildlife habitat corridors in community-owned private land connecting the existing protected areas and reserved forests. It also delineates core areas, which form the important habitats for interior wildlife species. Chapter five discusses the wildlife species and provides an extensive review of the published and un-published literature available with individuals, government and non-government agencies. This chapter analyses the wildlife habitat relationship for select species in four segments, including mammal-habitat relationship, elephant-habitat relationship, mammal-tree relationship, and bird-habitat relationship. An appendix to chapter five analyses the elephant census data and their correlation with the existing vegetation and landuse of the landscape and suggests model elephant-habitat relationships for specific study area (2459 km^2) and the whole Garo Hills (8167 km^2) area. Chapter six identifies links between current landuse pattern and resource dependency of the local Garo population, and the impact on protected areas and the overall biodiversity of the region. It also discusses the existing conservation issues and the role of the past and present development programmes of the government as well as existing informal forestry practices of the native Garo society. Chapter seven concludes the thesis and delineates the management recommendations for biodiversity conservation and sustainable utilization of natural resources. The appendices of this chapter discuss the biosocial implications of conserving biodiversity in the region. Finally, the thesis advocated for the serial nomination of the landscape as UNESCO's World Heritage Property based on the overall findings of the present investigation.

CHAPTER 2

THE STUDY AREA: LANDSCAPE, ADMINISTRATION AND MANAGEMENT

2.1 Introduction

Meghalaya is one of the most important states of India from a biodiversity point of view. In the Hindi language, the Meghalaya is made up of two words, 'Megh' meaning clouds and 'Aalaya' meaning home and is popularly known as 'the abode of clouds'. Its towns Cherrapunjee and Mawsynram recorded the highest average annual rainfall in the world. There are two National Parks (NPs), three Wildlife Sanctuaries (WLSs), 23 Reserved Forests (RFs) and five Protected Forests (PFs) owned by the State Forest Department of Meghalaya (SFD, 1995). Collectively, government manages forest cover over only 4.7% of land, whereas the native tribal community owns the remaining forest cover over 65% of forest land.

The state-owned forests were constituted between 1883 and 1888 and have been managed systematically since then. The first working plan for state-owned forests in Meghalaya was prepared in 1887 (1887-1902), mainly to exploit sal (*Shorea robusta*). The emphasis on exploitation of sal and other timber trees of the managed forests was evident until the working plan (1956-57) of M.M. Islam, which gradually shifted the focus of forest management towards protection of wildlife and other non-timber natural resources. The first wildlife sanctuary of the state, Siju Wildlife Sanctuary (SWS), was constituted in 1979; and the first national park in the state, Balpakram National Park (BNP), came into being in 1986 by acquiring land from tribal communities. The flora of Meghalaya (Haridasan & Rao, 1985) includes about 1151 woody dicotyledonous plant species among 552 genera and 119 families.

The Garo Hills spread over 8167 km^2 in the western part of Meghalaya state. Out of a total of five PAs and 23 RFs in Meghalaya, four PAs and fifteen RFs are located in Garo Hills (SFD, 1995). In the Garo Hills, *Jhum* is used to grow cashew nuts, for latex processing, and the growing and harvesting of tea, pepper, cinnamon, bamboos, and other agricultural and forest products (Ramakrishnan, 1985). There are three revenue districts in Garo Hills, *viz.* East Garo Hills (2603 km^2), West Garo Hills (3714 km^2) and South Garo Hills (1850 km^2).

2.2 People and community

The ancestors of the present Garo tribe reached the north-eastern part of India during the Neolithic period from about 5000 B.C. out of their original homeland in southwest China. The Neolithic people were food producers and practised shifting cultivation. They lived in semi permanent settlements consisting of small agricultural communities, and knew the art of making earthen vessels from clay (Sharma, 1984). The Garo tribe constitutes the major ethnic community living in the Garo Hills. Though they are known as 'Garo' they like to be referred as *Achiks* or *Achik mande* (*Achik* means hills and *mande* means man). After the initial settlements in the area, Garos spread over the whole Garo hills range and formed different groups or *Akings (clans).* The details of Garos and their society is provided in chapter six on the socio-economics of native society.

2.3 Location

The South Garo Hills district came into existence in 1992 by separating the southern portion of West Garo Hills district. Among three districts of the Garo Hills, South Garo Hills is the least exposed area so far as developmental activities are concerned. At the 1991 census, the total population of the district was 77,073. The human density of South Garo Hills of 42 persons/ km^2 is also relatively less than the whole of Garo Hills, which is 82 persons/ km^2. The study area spreads over 2459 km^2, covering the entire South Garo Hills district (area 1850 km^2) and parts of the East and West Garo Hills districts. The identified landscape is situated in the south-eastern portion of the Garo Hills, Meghalaya in northeast India. It belongs to the biogeographic zone 9B (north-eastern India), between 90°07' and 91° E longitude, and 25° 02' and 25° 32' N latitude (Rodgers and Panwar, 1988) (**Fig. 2.1 a and b**). The major portion of the landscape is extremely rugged and undulating hill ranges, mostly running from east to west, with deep gorges and many streams flowing along the north-south gradient.

As the study proceeded I collected samples from greater landscape, which is the proposed study site for the WII-USFS collaborative project - a parent project of this study. In the east, the landscape boundary follows the district boundary between the South Garo Hills and the West Khasi Hills. Then it follows the river Simsang and joins the road north to Tura in the northwest corner of the study area in the north. The western boundary follows the road from Tura to Dalu. The southern boundary follows the international border between India and Bangladesh. The earlier proposed intensive study area was comparatively smaller (1030 km^2), however, compared to the one I studied for this thesis.

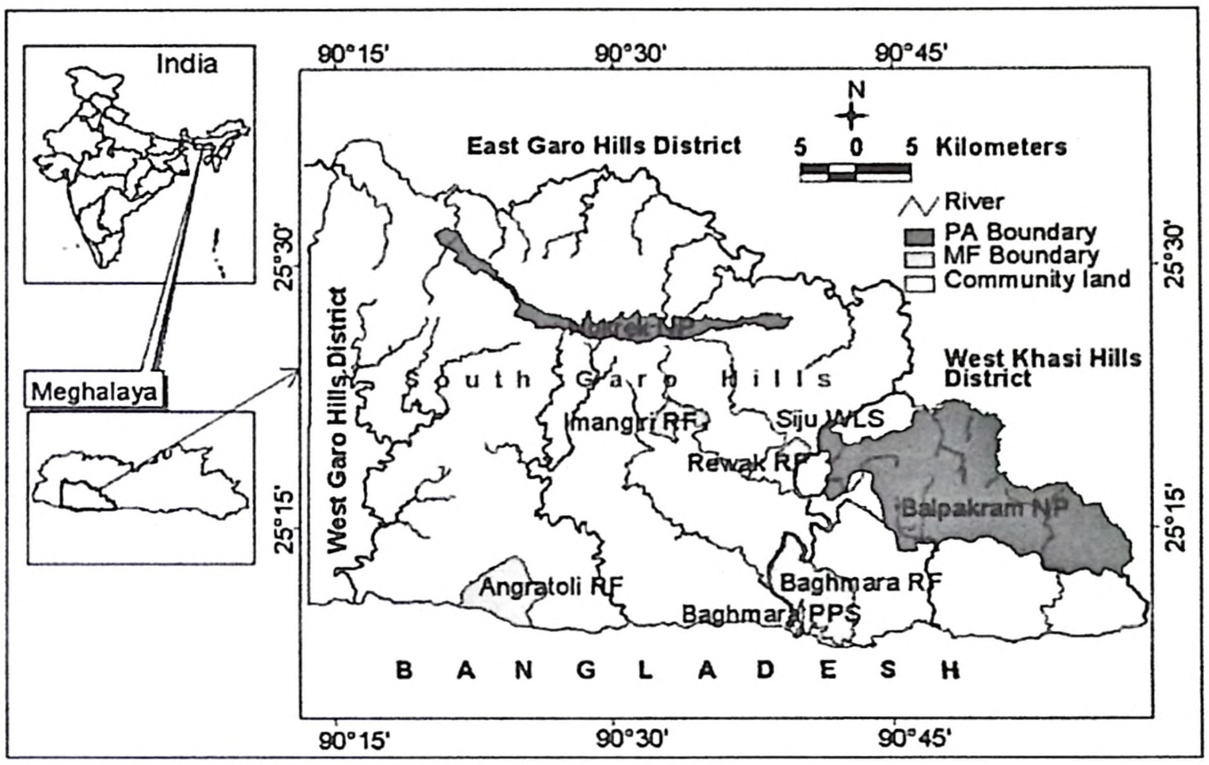


Fig. 2.1: **Study area of Garo Hills in western Meghalaya, northeast India. PA = protected area, MF = managed forest, RF = reserved forest, WLS = wildlife sanctuary, PPS = pitcher plant sanctuary.**

2.4 Physiographic features

2.4.1 Geological history

The Garo Hills region is part of the Meghalaya plateau. Rock types from most ancient to recent period, occur in different locations in these hills. The oldest known rocks comprise the 'Archean Group' about 3,600 million years old occupying about sixty percent of the Garo Hills. Over these rocks, localised patches of rocks belonging to the 'Gondwana group', some 350 million years old, are also present. The sediments of the Tertiary age (65 million years ago) occur around Baghmara and many other localities in the South Garo Hills. At the end of of Miocene age, continuous sedimentation over the southern and western parts of the Garo Hills caused the uplifting of the Meghalaya plateau and the formation of Khasi and Garo Hills (Momin, 1984; and Gogoi, 1984).

2.4.2 Altitudinal ranges and the physiographic regions

Physiographically, the Garo Hills represent the remnant of an ancient plateau of the Pre-Cambrian peninsular shield. This plateau forms a watershed between the Surma

River valley of Bangladesh to the south and the Brahmaputra River valley to the north. Nokrek peak elevation 1515 m, which is situated on the Tura ridge in the northeast portion of the study area is the highest peak of the Garo Hills. The Maheshkola Adugiri range divides the plateaux of the Khasi and Garo Hills. The most salient features of the study area are the Tura range and the Simsang River valley. The Tura range runs west to east, extending from Tura town to Siju, a distance of 50 km. The Simsang River valley runs north to south and culminates in Bangladesh.

The Balpakram National Park, which includes the Balpakram Plateau, is the most famous place in the Garo Hills. The national park is located near the Maheshkola and Pindenggru hills end of the Tura range. Balpakram means 'wind blows continuously' in the local Garo dialect, and Balpakram Plateau is regarded as the home of the spirits of the dead by the Garos. The Siju area includes a deep limestone cave that provides a habitat for several bat species, including Kelaart's Leaf-nosed Bat, *Hipposideros lankadiva* (specimens at Zoological Survey of India, Shillong). No one has yet explored the end of the cave. The Kailash hill (elevation 1023 m) locally known as Chutmang, is the highest peak of not only the Balpakram area but the broader South Garo Hills district as well. Chutmang towers above most of the peaks in the vicinity. The Garo Hills can be divided into the following five physiographic regions on the basis of altitude (Momin, 1984).

Above 1350 metres msl

This region includes the Nokrek peak and the nearby areas of the Tura peak. The region consists of wet tropical forests with a few elements of sub-topical forests. It is also regarded as the wilderness area.

Between 901-1350 metres msl

This region lies in three pockets, a part of Nokrek, Chutmang and Balpakram hills. There are no human settlements. Mainly primary forests occur here.

Between 301-901 metres msl

This region lies in the central part of the Garo Hills from which the Simsang river originates. There are very few human settlements, due to poor accessibility

Between 151-300 metres msl

This region constitutes the inner parts of the Garo Hills touching the Khasi Hills in the east and northeast. This tract forms the important catchments of almost all the rivers and streams of the Garo Hills region. The area is hilly and covered with thick forest, thinly populated and economically very weak.

Below 151 metres msl

This region includes all the fertile plains and river valleys from the north-eastern Garo Hills to the north and northwest touching Assam, the southern and south-western part of the district bordering Bangladesh, and the Maheshkola area. Nearly half the area of Garo Hills falls in this region. The valuable Sal and Teak forests/stands (very old plantations) cover the hill slopes.

2.4.3 Rivers and drainage pattern

The drainage system of the Garo Hills is divided directly by the central upland zone, which divides rivers, which flow south to the Surma valley of Bangladesh from rivers, which flow north to the Brahamaputra 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 important features of a few of these rivers are as follows.

The Simsang river

This river flows south through the centre of the study area. It originates in the Tura range near the Nokrek peak and flows east then south until it 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 township. 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 a many cataracts and boulders. The lower course, however, has many deep pools and falls, namely Mrik, Matma, Kon'chru Suk, Warisik, Bobra and Goka. Of these pools the Kan'chru Suk is the deepest. 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 to monitor and halt such activities and catch the culprits.

The Dareng or (Nitai) river

The source of this south-flowing river is the southern side of the Nokrek Range. It has many famous, deep pools such as Warima, Rong'ang and Bamon, of which the Bamon is the deepest. The tributaries of this river are the Kakija, Daji and Rompa. The Redingsi is the deepest pool in the Kakija river.

The Bogoi river

This is locally known as the Bugi river, and flows in a southward direction. It originates on the southern side of Nokrek. It also has deep pools such as the Nosari, Bandari and Warima.

The Mahadeo river

The source of this river is near the Balpakram Hills, and it flows through a picturesque, very deep gorge in Balpakram National Park.

The Maheshkola river

The source of this river is on the eastern side of the Balpakram hills, and it flows along the border between South Garo Hills and West Khasi Hills. There are a number of waterfalls along this river. Those with scenic beauty are the Chibbok, Gongja, Renang, Imilchang and Dare.

2.5 Weather and climate

From November to February is the coldest period of the year. The Garo Hills receive rainfall from the north-eastern monsoon in winter and from the south-eastern monsoon in summer. Records during 1931 to 1960 indicate that the mean minimum and mean maximum temperatures were 12.3 °C and 32.5 °C for the months of January and April, respectively. The total average annual rainfall was 3361.6 mm with an average of 114 rainy days. June has consistently been the wettest month averaging 21.3 rainy days.

2.6 The landscape

There are four Protected Areas and Managed Forests, comprising four Reserved Forests. The government manages only fifteen percent (362 km^2) of the total land in the form of protected areas and reserved forests, and the remaining land belonging to local Garo communities, is used widely for *Jhumming* and as a non-timber forest resource. Forests of the study area occur in three main land-use classes: i) protected areas (PAs), which include biosphere reserves, 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. PF is mainly confined to PAs, but, there are a few intact patches of PF over community land in the interior hills. The SF is confined mainly to community land and some newly acquired PAs.

2.6.1 Protected area

These were created recently either by acquiring community-owned forest land from tribals, for example, Balpakram National Park (BNP), or from the existing reserved forests, for example, Siju Wildlife Sanctuary (SWS). BNP was created in 1986 by acquiring 220 km^2 of land (notified), followed by the addition of another 133 km^2 of land (not notified and not considered in the analysis for present study). The Nokrek National Park (NNP) was also constituted with the BNP during 1985 by acquiring 47 km^2 land over the Nokrek ridge. Later, the government acquired pieces of land around the national park and declared Nokrek Biosphere Reserve to be 80 km^2 of land over the ridge top, which encompasses the 47 km^2 of NNP. The SWS, 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.

2.6.2 Reserved forest

The reserved forests of the region were managed through working plans since formal forest management began in the country during the late 19th century. The four reserved forests, namely Baghamara Reserved Forests (BRF), Rewak Reserved Forests (RRF), Emangiri Reserved Forests (ERF), and Angratoli Reserved Forests (ARF) were created at the turn of twentieth century and since then they are managed by the State Forest Department. Secondary forests do not occur in these RFs 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 RFs in the 1930s. Therefore, mainly two categories of vegetation are found in these reserved forests, the primary forests and old plantations. 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.

2.6.3 Community owned land

Most of the remaining area, other than PAs and RFs, 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. The major concern of the GDC is to manage and maintain forestry, agriculture, civil works, taxation, revenue, justice, transport, education and other developmental activities. 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 of that particular Aking by the *Nokma*. In case of any social or legal dispute, the *Nokma*'s decision is final and bound on the villagers. The *Nokma* has the authority to allot land to a particular family. 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 five to six years or even less. In recent times, some settled agriculture has been established, especially in valleys where water is available for irrigation, and plantations have been raised.

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.

Among the non-forest landuse categories, the *Jhum* fields, adjoining habitations and associated scrublands predominate in the study area. 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. Recently, the local office 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.

2.7 Current administration

The current administration of the study area has the similar administrative structures followed in all the seven districts of Meghalaya. Being a new district, South Garo Hills does not have a well-developed administrative infrastructure. A Deputy Commissioner (DC) has been appointed as the head of district administration. The DC controls various administrative units headed by governmental officials. These units are called administrative branches, such as General or Establishment Branch, Judicial Branch, Revenue Branch, Loan Branch, Registration Branch, In-charge of Supply, Housing Elections, Block Development and the District Selection Committee, and so on. In general, the hierarchy of district administration includes the Deputy Commissioner, Sub-Divisional Officer (SDO), Extra Assistant Commissioner (EAC), Deputy Director of Supply (DDS), Deputy Superintendent of Excise (DSE), Enforcement Inspector (EI), Inspector of Supply (IS) and the District Transport Officer (DTO). The DC office for the South Garo Hills District is situated in Baghmara, the district headquarters.

2.7.1 Village administration

All the administrative powers related to the domestic matters of villagers and the village community belongs to the *Nokmas* of individual villages. The *Nokma* is the head or chief from the dominant clan or group of clans. He presides over the council (*Melaa Saldonga*) and decides all the issues and disputes. The *Nokma* deals with all the customary laws and affairs, fixes the dates of festivals and observance, and arranges for community participation in festivities, sacrifices and other rituals connected with the community. Following the creation of the class of officials, however, the powers of the *Nokmas* have been reduced, particularly since their powers to try legal cases were taken away from them (Simon, 1996).

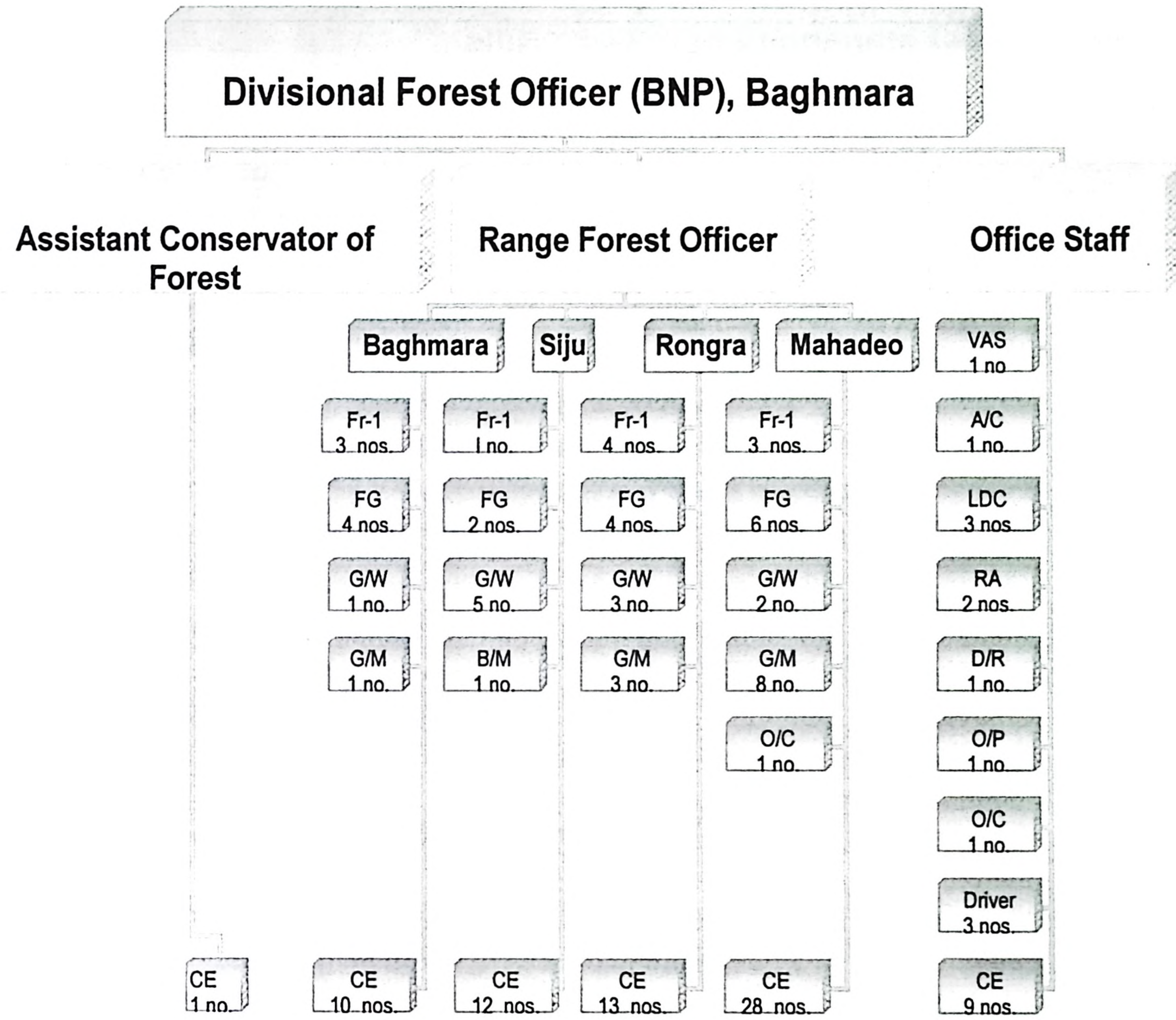
2.7.2 District council administration

The Garo Hills District Council (GDC) came into being in 1952 under the provision of the sixth schedule to the Constitution of India, the Assam and the Meghalaya (Constitution of District Councils Rules, 1951). At present, the jurisdiction of the GDC is over the entire geographical area of the Garo Hills, and across the district boundaries. An executive committee was constituted under the Autonomous District Rules headed by the Chief Executive Member. This body looks after the administration of the Garo Hills. Under the Chief Executive Member are two

Executive members. The major duties assigned to the Council are forests, civil works, taxation, revenue, judiciary, transport and education. Forest management, education, revenue and tax collection are among activities that have suffered considerably over the past few years. In the case of forest management, the District Council appoints its own staffs for regulating removal of forest resources. Revenue is derived from royalties on timber, bamboo, cane, reeds and minerals.

2.7.3 Forest (and wildlife) administration

The PAs and MFs comprising, fifteen percent the landscape area are being managed and administered under the existing laws and policies of the State Government. The Principal Chief Conservator of Forests (PCCF) is the head of the forest department of the state of Meghalaya. The Chief Wildlife Warden (also Chief Conservator of Forest for Wildlife) and a Conservator of Forests (Wildlife) deal with all matters related to wildlife in the state. Four Divisional Forest officers positioned at Shillong, Jowai, Tura (East and West Garo Hills division - Wildlife) and Baghmara (Balpakram National Park division) are responsible for managing the forest and wildlife at district and local level within their jurisdiction. The organisation chart below shows the manpower engaged in Wildlife Management and Conservation (of most of the study area) under the Balpakarm NP division controlled by the Divisional Forest Officer at Baghmara, the headquarter of South Garo Hills district (**Fig. 2.2**).



DFO = Divisional Forest Officer
BNP = Balpakram National Park
ACF = Assistant Conservator of Forests
Fr-1 = Forester Grade 1
FG = Forest Guard
LDC = Lower Divisional Clerk
RA = Range Assistant
G/W = Game Watcher
VAS =Veterinary Assistant Surgeon
A/C = Accountant
D/R = Draftsman
O/C = Office Clerk
B/M = Boat man
O/P = Office Peon
G/M = Gate Man
CE = Casual Employee

Fig. 2.2: Organisation chart of Balpakram NP Division, South Garo Hills, Meghalaya as on 01 April, 1995 (Source: SFD, 1995)

2.8 Forest management in Garo Hills

Unlike in other states of India, Most of the Meghalaya land, including forests, is owned by tribal communities. During the British rule, the government acquired 263 km^2 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 (WC), based on the commercial value and silvicultural characteristics of the forests, for the next 190 years. M.M. Islam prepared the second detailed plan (1956-57) for all reserved forests, after detailed stock mapping and ground inventory, and constituted the following four working circles.

- Sal selection WC
- Sal improvement WC
- Miscellaneous WC
- Ghugra WC

The latest working plan for the Garo Hills by F. Suchiang (1975-76) was in operation until 1990. The following six working circles were constituted in that plan.

- Sal Selection WC (12.90 km^2)
- Sal Conversion WC (21.71 km^2)
- Plantation WC except Siju (91.71 km^2)
- Bamboo WC (20.77 km^2)
- Protection WC (4.79 km^2)
- Ghugra (*Schima wallichii*) overlapping WC (Overlapping all reserves)

The sal area of Angratoli and other RFs of the east and west Garo Hills district were allotted to Sal conversion working circle with the objective of attaining maximum sustained yield. The Ghugra overlapping working circle focused on Schima wallichii associated with Sal, to be worked through the selection system. The Taungya WC was allotted to those areas which were under plantations and all the known areas of RFs suitable for plantations. Sal improvement working circle was allotted to the Rewak, Emangiri, Baghmara, Angratoli and Siju RFs plus some other RFs 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 RFs were allotted to the Miscellaneous WC with the objective of maximizing the sustained yield and replacing existing poor stock by valuable species.

The State Forest Department has raised the forest plantations from time to time and established the 'taungya' plantation in the Garo Hills during 1905 and 1906 over 60 km^2 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 km^2. Shuching's Working Plan also started the process of conservation and wildlife protection in the Garo Hills, as illustrated in the following two objectives of the plan including, 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.

2.9 Wildlife management and conservation initiatives

A unique land-holding pattern and traditional forestry practices distinguish the study area from other forested landscapes in India. About 85% of the land in study area is still under the control of local communities and used extensively for shifting cultivation, that is *Jhumming*. The practice of shifting cultivation has created a mosaic of various landuse categories and successional stages of vegetation. During the late nineteenth and early twentieth centuries, the British government acquired land from local communities and created RFs. The British managed about ten percent of the study area forest land and their interest was in providing timber by harvesting older forest stands for commercial benefit. The Meghalaya state government initiated wildlife management and protection measures in the late twentieth century by acquiring twenty-five percent of the forest land from native Garo community and created protected areas including the Siju Wildlife Sanctuary (SWS) in 1979, the Balpakram National Park (BNP) in 1985, the Nokrek National Park (NNP) in 1985 and Baghamara Pitcher Plant Sanctuary (BPPS) in 1984. 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

Management options/priority	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 Mangement	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 landuse planning
	Management Plan	S.N. Sangma, ACF	
	Eco-development and sustainable development	Eco-development Society of Meghalaya	Covering 134 villages around PAs

2.10 Broad vegetation categories reported in BNP

Kumar and Rao (1985) conducted an intensive study in the Balpakram National Park area and identified following tropical forest formations based on the classification scheme suggested by Holdridge *et al.* (1971).

2.10.1 Tropical moist evergreen forests

These forests generally occur in the interior hills of BNP. Most of these hills are inaccessible or very difficult to approach with deep gorges in Balpakram, Pindengru, Naksalgoa, Nongchigoit, Chuntmang, Maram, Bytit and Penda limestone areas with a moderate slope. The limestone belt between Maheshkola on the border of Garo-Khasi Hills to the Siju area preserves the evergreen forests and forms the climatic climax. This belt is exposed over the ground in many places inside the national park and the sanctuary as well as outside, for example, at Chimitab, Hangsapal, in the Chutmang hills, at Rongsu and Goerapattar. Most of the land is unsuitable for shifting cultivation; hence, the micro-climate is maintained. These forests also support the growth of rare herbs, terrestrial orchids and ferns. The periphery of these forests on a steep slope forms an excellent habitat for the carnivorous and endemic Khasi Pitcher Plant (*Nepenthes khasiana*).

The common species in these forests include *Acrocarpus fraxinifolius, Castanopsis* spp., *Cynometra polyandra, Diospyros gobara, D. stricata, Dysoxylum binectariferum, D. kurzii, Elaeocarpus floribundus, Kayea floribunda, Engelhardia spicata, Walsura robusta, Mesua ferrea, Parkia roxburghii, Pterospermum acerifolium, Sapium baccatum, Fermiana colorata* and *Schima wallichii.* Deciduous species such as *Hibiscus macrophyllus* and *Tetrameles nudiflora* are present in forest openings and gaps. The middle canopy is composed of *Aquilaria agallocha, Antidesma acuminata, Garcinia cowa, Saraca asoca, Sterculia roxburghii* and *Syzygium* spp. The lower canopy comprises smaller trees such as *Ficus* spp., *Leea umbraculia, Saprosma ternata, Dracaena spicata, Ixora* spp., and *Miliosa roxburghiana.* The vegetation of these forests is mixed without the dominance of any single species. Species belonging to families, like *Ebenaceae, Fagaceae, Lauraceae, and Clusiaceae*, tend to predominate.

2.10.2 Tropical semi-evergreen forests

These forests show the stratification with the predominance of evergreen species such as *Castanopsis* spp., *Mesua ferrea, Lithocarpus elegans, Pterospermum lancaefolium.* Trees like *Mesua ferrea, Acrocarpus fraxinifolius, Albizia* spp., *Careya arborea, Terminalia* spp., *Sterculia* spp., *Lagerstroemia parviflora, Stereospermum chelonoides,* forms the top canopy tree species. In the semi-evergreen areas *Crateva nurvala, Maesa rementacea, Rhus javanica, Phoebe lanceolata, Styrax serrulatum, Ligustrum robustum, Capparis* spp. and *Calliandra umbrosa* are some common middle canopy tree species.

2.10.3 Tropical deciduous forests

These are the sub-climax type and are man-made. These forests occur in the border areas and the gently sloping area of the park, where *Jhumming* was practised prior to the acquisition of the land by the state government. The important economic species in these forests are *Albizia lebbeck, A. lucida, Dillenia pentagyna, Elaeocarpus floribundus, Erythrina stricata, Glochidion spp., Gmelina arborea, Holarrhaena antidysentrica, Kydia calycina, Lagerstroemia* spp., *Ochna integerrima, Salmalia malabarica, Schima wallichii, Sterculia villosa, Terminalia bellerica, Vitex glabra,* and *V. peduncularis.* The second story is composed of *Aporusa dioica, Bredelia retusa, Croton joufra, C. roxburghii, Grewia microcos, Glochidion lanceolarium, Mallotus phillippinensis, Rhus javanica*, and other species. These are very disturbed forests so

Bauhinia purpurea, Callicarpa arborea, Emblica officinalis, Grewia microcos, Kydia calycina, Macaranga denticulata and other fast growing species are common.

2.10.4 The secondary forests

These are relatively less diverse with few common species such as *Callicarpa arborea, Glochidion lanceolaria, Careya arborea, Phyllanthus emblica*, plus some saplings of *Holarrhaena antidysentrica, Micromelon integrefolium, Lagerstroemia parvifloram, Macaranga denticulata,* and *Syzygium* spp. Tropical moist deciduous forests that are man-made and sub-climax type occur in old *Jhum* fallows. Important tree species found in this type of forests are *Albizia lebbeck, A. lucida, Dillenia pentagyna, Elaeocarpus floribundus, Erythrina stricta, Glochidion Parkia roxburghii, Gmelina arborea, Holarrhaena antidysentica, Kydea calycina, Lagerstroemia species, Salmalia malabarica, Schima wallichii, Sterculia villosa, Terminalia ballerica, Vitex glabra, V. peduncularis, Aporusa dioica, Bredalia retusa, Grewia macrocos, Glochidion lanceolarium, Mallotus phillippinensis,* and *Rhus javanica*.

Several species of bamboo form thickets chiefly as secondary growth. The dominant bamboo species, which are mainly found on the degraded land in older *Jhum* fallows, are *Bambusa species, Melocanna bambusifolia* and *Dendrocalamus hemiltonii.* A few palms, such as *Areca, Caryota, Pinanga and Didymosperma* are also conspicuous. Species of epiphytic orchids, including *Aerides, Bulbophyllum, Dendrobium, Eria, Liparis, Pholidota, Thunia and Vanda*, are seen in the evergreen forests. Ferns, liverworts and mosses are seen on old tree trunks and stones near water sources, and in shady places of the evergreen forests. *Artocarpus* spp. are common in the vicinity of villages and towns. In open moist localities and near water sources, herbs such as *Dictyospermum, Aneilema scaberrium, Burmania* spp., *Coix* spp., *Cyperus* spp., *Oxalis corniculata, Anemone* spp., and *Ericcaulon* spp., can be seen.

2.10.5 Other vegetation types

Kumar and Rao (1985) have described the species composition of the Shola type forests, Riverine forests, Grassland & Tree-Savannas, and Bamboo forests. Shola type forests occur around the Balpakram plateau. Important species are *Helicia nilagirica, Engelhardia spicata, Fermiana colorata, Pittosporum nepalense, Kayea floribunda, Schima wallichii.* Riverine forest trees are small, much branched from ground level with smooth bark. Species such as *Syzygium polypetalum, Ficus pyriformis, F. squamosa and Homonoia riparia* are the common species growing in rocky and sandy areas. Grasslands and tree savannas are confined to the northern tip of BNP at Rongcheng and Lumsorjong areas. The common species are *Alloteropsis semialata, Arundinella bengalensis, Centotheca lappacea, Cymbopogon khasianum, Imperata cylinderica, Ischaemum geobelli* and *Neyraudia reynandiana*. Other associated plants are *Grewia hirsuta,Curcuma* spp., *Costus speciosus.* In wet rocky area the grasses are dwarf and associated with *Urticularia, Eriocaulon* spp., *Drosera* spp. In Savannas the common tree species are *Dalbergia rimosa, D. stipulata, Dillenia pentagyna, Phylanthus officinalis* and *Schima wallichii.* Bamboo forest occurs on eighteen to twenty year old fallows on degraded soil and the common bamboo species are *Bambusa* spp., *Melocanna babusifolia,* and *Dendrocalamus hamiltonii.* Associated tree species are *Callicarpa arborea, Glochidion lanceolaria,* and *Careya arborea* in the gaps.

2.11 The important tree species in the study area

The following is a list of a few important tree species of the study area, with their scientific and vernacular names, growth form and height, taxonomic family, flowering and fruiting phenology, geographic distribution, other species associates, information on ecology and uses (Naridasan and rao, 1985).

Aporusa dioica
Vernacular name - Chamolja, Deciduous (D), 6-12m high
Euphorbiaceae,
Flowers and Fruits: November-May
Bangladesh, Burma, and NE India, common in Meghalaya at lower elevations below 800m in deciduous and mixed deciduous forest.
Associates: *Croton roxburghii*

Diospyros variegata
Bolgisem, (Evergreen), 10-20m high
Ebanaceae,
Fruits and Flowers: April-December
Burma and NE India, Common in Meghalaya in tropical evergreen forests, often in open places, Tura, Khasi hills.
Diseases: the trees are often malformed due to disease caused by witches' broom.

Michelia champaca
Bolnabat, (E), large (20-25m)
Megnoliaceae,
Fruits and Flowers: May to April
50 Species in tropical Indo-Malayan region 12 in India, 8 in Meghalaya, few cultirated Indo-malayan, usually cultivated for their fragrant flowers, cultivated as well as wild in foot hlls, also in Tura.
Uses: Wood durable, used in furniture and building work.

Schima wallichii
Boldok, (E), 15-50m large
Theaceae,
Fruits and Flowers: February to April; January to February (Following year).
16 genera and 500 species in tropics and subtropics, Mainly in Asia, 8/23 in India 6/13 in Meghalaya, Indo-Burma, Nepal, Bhutan, Bangladesh, Eastern Himalaya, NE India, throughout Meghalaya in all types of forests.
Uses: Plywood. Bark in allergic treatment.

Styrax serrulatum
5-15m
Styracaceae
12/190 in the tropical and temperate region 2/5 in India, 2/3 in Meghalaya 125 species in tropics/temperate 43 in India, 2 m high.
Fruits and Flowers: March to December
Indo-Malayan, confined to East and NE India, Common in Meghalaya at lower elevations along forest margins and secondary forests.
Associates: *Friesodielsia forniculata, Milletia caudata.*

Messua ferrea
Karai, Khimdi, large [up to 40m]
Clusiaceae: 35/400 (Genera/Species)
Largely confined to the tropics, 6/22 in India 4/11 in Meghalaya. (3 species in world, 1 in Meghalaya)
Flowers and fruits: April to October.
Indo-Malayan, confined to Western Ghats, and NE India; Important element in evergreen fruits in Meghalaya, at lower elevation
Uses: Wood is very heavy and strong, used for construction purposes, handles of agricultural equipment, and so on.

Castanopsis purpurella
Chako, large tree
Fagaceae: 8/500 in tropical/temperate region, except S. Africa, 5/40 in India, 4/13 in Meghalaya
Burma and NE India very common in Meghalaya, forming canopy tree in associates with *C.tribularis*

Castanopsis indica
Fagaceae.
Large tree
Flowers and Fruits: February to December.
NE India and neighbouring countries: very common in Meghalaya, in evergreen forest through out the state.

Tetrameles nudiflora
(D), tall up to 50m
Tetramelaceae: A monotypic family of the Indo-Malayan region.
Flowers and Fruits: March to June.
Occurs in open deciduous forests in the Garo hills, associated with *Duabanga grandiflora, Gmelina arborea, Largerstroemia parviflora, wrightia tomentosa.*
Uses: Wood is useful in match industries. Fast growing tree, easily distinguishable due to its towering size and nodding branches.

Cynometra polyandra
Chherasu (E), large (upto 20m)
Caesalpiniaceae 152/2800 in tropics and sub-tropics, 23/80 India, 13/28 in Meghalaya (60 species in tropics, 6 in India and 1 in Meghalaya)
Flowers and Fruits: March to August.
Indo-Malayan; confined to north-east India, common in tropical evergreen forests, associates with *Premna latifolia, Garcinia paniculata, Sarchochlamys, Pulcherrima, Schima wallichii, Mallotus,Lutra coccous*
Uses: Wood is useful for construction purposes, plywood and charcoal.

Trewia nudiflora
Boldiktak, Bol-khap, (D), up to 20 m.
Euphorbiaceae Arugong.
A large cosmopolitan family 300/5000
61/336 in India, 30/90 in Meghalaya
(5 species in Indo-Malayan region. 2 in India and 1 in Meghalaya)
Flowers and Fruits: January to September.
Indo-Malayan; nearly throughout India; fairly common in Meghalaya in deciduous forests, particularly in along river and water courses, associated with *Aesculus assamicus, Vatica lanceaefolia.*

Stereospermum chelonoide

Bolsel middle to lofty trees up to 40m.

Bignoniaceae 20/37 in India, majority cultivated; 5 genera and 5 species in Meghalaya [25 species in Afro-Asia, 4 in India, 1 in Meghalaya].

Flowers and Fruits: April to March.

Indo-Burma, throughout the greater part of India, very common in Meghalaya in tropical evergreen and deciduous forests (below 800m) associated with *Vitex species, Dillenia species, Oroxylum indicum, etc.*

Uses: Linear fruits, which persist nearly throughout the year; yields straight, sturdy and durable timber.

Callicarpa arborea

Khimber, Makhanchi, Middle (up to 15m)

75/3000 in tropics and sub-tropics, 17/96 in India, 13/40 in Meghalaya.

[140 species in tropics and sub-tropics, 10 in India, 6 in Meghalaya]

Flowers and Fruits: Nearly throughout the year, (more from April to September)

Indo-Malaya; mostly in northern India, Abundant in Meghalaya at all elevations in secondary forest, usually associated with *Styrax serrulatum.*

Grewia microcos

(D) Bolchibins, Borsubret (5-15m)

Tiliaceae: 50/450 in tropics and temperate 8/64 nearly through out India, 3/11 in Meghalaya.

(150 species in tropics, 42 in India, 6 in Meghalaya)

Flowers and Fruits: May to February.

Indo-Malaya, throughout the warmer part of India, in Meghalaya this species occurs in deciduous forests of lower ranges, associated with *Holarrhena antidycenterica, Careya arborea, Embica officinalis,* and *Callicarpa arborea.*

Uses: Green to purple fruits.

Persea vrillosa

Nameaga tall (up to 25m)

Lauraceae 47/1900 in tropics and sub-tropics 17/175 in India, 11/50 in Meghalaya.

(150 species in tropical Asia and America, 15 in India and 10 in Meghalaya)

Flowers and Fruits: January to May.

NE India and neighbouring countries; very common in Meghalaya, particularly in tropical evergreen and mixed deciduous forests; also in secondary forest at lower elevation, associated with *Stereospeesmum chelanoides, Artocarpus chaplasha,* and *Castanopsis pecies.*

2.12 Loss of tropical forest cover

The tropical forests in northeast India are being cleared, logged, burned, fragmented, and the wildlife being over-hunted at a greater pace than ever. However, in some locations large tracts have still remained intact. Studies show that from 1995 to 1997, about 1875 km^2 of tropical forest (1.14% of northeast Indian forest) in northeast India was converted to cropland under *jhumming*, (FSI, 1997). This followed large scale timber harvesting during past few decades. Bamboo growth, a seral community, is harvested both for commercial purpose (pulp industries) and local uses (Ramakrishnan, 1992; Ramakrishnan and Toky, 1983).

In 1999, the total forest cover of the seven states of northeast India was 163,799 km^2 (64% of the geographic area of the region) compared to 164,043 km^2 in 1997 and 164, 359 km^2 in 1995 (FSI, 1997 and 1999). Shifting cultivation (*jhumming*) is the major landuse practice responsible for deforestation in the region. According to the National Commission on Agriculture, the practice of *jhum* has affected about 2.7 million ha of forest cover (16 % of total forest cover) in northeast India (Anon., 1976; Negi, 1984). Other such estimates are 3.81 million ha by a Task Force on shifting cultivation (1983, back cited ijn Negi, 1984); 2.80 million ha by North-Eastern Council and 7.40 million ha by FAO in 1975 (back cited in Anon. 1976). The FAO estimate may be biased high because of the small-scale resolution of their analysis; the values of 2.7 to 2.8 million ha might be more accurate estimates. Momin (personal commmunication quantified the loss of soild and vegetation cover by *jhumming*, which equaled around Rs. 12,200 /ha/years (**appendix 2.1**).

The Garo Hills still harbour good forest cover compared with many other areas of northeast India. However, increasing human population pressure from 406,615 people in 1971 to 668,930 in 1991, and the resultant increase in area under shifting cultivation, has caused a large-scale conversion of primary forests (before *jhum*) into secondary forests (after *jhum*). A study on forest cover in Garo Hills has shown that the annual rate of forest recession was 4.5% between 1972-73 and 1977 (Negi, 1984). This study intensively estimated the forest recession for a small area between the latitude 25° 15' 25" to 25° 30' north and longitude 90° 15' to 90° 45'. It covered 1394 km^2 and includes the entire Tura ridge (Nokrek area), Rewak and Emangiri Reserved Forests, Siju area and the part of Baghamara RF. Total forest cover of area under the study by Negi (1984) was 515 km^2 (37% of the study area) in 1972-73, which was reduced to 264 km^2 (19% of the study area) in 1977. During this period, 251 km^2 (18% of the study areas) of the forest cover has been lost due to shifting cultivation. Non-forest land increased form 879 km^2 to 1,130 km^2 (from 63 % to 81 % of the study area, respectively). Area under *jhum* increased from 784 km^2 to 1061 km^2 (56 % to 76 % of the study area). The rate of forest recession during 1973 to 1977 was 18 %, or 4.5 % per year (**Table 2.2**).

Table 2.2: Comparative areas in figures obtained from photo interpretation map via a vis landsat map

Particulars / Landuse type	Forested land	Non-forested land			Total
	Forested	*Jhum*	Others	Total	
From aerial photograph of year 1972-73 (km^2)	515	784	95	879	1394
Percentage	37	56	7	63	100
From Landsat imageries of Jan.1977 (km^2)	264	1061	69	1130	1394
Percentage	19	76	5	81	100
Change in Area (km^2)	-251	+277	-26		+251
Change in Percentage	-18	+20	-2		+18

Source: Negi 1984

2.13 Conservation significance of landscape and resource dependence

The area is highly significant from a biodiversity point of view with great many endemic plants and animals. Some of the remaining undisturbed or less impacted tracts of Tropical Evergreen and Semi Evergreen forests of the state are within the study area. Champion and Seth (1968) classified the forests of the study area as Tropical Evergreen Forest (TEF), Tropical Semi-evergreen Forest (TSEF) and Tropical Moist Deciduous Forest (TMDF). The landscape consists of primary and secondary forest growth of these types, and associated degraded land. Other vegetation types include Grassland, Riparian forests, Shola type forest (Kumar & Rao, 1985), degraded land with bamboo (a seral stage) and scrub vegetation. These primary forests contain a great diversity of flora and fauna.

Endemic plants, such as pitcher plant (*Nepenthes khasiana*) and many *Citrus* spp., have the best chance of survival in the region. Out of total of 23 species of Citrus in

India, 6 grow in the study area, that is, *Citrus medica, C. Macroptera, C. latipes, C. ichangensis, C. assamensis* and *C. indica.* All of them except *C. medica* are in the wild and semi-wild state (Singh, 1981). About ninety species of Bamboo and forteen species of cane (Lakshmana, 1993) have been reported from North-east India, of which eighteen and five, respectively, are found in the study area, respectively.

Population density of the Asian elephant (*Elephas maximus*) is very high in Meghalaya with a crude density of one elephant per 2 km^2. The Balpakram National Park (BNP) and Baghamara Reserved Forests (BRF) linked with corridors of contiguous, closed-canopy forests are among the one of the most suitable habitats for the wide ranging elephants. The BNP and its adjoining forests provide habitats for the tiger (*Panthera tigris*), hoolock gibbon (*Bunipithecus hoolock*), clouded leopard (*Neofelis nebulosa*), Malayan giant squirrel (*Ratufa bicolor*), binturong (*Arctictis binturong*), yellow throated marten (*Martes flavigula*), large Indian civet (*Viverra zibetha*), small Indian civet (*V. indica*), capped langur (*Trachypithecus pileatus*), Indian Bison (*Bos gaurus*) besides many other mammals and bird species. Hornbills are widely distributed, too.

The Garo Hills form important catchments for two major rivers, 1) the mighty Brahmaputra to the north, and 2) river Simsang towards the central and southern direction. The native Garo tribes are culturally rich, which is quite evident from some of their important mythological sites. The landscape is heavily influenced by human resource use activities, predominantly by shifting cultivation. The land area affected by, and frequency of, *Jhumming* of native tribes has greatly increased in recent decades concurrent with an increasing human population. Illegal and legal export of timber and other forest products occur in the region. Other resource use activities in study area, which might have adverse effects on the old native forests of the region, are mining (coal and limestone), excessive collection of non-timber forest produce (NTFP) and the hunting of animals (for meat and skin).

The native tribes are highly dependent on forest resources such as timber, small wood, bamboo and a variety of Non-Timber Forest Products (NTFPs) in support of their economy. Their traditional style of agriculture, the shifting cultivation or *Jhumming*, is a system that is heavily subsidized by nutrients accumulated in forest soils. Major conservation problems of the area include unsustainable landuse activities and the increase of people's dependency on forest resources. The community forests are being depleted rapidly due to shifting cultivation, unscientific logging, intensive extraction of NTFPs, and the enlargement of settlements. Increasing incidence of *Jhum* and shortening of the *Jhum* cycle are the main factors responsible for the loss of forest cover and significant reduction in agricultural output (Ramakrishnan, 1985; Ramakrishnan and Toky, 1983; Mishra and Ramakrishnan, 1982; and Kushwaha and Kuntz, 1993). Considering all these factors, it is clear that the current trend in landuse practices 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 area.

The existing network of primary and old secondary forests in study the area occurs in PAs, in managed forests, and even in the remaining undisturbed primary forest patches, including sacred groves in community-owned lands. This network offers prospects of conserving the existing old-forest biodiversity of the region, and improving the overall conservation of wildlife and forests through sensible landuse planning. The following chapter (3) will focus on a detailed account of these primary and secondary forests throughout this landscape.

CHAPTER 3

TREE COMMUNITIES: SPECIES DIVERSITY AND SUCCESSIONAL CHANGES

3.1 Introduction

The old native forests of the Garo Hills in tropical western Meghalaya, northeast India, harbour one of the most diverse and luxuriant vegetations in the tropics (Kumar et al. 2002). The native primary, secondary forests and sal plantations (Shorea robusta) comprise the main forest vegetation types, which are subjected to anthropogenic pressure, particularly shifting cultivation (locally known as *jhum*). Most of the primary forests (PF) of the Garo Hills occur as remnant patches in remote localities in the interior hills. The adjoining secondary forests (SF) originate from many years of practising *jhum* causing patchy SF of various ages to be dispersed across the region.

Two decades ago, the *jhum* cycle (rotation of *jhumming* over the same land) was twenty years or more (**Fig. 3.1**), and the rate of forest recession and subsequent recovery were not a problem (personal communication with old local people and records of the State Forest Department). In recent years, however, the *jhum* cycle has been decreased to three years or less, which has largely depleted the old forest growths or PF. Sal forests occupy the alluvial plains and adjoining hillocks. Some sal forests were planted by the British during the early twentieth century and have achieved relatively old age and large sal trees.

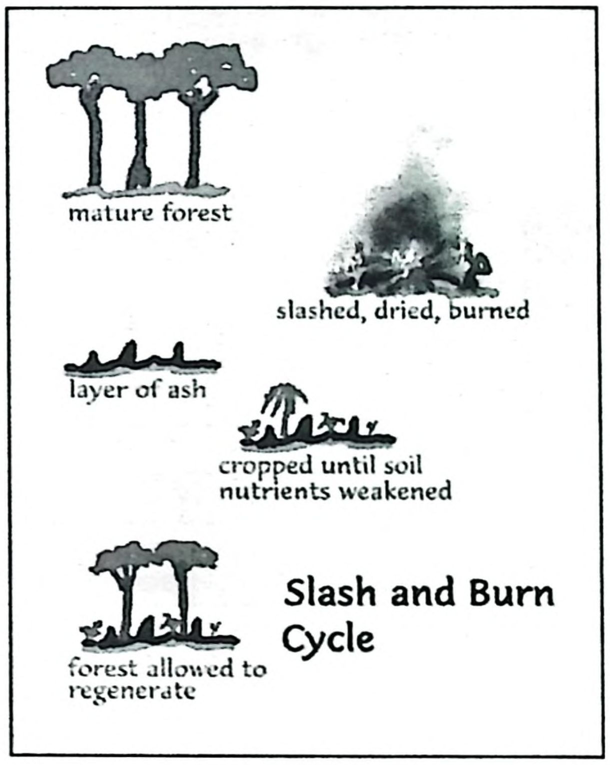


Figure 3.1: The shifting cultivation
Source: http://www.uwgb.edu/galta/a100/sg.htm

Many recent studies have described vegetation characteristics and the diversity of the tropical forests of India and other parts of the world (Table 3.1). Meghalaya, however, has remained largely unstudied except for a few landscape level assessments in recent years (Kumar el al., 2002 and Khan et al., 1997). This chapter presents empirical data on the diversity of tree species in the tropical forests of western Meghalaya, northeast India.

Table 3.1: Vegetation (tree species) characteristics of various forest communities in the tropics of India and other countries (- = not reported)

Forest type	Location	Plot size (ha)	Girth studied (cm)	Density (no./ha)	Basal area (sq m/ha)	Source
I N D I A						
Evergreen forest	Silent Valley, Kerala	-	≥ 31.5	620-709	29-103	Singh *et al.* (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 *et al.* (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)
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 *et al.* (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-**
O T H E R T R O P I C A L F O R E S T S						
Tropical rain forests	Barro Colarado Island, Panama	5	60.0	171	-	Thorington *et al.* (1982)
Tropical rain forests	Barro Colarado Island, Panama	50	>62.8	152	-	Hubbell & Foster (1983)
Tropical rain forests	Amazonia	3	31.4	1420	28-68	Campell *et al.* (1986)
Equatorial insular forests	Eastern Carolline Island, Panama	50	>31.4	98-114	17	Itow (1986)
Tropical rain forests	Jengka Reserve, Malaysia	11	91	104	23	Ho et al. (1987)
Tropical rain forest	Gunung Silam, Malaysia	0.04	31.4	513-1596	23-46	Procter *et al.* (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	Campell *et al.* (1992)

3.2 Methods

I prepared an inventory of tree species from all the systematic sampling and opportunistic surveys during the project period (1996-2002). 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 and Haridasan, 1981; Haridasan and Rao, 1985; Kumar and Rao, 1985; Awasthi, 1999; Nengminza, 1996; Tiwari *et al.*, 1999; and Kanjilal *et al.*, 1934-40) and unpublished records of local NGOs, individuals, the State Forest Department, and other government agencies. Further, I collected the primary field data and analysed them using MS EXCEL, SPSS, STATECOL and BIODIVERSITY_PRO for phyto-sociological, cluster, diversity and richness, and rarefaction analyses, respectively.

3.2.1 Field data collection

I used stratified random sampling to collect tree data by surveying along existing footpaths and elephant travel lanes using belt transects (1000m x 10 m, thus 1 ha each) suggested (Sykes & Horrills, 1977) for such conditions. I established 35 belt transects (**appendix 3.1**) of which 21, 10 and 4 were in PF, SF and sal forests, respectively and verified the age of sample forests with local residents in nearby villages. The local names and girths of all those trees with ≥ 30 cm girth at breast height were recorded.

3.2.2 Stratification of forests

The PF was stratified 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. Likewise, the SF was stratified into three successional stages based on age (years since stand-replacing disturbance, principally *jhum*): SF1 five years or younger (n = 3), SF2 between fifteen and thirty years (n = 4), and SF3 older than 30 years (n = 3).

3.2.3 Analysis method

3.2.3.1 Number of tree species versus number of samples

I plotted out the cumulative number of tree species as a function of the cumulative number of samples for all PF (n = 21 belt transects), and separately for all SF (n = 10 belt transects). The PF curve levels off, but the SF curve does not, nor are there as many samples as with PF. This suggests that cumulative sample size of SF may not be sufficient to estimate the total number of tree species at all SF sites in the study area (**Fig. 3.2**), so I did the rarefaction analysis to compare tree species diversity between and within PF and SF.

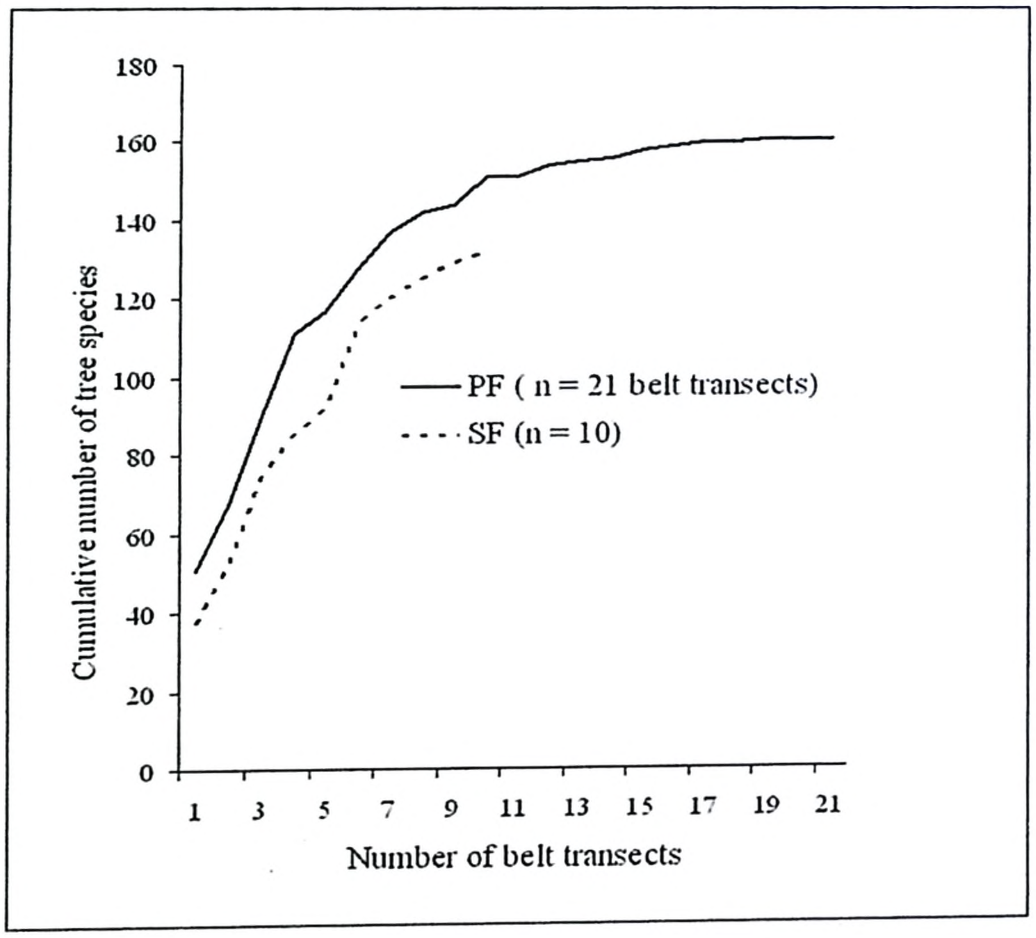


Fig. 3.2: **Cumulative number of tree species as a function of cumulative number of samples in primary forest (PF, n = 21 belt-transect) and secondary forest (SF, n = 10).**

3.2.3.2 Phyto-sociological analysis

I computed the following phytosociological characteristics of tree species from primary and secondary forests or understanding the tree community structure in the study area (Misra, 1968).

Frequency (F)	=	number of sampling units of species occurence / total number of sampling units.
Percentage frequency	=	F x 100.

I grouped all the species into five frequency classes (FC) including 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).

Density (D)	=	Total number of individuals/total number of sampling units
Abundance (A)	=	No. of individuals/ total number of sampling unitsof occurrence.
A x F	=	100 x D

HIGH FREQUENCY X LOW ABUNDANCE	=	*REGULAR DISTRIBUTION*
LOW FREQUENCY X HIGH ABUNDANCE	=	*CONTAGIOUS DISTRIBUTION*

The ratio of abundance to frequency is a relative measure of degree of contagiousness of the distribution of any species in a stand (Misra, 1968).

I computed tree density (number of trees/ha) and basal area (m2/ha) for all three vegetation types and compared the frequency of tree species in PF and SF only. I calculated the species importance values (SIV) of each tree species as per Misra (1968), who used the term "importance value index" or IVI for same.

SIV = RELATIVE DOMINANCE + RELATIVE DENSITY + RELATIVE FREQUENCY

Where relative dominance is the ratio between the total basal area of the species and the total basal area of all species (x 100), relative density is the ratio between the number of individuals of the species and the number of individuals of all species (x 100), and relative frequency is the ratio between the number of occurrences of the species and the number of occurrences of all species (x 100).

3.2.3.3 Similarity measures

I computed similarity measures using Jacard's (JI), Sørenson's (SI) and Czekanowski's indices (CI). 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). Calculations are based on the number of trees of each species in the vegetation categories and forest formations. I considered various combinations of forest types and formations including PF versus SF, PF versus sal forests, SF versus sal forests; PF low versus PF mid; PF mid versus PF high, PF low and PF high; SF1 versus SF2; and SF2 versus SF3 and SF1 versus SF3 (**Fig. 3.3**).

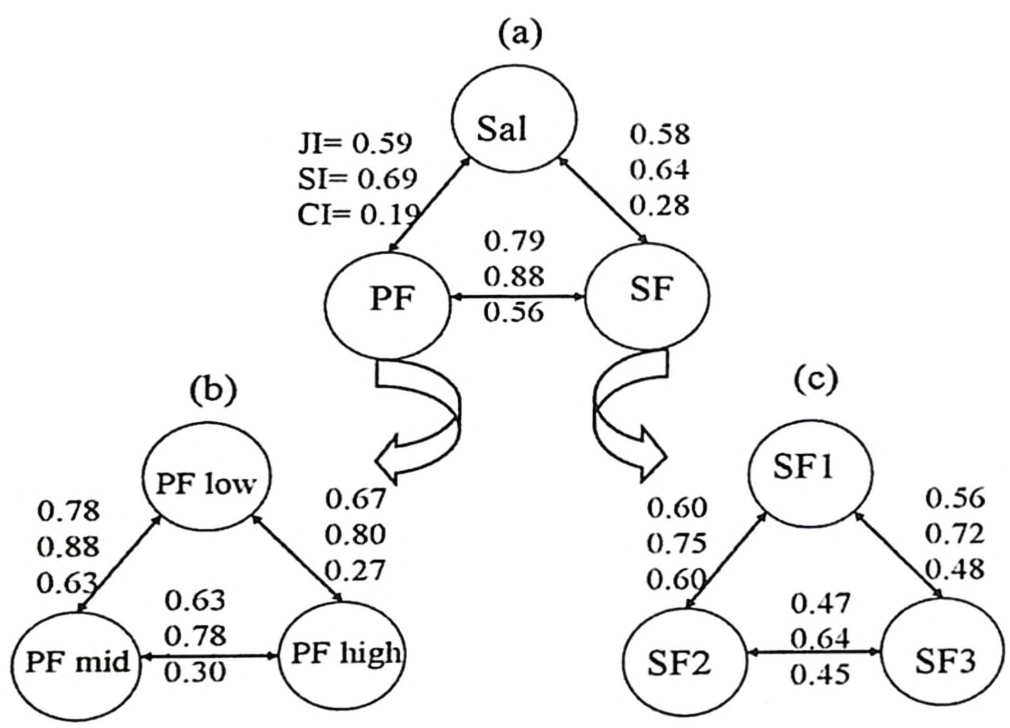


Fig. 3.3: Jacard's (JI), Sørenson's (SI), and Czekanowski's (CI) indices of similarity measured among: (a) three broad vegetation types of primary forest (PF), secondary forest (SF), and sal plantations (Sal); (b) three formations of PF; and (c) three successional stages of SF.

3.2.3.4 Species richness, diversity and rarefaction

The statistical software STSTECOL was used to compute species richness (Menhinick index), species diversity (Shannon-Wiener diversity index) and evenness (modified Hill's ratio) based on the number of trees of each species in various vegetation categories and forest formations (Ludwig and Reynolds, 1988). Since these measures of diversity are controversial I compared the diversity of PF, SF and several successional stages and forest formations in these forests using rarefaction, which produces a graph 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).

3.2.3.5 Hypotheses testing

I compared the primary (n = 21 belt transects) and secondary forests (n = 10 belt transects) 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 NUMSPS (no. of species), TREDEN (tree density), BASARE (Basal area), MENIND (Menhinik index for species richness), SHANIND (Shannon Index for species diversity) and HILIND (Modified Hill's ratio for species evenness) for comparing these primary and secondary forests. Similarly, I used the analysis of variance (ANOVA) for comparing the identified formations of PF and successional stages of secondary forests, and testing hypothesis, which states, "*there is no difference among tree diversity values of the successional stages of secondary forests and primary forests*".

3.2.3.6 Tree species versus successional changes

I quantified the successional changes across the age gradient among three seral stages of SF represented by SF1, SF2 and SF3 along with the mature PF 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 PF for providing an idea of the invasion of the climax species during the course of time as an SF converts into a PF.
- Species with the highest SIV representing the most important species in SF.
- Important species providing food to the native wildlife.
- Important species providing timber and other non-timber forest products to the native community.

Three species are common between groups 1 and 2 so there only seven species left, which I considered together to discuss the quantitative changes among identified seral stages. The species are *Polyalthia simiarum, Schima wallichii, Castanopsis purpurella, Syzygium cumini, Grewia microcos, Shorea robusta, and Macaranga denticulata*. I discussed groups 3 and 4 separately by plotting the smooth line curve for selected species as a function of SIV in several seral stages (**Table 3.2**).

Table 3.2: Identified groups of tree species selected for discussing the quantitative changes among various successional stages of tropical forests

Group of tree species	Criteria of selecting species	Top five species
Group 1	Species with the highest SIV in PF	*Polyalthia simiarum, Schima wallichii, Castanopsis purpurella, Syzygium cumini,* and *Grewia microcos*
Group 2	Species with the highest SIV in SF	*Schima wallichii, Castanopsis purpurella, Shorea robusta, Macaranga denticulata,* and *Grewia microcos*
Group 3	Species providing food for wildlife (see table 5.12 in chapter 5)	*Grewia microcos, Artocarpus chaplasha, Syzygium cumini, Lepisanthes rubiginosa,* and *Artocarpus gomezianus*
Group 4	Species providing timber and other non-timber forest products to the native community (see table 6.18 in chapter 6)	*Dillenia pentagyna, Terminalia citrina, Artocarpus chaplasha, Callicarpa arborea,* and *Careya arborea*

3.3 Results and discussion

A total of 411 tree species and their conservation status and potential habitats were recorded from all surveys in study area (**appendix 3.2**). I enumerated a total of 29,884 trees of 165 species and 54 families across all 35 samples (one-hectare belt transects) vegetation categories and forest formations, of which 153 were identified at specific level. The ten most versatile (species occurring in the maximum number of samples *i.e.*, belt transects) are *Castanopsis purpurella* (present in 33 belt transects), *Syzygium cumini* (33), *Dillenia pentagyna* (32), *Sapium baccatum* (32), *Grewia microcos* (31), *Aporusa dioica* (30), *Litsea monopelata* (30), *Schima wallichii* (30), *Persea villosa* (29) and *Stereospermum chelonoides* (29). A few species, however, including *Adina cordifolia*, *Anacardium occidentale*, *Bauhinia* spp., *Dysoxylum alliarium* and *Lepisanthes rubiginosa* occurred in only one belt transect. The 10 most important tree species (listed in decreasing order of SIV) among all vegetation conditions and forest formations combined were *Shorea robusta, Schima wallichii, Castanopsis purpurella, Polyalthia simiarum, Syzygium cumini, Grewia microcos, Aporusa dioica, Dillenia pentagyna, Drimycarpus racemosus* and *Eurya acuminata.*

3.3.1 Community structure as a function of tree species

Frequency expresses the distribution or dispersion of various species (listed in decreasing order of percentage frequency) in a community (**Fig. 3.4**). The following are the ten most frequently found species in primary and secondary forests:

- **Primary forests:** *Drimycarpus racemosus, Sapium baccatum, Castanopsis purpurella, Syzygium cumini, Dillenia pentagyna, Cynometra polyandra, Persea villosa, Kayea floribunda, Lannea coromandelica* and *Polyalthia simiarum.*
- **Secondary forests**: *Castanopsis purpurella, Schima wallichii, Grewia microcosm, Syzygium cumini, Aporusa dioica, Eurya acuminate, Dillenia pentagyna, Vitex peduncularis, Ilex umbellulata* and *Holarrhena antidysenterica.*

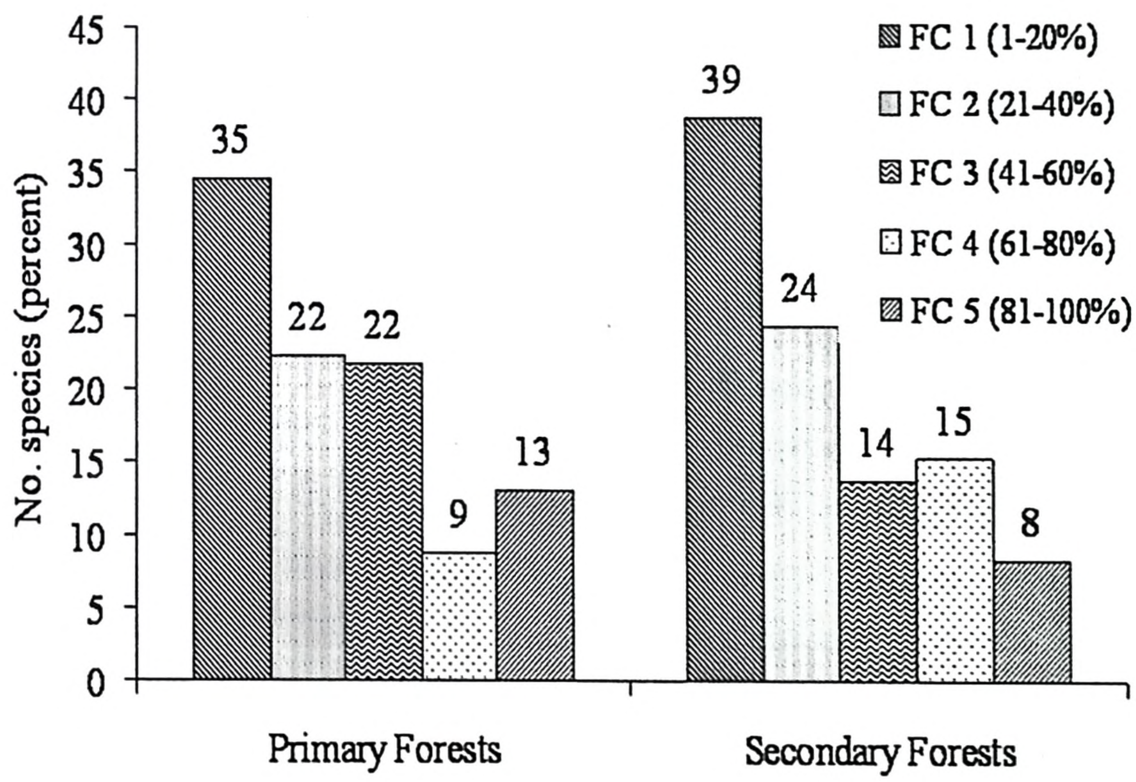


Fig. 3.4: **Raunkiaer's frequency classes for tree species in primary and secondary forests**

I plotted the cumulative number of tree species as a function of the cumulative number of sample plots, the SF curve was consistently lower than the PF curve, and that, coupled with t-test results, suggests that PFs are more tree-diverse. Raunkiaer's law of frequency class is FC 1 > FC 2 > FC 3 ≥≤ FC 4< FC 5. The frequency diagram (**Fig. 3.6**) represents the homogeneity (high FC 5) or heterogeneity (low FC 5) of a community, as floral diversity varies with the value for classes FC 1 and FC 5 (Misra, 1968). Classes FC 2, FC 3 and FC 4 are relatively low in PF compared to those in SF. The result suggests that SF are more heterogeneous compared with PF. The abundance and frequency gives an idea of the distribution pattern of the species, whilst the density represents the number of individuals per unit area. The density and frequency, if considered together, are of prime importance in determining community structure and have a variety of uses far beyond those of other quantitative values (Misra, 1968). I used the ratio of abundance and frequency as a measure of contagion among tree populations (Misra 1968).

The ten species (listed in increasing order of A/F ratio) with the most regular distribution in primary and secondary forests are

- **Primary forests:** *Artocarpus gomezians, Artocarpus* spp., *Oroxylum indicum, Macaranga indica, Moringa oleifera, Alstonia scholaris, Rhus acuminata, Duabanga grandiflora, Albizia chinensis* and *Ficus nervosa.*
- **Secondary forests:** *Artocarpus gomezians, Garcinia tinctoria, Gmelina arborea, Pterygota alata, Mesua ferrea, Mallotus roxburghianus, Oroxylum indicum, Litsea sebifera, Rhus acuminate* and *Saraca asoca.*

The ten species (listed in decreasing order of A/F ratio) with the most contagious distribution in primary and secondary forests are

- **Primary forests:** *Tectona grandis*, *Casearia glomerata, Boehmeria hamiltoniana, Ilex embelioides, Syzygium* spp., *Cinnamomum tamala, Castanopsis* spp., *Syzygium balsameum, Saurauia nepaulensis,* and *Shorea robusta.*
- **Secondary forests:** *Castanopsis* spp., *Boehmeria hamiltoniana, Viburnum colebrookianum, Saurauia nepaulensis, Shorea robusta, Calophyllum polyanthum, Syzygium operculatum, Acronychia pedunculata, Lagerstroemia speciosa* and *Schima wallichii.*

3.3.2 Tree species, richness and diversity

Primary (n = 21 belt transects), secondary (n = 10 belt transects) and sal (n = 4 belt transects) forests contained 162, 132 and 87 tree species and 54, 53 and 37 tree families, respectively. The average tree density was greatest in SF and lowest in PF, whereas basal area was highest in primary forest and lowest in secondary forest (**Fig. 3.5**). Tree species richness and diversity were highest in primary forest and lowest in sal forest, and evenness was highest in secondary forest and lowest in sal forest (**Fig. 3.6**). The ten most important tree species (listed in decreasing order of SIV values) in each of the forests were

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

- **Secondary forests:** *Schima wallichii, Castanopsis purpurella, Shorea robusta, Macaranga denticulata, Grewia microcos, Syzygium cumini, Aporusa dioica, Eurya acuminata, Dillenia pentagyna,* and *Callicarpa arborea.*

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

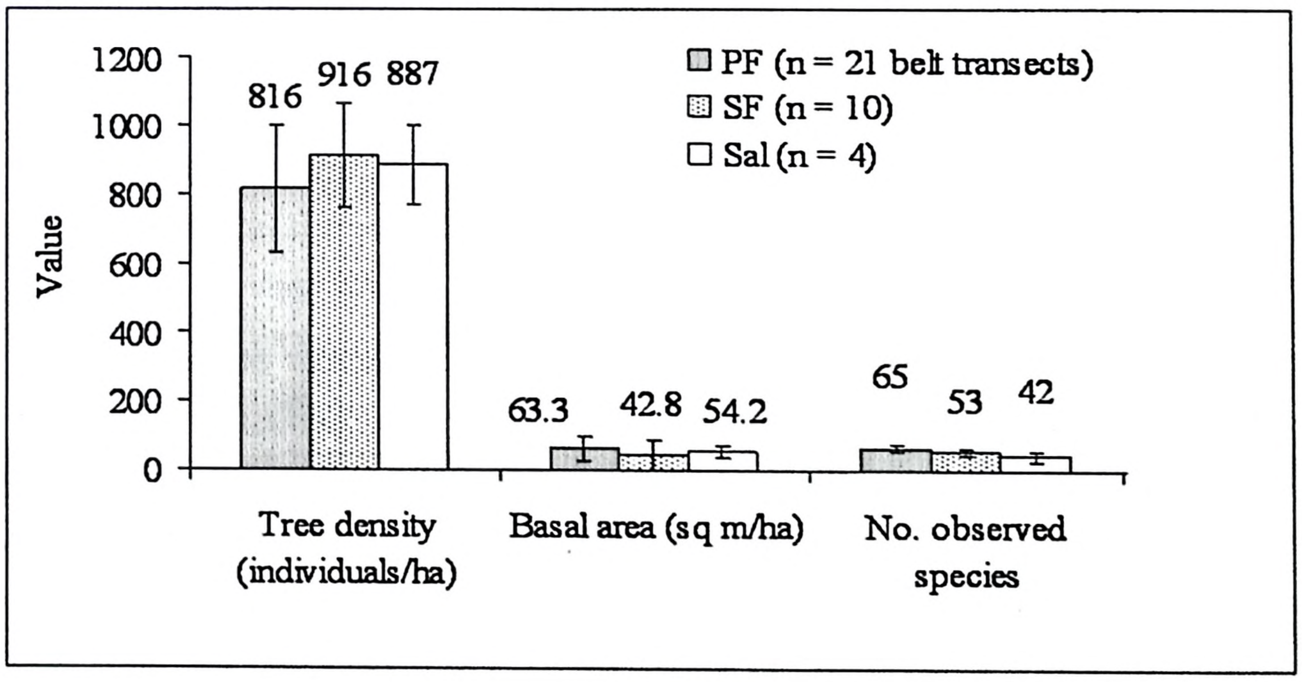


Fig. 3.5: **Tree density and basal area in three main vegetation types (error bars denote standard deviation).**

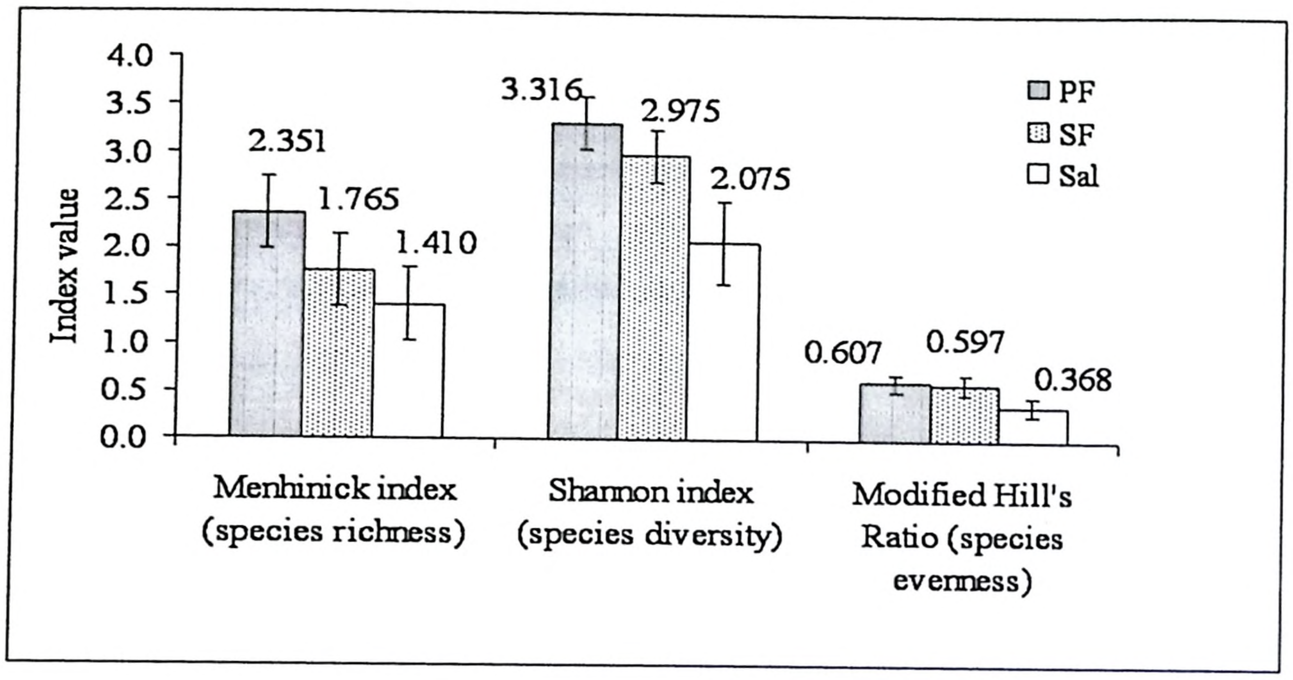


Fig. 3.6: **Indices of richness (Menhinick), diversity (Shannon-Wiener), and evenness (Hill) of three main vegetation types (error bars denote standard deviation).**

PF and SF (JI= 0.79, SI= 0.88 and CI= 0.56) showed a closer affinity to each other compared with PF versus sal forests (0.59, 0.69 and 0.19) and SF versus sal forests (0.58, 0.64 and 0.28); also CI, which considers the abundance of species, suggested that sal forests are closer to SF (0.28) than PF (0.19), two other indices (JI and SI), however, which solely depend on presence/absence of species, did not show much difference (**Fig. 3.3a**).

The t-test results suggest that the differences in number of tree species (t = 3.098, df = 17 and p = 0.006), Menhinik index for species richness (t = 3.767, df = 15 and p = 0.001) and Shannon index for species diversity (t = 2.991, df = 22 and p = 0.007) were highly significant between primary and secondary forests. However, the difference is not significant in case of tree density (t = -1.587, d f= 22 and p = 0.127), basal area (t = 1.326, df = 15 and p = 0.205) and modified Hill's ratio (t = 0.267, df = 18 and p = 0.793). Except for tree density, the mean values for all variables are greater in PF. The mean values of variables including the number of species, tree density (individual/ha), basal area m^2/ha, species richness, species diversity and species evenness for PF are 65, 816, 63.34, 2.35, 3.32 and 0.61, respectively; while for SF these values are 53, 916, 43, 1.77, 2.98 and 0.60, respectively. This analysis rejects the first null-hypothesis which states, "*There is no difference between the tree diversity values of primary and secondary forests*".

The rarefaction results and graph (**Fig. 3.7**) revealed the expected number of species, that is, E (Sn), when certain individuals are drawn from populations of both PF and SF.

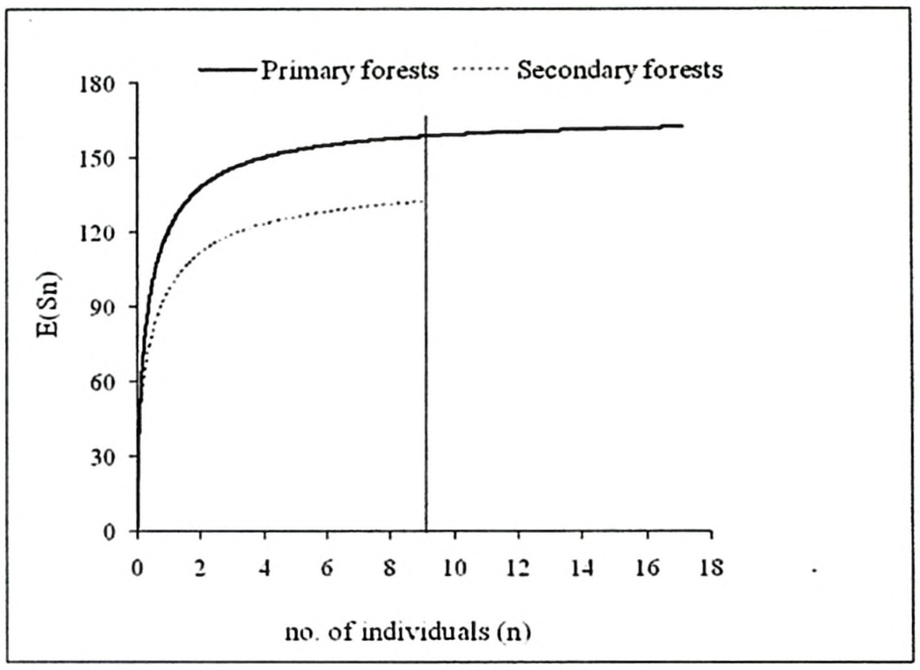


Fig. 3.7: Rarefaction curves standardizing the number of samples for comparing tree species richness in PF (top curve) and in SF (bottom curve). E(Sn) = expected number of tree species.

The results suggest that if one individual is selected from each community, there are chances of getting one species from PF and one from SF. Likewise, when 101 individuals are drawn from the same populations, there are 51 species in PF and 41 species in SF. When 9151 individuals are drawn, the expected numbers of species would be 158 and 132 in primary and secondary forests, respectively. Afterwards, as the number of individuals drawn increases, the number of species keeps increasing in primary forests and ZERO (0) in case of secondary forests.

I identified three distinct formations based on an elevation at 400 m class interval.

- **PF low** (less than 400m msl): 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 were *Tectona grandis, Castanopsis purpurella, Canarium strictum, Polyalthia simiarum, Drimycarpus racemosus, Grewia microcos, Dillenia pentagyna, Tetrameles nudiflora, Schima wallichii,* and *Shorea robusta.*

- **PF mid** (400 - 1000 m above msl): Mid-altitude primary forests support vast tracts of dense primary forest cover, the major portion of which occurs 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** (more than 800 m above msl): High altitude primary forests occur near Nokrek and Tura peak areas and in the high reaches of the Chutmang hills near Balpakram. This formation was characterized by a very humid microclimate. The ten most important tree species, in decreasing order of importance, 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*.

Among primary forest formations only, tree density was significantly greatest in PF high and lowest in PF low, whereas the basal area was highest in PF high and lowest in the other two PF formations (**Fig. 3.8**).

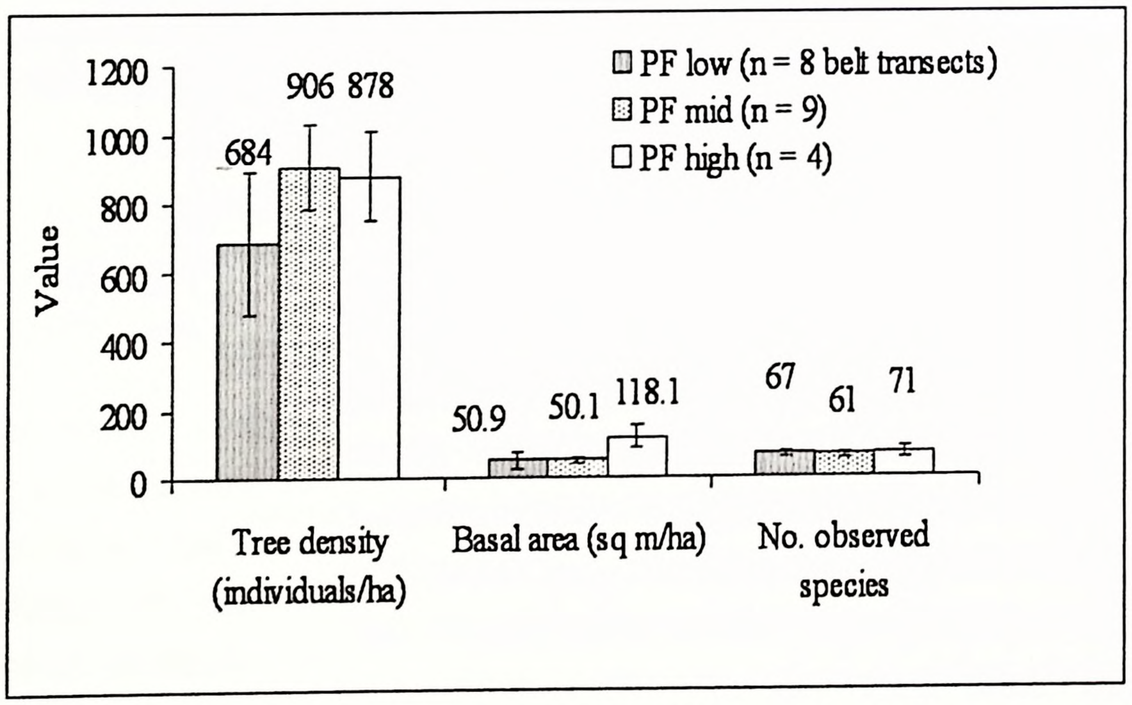


Fig. 3.8: **Tree density and basal area in PF formations (error bars denote standard deviation).**

Number of observed species did not vary significantly across the 3 PF formations (Table 3.3). Tree species diversity and evenness were not so different among three PF formations, whereas tree species richness was slightly lower in PF mid but not significantly (**Fig. 3.9**). The rarefaction analysis suggested that PF low was the most tree-diverse followed by PF high and PF mid (**Fig. 3.10**). The JI, SI and CI values showing similarities between PF low and PF mid are 0.78, 0.88 and 0.63, respectively. These values between PF mid and PF high were 0.63, 0.78 and 0.30, respectively (**Fig. 3.3b**).

Table 3.3: 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

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 < 0.1

P < 0.05

*** 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.

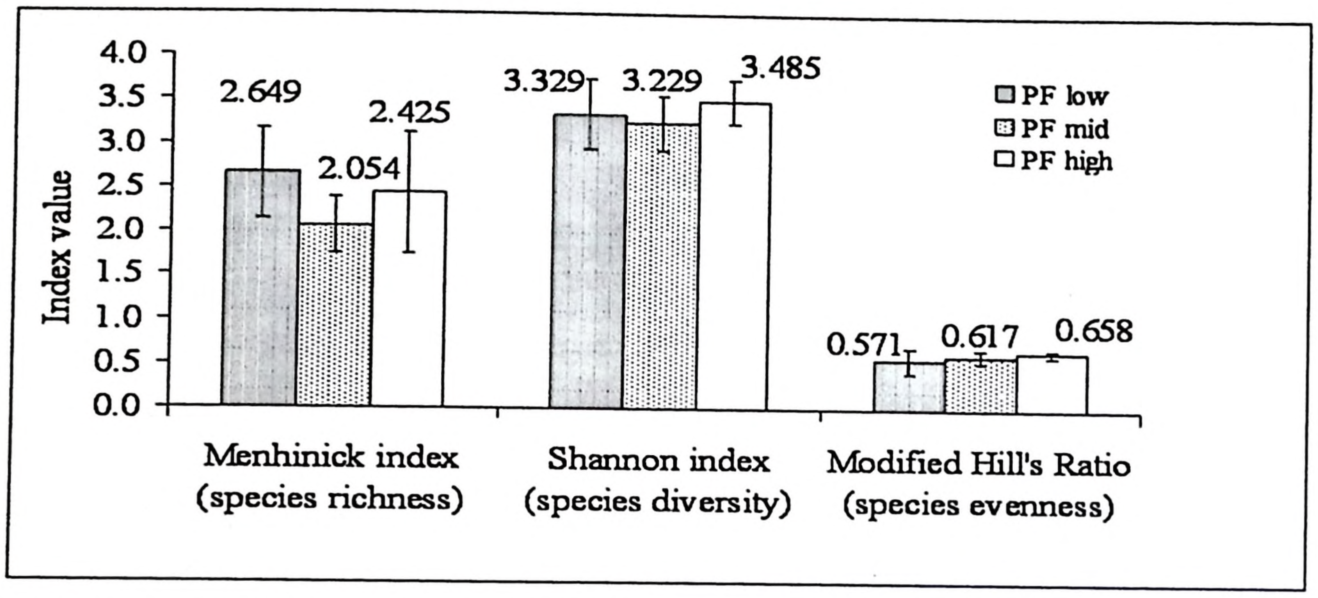


Fig. 3.9: Indices of richness (Menhinick), diversity (Shannon-Wiener), and evenness (Hill) of PF formations (error bars denote standard deviation).

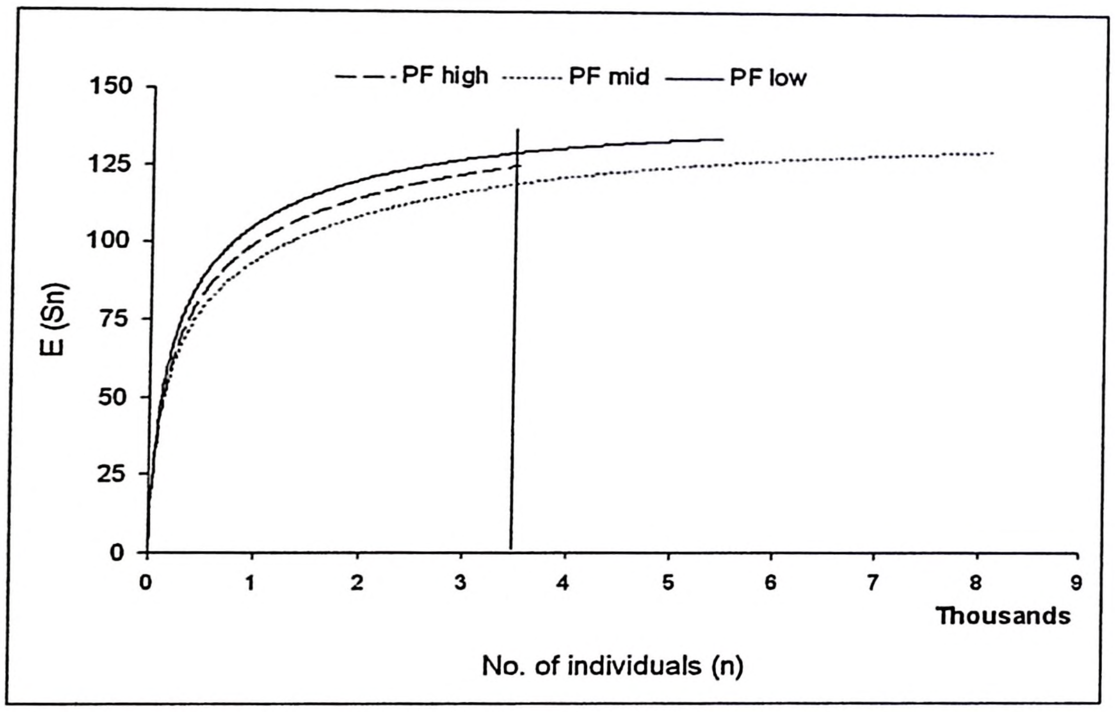


Fig. 3.10: Rarefaction curves standardizing the number of samples for comparing species richness in three PF formations: PF high (n=4 belt-transects; middle curve), PF mid (n=9; bottom curve) and PF low (n=8; top curve). See Fig. 3.7 and text for explanation.

The ten most important tree species in the secondary forest, listed in decreasing order of importance (SIV), were *Schima wallichii, Castanopsis purpurella, Shorea robusta, Macaranga denticulata, Grewia microcos, Syzygium cumini, Aporusa dioica, Eurya acuminata, Dillenia pentagyna,* and *Callicarpa arborea.* In three SF age classes, 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.

The JI, SI and CI similarity index values between SF1 and SF2 are 0.60, 0.75 and 0.60, respectively. The same values for sets of SF2 versus SF3 and SF1 versus SF3 were 0.47, 0.64, & 0.45; and 0.56, 0.72, & 0.48, respectively (**Fig. 3.3c**). The results of statistical analyses of tree parameters among forest formations are presented in **Table 3.3**. Among all formations of PF, SF, and Sal forests, tree density was significantly highest in SF3 and lowest in PF low, and tree basal area was highest in PF high and SF3, and lowest in SF1 and SF2 so (**Fig. 3.11**).

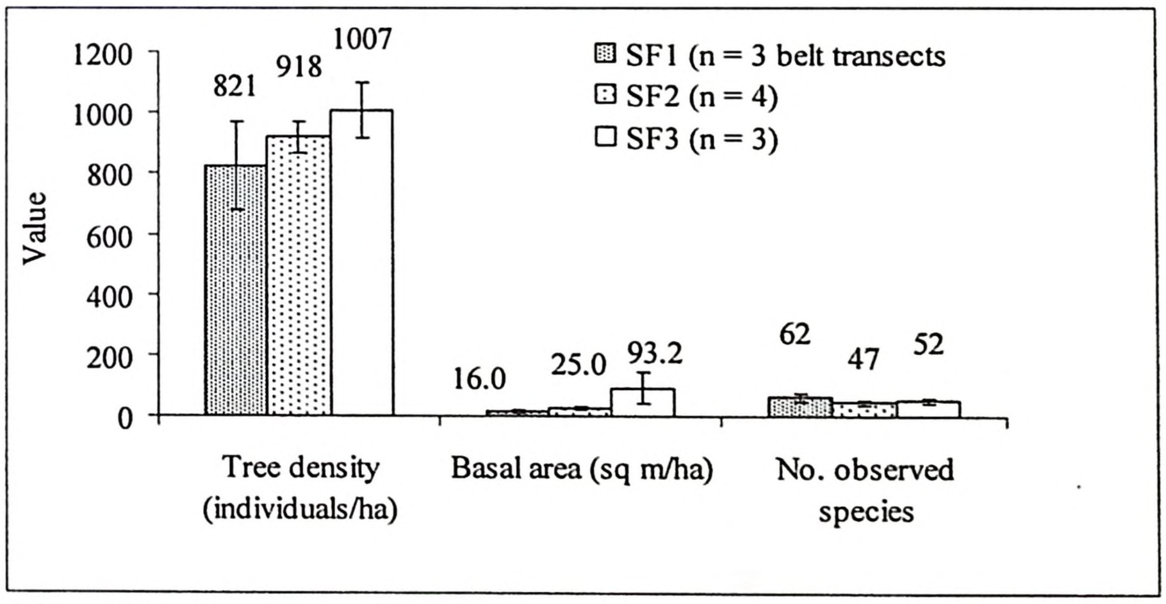


Fig. 3.11: Tree density and basal area in three successional stages of secondary forest (SF) (errors bars denote standard deviation)

Tree species diversity was lowest in Sal forest but differed only marginally among PF and SF formations; the same trends held for evenness. Tree species richness varied significantly in all forest formations, with the highest values in primary forests and the lowest in SF2, SF3, and Sal forest formations (**Table 3.3**).

I identified three formations of secondary forest (SF1, SF2, and SF3), based on increasing age classes. Among secondary forest formations only, tree density and basal area tend to increase over the growth sequence of SF1, SF2 and SF3, although only the basal area was significantly greater in SF3 (**Fig. 3.11**). Tree species richness was slightly greater in SF1, but not significantly so over three SF formations, although richness of SF1 was significantly greater than SF2, indicating an initial flush of many tree species following *jhum* in SF1, followed by a decrease in SF2 and then a subsequent increase in SF3 as new tree species recover or re-invade. Diversity and evenness were not significantly different among three SF formations. Number of observed species did not vary significantly across the 3 SF successional stages (**Table 3.3** and **Fig. 3.12**). Rarefaction analysis suggests that SF3 are the most tree–diverse, followed by SF1 and SF2, respectively (**Fig. 3.13**). The t-test results disprove the second null-hypothesis, which states, "There is no difference among tree diversity values of the successional stages of secondary forests and primary forests" (**Table 3.3**).

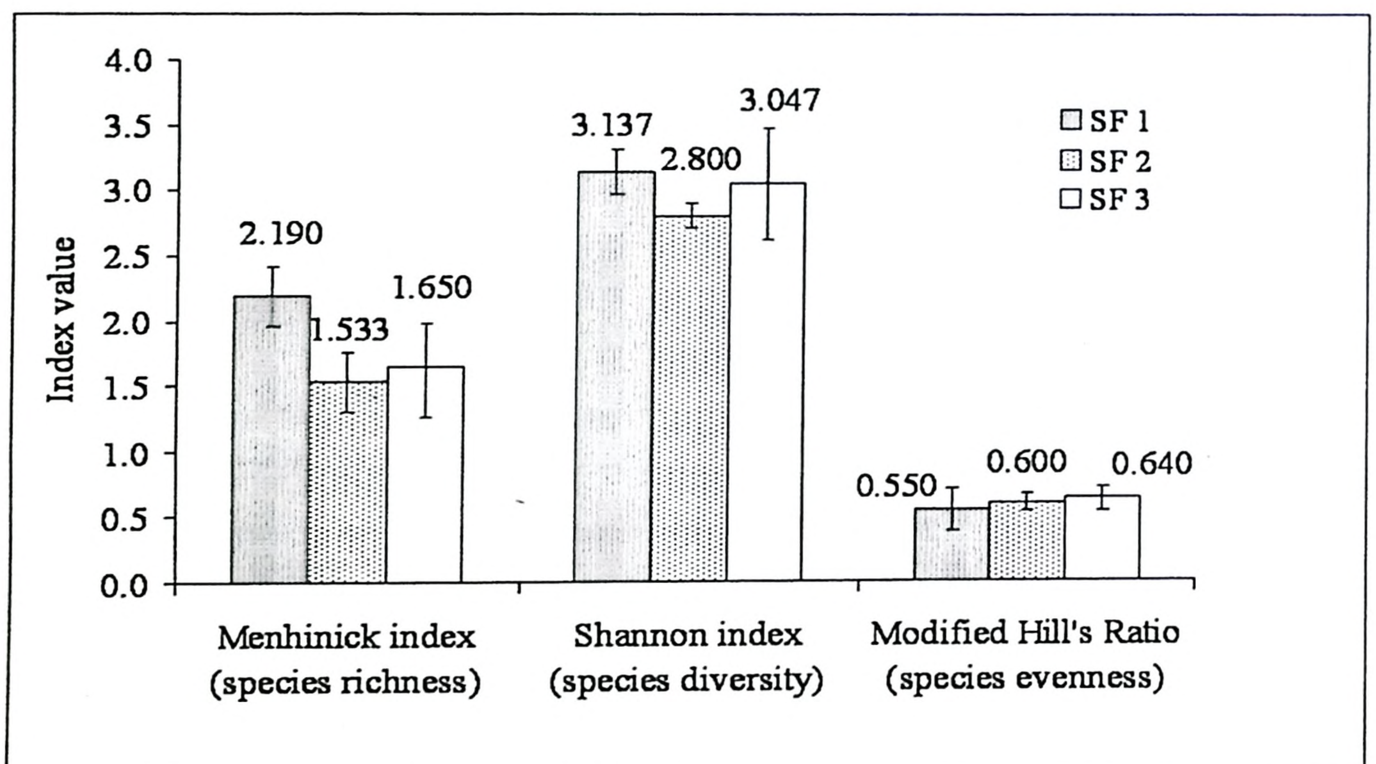


Fig. 3.12: **Indices of richness (Menhinick), diversity (Shannon-Wiener), and evenness (Hill) of three successional stages of secondary forest (SF) (error bars denote standard deviation).**

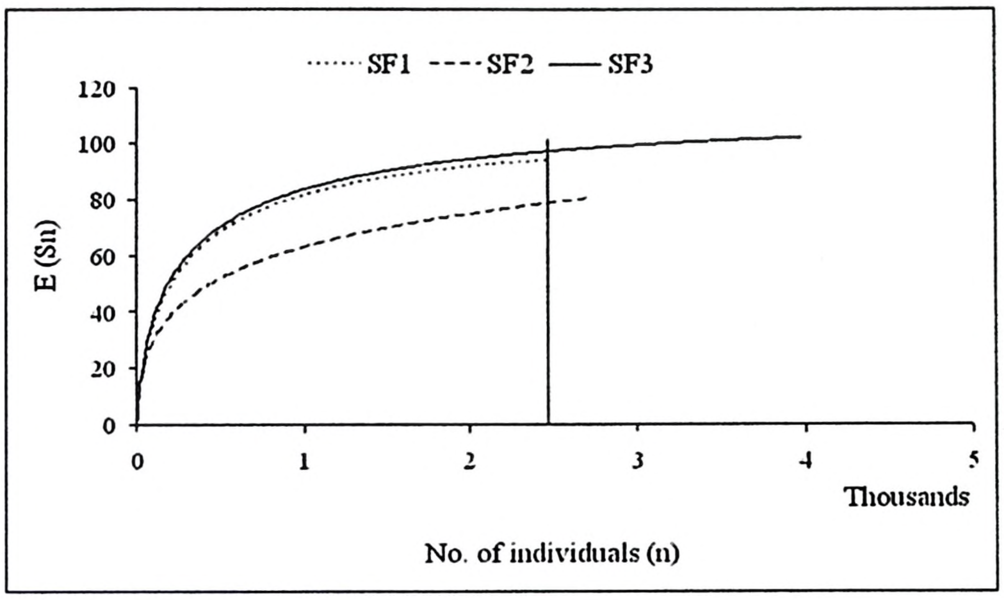


Fig. 3.13: **Rarefaction curves standardizing the number of samples for comparing species richness in three successional stages of secondary forest (SF). SF 1 (n = 3; middle curve), SF 2 (n = 4; bottom curve) and SF 3 (n = 3; top curve). See Fig. 3.7 and text for explanation.**

3.3.3 Comparision with other tropical forests

A database of all plant species of Meghalaya includes 830 tree species, out of which 305 and 58 species are from low (0-750 m) and mid (750-1500 m) elevations, respectively, in Garo, Khasi, and Jhantia Hills throughout the state (Khan *et al.*, 1997). The present study area is confined to these elevation ranges in the Garo Hills only. The systematic surveys in the present study revealed a comparable 165 tree species (>30 cm gbh) for a relatively small portion of Meghalaya at low and mid-elevations covering only a 2549 km^2 area. The indices showing similarity suggested that PF and SF are closer to each other than the sal forests. PF low and PF mid are closer to each other than PF high. Likewise SF1 and SF2 are closer to each other as than SF3.

3.3.3.1 Tree density and basal area

Estimates of tree density from the study (430- 1145 individual /ha of trees >30 cm gbh, among all vegetation types) are within the ranges of estimates from a variety of other tropical forest studies (30-283/ha; 1). 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 tree densities (n/ha): 1420 and 1720 (both higher than the present study) (Campell *et al.*, 1986 and Campell *et al.*, 1992) in tropical rain forests of the Amazon

Basin; 98-114 (lower) (Itow, 1986) in equatorial insular forests, eastern Caroline Island, Panama; 513-1596 (higher) (Procter *et al.*, 1988) in tropical rainforests of Gunung Silam, Malaysia; 391-617 (lower) (Heany and Procter, 1990) in tropical rainforests of Costa Rica; 1533 and 1183 (higher) (Jeffre and Veillon, 1990) in slope and alluvium forests, respectively, of New Caledonia, reported for trees $\geq$31.4 cm gbh (**Table 3.1**). Here I found that the tree density of the study area compares well with that reported from other tropical forests. In most of these studies, values were based on approximately the same size trees (30-32 cm gbh) so results are comparable. The highest basal area recorded in this study was 163 m^2/ha, far greater than the highest value of 107 m^2/ha (Parthasarathy *et al.*, 1992) in any tropical forests of the world. 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.

3.3.3.2 Tree species diversity

The Shannon-Wiener diversity index values for species diversity in the present study were 4.27, 3.78 and 2.47 for primary, secondary and sal forests, respectively, which is quite high compared to 2.2-2.65 for the tropical forests of Kodayar in the Western Ghats (Sundarapandian and Swamy, 2000). Very close figures were found in Silent valley, Kerala, where the index values were reported to be 4.15, 4.08 and 3.52 in riparian, mesic upland and less-mesic upland habitats, respectively (Singh *et al.*, 1984). The tropical forest showed comparatively lower values of 3.31 and 3.69 in Kalakad Reserved Forests in Western Ghats (Parthasarathy *et al.*, 1992). The Shannon-Wiener diversity index, however, gave a value of 4.8 for the tropical forests of Barro Colarado Island (Knight 1975). It is very difficult to draw any valid comparisons due to significant differences in sample size, plot size and dimensions, choice of standard gbh by researchers, environmental conditions, and other site factors mentioned above. Sorting tropical forests by tree species richness, density, basal area, and diversity can, however, serve as indicators to compare broad vegetation characteristics of the world's tropical forests.

3.3.3.3 Comparing species diversity through rarefaction

The diversity and evenness indices discussed above are widely used by ecologists for comparing different communities or ecosystems (or habitats or vegetation categories) and considered very useful, but they are equally controversial in certain conditions or without certain assumptions (Hurlbert, 1971; Peet, 1974 and1975; Poole, 1974;

Pielou, 1975; and Southwood, 1978). There are chances of losing information while expressing community structures (Southwood, 1978) and sometimes they become meaningless due to semantic, conceptual and technical problems (Hurlbert, 1971). One of the major problems is sample size; adequate computation of these indices may require a large number of sample sizes for obtaining the precise diversity and evenness values of certain communities (James & Rathbun, 1981; Pielou, 1966a, b and c; and Bowman *et al.*, 1971).

Considering the broad scale of the landscape (2459 km^2), I took bigger samples (one hectare belt transect of 1000 m x 10 m dimensions) and collected 31 such belt transects, of which 21were in primary forests, and ten in secondary forests. Here, I used the rarefaction method to compare the species diversity of primary and secondary forests (**Fig. 3.7**). The rarefaction curve suggests that primary forests are always more tree-diverse, even if I compare only 5000 individuals from both communities, the PF assembles more species than secondary forests. Similarly, the rarefaction results revealed that PF low and SF3 as the most tree diverse of all categories of primary and secondary forests, respectively.

3.3.5 Successional changes

The Garos prefer to do *jhumming* on 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 pioneers occupy the bare land, which includes a very dense and impenetrable growth of stem of a few species during first few years. The light-loving climbers (convolvulaceae, Cucurbetaceae 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 course of time giving the way to other species. If undisturbed, the succession proceeds: young forest gives the way to old secondary forest (Jacobs, 1981). Due to long life of trees, the changes take place gradually and difficult to observe without very concrete and long term efforts. The Budowski's table provided the ecological characteristics of primary and various successional stages of secondary forests. The age of various communities and the species observed by Budowski may slightly differ as in our study area, but the table provides an idea of the process and vegetation conditions of various seral and climax stages (**Table 3.4**).

Table 3.4: Budowski's table for comparison among four successional stages from pioneer to mature climax primary forest with special reference to the American tropics (Budowski 1965)

Characteristics	Pioneer	Earlv	Late Secondarv	Climax
Aqe of communities	1-3	5-15	20-50	More than 100
Heiqht. meters	5-8	12-20	20-30. some	30-45. some up
Number of woodv	Few. 1-5	Few. 1-10	30-60	Up to 100 or a
Floristic composition	Euphorbiaceae.	*Ochroma.*	Mixture. manv	Mixture. except
Natural distribution	Verv wide	Verv wide	Wide. include drier	Usuallv
Number of strata	1. verv dense	2. well	3. increasinqlv	4-5 difficult to
Upper canopv	Homoqeneous.	Verticillate	Heteroqeneous.	Manv variable
Lower stratum	Dense. tangled	Dense. larqe	Relativelv scarce.	Scarce. with
Growth	Verv fast	Verv fast	Dominants fast.	Slow or verv
Life span. dominants	Verv short. less	Short. 10-25	Usuallv 40-100	Verv lonq. 100-
Tolerance to shade.	Verv intolerant	Verv intolerant	Tolerant to	Tolerant. except
Reqeneration of	Verv scarce	Practicallv	Absent or	Fairlv abundant
Dissemination of	Birds. bats. wind	Winds. birds.	Wind principallv	Gravitv.
Wood and stems.	Verv liqht. small	Verv liqht.	Liqht to medium	Hard and
Size of seed. or	Small	Small	Small to medium	Larqe
Viabilitv of seeds	Lonq. latent in	Lonq. latent in	Small to medium	Short
Leaves of dominants	Everqreen	Everqreen	Manv deciduous	Everqreen
Epiphvtes	Absent	Few	Manv in numbers.	Manv species
Vines	Abundant.	Abundant.	Abundant. but few	Abundant.
Shrubs	Manv. but few	Relativelv	Few	Few in numbers
Grasses	Abundant	Abundant or	Scarce	Scarce
***Cecropia. Heliocarpus. and Trema* belonqs to the families Urticaceae. and Tiliaceae.**				

This study provides 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 southwest China using importance values, in which they combined the effects of tree abundance and dominance on individual plots. The present study compares the SIV, including the combined effects of abundance, density and basal areas) among the selected groups of 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). The identified groups 1 and 2 (**Table 3.2**) have three species in common, so I discussed the remaining seven species together.

3.3.5.1 Group 1: Species with the highest SIV in PF and SF

The top five tree species of PF, 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 PF (**Fig. 3.14**). *S. cumini* contributed significantly in SF1 and SF2, followed by a general decline in SF3 and PF. The other three tree species showed higher levels in some formation of secondary forest than in PF. The findings confirmed that *S. cumini* is an early secondary forest species.

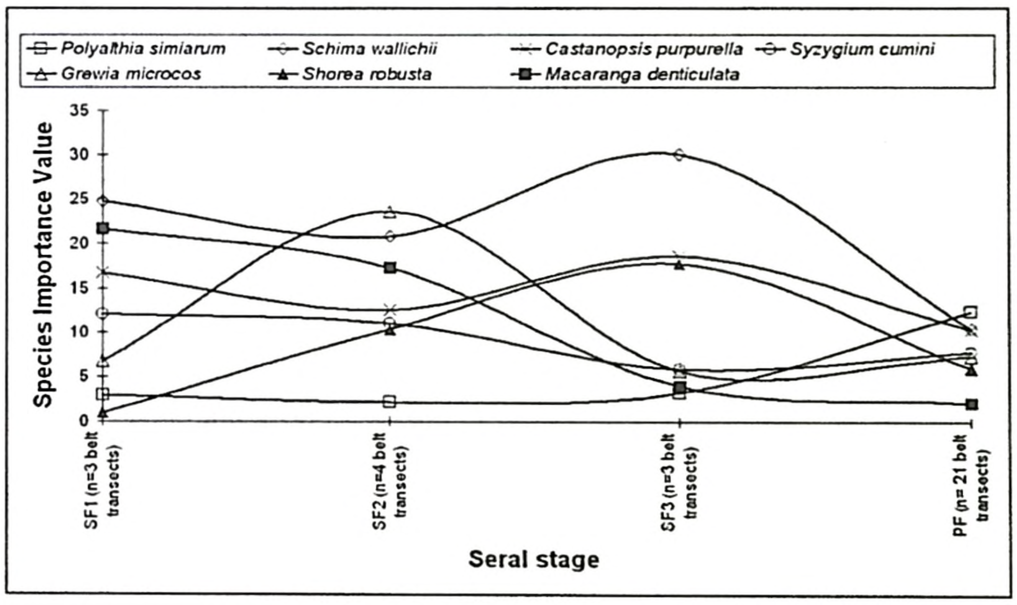


Fig. 3.14: **Changing species composition of top 5 secondary forests' tree species from PF and SF amongst various seral stages representing temporal succession**

The five most important tree species of secondary forests, among all three successional stages of SF listed in decreasing order were *Schima wallichii, Castanopsis purpurella, Shorea robusta, Macaranga denticulata*, and *Grewia microcos*. These species changed their relative importance among 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). Of these species, *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 PF stages. *Castanopsis purpurella* showed less variation between SF and PF. *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 PF.

3.3.5.2 Group 2: Species providing food for wildlife

G. Microcos is the species, which most animals in the study area used (**Table 5.12 in chapter 5**).This species did not show the extreme importance in SF1 but a significant increase in middle aged SF, then again reduced drastically in old SF and PF, 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 PF. These findings reveal that the middle aged SF are 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. 3.15**).

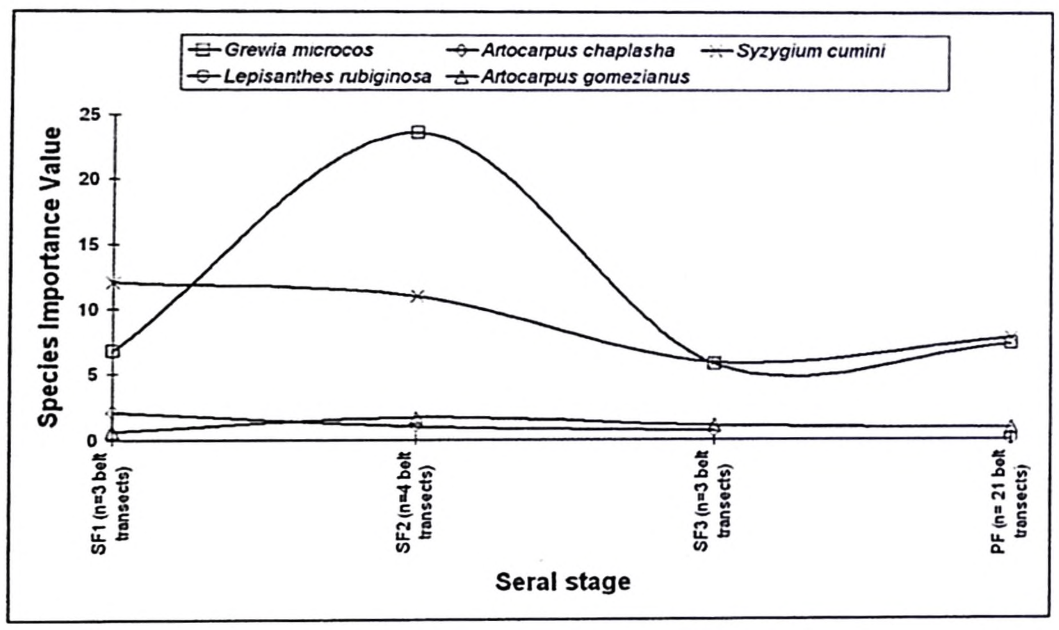


Fig. 3.15: Changing species composition of top five tree species as important food for native wildlife

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; they need further research in managing food species for wildlife in SF conditions.

3.3.5.3 Group 3: Species providing timber and non-timber forest products

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 PF. *Carea arborea* and *A. chaplasha* showed the least in all seral stages (**Fig. 3.16**).

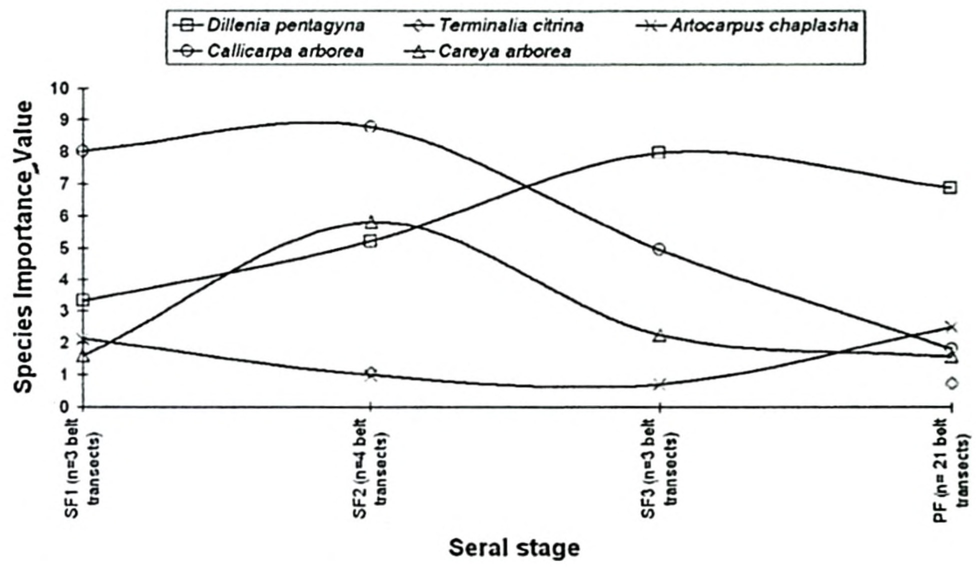


Fig. 3.16: Changing species composition of five tree species as important for native society

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 help forest managers and planners to use the correct strategies to arrest the succession at the right stage and to regulate the *jhum* for the maximum benefit of the native wildlife and humans.

3.4 Conservation significance

Tropical forests in Garo Hills of western Meghalaya are extraordinarily rich in floral resources, especially tree species (**Appendix 3.1**). Overall, stand density, basal area, and diversity of tropical forests of western Meghalaya equal or exceed those of the densest tropical rain forests anywhere in the world.

The removal of primary forest creates gaps where secondary forest can grow, which if allowed to flourish, plays an important role in rehabilitation of vegetation and soils after *jhum*. PF or old SF are cleared, *jhumming* is done, and then SF are allowed to return, depending on subsequent land use practices and length of the fallow period before subsequent *jhumming*. Young secondary forests develop into mature secondary forests and finally primary forests with climax communities. I examined the secondary successional stages to find out the process of invasion of forest tree species from the young seral stage to the old forest growth where it resembles the PF. The criteria for selecting the species include (i) the species importance value, (ii) the use of species by native wildlife and (iii) the use of species by native people.

Present chapter provided a landscape level assessment of the tropical forests with special reference to the tree species of secondary forests in the Garo Hills, situated in the western Meghalaya of northeast India. The major vegetation types are primary and secondary forests occupying most of the landscape with their various formations. The *jhumming* is the major cause of destruction of virgin primary forest, which leads to the development of secondary forests. This chapter analysed various successional stages of secondary forests using SIV of select tree species. The phytosociological analysis helped in determining the forest structure. The diversity analysis also revealed that PF are the most tree-diverse and revealed that PF were more tree-diverse compared to SF. We confirmed this by performing rarefaction analysis, however, the chapter discussed the importance of secondary forests for native wildlife and human beings. The analysis of various successional stages revealed that practice of regulated form of *jhumming* might help maintain the diversity of habitats for wildlife and provide valuable services to humanity and help recover the primary forests during the course of time.

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 rationalizing the ecologically sound fallow period with longer *jhum* cycle. This would help implementing 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 PF, successional stages of SF and response by individual tree species would provide information useful in recovering PF 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 PF could be restored and retained throughout the region to reduce the impact of forest fragmentation, which frequent *jhumming* is posing over the landscape.

CHAPTER 4

THE TROPICAL FORESTS: CLASSIFICATION AND FRAGMENTATION

4.1 The forests and fragmentation

Tropical forests are the most ancient, diverse, and ecologically complex of land communities (Lewin, 1986). Although they cover only seven percent of the Earth's surface, they sustain more than half the planet's life forms (Myers, 1984). With only 2.4 % of the total land area of the world, the known biological diversity of India – including that in tropical forests -- contributes eight percent to the known global biological diversity (Sarat Babu & Arora, 1999). Laurance and 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 northeastern Indian region belong to the second and third categories.

The tropical forests in Meghalaya occur up to 1200 m elevation with an average annual rainfall of 1000 - 2500 mm (Haridasan and Rao, 1985). Tree species of lower subtropical forests are present on higher hills of the state. It has a geographical area of 22,429 km^2 of which 15,584 km^2 (70 % of Meghalaya and 2.3 % of India) is under forest cover (**Fig. 4.1**). However, the recorded forest area under reserved, protected and unclassed forest remains at 9496 km^2 (42 % of Meghalaya and 1.2 % of India). Per capita forest and tree cover in Meghalaya is 0.68 ha compared to 0.074 ha in India. The state is predominantly tribal with 85.5 % population of tribal communities. The state ranks seventh out of all states and union territories in percentage of state's geographic area under forest cover (FSI, 2001). A few notable landscape level assessments for Meghalaya have been done by Roy and Tomar (2000, 2001), Talukdar (2004).

The study area addressed in this chapter includes the southwestern portion of the Garo Hills in western Meghalaya. Sudhakar and Singh (1993) provided district-wise landuse classification of the Garo Hills plus other areas of Meghalaya at 1:250,000 using LISS II satellite data (**Table 4.1**).

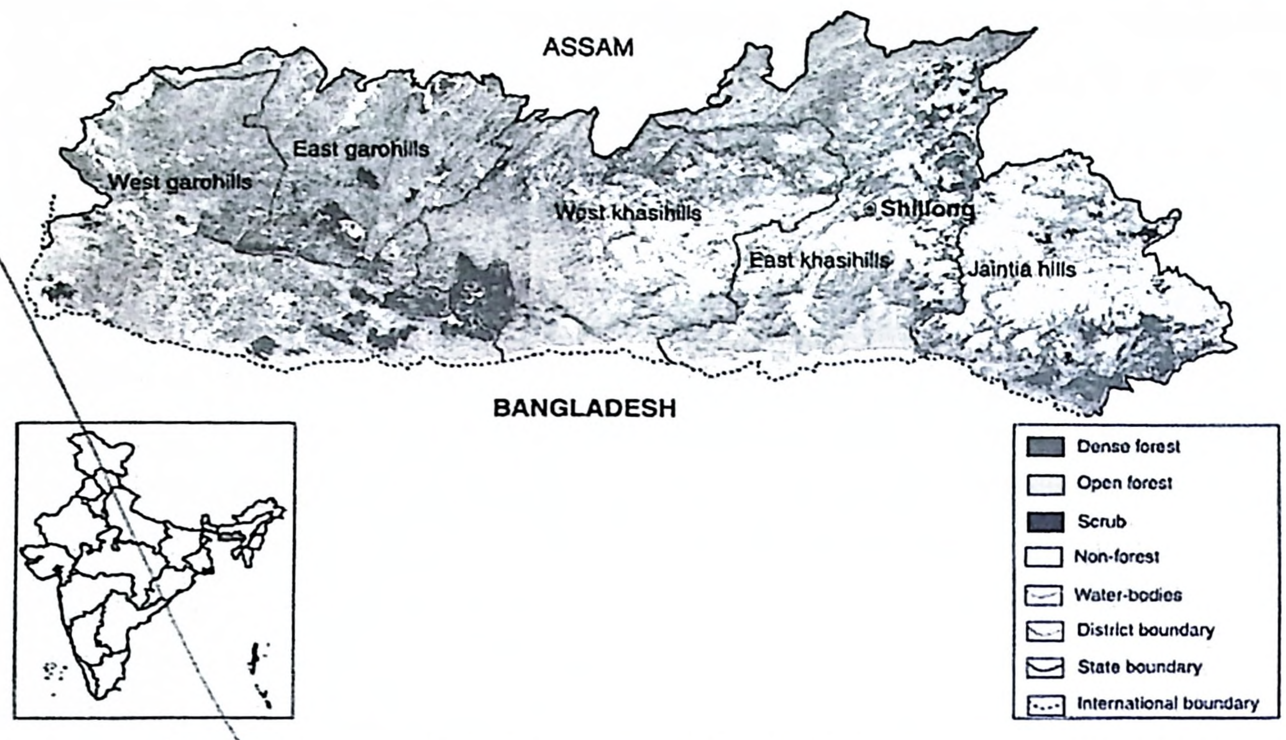


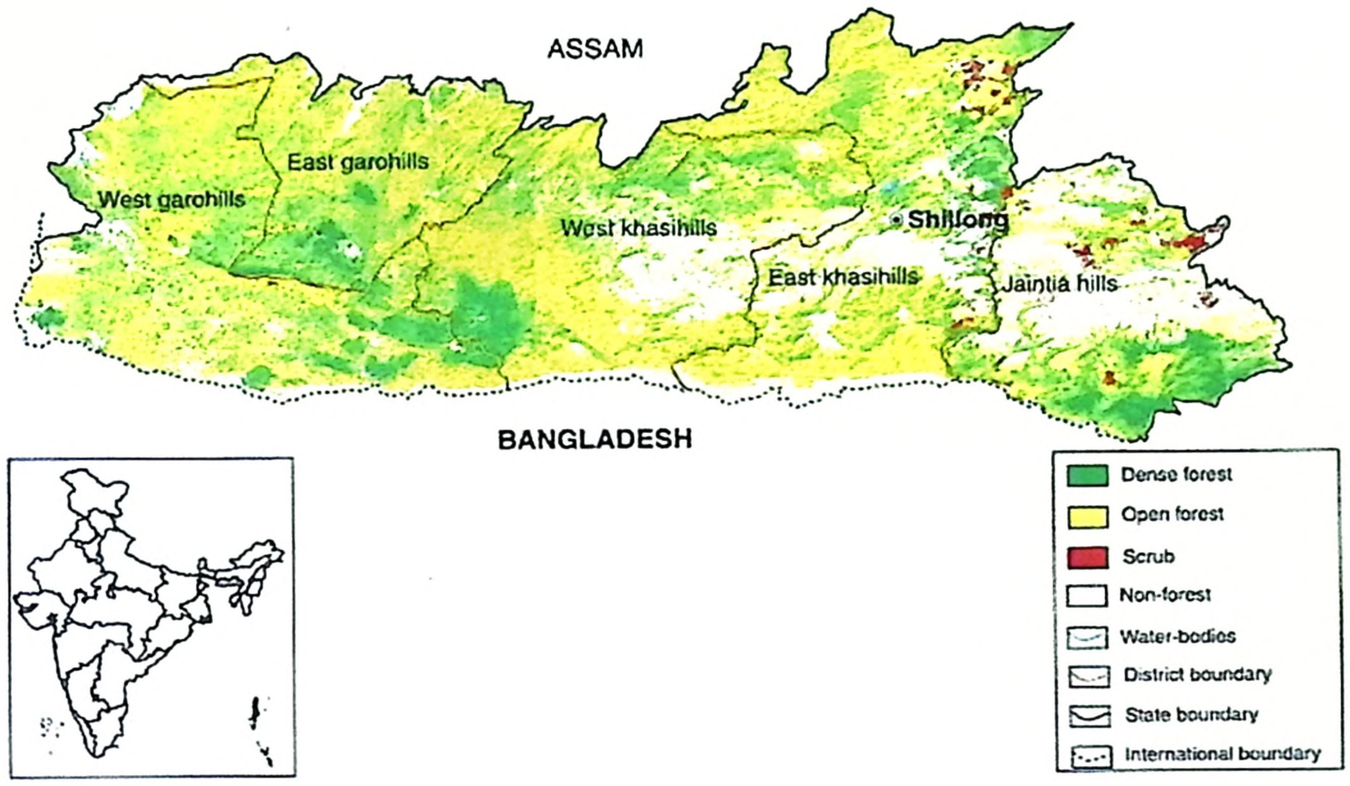
Fig. 4.1: Forest cover of Meghalaya (source: FSI, 2001)

Table 4.1: Landuse in Garo Hills during 1993 classified with remote sensing data (in km^2)

Land use classes	West Garo Hills	South Garo Hills	East Garo Hills
Tropical Semi-evergreen Forests	481	292	454
Tropical Moist/ Dry Deciduous Forests	1257	716	956
Tropical Dry Deciduous +Bamboo mix Forests	317	177	110
Degraded Forests	656	111	360
Grasslands	-	29	35
Agriculture/Non forest	470	471	675
Sandy area	33	38	9
Water bodies	56	16	4

Source: Sudhakar and Singh (1993)

Fragmentation is defined as the anthropogenic isolation of forests and severing of connectivity among forest patches. For this study, fragmentation refers to such changes in native, old (>30 years old) tropical forests of the landscape, the specific study area in and around the South Garo Hills district in Garo Hills, Meghalaya, northeast India. In general, fragmentation can reduce the amount of core habitat (old forest within the centre of forest patches, away from edge influences) for wild



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This chapter presents an analysis of landuse landcover, identifies and quantifies the forest fragmentation, and classifies old native forests to evaluate the landscape characteristics. It uses fragmentation analysis to identify critical wildlife habitats including remaining core areas and potential wildlife habitat corridors.

4.2 Methods

The study area was stratified as per existing vegetation cover or land-use practices and the legal status of the land. Opportune sampling to survey the plant species and the stratified random sampling to collect the field data on forest tree species were employed during fieldwork. The data on tree species were analysed for classifying the tropical forests and developing an aspatial database, whereas the spatial database was developed through remotely sensed satellite data.

4.2.1 Classification of tropical forest

I recorded plant species opportunely along natural trails. In addition, I used stratified random sampling along 35 belt transects (**appendix 3.1**) each 1000 m X 10 m, to sample the tree communities in primary and secondary forests within randomly selected locations. Girth at breast height (gbh) of trees ≥30 cm gbh within the transects was recorded (Sykes & Horrills, 1977). Plant specimens were deposited in the herbarium section of Wildlife Institute of India, Dehradun. Community classification was done by using cluster classification of the 35 such belt transects. Certain groups of tree species were used as criteria for classifying tropical forests of the study area. I used polythetic, agglomerative cluster classification to classify the forests, using the minimum variance technique known as Ward's method to classify ecological communities (Ludwig and Reynolds, 1988).

4.2.2 Landscape level analysis

The landscape boundaries were drawn from the Survey of India toposheets and visual identification of hill ranges for the southern portion of the study area. I delineated the protected area boundaries within the study area from available records in the State Forest Department of Meghalaya. Remote sensing data was analysed using the GIS ArcInfo and ArcView. Maps of the recently extended boundaries of Balpakram National Park were not available as the area falls in the international restricted area zone. Hence, in the present study, the extent of Balpakram National Park is considered without the extended boundary, that is, an area of 220 km^2. Furthermore, the fragmentation and core area images were prepared using Bio_CAP, a GIS based software for landscape analysis, and modelling developed by the Indian Institute of Remote Sensing, Dehradun.

4.2.2.1 Landuse landcover mapping

The IRS-1D satellite LISS III digital data of February 1999 were used to generate maps of land use and vegetation classes in ERDAS images, a GIS based mapping and analytical software. The landuse landcover map (**Fig. 4.2**) was prepared through supervised classification, using ground control points observed and recorded with the help of field photographs during field visits as well as Survey of India toposheets.

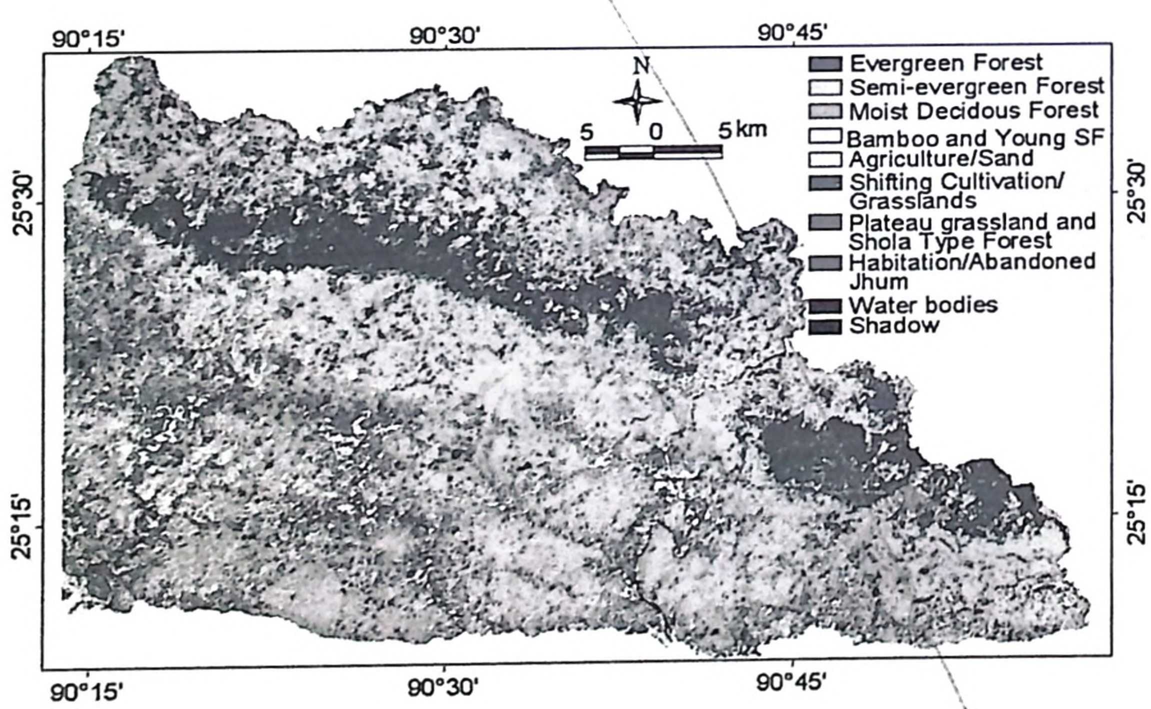

Fig. 4.2: Landuse landcover map of the landscape

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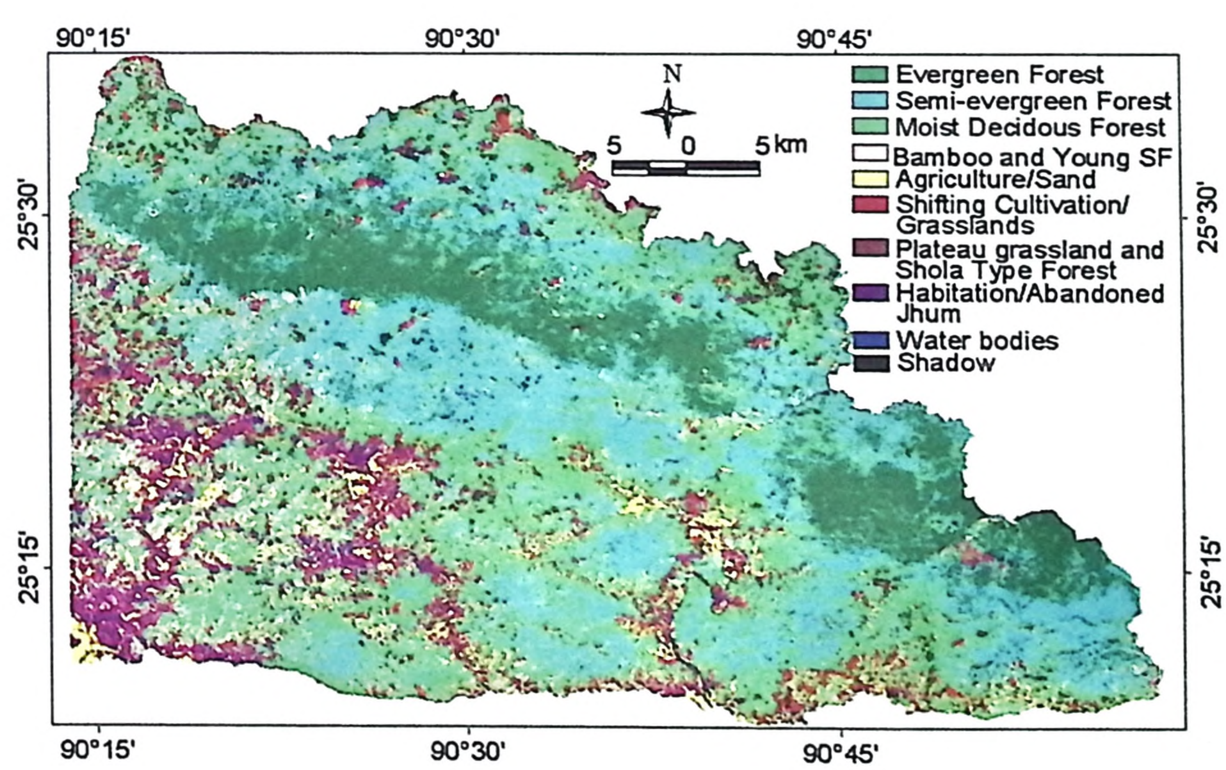

Fig. 4.2: Landuse landcover map of the landscape

The output, a classified landuse landcover map obtained through supervised classification, was smoothed to reduce extraneous noise. The majority filter was applied separately to forest and non-forest categories to avoid intermingling of non-forest categories pixels with forest pixels (Lillesand and Kiefer, 1994).

4.2.2.2 Forest fragmentation

Fragmentation is defined as the anthropogenic isolation of forests and severing of connectivity among forest patches (Forman, 1995; and Frohn, 1998). Bio_CAP defined fragmentation as the number of forest and non-forest types patches per unit area (Romme, 1982; Roy & Tomar, 2001). The landscape analysis programme (LAP) in Bio_*CAP* provides a useful measure of forest fragmentation by using a convolution of a specific size window moved over spatial data; this derives the number of forest patches under forest and non-forest categories.

$$F = \sum_{i=1}^{n} Di$$

Where Di is the dissimilarity value for the ith boundary between adjacent cells, and N is the number of boundaries between adjacent cells.

The final image, that is the landuse landcover map, was converted into a grid image with a grid (pixel) size of 23.5×23.5 m and was then transformed into polygons for assessing patch fragmentation. The landuse landcover map was reclassified in two classes (forest and non-forest) for this analysis. A window of 250x250 m was convolved with the forest/non-forest map to derive the number of forest patches within the window. This was itrated by moving the window through the entire forest/non-forest map.

4.2.2.3 Core areas

The core area is defined as the area within a patch beyond some specified edge distance or buffer width. The core area metrics reflect both landscape composition and landscape configuration (McGarigal & Marks, 1994). Core area of forest patches has been found to be a much better predictor of habitat quality than patch area for forest interior specialist wildlife species (Temple, 1986). Core areas were measured at edge distances of 250 m, 500 m, 1000 m and 2000 m throughout the forest patches, considering the views of various studies for assessing edge effects and microhabitat conditions at differing interior edge distances - see above. I identified core areas using the Bio_CAP, which mapped all the core areas as potential habitat for interior wildlife species.

4.2.2.4 Potential wildlife corridors

A wildlife corridor is defined as an approximately linear two-dimensional landscape element that connects two or more patches of wildlife (animal) habitat that had been previously connected in the past (Soule & Gilpin, 1991). The potential wildlife corridors were identified on the basis of forest fragmentation maps. The area within the least-fragmented classes was used to delineate corridors visually among existing protected areas and managed forests. Boundaries of potential wildlife corridors were then integrated into the landuse landcover map.

4.3 Results and discussion

Sudhakar and Singh (1993) classified the forests of entire Meghalaya at broader scale and identified somewhat different three forest types (Table 3) namely, tropical semi-evergreen forests, tropical moist/ dry deciduous forests, and tropical dry deciduous + bamboo mix Forests. Kumar and Rao (1985), however, based on classification scheme of Holdridge et al. (1971), identified 3 broad forest types (very similar to our study) for comparatively smaller area of BNP and termed them as tropical moist evergreen forests, tropical semi-evergreen forests, and tropical moist deciduous forests. We were able to map these forest types with available satellite data and resources. Other forest types identified by Kumar and Rao (1985), which we could not map distinctly, include secondary formations, shola type forests, riverine forests, grassland and tree-savannas, and bamboo forests. Unfortunately, they did not map the extent of various forest and non-forest types.

The different results from these two studies may be due to the use of different scales. Later, Kumar and Singh (1997) classified the forests of BNP and adjoining community land covering area of 447 km2 and delineated the evergreen, secondary formation/semi-evergreen, moist deciduous forest types (Table 4) at 1:250,000. Sudhakar and Singh (1993) used LISS II satellite data at broader scale (1:250,000) and mapped entire Meghalaya with 22429 km2 of area, however, Kumar and Rao (1985) and Kumar and Singh (1997) studied comparatively smaller landscape of BNP covering only 220 km2. We also worked on finer scale (1: 50,000) for comparatively smaller landscape (2459 km2). This may be one of the reasons for identifying different forest types.

Primary forests exist in all three landuse categories. Secondary forests, formed due to the long history of shifting cultivation or *jhum* by the local communities, were not found in the RFs, mainly because the RFs were created long ago during the late nineteenth century, and because no clear felling has been conducted in the RFs except for a few silvicultural treatments by the State Forest Department. Some plantations of Sal (Shorea robusta) and Teak (Tectona grandis), however, have been raised in certain pockets within the RFs. Table 4.2 lists the prominent forests types (as per Champion and Seth's classification) in the study area and the equivalent primary and secondary forests and their formations.

Table 4.2: Primary and secondary forest growths within the study area

Forest Type	Primary or Secondary Forests
Tropical Moist Evergreen Forests (TMEF)	Primary forests, *Macaranga denticulata* colonises at initial stages of succession. These forests are evergreen in nature, small patches of which are found in the 8-10 years old *jhum* fallows.
Tropical Semi-evergreen Forests (TSEF)	Primary and old secondary (> 25 years old) forests at edges. Sometimes include riparian forests near gorges in Balpakram National Park. In Siju Wildlife Sanctuary, the semi-evergreen nature of these forests is mainly due to the presence of Sal patches in the heart of the sanctuary.
Tropical Moist Deciduous Forests (TMDF)	Old Sal and Teak plantations and young secondary forests at lower elevations, 10-20 (occasionally 25, based on soil condition) years old.

A total of 1062 plant species belonging to 154 families and 578 genera have been recorded through opportune survey (**appendix 4.1**). The species to genus ratio (S/G) for plant species is 1.84. The same ratio has been found for tree species. The S/G ratios for shrubs, herbs, climbers, bamboos, canes and ferns are 1.69, 1.53, 1.60, 1.55, 2.17, 2.67 and 1.12, respectively (Table 4.3).

Table 4.3: The number of plant species in the tropical forests of study area

Plant group (TAXA)	Family	Genera	Species
Trees	71	224	411
Shrubs	51	137	231
Herbs	55	135	206
Grasses	1	25	40
Climbers	36	80	124
Bamboos	1	6	13
Canes	2	3	8
Ferns	16	26	29
All plants	154	578	1062

Euphorbiaceae (33 species), Lauraceae (31), Moraceae (30) and Rubiaceae (26) are the families found with more than 25 species. There were 54 families with five or fewer species; 23 of these families were represented by a single species. The number of species varied from six to fifteen for nineteen families. Ficus was observed as the largest genera with 21 tree species. Other diverse genera were Syzygium (11 species), Garcinia (8), Litsea (7), Albizia (6), Diospyros (6) and Premna (6). There were 140 genera each represented by only a single species.

From all 35 belt transects, I recorded a total of 165 tree species, of which 153 were fully identified to species. The ten most common species among the transects were Castanopsis purpurella (present in 33 belt transects), Syzygium cumini (33), Dillenia pentagyna (32), Sapium baccatum (32), Grewia microcos (31), Aporusa dioica (30), Litsea monopelata (30), Schima wallichii (30), Persea villosa (29) and Stereospermum chelonoides (29). The most uncommon species were Adina cordifolia, Anacardium occidentale, Bauhinia spp., Dysoxylum alliarium and Lepisanthes rubiginosa, which occurred in only one belt transect each. I (with the help of project field assistant and a few frontline staff of the State Forest Department) counted a total of 29,884 trees of 165 species and 54 families in all vegetation types and forest formations.

4.3.1 Classification of tropical forests

The groups obtained from the cluster analysis were hierarchically nested in a dendrogram chart (**Fig. 4.3**), which suggested three main groups and two of them were further divided into two sub-groups. Group 1, identified as Tropical semi-evergreen forests, is a cluster of 22 belt transects. The 22 belt transects falling in this group were well distributed throughout the study area. Seven of these belt transects were located in and around Balpakram National Park, three in Siju Wildlife Sanctuary, three in Baghmara Reserved Forest, three in Emangiri Reserved Forest, three on community land around Emangiri Reserved Forest, two in Rewak Reserved Forest and one at the Tura Peak Reserve.

Rescaled Distance Cluster Combine

```
    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 BNPPFB      7    ---+-----+                             +-------+
31 BNPPFC      8    ---+     +--------+                    I
32 BNPPFA      6    ---------+        +--------------------+
33 BNPBASE1    3    ---------+        I 3. Moist Evergreen Forest
34 BNPBASE2    4    ---------+--------+
35 BNPBASE3    5    ---------+
```

Fig. 4.3: **Cluster dendrogram using Ward's method with abundance of tree species**

4.3.2 Landscape and critical wildlife habitats

4.3.2.1 Landuse landcover mapping

The landscape consists of three forest types - tropical moist evergreen forest (TMEF), tropical semi-evergreen forest (TSEF) and tropical moist deciduous forest (TMDF). Other categories include Grassland, Shola type forest (Holdridge *et al.*1971, and Kumar & Rao, 1985) and degraded land with bamboo growth. Forest patches, either in isolation or with bamboo brakes and grassland, form the habitats for a number of wild animals. The TMEF, TSEF and TMDF together constitute 68 % of the landscape (**Fig. 4.2**). TMDF covered an area of 703 km^2 (29 % of entire landscape), TSEF covered 624 km^2 (25 %), and TMEF covered 353 km^2 (fourteen percent). Among non-forest landuse categories, human habitation and associated scrubland and habitation covered 234 km^2 (ten percent) of the total land, shifting cultivation covered 175 km^2 (seven percent), and bamboo patches in young secondary forest covered 184 km^2 (seven percent) (**Table 4.4**).

Table 4.4: Landuse landcover in study area (km^2)

Landuse/Forest types	PAs	RFs	Community Land (CL)	Total
TMEF	141	0	212	353
TSEF	89	35	500	624
TMDF	26	37	640	703
Plateau Grassland	3	0	0	3
Bamboo +Young secondary forest	4	6	175	184
Permanent Agriculture	1	2	93	96
Shifting Cultivation	5	4	166	175
Habitation/scrub/ abandoned *jhum*	3	4	228	234
Water bodies	0	1	4	5
Shadow	5	1	75	81
Total	277	90	2093	2458

Table 4.5 provides data on the distribution of forest types in national parks, reserved forests and community owned private land. It was observed that the most forest cover of TMEF, TSEF or TMDF occurred outside the boundaries of legally managed government controlled land, and accounts for about 80 % of the total forest cover or 1680 km^2. Old and native forest cover of TMEF and TSEF comprised about 73 % of total forest cover (977 km^2) outside the legal boundaries.

Table 4.5: Distribution of three forest types in various PAs and MFs in study area

Land Ownership	Forest Types					
	TMEF (km^2)	% of TMEF	TSEF (km^2)	% of TSEF	TMDF (km^2)	% of TMDF
Community Land	212	60	500	80	640	91
Balpakram NP	115	33	72	12	21	3
Nokrek NP	26	7	14	2	4	1
Siju WLS	0	0	4	1	1	0
Baghmara RF	0	0	15	2	19	3
Angratoli RF	0	0	10	2	13	2
Emangiri RF	0	0	7	1	3	0
Rewak RF	0	0	2	0	2	0
Total	353		624		703	

4.3.2.2 Forest fragmentation

Talukdar (2004) analysed the forest fragmentation of Meghalaya for the years 1980, 1989, 1995 and 2000 (**Fig. 4.4 and table 4.6**). There is a decrease in intact forest cover from 54 % to 30 % during the period of twenty years from 1980 to 2000. There was an increase in non-forest cover from 24 % to 50 % during this period. The actual fragmented area in 1980 was 23 %, which increased to 25% in 1989 and 1995, then decreased to 20 % in 2000. The earlier highly fragmented areas were converted to non-forest landuses during this period.

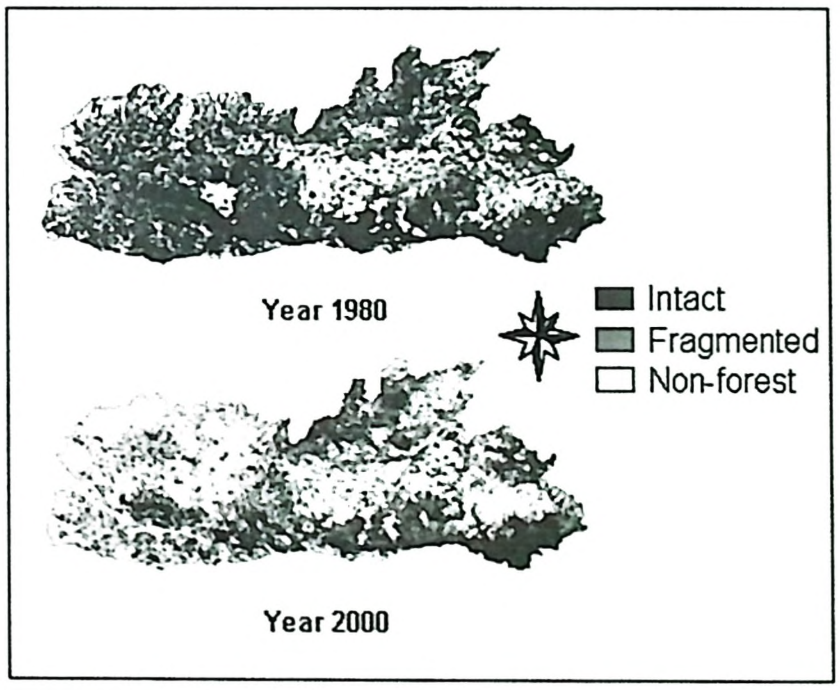

Figure 4.4: Fragmentation in the forests of the Meghalaya (source: Talukdar, 2004)

Table 4.6: Fragmentation in the Meghalaya

Categories	1980		1989		1995		2000	
	% Area	Area in km^2	% Area	Area in km^2	% Area	Area in km^2	% Area	Area in km^2
Intact	54	12022	39	8678	38	8464	30	6738
Fragmented	23	5114	25	5524	25	5606	20	4532
Non-Forest	24	5293	37	8227	37	8359	50	11160

Source: Talukdar (2004)

Likewise, Talukdar (2004) presented the year wise comparative analysis for the Garo Hills region, which revealed that fragmented areas have increased from 23 % in 1980 to 25 % in 1995 and decreased to 17 % in the year 2000 (**Table 4.7** and **Fig. 4.5**). He attributed this drastic decrease in fragmentation level during the year 2000 to the fact that highly fragmented lands in the year 1995 were converted to non-forest, and very few areas were available for fresh fragmentation. The area available for shifting cultivation has reached a saturation point and intact areas (17 %) are not available for shifting cultivation.

Table 4.7 Forest fragmentation in the Garo Hills

Categories	1980		1989		1995		2000	
	% Area	Area in km^2	% Area	Area in km^2	% Area	Area in km^2	% Area	Area in km^2
Intact	54	4430	26	2111	25	2010	17	1383
Fragmented	23	1912	27	2202	28	2252	17	1410
Non-Forest	22	1825	47	3854	48	3905	66	5374

Source: Talukdar (2004)

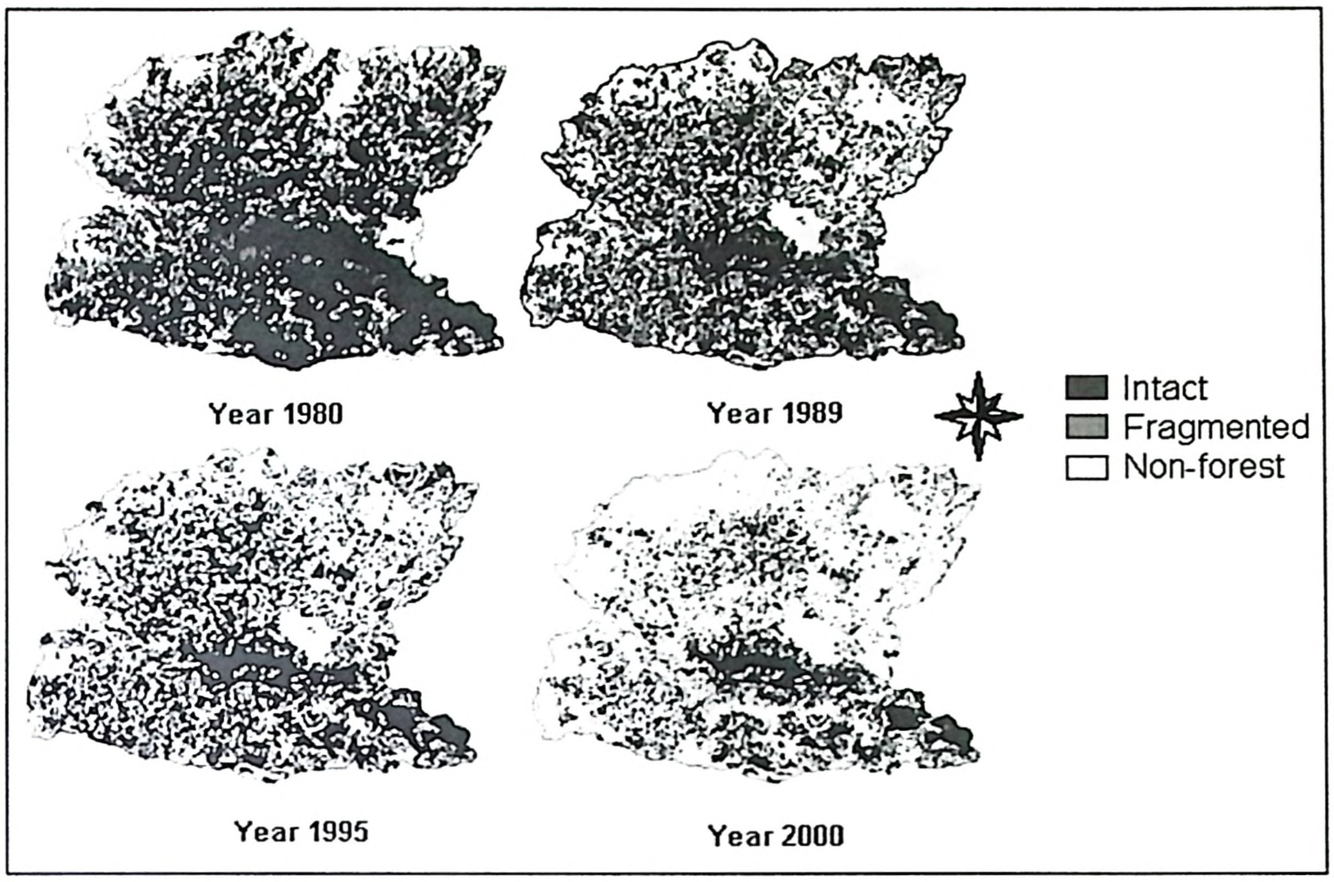

Fig. 4.5: Fragmentation in the forests of the Garo Hills, Meghalaya (source: Talukdar, 2004)

In the study area, the fragmentation of native, old (>30 years old) tropical forests served to reduce the amount of core habitat (old forest within the centre of forest patches away from edge influences) for wild animals. Results from this study showing the fragmentation analysis presented as a fragmentation map (**Fig. 4.6**), and as data on the number of patches of old native forest per map cell, normalised in the range of 0 to 10 (**Table 4.8**).

Table 4.8: Fragmentation values using Bio_*CAP*

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

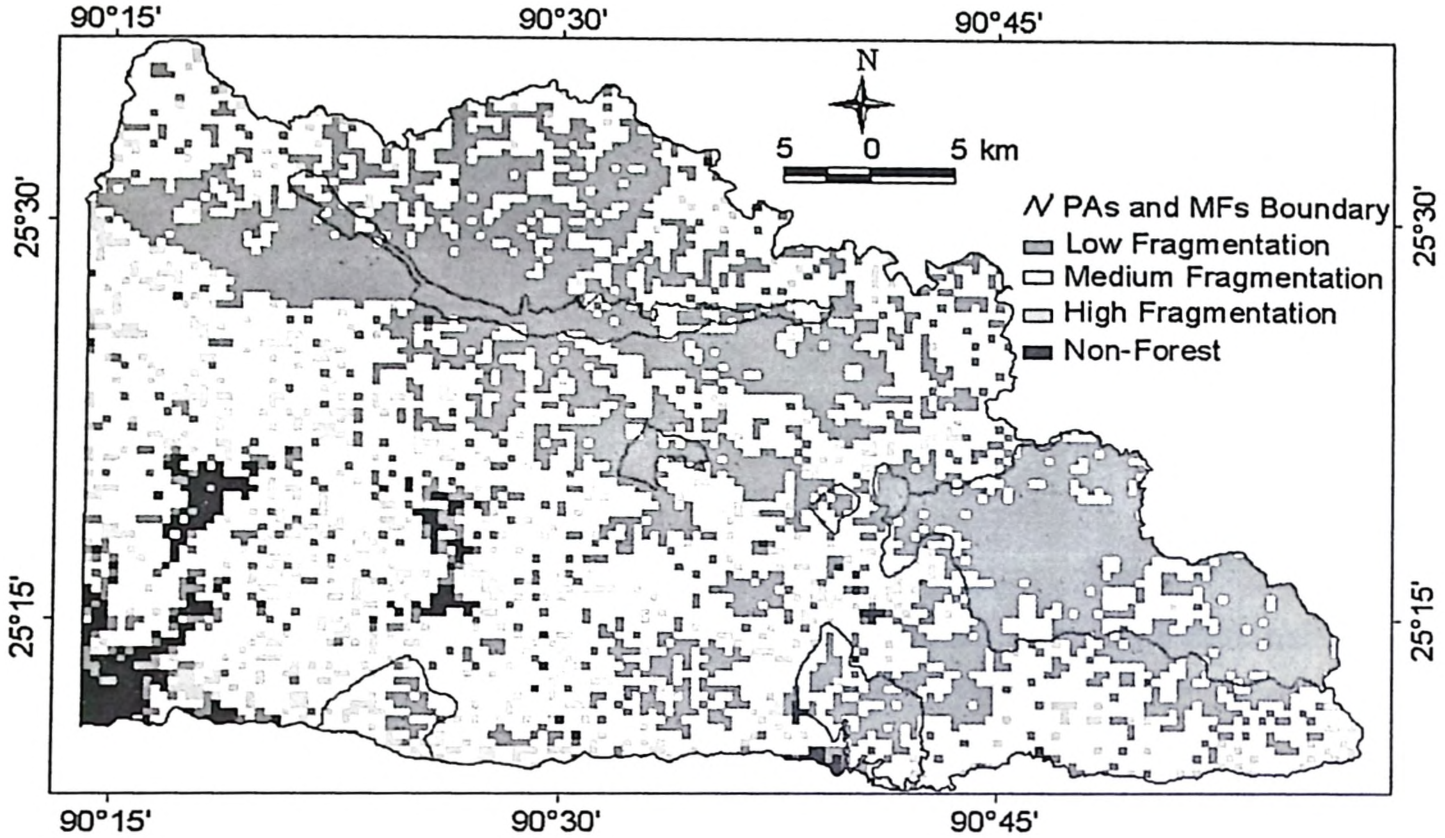

Fig. 4.6: The levels of forest fragmentation in the study area

4.3.2.3 Core areas

Processed vegetation and land use cover map of the study area is a mosaic showing a large number of patches of various sizes and shapes. The shape of the patch might also play an important role (Patton, 1975; Covich, 1976; Marcot and Meretsky, 1983; Forman and Godron, 1986) in determining the effective area for potential wildlife use, depending on the species of wildlife and its sensitivity to edge conditions.

The number of core areas along with patch sizes at edge-distances of 500m 1000m and 2000m are presented in **table 4.7**. A total of 2,236 forest patches occur in the study area (**Table 4.8**) with a total core area of 561 km^2 (assuming a 250-m edge distance) (**Table 4.8** and **Fig. 4.7**). As edge distance increases, total core areas decreases (**Table 4.9**).

Table 4.9: **Core Area (km^2) at specified distances from edges in different forest types**

Forest type	Core Area at 500 m		Core Area at 1000 m		Core Area at 2000 m	
	No.	Area	No.	Area	No.	Area
Evergreen	55	214	23	143	8	68
Semi-evergreen	313	203	110	54	12	3
Moist Deciduous	618	150	102	16	1	<1

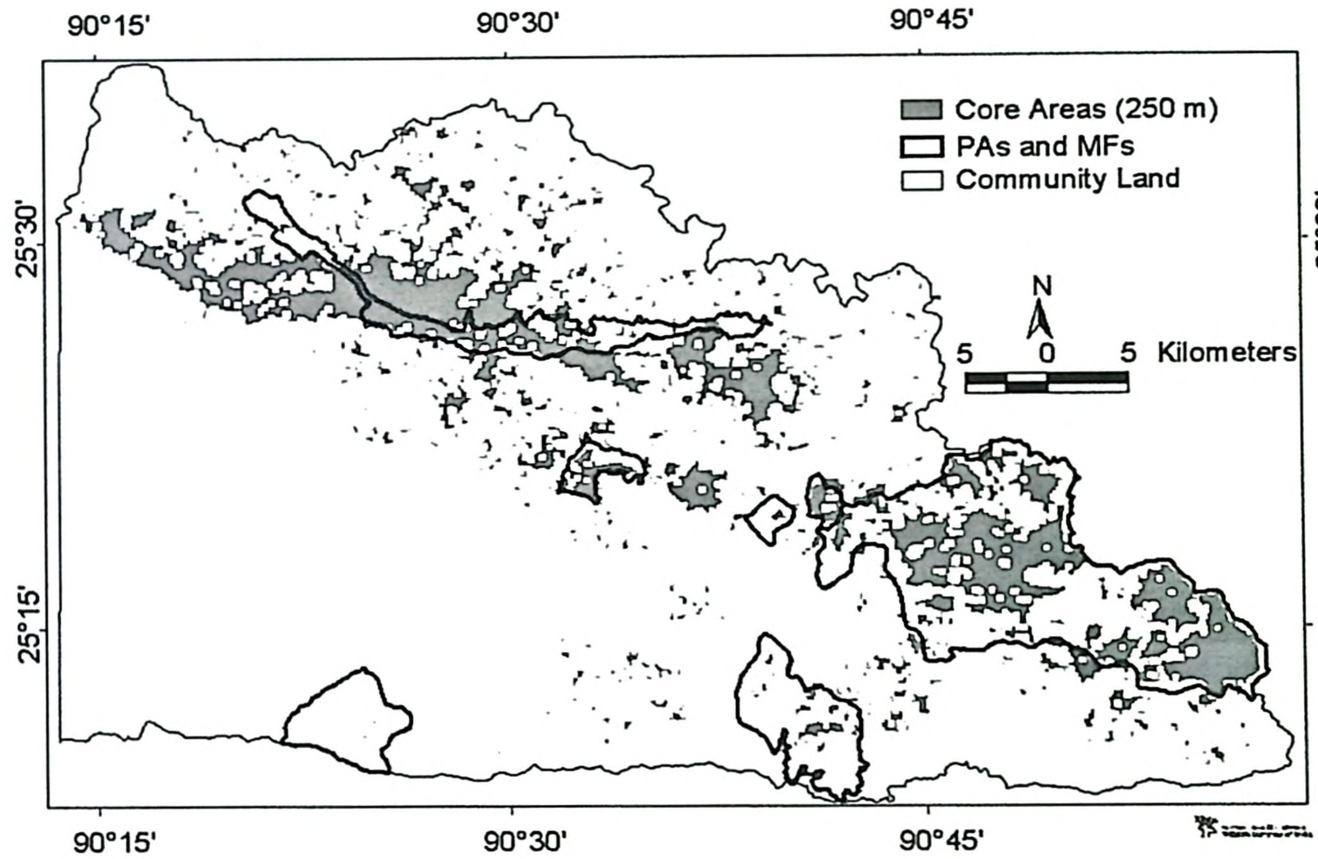

Fig. 4.7: Core area image at the specified edge distance of 250 m

At an edge distance of 250 m, nearly 92 % of the patches in the first three size classes (below 0.1 km^2) were found with less than five percent of the available core area, whereas about 78 % area has been covered by five patches in larger sized categories (>10 km^2). When the edge distance was increased to 500 m, the number of core areas decreased to 644 with a total core area of 291 km^2. A total of 80 % of smaller sized patches (<0.1 km^2) contributes less than four percent to the available core area; the four larger patches (>10 km^2), however, contribute 73 % to the total core area (**Table 4.10** and **Fig. 4.8**).

Table 4.10: Distribution of core area (CA) of forest patches

Size Class	No. of CA	Area (km^2)	% Area	No. of CA	Area (km^2)	% Area
	CA at 250 m edge distance			CA 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	

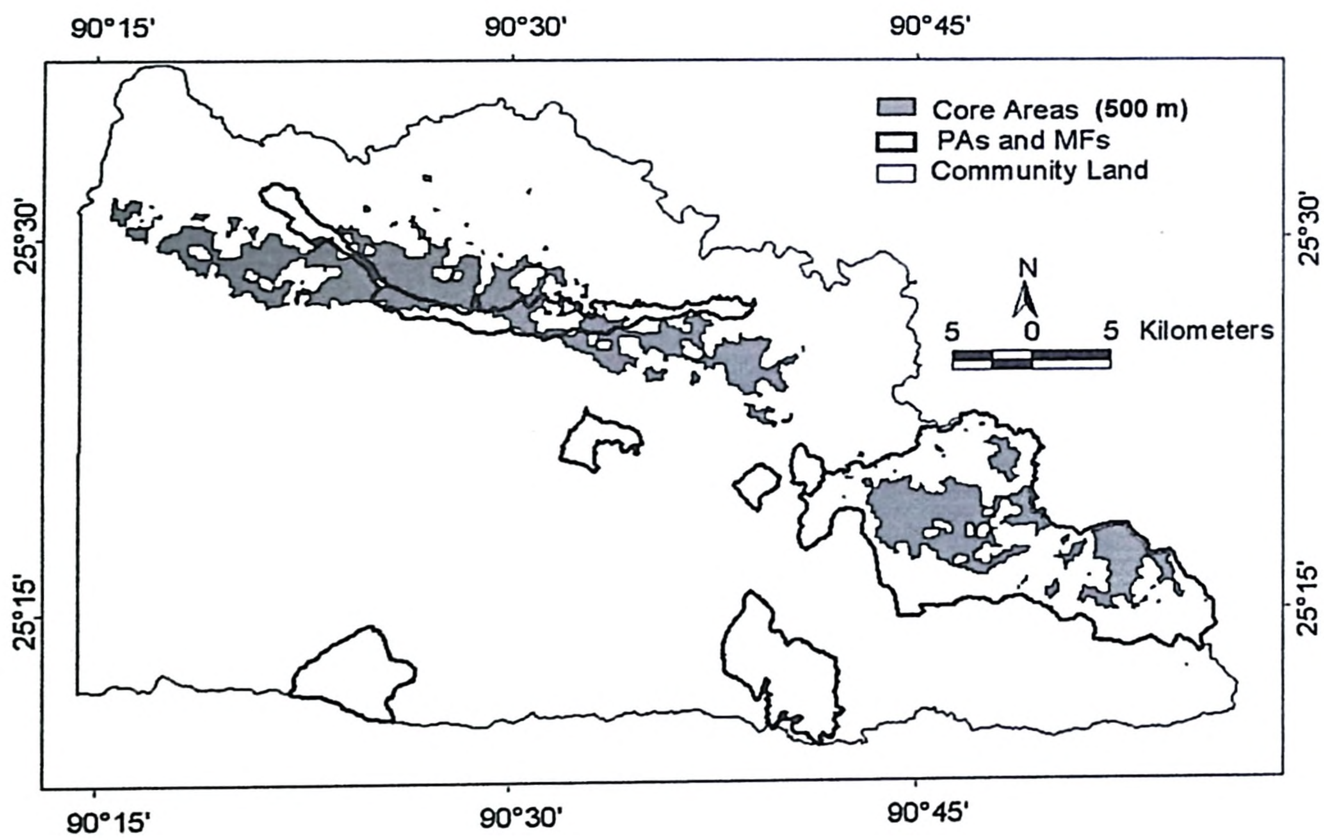

Fig. 4.8: Core area image at the specified edge distance of 500 m

4.3.2.4 *Potential wildlife corridors*

Habitat corridors can play an important role in the dispersal of some biota as well as facilitating gene flow between populations, thereby maintaining or increasing the heterozygosity within taxa and the biodiversity of the region (Norton and Nix, 1991). Remotely sensed data is useful in identifying and mapping forest habitat corridors (Gulinck *et al.*, 1991). There are no forest habitat corridors connecting the PAs and MFs, which are geographically scattered throughout the study area. The community-owned land, which occurs as the matrix among the PAs and MFs, contains extensive forest cover. In many places, this community-owned forest cover forms contiguous forest tracts with low fragmentation (**Table 4.8**). These low fragmentation areas were identified and analysed as potential wildlife corridors (**Fig. 4.9**). The re-classed fragmentation image was used to delineate seven major corridors that provide links between most PAs and MFs. The total area of these seven corridors is 274 km^2, of which 253 km^2 (92 %) is in the forest cover of TMEF, TSEF and TMDF, constituting 23 %, 54 % and 23 %, respectively (**Tables 4.11** and **4.12**).

Corridors can help connect Balpakram National Park (BNP) with Nokrek National Park (NNP) in the northwest, Rewak Reserved Forest (RRF) in the west and Baghmara Reserved Forest (BRF) in the southwest. The corridors also connect the adjoining Siju Wildlife Sanctuary (SWS) with NNP and RRF, respectively. The smallest corridor identified has an area of 1 km^2 and it connects SWS and RRF with the existing forest cover of 1 km^2. A corridor connecting RRF with the Emangiri Reserved Forest (ERF) is 15 km^2, of which 95 % is forested. NNP can link to ERF with two corridors, covering an area of 23 km^2 and 16 km^2, containing 22 km^2 (93 %) and 15 km^2 (96 %) of forest cover, respectively. Williams and Johnsingh (1996) had earlier identified three elephant habitat or elephant travel corridors in the study area based on a short-term field survey. These corridors were named Siju-Rewak, BNP-Baghmara and Emangiri-Nokrek covering the area of 8 km^2, 31 km^2 and 48 km^2, respectively. The seven corridors identified in the present study include these three corridors identified earlier.

Table 4.11: Forest and non-forest areas in the identified Corridors

Corridors	Forest Area (km^2)	Non-forest Area (km^2)	Total area (km^2)
BNP/SWS-NNP3	167	14	181
BNP-BRF	30	3	33
ERF-NNP1	22	2	23
ERF-NNP2	15	1	16
RRF-ERF	14	1	15
BNP/SWS-RRF	4	1	5
SWS-RRF	1	0	1
Total	253	22	274

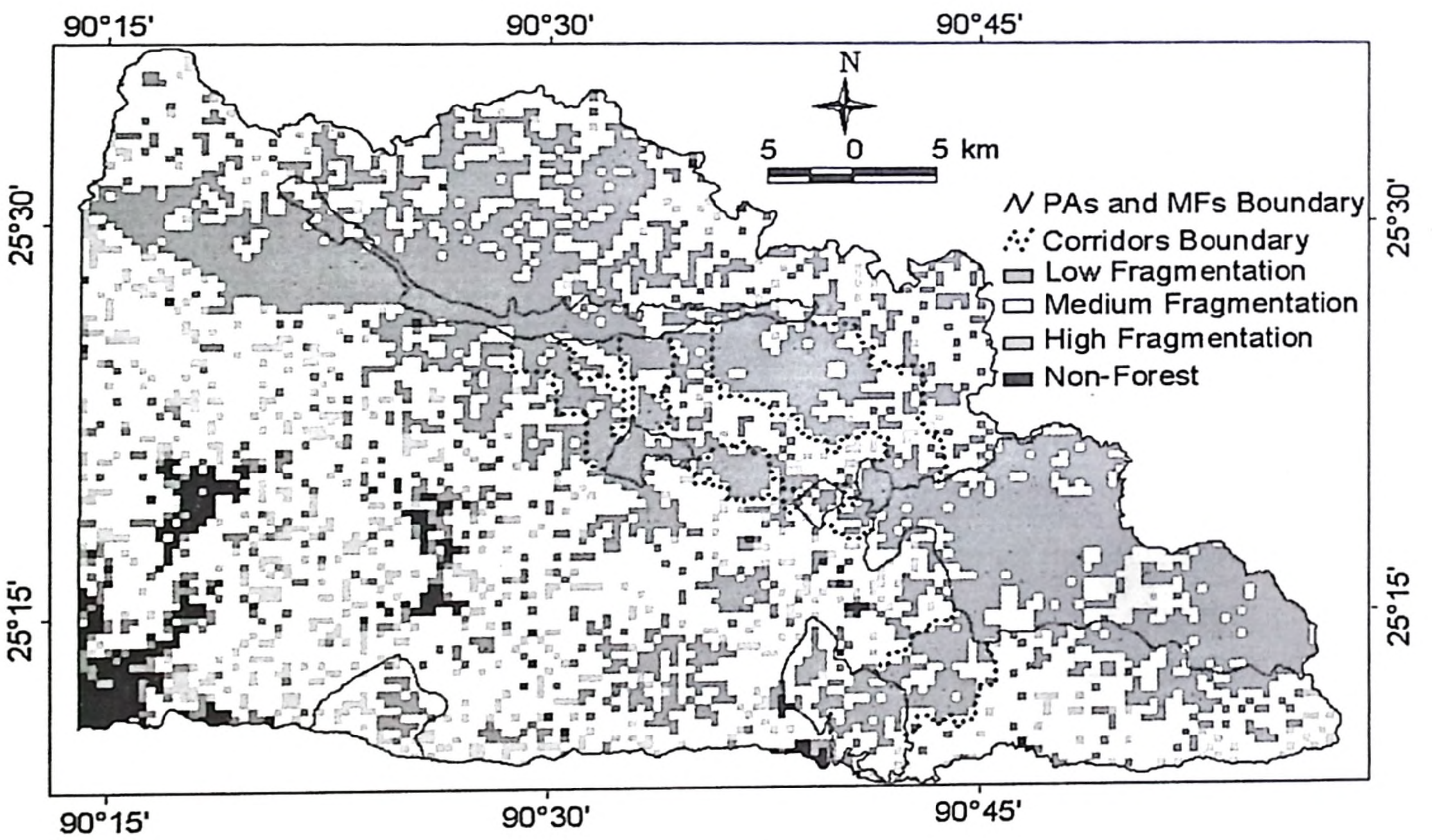

Fig. 4.9: Potential wildlife habitat corridors delineated from the fragmentation image

Table 4.12: Distribution of forest types in the identified corridors

Corridors	TMEF Area (km^2)	TSEF Area (km^2)	TMDF Area (km^2)	Total Area (km^2)
BNP/SWS-NNP3	49	81	35	167
BNP-BRF	1	19	10	30
ERF-NNP1	1	17	4	22
ERF-NNP2	7	7	1	15
RRF-ERF	0	10	4	14
BNP/SWS-RRF	0	0	4	4
SWS-RRF	0	0	0	1
Total	58	136	58	253

4.3.3 The landscape versus forest types

4.3.3.1 Tropical moist evergreen forest

Tropical moist evergreen forests cover 353 km^2,that is 14 % of the entire landscape, mainly confined to the Nokrek and Balpakram areas. The former includes the Nokrek ridge, running eastwards from 'Tura peak' in the upper northwest corner of the study area to the north of the Siju Wildlife Sanctuary across the river Simsang. It forms the upper and middle catchments of the Simsang River, the major river of the study area. Balpakram area includes catchments for Mahadeo and Maheshkola Rivers. These areas are characterised by hilly terrain, steep slopes, and moist and sometimes really wet, vegetation conditions. Average annual precipitation is higher than the surrounding areas.

A few small patches of dense TMEF still exist near habitations. These patches can be seen in the south of Nokrek ridge near Emangiri and also near the southern boundary of Balpakram National Park near Shooling. Tropical moist evergreen forests occurring near Chimitab, Nadankol and Shooling are unprotected. The largest patch of TMEF is 180 km^2, situated over the Tura ridge, and extending from the northwest corner of the study area to the north of Rewak near the eastern boundary of the study area (**Table 4.13**).

Table 4.13: Size class wise distribution of TMEF patches

Size class	No. of patches	Area (km^2)	% Area
0.5-1 ha	906	6	2
1-10 ha	873	23	7
10-50 ha	77	16	5
50-100 ha	5	3	1
1-10 km^2	7	16	5
10-50 km^2	1	33	10
> 50 km^2	2	249	70
Total	**1871**	**346**	

The important tree species of TMEF are *Polyalthia simiarum, Walsura tubulata, Syzygium operculatum, Mesua ferrea, Castanopsis purpurella, Diospyros variegata, Castanopsis* sp., *Aphanamixis polystachya, Michelia champaca,* and *Pterospermum lancifolium.* The two forest formations of TMEF are as follows.

i. *Syzygium operculatum-Diospyros variegata-Castonopsis spp.*

These forests occur in higher elevations (above 1,000 m) in very moist conditions in the Nokrek area. They include the species from very old (about sixty years) secondary forests, which resemble the species composition of old primary forests. The important species are *Syzygium operculatum, Diospyros variegata, Castonopsis spp., Castonopsis purpurella, Aphanamixis polystachya, Calophyllum polyanthum, Casearia graveolens, Boehmeria spp., Garcinia kydea* and *Betula alnoides.*

ii. *Polyalthia simiarum-Walsura tubularis-Canarium strictum*

These forests occur at medium and lower elevations (between 100 to 700 m) inside the Balpakram National Park. Limestone forms the substrate for this forest formation in the medium elevations. The important species in these forests are *Polyalthia simiarum, Walsura tubularis, Canarium strictum, Mesua ferrea, Michelia champaca, Tetrameles nudiflora, Drimycarpus racemosus, Cynometra polyandra, Pterospermum lancifolium* and *Sapium baccatum.*

4.3.3.2 Tropical semi-evergreen forest

Tropical semi-evergreen forests cover 624 km^2 (25 %) of the study area. These forests are well distributed on the hill portions of the landscape, but are highly fragmented due to the increasing *jhum* practice. A large belt of semi-evergreen forests occurs to the south of the Nokrek area, starting from the Emangiri area to the Rewak area across the river Simsang in the Siju area.

TSEFs generally exist on the periphery of dense evergreen forests. A significant proportion of TSEF occur within reserved forests and community-owned private land. The semi-evergreen forests in the study area form upper catchments of the Nareng, Bugi and Dareng rivers. A few patches in the central and southern portion of the study area form the middle and lower catchments of the river Simsang. These patches also form major catchments for the Maheshkola river and other small rivers such as the Rompa and the Rongdik, the main tributaries of the Simsang.

The largest TSEF patch covers 113 km^2 and extends along the southern side of the Tura ridge. Most TSEF patches occur on community-owned private land and total 500 km^2. These forests are mainly confined to the periphery of large contiguous patches of dense TMEF. The BNP and NNP, respectively, have 72 and 14 km^2 of semi-evergreen forests (**Table 4.14**).

Table 4.14: Size class distribution of TSEF patches

Size class	No. of patches	Area (km^2)	% Area
0.5-1 ha	2560	18	3
1-10 ha	2572	71	12
10-50 ha	293	60	10
50-100 ha	45	31	5
1-10 km^2	43	121	20
10-50 km^2	11	188	31
> 50 km^2	1	113	19
Total	5525	602	100

The important tree species of TSEF are *Schima wallichii, Castanopsis purpurella, Shorea robusta, Macaranga denticulata, Dillenia pentagyna, Syzygium cumini, Tectona grandis, Grewia microcos, Aporusa dioica,* and *Eurya acuminata.* The following are two forest formations of TSEF.

i. Grewia microcos-Schima wallichii-Castonopsis purpurella

These semi-evergreen forests contain more deciduous species.. The most important species are *Castonopsis purpurella, Shorea robusta, Syzygium cuminni, Aporusa dioica, Dillenia pentagyna, Cynometra polyandra, Sapium baccatum* and *Polyalthia simiarum.*

ii. Schima wallichii-Castonopsis purpurella-Shorea robusta

These semi-evergreen forests contain more evergreen species. The most important species are *Schima wallichii, Castonopsis purpurella, Shorea robusta, Macaranga denticulata, Dillenia pentagyna, Syzygium cuminni, Tectona grandis, Grewia microcos, Aporusa dioica* and *Eurya accuminata.*

4.3.3.3 Tropical moist deciduous forest

Tropical moist deciduous forests cover an area of 703 km^2 (29 % of the study area) and are distributed throughout the study area as non-contiguous, small to medium sized patches. The major portion of TMDF occurs in areas affected by human activities, especially *jhumming*. TMDF is generally found on flat ground or on very gentle slopes of the smaller hills. Most TMDF occurs on community-owned private land. These sites are easily approachable so are being used for a variety of practices such as agriculture, horticulture, habitation, township, road network and infrastructure development.

The largest TMDF patch is 41 km^2. TMDF forests naturally occur in the alluvial plains and are comprised of Sal forests, most of which are found within the existing PA network. The community land has the major portion of TMDF in the study area, 640 km^2 (91 % of total TMDF) (**Table 4.15**).The important tree species of TMDF are *Grewia microcos, Schima wallichii, Castanopsis purpurella, Shorea robusta, Syzygium cumini, Aporusa dioica, Dillenia pentagyna, Drimycarpus racemosus, Cynometra polyandra*, and *Sapium baccatum.*

Table 4.15: Size class distribution of TMDF patches

Size class	No. of patches	Area (km^2)	% Area
0.5-1 ha	3950	27	4
1-10 ha	4049	110	17
10-50 ha	522	109	17
50-100 ha	88	62	9
1-10 km^2	76	223	34
10-50 km^2	7	127	19
> 50 km^2	0	0	0
Total	8692	658	

4.4 Significance from management point of view

The study area offers good forest wealth with large contiguous patches of old native forests. Most of the forest tracts in the interior hills are almost inaccessible and, hence, remain intact, however, *jhum* agriculture is proceeding in areas of primary forests immediately adjacent to Balpakram National Park. The existing protected area network in the study area covers only 17 % of the landscape (2459 km^2). The forests of the study area covers 68 % of the landscape. The total forest cover over community land is 1,352 km^2. Thus, 55 % of the study area (80 % of the total forest cover) lies outside the existing protected areas or managed forests, and is subjected to anthropogenic pressure. A further analysis of how well existing or potential boundaries of protected areas and reserved forests could help maintain the biodiversity of the region would aid future conservation planning. The older forests in the study area are comprised of TMEF, TSEF, and TMDF, which cover 212 km^2, 500 km^2 and 640 km^2, respectively. These native forests harbour a high diversity of flora and fauna (Kumar and Rao, 1985; ZSI, 1995). Many of these forests outside PAs are becoming increasingly fragmented from human use, particularly in the southwestern portion of the Garo Hills. The loss of large sized forest tracts might adversely affect wildlife closely associated with forest interior conditions, such as tiger, hollock gibbon, flying squirrel, Malayan giant squirrel, large Indian civet, peacock pheasant and others; the effects on these species, however, from old-forest habitat loss and fragmentation, incursion of *jhum* lands, and associated forest edges has not yet been studied in this region.

Studies elsewhere have demonstrated the varied impact of edge effects on forest interior microclimatic conditions. Measurable microclimatic changes are generally limited to a zone within 15-60 m of the forest edge (Kapos, 1989; Williams-Linera, 1990; Kapos *et al.*, 1997; Turton and Freiburger, 1997). For many physical phenomena, a reasonable assumption for the maximum penetration for edge effect is about 100 m (Didham, 1997). Some physical edge effect phenomena, however, such as wind disturbance, can occur deeper in to a forest patch (200-500 m: Laurance 1991). Some animals, such as certain insects, birds, and small mammals, are "edge advisor," often becoming uncommon within 50-100 m of forest edges (Quintela 1985; Lynam, 1995 and Laurance, 1997). Edge effects have not been studied in the Garo Hills. As a precaution, estimates of the maximum penetration of edge effects into forests should be doubled from those reported above for management purposes (Laurance and Yensen, 1991; Laurance and Bierregaard, 1997). The analyses of forest core areas measured the status of forest patches forming critical forest interior environments particularly for wildlife closely associated with them that are sensitive to forest edges. Such wildlife species in the study area include tiger, clouded leopard, gibbon, flying squirrel, peacock pheasant, and Malayan giant squirrel and other species.

CHAPTER 5

THE WILDLIFE AND HABITAT RELATIONS

5.1 Introduction

The purpose of this chapter is to present information on the presence of fauna species and their habitat associations within the Garo Hills of western Meghalaya, with particular focus on the South Garo Hills and adjoining Nokrek National Park and Biosphere Reserve. The information presented here was collected and compiled as part of a broader study of wildlife in selected landscapes of India (Mathur *et al.* 2002).

The State of Meghalaya contains some 5538 species of vertebrates and invertebrates. This immense biological diversity (or biodiversity) is a significant proportion of the overall fauna diversity of India (ZSI, 1995a and 1995b). The ratio of invertebrate species to vertebrate species is about 5:1, although it is likely that many invertebrate species -- particularly arthropods and molluscs -- have yet to be discovered and scientifically described. To date, a total of 4580 species among 2094 genera of invertebrates has been recorded by ZSI (1995b) from the state. Although the area of Meghalaya is less than one percent (1%) that of India, it is home to more than 35% of the mammals and 50% of the birds in India (ZSI, 1995a). A total of 958 species in 451 genera of vertebrates has been recorded from Meghalaya (**Fig. 5.1**).

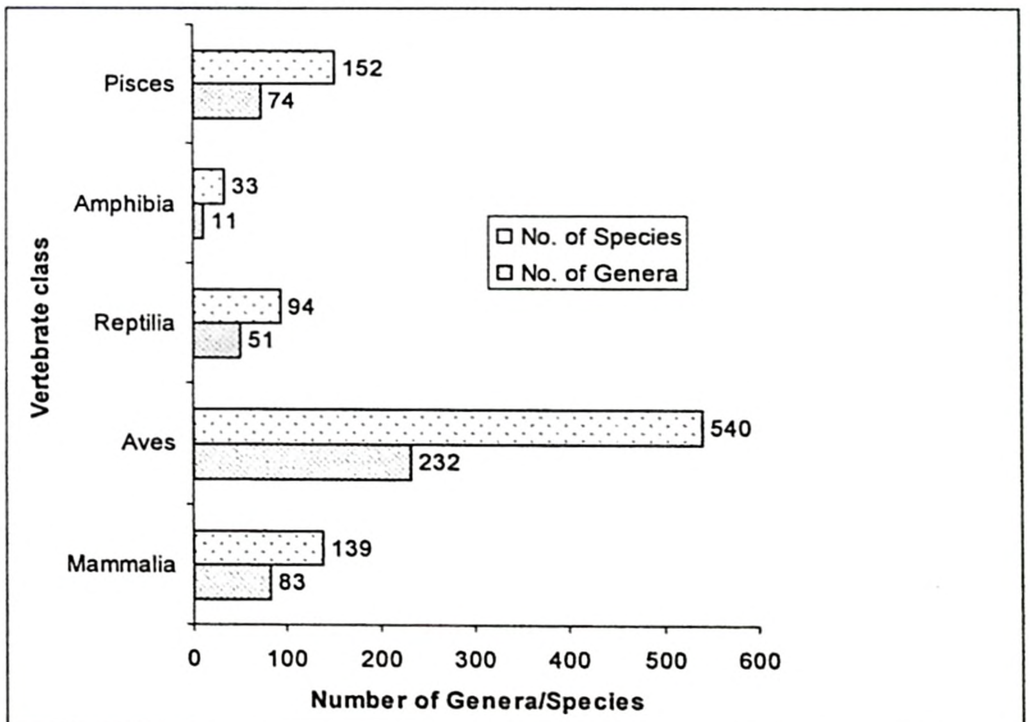

Fig. 51. Vertebrate fauna in Meghalaya (Source ZSI, 1995)

The Garo Hills consist of three districts, namely East Garo Hills, West Garo Hills and South Garo Hills, which together constitute about one third of Meghalaya. The Garo Hills contain a rich diversity of fauna with 859 vertebrate species recorded or suspected (ZSI, 1995a). The avifauna in the Garo Hills contribute about 60% of all the vertebrate species found there, followed by fish, mammals, reptiles, and amphibians (**Fig. 5.2 a**).

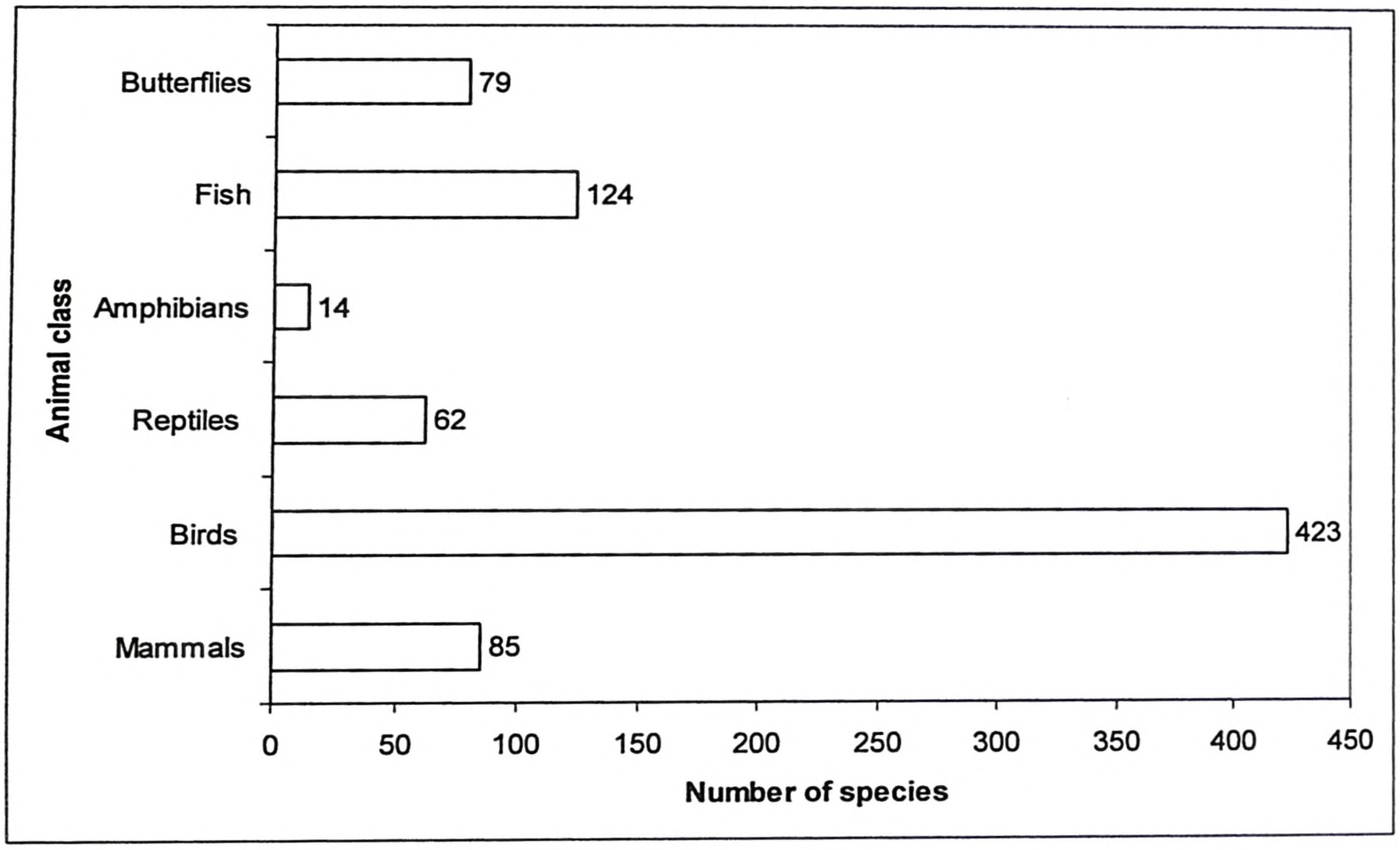

Fig. 5.2 a: Vertebrate fauna in Garo Hills
(*sources: ZSI, 1995 for mammal and fish; and Ghosh, 1984 for others*)

There is a total of 85 mammal species in the Garo Hills, which is 61% of the mammals in all Meghalaya. Rodents contribute 23% of all mammal species in the Garo Hills, followed by bats (Chiropters, 20%). Other mammalian groups, such as insectivores, primates (apes and monkeys), canids, felids, bovids and viverids, contribute less than ten percent to the mammal species of the Garo Hills (**Fig. 5.2 b**).

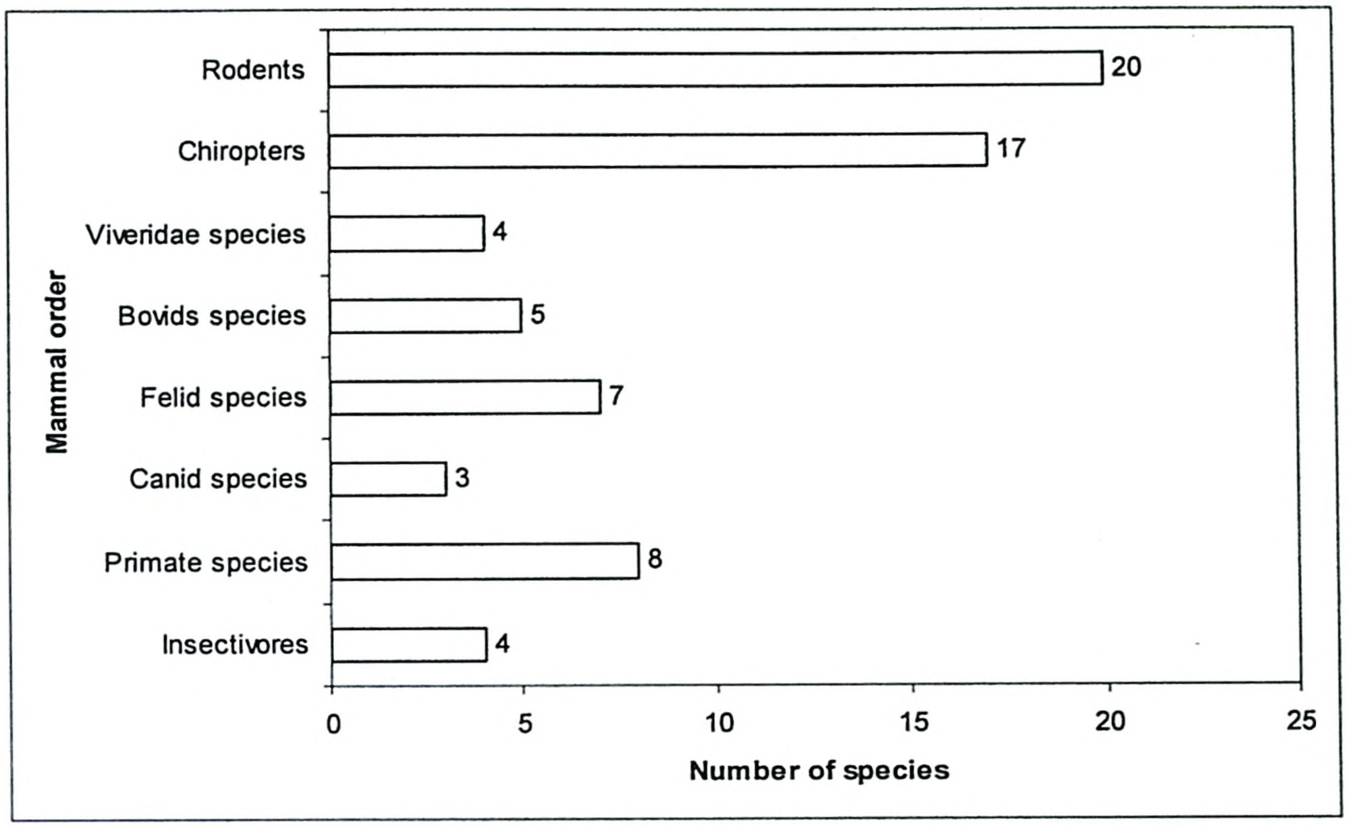

Fig. 5.2 b: Mammalian fauna in Garo Hills
(*source: ZSI, 1995*)

The earliest detailed assessment of fauna in Garo Hills was done in Siju Cave by Kemp and Chopra (1924), who described various taxa (**Fig. 5.3**) and the cavernicolous (cave-adapted) animal life.

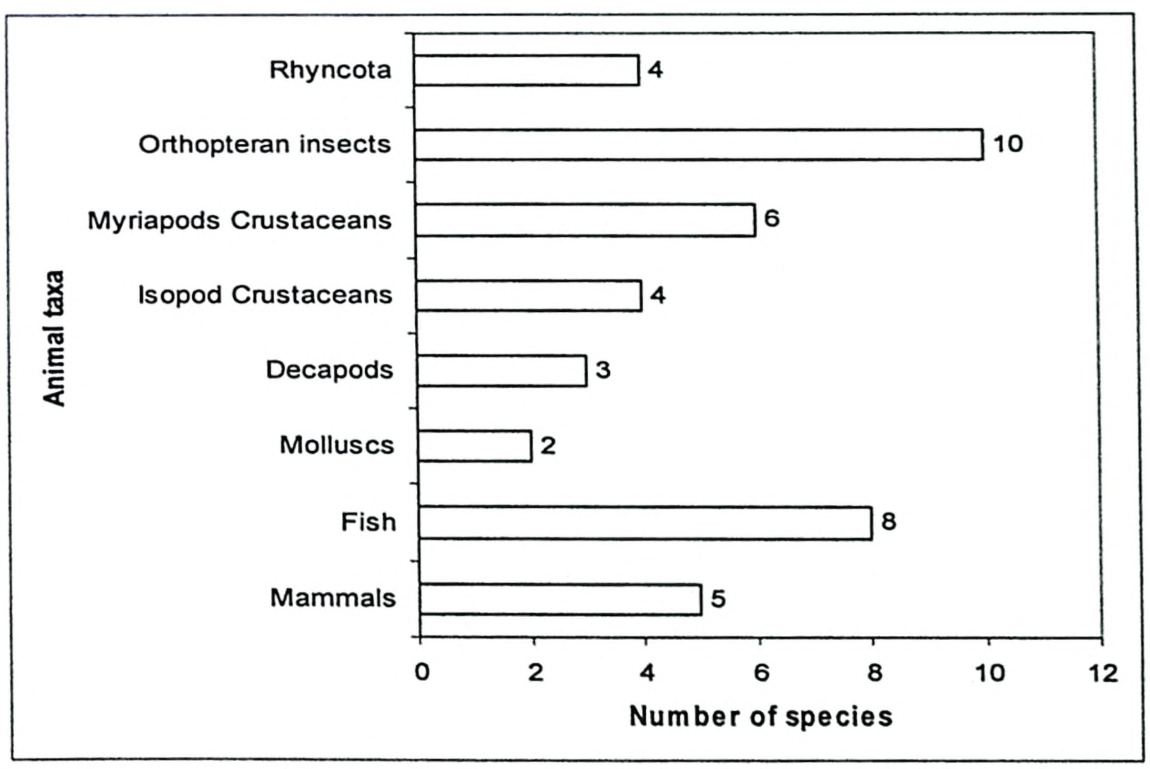

Fig. 5.3: Fauna in the Siju cave (*source: Kemp and Chopra, 1924*)

A few ecological studies have been carried out in the adjacent northeast states of Arunachal Pradesh and Assam states by the Wildlife Institute of India and regional universities. The rest of northeast India, however, has remained largely unstudied due to poor accessibility or underdeveloped transportation and communication infrastructures, although some authors have written on primates of Tripura (e.g., Gupta, 2000; Mukharjee, 1982) and northeast India (Srivastava, 1999). Until recently, the Garo Hills too, have been one of the least explored corners of northeast India in terms of ecological studies. Various state government departments, including forest, agriculture, soil and water conservation, and ecodevelopment, contributed such studies after the statehood of Meghalaya was declared in 1972. In our present study, I collected this information and collated it with information generated from other sources, including interviews with local resident people and non-government organisations (NGOs), and our field research experience in the Garo Hills during 1997-2001. Most information on wildlife in this chapter is for the South Garo Hills, especially the Balpakram portion. Little information is available on the wildlife of the East Garo Hills and the plains of the West Garo Hill.

5.1.1 Mammals

Ghosh and Biswas (1977) and Ghosh (1984) reported a number of mammalian species in the Balpakram portion of the South Garo Hills. They recorded five species of primates -. hoolock gibbon (*Bunopithecus hoolock*), rhesus macaque (*Macaca mulatta*), Assamese macaque (*Macaca assamensis*), capped langur (*Trachypithecus pileatus*) and slow loris (*Nycticebus coucang*) in what was the Balpakram Wildlife Sanctuary (now the National Park) with an area of 120 km^2. Among the carnivores recorded there by Ghosh were tiger (*Panthera tigris*), leopard (*Panthera pardus*), jungle cat (*Felis chaus*), leopard cat (*Felis bengalensis*), wild dog (*Cuon alpinus*), large Indian civet (*Vivera zibetha*), hog-badger (*Arctonyx collaris*), yellow-throated marten (*Martes flavigula*), Himalayan black bear (*Selenarctos thibetanus*) and jackal (*Canis aueius*). Other species he recorded were Indian bison (*Bos gaurus*), goral (*Nemorhaedus goral*), elephant (*Elephas maximus*), barking deer (*Muntiacus muntjak*), sambar (*Cervus unicolor*), porcupine (*Hystrix indica*) and Indian hare (*Lepus nigricollis*). ZSI (1995a) provided an inventory of 85 mammal species for the Garo Hills. Both these studies reported only the presence of mammal species and should be interpreted as a preliminary inventory of the larger-bodied mammals of the area, whereas Kumar and Rao (1985) linked selected mammal species with broadly-defined habitat types (broad one) in the Balpakram area.

The report of an elephant census in what was then the proposed Balpakram Wildlife Sanctuary during 1981 also provided the approximate number and broad habitat-type associations of twenty mammal species at an opportune count during the study on the flora and fauna of the Balpakram National Park, which has a total area of 220 km^2 (Kumar and Rao 1985; **table 5.1**). Evergreen forests in the interior hills, limestone outcrop areas and grassland plateaux form the major habitats of many native mammals in the Balpakram area (Kumar and Rao, 1985).

Table 5.1: Common wild mammals in Balpakram area, South Garo Hills (1981)

Species	Common Name	Habitat	Approx. No.
Elephas maximus	Asian Elephant	EF (Evergreen Forest)	860
Panthera tigris	Tiger	EF at Lime stone	10
Panthera pardus	Leopard	Dense EF	7
Neofelis nebulosa	Clouded leopard	Dense EF	1
Felis bengalensis	Leopard cat	Dense EF	4
Felis Temmincki	Jungle cat	EF	6
Bos gaurus	India bison	EF near grassland	54
Bibos species	Mithun	EF near grassland	24
Bubalus bubalis	Wild buffalo	EF near grassland	2
Trachypithecus pileatus	Capped Langur	EF	193
Bunopithecus hoolock	Hoolock gibbon	EF	102
Selenarctas thibetanns	Himalayan black bear	EF	19
Sus scrofa	Wild pig	EF	102
Cervus unicolor	Sambar	All types of forest	79
Muntiacus muntjak	Barking deer	All types of forest	172
Cuon alpinus	Wild dog (Dhole)	EF	15
Capricornis sumatraensis	Serow	EF	23
Nycticebus coucang	Slow loris	EF	2
Petaurista candidatus	Flying squirrel	EF	21
Ratufa indica	Giant squirrel	EF	4
Source: SFD, 1981 and Kumar and Rao, 1985			

5.1.2 Birds

This study area, that is, the South Garo Hills and the adjoining Nokrek National Park and Biosphere Reserve, provides habitats for a large number of bird species but no systematic study of bird-habitat relationships has been carried out in the Garo Hills. Ghosh (1984) provided a tentative list of 423 bird species in the Garo Hills, which was solely based on a review of bird field guides coupled with a few *in situ* observations. Kumar and Rao (1985) studied the quantitative ecology of selected bird species, in which they provided an imprecise estimate of the abundance of nine bird species in the Balpakram National Park (220 km^2) (**Fig. 5.4**).

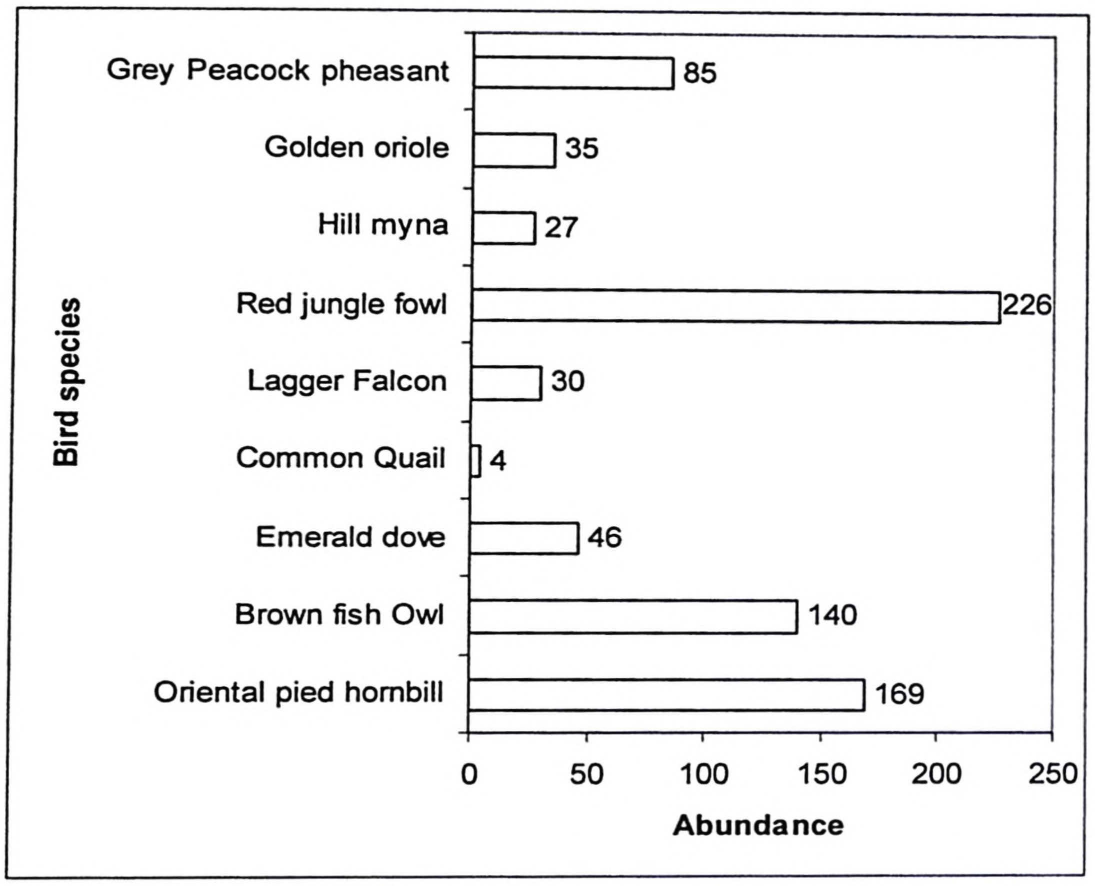

Fig. 5.4: Abundance estimates of selected bird species of BNP (source: Kumar and Rao, 1985)

A recent and reliable inventory of the birds in the Garo Hills was conducted by the students of the Wildlife Institute of India, Dehradun during a study tour in 1996-97. Manoj and Jayapal (personal communication, 1996) provided a checklist of selected species (see **table 5.13** of this chapter for a detailed list) that the students observed in the Garo Hills, most species of which were confirmed by us during field surveys for the present study. The students also provided information on habitat use by selected bird species, which was used to develop the bird-habitat relationships of the region (presented in the following sections of this chapter).

5.1.3 Reptiles

A total of 62 species of reptiles, including eight species of turtles and tortoises, eighteen species of lizards and 36 species of snakes, were reported from the Garo Hill regions by ZSI (1995a).

5.1.4 Fish

Fish constitute a major natural resource used by the local Garo people. A study conducted over seven years revealed 62 fish species from streams, rivers and water bodies of the area (Pillai and Yazdani, 1977). The electric eels (*Electrophorus electricus*) in the Simsang River (Ghosh, 1984) are one of the special interest to biologists. A detailed fish inventory is available in 'Fauna of Meghalaya' published by ZSI (1995a).

5.1.5 Amphibians

Amphibians of the Garo Hills include frogs. Out of a total of forty amphibian species that ZSI (1995a) reported from northeast India, fourteen species (including several endemics) were from the Garo Hills region.

Four toad and frog species were reported by Pillai and Murhy (1989) to be endemic to Megahalya in general or to the adjacent Khasi Hills, although there is no information on their presence in the South Garo Hills per se:

i. Garo Hills Tree-Toad, *Pedostibes kempi* (family Bufonidae); rare species endemic to the Garo Hills. Collected from the Tura area of the Garo Hills in 1919 - extremely rare. Expert tree climber, eats ants from tree trunks.

ii. *Bufoides meghalayana* (family Bufonidae), genus (and species) endemic to Meghalaya.

iii. *Leptobrachium hasselti* (family Pelobatidae), species endemic to the Khasi Hills.

iv. *Hyla annectens* (family Hylidae), occurs in forests of Meghalaya. Calls loudly from the tree canopy. Species endemic to Meghalaya.

5.1.6 Invertebrates

Of the invertebrates in the Garo Hills, insects constitute the most diverse fauna component. Other numerous invertebrates of the Garo Hills are annelids, molluscs, and arachnids. ZSI (1995b) reported that almost 60% of the total aphid fauna in India is represented in the northeastern region, and of these many species occur in the Garo Hills. Some of the butterflies (Dr. S.P. Singh, personal communication) reported during present study from the South Garo Hills are given in **table 5.2.** ZSI (1995b) published a series of volumes on the invertebrate fauna of Meghalaya, ranging from primitive the protozoan to more recently evolved species of insects.

Table 5.2: List of butterflies in South Garo Hills

Species	Family	Common Name	Location
Danus genutia	Danaidae	common tiger	Mahadeo
Danus chrysippus	Danaidae	plain tiger	Mahadeo
Euploeacore	Danaidae	common India crow	Mahadeo
Melanitis ledaismene	Satyridae	common evening brown	Mahadeo, Baghamara Road, Angratoli RF
Argynnis spp.	Nymphalidae	(no common name)	Mahadeo
Neptis spp.	Nymphalidae	(no common name)	Angaratoli RF
Precis atlites	Nymphalidae	grey pansy	BNP, Angratoli RF
Precis lemonias	Nymphalidae	lemon pansy	Mahadeo, Siju, Baghmara RF
Papilio helenus	Papilionidae	red Helen	Baghmara-Siju-Tura
Papilio polytesromulus	Papilionidae	common mormon	Mahadeo. Siju, Baghamara
Papilio chaon	Papilionidae	yellow Helen	Baghamara-Tura
Troides Helena	Papilionidae	common birdwing	Baghamara-Tura
Catopsilia crocale	Papilionidae	common emigrant	Mahadeo, Baghamara-Tura
Eurema spp.	Papilionidae	(no common name)	Mahadeo, Baghamara-Tura
Ixias pyrene	Pieridae	yellow orange tip	Angratoli RF,
Pelopidas mathias	Hesperiidae	small banded swift	Tura
Udaspes folus	Hesperiidae	grass demon	Tura
Issoria sinha	Hesperiidae	Vagrant	Baghmara

5.2 Methods

I developed an information base on wildlife-habitat relationships (WHR) for selected wildlife species of Garo Hills. A variety of sources were used to develop the information base, including: (1) published and unpublished reports and articles, (2) survey data on wildlife from the State Forest Department of Meghalaya, NGOs, and local wildlifers and researchers, and (3) interviews with local forest and wildlife staff personnel and local villagers. The animal species included in the WHR database were based on Sawarkar and Marcot (2002). Methods for evaluating specific species groups or habitat relations included the following.

5.2.1 Mammal-habitat relationships

The mammal species included in the WHR database were tiger, macaques (rhesus, Assamese, stump-tailed and pig-tailed), slow loris, serow, deer (sambar and barking deer), hoolock gibbon, squirrels (Malayan giant, hoary-bellied Himalayan and orangebellied Himalayan), capped langur, Indian bison, Himalayan yellow-throated marten, wild pig, bats in general, Himalayan black bear, porcupine, civets (large, small and Himalayan palm) and the Asian elephant. The local names of these species were used to gather the information on their habitat relations through interviewing local wildlife staff and villagers. Questions regarding local distribution, habits and use for habitats of selected species were asked while conducting the interviews (Kumar *et al.* 2002).

5.2.2 Elephant-habitat relationships

I used elephant census results from 1993 (Office of Divisional Forest Office, East and West Garo Hills Wildlife Division, Tura, Meghalaya) and 1997-98 (Marak 1998) to calculate elephant crude density (numbers of elephants per total unit area of land over all vegetation communities) and percent change in crude density between the two census periods. The vegetation and landuse categories identified during landuse and landcover mapping (Kumar *et al.* 2002) were used to describe the elephant habitat **(Table 5.3)**.

Table 5.3: Vegetation and landuse of the study area

Landuse classes/Forest types	Total area (km^2)
Evergreen Forest	353
Semi-Evergreen Forest	703
Deciduous Forest	624
Plateau Grassland	3
Bamboo + Young secondary forest	184
Permanent Agriculture	96
Shifting Cultivation	175
Habitation/scrub/ abandoned *jhum*^	234
Water bodies	5
Shadow	81
Total	2459

^*Jhum* is the left-over fallow land after clearing old forest growth and the subsequent practice of shifting cultivation.

The boundaries of the 21 elephant census zones (**Fig. 5.5**) delineated by State Forest Department, Meghalaya, were digitized in GIS so that the elephant density variables could be correlated with habitat and landscape attributes. For detailed methodology, refer to Marcot *et. al* (2002) who used correlation and multiple linear regression to quantify the relations between elephant density and habitat variables.

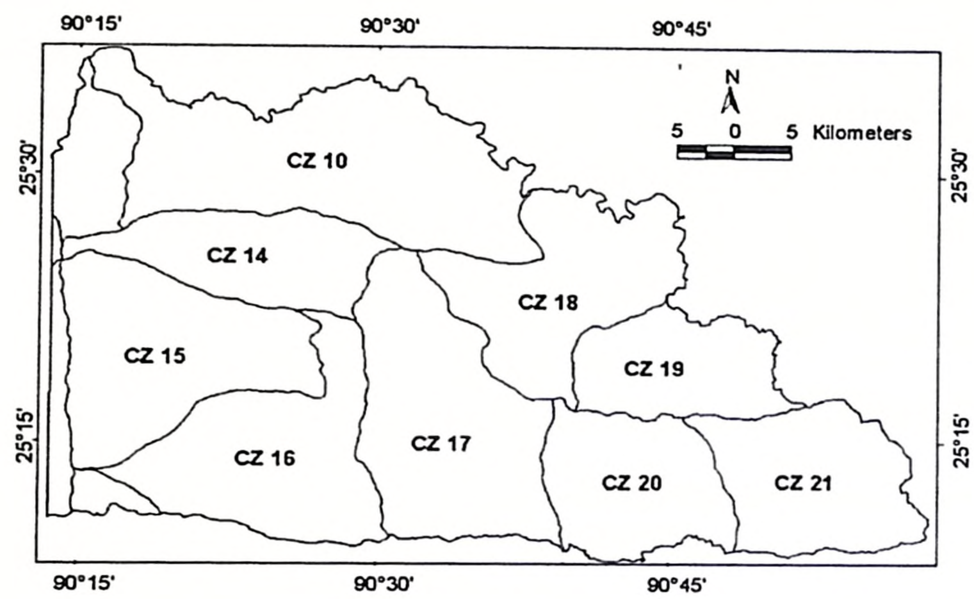

Fig. 5.5: Elephant census zones in the study area (source: Marak, 1998; Marcot et al. 2002)

5.2.3 Mammal-tree relationships

During the background project (WII-USDA Forest Service collaborative project, 1996-2002; Kumar *et al.* 2002), a list of the scientific and Garo language names of 150 locally-occurring tree species (see **table 5.12**) was used during interviews with local forest guards, foresters and permanently resident people, to help determine how selected mammal species used specific tree species as food sources. During the interviews, the interviewees identified which of the 150 tree species were used as food sources for each of the selected mammal species or group of species (macaques, deer, bats, civets). Once the forest staff and other locally resident people jointly agreed on use of a given tree species as a food item for a given mammal species or species group, the edible parts of the tree were identified and recorded, using the following list:

- B = Bark
- Fl = Flower
- Y = Young
- F = Fruit
- S = Shoots
- Blank = information not available

Some of the favourite grass species were also recorded with the tree species because grasses constitute a major part of some animals' diet.

5.2.4 Bird-habitat relationships

I used inventories of selected birds conducted by Manoj and Jayapal (personal communication, 1996) to determine bird-habitat relationships.

5.3 Results and Discussion

This section presents the results of information on wildlife-habitat relationships in the form of individual species accounts. Local names refer to animal names in the Garo language. Additional, specific information on elephant-habitat relationships, mammal-tree relationships, and bird-habitat relationships follow the species accounts below.

5.3.1 Mammal-habitat relationships

5.3.1.1 Tiger (Panthera tigris)

Local name: Matcha.
Prey species are sambar, barking deer, wild pig, Indian bison, wild pig, hare, goat, fowl, langur, hoolock, macaques and other species.

Local distribution:
Forests that provide a suitable habitat for tigers occur near villages in the Balpakram area, the Sinaru area, and near Agal-chongoppa in the way of Rongcheng from Balpakram plateau, and include forests near the villages of Pindengru, Maogipeng, Penda, Marakabari, Pusul chiring, Deoban area, Dogep chiring, Teptepa area, Ailatoli area, Maheshkola, Bellibari, Narangbari, Sochet chiring, Rongdi-bisik, Nowa chiring, Ronsu-agal, Chutmang, Ampangiri, Hatitia, Passgaon, Bonbera, Nadankol, Atambing, Rongsu, and Rewak villages.

Habitat:
Dense Primary Forest, Bamboo forest, Grassland.

The State Forest Department of Meghalaya conducted a tiger census during 1992 and 93. The census covered 9676 km^2 area (43%) of Meghalaya, although there is no published information on how the census was conducted and how the census routes and areas were chosen. The total number of tigers counted in the Meghalaya tiger census was 63, of which 34 (54% of total in Meghalaya) were in the Garo Hills. The densest population was found in the South Garo Hills district, which is only 16% of the census area and housing 27% of all tigers counted (**Fig. 5.6**).

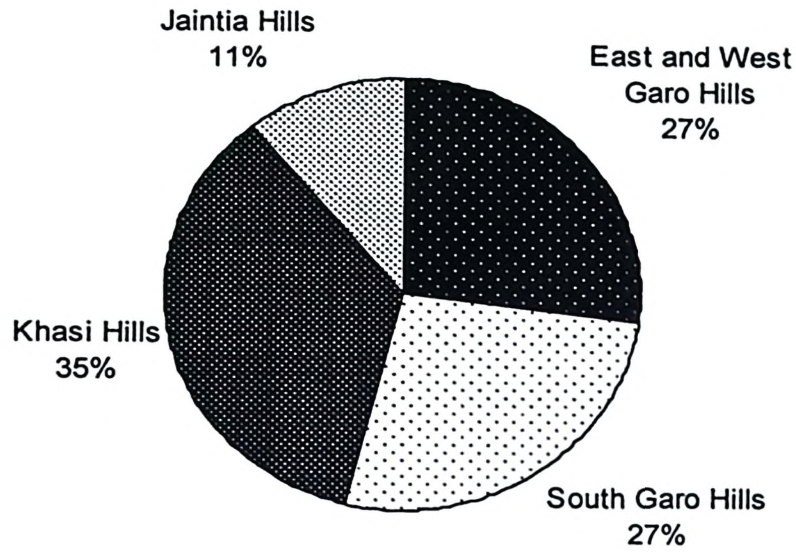

Fig. 5.6: Tiger census statistics in Garo Hills (*source: State Forest Department, Meghalaya*)

5.3.1.2 Macaques (Macaca mulatta, Macaca arctoides, Macaca assamensis, Macaca nemestrina)

Local names: Rhesus (Makri-chiran), Assamese (Makri-ugong), Stump-tailed (Makri-dalgappa) and Pig-tailed Macaques.

Local distribution: The Rhesus macaque occurs throughout the Garo Hills (or study area). The Assamese macaque is more difficult to see but is said to be abundant in undisturbed forest areas. Stump-tailed and pig-tailed macaques are very rare in the South Garo Hills and mainly confined to the interior of the BNP.

Habitat: The Rhesus macaque is found in every type of forest and in villages near forests, large groups are often found near river plains in the valleys. The Assamese macaque can be seen in dense forests in the limestone areas of the Balpakram National Park and the Siju Wildlife Sanctuary. Stump-tailed and pig-tailed macaques use undisturbed primary forest (mainly Evergreen and sometimes Semi-evergreen forests), very rarely occurring near human habitation and open areas.

5.3.1.3 Slow loris (Nycticebus coucang)

Local name: Gilbe

Local distribution: In the old forest growth near villages, namely Hatitia, Teptepa, Kanai, Rompa, Rongmenchiring, Passgaon, Ranthangri, Rongcheng, Siju, Rewak, Rongsu, Chimitab, Maheshkola, Shooling, Pindengru, Maogipeng, Chutmang and others.

Habitat: Sometimes seen near three to four year old *jhum* (slash-and-burn shifting cultivation) fallows, as reported by local people, but likely to be more closely associated with older forests, including dense primary and riparian.

5.3.1.4 Serow (Capricornis sumatraensis)

Local name: Matrong

Local distribution: Forests and the Gorge area near Rompa Dare ("Dare" means gorge in the Garo language), Chidokthak Dare, Hamdangi Dare, Kundulgop Dare, Rongdibisek Dare, Nowa Dare, Maogapeng Dare, Sprichiring Dare, Ranthangsora chiring Dare, Deoban Dare, Kanai Dare, Chutmang Dare. *Dare* (Gorges) are named after villages where they occur.

Habitat: Thickly wooded gorges, with boulders, in hilly terrain.

5.3.1.5 Sambar (Cervus unicolor) and Barking deer (Muntiacus muntjak)

Local names: Sambar (Matchok) and Barking deer (Balgitchok)

Local distribution: Throughout Garo Hills.

Habitat: Serow visit new *jhums* and cultivated fields frequently to forage, as well as grasslands and all types of forests except those in limestone areas.

5.3.1.6 Hoolock gibbon (Bunopithecus hoolock)

Local Name: Huru,

Local distribution: Forests near villages or streams such as Rokpa chiring/Rompa chiring (Chiring means stream), Hamdangi chiring, Narang chiring, Nongal gat, Kundulgop, Rongchun area, Panda area, Pindengru, Nawa chiring, Chutmang, Rongcheng, Rongsu, Chimitab, Shooling, Siju, Rewak, Balpakram area, Maheshkola, Bellibari area, Kanai-Rongtherasrea area, Rongra area, Taidang area, Kunchung area, Dambuk-Jongkol area, Teptepa. Group size varies from two to six individuals (A. Kumar, personal observation). This observation confirms the findings of Alfred and Sati, 1990).

Habitat: Undisturbed old primary forest with closed tree canopies. Sometimes seen in the dense forests with tall trees near villages in the interiors hills.

Alfred and Sati (1990) surveyed 200 localities (covering 5075 km^2 area of South and West Garo Hills districts), which were reported as gibbon habitats, and observed 130 gibbons in only 32 of these localities (812 km^2). Out of these 130 (126 in groups plus four floating individuals) gibbons about two-thirds were adult (more than seven years old). The populations of sub-adults (four to seven years), juveniles (two to four years) and infants (less than two years) were 6%, 12% and 15%, respectively **(Table 5.4)**.

Table 5.4: Population status of Gibbons in the South and part of the West Garo Hills districts

Parameter			Estimate		% of total individuals (N=126)
Number of localities				32	---
Area surveyed (km²)				812	---
Territory size (km²)				14	---
Number of groups				42	---
No. of individuals	Adult	Male	42	85	33
		Female	43		33
	Sub-adult	Male	6	11	4
		Female	5		2
	Juvenile			15	12
	Infants			19	15
Total				130	
Source: Alfred and Sati, 1990					

Group sizes reported by Alfred and Sati varied from two to six individuals per group. They observed an average of three groups and nine individual gibbons per km^2. Only one group was observed with six individuals. Most groups had three individuals. Some 50% of all gibbons were reported with 21 groups each with three individuals **(Table 5.5)**.

Table 5.5: Hoolock gibbon group counts

Group size	Frequency	No. of individuals
6	1	6
5	3	15
4	4	16
3	21	63
2	13	26
Total	**42**	**126**
Source: Alfred and Sati, 1990		

Territory size of groups varied from 14 ha to 55 ha (Alfred and Sati, 1990), whereas a study in Tripura (India) reported far larger territory sizes of 300-400 ha **(Table 5.6)**.

Table 5.6: Territory size and density of gibbons compared with other studies

Location		Assam (India)	Tripura(India)	Sylhet (Bangladesh)	West Garo Hills (India)
Area surveyed (km^2)		8	11	162	812
Territory size (ha)	Range	18-30	300-400	3.2-?	14-55
	Mean	22	300	23	31
No. of groups		7	6	6	42
Total gibbons		26	16	21	130
Av. group size		3.4	3.2	3.5	3
Groups per km^2		2.2	0.55	4.4	3.01
Gibbons per km^2		7.55	1.45	5.25	9.03
Source		*Tilson (1979)*	*Mukharjee (1982)*	*Gittins (1984)*	*Alfred & Sati (1990)*

Out of 200 localities studied by Alfred and Sati as potential gibbon habitats (presumed based on forest cover or confirmed by local residents as having gibbons present), gibbons were observed in only 32 localities. The other 168 localities had similar vegetation types, and local villagers had confirmed the existence of gibbons during the late 1970s and early 1980s, but these sites lacked continuous dense forest canopy, which is a critical part of hoolock gibbon habitat. The area of 32 localities with observed gibbon varied from 300 to 41,500 ha with forest area of 14 to 277 ha, although no information was given on how such areas were delineated. Approximately 75% of all gibbons seen were observed near village sacred forests, where fruit trees such as mango, jackfruit, orange and guava were cultivated. The 32 localities also were surrounded by forested hills with potentially suitable gibbon forest habitat (Alfred and Sati, 1990). According to Hazarika (1988), *jhumming* destroyed about 550 km^2 forest area per year in Meghalaya.

The population of gibbons in the Garo Hills region was found to be under great threat at that time, so Alfred and Sati suggested the need for immediate attention to conservation in those 32 localities. Now, almost a decade after Alfred and Sati's survey, it is timely to re-inspect the gibbon population and assess the existing status of gibbons. This is vital for preparing the best conservation strategies for protecting gibbons and their habitat in the region.

5.3.1.7 *Squirrels (Ratufa bicolor, Dremomys lokriah and Callosciurus pygerythrus)*

Local name: Math (Malayan giant squirrel, Hoary bellied Himalayan squirrel and orange bellied squirrel)

***Local distribution*:** Rompa-bisek, Limestone area, Deoban, Kundulgop, Rongcheng, Nowa area, Chimitab, Siju and Shooling areas.

Habitat: Higher reaches of tall trees in denser forests, very rarely on the ground.

5.3.1.8 *Capped langur (Trachypithecus pileatus)*

Local name: Rangol

***Local distribution*:** Forest areas near villages, including Rompa chiring, Hamdangi chiring, Ronthersea, Pindengru, Narang chiring, Maogipeng, Narangbari area, chimitab, Taidang, Nowa, Rongcheng, Kundulgop, Rangthangsora, chiring, Deoban area, Kala Paharh (Paharh means Hill), area, Rongsu area, Penda area, Maheshkola, Shooling, Siju, Kanai, Marakabari, Dogep chiring, Teptepa, Chutmang.

Habitat: Undisturbed primary forests with dense canopied trees.

5.3.1.9 *Indian bison (Bos gaurus)*

Local name: Matle

***Local distribution*:** Forests near villages or locations such as Balpakram, Sochet chiring, Atambing, Pindengru, Nowa chiring, Maogipeng, Penda area (mainly during May andJune), Hamdangi area, Roncheng, Chimitab.

Habitat: Grasslands, Bamboo area, Secondary Forests in the interior of BNP.

5.3.1.10 *Himalayan Yellow-throated marten (Martes flavigula)*

***Local name*:** Gredong

***Local distribution*:** In the forests near villages including New Rongmenchiring, Kundulgop, Deoban, Rompa chiring, Rongcheng, Nowa area, Chtmang, Rongsu, Siju, Shooling, Narangbari, Hamdangi, Pindengru, Narang chiring and other similar areas.

***Habitat*:** Occurs on trees mainly in old forests. Sometimes seen near roads in relatively undisturbed areas.

5.3.1.11 *Wild pig (Sus scrofa)*

Local name: Wak-burung

Local distribution: Throughout study area.

Habitat: In the surroundings of limestone areas near habitation, very old secondary forests. Visits *Jhum* fields regularly.

5.3.1.12 *Bats (Cynopterus sphinx and other species)*

Local name: Dobak for all species of bats

Local distribution: Nongalgat, Rompa dare, Kundulgop, Rongthrasea Dare, Siju Dobak-kol, Nowa Dare, Rongdi-bisek Dare, Maogipeng Dare, Chutmang, Ranghtansora Dare, Kanai Dare, Deoban Dare, Spruchiring Dare, Chidokthak Dare. Probably more widely distributed throughout the Garo Hills.

Habitat: Caves, trees near caves, Ficus trees. Sometimes found on abandoned man-made structures such as ceilings of bridges, culverts and old buildings.

5.3.1.13 *Himalayan black bear (Selenarctas thibetanns)*

Local name: Makbil-bak

Local distribution: Old forest near villages and places, including Rokpa chiring area, Rongtherasea, Hamdangi, Deoban area, Kundulgop, NBalpakram plateau, Nowa area, Roncheng, Chimitab, Chutmang, Kunchung, Maogapeng, Rangthansora, Rompa, Kanai.

Habitat: Old *jhum* fallows, limestone areas in dense evergreen forests, visits new *jhum* areas for paddy, potato and tapioca. Also feeds on rotten meat of dead animals, honey and insects. During the rains builds a bed on tree branches and leaves to rest and sleep.

5.3.1.14 *Porcupine (Hystrix indica)*

Local name: Okchigipu

Local distribution: Forest near villages including Rompa ading, Hatitia, Dulbeta, Teptepa, Ranthagsora, Chimitab, Deoban, Kundulgop, Balpakram plateau, Maheshkola, Atambing, Siju, Rongsu, Rongcheng, Nowa, Ampangiri, Rewak.

Habitat: Small holes in rocks, burrows in soil.

5.3.1.15 Civets (Vivera zibetha and other species)

Local name: Matchuri

***Local distribution*:** Forests near villages, including Hatitia, Rompa, Kanai, Teptepa, Rangthansora, Passgaon, Balpakram plaeau, Rongcheng, Maogapeng, Chimitab, Rongsu, Siju, Rongra, Shooling, Deoban, Kundulgop, Chinaru.

Habitat: Primary and secondary forests. Sometimes seen near habitation and roadsides during the evening.

5.3.1.16 Elephant (Elephas maximus)

Local Name: Mongma

***Local distribution*:** Higher densities inside the BNP, including Kanai, Rongra, Siju, Gaobari, Teptepa, Pindengru, Balpakram, Rongcheng nowa, Narang chiring, Kundulgop, Deoban, Rangthansora chiring, Dogeo chiring, Shooling, Chimitab, and Chutmang. Also, the Nokrek area, in and around the Nokrek National Park (NNP). Elephant can be seen roaming all over the Garo Hills.

Habitat: Primary forests. Visits secondary forests and habitation during January and February. Seen on hill slopes, in valleys. During January and February seen along streams for water.

IUCN's Species Survival Commission's Asian Elephant Specialist Group estimated a population of about 35,000 to 51,000 Asian elephants in world during the year 2000, with about 19,100 to 29,450 in India and about 7,200 to 11, 300 in Northeast India (WWF, 1996). A total of 2872 elephants were recorded in the Meghalaya, of which 1850 elephants were found in the Garo Hills, during a 1993 census **(Table 5.7)**. Out of these 1850 elephants, 1460 individuals were recorded through direct sighting and 390 were estimated on the basis of indirect evidence. The population estimate of elephants in the South Garo Hills district was 910, with 591 of these occurring in the Balpakram National Park. Kumar and Rao (1985) reported 860 elephants in Balpakram National Park based on elephant census data from State Forest Department taken during 1981 **(Table 5.1)**. Numbers of elephants sighted during the 1993 census, by age, sex, and tusker class, are presented in **table 5.7**.

Table 5.7: Elephant Population structure in Garo Hills (1993)

Elephant group	Male		Fe male	Unsexed	Total
	Tusker	Makna			
Adult	164	31	432	189	716
sub-adult	96	13	84	208	401
Calf		9	2	204	215
Total		313	518	601	1432
	18	2			28
Solitary		20			
Maljuria	6	2			
		8			
Total Direct sighting					1460
Indirect Sighting					390
Grand total					**1850**
Source: SFD, Meghalaya, 1993					

An elephant census was taken in the Garo Hills in 1993 over 5909 km^2 (72% of the entire Garo Hills). Of this, about 2636 km^2 land is private forest on which 307 elephants were found, whereas the 1153 individuals were found over the other area of 3273 km^2 area, which includes government-owned forests in the form of Protected Areas and Reserved Forests and their adjoining forest land **(Table 5.8**).

Table 5.8: Elephant bearing areas in the Garo Hills

S. No.	Name of forests	Location	Approximate area of Forests (km^2)	No. of Elephants
A.	Government owned Forests and adjoining forest land			
1.	Balpakram NP	South GH	538	591
2.	Nokrek NP	West GH and part of East GH	516	161
3.	Rewak-emangiri RF	South GH	657	172
4.	Angratoli RF	South GH	307	98
5.	Dibru Hills RF	West GH	180	27
6.	Songsak RF	East GH	434	51
7.	Dambu-Darungiri RF	East GH	398	17
8.	Dhima-Rajasimla-Ildek RF	East GH	243	36
	Total		*3273*	*1153*
B.	**Unclassed Private Forests**			
1.	Rongchugre-Chesingre RF	South GH	1069	87
2.	Moranga RF	South GH	279	4
3.	Rangira-damalgre RF	West GH	586	83
4.	Kherapera-Dana-Adugre- Rongmagre	West GH	702	133
	Total		*2636*	*307*
GRAND TOTAL			**5909**	**1460**
Source: SFD, Meghalaya, 1993				

According to Gogoi and Chowdhary (1982), the proposed Balpakram wildlife sanctuary (292 km^2) and its buffer zone (292 km^2) harboured 580 (including three solitary individuals) and 280 elephants, respectively **(Table 5.9)**. The ratios among adults, sub-adults and calves in the total census area and the proposed Balpakram Sanctuary (Now Balpakram National Park) are 3.14: 1.57: 1 and 2.87: 1.73: 1, respectively.

Table 5.9: Elephant population during 1981 in proposed Balpakram Wildlife Sanctuary and its surroundings

Population structure	**Proposed Balpakram WLS**	**Buffer zone**	**Total Census Area**
Adult	296+3 solitary	115	471
Sub-adult	178	58	236
Calf	103	47	150
Total	577+3=580	280	860
Source: Gogoi and Chowdhary, 1982			

Elephant mortality and killing

The latest estimate (in 1998) of elephant populations in Meghalaya is 1,840 elephants (Marak, 1998). In the late 1970s, when the large population of elephants in Meghalaya started creating problems for local people, the government initiated some control measures to check elephant population in the state. A total of 256 elephants were captured from different districts of Meghalaya during the period 1977 to 1981. Most elephants, that is, 60% (152 elephants), were captured from the Garo Hills **(Table 5.10)**. The greatest number of elephants captured during any one year (1979-80) was 69. A total of 76 elephants were shot dead in Garo Hills under the Elephant Control Scheme during 1970 and 1976. Most of them (63) were eliminated during 1971 and 1972 **(Table 5.11)**. The control programme was then discontinued afterwards due to policy changes.

Table 5.10: Number of elephants captured in Meghalaya under the Elephant Control Scheme (1977-1981)

Financial year	**East Garo Hills**	**West and South Garo Hills**	**Total**	**East Khasi Hills**	**West Khasi Hills**	**Jayantia Hills**	**Grand Total**
1977-78					24		*24*
1978-79	11	34	*45*		15		*60*
1979-80	42	27	*69*	11	14		*94*
1980-81	21	17	*38*	34	6		*78*
Total	74	78	*152*	45	59		*256*
Source: SFD, Meghalaya 1995							

Table 5.11: Number of elephants captured and eliminated in the Garo Hills, Meghalaya during 1970-1981

Year of Elimination	Shot under Elephant control Scheme		Shot as proclaimed rogue			Shot by poachers		Death due to unknown causes		Death due to epidemic		
	Tu/Ga	Ma	Tu	Ma	Fe	Tu	Ma	Tu	Ma	Tu	Ma	Fe
1970	29	12	15									
1971	11	11	1						1			
1972	3	4										
1973												
1974	1	1		1								
1975	1	1		1		2						
1976	2		1		1					1		
1977												
1978												
1979									1			
1980				1		1	1					
1981									1			
Total	**47**	**29**	**17**	**3**	**1**	**3**	**1**		**3**	**1**		

Source: SFD, Meghalaya 1995
Note: Tu: Tusker,Ga: Ganesh, Ma: makna and Fe: Female

According to the IUCN's Species Survival Commission's Asian Elephant Specialist Group (WWF, 1996), "the population of elephants in the Garo Hills, West Meghalaya, is probably the most threatened population of its size throughout the entire range of the Asian elephant". The 1993 elephant census estimated the population in the Garo Hills to be 1,850 elephants (SFD, 1993). The latest census in 1998, however, revealed only 1,306 elephants in the Garo Hills; this is about 71% of the total elephant population of Meghalaya (Marak, 1998). In the Garo Hills, there appears to be a decline in the elephant population of about 30% over a five-year period, although it is unclear whether this numbers reflects the true population trend or differences in census methods. Marak (1998) reported, however that of the deaths of 46 elephants due to both natural and unnatural causes from 1994 to 1999, poaching accounted for 46% of them.

According to the records of the state forest department, a total of 54 elephant deaths were observed in the Balpakram National Park (BNP) division, Baghmara -

25 deaths and in the East and West Garo Hills Divisions and Tura - 29 deaths. Though, the area under the jurisdiction of the BNP division is much less than the East and West Garo Hills Division, the high mortality of elephants per unit area in the BNP division suggests an initially high elephant density there. Five census zones (Zones GH/XVII, GH/XVIII, GH/XIX, GH/XX and GH/XXI as shown in (**Fig. 5.5**) that are under the BNP division have recorded 650 elephants, compared to a total of 1306 elephants in all 23 elephant census zones throughout the Garo Hills (Marak, 1998). The elephant population in these five BNP elephant census zones during the 1993 census was estimated to be 763, and this area showed a loss of 113 elephants at the 1998 census. A sixth zone (GH/XVI) under the BNP division, however has shown the most drastic decline in elephant numbers, dropping 78 elephants in 1993 downto ten elephants in 1998, that is a decline of about 87 % during the five year period. The extent to which this is a real numerical loss, or complicated by elephants redistributing themselves across census zones between the two census periods is unknown.

Elephant deaths in the South Garo Hills District

BNP division reported a total of 25 deaths(sixteen male, seven females, two sex unidentified) between October 1994 and April 1999. These included eight natural and seventeen unnatural deaths. All deaths due to causes other than poaching were referred to as natural, and included disease (three cases), forest fire (one case), accident (three cases) and normal old age mortality (one case). Each of these causes is discussed further below here.

Natural deaths

Diseases killed three elephants. A four-month-old infant male died from starvation and dehydration near Jodigittam under Siju range. One two-year-old female died from an unknown disease near Panda area under the Bahamian range, while another sub-adult female (sixteen years old) died from a chronic infection in her respiratory system, near Jodigittam under Siju range. One female sub-adult (ten years old) was trapped in the forest fire near Dagal stream (Angratoli). The forest department collected two small tusks weighing a total of 250 gm from the dead body of this elephant. An inexperienced young male (four years old) fell off a 62ft. high cliff while moving on a narrow path on a steep hill slope near Ropwari, Thaidang under Rongra range; this four-year-old animal had two small tusks weighing a total of 280 gm. An elephant (age and sex unknown, probably female) fell off a high cliff near Rewak. One 22 year-old domestic female was accidentally drowned in the Kanai River (near the place where departmental elephants are kept) under the Mahadeo range. Only one normal death was reported, of a 55 year-old male elephant that died from normal weakness in old age.

Unnatural deaths

The BNP division reported a total of seventeen unnatural deaths, sixteen of which were cases of poaching. Villagers near Badri Rongdong aking (community-owned forest lands) had killed one elephant in self-defence. Three adult female elephants (aged 42 years, 45 years, and unknown) were killed by poachers. These three killings might have been accidental. Out of a total thirteen cases of poaching, only one was of a sub-adult, seven were adults and the ages of five others were not recorded. A sub-adult male tusker (ten years old) was killed near Gingsning stream, Gulpani, under the Rongra Range in December 1994. Seven adult males at various places in Rongra, Siju, Angratoli and Mahadeo in South Garo Hills were also found killed. In all cases except two under the Rongra range (28 October 1994 and 13 July 1995), the tusks had been removed by poachers. Out of a total sixteen cases of poaching, ten were in the Rongra range.

5.3.2 Modelling elephant-habitat relationships

Meghalaya is one of the most famous elephant areas in northeast India. The main problem with elephant conservation in Meghalaya is the overharvesting of native forests for *jhum* and other uses. Due to the large-scale indiscriminate shifting cultivation, native forests constituting elephant habitat in the region are becoming fragmented. The problem is worst in west Meghalaya (Garo Hills). The only protected areas there are in the Siju Wildlife sanctuary, Balpakram National Park, Nokrek National Park and Nongkhyllem Sanctuary (East Khasi Hills), which seem inadequate for extensive protection of elephant habitats and population to ensure long-term viability of the species there (Marak, 1998).

In the South Garo Hills District and Norkrek area of western Meghalaya, statistical analyses suggest very low elephant densities and the greatest decline of elephants in areas with more than ten percent bamboo and secondary forest (six to ten years old) and more than ten percent scrub and abandoned *jhum* fields (old fallow *jhum* three to six years old). Elephant densities are highest, and declines are least, in areas with more than twenty five percent semi-evergreen forest (old secondary forests fifteen to thirty years old). Data on elephant sign (use) in the field generally support these findings, with selection by elephants (use significantly exceeding availability) for native semi-evergreen forest, and lack of selection (use significantly less than availability) for deciduous forests (including sal forest, teak, and cashew plantations) and for scrub and abandoned *jhum* fields. To maintain the elephant population in the South Garo Hills District and Nokrek areas, provision of official delineation is suggested of seven elephant habitat corridors that were mapped as having a low degree of fragmentation of forest cover and a high proportion of contiguous, semi-evergreen and evergreen forest cover (Marcot et. al, 2002).

Marcot *et al.* conducted a statistical analysis to determine the major landscape correlates of elephant densities and elephant population changes in the Garo Hills of Meghalaya from the two elephant census periods of 1993 and 1998. Census results reported by state forestry officials suggest a thirty percent decline in elephant numbers between census periods. In the Garo Hills, crude densities were 0.35 ± 0.39 elephant / km^2 in 1993 and 0.25 ± 0.26 elephants / km^2 in 1998 (mean $\pm$ SD). Elephant densities in 1998 were significantly and negatively correlated with the proportion of land in current *jhum* (slash-and-burn shifting cultivation), abandoned *jhum*, and density of villages. Linear regression modelling also suggested significant influence on elephant density from percent cover in deciduous forest (positive influence), percent cover in high terrain complexity (positive), and village density (negative); this suggested that elephants were more numerous in parts of the Garo Hills with more deciduous forest in steep areas away from villages. The analyses suggest that higher elephant densities occurred in elephant census zones with at least four percent of the landscape in deciduous forest cover; less than thirty percent in current *jhum* and abandoned *jhum*; less than five percent in current *jhum* alone; less than twenty percent in high forest patchiness (caused by *jhum*); and village density less than about 0.4 / km^2. These values can be used as testable management hypotheses for guiding conservation or restoration of habitat conditions for elephant conservation in the Garo Hills (Marcot *et al.* in press).

5.3.3 Mammal-tree relationships

Trees are an integral part of forest wildlife habitats. Local environmental and anthropogenic factors affect the distribution of various tree species. Tree species are distributed according to environmental factors and also comprise forest and woodland vegetation communities. Trees also significantly provide wildlife with food, shelter and cover. Kumar *et al.* (2002) described the distribution of various tree species among forest types and habitats.

Out of a total of 150 tree species (**appendix 5.1**) identified in the Garo Hills, the fifteen mammal species used 56 tree species (**Fig. 5.7 and table 5.12**). Macaques (rhesus, Assamese, pig-tailed and stump-tailed macaques), slow loris, serow and deer (sambar and barking deer) had a wide range of food use for tree species by consuming various body parts of 28, 27, 25 and 25 tree species, respectively (**Table 5.12**). Squirrels, hoolock and capped langur had the next most diverse use of trees, feeding on 21, 20 and 20 tree species, respectively.

Grewia microcos, Artocarpus chaplasha, Syzygium cumini, Lapisanthus rubiginosa, Artocarpus gomezianus, Ficus semicordata and *Lannea grandis* are the tree species used by most number of the fifteen mammal species assessed. Ten or more wildlife species consume fruits, leaves, flowers, or bark of these tree species. All fifteen selected mammal species use *Grewia microcos* as food. The fruits of this tree species are also used by many other mammals and bird species of the Garo Hills. The interviews conducted suggested that there were sixteen tree species that are used as food sources by only one of the mammal species of the set fifteen assessed here, six tree species are used by two mammal species, and six tree species are used by three mammal species (**Table 5.12**).

Table 5.12: Tree species and parts used as food items by fifteen selected mammal species of the Garo Hills. B = bark, F = fruit, Fl = flower, S = shoots, Y = young, blank = not used or information not available.

Tree species	Macaques	Slow loris	Sambar and Barking deer	Serow	Squirrels	Hoolock gibbon	Capped Langur	Asian Elephant	Indian Bison	Wild pig	Himalayan yellow throated Martin	Himalayan black bear	Bats	Civets	Porcupine	Total
Grewia microcos	B	F	F,L	F,L	F	YL	L	F, L	F	F	F	F	F	F	F	15
Artocarpus chaplasha		F	F	F	F	F,L	F,L	F, L	F	F	F	F	F		F	13
Syzygium cumini		F		F,L	F	F		F	F	F	F	F	F	F	F	12
Lepisanthes rubiginosa		F	F	F,L	F	L	F,L	L		F		F	F		F	11
Artocarpus gomezianus	B,L		F		F	F	L	L	F		F	F	F			10
Ficus semicordata	B,L		F		F	L	L	L	F		F		F	F		10
Lannea grandis		F	F,L	F,L	F	L		F,L	F			F	F	F		10
Bursera serrata	B,L	F	F		F	F,L	L	F		F	F	F				9
Dillenia pentagyna		F	F	L	F	F,L	F,L	F,L			F	F				9
Ficus subulata	B,L			F,L		F,L	L	F,L	F		F	F		F		9
Garcinia lancifolia		F	F	F	F	F		F				F	F		F	9
Ilex umbellulata		F	F	F,L	F			F	F	F			F			8
Syzygium balsameum	B,L, F		F			F,L	F,L	L	F		F		F			8
Alangium chinense		F	F	F	F					F		F	F			7
Bauhinia stipularis		Y.L, Fl	F	F,L	Fl	L,Fl	F,L	F,L								7
Garcinia kydia		F	F		F	F	F,L			F			F			7
Macaranga indica		F	F	F,L		L				F			F			6
Mangifera indica	F		F			F			F		F		F			6
Mangifera sylvatica	F		F			F			F		F		F			6
Trema orientalis	B,L		F	L		L	L	L								6
Callicarpa arborea		F	F	F,L			L			F						5
Flacourtia jangomas		F	F	F	F							F				5
Abrus precatorius			F			F,L	F,L	F,L								4
Ficus foveolata						L	F,L	L					F			4
Garcinia tinctoria	B,L	F	F		F											4
Gmelina arborea				L		F, YL	F,L	F,L								4
Morinda augustifolia		F	F	F	F											4
Pterigota alata	B,L			F	F			F,L								4
Aporusa dioica				F	F								F			3
Emblica officinalis						F,YL		F					F			3
Eurya accuminata		F		F				F								3
Maesa sarmentosa		F	F					L								3
Syzygium operculatum			F,YL		F						F					3

Tree species	Macaques	Slow loris	Sambar and Barking deer	Serow	Squirrels	Hoolock gibbon	Capped Langur	Asian Elephant	Indian Bison	Wild pig	Himalayan yellow throated Martin	Himalayan black bear	Bats	Civets	Porcupine	Total
Wendlandia excelsa						L	L	L								3
Bridelia retusa			F					F,L								2
Croton joufera				F,L									F			2
Hodgsonia macrocarpa	F						F,L									2
Holarrhena antidysenterica				L		L										2
Pterospermum acerifolium	B		F													2
Vitex peduncularis						B,L				F						2
Aesculus assamica				L												1
Albizia chinensis				L												1
Albizia odoratissima				L												1
Anthocephalus chinensis														F		1
Aristolochia tagala				F												1
Bridelia monoica		F														1
Careya arborea								L								1
Dalbergia paniculata				L												1
Elaeocarpus rugosus	B,L															1
Erythrina stricta	B															1
Glochidion spharogynum													F			1
Mallotus roxbughianus	B,L															1
Ostodes paniculata													F			1
Polyalthia simiarum			F													1
Pterospermum lancifolium	B,L															1
Tetrameles nudiflora	B															1
Total species used	28	27	25	25	21	20	20	18	18	12	12	11	11	6	5	

The trees *Arundinella bengalensis, Neyraudia reymendiana, Calamus* spp., leaves and fruits of *Trema orientalis, Bauhinia purpurea, Rhus javanica, Dillenia indica, D. pentagyna, Artocarpus chaplasha, Sterculia roxburghii, Stereospermum chelonoides* and *Litsea polyantha* and many species of wild banana and bamboo were the major food items of elephants. Elephants visited nearby villages and *jhum* fields during the dry season in search of food. The *jhum* and cash crops of tapioca, sweet potato, pineapple, banana and other cultivated plants were the preferred food of elephants. Considerable damage was done to *jhum* fields and horticultural *bagans* (gardens around homes or villages) by elephant herd raids.

Sambar and barking deer used thick undergrowth and sometimes were also seen in open areas, in *jhum* fields and on roadsides. The fruits of *Dillenia indica, Olea dentata, Emblica officinalis, Semicarpus anacardium, Spondius pinnata, Terminalia bellirica, T. chebula, Vitex peduncularis, Solanum* spp. and Convolvulaceae climbers plus sweet potato and some crop plants in the *jhums* were the usual food items of sambar and barking deer (Kumar and Rao, 1985).

Large herbivores, including the Indian bison and wild buffalo, were confined to the grasslands of the Balpakram plateau and the nearby evergreen and mixed evergreen patches of undisturbed forests. The grass species consumed by these animals were *Alloteropsis semialata, Arundinella bengalensis, Centotheca lappacea, Cymbopogon khasianum, Echinochloa colonum* and *Ischaemum geobelli.*

Hoolock gibbons were mostly confined to the undisturbed evergreen forest with tall and contiguous canopied trees. Hoolock generally ate the fleshy fruits of *Ficus, Spondius pinnata, Garcinia cowa, Terminalia bellirica* and *T. chebula.*

5.3.4 Bird-habitat Relationships

Manoj and Jayapal (personal communication, 1996) provided a checklist of 184 bird species (**appendix 5.2**) from BNP and its surrounding areas. They also described the habitats of 110 of these species **(Table 5.13**), reported that 26 bird species were restricted to primary forests, and a total of 51 bird species used primary forest habitat and at least one other habitat. . The species restricted to, or using, primary forest may be the focus of conservation, because the conversion of old primary forests to secondary forest may greatly reduce available habitat for these specialist species.

Manoj and Jayapal also reported that 55 bird species were associated with the secondary forests of BNP, of which eighteen bird species were restricted to secondary forests only. Out of 36 birds that they recorded from *jhum* areas, ten were completely restricted to *jhum* patches **(Table 5.13**). An additional bird species observed in the BNP area (during March-April 1998) that was not included in their list **(Table 5.13**) was the Large Niltava (*Niltava grandis*), seen in the secondary forest. Additionally, the Fairy Bluebird in the secondary forest, and the large-billed (Jungle) Crow (*Corvus macrorhynchos*), White-bellied Yuhina (*Yuhina zantholeuca*), Peacock pheasant, Kalij pheasant (*Lophura leucomelanos*), and Pale-capped (Purple Wood)

Pigeon (*Columba punicea*) on the slopes of Balpakram Plateau were also observed. I also confirmed the presence in BNP of the other bird species reported by them.

Table 5.13: Habitats of selected bird species in and around Balpakram National Park. 1 = reported to occur; blank = reported absent occur or no information

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum* Areas	Balpakram Plateau
1	Red Jungle Fowl	*Gallus gallus*	1	1	1	1
2	Brown shrike	*Lanius cristatus*		1	1	1
3	Red whiskered bulbul	*Pycnonotus jocosus*		1	1	1
4	Red vented bulbul	*Pycnonotus cafer*		1	1	1
5	Yellow browed leaf warbler	*Phylloscopus inornatus*	1	1		1
6	Grey headed flycatcher warbler	*Seicercus xanthoschistos*	1	1		1
7	Franklin's wren warbler	*Prinia hodgsoni*		1	1	1
8	Yellow backed sunbird	*Aethopyga siparaja*	1	1		1
9	White-eye	*Zosterops palpebrosus*	1	1		1
10	Sparrow Hawk	*Accipiter nisus*		1		1
11	Kestrel Falcon	*Falco tinnunculus*			1	1
12	Kaleej Pheasant	*Lophura leucomelana*	1	1		
13	Thickbilled green pigeon	*Treron curvirostra*	1	1		
14	Rufous turtle dove	*Streptopelia orientalis*			1	1
15	Emerald dove	*Chalcophaps indica*	1	1		
16	Lorikeet	*Loriculus vernalis*	1	1		
17	Common hawk cuckoo	*Cuculus varius*		1		1
18	Coucal	*Centropus sinensis*		1	1	
19	Palm swift	*Cypsiurus parvus*			1	1
20	Great hill barbet	*Megalaima virens*	1	1		
21	Large green barbet	*Megalaima zeylonica*	1	1		
22	Golden oriole	*Oriolus oriolus*		1		1
23	Maroon oriole	*Oriolus trailii*	1	1		
24	Blackheaded oriole	*Oriolus xanthornus*	1	1		
25	Greybacked shrike	*Lanius tephronotus*			1	1

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum* Areas	Balpakram Plateau
26	Grey drongo	*Dicrurus leucophaeus*		1		1
27	Bronzed drongo	*Dicrurus aeneus*	1	1		
28	Lesser rackettailed drongo	*Dicrurus remifer*	1	1		
29	Greater rackettailed drongo	*Dicrurus paradiseus*	1	1		
30	Ashy swallow shrike	*Artamus fuscus*			1	1
31	Greyheaded myna	*Sturnus malabaricus*		1		1
32	Pied flycatcher shrike	*Hemipus picatus*		1		1
33	Scarlet minivet	*Pericrocotus flammeus*	1	1		
34	Common iora	*Aegithinia tiphia*	1	1		
35	Goldmantled chloropsis	*Chloropsis cochinchinensis*		1		1
36	Olive bulbul	*Hypsipetes viridiscens*	1	1		
37	Brown eared bulbul	*Hypsipetes flavalus*	1	1		
38	Spotted babbler	*Pellorneum ruficeps*	1	1		
39	Slatyheaded scimitar babbler	*Pomatorhinus horsfieldii*	1	1		
40	Nepal babbler	*Alcippe nipalensis*	1			1
41	Greyheaded flycatcher	*Culicicapa ceylonensis*	1	1		
42	Blyth's reed wabbler	*Acrocephalus dumetorum*			1	1
43	Dull green leaf warbler	*Phylloscopus trochiloides*	1	1		
44	Dark grey bush chat	*Saxicola ferrea*			1	1
45	Indian tree pipit	*Anthus hodgsoni*			1	1
46	Purple sunbird	*Nectarinia asiatica*		1		1
47	Crested surpent eagle	*Spilornis cheela*				1
48	Buzzard spp	*Buteo spp*				1
49	Blackcrested Baza	*Aviceda leuphotes*			1	
50	Short-Toed Eagle	*Circaetus gallicus*				1
51	Oriental hobby	*Falco severus*			1	
52	Lesser Kestrel	*Falco naumannii*			1	
53	Peacock Pheasant	*Polyplectron bicalcaratum*	1			

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum* Areas	Balpakram Plateau
54	Indian cuckoo	*Cuculus micropterus*		1		
55	Drongo cuckoo	*Surniculus lugubris*	1			
56	Large green billed malkoha	*Rhopodytes tristis*	1			
57	Longtailed nightjar	*Caprimulgus macrurus*		1		
58	Red headed trogon	*Harpactes erythrocephalus*	1			
59	Himalayan swiftlet	*Collocalia brevirostris*				1
60	Whitebreasted kingfisher	*Halcyon smyrnensis*				1
61	Chestnut headed bee-eater	*Merops leschenaultii*		1		
62	Indian roller	*Coracias benghalensis*				1
63	Indian pied hornbill	*Anthracoceros coronatus*	1			
64	Bluethroated barbet	*Megalaima asiatica*		1		
65	Speckled piculet	*Picumnus innominatus*	1			
66	Rufous piculet	*Sasia ochrasia*		1		
67	Rufous woodpecker	*Micropternus brachyurus*	1			
68	Longtailed broadbill	*Psarisomus lunatusdalhousiae*	1			
69	Swallow	*Hirundo rustica*				1
70	Sand Martin	*Riparia riparia*				1
71	Refousbacked shrike	*Lanius schach tricolor*		1		
72	Hill myna	*Gracula religiosa*	1			
73	Large wood shrike	*Tephrodornis virgatus*		1		
74	Large cuckoo shrike	*Coracina novaehollandie*		1		
75	Smaller grey cuckoo shrike	*Coracina melaschistos*		1		
76	Longtailed minivet	*Pericrocotus ethologus*		1		
77	Goldfronted chloropsis	*Chloropsis aurifrons*	1			
78	Orange bellied chloropsis	*Chloropsis hardwickii*	1			

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum* Areas	Balpakram Plateau
79	Fairy bluebird	*Irene puella*	1			
80	Finchbilled bulbul	*Spizixos canifrons*	1			
81	Blackheaded yellow bulbul	*Pycnonotus melanicterus*	1			
82	Black bulbul	*Hypsipetes madagascariensis*	1			
83	Whitethroated bulbul	*Criniger flaveolus*	1			
84	Redfronted babbler	*Stachris ruficeps*			1	
85	Blackchinned babbler	*Stachyris pyrrhops*		1		
86	Yellow breasted babbler	*Macronous gularis*			1	
87	Redcapped babbler	*Timalia pileata*			1	
88	Necklace laughing thrush	*Garrulax moniligers*		1		
89	Blackgorgetted laughing trush	*Garrulax pectoralis*		1		
90	Blackcapped sibia	*Heterophasia capistrata*	1			
91	Little pied flycatcher	*Ficedula westermanni*		1		
92	Redbreasted flycatcher	*Ficedula parva*			1	
93	Pygmy blue flycatcher	*Muscicapella hodgsonii*				1
94	Bluethroated flycatcher	*Cyornis rubeculoides*	1			
95	Whitethroated fantail flycatcher	*Rhipidura albicollis*		1		
96	Blacknaped blue flycatcher	*Hypothymis azurea*				1
97	Large billed leaf warbler	*Phylloscopus magnirostris*	1			
98	Large crowned leaf warbler	*Phylloscopus coronatus*	1			
99	Allied flycatcher warbler	*Seicercus affinis*		1		
100	Sultat tit	*Melanochlora sultanea*	1			
101	Scarlet backed flowerpecker	*Dicaeum cruentatum*	1			
102	Rubycheek	*Anthreptes singalensis*	1			

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum* Areas	Balpakram Plateau
103	Nepal yellowbacked sunbird	*Aethopyga nipalensis*		1		
104	Little spider hunter	*Arachnothera longirostris*	1			
105	Streaked spider hunter	*Arachnothera magna*	1			
106	Blackbreasted sunbird	*Aethopyga saturata*	1			
107	Tree sparrow	*Passer montanus*		1		
108	House sparrow	*Passer domesticus*			1	
109	Whitebacked munia	*Lonchura striata*			1	
110	spotted munia	*Lonchura punctulata*			1	
	Total		51	55	24	36

Source: Manoj and Jayapal, personal communication, 1996

5.4 Significance from management point of view

This chapter presents nearly all the available literature collected by several agencies and individuals on the diverse fauna of the region. The researchers and managers did several surveys, inventories and research studies using various methods and field techniques, which were popular in a particular timeframe. I observed some uncertainty in some of the findings and the variation in methods used while scanning these studies. One example is the elephant census studies, which combined information from field observations with local interviews of villagers to determine numbers of elephants. Such methods result in some uncertainty of total numbers, double-counting elephants, the use of sign (e.g., tracks) in making counts, and the reliability of interviewees' observations. In this example, it was neither possible to calculate how errors might combine, nor to calculate confidence intervals of elephant population estimates.

Present chapter provides a preliminary synthesis of information on fauna of the region. Information is from many sources, including inventories, surveys, and research. In most cases, the ecological relationship of animals to their habitat is not available. Marcot *et al.* (2002) assessed habitat relationship for the elephant, an organism that could serve as a flagship and umbrella species for the region. Further Manoj and Jayapal (personal communication, 1996) suggested a few birds from broad habitats including primary forests, secondary forests, shifting cultivation (*jhum*) area and the Balpakram plateau area. I hope that such initial studies will serve as a prelude to more extensive wildlife inventories.

The Mangers may use the above information for developing the WHR Matrix for all wildlife species of conservation importance to summarize the descriptive information on species into a database. The WHR data dictionary (**appendix 5.3**) can be used to develop the WHR matrix database. Mathur *et al.* (2002) produced the WHR matrix database for the selected wildlife species of the four project sites (see **section 1.1 of chapter 1**) including this landscape. WHR matrices provides a systematic means of synthesizing information on vertebrate species and are useful for helping make general habitat allocation decisions at a broad scale of land resource planning (Bruce G. Marcot, personal communication).

CHAPTER 6

SOCIOECONOMICS OF MODERN GARO TRIBES

> "In 1807, four times within a few days the Garos rushed from their hills, plundered two official headquarters, fired several hamlets, and left the headless corpses of twenty-seven men and women on the ground. A month later an armed band attacked a large village within two miles of a strong police force, inhumanly killed four women, and carried off a man whom they probably tortured later in the hills."
>
> *- Carey (1919), pp. 11*

6.1 Introduction

Those hills were the Garo Hills, and so the people there were the Garo tribes that form the dominant community in the study area.

The Garo society is matrilineal (Burling 1997, Kar 1982) and consists of five exogamous groups or clans. Each clan is divided into many sub-clans, called *Maharies*, related on the mother's side. Each *Mahari* lives in a particular area of its own, called *Aking*, under the authority of a local chief or *Nokma*, who is the husband of the inheriting daughter of the oldest family of *Aking* (Kar, 1982).

The British constituted the 'Garrowana' (now Garo Hills) as a separate administrative unit during 1866 and headquarters were established at Tura. Since then direct administration has been introduced in the Garo Hills, and the British started collecting revenue and enforcing law and order over the local Garo people. When the British took command of the Garo Hills administration in 1867, the hill community was so wild and violent (as mentioned in the opening paragraph of chapter) that blood shedding in the nearby plain areas was a common occurrence. Thus, the Garos accumulated an evil reputation as head-hunters.

Later, the British authorities invited the American Baptist Mission to develop education among the Garos.

> Before the beginning of Missionary education, Bengla and the Garo were the medium of the instructions in all the school, and the Bengali script was used for teaching the Garo language. Around 1901, Bengla was finally dropped from the lower primary courses of studies and made elective in advance stage. The [Bengali] script was also changed in favour of roman. The Government gave a grant of Rs. 1000 (Rupees One thousand) only for the printing of books in Roman script.
>
> *- P. C Kar (1975), pp. xiv.*

Though the Garos dominate, they are not the only aboriginal tribe in Garo Hills. Other tribes, such as the Hajongs, Koches, Rabhas, Dalus and Banais, constitute the native minority population. Among non-tribal people of the region, Bengalese (including Muslims), Nepalese, and the other plains people have settled in the Garo Hills district since the British period.

The Garos received the benefit of education and modernization, whereas the other native groups were neglected both by the British authorities and the Mission.

> A literacy gap, backed by religious difference, arose between the Garo and the non-Garo tribes. Besides the historical, social and ethnic reasons, the unrest in Garo Hills, especially in post-independence period (after 1947), has been predominantly due to disparities in economic development and the uneven distribution of material benefits between the people of the hills and the plains. There has also appeared a growing economic gap between the greater mass of the illiterate hillmen (of the traditional society) and a very small middle class of the literate hillmen in the post-independence period. The benefits of development expenditure go largely to the latter. Outside contractors and traders by virtue of their ability and wealth have been able to control the economic benefits, many a time avoiding tensions through a partnership with literate hill men. A majority of the tribal population is still in the abject poverty, practicing *jhum* cultivation and maintaining a bare subsistence level of living.
>
> *- P. C Kar (1975), pp. xix*

6.2 Methods

I explored some of the available literature on selected aspects of socio-economics of the native Garo tribes. Several sociologists, economists and anthropologists have done intensive research on various aspects of Garos. The study concentrated more on analysing and interpreting information, which is relevant in a modern context, and which describes their family as well as society structure, ethnic identity, and economic growth including existing market forces and the lifestyle of the local people. From existing literature, I identified links between current landuse patterns the resource dependency of local Garo populations, and impacts on protected areas (PAs), and the overall biodiversity of the region. Present study also discussed some of the conservation issues, the roles of past and present development programmes of the state government, and the existing informal forestry practices of the native Garo society.

I collected primary data through questionnaire surveys and geographic information system (GIS) analysis of the distribution of the Garo people and the natural resources of the region. I conducted village and household surveys using open- and closed-ended questionnaires covering a total of 75 households from fifteen villages around PAs. Through GIS, I evaluated buffers of 2 km and 5 km around PAs (**Fig. 6.1**) as 'zones of Influence (ZI) '.

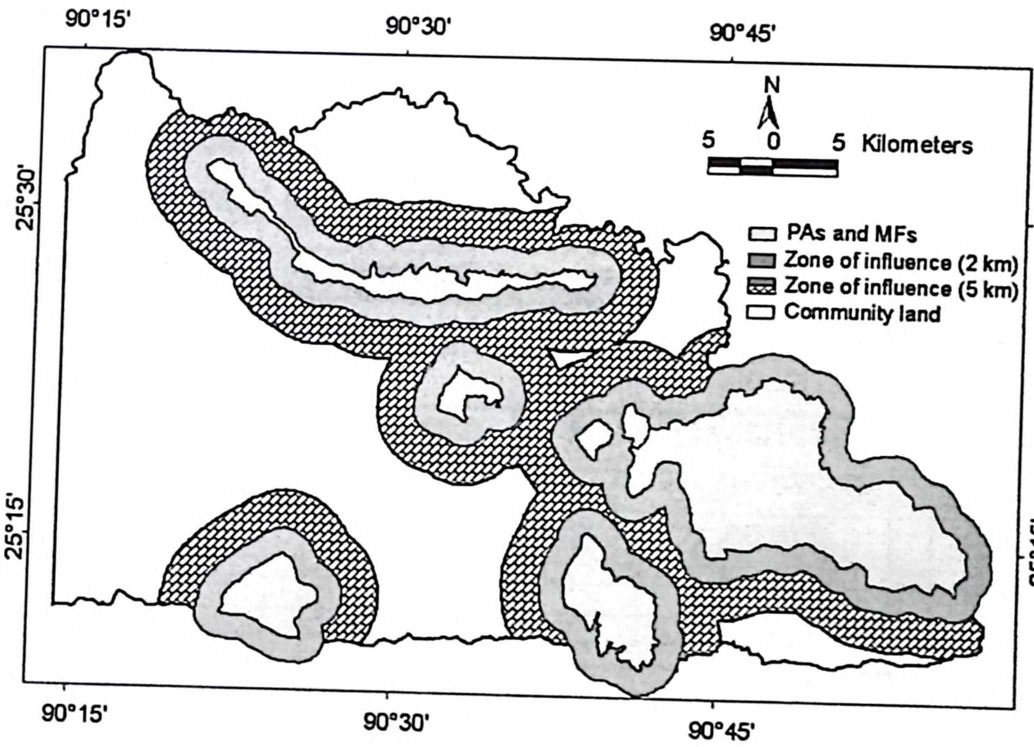

Fig. 6.1: The 2-km and 5-km zones of influence around the boundaries of existing protected areas

The ZI analysis was used to determine the potential and real impact of local Garo populations on natural resources, as well as the availability of rich floral and faunal resources to people living near the PAs. I evaluated human use of selected tree species from a list of 150 tree species (see **appendix 5.1**). The list included local name of each species, and was prepared during a vegetation survey under the parent project that is, the Wildlife Institute of India-USDA Forest Service (WII-USFS) collaborative project (Kumar *et al.*, 2002). I interviewed local forest guards, foresters and permanently resident people on their use of the various parts of each tree species in this list (Kumar *et al.* 2002).

6.3 Results and discussion

6.3.1 Population influx

The Garo Hills were sparsely populated when the British came. According to Hunter (back cited in Sangma, 1995), the population of the Garo Hills was approximately 80,000 in 1872. During that time, there was little immigration and the hills were populated mostly by the Garos.

The total human population in the Garo Hills increased rapidly in the following years, and the proportion of Garos dropped. In 1901, Garos were 74% of the total population, 78% in 1951, 85% in 1961, and 79% in 1971 (**Table 6.1**). By 1991, the total population of the Garo Hills had increased to 666,000.

Table 6.1: Population trends in the Garo Hills and decennial growth rate of population

	Population In Lakhs			Decennial Growth (%)		
Year	**India**	**Meghalaya**	**Garo Hills**	**India**	**Meghalaya**	**Garo Hills**
1901	238.39	3.41	1.38	-	-	-
1911	252.09	3.94	1.59	5.75	15.71	14.94
1921	251.23	4.22	1.79	0.31	7.21	12.71
1931	278.97	4.81	1.91	11	13.83	6.57
1941	318.66	5.56	2.24	14.2	11.59	17.11
1951	361.08	6.06	2.42	13.3	8.97	8.28
1961	439.24	7.69	3.67	21.5	27.03	26.91
1971	548.16	10.12	4.07	24.8	31.5	32
1981	6851.90	13.36	5.06	25	32.04	27.33
1991	8439.30	17.6	6.66	23.5	31.8	31.62

Sources: 1. Census of India, 2.Basic statistic of North-Eastern Region and 3.Statistical Hand Book Meghalaya

Variation in the growth rate of the population in the Garo Hills during the Pre and Post-Independence periods can be noted from the following statistics (**Table 6.2**).

Table 6.2: Percentage increase in population

Period	India	Meghalaya	Garo Hills
1901-1951	54.46	77.77	75.3
1951- 1991	133.79	190.42	175.2

During pre-independence, it took fifty years to double the population, while in the second phase it took only thirty years. If the present trend of population growth continues, the population of the Garo Hills will double during the next eighteen to twenty years, compared with the country as a whole, which takes 30 to 35 years to double the population (Sangma, 1995). This rapid increase in Garo population density will have important repercussions on the intensity of land use and the impact on natural resources, particularly biodiversity, of the region.

6.3.2 Sex ratio

Prior to 1951, there was a gradual decline in the sex ratio (males: females) in the Garo Hills and also in Meghalaya. In the Garo Hills, the sex ratio increased in 1941 from 959 to 975, which was even higher than the 1901 figures (This could be an error and actual figures may have been 957). After 1941 there was again a decline in the sex ratio. 1981 figures indicate that in the West Garo Hills the sex ratio is higher than in the East Garo Hills and in Maghalaya as a whole (**table 6.3**). Declines in the sex ratio can be attributed to (i) Growth of urban centres (ii) Influx of male population from outside. The trend in urban and rural areas is similar when the male and female populations of the rural and urban areas are analysed (Sangma, 1995).

Table 6.3: Sex ratio (males: females) in Garo Hills (1901-1991), represented as numbers of females per 1000 males

Year	1901	1911	1921	1931	1941	1951	1961	1971	1981	1991
Rural	974	956	959	959	975	951	960	950	939	964
Urban	974	956	959	959	975	951	992	958	945	973
Meghalaya	-	-	-	-	-	-	639	779	772	890

6.3.3 The existing situation and zones of influence

The overall study area covers 2459 km^2 and includes the entire South Garo Hills district (area 1850 km^2) and the eastern and southern portions of the West Garo Hills and the East Garo Hills districts, respectively. The South Garo Hills district is divided into three administrative units called Community Development Blocks (CDB): Chokpot CDB, Baghmara CDB and Rongra CDB. The study area encompasses three CDBs of the South Garo Hills District, and parts of Dalu and Rongram CDBs in the West Garo Hills District and Samanda CDB in the East Garo Hills District.

Nearly fifty percent of the existing population in the study area (14,127 families from 1087 villages) are engaged in slash-and-burn agricultural cultivation, locally known as *jhumming*. The families average 5.16 members and *jhum* 0.28 to 0.8 ha (averaging 0.7 ha) of land per year (**Table 6.4**). On average, a total of 10,432 ha land is *jhummed* per year in following six CDBs (studya area) of Garo Hills (Direcotrate of Soil Conservation, Government of Meghalaya, 1995).

Table 6.4: Demographic composition of villages in six community development blocks (CDB)

Name of CDB	Total Villages (No.)	Total Families (No.)	Total *Jhumia* Families (No.)	*Jhummed* area per family (ha)	Total area under *jhum* (ha)	Average persons per family
Chokpot	343	5519	2991	0.80	2393	5
Baghamara	147	5100	763	0.72	549	5
Rongra	107	2001	989	0.28	277	5
Dalu	257	8834	3681	0.72	2650	5
Rongram	233	8526	5703	0.80	4562	5.8
Samanda	NA	NA	NA (35) *	0.73	-	5.18
Total	1087	29980	14127	0.675	10432	5.16

* *indicates the average numbers of Jhumia families in surveyed villages*
Source: Directorate of Soil Conservation Department, Meghalaya (1995); NA = datum not available

The ZIs in the present study represent the land within specified distances from the peripheries of existing PAs (protected natural areas, such as national parks, wildlife sanctuaries and managed forests). The ZIs includes community or privately owned land in the study area. I delineated two ZI areas based at 2 km and 5 km distances from PA boundaries.

Jhumming is the most salient human activity within the ZIs that has had, and continues to have, the greatest negative effect on old, native forests of the region and their biodiversity. Specifically, it is not *jhum* per se but rather its increasing area of usage and shortened fallow period (as little as three to five years) between burning cycles that is causing the loss of components and cover of old forests in the area. Excessive *jhum* is causing soil erosion, water loss, decreases in soil fertility, and the spread of weedy plant species (Jha, 1997). *Jhum* cycles (fallow periods between burning) of ten to fifteen years provide for better for humus and nutrients to sustain the agriculture (Jha, 1997), and cycles of twenty to over thirty years would allow re-growth of moderately old forests and old-forest components for wildlife associated with such conditions.

Jhum agriculture is a vital part of the Garo way of life. Garos have many religious rituals and cultural rites associated with each phase of *jhum* (for example, clearing, burning, initial planting, and first harvest). Alternatives to *jhum* have been proposed, such as permanent agriculture, terracing of slopes, and mixed timber and food crop planting (for example, alley-cropping agro-forestry). Each alternative, however, has shortcomings; for example, permanent agriculture and terracing can be labour intensive to initiate and expensive to maintain, as the land would not be self-fertilizing as under shifting cultivation with appropriate fallow periods between reuse. Also *jhum* being a vital part of the Garo culture, would not be eliminated. Rather, alternative agricultural methods could be sought to complement rather than replace *jhum*.

Other major factors influencing the ZI include the use of permanent agriculture in valley plains, establishment of horticultural fields (*bagan*) and cash crops, collection of non-timber forest products (NTFPs), and tree plantations established by the Department of Forest and Soil & Water Conservation, Meghalaya. Grazing pressure is almost negligible due to the low cattle population (personal observation).

The land outside the PAs, within the ZIs, belongs either to local communities or individuals and is controlled by local *nokmas* or by district councils (Kar, 1982). The people for their day-to-day needs are utilizing the land and forest resources within the ZIs. Since the area is thinly populated around the PAs boundaries, the pressure of resource exploitation is low compared to other parts of the study area.

Four PAs occur within the study area, namely Balpakram National Park (BNP), Nokrek National Park (NNP), Siju WLS (SWLS) and Baghamara Pitcher Plant Sanctuary (BPPS). BPPS is located in the middle of Baghamara town on a very steep slope, whereas the other PAs are surrounded either by current and abandoned *jhum* fields with secondary growth or by human habitations along with their actively-used crop and *jhum* fields. Patches of old primary forests still exist in a few remote locations such as at Thaidang, Chimitab, Shooling, Kalu-Rongcheng, Rongsu and Hangsapal around BNP, and at Mandalgiri, Ampangiri, and Bandigiri around NNP. BNP shares a common boundary with SWLS in the north, and is considered as a single PA unit in our analysis.

6.3.3.1 The location, extent, boundaries and natural attributes of ZI

There are no villages within any of the protected areas, although villages do occur within the ZIs.

ZI at 2 km distance

The ZI defined by a 2 km distance from PA boundaries (with the exception of Angratoli Reserved Forest) contains more forest area in (secondary forests, deciduous, and evergreen forests) than non-forest. Even in the case of combined ZI for three PAs, the forested areas were greater in the ZI than non-forested areas. The most redeeming feature of ZI at a 2 km distance is the low proportions of agricultural, *jhum* and scrubland areas, suggesting that biotic pressures within the ZI at 2 km are not very high (**Tables 6.5 and 6.6**).

Table 6.5: Area (km^2) of forest and non-forest types in the 2 km zone of influence around protected areas and reserved forests

Forest and Non-forest types	ARF	BRF	IRF	RRF	BNPSWS	NNP
Bamboo/Secondary forest (6-10 years)	6	19	22	13	48	24
Deciduous forests	16	8	1	2	36	3
Semi-evergreen forest	3	10	1	2	4	52
Waterbodies	0	8	3	9	8	7
Evergreen forest	0	3	17	3	3	5
Permanent Agriculture	2	7	0	1	7	2
Shifting Cultivation/ grasslands	4	1	1	0	9	78
Shadow	1	0	0	1	3	1
Scrub/Abandoned *jhum* fields	7	5	0	0	1	0
Plateau grassland	0	0	0	0	0	0
Unclassified	21	5	0	0	71	0
Total	60	66	46	31	189	172

ARF = Angratoli RF, BRF = Baghmara RF, IRF = Imangiri RF, RRF = Rewak RF, BNPSWS = Balpakram National Park and Siju Wildlife Sanctuary, NNP = Nokrek National Park.

The ZIs of BNP, SWS, and RRF overlapped when ZI was considered at a2 km distance. Therefore, a combined ZI was calculated (**Fig. 6.1 and Table 6.6**).

Table 6.6: Forest and non-forest cover in the 2 km zone of influence for combined BNP, SWS and RRF, accounting for overlap

Forest and Non-forest types	No. of Patches	Total Area (km^2)
Bamboo/Secondary forest (6-10 years)	3139	8
Deciduous forests	2493	42
Semi-evergreen forest	1534	52
Waterbodies	154	1
Evergreen forest	946	9
Permanent Agriculture	464	4
Shifting Cultivation/ grasslands	2409	9
Shadow	723	5
Scrub/Abandoned *jhum* fields	883	5
Plateau grassland	2	0
Unclassified	1	71
Total	12747	134

ZI at 5 km distance

The 5 km ZI had much overlap among the zones around Balpakram NP, Nokrek NP, Siju WLS, Baghamara RF, Imangiri RF and Rewak RF. Accounting for this overlap (**Fig. 6.1**), within the combined 5 km ZI the overall forest area was much greater than the overall area in non-forest (**Table 6.7**). Almost 80% of the total 5 km ZI area is deciduous, semi-evergreen, or evergreen forests (**Tables 6.7 and 6.8**).

In the 5 km ZI around some individual PAs (viz., ARF, BRF, BNP, and SWS) however, the area under *jhum* was quite substantial. BNP and SWS, with an area of about 130 km^2 under evergreen and semi-evergreen forests has the most forested and the least disturbed 5 km ZI.

Table 6.7: **Area (km²) of forest and non-forest types in the 5 km zone of influence around PA and RF. See Table 6.5 for description of acronyms**

Forest and Non-forest types	ARF	BRF	IRF	RRF	BNPSWS	NNP
Bamboo/Secondary forest (6-10 years)	17	15	52	41	19	14
Deciduous forests	47	50	66	40	93	76
Semievergreen forest	10	38	0	1	108	152
Waterbodies	0	1	12	8	1	0
Evergreen forest	0	1	1	6	21	155
Permanent Agriculture	8	12	10	9	9	2
Shifting Cultivation/ grasslands	10	18	3	3	23	20
Shadow	3	6	6	6	12	14
Scrub/Abandoned *jhum* fields	25	19	0	0	12	7
Plateau grassland	0	0	0	0	0	0
Total	119	160	150	114	298	441

Table 6.8: **Forest and non-forest cover in the 5 km zone of influence for combined BNP, NNP, SWS, BRF, IRF, and RRF, accounting for overlap. See Table 6.5 for description of acronyms**

Forest and non-forest types	No. of Patches	Total Area (km²)
Bamboo/Secondary forest (6-10 years)	20289	49
Deciduous forests	15723	248
Semi-evergreen forest	8713	327
Waterbodies	769	2
Evergreen forest	3891	178
Permanent Agriculture	2859	21
Shifting Cultivation/ grasslands	16906	66
Shadow	4001	31
Scrub/Abandoned *jhum* fields	6973	37
Plateau grassland	2	0
Total	80126	959
Unclassified	7	204

6.3.3.2 *Villages inside and outside the PAs. Ethnic identities, traditions, customs, relationships between distinct groups of people, relationship with forest villages inside and outside the PAs*

No villages occur within the PAs. The following 72 villages are within 10 km from the boundaries of BNP (SFD, 1995).

Ailatoli
Alokpang
Amonggri
Ampanggre
Babanipur
Badimbari
Baghmara
Balkal
Batlaban
Bilda
Bilkona
Bolbokgri
Bonbera
Champa
Chandrasuk
Chenggni
Chimitap
Dalenggittim
Dambuk Aga
Dambuk Apal
Dambuk Atong
DambukJongkol
Galasora.
Gaobari

Ghandhigri
Goka
Gonggrot
Gulpani
Halwa Atong
Hangsapal
Hatisia
Imbloka
Inolgiri
Kalu
Kanai
Karukol
Kasarisora
Kosi
Kunchung
Maduawe
Mahadeo
Malengma
Meata
Mongmabel
Nadangkol.
Nengsara
New Rompa
Nokat.

Panda
Pasgao
Rangri
Rangsora
Rangtanggri
Rangtangsora
Rewak
Rongara
Rongcheng
Rongjol
Rongmin Chiring
Rongrengpal
Rongruasim
Rongsuagal
Rongwak
Sanbana
Seelpang
Siju
Sooling
Teptepa
Thaidang.
Toklekbari
Wachalchiring
Wagekona

The Eco-development Society of Meghalaya has identified 101 and 33 villages around BNP and NNP, respectively for implementing their eco-developmental projects. All these villages are dominated by Garos.

A total of 25 forest villages are within the boundaries of RFs in the Garo Hills. Most of these villages within reserved forests occur within the southern range of the Garo Hills (**Table 6.9**). These villages were originally established as 'forest-villages' for the purpose of providing ready employment in forestry, in times of need. The forestry work conducted by the villagers was compensated in terms of their land revenues paid to the State Forest Department. In addition, the villagers also enjoyed the rights and privileges of collecting firewood and thatch grass from the reserves. Currently, these reserved forest villages no longer enjoy such rights and privileges, and are more or less revenue paying villages only.

Table 6.9: Reserved forest villages in the Garo Hills, Meghalaya

Name of range or beat	**Name of the forest villages**
Rongrenggiri range	Chidikgiri and Rongmalgiri
Darugiri range	Darugiri, Dambu and Rongjeng
Danadubi range	Dangkhong, Chisimapal, Tengasot, Bolmedang and Nag
Kharkutta range	Kharkutta, Rajasimla, Adokgiri
Southern range	Emangiri, Rewak, Baghmara, Mahota, Bhabanipur and Rangajhora
Angratoli beat	Kondok, Telikali, Rakipara
Hollaidanga beat	Hollaidanga, Paham, and Sorakpara

Source: SFD,1995

The exact number of villages within ZIs (2 and 5 km) around Reserved Forests could not be counted, however, three out of the four Reserved Forests are located on or very near to highways and may occur within some of the ZI area. Emangiri Reserved Forest is distant from the local highway in the southeast of NNP, but is surrounded by large patches of human habitations.

Ethnic identities

Garo' is a term generally used by other communities to refer to a particular group of people commonly known as the 'Garos' whose population is concentrated in the Garo Hills District, and who also formed one of the racial elements in the basic population of north-east India including West Bengal and Bangladesh.

The people inhabiting the areas near PAs and reserved forests are predominantly Garos. There are also a small number of Rabhas, Hajong and Kochs. The Hajongs practice wet rice permanent cultivation. The Kochs and Rabhas are sections of the Bodo race like the Garos, and appear to be offshoots of the Garos. Their original habitation seems to have been the northern slopes of the Garo Hills with cultivation areas in the valley plains.

Growth of Tribal Communities

Table 6.10 gives the population of tribal communities in Meghalaya. The tribal communities in the Garo Hills are represented by Garo, Khasi, Hajong, Koch, Kuki, Mizo, Naga, Rabha and Bodo. In addition to these there are other tribal communities in the Garo Hills, but their numbers are few.

Table 6.10: Growth of tribal communities

	Population			Decennial Growth		Percentage		
	1961	1971	1981	1971	1981	1961	1971	1981
Garo	254784	411532	405449	62.5	-1.47	33.1	40.6	30.3
Hajong	22652	23978	24331	5.85	1.46	2.94	2.3	1.8
Khasi-Jaintia	352031	468499	628104	33.1	34.1	45.7	46.3	47
Other-Tribes	9694	10918	15921	0.01	45.8	1.25	1	1.1
Other	130219	96772	262014	170	170	16.9	9.5	19.6
Total	769380	1011699	1335819	31.5	32	100	100	100

Source: Census of India 1991 records.

Most of the area of the Garo Hill District is inhabited by the Garos. The district is comprised of a number of independent clusters of villages. Each cluster forms an Aking land. According to the different dialects, different practices of socio-political, cultural and religious beliefs, the areas of the district were divided among the sub-tribes.

The various Garo sub-tribes share similar community political structures, social institutions, marriage systems, inheritance of properties, pre-missionary religion and beliefs. The sub-tribes, nonetheless, were isolated from one another and have developed their specific, local variations of political, social, cultural and religious institutions. One example is the variation in song, dances and music, which are mostly associated with traditional religious functions and ceremonies.

One such important ceremonial function is the Mangona Ceremony. It is based on the concept of punishment and reward hereafter, and that sin in one life affects the form of incarnation in the next. Garo beliefs in this regard include:

- The lowest form of reincarnation is that in the shape of insects and plants.
- The next is in the shape of animals and birds,
- The highest is that in human form and,
- The greatest reward for a virtuous life is to be reborn into the same motherhood as before.

Sangma (1995) noted that the boundaries between Garo villages had been established from time immemorial. Playfair (1998) noted that earlier, Garo villages had been larger in the past, consisting of two to three hundred houses.

6.3.4 The state of people's economy: Vocations, landuse, use of forest and non-forest based resources by peoples and seasonal patterns

6.3.4.1 Vocations

The main vocation of the people in Garo Hills is agriculture, especially shifting cultivation (*jhumming*). About 49% of all families in our Garo Hills study area practise shifting cultivation (**Table 6.4**), covering about 10,431 hectares under *jhum*. Other vocations, which constitute a very small proportion of their *jhum*-based economy, include livestock rearing, fishery, seri-culture, weaving and other small-scale industries.

Garo communities have a well-structured socio-economic system. Most Garo families are of medium size (five to eight), and the average number of working members ranges between two to six per family (**Table 6.11**). The well-knit tribal communities are economically dependent on the natural forest resources, forest land for shifting cultivation, collection of NTFPs and timber for construction and other uses.

Crops produced include paddy, cotton, turmeric, tapioca, ginger and vegetables. As horticulture is being gradually developed within home gardens, especially in larger villages, it indicates a change from shifting cultivation to a more settled or permanent form of agriculture. The horticulture and cash crops grown are betal nut, betal leaves, bay leaves, pineapple, banana, rubber, cashew nut, mango, orange, and others. Apart from this, pig keeping, ducks and poultry are other activities of the tribes. NTFPs collected, used, and sold by the Garos include fuel wood, broom grass, thatch grass, bamboo, agar wood, cane, wild fruits and tubers, medicinal plants, fish and other wild animals.

Table 6.11: Demographic composition of villages around BNP

Family size	No. of Families (no. of individuals)	Average No. of working members per family	Per family land holding in ha	
			Jhumming	Orchard
Small (1-4 ind.)	20 (66)	2	0.62	1.07
Medium (5-8 ind.)	37 (231)	3	0.82	0.99
Large (>8 ind.)	7 (69)	6	0.68	1.29

Source: present study

6.3.4.2 Economic trends

Livelihood Pattern

As per the 1971 census, the population of the single district of the Garo Hills as it was then was divided into two categories, namely workers and non-workers. The working population was subdivided into nine categories given in the **table 6.12**.

Table 6.12: Male and female populations engaged in various professions in the Garo Hills

S. No.	Category of workers	Rural		Urban		Total		Grand Total
		Male	Female	Male	Female	Male	Female	
1	Cultivators	86131	55376	106	61	86237	55437	141674
2	Agricultural labourers	7515	2856	24	1	7539	2857	10396
3	Livestock, forestry, hunting and plantations, orchards, and allied activities	618	57	32		650	57	707
4	Mining and quarrying etc.	10				10		10
5a	Household industries	1024	480	53	23	1077	503	1580
5b	Other than household industry	387	50	193	3	580	53	633
6	Construction	259	9	181	2	440	11	451
7	Trade and Commerce	1726	70	714	32	2440	102	2542
8	Transport, Storage and communications	370	8	101	6	471	14	485
9	Other Services	6400	504	2477	298	8877	803	9680
10	Non-workers	95353	131922	4824	6358	100177	138280	238457
	Total population	**199793**	**191333**	**8705**	**6784**	**208498**	**198117**	**406615**

Source: Simon, 1996

Of the total population of 406,615 people in the original district, 168,158 were engaged in economic activity and 238,457 were classified as non-workers, the ratio being 0.71:1. Comparative figures for the state of Meghalaya as a whole were 446,828 workers to 564,871 non-workers or a slightly higher ratio of 0.79:1. This is an indication of the somewhat poorer economic conditions of the Garo Hills District as compared to Meghalaya as a whole. The figures in **table 6.13** give the percentage distribution of workers and non-workers between rural and urban areas of the district in different work classes.

Table 6.13: Population engaged in various professional categories in Garo Hills

Category of workers		Percentage	
	District	Rural	Urban
Cultivators	34.84	34.84	0.04
Agricultural labourers	2.56	2.56	0
Livestock, forestry, hunting and plantations, orchards, and allied activities	0.17	0.17	0
Mining and quarrying	0	0	0
Household industries	0.39	9.37	0.02
Other than household industry	0.16	0.1	0.06
Construction	0.11	0.06	0.05
Trade and Commerce	0.63	0.44	0.19
Transport, Storage and communications	0.12	0.09	0.03
Other Services	2.38	1.69	0.69
Total	41.36	40.27	1.08
Non-workers	58.64	55.89	2.75
Total	100	96.16	3.84

Source: Simon, 1996

Cultivators and agricultural labourers comprised about 90% of the total number of workers in the district. Out of 152,070 people, 90% lived in the rural area and about 10% in the urban area. The next higher percentage of workers in the rural and urban areas falls in class 5 (household and other than household industries), with about 1.15% in the rural area and 0.16% in urban areas. The minimum number of people in employment, both in rural and urban areas, is in class 6 (construction). In the class No. 9 (other services), the proportion of workers in rural and urban areas was about 2.5:1.

Standard of Living

From their reputation of being headhunters in the nineteenth century (Carey 1919), the Garo community has long been transformed into a well-developed society. Their economic status, however, is comparatively poor. To understand the general economic condition of the people, it is useful to know the standards of living of the various groups in Garo society (**Table 6.14**).

Table 6.14: Average monthly expenditure on various items

S. No.	Items	Hills region				Plains region			
		Border		Non-Border		Border		Non-Border	
		Rs.	%	Rs.	%	Rs.	%	Rs.	%
I	Food items	146.34	75.77	116.93	70.32	163.61	70.32	129.94	73.96
II	Non-food items								
A	Beverages	2.28	1.18	1.54	0.93	2.60	1.39	2.36	1.02
B	Betel nut and leaf	3.64	1.89	0.84	0.50	2.91	1.55	2.44	1.06
C	Tobacco	4.68	2.42	11.94	7.18	4.31	2.30	4.61	1.99
D	Drugs and intoxicants	1.76	0.91	4.91	2.951.	2.32	1.24	5.10	2.21
E	Toilet articles	3.61	1.87	1.72	1.04	3.24	1.73	3.47	1.50
F	Fuel and light	11.69	6.05	10.84	6.52	11.30	6.02	17.95	7.76
G	Others	1.55	0.80	2.13	1.28	0.92	0.49	4.07	1.76
Sub-total		***29.21***	***15.12***	***33.92***	***20.40***	***27.60***	***14.72***	***40.00***	***17.30***
III	Miscellaneous								
A	Clothing, bedding, and footwear	8.11	4.20	5.04	3.03	6.90	3.68	8.94	3.86
B	Sports, amusements	0.05	0.02	3.03	0.01	--			
C	Education	0.71	0.37	0.01	0.16	.14	0.08	1.19	0.51
D	Sundry goods	0.01	0.01	0.08	0.01	.04	0.02	0.06	0.03
E	Ornaments	0.19	0.10	0.38	0.08	.07	0.04	0.16	0.07
F	Medical aid	0.85	0.44	0.81	0.38	0.60	0.32	2.23	0.97
G	Ceremonials	1.01	0.52	1.55	0.81	1.99	1.06	0.25	0.11
H	Construction andrepairs	1.28	0.66	1.01	1.55	3.12	1.66	6.45	2.79
I	Domestic help								
J	Traveling	1.08	0.56	2.24	1.01	1.30	0.69	3.75	1.62
K	Others	4.31	2.23	9.28	2.24	4.02	2.14	4.87	2.11
Sub-total		***17.60***	***9.11***	***100***	***9.28***	***18.18***	***9.69***	***27.90***	***12.07***
Total		**193.15**	**100**	**166.29**	**100**	**187.57**	**100**	**231.21**	**100**

Source: Simon, 1996

The two common factors, which determine the standard of living of people are the total income that a family earns and the total expenditure that the family incurs for maintaining a living. According to the report on the socio-economic Survey of the Garo Hills District conducted by the Directorate of Economics, Statistics and Evaluation for

1970, the total monthly expenditure on food by an average Garo rural family was 74 % in the hills region and 73 % in the plains region of the Garo Hills (**Table 6.14**).

About 16 % was spent on non-food items in the hills region and 16 % in the plains region; these items included beverages, betel nut and leaf, tobacco, fuel and light, and toilet articles. The balance of 10 % in the hill regions and 11 % in the plain regions was spent on miscellaneous articles such as clothing, sports and amusement, education, furniture, ornaments, medicine, ceremonials, repairs and maintenance of dwelling houses, litigation, domestic servants, and travelling. The high percentage of expenditure on essentials of clothing, housing, and education indicates a low standard of living in an average Garo rural family. The consumption expenditure pattern (percentage) on principal items is given in the **table 6.14**.

6.3.4.3 Family Budget

Table 6.15 below gives the budget of an average family per month in the rural areas of the Garo Hills (Simon, 1996).

Table 6.15: The budget of an average rural family

Family budget per head	Hill region		Plains region		District
	Border	*Non-border*	*Border*	*Non-border*	
Gross income	198.39	171.97	191.4	288.9	189.52
Outlay	11.32	11.65	15.78	25.68	12.36
Net income	187.07	160.32	175.62	263.22	177.36
Expenditure	***193.15***	***166.29***	***187.57***	***231.21***	***175.69***
Food items	146.34	116.93	141.79	163.31	129.94
Non-food items	29.21	33.92	27.6	40	28.52
Miscellaneous	17.6	15.44	18.18	27.9	17.23
Total expenditure	***193.15***	***166.29***	***187.57***	***231.21***	***175.69***
Difference between the total expenditure and Net income	**-6.08**	**-5.97**	**-11.95**	**+32.01**	**+1.67**

Source: A report of Socio-economic survey of Garo Hills district, 1970

6.3.4.4 Employment Situation

Agriculture is the main occupation of people living in the Garo Hills. According to the 1971 census, there were 152,070 cultivators. The number of agricultural labourers in the old undivided Garo Hills district increased from year to year indicating a favourable scope for employment not only for men but also women. The total number of applicants for employment between 1974 and 1981 in both districts was 360. Most of the jobs sought by the candidates were white-collar jobs in government offices. During the same period, the monthly average numbers of employees who used the Employment Exchanges were ten in the West Garo Hills and three in the East Garo Hills.

Employment formation scheme

The main objective of the employment formation scheme was to collect employment data both from Public and Private Sector Establishments located within the jurisdiction of the Employment Exchanges. The scheme was introduced after the establishment of the original exchange. The following statement of Employment Market Information Scheme shows the changes in the volume of employment in both the sectors during the period from 1 January 1973 to 31 December 1982 (**Table 6.16**).

Table 6.16: Employment formation schemes in the Garo Hills

Industrial division	No. of establishments	No. of Employees
Agriculture	17	855
Mining and quarrying	1	31
Manufacturing	4	50
Construction	10	851
Electricity	2	395
Water supply		
Public health	4	122
Trade and commerce	1	10
Transport, storage and communication	2	357
Other services	119	6777
Total	160	9448

6.3.4.5 Planning and community development

The Government of India set up the state level Planning Department with the main objective of bringing about a well-balanced growth of the different sectors of the under-developed economy. Three five-year plan periods have been covered since the inception of Meghalya as a state in 1972. Prior to 1972, the Government of Assam was responsible for the development of hill districts, including the Garo Hills. From the start, the government had been giving top priority to the development of transport and communication infrastructures, with the next priorities being development of agriculture, education, health and industries.

6.3.4.6 Community development

The first Community Development Block was inaugurated in the Garo Hills District in 1953. This was the Resubelpara Development Block opened on 1st October 1953, followed by the Dalu Development Block opened on 1 April 1954. More blocks were opened after 1954 and, as of 1981, the districts are being covered by thirteen Community Development Blocks.

The important schemes taken up by the Community Development Blocks are agriculture, communication, animal husbandry and veterinary medicine, health and sanitation, education and social welfare, and industries and co-operation. The Community Development Blocks also administer all the normal rural works and other rural development programmes as the Integrated Rural Development Programme (IRDP), the National Rural Employment Programme (NREP), the Rural Godowns, and programmes in respect of public co-operation and nutrition.

6.3.5 Agricultural customs and needs of population

The main agriculture of Garo communities is *jhumming*. In this practice, a plot of land is selected on the hillside and the rice crop is planted in April at the commencement of the rains. Shortly afterwards, the seeds of vegetables, cotton, pepper and pulses are sown in the same clearing and each crop is reaped in rotation as it comes to maturity. Miscellaneous crops include potatoes, *arhar*, ginger and turmeric and other plants for the rearing of lac insects. In the second year, only rice is grown and after two years of cultivation the clearing is abandoned and allowed to lie fallow for about five to seven years (sometimes less). The sole implement of agriculture is a short dao fixed in a long handle with which the jungle is cleared.

6.3.6 Forest and non-forest resources and their use

Use of forest resources

Villagers use a variety of forest and non-forest resources for their sustenance. These resources vary both in quantity and periods of use. The main forest based resources include: fuel wood, broom grass, thatch grass, bamboo, Agar wood, Cinnamon leaves, bark of *Persia villosa, m*edicinal plants, cane, fish, wild fruits, wild tubers, and wild animals.

The most common forest resources are the food plants. Biswas and Bhuyan (1986) identified some food plants of Garo Hills. They mentioned that the forests are an important source of food, particularly for the tribal population, which depends substantially on the edible products of the forests. They found that plants and vegetables eaten by the people living in the forest are sometimes included in the list of famine foods. They also reported that during a period of drought and when a supply of good cultivated vegetable and crop is not procurable, various forest products are utilized, for example, rice is substituted by yams (*Dioscorea alata, D. pentaphylla* and *D. bulbifera*). The tuberous crop is a cheap source of calories and valuable vitamins and minerals with a low protein content. The cultivation of *Dioscorea* spp., whose tubers are collected and grown in crop fields and gardens, is common. Manihot (*Manihot esculenta*) is one of the widely grown root crops in the region, and it furnishes the basic food next to yams and paddy. In the folklore of the Garos, the importance of Manihot is well versified in words, which mean in English: "*I could live without rice but not without Manihot.*"

The forest vegetables consist mostly of young bamboo shoots (*Bambusa balcooa* and *Dendrocalamus hamiltonii*). Other vegetables commonly used are banana flowers (both wild and cultivated) and leaves of various species including *Zanthoxylum oxyphyllum*, *Bauhinia* spp., *Corchorus* spp. and *Amaranthus* spp. A list of 28 useful tree species is provided below together with their local names, important characters and the parts used (**Table 6.17**).

Table 6.17: Some plant species and their use as food in the Garo Hills

Species Name	Local name	Habit	Parts used	Use
Dillenia pentagyna	Agachi	T	Young tender leaves and flower buds	Eaten raw or cooked
Corchorus olitorius	Me-kha	US	Young shoots	Eaten as pot-herb
Zanthoxylum oxyphyllum	Me-chang	S	Young shoots and leaves	Eaten raw or cooked
Bauhinia malabarica	Phak-Phakil	T	Young tender leaves	Eaten as vegetable
B. purpurea	Phak-Phakil	T	Young tender leaves	Eaten as vegetable
Momordica cochinchinensis	Khang Kelong	C	Fruits	Eaten as vegetable
Eryngium foetidum	Phut Masala	H	Leaves	Flavouring rice and curries
Solanum indicum	Kimka	S	Unripe fruits	Employed in the preparation of curries, chutneys and preserves
Stereospermum personatum	Bol-sel	T	Young tender leaves	Eaten as vegetable
Premna latifolia	Dukh-me	T	Young tender leaves	Eaten in curries
Amaranthus gangeticus	Sandli	H	Stems and leaves	Eaten as pot-herb
A. spinosus	Sandli	H	Stems and leaves	Eaten as pot-herb
A. viridis	Sandli	S	Tender tops	Eaten as vegetable
Manihot esculenta	Tha-belchu	S	Tubers	Liquour 'Hardy'
Artocarpus heterophyllus	Thebrong	T	Fruits, Seeds	Seeds are roasted and eaten as vegetable. Unripe fruit is also used as vegetable
Artocarpus chaplasha	Chram	T	Fruits	When ripe.
Costus speciosus		H	Leafy stems, Rhizomes	Used as vegetable
Musa spp.	Therek rechu	T/S	Inflorescence with tender bracts	Made into curries with black pepper and salt
Dioscorea alata	Tha-Jong		Tubers	Extensively exploited during famine
Dioscorea bulbifera	Tha-Thorak		Tubers and bulbils	Used as famine food
Dioscorea pentaphylla	Tha-Steng		Tubers	Used as vegetable
Dioscorea hamiltonii			Tubers	Used as vegetable
Dioscorea trinervia			Tubers	Used as vegetable
Dioscorea esculenta	Tha-Thorak		Tubers	Used as vegetable
Amorphophyllus bulbifera	Chongrura	H	Petiole and Peduncle	Boiled and eaten with salt and chillies by extremely poor people
Bambusa balcooa	Wamna, Boluka	B	Young shoots	Largely eaten as vegetables during rainy season
Dendrocalamus hamiltonii	Mia,Kaku, Wa-ah	B	Young shoots	Eaten as vegetable
Echinochloa frumentacea			Grains (millet)	Used in place of rice.

T = Tree, US = Understoried trees, S = Shrub, C = Climber, H = Herb, B = Bamboo, and blank = others.
Source: Biswas and Bhuyan (1983)

6.3.7 Seasonal pattern in the collection and use of NTFP from the forests of community land

Fuel wood: Every family in Garo villages collects fuel wood regularly during the dry season and stores it for use during the rainy season. Each woman in the family collects one basket (12-15 Kg) daily from October to April, mainly for self-use and very rarely for commercial purposes.

Broom Grass: This is collected mainly during January and February. On average, a group of families (three to five persons) collect 80-100 Kg per day. It is sold to local contractors (mainly Marwaries) @ Rs. 2 per Kg.

Thatch Grass: About ten percent of the families in a village collect thatch grass. Collection is done during January and February, and thatch grass is sold @ Rs. 2 per bundle (one bundle is 1-1.5 Kg) in the local markets.

Bamboo: About ten percent of the families in a village collect bamboo, mainly during the rainy season. The bamboo is immediately supplied to Bangladesh via the river Simsang. It is sold @ 1 Taka per Bamboo (Taka is the currency of Bangladesh, more or less equalling the Indian Rupee). New shoots of bamboo and cane are used as food.

Agar wood: The bark of agar trees (previously *Aquilaria agallocha*, currently *Aquilaria malaccensis*) is removed, cut into small pieces and sold @ Rs 30 per Kg. One mature tree produces about 50-60 Kg on average.

Tree Bark: For medicinal purposes.

- Boldukaki (*Litsea sebifera*) dried bark is sold @ Rs. 4 per Kg; fresh bark is sold @ Rs. 2.
- Nameaga (*Persia villosa*) bark is sold @ Rs. 4 per Kg for dried bark and Rs. 2 for fresh bark.
- Kiring (*Oroxylum indicum*) bark is sold @ Rs. 6 per Kg for dried bark and Rs. 4 for fresh bark.
- A mixture of crushed bark of Tegatchu (*Mangifera indica*), Ambre (previously *Emblica officinalis*, currently *Phyllanthus emblica*), Gimbal (*Careya arborea*), and Artak (*Terminalia citrina*) is used to control dysentery. It is collected in small quantities for self-use. Commercial exploitation of this resource is not reported.

Root

- Makkal (vernacular name in Garo dialect), a climber, is crushed into powder and thrown into a body of water to kill fish. A quantity of 2-3 Kg of powder is enough to kill all the fish in a small pond.
- Thagachak (vernacular name in Garo dialect), boiled timber of this species is used as food.

Flower

- The flowers of the shrub Ellot (*Phlogacanthus thyrsiflorous*) are used as a vegetable.
- The flowers of a tree, locally known as Tekring or Ambi-lathong (*Burserra serrata*), are used as vegetable and pickle. The fruits of this species are also consumed.

Fruit The raw fruits of the following tree species are used as vegetables

- Chrum *(Artocarpus chaplasha)*
- Armu *(Artocarpus gomezianus*)
- Micheng *(Zanthoxylum rhetsa)*
- Olmak *(Sterculia villosa*)
- Banana fruit *(Musa spp.)*

Leaves The leaves of the following species are used either as culinary or plates for serving meals.

- Megong *(Bauhinia stipularis)*
- Tejpatta *(Cinnamomum tamala)*
- Chhagro *(Macaranga denticulate)*
- Mao *(Hibiscus macrophyllus)*
- Agatchi *(Dillenia pentagyna*)
- Banana *(Musa species)*
- Gimbal *(Careya arborea)*

Cane is used for making furniture and other handicraft items including:

- Chairs and tables. Chairs are sold in the local markets @ Rs. 150 per piece, and tables @ Rs. 250 per piece.
- Stools (Morah) sold @ Rs. 80 per piece.

- Wardrobes or book shelves sold @ Rs. 400 per piece.
- *Sup*, which is made of cane and is used for removing the husk from cereals and pulses before cooking, is sold @ Rs. 50 per piece.
- Mats are sold @ Rs. 125 per piece.
- Baskets are sold @ Rs. 20-40 per piece (depending upon size).

Coal deposits are one of the important source of local economy for the native people. Several families collect it @ 80-100 Kg per family per day.

A total of 108 tree species out of 150 (**appendix 5.1**) were found to be used by local people as food sources (33 tree species), medicine (20 species), timber (54 species), fuelwood (98 species), and boat construction material (43 species). There are numerous uses of trees and other plant species, but our present survey was restricted to these five categories of use by society. Two tree species *Dillenia pentagyna* and *Terminalia citrina* were found to be the most versatile species. Most of these species were used as fuelwood (**Table 6.18**).

Table 6.18: Use of important tree species (Number '1' in cell indicate the use of species for particular purpose; blank means either not used or use is unknown)

S. No.	Species	Botanical name	Edible	Medicine	Timber	Fuel wood	Boat
1	Agatchi	*Dillenia pentagyna*	1	1	1	1	1
2	Artak	*Terminalia citrina*	1	1	1	1	1
3	Chrum	*Artocarpus chaplasha*	1		1	1	1
4	Kimbol/makanchi	*Callicarpa arborea*	1		1	1	1
5	Gambil/dambil	*Careya arborea*		1	1	1	1
6	Bolbret	*Cedrala toona*	1		1	1	1
7	Chambu sirsang	*Euginia aquea*	1		1	1	1
8	Aruwak	*Garcinia tinctoria*	1	1	1	1	
9	Tebe	*Hodgsonia macrocarpa*	1		1	1	1
10	Bolbet	*Litsea monopelata*	1		1	1	1
11	Thegatchu	*Mangifera indica*	1		1	1	1
12	Thegatchu	*Mangifera sylvatica*	1		1	1	1
13	Aburispil	*Micromelon pubescens*	1	1	1	1	
14	Tebrong	*Syzygium balsameum*	1		1	1	1
15	Dodikimsong	*Actinodaphne obovata*			1	1	1
16	Bolribu	*Aesculus assamica*			1	1	1
17	Chandana	*Ailanthus grandis*			1	1	1

S. No.	Species	Botanical name	Edible	Medicine	Timber	Fuel wood	Boat
18	Shishu	*Albizia lebbek*			1	1	1
19	Khilbe	*Albizia odoratissima*			1	1	1
20	Bolapal	*Aphanamixis polystachya*			1	1	1
21	Armu/arimu	*Artocarpus gomezianus*	1	1		1	
22	Gakkal	*Betula alnoides*			1	1	1
23	Dongram	*Canarium strictum*			1	1	1
24	Chako chiring	*Castonopsis hystrix*			1	1	1
25	Chako	*Castonopsis purpurella*			1	1	1
26	Teja bifa	*Cinnamomum bejolghota*			1	1	1
27	Rongrip	*Cynometra polyandra*			1	1	1
28	Bolasin	*Disoxylum hamiltonii*		1	1		1
29	Bolchhim	*Duabunga grandiflora*			1	1	1
30	Ambre	*Emblica officinalis*	1	1		1	
31	Bokta	*Ferminiana colorata*			1	1	1
32	Bolchiring	*Glochidion velutinum*		1		1	1
33	Gambari	*Gmelina arborea*			1	1	1
34	Mugasalgro	*Heteropanax fragrans*			1	1	1
35	Bolong	*Kaeya floribunda*			1	1	1
36	Bolanchi	*Knema limifolia*		1	1	1	
37	Khimde	*Mesua ferrea*			1	1	1
38	Champa	*Michelia champaca*			1	1	1
39	Solwa	*Polaquim polyanthum*			1	1	1
40	Adingok	*Pterospermum acerifolium*			1	1	1
41	Adambit/Laisa	*Pterospermum lancefolium*			1	1	1
42	Boldak	*Schima wallichii*			1	1	1
43	Bolsal	*Shorea robusta*			1	1	1
44	Churi	*Terminalia bellirica*	1	1		1	
45	Bolbok	*Tetrameles nudiflora*			1	1	1
46	Khrenti/Kranchi	*Walsura arborea*			1	1	1
47	Kitma/Sabong	*Abrus precatoius*	1			1	
48	Bolpha	*Albizia chinensis*				1	1
49	Kadam	*Anthocephalus kadamba*			1	1	
50	Megong	*Baunia purpurea*	1			1	
51	Ambilatong	*Bursera serrata*		1		1	
52	Matmi	*Croton joufera*	1			1	
53	Bolmendu	*Dalbergia paniculata*			1		1
54	Gap	*Diospyros embryopteris*	1			1	
55	Ankisipak	*Elaeocarpus rugosus*			1	1	
56	Chamisi	*Eurya accuminata*			1	1	
57	Goerangsang	*Ficus foveolata*	1			1	
58	Aminsep	*Ficus semicordata*	1			1	
59	Dengaduti	*Garcinia kydea*	1			1	

S. No.	Species	Botanical name	Edible	Medicine	Timber	Fuel wood	Boat
60	Boljagro	*Glochidion spharogynum*			1	1	
61	Bolsubret/Damsuri	*Grewia macrocos*	1			1	
62	Bolibu	*Gynocardia odorata*			1	1	
63	Mao	*Hibiscus macrophyllus*			1	1	
64	Ajakari/Bolasari	*lagerstroemia speciosa*			1	1	
65	Gawigran	*Lapisanthus rubiginosa*	1			1	
66	Boldukaki	*Litsea sebifera*		1		1	
67	Rimikgital	*Macaranga indica*		1		1	
68	Kiring	*Oroxylum indicum*	1	1			
69	Nameaga	*Persia villosa*		1		1	
70	Bolgisim	*Polyalthia simiarum*			1	1	
71	Dokimi	*Premna latifolia*	1			1	
72	Changsim/Cherasu	*Sapium baccatum*				1	1
73	Kimkol	*Saraca indica*	1			1	
74	Chambu	*Syzygium cumini*	1			1	
75	Pakram	*Trema orientalis*	1			1	
76	Bolkha	*Trewia nudiflora*		1	1		
77	Rangri	*Vitex peduncularis*			1	1	
78	Garadek	*Wendlendia excelsa*	1			1	
79	Boljalik	*Actinodaphne augustifolia*				1	
80	Rengokmi	*Alangium chinense*				1	
81	Bolapu	*Albizia stipulata*				1	
82	Sokchon	*Alstonia scholaris*		1			
83	Chamolja	*Aporusa dioica*				1	
84	Terimu	*Aristolochia tagala*				1	
85	Bolchhu	*Bombax ceiba*			1		
86	Kasi	*Bredelia retusa*				1	
87	Kasi dupret	*Bredelia stipularis*				1	
88	Sinaru	*Cassia fistula*		1			
89	Tejpatta	*Cinnamomum tamala*	1				
90	Tewak	*Ficus hispida*	1				
91	Chigambil	*Garuga pinnata*				1	
92	Bolgolmatra/Matalwe	*Holarrhena antidysentrica*				1	
93	Bolchhenda	*Ilex embedioides*				1	
94	Boltajong	*Ilex umbellulata*				1	
95	Boldubok	*Kydia calycina*				1	
96	Sidai	*Lagerstroemia parviflora*				1	
97	Bolgreng	*Ligustrum robusm*				1	
98	Chhagro/Bolajak	*Macaranga denticulata*				1	
99	Mangritchok	*Maesa sarmentosa*				1	
100	Boltatu	*Mallotus roxbughianus*				1	
101	Matchmikong	*Mallotus tetracoccus*				1	

S. No.	Species	Botanical name	Edible	Medicine	Timber	Fuel wood	Boat
102	Kilkira	*Oriocnoides integrefolia*				1	
103	Charapak	*Pterigota alata*				1	
104	Bolmising/Bolmicheng	*Rhus accuminata*		1			
105	Chengsu	*Sterculia colorata*				1	
106	Olmak	*Sterculia villosa*				1	
107	Bandikuri	*Vitex glabrata*				1	
108	Bolkingrak	*Walsura tubularis*				1	
Total			**33**	**20**	**54**	**98**	**43**

6.3.8 Non-forest resources

Agricultural and related products

- Paddy
- Cotton
- Turmeric
- Ginger
- Tapioca
- Vegetables
- Fodder
- Pig rearing
- Poultry

Horticultural and cash crop products

- Betel nut
- Betel leaf
- Pineapple
- Banana
- Jackfruit
- Mango
- Orange
- Rubber
- Cashew nut

6.3.9 Implications of the landuse and resource dependency

The main landuse pattern in the Garo Hills is shifting cultivation (*jhum*). This accounts for most of the fragmentation and loss of old, native forest cover as habitat for wildlife and as sources of many forest resources. *Jhum* cycles vary from three to fifteen years. Short cycles (for example, three to eightyears) result in much erosion. Medhi (1984) noted that erosion due to *jhumming*, cultivation in hill plains, and construction causes wastage of 33-201, 40-50 and 18 tons of soil per hectare per annum, respectively. A case study by Dutta (1982) showed the loss of 19 million tons of soil annually in the Garo Hills.

The resource dependency of people in the Garo Hills is for the land as such and other natural forestry resources including NTFPs and wild animals leading to hunting and poaching.

Wants of the Population

As described above, the common requirements of the local villagers for forestry resources are for bamboo, firewood, timber for house construction and agricultural implements, and other resources. When it is affordable, people will use timber posts and poles as house posts, beams, and rafters, made of sal timber. The roofing material is collected from their own *jhum* lands. The demand for grazing land is very limited. Some communities (for example, the Rabhas and Hajongs) collect forest resources within unclassed state forests.

Hunting

I interviewed local people to determine the status and methods of hunting in the Garo Hills. Basically, the Garos are hunters by nature. "Whatever moves is being eaten" many of the people declared proudly. They eat wild animals ranging from big elephants to small rats, bats, birds and even insects, including grasshoppers and cicadas.

They have developed many devices for hunting. *Agrip, doja, jaga, suchikang* (*khelkha*) and *baging* are examples of kinds of traditional traps used for capturing and killing such animals as myna, barking deer, hare, jackal, sambhar and elephant. These killing trap designs and their operation requires a fair degree of skill. For example, a device locally known as *suchikang* (*khelkha*) is used to capture and kill elephants. It is constructed using strong pointed iron rods. *Doja* is a small house (room), which is made to collect and store paddy. Sometimes it is also used to capture barking deer and small animals. *Agrip* is made of poles and is used to capture small animals such as barking deer. *Bagging* is used to capture hare, jackal and wild pig. The animal's neck or leg is trapped very strongly, and sometimes the animal dies in the trap.

6.3.10 Forest management practices and implications on people

Only fifteen percent of the Garo Hills study area consists of officially protected areas or managed forests, and the remaining 85 % is local community land. The 1998 ruling of the Supreme Court established that no timber operations should occur within the reserved forests. The protected areas are governed by the provision of WL (P) Act, wherein limited scope exists for forest working only to improve the habitats as a part of a Wildlife Management Plan. Reserved Forest areas in the Garo Hills study area were managed under the last Working Plan of 1975 that was in operation until 1990. According to this plan, forest management was effected through the creation and management of five working circles (WC): Sal WC, Plantation WC, Bamboo WC, Protection WC, and Ghugra (*Gmelina arborea*) overlapping WC. Forest management practices until 1990 also included the raising of 'taungya' plantations, mainly of *Tectona grandis* and *Shorea robusta*, and extensive social forestry plantations using these two species and *Gmelina arborea*.

The most notable aspect of the last Working Plan was that it advocated management practices that could help in overall wildlife conservation. Such forest management practices aimed at conserving and improving the status of wildlife in RFs without, of course, compromising the principles of scientific forestry. Since 1990, there has not been any forestry management practice inside the RFs or PAs.

6.3.11 Water resources and informal forestry practices

The Garos are intimately associated with forests, since the forests fulfill most of their daily needs. The Garos are very much concerned with the loss of forest resources. In recent years, water availability has been reduced to a critical level. Many villages have moved from the tops of hills to near rivers recently (personal observation). They understand that the loss of forest cover has increased recently, and this loss is the major reason for disturbed monsoon patterns and the decline in water resources. The rural community in the Garo Hills has its own way of conserving water resources by keeping some forest tracts as a watershed reserve.

As regards the forest management practices inside the community owned areas, the main emphasis has been on the strict protection of the 'Village Community Reserves' in the midst of *jhum* areas. The sizes of these reserves vary between 2 and 5 ha, sometimes exceeding 10 ha depending upon the availability of forested land that is important for serving as a water catchment. Such examples of village community reserves are found near Nokrek, Balpakram, Baghmara and Emangiri.

6.3.12 The development programmes and conservation issues

Dutta (1984) discussed various schemes initiated by the Soil Conservation Department of the Government of Meghalaya, and found significant social changes caused by these economic innovations. These schemes included.

i) The *Jhum* Control Scheme

ii) General Land Development Schemes

- Terracing
- Erosion Control Work
- Afforestation Scheme (**Table 6.19**)
- Water Conservation and Distribution work
- Urban Area Conservation work

iii). Watershed Management scheme.

Table 6.19: Plantations under the afforestation scheme of social division south Garo Hills, Baghmara (All the plantations will be handed back to Nokma after ten years). Teak (*Tectona grandis*) and Gamari (*Gmelina arborea*) were planted instead of fuel wood and fodder considering the preference of villagers for timber species.

S. No.	Year of Creation	Name of Centre	Area (Hectare)
1	1988-1989	Rongsepgiri	100
2	1990-1991	Goka	100
3	1990-1991	Jaksongram	80
4	1991-1992	Balkai-1	25
5	1991-1992	Balkai-2	100
6	1992-1993	Eringiri	50
7	1992-1993	Beta	100
8	1992-1993	Eringiri	50
9	1992-1993	Eringiri	28
10	1993-1994	Rewak-1	50
11	1993-1994	Dilsingre	70
12	1993-1994	Jadugiri	100

S. No.	Year of Creation	Name of Centre	Area (Hectare)
13	1993-1994	Magua Aobagre	40
14	1994-1995	Chorengpara	80
15	1994-1995	Doragiri	40
16	1994-1995	Kapasipara	27
17	1994-1995	Rewak-11	13
18	1994-1995	Dilsingiri-11	40
19	1995-1996	Chorengpara	75
20	1995-1996	Rongsopgre	50
21	1995-1996	Mangkengre	23
22	1995-1996	Gaobari	52
23	1996-1997	Atisia	45
24	1996-1997	Mindikgre	05
25	1996-1997	Gaijangre	25
26	1996-1997	Chonggni	35
27	1996-1997	Gaobari-11	05
28	1996-1997	Jaksongram-11	35
29,	1996-1997	Mindikgre	25
30	1996-1997	Bandapara	11
31	1996-1997	Alokpang-1	35
32	1996-1997	Alokpang-11	24
33	1996-1997	Masighat-1	16
34	1996-1997	Masighat-11	04
Grand Total			**1558**

6.3.13 Evaluation of developmental programmes

The three-tier administration of the Garo Hills consists of Deputy Commissioner at the district level, Heads of District Councils at the Autonomous district council level, and Nokmas at village level. At each of these three levels, various government departments, non-government societies and co-operative societies perform various activities pertaining to economic development. The Deputy Commissioner, assisted by lower-ranking staff, carries on the district administration.

The District Council administration is carried on by the Executive Commissioner and is headed by the Chief Executive Officer. The major subjects assigned to the District Council are forests, civil works, taxation, revenue, judiciary, transport and education. Development programmes are undertaken at all three levels of administration by different departments, including: Agriculture; Animal Husbandry and Veterinary; Co-operative; Education, Information and Publicity; Public Health Engineering; Social Welfare; Soil Conservation; and Co-operative Departments. Each department has the goal of adopting an overall strategy to achieve a higher economic or development output through its programmes. Their programmes can be identified as feasible for implementation and can be accepted by the traditional communities within their culture and traditions.

The Co-operative Department has the special role, through its various societies, of helping implementation of the programmes of other line-departments at the ground level with the active involvement of local people both at the planning and implementation stages. The main duty of the Co-operative Department is to organize and register various types of societies and, in addition, to audit the funds and generally oversee the affairs of registered co-operative societies whose responsibility is to foster the economic development of weaker sections of the society. Some of the societies involved with the Co-operative Department's activities are as follows.

i). Service Co-operative Society
ii). Fishery Co-operative Society
iii). Thrift Co-operative Society
iv). Horticulture Society
v). Sub-area Marketing Society
vi). Handloom Weavers Society
vii). Housing Co-operative Society
viii). Canes and Bamboo Industries Co-operative Society
ix). Dairy Farming Co-operative Society
x). Women Multipurpose Crop Society
xi). Eco-development Society

The Eco-development Society

The Ecodevelopment Society was constituted in 1985 (with BNP and NNP), with the basic aim of ensuring compatibility between the protected areas and their surroundings, which were identified as Special Areas for Eco-Development (SAEDs). Activities within SAEDs focus on conservation-oriented development programmes. The Eco-development Society covers 33 villages in the surroundings of the Nokrek NP, the villages covered by the Rongra Development Block in the West Garo Hills, the villages near Balpakram NP and Siju WLS in the Garo Hills. The main objectives of this society are as follows.

- To meet the basic needs of the people in the villages surrounding the National Parks.
- To improve their economic condition as a whole through better agricultural practices and facilities and, where possible, development of some cottage resources.
- To educate local people in the importance of conservation and to train them as custodians of forest resources.

- To increase employment facilities so that the people can become self-supporting and a viable socio-economic part of society.
- To rehabilitate the villagers who have been moved from the core areas of the NPs and take up schemes for their economic development.
- To provide alternative sources of forest produce to remove people's dependency for it in the biodiversity rich areas.
- To build up the confidence of tribal people by including them in the mainstream of development activities, thereby increasing their own benefits and maintaining prosperity the area for its biodiversity values.

To achieve the above-named objectives, the following development works were taken up by the Eco-development Society in the project area

- Land Development
- Flow Irrigation
- Horticulture Development
- School Buildings
- Drinking water
- Afforestation
- Roads and footpaths
- Handloom Development
- Rehabilitation

In spite of all the above-mentioned efforts, including the fact that to ensure speedy development the tribal development blocks also came into existence, the pace of economic development has been very slow, mainly due to communication bottlenecks, soil erosion and loss of soil fertility.

The most significant changes, however, from the adoption of department programmes have been (1) a shift from barter-economy to monetary-economy, (2) a shift from *jhumming* to settled cultivation with the help of *jhum* control schemes, (3) general land development schemes with terracing erosion control, (4) afforestation schemes, (5) water conservation and distribution works under the Water Conservation Scheme of the the Social Conservation Department, and (6) relying more on horticulture and cash crops. Collectively, these significant changes have helped raise the economic welfare of some of the tribal societies. The growth of population and markets has inspired many families to establish their own businesses, which has reduced their dependency on the natural forest and wildlife resources. The shift to wage-earning labour, however, has also caused migration of workers to outside areas, which has disintegrated the communal mode of living as satellite family groups.

6.3.14 The interplay of market forces and their impact on the subsistence economy of the local people

Garos have traditionally traded goods in *hats* (weekly markets) by bartering their produce for their needs, which in the past were few. Playfair (1998) mentioned the *marwari* to be engaged in cotton trade. The British introduced a restriction on the traders in the Garo Hills. After independence, trade came to be highly regulated, but the regulated system of licence, contract and sub-contract did not protect the people from exploitation. Kar (1975) reported the practice of non-tribal people carrying on trade and contracts in the name of tribal people. I learned of advances being made for cotton, cash crops and horticultural produces at prices determined at the time of making the advance. Professional moneylenders do not operate in the Garo villages but loans come from licenced traders and their agents. Incidents of gambling, hitherto unknown among Garo communities, are increasing. Kar (1975) pointed out the decline of the traditional customs of mutual help in time of need, collective action, and labour exchange. The rise in wage labour is noticable. To understand the implications of these changes better, a systematic examination of the impact of money on the lives of the Garos is needed. It may be possible to protect the Garos from further exploitation by adopting appropriate corrective measures.

6.3.14 Market and marketable produce

The reserved forests of Garo Hills had been the main source of revenue for the state Forest Department. The Railway Department was the main buyer of timber harvested from the RFs. The same is not currently practised, however, since green felling has been stopped in the hilly regions of north east India.

Market - The most important centers of the consumption of the produce were Rongjuli, Damara, Krishnai, Tura, Mendipather, Dalu, Mankchar, Goalpara, Dhubri, and other towns in Assam. There was only one depot in Garo Hills, *i.e.,* Mendipather to supply the railways sleepers. The sale of other timber was conducted through sale of forest coupes to contactors. All drift and seized material were and still are sold by auction.

6.3.15 Summary of problems faced by people

The local Garo community owns about 85% of the total land in the study area. This community land contains much dense forest cover that meets most of their requirements. However, in recent years, the rapidly increasing population and its demands for forest resources have created pressure on the government-controlled forests within national parks and reserved forest areas. The people are entering national parks to collect broom grass, thatch grass, agarwood and other NTFPs.

6.3.15.1 Park Management versus local people

Park management imposes several restrictions to the local people regarding entry and the use of forest resources. The Garo people believe that the entire land and all natural resources in the Garo Hills belong only to Garos, but the existing legislations on wildlife and forests do not allow the local people to utilise all the resources of their own land. In some cases the land has been purchased by the government, but some of the local people want to take it back. For example, the Nokma who sold the land around Balpakram area was very much annoyed when he discovered that the land is rich in coal mines. Also there is the possibility of mining uranium inside Balpakram National Park. The existence of uranium there has been confirmed by the Geological Survey of India (Shillong), which also discovered specific extant species, and fossils of extinct species of trees and other plants, which usually occur at or near such sites (personal communication).

6.3.15.2 Wild animals versus local people

Wild animals sometimes directly clash with local people. Food crops grown in the valley plains and *jhums* often attract wild animals, which also compete for drinking water at many places. The main wild animals competing with humans include elephants, sambar, barking deer, wild pig and rats. These animals raid and damage agricultural crops of villages adjacent to forest boundaries, very frequently. Big cats, especially tigers and leopards, lift cattle and fowl from villagers. Hundreds of cases regarding animal depredation and cattle lifting are reported each year.

The local society is basically non-vegetarian and their requirement of milk and milk products is negligible and, therefore, the domestic cattle population is small. It is likely that the community land is able to sustain cattle and other domestic animals at current use levels. Rarely do domestic animals come in contact with wild animals, except the carnivores that lift cattle and other domestic animals from villages. Therefore, the rate of spreading contagious diseases between domestic and wild animals is likely to be low.

6.4 Significance from management point of view

Garo Hills contains a wealth of natural resources, but only limited study has been made to assess the Garos' resource dependency and utilisation. There is a need to assess the key cultural functions of native plants and animals, including determining how various resources are used and valued, and rates of extraction. Such information would help provide a basis for improving resource management and sustainable development in the area. Also, the efficacy of current government schemes including ecodevelopment activities, informal forestry practices and other society welfare programmes need to be re-evaluated in the context of present scenario. Conflicts between park authorities and the local people could be reduced or resolved by involving local communities in conservation and development activities. The outreach programmes of Ministry of Human Resource Development (HRD) and several other local NGOs are to be implemented in consultation with local stakeholders. Several government and non-government agencies could initiate innovative and new cooperative conservation oriented programmes instead of conducting only research and assessment of existing problems.

CHAPTER 7

CONCLUSION: CONSERVATION IMPLICATIONS AND MANAGEMENT RECOMMENDATIONS

The studied landscape is a mosaic of natural forest and human induced non-forest patches. The relatively larger patches of old virgin PF all over landscape are the characteristic features of the study area. The practice of *jhum* over the centuries in this region has resulted in the fragmentation of primary forest landscover and created a number of secondary forest patches of varying ages adding to the diversity of habitats for the benefit of several specialist wildlife species. The Garo Hills (geographical area 8167 km^2) had 54 % of land under intact forest cover during year 1980, which was reduced to 17 % in 2000 (Talukdar, 2004). These figures clearly reflect the growth in native populations and subsequent anthropogenic pressure over the landscape during last couple of decades.

Shifting cultivation or *jhum* is good as long it diversifies the wildlife habitats. But, nowadays it has become the main cause of large-scale deforestation, because majority of native tribes in rural and semi-urban environment practise *jhumming* for their sustenance. After visiting several *jhum*-influenced localities in the Garo Hills over the years, I realize that *jhum* itself is not harmful, but when coupled with shortened *jhum* cycle, speeden up the process of forest fragmentation and habitat loss. About three to four decades ago, the *jhum* cycle was some twenty years, but nowadays it has reduced to two or three years (personal observation confirmed by several senior residents and the forest managers). It is self-evident that how vital is to assess the impact of forest fragmentation, resultant successional habitats and species diversity of the *jhum*-influenced tropical landscapes for better management planning and biodiversity conservation in the tropical forest ecosystem of western Meghalaya.

7.1 The approach

The present research study performed an ecological assessment of tropical forests plus selected taxa of vascular flora and vertebrate fauna of the Garo Hills in western Meghalaya at landscape level. The study developed an ecological information base for managing forest and wildlife resources in northeast India by adopting recent advances in the fields of landscape ecology, and wildlife-habitat relationships modelling, in combination with intensive fieldwork in the interior of western Meghalaya. It generated spatial and non-spatial databases for landscape and vegetation attributes, which will be of immense use to planners and forest managers for wise landuse planning and forest resource management.

The 'fragmentation' is a key research area for the development of sustainable forestry because it is a key biodiversity indicator (Kupfer *et al.*, 2004). Fragmentation is a relatively new concept, which was highlighted in literature during the 1990s (Crim *et al.*, 2002), however, a French ecologist, De Candolle, probably noticed the phenomena of forest fragmentation and its deleterious impacts first time in the year 1855 (Harris & Silva-Lopez, 1992). De Candolle stated that 'the breakup of a large landmass into smaller units would necessarily lead to the extinction or local extermination of one or more species and the differential preservation of others'. Latter, MacArthur and Wilson (1967) introduced the 'Island biogeography theory', which states, "The basic equilibrium model postulates that immigration rate curves will fall and extinction will rise with an increase in the number of resident species."

This concept of the island biogeography equilibrium theory was extrapolated to 'fragmentation' during late 1970s and 1980s (Crim *et al.* 2002). A few ecologists (Middleton & Merriam, 1983; Howe, 1984; and Klein, 1989) questioned the applicability of this theory to fragmentation; for example, Klein (1989) opined that the island biogeographic theory has low explanatory power and that there are differences between the habitat surrounding a true island and habitat islands. *Fragmentation, thus, replaced the concept of the island biogeographic theory and became widely accepted and understood over time.*

In latter years, the island biogeographic representations of the landscape have been gradually transformed into the corridor-patch-matrix model (Forman & Godron, 1986; Forman 1995; and Kupfer, 2004), which conceived the landscapes as mosaics of discrete landscape elements, (corridors, patches) within a more extensive, better-connected landscape matrix. Recently, McIntyre and Hobbs (1999) proposed the landscape continuum model, which focused on variation in habitat quality so that boundaries amongst landscapes are not recognized. Kupfer (2004) cited the relevant studies for detailed comparison of these two models and stated that examining fragmented landscape from both models emphasized the relationship between changes in landscape structure (for example, deforestation or patch isolation) and the underlying functional changes (for example, in dispersal or migration).

7.2 The research findings

The tropical forest ecosystem of the study area is rich in terms of floral resources, especially tree species (**appendices 3.3 and 4.1**). The major forest vegetation types are primary and secondary forests, which occupy most of the landscape. Forest stand density and vigour compare well with the densest tropical rain forests anywhere in the world. These forests have the highest tree basal area ever reported from tropical forests anywhere in the world. The study compared tree species diversity between the primary and secondary forests as well as within various forest formations of PF and successional stages of SF and concluded that the PF are more tree-diverse forest types. The cluster analysis identified the PF into three distinct forest formations located in different altitudinal zones including low (less that 400 m elevation), mid (400 – 800 m elevation) and high (more than 800 m elevation) formations. At the same time, it clustered the SF into three successional stages including young (under fifteen years old), mature (between fifteen and thirty years) and old (over thirty years old) seral stages.

The phyto-sociological analysis of tree species data determined the forest structure in terms of tree species and revealed the relative frequency, abundance, dominance and importance values of 165 species sampled (n = 35 belt transects). The standard indices of Menhinick index, Shannon index and Hill's ratio compared the PF and SF for species richness, diversity and evenness, respectively. The diversity analysis also revealed that the PF are the most tree-diverse. I confirmed this by performing rarefaction analysis and plotting the number of cumulative tree species as a function of the cumulative number of samples in PF (n = 21 belt transects) and SF (n = 10 belt transects). The ten most important species of PF are *Polyalthia simiarum, Schima wallichii, Castanopsis purpurella, Syzygium cumini, Grewia microcos, Drimycarpus racemosus, Dillenia pentagyna, Cynometra polyandra, Aphanamixis polystachya,* and *Walsura tubulata*, whereas the ten most important species of SF are *Schima wallichii, Castanopsis purpurella, Shorea robusta, Macaranga denticulata, Grewia microcos, Syzygium cumini, Aporusa dioica, Eurya acuminata, Dillenia pentagyna,* and *Callicarpa arborea*.

Though these findings reveal that SF are less tree-diverse, however, one should not undermine the values of SF. The SF may be less diverse, but are of the utmost importance to the native wildlife and cultural societies. The Centre for International Forestry Research (CIFOR) hosted a workshop "Tropical Secondary Forests in Asia: Reality and Perspective" in the year 2000 and published the workshop's overall findings in the "Journal of Tropical Forest Science'. [1] This special issue identified the status, trends and potential of SF in tropical Asia. In the introductory chapter of the same issue, De Jong *et al.* (2001) suggested the need for optimizing the external forces or conditions influencing the goods and services from SF, and emphasized on understanding the 'underlying causes' of SF formations and their subsequent dynamics, and how those underlying causes can be influenced. Without such knowledge, the SF management, application of silvicultural techniques, or opportunities to market secondary forest products, will have little effect on the condition of SF on a wider scale.

I plotted the SIV of selected tree species as a function of successional stages (age classes) of secondary forests to find out the process of invasion of forest tree species from the young seral stage to the old forest growth where it resembles the PF. The criteria for selecting the species include (i) the species importance value, (ii) the use of species by native wildlife and (iii) the use of species by native people. This gave the idea of arresting desired successional stages and identifying the scientifically sound fallow period with longer *jhum* cycle. This would help implementing adequate silvicultural treatment to the stand 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 PF, successional stages of SF and response by individual tree species would provide information useful in recovering PF 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 PFs could be restored and retained throughout the region to reduce the impact of forest fragmentation, which frequent *jhumming* is posing over the landscape now.

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1 The CIFOR is an international research and global knowledge institution committed to conserving forests and improving the livelihoods of people in the tropics. CIFOR co-organized this workshop at Samarinda (Indonesia) during 10-14 April 2000 in collaboration with the German Agency for International Development and the Dutch National Reference Centre for Agriculture, nature and Fisheries. The proceedings of workshop were published in the special issue of the '*Journal of Tropical Forest Science*' volume 13, number 4, October 2001.

The present study used remote sensing satellite data to map the landuse landcover of landscape and further quantify the forest fragmentation using standard technique. The analysis and modelling of forest fragmentation and core areas provided the information about potential wildlife habitats in the region. The core areas identified and mapped the sufficiently large forest patches providing potential habitats for these species. These sites can be considered for further wildlife habitat management and conservation planning especially for forest interior wildlife species. I delineated the low fragmentation areas, including the intact forest cover area linking the existing protected areas, such as the biosphere reserve, national parks, wildlife sanctuaries and reserved forests, to identify the potential wildlife habitat corridors over landscape. The forest cover occupied more than ninety percent of these corridor areas. These potential corridors are providing valuable ecological functions to native wildlife species especially the Asian elephant population in the study area.

The Asian elephant is the flagship and umbrella species of the region. The study examined the elephant distribution and landscape composition to evaluate the available habitat conditions in the study area; and identified seven corridors of old forest as possible dispersal or population connected habitats that currently join the larger extant forest patches within protected areas and reserved forests. The state government could manage these corridors as actual or de facto wildlife sanctuaries, the purpose being to protect the old forest stands from excessive *jhum* and enhance the conservation status by protecting and monitoring them.

This investigation provided base line information for the habitat relationship assessment of selected wildlife species including Asian elephants, hoolock gibbon, tiger, clouded leopard, Himalayan black bear and other species. It also gave a preliminary assessment regarding the distribution pattern of wildlife species and their relationship with the selected tree species (**Table 5.12 in chapter 5**). Further research may address the assessment of the role of organisms (wildlife species) in their environment. The following section of this chapter, "Management Implications" will explain something of the potential role of wildlife species in their environment as key ecological functions. Likewise, all wildlife species including plants provide a number of goods and services to human society. The present study evaluated a few uses of selected tree species by native people (**Table 6.18 in chapter 6**).

The following section will discuss all such roles of species as key cultural functions and link all functions with the key environmental correlates to enable managers to ask relevant questions, formulate management hypotheses and prescribe more focused strategies to implement in the conservation planning of the landscape.

7.3 Management implications

The findings suggest the need for designing further research studies to assess the use of 'key environmental correlates (KECs) ' for wildlife species of conservation importance especially for species closely associated with old primary forests (**appendix 7.1**). The term KECs refers to wildlife habitats, habitat elements, and other non-habitat influences on the distribution and abundance of organisms. This would help in developing our understanding of wildlife habitat relationships and, in particular, which elements of old forests could be provided in various portions of the landscape such as habitat corridors, recovered *jhum* fields, protected area buffers, and reserved forests, to help provide for old-forest wildlife. Likewise, understanding key ecological functions, especially of keystone species is vital for their management, and these should be included in decision making for wildlife management and conservation planning. The term 'key ecological functions (KEFs) ' refers to the principal set of ecological roles performed by a species in its ecosystem and the main ways organisms use, influence, and alter their biotic and abiotic environments (**appendix 7.2**).

The study area, as described above, contains a wealth of natural resources and cultural heritage. Several scientists studied the biological, geological, anthropogenic features of Garo Hills and tribes; however, very few of them have been linking the native natural resources with their use by native cultural society. It is important to assess the key cultural functions (KCFs) of native wild plants and animals, including determining how various resources are used and valued, and rates of extraction. KCFs refer to the principal set of cultural roles performed by a species in the culture and society of the native Garo population (**appendix 7.3**). Such information would help provide a basis for improving resource management and sustainable development in the area. The understanding of such cultural roles is imperative to developing any conservation strategy that will be acceptable to the Garo people and nokmas.

Some of the KCFs are unique to Garo tribes, and differ substantially from how plants and animals are used by other people of Meghalaya or Northeast India. Jadorang represents the Psycho-cultural religion/philosophy of the Garos. It involves the rather startling, animistic-like beliefs of this religion. The Garo's use of plants and animals in Jadorang is far different from usual ethnobotany or ethnozoology. Some plants play psychotropic roles; others are used as ritual or metaphorical symbols. Others, including some plants and animals, are believed to wield great animistic power of various specific natures. The terms 'psychobatany' and 'psychozoology' refer to a culture's use of plants and animals, respectively, for specific rites, rituals, religious interests, and other KCFs of organisms. These terms refer to the use of plants and animals that include, but extend well beyond, the traditional concept of 'ethnobotany' (for plants) that depicts the use of organisms for medicines and trade (Bruce G. Marcot, personal communication). The examples of key cultural functions of plants and animals used by the Garo people in the Garo Hills of western Meghalaya for religious rites and rituals are provided in **appendix 7.4**.

Once the KCFs are described, it is simple matter to query the relational databases of KCFs and KEFs to ask some rather profound things, for example, asking such questions as, what are the species of wildlife important to Garo tribes used as ritual sources of sustenance, and what habitats and KECs do such species use? It would help managers and planners to link the species geographically; map out concentration areas of species or populations having specific KCFs; and project their distribution over time under different management options. Furthermore, managers can link the species to their KEFs as well, and thereby -- perhaps for the first time -- ask joint questions about their specific cultural and ecological roles in the ecosystem. Managers can map the answers and project the effects of historic and potential future landuse practices on them.

Bruce G. Marcot (personal communication) suggested the same approach for developing salmon-wildlife management strategies. He used the term 'species-environment relations (SER)' instead of the more traditional 'wildlife-habitat relationships' because the databases extend beyond just wildlife - terrestrial vertebrates - and beyond what is traditionally considered 'habitat' per se. In the SER database, each species was characterized according to its, (i) General Macrohabitat associations, (ii) Specific Habitat Structures (structural or seral stages), (iii) Key Environmental Correlates (specific substrates or stressor influences; KECs), (iv) Key Cultural Functions (KCFs), (v) Life History attributes, (vi) Key Ecological Functions (KEFs) and (vii) eographic location or range distribution (Marcot & Heyden, 2001).

(Bruce G. Marcot, personal communication) suggested a generalized, broad-scale catalogue of existing or potential management activities, and a database depicting which KECs each activity might influence. So, through the database linkages, the managers can describe a management activity, determine which KECs the activity influences, which species use those KECs, and the collective set of habitat associations, life history attributes, and both ecological and cultural functions of those species that are influenced by the activities. Conversely, the manager can start with a particular KCF category and query the database to determine which species have this function, what their collective ecological functions are, what habitats they ascribe to, and what management activities might influence their KECs. To some Native American tribes, being able to describe both the cultural and ecological roles of native organisms, and to determine (in a very general way) what potential management activities influence them, is a major step forward in integrating (and, in a sense, "equalizing") the natural ecological with human ecological (cultural anthropological) dimensions.

Each species or entity in the SER database can be seen to have particular KCFs as well as KEFs. The KCFs provide for social or cultural integrity of the human system, that is, they influence (at least in part) the social and cultural diversity and the quality of life of the human community. Likewise, KEFs of the species influence the ecological integrity of the ecosystem, that is, they affect (at least in part) the biodiversity, productivity, and sustainability of the system. Specific management goals and objectives, both ecological and cultural in nature, might describe the degree of social/cultural integrity and ecological integrity desired. In turn, achieving these goals of social/cultural integrity and ecological integrity means specifying a set of land and resource management activities which directly influence various environmental features of the land, which in turn serve as habitats for the species of interest. This is a species- or organism-centric approach, to be sure, although the 'species' can equally well be described with functional or taxonomic groups of organisms, not just single species. Therefore, this can be a multi-species 'systems' approach as well (Marcot, personal communication).

The broad scale studies are of great importance in understanding the ecological processes and functions at landscape level. The specific findings depicting fragmentation levels and core areas of landscape can be used for designing and implementing conservation-oriented programmes or research studies as Schadt *et al.* (2002a) did for assessing the suitability of central European landscapes for the reintroduction of Eurasian lynx. They suggested an approach illustrating how information on habitat fragmentation on large scale can be linked with local data for conservation of native species in a landscape. Such programmes can be developed to help conserve the dwindling populations of clouded leopard, gibbon and other vulnerable species in the Garo Hills. Furthermore, assessment of suitable habitat and patch connectivity for such species may help understanding and modeling the influences of environmental and anthropogenic factors on the dispersal of these species (Schadt *et al.* 2000b and 2004). Their approach demonstrated how biologically plausible rules can be applied in conservation to identify potential habitats successfully, even when few empirical data are available. The same approach can be used to conserve the species of interest in the Garo Hills, where collecting empirical data is an extremely challenging task.

Basic field inventories of faunal species are very helpful for initiating wildlife conservation and management activities. The northeast centre of the Zoological Survey of India (ZSI, Shillong) and the zoological and wildlife departments of local universities in the northeast region have done several surveys and prepared an information base by listing many taxonomic groups of vertebrate and invertebrate fauna of the region. The autecological studies of wildlife species, their life histories including population status and trend especially for endemics, habitat specialists and rare species are very important in setting good management goals and for aiding conservation planning of wildlife. Now, the further research studies should focus more on conservation-oriented applied research, ZSI and local universities, however, can continue updating the inventories of all vertebrate and invertebrate fauna, which is equally important.

The efficacy of current government schemes including ecodevelopment activities, informal forestry practices and other society welfare programmes needs to be re-evaluated in the context of the present situation. Efforts should be made to resolve conflicts between park authorities and the local people by involving local communities in conservation programmes and developmental activities. The outreach programmes of the ministry of Human Resource Development (HRD) and local NGOs should be implemented in consultation with local stakeholders. Several government and non-government agencies could initiate innovative and new co-operative conservation-oriented programmes instead of conducting only research and assessment of existing problems. The following are a few recommended applications of findings at landscape level generated from the present study (Marcot *et al.* in press).

- Conservation of specific sites particularly special and unique habitats.
- Wildlife habitat corridors especially for the native elephant population.
- Management of specific substrates in forest management and *jhum* activities for biodiversity conservation.
- Consideration for Garo Beliefs while decision making and implementing developmental and conservation-oriented programmes.
- Better NTFP policy for sustainable use of natural resources, e.g. scientific extraction of wild medicinal plants.
- Diversifying the economic base of Garo villages by providing alternative sources of economy.
- Targeting the young generation for alternative livelihood options.

7.4 Specific recommendations

7.4.1 Recommended PAN structure

The landscape (2459 km^2) has four Protected Areas (PAs) out of five in the entire Meghalaya state (area 22,429 km^2). The entire landscape is a mosaic of patches of primary, secondary forest growth and other landuses. Most of these forest patches lie in unprotected community land, leaving a large gap in the existing PAN. The study identified potentially critical, though unprotected wildlife areas that would contribute to a far more effective PAN in the region. The state government may select the identified critical areas for targeting their conservation efforts, and arrange the PAN structure as in the following four categories.

- Government-designated national parks, wildlife sanctuaries for conserving biodiversity
- Reserved forests for sustainable resource use
- Zones, buffers, corridors within and among the above categories for local protection, and for the connectivity of habitats and plant and animal populations
- Specific substrates and vegetation elements within croplands, managed forests, and other high-use areas for providing specific habitat elements

7.4.2 Recommended specific substrates for wildlife management

There are a few elements of habitats, which provide specific substrates to the wildlife species. Managers may consider these substrates while doing management planning for wildlife conservation. The following are a few examples of special habitat elements of biological origin facilitating the breeding, feeding, or other functions of wildlife species (Marcot *et al.*, in press).

- Snags – greater racket-tailed drongo, verditer flycatcher, dollarbird, peregrine falcon, stork-billed kingfisher
- Snag recruits (dying trees, live trees with dead portions) – white-rumped vulture, grey-headed fish-eagle, vernal hanging parrot
- Hollow trees, chimney trees (living or dead) – pigtail macaque, barking deer, brown hawk owl, India pied hornbill
- Tree cavities (natural or created) – slow loris, leopard, tiger, streak-throated woodpecker
- Large old trees (living) – white-throated fantail, red-headed vulture, small Indian civet, India pied hornbill
- Trees with fluting boles and buttresses – little spiderhunter, greater racket-tailed drongo, red junglefowl
- Down wood – painted francolin, red junglefowl, Indian porcupine, barking deer, Manipur bush quail
- Litter and duff (decaying matter) – spotted deer, gaur, sambar, Tickell's blue flycatcher
- Litter in streams – lesser whistling duck, pintail snipe
- Lianas – little spiderhunter, spotted deer, gaur, green imperial pigeon
- Fruit-bearing shrubs – spotted deer, gaur, sambar, wild pig, peafowl
- Fruit-bearing trees – barking deer, pigtail macaque, stumptail macaque
- Epiphyte patches – vernal hanging parrot, hoolock gibbon

7.4.3 Recommended forest landscape composition for maintaining elephant habitats

The elephant is a flagship and umbrella species of the landscape. Several forest types, successional habitats and non-forest landuse landcover categories influence the distribution pattern of elephant through landscape. The densest elephant population was found when following combination of landscape elements was observed and is recommended to help provide the better habitat conditions to the native elephant population (Marcot *et al.* 2002 and in press).

- Moist evergreen, semi-evergreen, and moist deciduous forest cover ≥ 40% of the landscape.
- Current *jhum* < 5% of landscape.
- Current plus abandoned *jhum* < 30% of landscape.
- Village density < 0.4 / km^2.
- Bamboo and young secondary forests >10%.
- Scrub and abandoned *jhum* fallows >10%.

7.4.4 Recommended pilot demonstration projects

One of the most important outcomes of the present study is a proposal on pilot demonstration projects, which could be focussed on testing and implementing modifications to *jhum* agriculture (shifting cultivation) in Garo Hills, to conserving and restoring older-forest habitat elements, corridors, and buffers to protected areas. The suggested demonstration projects base on the following three themes (**appendix 7.5**).

- Additions to protected areas
- Protection of primary and mature forests in wildlife corridor habitat areas.
- Provision of older secondary forests (as wildlife habitat) in heavily *jhummed* areas.

7.5 The road ahead

Visualising landscape as UNESCO's World Heritage Site

The UNESCO's world heritage (WH) mission is to encourage the identification, protection and preservation of outstanding cultural and natural heritage around the world (UNESCO, 2004). The UNESCO encourages countries and state parties to nominate their natural and cultural properties. Up to now India has only five natural heritage sites including (1) Kaziranga National Park (1985), (2) Keoladeo National Park (1985); (3) Manas Wildlife Sanctuary (1985), (4) Sundarbans National Park (1987), and (5) Nanda Devi National Park (1988). A few Indian states including Arunachal Pradesh, Assam, Chattishgarh, Goa, Gujrat, Madhya Pradesh, Maharashtra, Rajasthan and Tamilnadu presented their ideas of proposing several natural and cultural sites for serial nomination in a National Workshop on World

Heritage Property dated 23 September 2004 at WII, Dehradun (Vinod B. Mathur, personal communication).

Recently, UNESCO has made provisions for serial nomination of cultural or natural properties with high outstanding universal value (OUV) for declaring a WH site. The proposed landscape satisfies the criterion no. 3 of OUV, which states that the site should contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation. A State party needs to fulfill certain criteria and conditions of integrity to propose a property for nomination. A serial nomination consists of two or more unconnected areas and, thus, a single WH serial nomination should contain a series of cultural and/or natural properties (IUCN, 2004). The following research findings of the present study may be used for establishing its OUV and fulfilling the conditions of integrity.

The overall biodiversity assessment of the study area, which the parent WII-USFS project (1996-2002) referred to as the Garo Hills Conservation Area (GCA) revealed several biological, ecological and cultural functions of the landscape. The State Government of Meghalaya may use the findings in present thesis to strengthen the nomination proposal for designating GCA a WH Site. The GCA represents the faunal and floral index of Meghalaya state and is probably one of the best-suited properties for serial nomination due to its highly sensitive Protected Area Network (PAN) comprising biosphere reserve, national parks, wildlife sanctuaries and adjoining government-managed stands along with unprotected forests over community owned land.

The present study identified more than 1000 vascular plant species including more than 400 tree species in the tropical forest ecosystem of the landscape. Many of these species are rare, endangered, endemic and thus are of great conservation importance. There exists a significant population of Asian elephant, which is declining at a rapid rate (Marcot *et al.*, 2000). Recently the state government has declared the region an Elephant Reserve, which includes all the GCA along with adjoining elephant habitat areas through community land of the Garo Hills in western Meghalaya. There is no adequate information on the population status of tiger; their numbers, however, can be counted on the fingers. The clouded leopard population seems to be on the verge of (local) extinction. The habitats of hoolock gibbons, the only ape of India, and several other animal species are shrinking with reducing forest cover mainly due to practising age-old traditional shifting cultivation. The culture and traditions of native Garo tribes are still closely associated with nature. They have a forest based socio-economic society structure especially in rural and semi-urban environments (Kumar *et al.* 2002). The sacred groves are of utmost importance from an anthropological point of view; in fact, they are more important because they sustain enormous natural properties, too (Tiwari *et al.*, 1999). The study area is of extreme biological, ecological and cultural significance. The entire property, however, is subjected to great anthropogenic pressure in the form of shifting cultivation; developmental activities; illegal removal of natural resources; mining of coal and other mineral ores; encroachment; infiltration from the adjoining international border, and current insurgency.

The above-mentioned research findings of the present study suggest that the GCA has a high OUV and fulfills the conditions of integrity, and thus qualifies in the UNESCO's criteria for inclusion in the tentative list and further nomination to the WH Centre. At present, a tentative list of priority areas for future nominations includes the Western Ghats rivers, Western Ghats forests and Andaman sea. The GCA could be the next one in the series of WH sites with several protected natural areas and cultural sites for a serial nomination. The normal procedure for nomination includes (1) the selecting a property of high OUV fulfilling certain criteria and submitting the proposal to WH Centre; (2) WH Centre checks the nomination; (3) Experts from the International Council on Monuments and Sites (ICOMOS) and/or World Conservation Union (IUCN) visit the site, evaluate the status, assess the OUV of property and submit a technical report to WH Bureau; (4) WH Bureau examines the evaluation and makes recommendations or asks the state party for further information; (5) Finally, the WH Committee makes the final decision to inscribe the site on the WH list. The committee may ask for more information or refuse the inscription.

A serial nomination proposal may suggest the nomination of NBR, BNP and BPPS along with adjoining protected and unprotected forestlands, which provides the valuable wildlife habitats. Nominating the GCA as a WH Site will help the state government to receive the technical and financial co-operation from several national as well as international agencies to help protect this conservation area of global significance in western Meghalaya.

REFERENCES

Alfred, J.R.B. and J.P. Sati. 1990. Survey and census of hoolock gibbon in west Garo Hills, northeast India. *Primates*, 31 (2): 299-306.

Anon. (1976). National Commission on Agriculture 1976 Part IX. Forestry Chapter-Production and Social Forestry, 42-12-1 to 42-12-25, 147-58 (Report).

Biswas S. and T.C. Bhuyan. 1983. On the identity of some food plants of Garo Hills, Meghalaya. *Indian Journal of forestry* 6 (3): 208-213.

Bowman, K.O., K. Hutcheson, E.P. Odum, and L.R. Shenton. 1971. Comments on the distribution of indices of diversity. pp. 315-366 in International symposium on statistical ecology, vol. 3 (G.P. Patil, E.C. Pielou, and W.E. Waters, eds.). Fairland, Maryland, intern. Cooperative Publ. House.

Burkey, T.V. 1995. Extinction rates in Archipelagoes: Implications for populations in fragmented habitats. Conservation Biology 9 (3):527-541.

Burling, R. 1997. Rengsanggri: Family and kinship in a Garo village. Tura Book Room, Tura, Meghalaya. pp. 409.

Campell, D.G., D.C. Daly, G.T. Prance and U.N. Maciel. 1986. Quantitative ecological inventory of Terra firma and the Varzea tropical forest on the Rio Xingu, Brazilian Amazon. *Brittonica* 38: 369-393.

Campell, D.G., J.L. Stone and A. Rosas, Jr. 1992. A comparison of phytosociology and dynamics of three flood plains (Varzea) forests of known age, Rio Jurua, Western Brazilian Amazon. *Botanical Jounal of Linnaean Society* 108: 213-237.

Carey, W. 1919. The Garo Jungle Book. Second edition reprinted in 1993 by Tura Book Room, Tura, West Garo Hills, Meghalaya. 267 pp.

Champion, H.G. and S. K. Seth (1968). A revised Survey of the Forest Types of India; Manager of Publication, Government of India, New Delhi.

Covich, A.P. 1976. Analyzing shapes of foraging areas: some ecological and economic theories. *Ann. Rev. Ecolo. Systematics* 7:235-257.

Crim, S., M.R. Dubois, J. Finley, R. Fletcher, L.J. Robinson and C. Blanche. 2002. Deliverable # 1 -- White paper on the 'state of knowledge of fragmentation'. In Forest Fragmentation Extension Programming: A National Initiative. A technical report of a collaborative project of USDA Cooperative State Research, Extension and Education Service, and the Natural Resources and Environment Base Program. pp. 88.

De Jong, W., U. Chokkalingam, J. Smith and C. Sabogal. 2001. Tropical secondary forests: Introduction and Synthesis. Journal of Tropical Forest Science, 13 (4): 563-576.

Didham, R.K. 1997. The influence of edge effects and forest fragmentation on leaf litter invertebrates in central Amazonia. In Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities. Eds. Laurance W.F. and Bierregaard, R.O., Jr. (1997). University of Chicago Press, Chicago & London. pp. 55-70.

Dutta, B.B. 1984. Modernisation of a tradition: The Garo Dimension. In Garo Hills Land and the People By L.S. Gassah. Omsans Publications, New Delhi. pp. 235.

Dutta, T. C. 1982. Krishi Batoriin Senj: a Monthly Assamese Agricultural Bulletin, 5th year: 5th issue (Feb-Mar Volume). pp. 75-78.

Forman, R. T. T. 1995. Land Mosaics: The ecology of landscapes and regions. Cambridge University Press, Cambridge. 632 pp.

Forman, R. T. T. and M. Godron. 1986. Landscape ecology. John Wiley and Sons, Inc. New York. 619 pp.

Frohn, R. C. 1998. Remote Sensing for Landscape Ecology; New meric, indicators for monitoring, modeling, and assessment of ecosystems. CRC Press LLC, Lewis Publishers, New York. 99 pp.

FSI. 1997. State of Forest Report. Forest Survey of India (MoEF, GOI), Dehradun.

FSI. 1999. State of Forest Report. Forest Survey of India (MoEF, GOI), Dehradun. At URL: http://envfor.nic.in/fsi/sfr99/sfr.html.

FSI. 2001. State of Forest Report. Forest Survey of India (MoEF, GOI), Dehradun. pp. 130.

Ganesh, T., R. Ganesan, M.S. Devy, P. Davidar, and K.S. Bawa. 1996. Assessment of plant biodiversity at a mid-elevation evergreen forest of Kalakad-Mundanthurai Tiger Reserve. *Current Science.* 71 (5): 379-392.

Ghosh, A. K. 1984. Faunal resources of Garo Hills. pp. 72-96 in: L. S. Gassah, editor. Garo Hills Land and the People. Omsons Publications, New Delhi, India. 235 pp.

Ghosh, A. K. and S. Biswas. 1977. A preliminary report on wildlife in Balpakram - a proposed sanctuary in Meghalaya, India, *Tigerpaper*, 4(1) 24-25.

Gittins, S.P. 1984. Feeding and ranging in gibbons: A summary. In: The Lesser Apes: Evolutionary and Behavioural Biology, pp. 258-266. H. Preuschoft, D.J. Chivers, W.Y. Brokelman, and N. Creel (eds.), Edinburgh Univ. Press, Edinburgh.

Gogoi, K. 1984. Geology and Mineral Resources of Garo Hills. pp. 40-51 in: L. S. Gassah, editor. Garo Hills Land and the People. Omsons Publications, New Delhi, India. pp. 235.

Gogoi, P.C. and Chowdhary 1982. Paper presented in the workshop on Elephant management in the wild and captivity at Jaldhapara, West Bengal from 10-17 December, 1982.

Gulinck, H., O. Walpot, P. Janssens and I. Drie. 1991. The visualization of corridors in the landscape using SPOT data, pp. 9-17. In D.A. Saunders and R.J. Hobbs (Eds.), Nature Conservation - 2: The Role of Corridors. Surrey Beatty & Sons Pty Limited, NSW 2170, Australia. 442 pp.

Gupta, A. K. 2000. Primates of Tripura. Micro Mint, Dehradun. 40 pp.

Haridasan, K. and R.R. Rao. 1985. The flora of Meghalaya Volumes I and II. Bishen Singh Mahendra Pal Singh, Dehradun. 937 pp.

Harris, L. D., and G. Silva-Lopez. 1992. Forest fragmentation and the conservation of biological diversity. In Conservation biology: the theory and practice of nature conservation preservation and management. New York USA: Chapman and Hall Ltd.

Hazarika, M.P. 1988. Basic statistics of north eastern region. N.E.C. Pub. No. 12. North Eastern Council, Shillong, India.

Heaney, A. and J. Procter. 1990. Preliminary studies on forest structure and floristics on Volcan Barva, Costa Rica. Journal of Tropical Ecology 6: 307-320.

Hmaier. 2002. A lecture note on Similarity Indices, available online at URL: http://www.geobotany.uaf.edu-teaching-biol475-lecture07_ho.pdf

Ho, C.C., D.McC. Newbery and M.E.D. Poore. 1987. Forest composition and inferred dynamics in Jengka forest reserve, Malaysia. Journal of Tropical Ecology 3: 25-26.

Hobbs, R.J., B.M.J. Hussey, D.A. Saunders (1989). Nature Conservation 2: The Role of Corridors. IALE Bulletin. Vol. 7 no. 2, December 1989. (URL:http://www.crle.uoguelph.ca/iale/)

Holdridge, L.R., W.C. Grenke, W.H. Hathway, T. Liang and J.A. Toshi (Jr.). 1971. Forest Environment in Tropical life zones: A pilot study. Pergamon Press, Oxford.

Howe, R. W. 1984. Local dynamics of bird assemblages in small forest habitat islands in Australia and North America. Ecology 65 (5):1585-1601.

Hubbell, S.P. and R.B. Foster. 1983. Diversity of canopy species in a neotropical forest and implications for conservation. pp. 22-42. In: S. L. Sutton, T. C. Whitmore and A. C. Chadwick (eds.) Tropical Rain Forest: Ecology and Management. Blackwell Sci. Publ., Oxford.

Hurlbert, S.H. 1971. The monoconcept of species diversity: a critique and alternative parameters. *Ecology*. 52: 577-586.

Itow, S. 1986. Species diversity of equatorial insular forest on Ponape and Kosrae, Micronesia. *Ecological Research* 1: 223-227.

IUCN, 2004. The World Heritage List: Future priorities for a credible and complete list of natural and mixed sites. A strategy paper presented by IUCN circulated in the National Seminar on World Heritage Properties, 23 September 2004.

Jacobs, M. 1981. The Tropical Rain Forest-A First Encounter. Springer-Verlag Berlin Heidelberg, New York, 1981, pp. 295.

Jaffre, T. and J.M. Veillon. 1990. Bullétin de Muséum Nationale Histoire naturale Paris 12, 243-273.

James, F.C. and S. Rathbun. 1981. Rarefaction, relative abundance, and diversity of avian communities. The Auk 98:785-800.

Jha, C.S. and J.S. Singh. 1990. Composition and dynamics of dry tropical Forest in relation to soil texture. Journal of Vegetation Science 1: 609-614.

Jha, L.K. 1997. Shifting cultivation. APH Publishing Corporation, New Delhi, India. 194 pp.

Kanjilal, U.N, P.C. Kanjilal and A. Das. 1934-40. Flora of Assam, vol. I to V (reprinted in 1982). Published under the authority of the Government of Assam by A Von Book Company, Delhi. pp. 2242-21. Sundarapandian, S.M. and Swamy, P.S., *J. Tropical Forest Science*, 2000, 12, 104-123.

Kapos V., E. Wandelli, J.L. Camargo, and G. Ganade. 1997. Edge-related changes in environment and plant responses due to forest fragmentation in central Amazonia. In Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities. Eds. Laurance W.F. and Bierregaard, R.O., Jr. (1997).University of Chicago Press, Chicago & London. pp. 33-44.

Kapos, V. 1989. Effects of isolation on the water status of forest patches in the Brazilian Amazon. *Journal Tropical Ecology* 5:173-185.

Kar, P. C. 1975. A new introduction of second Indian edition of book 'The Garos' by Major A. Playfair. Spectrum publications, Guwahati. 172 pp.

Kar, P. C. 1982. Glimpses of the Garos. Garo Hills Book Emporium, Tura, Meghalaya. 293 pp.

Kemp, S. and B. Chopra. 1924. The Siju Cave, Garo Hills, Assam, Introduction, 3-22, *Rec. Indian Mus.*, 26(1): 1-22.

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

Klein, B.C. 1989. Effects of forest fragmentation on dung and carrion beetle communities in central Amazonia. Ecology 70: 1715-1725.

Knight, D.H. 1975. A phytosociological analysis of species rich tropical forest on Borro Colorado Island, Panama. *Ecological Monographs.* 45: 259-284.

Kumar, A., A.K. Gupta, B.G. Marcot, A. Saxena, S.P. Singh and T.T.C. Marak. 2002. Management of Forests in India for Biological Diversity and Forests Productivity - A New Perspective, Volume IV: Garo Hills Conservation Area (GCA). WII-USDA Forest Service Collaborative Project Report, Wildlife Institute of India, Dehradun. 206 pp.

Kumar, P. and T.B. Singh. 1997. Habitat Characterisation of Balpakram National Park (Meghalaya) using Remote Sensing and Geographic Information System. M.Sc. Dissertation. Indian Institute of Remote Sensing, Dehradun.

Kumar, Y. and R.R. Rao. 1985. Studies on Balpakram Wildlife Sanctuary in Meghalaya - 3: General account, forest types and fauna. *Indian J. of Forestry*, 8(4), 300-309.

Kupfer, J.A., G.P. Malanson and S.B. franklin. 2004. Identifying the biodiversity research needs related to forest fragmentation. A report prepared for the National Commission, on Science for Sustainable Forestry (NCSSF) and funded by National Council for Science and the Environment (NCSE). pp. 215

Kushwaha, S.P.S. and S. Kuntz. 1993. Detection of Environmental changes in the tropical forests of north east India. Proceedings, 25th International Symposium, Remote Sensing and Global Environmental change, Graz, Austria.

Lakshmana, A.C. 1993. Rattans of South India. Evergreen publishers, Banglore. pp.180.

Laurance, W.F. 1991. Edge effects in tropical forest fragments: Application of a model for the design of nature reserves. *Biological Conservation* 69:23-32.

Laurance, W.F. 1997. Hyper-Disturbed Parks: Edge Effects and the Ecology of Isolated Rainforest Reserves in Tropical Australia. In Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities. Eds. Laurance W.F.

and Bierregaard, R.O., Jr. (1997).University of Chicago Press, Chicago & London. pp. 71-84.

Laurance, W.F. and E. Yensen. 1991. Predicting the impacts of edge effect in fragmented habitats. *Biological Conservation* 55:77-92.

Laurance, W.F. and R. O. Bierregaard. 1997. Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities. Eds. Laurance W.F. and Bierregaard, R.O., Jr. (1997). University of Chicago Press, Chicago & London. 616 pp.

Lewin, R. 1986. A mass extinction without asteroids. *Science* 234:14-15.

Lillesand, T.M. and R.W. Kiefer. 1994. Remote Sensing and Image Interpretation. John Wiley & Sons, Inc., New York. 721 pp.

Ludwig, J.A. and J.F. Reynolds. 1988. Statistical Ecology: A primer on methods and computing. Wiley-Interscience publication, New York, 337pp.

Lynam, A.J. 1995. Effects of habitat fragmentation on the distributional pattern of small mammals in a tropical forest in Thailand. Ph.D. dissertation, University of California, San Diego.

MacArthur, R.A., and E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton, NJ: Princeton University Press.

Marak, T.T.C. 1998. The elephant census report for Meghalaya. Wildlife Wing, Forest & Environment Department, Shillong, Meghalaya. 22 pp.

Marcot, B.G. and V.J. Meretsky. 1983. Shaping stands to enhance habitat diversity. *J. Forestry* 81:527-528.

Marcot, B.G., A. Kumar and Atul K. Gupta (2004). *Conserving Biodiversity in South Garo Hills, Meghalaya: Biosocial Implications.* In Biodiversity Conservation and Utilisation (eds. Alfred *et al.*). Jyoti Publisher, Dehradun. (in press).

Marcot, B.G., A. Kumar, P.S. Roy, V.B. Sawarkar, A. Gupta, and S.N. Sangama. 2002. Towards a landscape conservation strategy: analysis of *jhum* landscape and proposed corridors for managing elephants in South Garo Hills District and Nokrek area, Meghalaya. (English with Hindi summary). *The Indian Forester*, February: 207-216.

Marcot, B.G., and M. Vander Heyden. 2001. Key ecological functions of wildlife species. Pp. 168-186 in: D. H. Johnson and T. A. O'Neil, eds. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis OR. pp. 736.

Marcot, B.G., Kumar, A., Roy, P.S. and G. Talukdar (2004). *Elephants, People and Landscapes in the Garo Hills of Meghalaya.* In Biodiversity Conservation and Utilisation (eds. Alfred *et al.*). Jyoti Publisher, Dehradun. (in press).

Maslekar, A. R. 2000. Biodiversity: Information needs and available geo-spatial database. Pp. 1-8 in: Proceedings of the Workshop on "Biodiversity & Environment – Remote Sensisng & Geographic Information System Perspectives" by Indian Remote Sensisng Institute (IIRS), Dehra Dun and International Institute of Aerospace Survey and Earth Resources (ITC), The Netherlands. Published by IIRS, DehraDun, 219 pp.

Mathur, P.K., J.F. Lehmkuhl and V.B. Sawarkar (Technical Coordinators). 2002. Management of Forests in India for Biological Diversity and Forests Productivity, A New Perspective - Volume II: Wildlife-Habitat Relationships (WHR) in Conservation Areas. WII-USDA Forest Service Collaborative Project Report, Wildlife Institute of India, Dehradun. 224 pp.

McGarigal, K. and B. J. Marks. 1994. FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure, version 2, Oregon State University, Corvalis.

McIntyre, S. and Hobbs, R. 1999. A framework for conceptualizing human effects on landscapes and its relevance to management and research models. Conservation Biology 13: 1282-1292.

Medhi, D. K. 1984. *Jhum* fire and the ecology of Garo Hills. In Garo Hills Land and the People By L.S. Gassah. Omsans Publications, New Delhi. 235 pp.

Middleton, J., and G. Merriam. 1983. Distribution of woodland species in farmland woods. Journal of Applied Ecology 20 (2):625-644.

Mishra, B. K. and P. S. Ramakrishnan. 1982. Energy flow through a village ecosystem with slash & burn agriculture in north eastern India. Agric. System 9:83-96.

Misra, R., Ecology Workbook. Oxford & IBH Co. New Delhi, 1968, pp. 244.

Momin, P. G. 1984. Physical setting of Garo Hills. In Garo Hills land and the people, edited by L. S. Gassha. Omsons publications, New Delhi. pp. 235.

Morrison, M. L., B. G. Marcot, and R. W. Mannan. 1998. Wildlife-habitat relationships: concepts and applications. Second edition. Univ. of Wisconsin Press, Madison WI. pp.435.

Mosango, M. 1991.Contribution 'A l'étude botanic biogéochimiquéde 1' ecosystem Forêt en région equatorial (Ile Kongolo,Zaire). Belgian Journal of Botany 124:167-194.

Mukharjee, R.P. 1982. Survey of non-human primates of Tripura, India *J. Zool.Soc. India,* 34(1-2):70-81.

Murti, K. 1986. Some rare plants of Garo Hills, Meghalaya and their conservational aspects. *Indian Journal of Forestry* 9(3):237-240.

Myers, N. 1984. The Primary Source: Tropical Forests and Our Future. W.W. Norton, New York.

Negi, G. S. 1984. Landsat data in study of forest recession due to shifting cultivation - A case study in Garo Hills of Meghalaya. Indian Journal of Forestry 7(4): 273-280.Awasthi, A. 1999. Plant diversity of Meghalaya and some issues for concern. *Indian Journal of Forestry* 22 (1):14-21.

Nengminza, D.S. 1996. The school dictionary Garo to English. Thirteenth edition. Garo Hills Book Emporium, Tura, Meghalaya, India. 268 pp.

Norton, T.W. and H.A. Nix. 1991. Application of biological modeling and GIS to identify regional wildlife corridors, pp. 19-26. In D.A. Saunders and R.J. Hobbs (Eds.), Nature Conservation - 2: The Role of Corridors. Surrey Beatty & Sons Pty Limited, NSW 2170, Australia. 442 pp.

Parthasarathy, N. 1986. Studies on the vacular Flora, Structure and Nutrient Cycling in Kalakad Reserve Forest, Western Ghats, Tamil Nadu. Ph. D. Thesis. University of Madras, Madras.

Parthasarathy, N., V. Kinhal and L. Praveen Kumar. 1992. Plant species diversity and human impacts in the tropical wet evergreen forests of southern western ghats. Indo-French workshop on Tropical Forest ecosystems: Natural Functioning and anthropogenic impact, French Institute, Pondicherry - November 1992.

Patton, D. R. 1975. A diversity index for quantifying habitat edge. *Wildl. Soc. Bull.* 394:171-173.

Peet, R.K. 1974. The measurement of species diversity. *Ann. Rev. Ecol. Syst.* 5: 285-307.

Peet, R.K. 1975. Relative diversity indices. *Ecology* 56: 496-498.

Pielou, E.C. 1966a. The measurement of diversity in different types of biological collections. J. Theor. Boil. 13: 131-144.

Pielou, E.C. 1966b. Species diversity and the pattern diversity in the study of ecological succession. J. Theor. Biol. 10:370-383.

Pielou, E.C. 1966c. Shannon's formula as a measure of species diversity: its use and misuse. Amer. Natur.100: 463-465.

Pielou, E.C. 1975; Ecological diversity. New York, John Wiley and Sons. pp. 165.

Pillai, R. S., and T. S. N. Murhy. 1989. Amphibia. pp. 186-209 in: T. C. Mujapuria, editor. Wildlife wealth of India. Tec Press Service, L.P., Bangkok, Thailand.

Pillai, R.S. and G,M. Yazdani. 1977. Ichthyo fauna of Garo Hills, Meghalaya (India). *Rec. Indian Mus.* 26(1):1-22.

Playfair, Major A. 1998. The Garos with a new introduction by Parimal Chandra Kar (Second Indian reprint, first published in 1909). Spectrum Publications, Guwahati. 712 pp.

Poole, R.W. 1974. An introduction to quantitative ecology. New York McGraw - Hill Book Company.

Procter, J., Y.F. Lee, A.M. Langley, W.R.C. Munro and T. Nelson. 1988. Ecological studies on Gunung Silam, a small ultrabasic mountain Sabah, Malaysia. I. Environment, Forest structure and Floristics. *Journal of Ecology* 74: 455-463.

Quintela, C.E. 1985. Forest fragmentation and differential use of natural and man-made edges by understory birds in central Amazonia. M.Sc. thesis, University on Illinois, Chicago, Ill.

Rai, S.N. and J. Procter. 1986. Ecological studies on four rain forests in Karnataka, India I. Environment, forest structure and vegetation. Journal of Ecology 74: 455-463.

Ramakrishnan P.S. and Toky, O.P. 1983. Some aspect of degradation in north eastern hill areas of India. In: T.V. Singh, and J. Kaur (Eds.) Studies in Ecodevelopment: Himalayas Mountains and Men. pp. 149-156. Print house (India), Lucknow.

Ramakrishnan, P. S. 1985. Conversion of rain forests in north eastern India. In: J. S. Singh (Ed.) Environmental regeneration in the Himalaya: Concept and strategies. pp. 69-84. Central Environmental Association, Nainital.

Ramakrishnan, P.S. 1992. Shifting agriculture and sustainable development- An interdisciplinary study from North-east India (Man and Biosphere Series) UNESCO, Paris and the Parthenon Publishing Group.

Rao, R.R., and K. Haridasan. 1981. Notes on the distribution of certain rare, endangered or endemic plants of Meghalaya with a brief remark on the flora. Journal of the Bombay Natural History Society 79(1):93-99.

Rodgers, W.A. and H. S. Panwar. 1988. Planning a wildlife Protected area network in India. The report prepared for the Department of Environment, Forests and Wildlife (Vol. 1 & 2), Government of India, Chandrabani, Dehradun. pp. 341 & 267.

Romme, W.1982. Fire and landscape diversity in sub alpine forests of Yellowstone National Park. *Ecological Monographs* 52:199-221.

Roy, P.S. and S. Tomar. 2000. Biodiversity characterization at landscape level using geospatial modeling technique. Biological Conservation, 95(1): 95-109.

Roy, P.S. and Tomar, S., 2001, Landscape cover dynamics pattern in Meghalaya. International Journal of Remote Sensing, 22(18), 3813-3825.

Sangma, M.S. 1995. Hill Societies - Their Modernization: A study of north east with special reference to Garo Hills. Omsons publications, New Delhi. 229 pp.

Sarat Babu, G. V. and S. Arora. 1999. Hotspots of Biodiversity. Available on line at URL: http://envfor.nic.in/news/aug99/biodiv.html

Sawarkar, V.B. and B.G. Marcot (2002). Introduction to Wildlife Habitat Relationships (P. K. Mathur, J. F. Lehmkuhl, and V. B. Sawarkar, editors). Management of forests in India for biological diversity and forest productivity, a new perspective. Volume II: Wildlife - Habitat Relationships (WHR) in Conservation Areas. Wildlife Institute of India-USDA Forest Service collaborative project report. Wildlife Institute of India, Dehradun. 224 pp.

Schadt S., E. Revilla, T. Wiegand, and U. Breitenmoser. 2004. Fragmented landscapes, road mortality and patch connectivity: modelling influences on the dispersal of Eurasian lynx. *Journal of Applied Ecology.* 41: 711–723.

Schadt, S., E. Revilla, T. Wiegand, F. Knauer, P. Kaczensky, U. Breitenmoser, L. Bufka, J. Cerveny, P. Koubek, T. Huber, C. Stanisa, and L. Trepl. 2002a. Assessing the suitability of central European landscapes for the reintroduction of Eurasian lynx. *Jouranl of Applied Ecology.* 39: 189-203.

Schadt, S., F. Knauer, P. Kaczensky, E. Revilla, T. Wiegand, and L. Trepl. 2002b. Rule-based assessment of suitable habitat and patch connectivity for the Eurasian lynx. *Ecological Applications.* 12 (5): 1469–1483.

SFD. 1981. Report of Elephant Census of Balpakram. State Forest Department, Government of Meghalaya, Shillong.

SFD. 1993. Report of Elephant Census of Balpakram. State Forest Department, Government of Meghalaya, Shillong.

SFD. 1995. Forestry in Meghalaya: An overview. The Directorate of Forests, Government of Meghalaya, Shillong. 34 pp.

Sharma, T. C. 1984. Meghalaya in Prehistoric Times. pp. 1-14 in: L. S. Gassah, editor. Garo Hills Land & the People. Omsons Publications, New Delhi, India. 235 pp.

Simon, I. M. 1996. Garo Hills district Gazetter, government of Meghalaya, India. Published by Directorate of Arts and Culture, District Gazetteers, Brook Site Complex, Meghalaya, Shillong. 240 pp.

Singh, B. 1981. Establishment of first gene sanctuary in India for Citrus in Garo Hills. Concept Publishing Company. New Delhi. pp. 182.

Singh, J.S., Singh, S.P., Saxena, A.K. and Rawat, Y.S. 1984. The forest vegetation of Silent Valley. Tropical rain forests - The Leeds symposium, pp. 25-52.

Soule, M. E. and M. E. Gilpin. 1991. The theory of wildlife corridor capability, In D.A. Saunders and R.J. Hobbs (Eds.), Nature Conservation - 2: The Role of Corridors. Surrey Beatty & Sons Pty Limited, NSW 2170, Australia. pp. 442.

Southwood, T.R.E. 1978. Ecological methods. London, Chapman and Hall.

Srivastava, A. 1999. Primates of northeast India. Megadiversity Press, Bikaner, Rajasthan, India. pp. 208.

Sudhakar S. and Singh S.B. 1993. Forest type and density mapping in Meghalaya through digital image processing of Indian Remote Sensing Satellite data. Under the collaborative project of Forest Resource Division, Meghalaya and Regional Remote Sensing Service Centre, Kharagpur. pp. 45.

Sundarapandian, S.M. and P.S. Swamy. 2000. Forest ecosystem structure and composition along an altitudinal gradient in the Western Ghats, South India. *J. of Tropical Forest Science*. 12 (1) 104-123.

Swan Jr., F.R. 1988. Tree distribution patterns in the Bukittimah nature reserve, Singapore. Garden Bulletin of Singapore 41: 59-81.

Sykes, J.M. and A.D. Horrills. 1977. Vegetation monitoring in Indian Tiger Reserves; A report to the WWF. pp. 121.

Takhtajan, A. L. 1988. Floristic Regions of the World. Bishen Singh Mahendra Pal Singh, Dehradun, India. pp. 522.

Talukdar, G. 2004. Geospatial Modelling of Shifting Cultivation Induced Landscapes of Meghalaya. Ph.D. thesis submitted to the University of Pune, Pune.

Temple, S.A. 1986. Predicting impacts of habitat fragmentation on forest birds: a comparison of two models. In J. Verner, M. L. Morrison, and C. J. Ralph, eds. Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates. Univ. of Wisconsin Press, Madison, WI. pp. 301-304.

Thorington, R.W., S. Tannenbaum, A. Tarak and R. Rudran. 1982. Distribution of trees in Baro colorado Islands: A five hectare sample. In: E. G. Leigh Jr., A. S. Rand and D.

M. Windsor (eds.) The Ecology of a Tropical Forest-Seasonal Rhythms and Long-term Changes. Smithsonian Institute Press, Washington D. C. pp. 468.

Tilman, D., R. M. May, C. L. Lehman, M. A. Nowak. 1994. Habitat destruction and the extinction debt. *Nature*. 371: 65-66.

Tilson, R.L. 1979. On the behaviour of hoolock gibbons (*Hylobates hoolock*) during different seasons in Assam, India. *J. Bombay Nat. hist. Soc.*, 76:1-16

Tiwari, B.K., S.K. Barik, and R.S. Tripathi. 1999. Sacred forests of Meghalaya. Regional Centre, North Eastern Hill University, Shillong, Meghalaya. 120 pp.

Turton and Freiburger. 1997. Edge and aspect effects on the microclimate of a small tropical forest remnant on the Antherton Tableland, northeastern Australia. In Tropical Forest Remnants: Ecology, Management, and Conservation of Fragmented Communities. Eds. Laurance W.F. and Bierregaard, R.O., Jr. (1997). University of Chicago Press, Chicago & London. pp. 45-54.

UNESCO, 2004. http://www.thesalmons.org/lynn/world.heritage.html

Visalakshi, N. 1995. Vegetation analysis of two Tropical Dry Evergreen Forests in Southern India. Tropical Ecology 36 (1): 117-127.

Williams, A.C. and A. J.T. Johnsingh. 1996. Threatened elephant corridors in Garo Hills, Northeast India. *Gajah* 16: 61-68

Williams-Linera, G. 1990. Vegetation structure and environmental conditions of forest edges in Panama. *Journal of Ecology* 78:356-373.

WWF. 1996. URL: http://www.panda.org/about_wwf/what_we_do/species/what_we_do/flagship_species/elephants/asian_elephant/population.cfm

Zhang, J. and M. Cao. 1995. Tropical forest vegetation of Xishuanbana, SW China and its secondary changes, with special reference to local nature conservation. . *Biological Sciences* 73: 229-238.

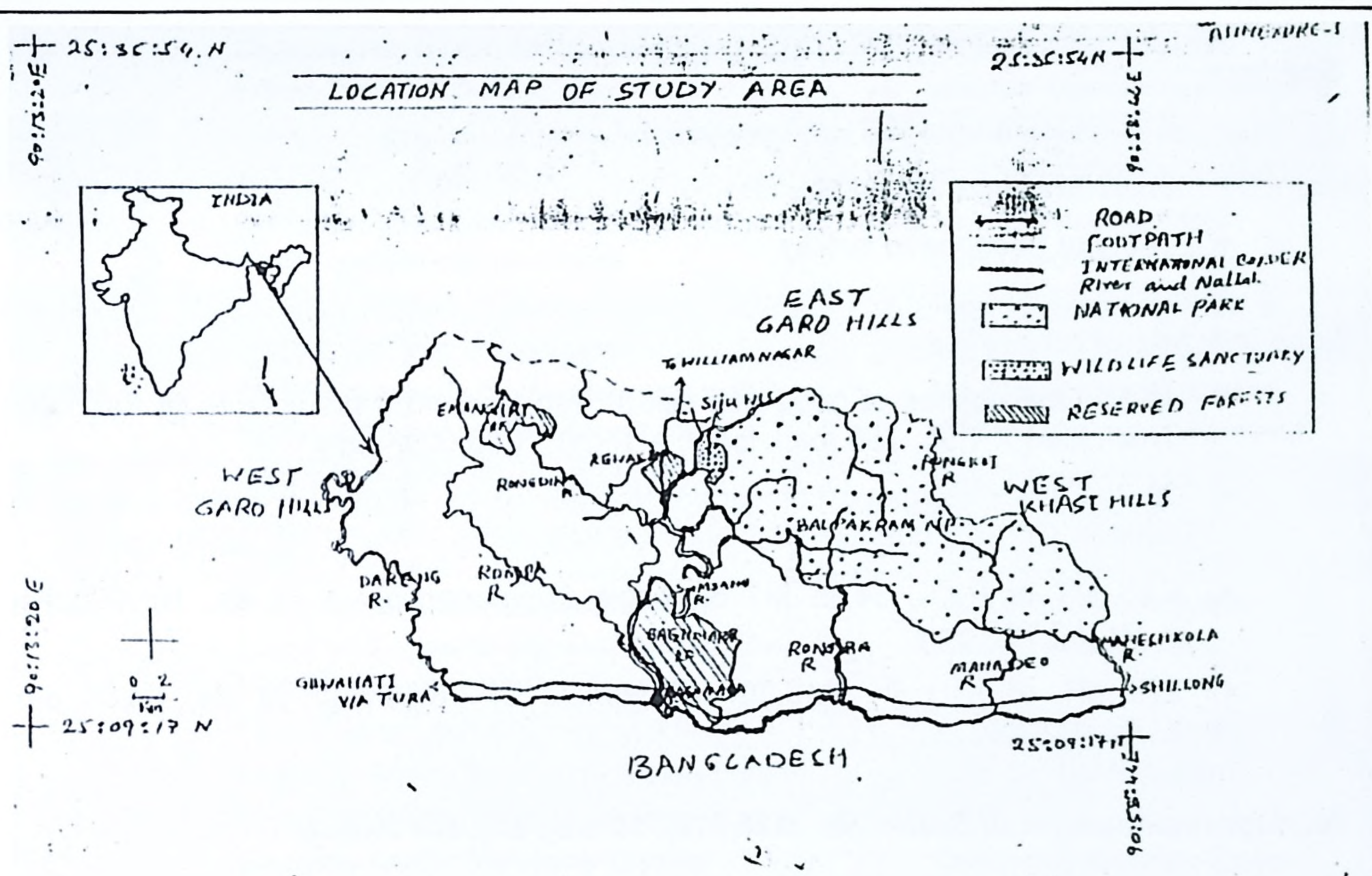
ZSI. 1995b. Fauna of Meghalaya Part - 3: Insecta. Zoological Survey of India, Kolkata. 455 pp. [State Fauna Series 4 To be complete in 10 parts].

ZSI. 1995a. Fauna of Meghalaya part -1: Vertebrates. Zoological Survey of India, Kolkata. 679 pp.

APPENDICES

APPENDIX 1.1

Proposed Study Area in synopsis



Proposed study area was a small portion of landscape studied in present study, which is located in the southern part of South Garo Hills district.

Longitude 90o25'8" to 90o58'49" E and Latitude25o9'15" to 25o24'8" N (area 1030 sq. km).

Proposed hypotheses as stated in synopsis

i) forest fragmentation has no effect on the tree diversity of primary forest ecosystems of the South Garo Hills

ii) there is no difference among tree diversity values of the successional stages of secondary forests and primary forests

Proposed objectives

i) to assess diversity patterns and successional changes among tree communities in various forest landuse categories
ii) to analyse landscape characteristics to evaluate critical wildlife habitats
iii) to develop models based on the above information using remote sensing and GIS to identify wildlife area priorities for conservation and management targets

APPENDIX 2.1

SOIL AND WATER VEGETATION LOSS DUE TO *JHUMMING* IN MONETARY TERMS

Source: Momin, 1995, Joint Director, Directorate of Soil Conservation, Shillong, Meghalaya (Personal Communication)

Soil loss

- 41 Metric Tonnes (MT) soil per year
- 0.703 MT Organic compounds
- 146 g of Phosphatic fertility

Loss in terms of money

- 15.58 Lakh tonnes of good rich soil for replacement if predictable @ Rs. 1,600 per Truck load X 1,94, 750 truck loads = Rs. 3,11,60,000/- only
- 26,714 MT of Organic compounds to replace by equivalent quantity of cow dung manure @ Rs. 3,000 per truck load X 3,340 trucks = Rs. 10,020,000 only.
- 5.55 MT of P_2O_5, 34.96 MT of Single Super phosphate @ Rs. 15, 000 per MT = Rs. 52,503 only
- 226 MT of K_2O = 443.30 MT Muriate of Potash @ @ Rs. 9,200 per MT = Rs. 4, 07,836

Total for replacement of Soil = Rs. 326,218,710 only say 326 Million.

Vegetation loss in terms of money

First class timber 95,000 Cubic m @ Rs. 1,000 per cubic m	= Rs. Rs. 95 Million
Firewood 4,56,000 MT @ say Rs. 2,00 per MT at MT/ha	= Rs. 91.2 Million
Fibre species say at 0.1 MT/ha = 3,800 MT @ Rs. 500	= Rs. 1.9 Million
Bamboo, say 0.5 MT/ha = 19,000 MT @ Rs. 625 per M	= Rs. 11.875 Million
Broom stick, say 19,000 MT @ 1,000 per MT	= 19 MT
Thatch grass, say 50 bundles/ ha @ Rs. One per bundle	= 1.9 Million
Cane, 15 Million running meters @ Rs. 1.50 per meters	=2.25 Million

Loss of vegetation	= Rs. 22,31,25,000
Adding the loss of Soil	= Rs. 32,62,18,710
Total Loss due to *jhum*	= Rs. 54,93,43,710 say 549 million
Return from *jhum* (380 sq km plot)	= Rs. 8,63,51,580 say 86 million
Net loss due to jhum	***= Rs. 462,992,130 say 462 million only***

This works out to Rs. 12,200 /ha/year.

APPENDIX 3.1

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	*Schima wallichii-Polyalthia simiarum-Aphanamixis polystachya*
BNP9	Young secondary forests in BNP near village Rongsu, about 7-8 km from Siju WLS	*Schima wallichii-Castonopsis purpurella-Callicarpa arborea*
BNPBASE1	Old Primary forest in Mahadeo gorge in BNP mainly riverine and semi-evergreen forest	*Michelia champaca-Kaeya floribunda-Grewia microcos*
BNPBASE2	Old Primary forest in the Mahadeo gorge in BNP mainly riverine and semi-evergreen forest	*Tetrameles nudiflora-Polyalthia simiarum-Canarium strictum*
BNPBASE3	Old Primary forest in the Mahadeo gorge in BNP mainly riverine and semi-evergreen forest	*Polyalthia simiarum-Canarium strictum-Drimycarpus racemosus*
BNPPFA	Primary forest in the limestone area of BNP sometimes touches the edges with old secondary forest of deciduous nature	*Polyalthia simiarum-Michelia champaca-Walsura tubularis*
BNPPFB	Primary forest in the limestone area of BNP sometimes touches the edges with old secondary forest of deciduous nature	*Walsura tubularis-Polyalthia simiarum-Mesua ferrea*
BNPPFC	Primary forest in the limestone area of BNP sometimes touches the edges with old secondary forest of deciduous nature	*Polyalthia simiarum-Walsura tubularis- Mesua ferrea*
BNPSF1	Secondary forest in BNP, below 10 years	*Castonopsis purpurella-Schima wallichii-Syzygium cuminni*
BNPSF2A	Secondary forest in BNP, 10-20 years	*Schima wallichii-Macaranga denticulate-Syzygium cuminni*
BNPSF2B	Secondary forest in BNP, 10-20 years	*Macaranga denticulate-Albizia odoratissima-Bignonia* spp.
BNPSF3A	Secondary forest in BNP, 20-30 years	*Grewia microcos-Aporusa dioica-Castonopsis purpurella*
BNPSF3B	Secondary forest in BNP, 20-30 years	*Grewia microcos-Aporusa dioica-Terminalia balerica*
BRFN5	Natural Forest at moist places in Baghmara Reserved forests surrounded by old Sal forest	*Castonopsis purpurella-Grewia microcos-Cynometra polyandra*
BRFN6	Natural Forest at moist places in Baghmara Reserved forests surrounded by old Sal forest	*Schima wallichii-Aporusa dioica-Castonopsis purpurella*
BRFN7	Natural Forest at moist places in Baghmara Reserved forests surrounded by old Sal forest	*Castonopsis purpurella-Dillenia pentagyna- Celtis tetranda*
BRFPL1	Sal Forest in alluvial soil and lower part of hills near simsang river in Baghmara Reserved forests (Locally known as Sal Plantation)	*Shorea robusta-Artocarpus chaplasha-Aporusa dioica*

PLOT CODE	DESCRIPTION OF PLOT	FOREST FORMATION
BRFPL8	Sal Forest in alluvial soil and lower part of hills near simsang river in Baghmara Reserved forests (Locally known as Sal Plantation)	*Shorea robusta- Schima wallichii-Aporusa dioica*
BRFPL9	Sal Forest in alluvial soil and lower part of hills near simsang river in Baghmara Reserved forests (Locally known as Sal Plantation)	*Shorea robusta-Glycosmis arborea-Tectona grandis*
ERF1	Old forest in side Emangiri Reserved Forest	*Schima wallichii- Shorea robusta-Syzygium cuminni*
ERF2	Old forest in side Emangiri Reserved Forest	*Schima wallichii-Lagerstroemia parviflora-Grewia microcos*
ERF3	Old forest in side Emangiri Reserved Forest	*Cynometra polyandra-Castonopsis purpurella-Sapium baccatum*
IVR1	Village reserve forest in the surrounding areas Emangiri Reserved Forest	*Shorea robusta- Schima wallichii-Dillenia pentagyna*
IVR2	Village reserve forest in the surrounding areas Emangiri Reserved Forest	*Schima wallichii-Sapium baccatum-Syzygium cuminni*
IVR3	Village reserve forest in the surrounding areas Emangiri Reserved Forest	*Schima wallichii-Castonopsis purpurella-Shorea robusta*
IVR4	Village reserve forest in the surrounding areas Emangiri Reserved Forest	*Schima wallichii-Macaranga denticulate-Shorea robusta*
NNP1	Old, moist Primary forest at Nokrek ridge near Nokrek peak in Nokrek National Park	*Syzygium operculatum-Aphanamixis polystachya-Castonopsis* spp.
NNP3	60 years old secondary forest (Looks like Primary forest), at neighbouring hills of Nokrek hills Outside Nokrek National Park	*Diospyros variegata-Castonopsis purpurella-Calophyllum polyanthum*
NNP4	Old, moist Primary forest at Nokrek ridge near Nokrek Peak inside Nokrek National Park	*Diospyros variegata-Castonopsis* spp.-*Castonopsis purpurella*
NNPTURAPE	Old, moist Primary forest at Tura Peak inside Tura reserve at the western most corner of Tura ridge, a very important catchment area.	*Castonopsis* spp.- *Schima wallichii-Aphanamixis polystachya*
RRF1	Old forest in Rewak resered forest nearby rivers	*Shorea robusta- Dillenia pentagyna-Lagerstroemia parviflora*
RRF2	Old forest in Rewak resered forest nearby rivers	*Tectona grandis-Shorea robusta-Tetrameles nudiflora*
SWS1	Semi-evergreen forest in Siju WLS	*Schima wallichii-Grewia microcos-Persia villosa*
SWS2	Semi-evergreen forest with the higher proportion of deciduous trees near lake in Siju WLS	*Diospyros variegata-Tetrameles nudiflora-Cynometra polyandra*
SWS3	Semi-evergreen forest in Siju WLS	*Shorea robusta- Aporusa dioica-Grewia microcos*

APPENDIX 3.2

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, MIXEDD = MIXED DECIDUOS FORESTS, RB = RIVER BANK AND BLANK = NOT KNOWN.

Scientific name	Family	Conservation status	Habitat
Alangium salvifolium	Alangiaceae		
Anacardium occidentale Linn.	Anacardiaceae	c	cult
Drimycarpus racemosus (Roxb.) Hk. f.	Anacardiaceae	o	ev
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	c	dd, SF, open
Mangifera indica Linn.	Anacardiaceae	o	cult
Mangifera sylvatica Roxb.	Anacardiaceae		ev
Rhus acuminata DC.	Anacardiaceae	f	open, edge
Rhus javanica Linn.	Anacardiaceae		SF, open, edge
Semecarpus anacardium Linn. f.	Anacardiaceae	c	dd, SF
Spondias axillaris Roxb.	Anacardiaceae	f	ev, mixdd
Spondias pinnata (Linn. f.) Kurz.	Anacardiaceae	c	dd
Alphonsea ventricosa Hk. f.	Annonaceae		
Miliusa roxburghiana (Wall.) Hk. f.	Annonaceae	c	ev
Miliusa tomentosa (Roxb.) Sinclair	Annonaceae		
Miliusa velutina Hk. f.	Annonaceae	r	Sal
Mitrephora tomentosa Hk. f. & Th.	Annonaceae		dd
Polyalthia jenkinsii Benth. & Hk. f.	Annonaceae	c	ev
Polyalthia simiamum (Hk. f. & Th.) Hk. f. & Th.	Annonaceae	r	ev
Alstonia scholaris (Linn.) R. Br.	Apocynaceae	f	dd, SF, edge
Holarrhena antidysenterica (Roth) A. DC.	Apocynaceae	c	SF, dry sandy
Plumeria rubra Linn.	Apocynaceae		cult
Thevetia peruviana (Pers.) K. Schum.	Apocynaceae	c	SF, dd
Wrightia arborea (Dennst.) Mabberley	Apocynaceae		cult
Ilex embelioides Hk. f.	Aquifoliaceae	r	
Ilex excelsa (Wall.) Hk. f.	Aquifoliaceae	c	ev
Ilex fragilis Hk. f.	Aquifoliaceae	r	
Ilex umbellulata (Wall.) Loes.	Aquifoliaceae	c	
Areca catechu Willd.	Araceae		
Aralia thomsonii Seem	Araliaceae		PF, road cutting
Brassiopsis glomerulata (Bl.) Regel	Araliaceae	f	ev

Scientific name	Family	Conservation status	Habitat
Heteropanax fragrans (D. Don) Seem	Araliaceae		ev, disturbed
Macropanax dispermus (Bl.) O. Ktz.	Araliaceae		broadleaved
Macropanax undulatus (Wall ex G. Don) Seem	Araliaceae	c	ev
Merilliopanax japonicum Seem	Araliaceae		
Parapentapanax subcordatum (G. Don) Hutch.	Araliaceae	c	rocky
Schefflera hypoleuca (Kurz.) Harms	Araliaceae	c	
Schefflera wallichiana (W. & A.) Harms	Araliaceae	c	ev
Trevesia palmata (Roxb.) Vis.	Araliaceae		ev, streamlets
Caryota urens Linn.	Arecaceae	f	
Licuala peltata Roxb.	Arecaceae		
Phoenix humilis Royle	Arecaceae		
Pinanga gracilis Bl.	Arecaceae		
Vernonia arborea Buch.-Ham.	Asteraceae	r	open
Vernonia volkameriifolia DC.	Asteraceae	f	Dry areas
Averrhoa carambola Linn.	Averrhoaceae		sandy,cult, wild
Careya arborea Roxb.	Barringtoniaceae	c	mixev
Betula alnoides Buch.-Ham. ex D. Don	Betulaceae	c	higher elevation
Jacaranda mimosifolia D. Don	Bignoniaceae	c	cult
Oroxylum indicum (Linn.) Vent.	Bignoniaceae	c	dd
Radermachera gigantea (Bl.) Miq.	Bignoniaceae	r	
Stereospermum chelonoides (Linn. f.) DC.	Bignoniaceae	c	ev, dd
Bischofia javanica Bl.	Bischofiaceae	c	ev,mixev
Salmalia malabarica (DC.) Schott. & Endlicker	Bombacaceae	c	SecF
Cordia dichotoma Forst. f.	Boraginaceae	r	dd
Cordia fragrantissima Kurz.	Boraginaceae	r	ev
Cordia grandis Roxb.	Boraginaceae	f	rb
Bursera serrata Colebr.	Burseraceae	c	ev, mixed
Canarium strictum Roxb.	Burseraceae	r	edge, ev, rb
Garuga pinnata Roxb.	Burseraceae	c	dd, open
Acrocarpus fraxinifolius Arn. ex Wt.	Caesalpiniaceae	f	dd
Bauhinia malabarica Roxb.	Caesalpiniaceae		
Bauhinia purpurea Linn.	Caesalpiniaceae	c	dd, SF, edge
Bauhinia retusa Ham.	Caesalpiniaceae		
Bauhinia variegata Linn.	Caesalpiniaceae	f	dd
Cassia fistula Linn.	Caesalpiniaceae	c	plantation, wild
Cynometra polyandra Roxb.	Caesalpiniaceae	c	ev

Scientific name	Family	Conservation status	Habitat
Delonix regia (Boj.) Rafim.	Caesalpiniaceae		cult
Saraca asoca (Roxb.) de Wilde	Caesalpiniaceae	r	ev, rb,cult
Crataeva nurvala Buch.-Ham.	Capparidaceae	r	ev
Crataeva religiosa Forst.	Capparidaceae		
Viburnum colebrookianum Wall. ex DC.	Caprifoliaceae	c	
Calophyllum polyanthum Choisy	Clusiaceae		PF
Garcinia acuminata Planch. & Triana	Clusiaceae	c	ev
Garcinia anomala Planch. & Triana	Clusiaceae		
Garcinia cowa Roxb. ex DC.	Clusiaceae	c	Mixed ev
Garcinia lancifolia (G.Don) Roxb.	Clusiaceae		ev
Garcinia morella Desr.	Clusiaceae		ev
Garcinia paniculata (G.Don) Roxb.	Clusiaceae		ev
Garcinia tinctoria (DC.) W. F. Wight	Clusiaceae	c	ev
Garcinia xanthochymus Hk. f.	Clusiaceae	c	
Kayea floribunda Wall.	Clusiaceae	c	ev
Mesua ferrea Linn.	Clusiaceae		ev
Microtropis discolor (Wall.) Arn.	Clusiaceae	f	ev
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	c	ev, dd
Terminalia chebula Retz.	Combretaceae	f	
Terminalia citrina (Gaertn.) Flem.	Combretaceae	c	
Terminalia myriocarpa Heurck & Muell.-Arg.	Combretaceae	c	ev
Crypteronia paniculata Bl.	Crypteroniaceae		
Dillenia indica Linn.	Dilleniaceae	c	ev, rb
Dillenia pentagyna Roxb.	Dilleniaceae	c	dd
Dillenia scabrella (D. Don) Roxb. ex Wall.	Dilleniaceae		dd
Shorea robusta Gaertn.	Dipterocarpaceae	c	dd
Vatica lanceaefolia Bl.	Dipterocarpaceae	c	dd, rb
Diospyros kaki Thumb.	Ebenaceae	f	open
Diospyros lancifolia Roxb.	Ebenaceae	c	ev, rb
Diospyros malabarica (Desr.) Kostel	Ebenaceae	f	
Diospyros montana Roxb.	Ebenaceae	f	SF, PF, edge
Diospyros toposia Ham.	Ebenaceae	f	PF, ev
Diospyros variegata Kurz	Ebenaceae	c	ev, open
Ehretia acuminata R. Br.	Ehretiaceae	c	ev, open
Echinocarpus assamicus Benth.	Elaeocarpaceae	c	rb
Elaeocarpus aristatus Roxb.	Elaeocarpaceae		

Scientific name	Family	Conservation status	Habitat
Elaeocarpus floribundus Bl.	Elaeocarpaceae		
Elaeocarpus lancifolius Roxb.	Elaeocarpaceae	c	
Elaeocarpus rugosus Roxb.	Elaeocarpaceae	c	
Elaeocarpus varuna Ham. ex Mast.	Elaeocarpaceae	c	Ev, dd
Alchornea tiliaefolia Muell.-Arg.	Euphorbiaceae	c	Mixed sal
Antidesma bunius (Linn.) Spreng.	Euphorbiaceae	c	
Antidesma nigricans Tul.	Euphorbiaceae	f	bmb
Aporusa aurea Hk. f.	Euphorbiaceae	f	dd, bmb
Aporusa dioica (Roxb.) Muell.-Arg.	Euphorbiaceae	c	dd, mixedd
Aporusa oblonga Muell.-Arg.	Euphorbiaceae	c	dd
Aporusa wallichii Hk. f.	Euphorbiaceae	f	
Baccaurea ramiflora Lour.	Euphorbiaceae		cult
Bridelia monoica (Lour.) Mess	Euphorbiaceae	c	dd
Bridelia retusa (Linn.) Spreng	Euphorbiaceae	c	sal, mixedd
Chaetocarpus castanocarpus (Roxb.) Thw.	Euphorbiaceae	c	sandy rb
Cleidion spiciflorum (Burm.) Merr.	Euphorbiaceae	c	ev
Cleistanthus chartaceus Muell.-Arg.	Euphorbiaceae	f	
Croton joufera Roxb.	Euphorbiaceae	c	dd, sal
Croton roxburghii Balak.	Euphorbiaceae	c	dd
Drypetes lancifolia (Hk. f.) Pax et Hoffm.	Euphorbiaceae	r	
Emblica officinalis Gaertn.	Euphorbiaceae	c	SF,dd
Glochidion acuminatum Muell.-Arg.	Euphorbiaceae	f	
Glochidion hirsutum Muell.-Arg.	Euphorbiaceae	f	sal
Glochidion sphaerogynum Kurz	Euphorbiaceae	c	SF,edge
Glochidion velutinum Wt.	Euphorbiaceae	c	SF
Hevea brasiliensis Muell.-Arg.	Euphorbiaceae		plt
Macaranga denticulata Muell.-Arg.	Euphorbiaceae	c	SF, *jhum*
Macaranga indica Wt.	Euphorbiaceae	f	ev
Mallotus albus Muell.-Arg.	Euphorbiaceae	c	Mixed ev
Mallotus leucocarpus (Kurz) A. Shaw	Euphorbiaceae	f	ev
Mallotus philippinensis (Lam.) Muell.-Arg.	Euphorbiaceae	o	dd
Mallotus roxburghianus Muell.-Arg.	Euphorbiaceae		
Mallotus tetracoccus (Roxb.) Kurz.	Euphorbiaceae	c	ev, mixed ev
Ostodes paniculata Bl.	Euphorbiaceae	c	ev
Sapium baccatum Roxb.	Euphorbiaceae	c	ev
Sapium eugeniaefolium Ham. ex Hk. f.	Euphorbiaceae		ev

Scientific name	Family	Conservation status	Habitat
Trewia nudiflora Linn.	Euphorbiaceae	c	dd, rb
Butea monosperma (Lamk.) Ktz.	Fabaceae	r	dd, SF, open
Dalbergia stipulacea Roxb.	Fabaceae	c	sal
Derris robusta (Roxb. ex DC.) Benth.	Fabaceae	c	ev, dd
Erythrina stricta Roxb.	Fabaceae	c	dd
Erythrina suberosa Roxb.	Fabaceae		
Milletia picsidia Wt.	Fabaceae	c	
Castanopsis armata Spach.	Fagaceae	c	ev, edges
Castanopsis indica A. DC.	Fagaceae	c	ev
Castanopsis kurzii (Hance) Biswas	Fagaceae		
Castanopsis purpurella (Miq.) Balak.	Fagaceae	c	ev, stream
Castanopsis tribuloides (Sm.) DC.	Fagaceae	c	ev, stream
Lithocarpus elegans (Bl.) Hatus ex Soep.	Fagaceae	c	lower elevation
Casearia glomerata Roxb.	Flacourtiaceae		Mixed ev
Casearia kurzii Cl.	Flacourtiaceae	f	ev
Casearia zeylanica (Gaert.) Thw.	Flacourtiaceae		
Gynocardia odorata R. Br.	Flacourtiaceae	c	ev,mixed ev
Homalium bhamoense Cubit et Sm.	Flacourtiaceae	r	lower elevation
Homalium schlichii Kurz	Flacourtiaceae	r	
Xylosma controversum Clos.	Flacourtiaceae		SF
Xylosma longifolium Clos.	Flacourtiaceae		
Exbucklandia populnea (R. Br. ex Griff)	Hamamelidaceae	c	
Engelhardtia roxburghiana Wall.	Juglandaceae	r	lower elevation
Engelhardtia spicata Leschn. ex Bl.	Juglandaceae		
Engelhardtia spicata var. colebrookeana (Wall.) Kds. & Val. Bijdr.	Juglandaceae	c	
Engelhardtia spicata var. spicata	Juglandaceae		
Actinodaphne augustifolia Nees	Lauraceae	c	
Actinodaphne obovata (Nees) Bl.	Lauraceae	c	Moist, shady, ev
Beilshmiedia fagifolia Nees	Lauraceae	r	ev
Beilshmiedia roxburghiana Nees	Lauraceae	c	Stream bank
Cinnamomum bejolghota (Buch.-Ham.) Sweet.	Lauraceae	c	ev, mixedd
Cinnamomum glanduliferum (Wall.) Meissn.	Lauraceae	c	
Cinnamomum glaucescens (Nees) Meissn.	Lauraceae	c	
Cinnamomum tamala Fr. Nees	Lauraceae	c	SF, cult,

Scientific name	Family	Conservation status	Habitat
Cryptocarya amygdalina Nees	Lauraceae	c	sal
Cryptocarya andersonii King ex Hk. f.	Lauraceae	r	
Lindera melastomacea Benth.	Lauraceae	c	
Lindera nacusua (D. Don) Merr.	Lauraceae	f	
Lindera pulcherrima (Nees) Benth.	Lauraceae	c	
Litsea cubeba (Lour.) Pers.	Lauraceae	c	SF
Litsea glutinosa	Lauraceae		
Litsea lancifolia (Roxb. ex Nees) Wall. ex Hk. f.	Lauraceae	f	ev
Litsea meissneri Hk. f.	Lauraceae	f	ev
Litsea monopelata (Roxb.) Pers.	Lauraceae	f	plt
Litsea salicifolia (Roxb. ex Nees) Hk. f.	Lauraceae	c	
Litsea sebifera Pers.	Lauraceae	c	ev
Litsea tomentosa Nees	Lauraceae		
Neocinnamomum caudatum (Wall. ex Nees) Merr.	Lauraceae	f	
Neolitsea umbrosa (Nees) Gamble	Lauraceae		
Persea odoratissima (Nees) Koster.	Lauraceae	c	
Persea petiolaris (Hk. f.) Deb.	Lauraceae	f	
Persea villosa (Roxb.) Koster.	Lauraceae	c	ev,SF,mixedd
Phoebe attenuata (Nees) Nees	Lauraceae	c	ev
Phoebe cooperiana U. N. Kanjilal	Lauraceae	r	dd
Phoebe goalparensis	Lauraceae		
Phoebe lanceolata (Nees) Nees	Lauraceae	c	ev,rb
Phoebe paniculata Nees	Lauraceae	r	
Leea compactiflora Kurz	Leeaceae	c	ev
Leea edgeworthii Sant.	Leeaceae	c	dd, mixed ev
Leea indica (Burm. f.) Merr.	Leeaceae	c	dd, SF, edge
Fagraea ceilanica Thumb.	Loganiaceae	r	dd
Lagerstroemia parviflora Roxb.	Lythraceae	c	dd, mixedd
Lagerstroemia speciosa (Linn.) Pers.	Lythraceae	c	rb, edge, cult
Magnolia pterocarpa Roxb.	Magnoliaceae	c	ev
Manglietia insignis (Wall.) Bl.	Magnoliaceae	c	ev
Michelia champaca Linn.	Magnoliaceae	c	ev
Michelia doltsopa DC.	Magnoliaceae	c	ev
Michelia oblonga Wall. ex Hk. f.	Magnoliaceae	c	ev
Talauma hodgsonii Hk. f. & Th.	Magnoliaceae		
Hibiscus macrophyllus Roxb. ex Hornem.	Malvaceae		ev dd

Scientific name	Family	Conservation status	Habitat
Kydia calycina Roxb.	Malvaceae	c	
Memecylon cerasiforme Kurz	Melastomataceae	f	stream
Aglaia edulis A. Gray	Meliaceae	c	ev
Aphanamixis polystachya (Wall.) Parker	Meliaceae	c	ev
Aphanamixis wallichii (King.) Haridasan et Rao	Meliaceae	c	ev
Chikrassia tabularis Anbr. Juss.	Meliaceae		ev
Chisocheton paniculatus (Roxb.) Hiem.	Meliaceae	c	ev, dd
Dysoxylum alliarium (Ham.) Balak.	Meliaceae		
Dysoxylum binectariferum Hk. f. et. Bedd.	Meliaceae	c	
Dysoxylum gobara (Buch.-Ham.) Merr.	Meliaceae	c	ev
Melia azedarach Linn.	Meliaceae		cultiv
Toona ciliata Roem.	Meliaceae	c	dd, mixedd
Walsura robusta Roxb.	Meliaceae	c	ev, edge
Walsura tubulata Hiem	Meliaceae	r	
Acacia auriculiformis A. Cuno. ex Benth.	Mimosaceae		
Albizia chinensis (Osb.) Merr.	Mimosaceae		
Albizia lebbek (Linn.) Benth.	Mimosaceae	f	dd, open
Albizia lucidior (Steud.) Neilson ex Hara	Mimosaceae	c	ev,dd,rb
Albizia mollis Boiv.	Mimosaceae	c	
Albizia odoratissima (Linn. f.) Benth.	Mimosaceae	c	dd
Albizia procera (Roxb.) Benth.	Mimosaceae	c	dd, SF, open
Calliandra umbrosa (Wall.) Benth.	Mimosaceae	c	SF
Parkia roxburghii G. Don	Mimosaceae	r	dd, mixed ev
Pithecellobium heterophyllum (Roxb.) Haridasan & Rao	Mimosaceae	c	dd, SF
Pithecellobium monadelphum (Roxb.) Koster.	Mimosaceae	f	ev, edge
Artocarpus chaplasha Roxb.	Moraceae		
Artocarpus gomezians spp. Gomezianus Wall. ex Trecul	Moraceae		
Artocarpus gomezianus spp. zeylanicus Wall. ex Trecul	Moraceae	r	dd
Artocarpus heterophyllus Lamk.	Moraceae	o	cult, wild
Broussonetia papyrifera Vent	Moraceae	r	cult
Ficus altissima Bl.	Moraceae	r	open area
Ficus benghalensis Linn.	Moraceae	f	bmb, others
Ficus benjamina Linn.	Moraceae	r	cult
Ficus cyrtophylla Wall. ex Miq.	Moraceae	c	ev
Ficus drupacea Thumb.	Moraceae	f	ev
Ficus elastica Roxb. ex Homem.	Moraceae	f	ev, rb

Scientific name	Family	Conservation status	Habitat
Ficus fistulosa Reinwdt.	Moraceae	f	dd, rb
Ficus gibbosa Bl.	Moraceae	f	
Ficus glaberrima Bl.	Moraceae	f	dd
Ficus heterophylla Linn. f.	Moraceae	f	rb
Ficus hirta Vahl	Moraceae	c	stream, bmb
Ficus hispida Linn. f.	Moraceae	c	stream
Ficus infectoria Roxb.	Moraceae	f	
Ficus ischnopoda Miq.	Moraceae	c	river, rocky area
Ficus lamponga Miq.	Moraceae	f	dd, mixedd
Ficus neriifolia J. E. Sm. Var. Trilepis (King) Corn.	Moraceae	c	subtropical
Ficus nervosa Heyne ex Roth	Moraceae	c	ev
Ficus oligodon Miq.	Moraceae	r	sev
Ficus religiosa Linn.	Moraceae	o	planted
Ficus rumphii Bl.	Moraceae	f	lower elevation
Ficus semicordata	Moraceae		
Morus australis Poir.	Moraceae		cult, wild
Morus macroura Miq.	Moraceae	c	dd, mix, cult
Streblus asper Lour.	Moraceae	r	dry
Streblus zeylanicus Kurz	Moraceae		
Moringa oleifera Lamk.	Moringaceae	c	cultiv, wild
Ardisia colorata Roxb.	Myrsinaceae	r	ev
Ardisia floribunda Wall.	Myrsinaceae	f	rb, edge
Ardisia paniculata Roxb.	Myrsinaceae	o	dd, mixed ev
Ardisia virens Kurz	Myrsinaceae	f	ev, stream
Maesa indica (Roxb.) Wall.	Myrsinaceae	c	shady
Maesa ramentacea Wall.	Myrsinaceae	c	SF, edge
Cleistocalyx operculatus (Roxb.) Merr. & Perr.	Myrtaceae	c	dd, mixev
Eucalyptus tereticornis Sm.	Myrtaceae		cult
Psidium guajava Linn.	Myrtaceae		cult
Syzygium balsameum (Wt.) Wall. ex AM. & SM. Cowan	Myrtaceae	f	edge, rb
Syzygium cumini (Linn.) Skeels	Myrtaceae	c	
Syzygium formosum (Wall.) Mas.	Myrtaceae	f	ev,
Syzygium grandis (Wt.) Wala.	Myrtaceae	r	
Syzygium kurzii (Duthie) Balak.	Myrtaceae	c	ev, sev
Syzygium operculatum (Roxb.) Wall	Myrtaceae		
Syzygium polypetalum (Wall. ex Wt.) Merr. & Perr.	Myrtaceae	f	rb

Scientific name	Family	Conservation status	Habitat
Syzygium praecoxum (Roxb.) Haridasan &. Rao	Myrtaceae	c	dd, mixedd
Syzygium ramosissimum (Wall. ex Duthie) Balak.	Myrtaceae	c	ev
Syzygium sizigioides (Miq.) Merr. & Perr.	Myrtaceae	c	
Syzygium tetragonum (Wt.) Kurz	Myrtaceae	c	
Ochna integerrima (Lour.) Merr.	Ochnaceae	r	
Chionanthus macrophylla Bl.	Oleaceae	c	ev
Ligustrum indicum (Lour.) Merr.	Oleaceae	f	ev, edge
Ligustrum robustum (Roxb.) Bl.	Oleaceae	c	
Olea dentata Wall. ex DC.	Oleaceae	c	ev, mixed ev
Olea dioica Roxb.	Oleaceae	f	ev
Pandanus foetidus Roxb.	Pandanaceae		
Pandanus odorattisimus (Lamk.) Linn.	Pandanaceae		
Pittosporum nepaulense (DC.) Rehdr. & Wils.	Pittosporaceae	c	
Podocarpus latifolia Wall.	Podocarpaceae		
Podocarpus neerifolia D. Don	Podocarpaceae		
Xanthophyllum flavescens Roxb.	Polygalaceae	r	ev
Grevillea robusta A. Cunn.	Proteaceae		cult
Helicia excelsa Bl.	Proteaceae	r	
Helicia nilagirica Bedd.	Proteaceae		
Helicia robusta Wall ex Benn.	Proteaceae	f	
Rhamnus nepalensis (Wall.) Laws.	Rhamnaceae		SF,open
Zizyphus rugosa Lamk.	Rhamnaceae	c	open
Carallia brachiata (Lour.) Merr.	Rhizophoraceae	c	ev, rb, edge
Eriobotrya bengalensis Hk. f.	Rosaceae	f	ev
Anthocephalus chinensis (Lam.) A. Rich. ex Walp.	Rubiaceae	c	
Canthium dicoccum (Gaert.) T. & T.	Rubiaceae	f	ev
Canthium glabrum Bl.	Rubiaceae	r	dd
Catunaregam spinosa (Thumb.) Tiruv	Rubiaceae		
Catunaregam uliginosa (Retz.) Siv.	Rubiaceae		
Cinchona ledgeriana Moons. ex Trim.	Rubiaceae		cult
Gardenia campanulata Roxb.	Rubiaceae	r	
Haldina cordifolia	Rubiaceae	r	
Hymenodictyon flaccidum Wall.	Rubiaceae	f	ev, mixedd
Hymenodictyon excelsum Wall.	Rubiaceae	f	
Hyptianthera stricta (Willd.) W. & A.	Rubiaceae	c	ev
Ixora undulata Roxb.	Rubiaceae	c	

Scientific name	Family	Conservation status	Habitat
Mitragyna rotundifolia (Roxb.) O. Ktz.	Rubiaceae	f	
Nauclea griffithii Hav.	Rubiaceae	f	ev
Pavetta indica Linn.	Rubiaceae	c	ev
Prismatomeris tetrandra (Roxb.) K. Schum.	Rubiaceae	c	ev
Randia griffithii Hk. f.	Rubiaceae	o	edge
Randia wallichii Hk. f.	Rubiaceae	f	ev
Saprosma ternatum Hk. f.	Rubiaceae	c	ev, dd, bmb
Tarenna asiatica (Linn.) Sant. & Merch.	Rubiaceae	f	
Tricalysia singularis K. Schum.	Rubiaceae	c	mixedd
Wendlandia glabrata DC.	Rubiaceae	f	
Wendlandia grandis Cowan	Rubiaceae	c	ev, SF
Wendlandia paniculata DC.	Rubiaceae	f	gorges
Wendlandia tinctoria (Roxb.) DC.	Rubiaceae	c	SF, edge
Xeromphis spinosa (Thunb.) Keay	Rubiaceae	f	SF, edge
Acronychia pedunculata (Linn.) Miq.	Rutaceae		
Aegle marmelos (Linn.) Correa	Rutaceae	r	cultiv
Atalantia monophylla Corr.	Rutaceae		
Citrus medica Linn.	Rutaceae		
Evodia glabrifolia Champ.	Rutaceae		
Glycosmis arborea (Roxb.) DC.	Rutaceae		
Glycosmis cymosa (Kurz.) Narayanswamy	Rutaceae		
Micromelem integerrimum (Roxb.) Wt. & Arn.	Rutaceae		
Murraya paniculata (Linn.) Jack.	Rutaceae		
Zanthoxylum hamiltonianum Wall.	Rutaceae		
Zanthoxylum rhetsa (Roxb.) DC.	Rutaceae		ev,
Meliosma arnottiana (Wt.) Walp	Sabiaceae	r	
Meliosma simplicifolia (Roxb.) Walp	Sabiaceae	c	ev, SF
Aesculus assamica Griff.	Sapindaceae	c	dd, rb
Aphania rubra (Roxb.) Radlk.	Sapindaceae		Mixed ev
Dimocarpus longan Lour.	Sapindaceae		
Lepisanthes rubiginosa (Roxb.) Leenh.	Sapindaceae	o	
Palaquium polyanthum (Wall. ex DC.) Engl.	Sapotaceae	r	
Sarcosperma arboreum Cl.	Sapotaceae	c	ev,
Saurauia cerea Griff. ex Dyer.	Saurauiaceae		
Saurauia nepaulensis DC.	Saurauiaceae		SF, edge
Saurauia panduana Wall.	Saurauiaceae		

Scientific name	Family	Conservation status	Habitat
Saurauia roxburghii Wall.	Saurauiaceae		edge, dsiturbed
Ailanthes excelsa Roxb.	Simaroubaceae		Pltd
Ailanthus integrifolia Lamk.	Simaroubaceae		ev
Picrasma javanica Bl.	Simaroubaceae	c	ev
Duabanga grandiflora (Roxb. ex DC.) Walp.	Sonneratiaceae	c	rb
Turpinia nepalensis Wall. ex W. & A.	Staphyliaceae	f	ev
Turpinia pomifera (Roxb.) DC.	Staphyliaceae	c	
Firmiana colorata (Roxb.) R. Br.	Sterculiaceae	c	dd
Heritiera acuminata Wall.	Sterculiaceae		
Pterospermum acerifolium Willd.	Sterculiaceae	c	dd
Pterospermum lancifolium DC.	Sterculiaceae		ev dd
Pterygota alata (Roxb.) R. Br.	Sterculiaceae	r	
Sterculia colorata Roxb.	Sterculiaceae		
Sterculia hamiltonii (O. Ktz.) Adelb.	Sterculiaceae		ev
Sterculia villosa Roxb.	Sterculiaceae	c	dd
Styrax serrulatum Roxb.	Styracaceae	c	SF, edge
Symplocos javanica (Bl.) Kurz	Symplocaceae	f	ev, rb
Symplocos laurina (Retz.) Wall. ex Rehd. & Wils.	Symplocaceae	c	ev, dd, edge
Symplocos lucida (Thumb.) S. & Z.	Symplocaceae	c	PF
Symplocos racemosa Roxb.	Symplocaceae	c	ev, edge
Symplocos sumuntia Buch.-Ham. ex D. Don	Symplocaceae	f	dd, sal
Cephalotaxus griffithii Hk. f.	Taxaceae		
Tetrameles nudiflora R. Br.	Tetramelaceae		open,dd
Eurya acuminata DC.	Theaceae	c	ev dd
Schima khasiana Dyer.	Theaceae		
Schima wallichii (DC) Korth.	Theaceae		
Aquilaria malaccensis Lamk.	Thymeliaceae	f	ev
Grewia disperma Roth.	Tiliaceae	c	ev
Grewia elastica Royle	Tiliaceae	c	dd
Grewia microcos Linn.	Tiliaceae	c	dd
Grewia multiflora Juss.	Tiliaceae		
Celtis tetranda Roxb.	Ulmaceae	f	dd
Celtis timorensis Spanogh.	Ulmaceae	c	ev
Holoptelea integrifolia (Roxb.) Planch.	Ulmaceae	r	
Trema orientalis (Linn.) Bl.	Ulmaceae	f	open,edge
Ulmus lanceifolia Roxb.	Ulmaceae	r	

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

APPENDIX 4.1

Inventory of Shrubs, herbs, climbers, Bamboo and Canes

c = Climber, F = Fern, G = Grass, H = Herbs, S = Shrub, SB = Bamboo and SC = Cane

Plant species	Family	Habit	Division
Abrus precatorius L.	Fabaceae	C	Angiosperms
Acacia caesia (L.) Willd.	Mimosaceae	C	Angiosperms
Acacia oxyphylla Grah. ex Craib.	Mimosaceae	C	Angiosperms
Acacia pennata (L.) Willd.	Mimosaceae	C	Angiosperms
Acacia pruinescens Kurz.	Mimosaceae	C	Angiosperms
Acacia sinuata (Lour.) Merill.	Mimosaceae	C	Angiosperms
Adenia trilobata (Roxb.) Engl.	Passifloraceae	C	Angiosperms
Ampelocissus latifolia Planch.	Vitaceae	C	Angiosperms
Anoectochilus elatus Lindl.	Orchidaceae	C	Angiosperms
Argyreia capitata Arn. ex Choisy	Convolvulaceae	C	Angiosperms
Argyreia nervosa (Burm.f.) Boj.	Convolvulaceae	C	Angiosperms
Artabotrys caudatus Wall. ex Hk.f. & T.	Annonaceae	C	Angiosperms
Aspidopteris elliptica A.Juss.	Malpighiaceae	C	Angiosperms
Aspidopteris indica (Roxb.) Hochr.	Malpighiaceae	C	Angiosperms
Aspidopteris wallichii Hk.f.	Malpighiaceae	C	Angiosperms
Atylosia scarabaeoides Benth.	Fabaceae	C	Angiosperms
Atylosia spp.	Fabaceae	C	Angiosperms
Bridelia pubescens Kurz.	Euphorbiaceae	C	Angiosperms
Butea minor Buch.-Ham. ex Baker	Fabaceae	C	Angiosperms
Butea parviflora Roxb.	Fabaceae	C	Angiosperms
Byttneria grandifolia DC.	Sterculiaceae	C	Angiosperms
Byttneria pilosa Roxb.	Sterculiaceae	C	Angiosperms
Caesalpinia cuccullata Roxb.	Caesalpiniaceae	C	Angiosperms
Cayratia japonica (Thunb.) Gagnep.	Vitaceae	C	Angiosperms
Cayratia pedata (Lour.) Gagnep.	Vitaceae	C	Angiosperms
Cayratia spp.	Vitaceae	C	Angiosperms
Cayratia trifolia (L.) Domin.	Vitaceae	C	Angiosperms
Celastrus paniculatus Willd.	Celastraceae	C	Angiosperms
Ceropegia longifolia Wall.	Asclepiadaceae	C	Angiosperms
Chonemorpha fragrans (Moon) Alst.	Apocynaceae	C	Angiosperms
Cocculus orbiculatus (L.) DC.	Menispermaceae	C	Angiosperms
Combretum punctatum subspp. squamosum Bl.	Combretaceae	C	Angiosperms
Cryptolepis buchanani R.&S.	Asclepiadaceae	C	Angiosperms
Cryptolepis sinensis (Lour.) Merr.	Asclepiadaceae	C	Angiosperms

Plant species	Family	Habit	Division
Dalbergia rimosa Roxb.	Fabaceae	C	Angiosperms
Dalbergia volubilis Roxb.	Fabaceae	C	Angiosperms
Derris marginata (Roxb.) Benth.	Fabaceae	C	Angiosperms
Derris scandens (Roxb.) Benth.	Fabaceae	C	Angiosperms
Derris trifoliata Lour.	Fabaceae	C	Angiosperms
Desmos longiflorus (Roxb.) Safford.	Annonaceae	C	Angiosperms
Dioscorea alata L.	Dioscoreaceae	C	Angiosperms
Dioscorea bulbifera L.	Dioscoreaceae	C	Angiosperms
Dioscorea pentaphylla L.	Dioscoreaceae	C	Angiosperms
Diplocyclos palmatus (L.) Jeffrey.	Cucurbitaceae	C	Angiosperms
Entada pursaetha DC.	Mimosaceae	C	Angiosperms
Erycibe albiflora Hall.f	Convolvulaceae	C	Angiosperms
Erycibe paniculata Roxb.	Convolvulaceae	C	Angiosperms
Fissistigma bicolor (Roxb.) Merr.	Annonaceae	C	Angiosperms
Fissistigma rubiginosa (A.DC.) Merr.	Annonaceae	C	Angiosperms
Fissistigma wallichii (Hk..f. &Th.) Merr.	Annonaceae	C	Angiosperms
Freisodielsia forniculata (Roxb.) Das	Annonaceae	C	Angiosperms
Gnetum montanum Markgraf.	Gnetaceae	C	Gymnosperms
Gnetum scandens Roxb.	Gnetaceae	C	Gymnosperms
Gongronema nepalense (Wall.) Decne.	Asclepiadaceae	C	Angiosperms
Gouania tiliaefolia Lamk.	Rhamnaceae	C	Angiosperms
Hemidesmus spp.	Asclepiadaceae	C	Angiosperms
Hodgsonia macrocarpa (Bl.) Cogn.	Cucurbitaceae	C	Angiosperms
Ichnocarpus frutescens (L.) R.Br.	Apocynaceae	C	Angiosperms
Ipomoea macrantha R.&S.	Convolvulaceae	C	Angiosperms
Jasminum azoricum L.	Oleaceae	C	Angiosperms
Kadsura heteroclita (Roxb.) Craib.	Schisandraceae	C	Angiosperms
Lasiobema scandens var. horsfieldii (watt. ex Prain) de Wit.	Caesalpiniaceae	C	Angiosperms
Luffa aegyptiaca Mill.	Cucurbitaceae	C	Angiosperms
Lygodium flexuosum (L.) Sw.	Schizaeaceae	C	Pteridophytes
Lygodium japonicum (Thunb.) Sw.	Schizaeaceae	C	Pteridophytes
Merremia umbellata (L.) Hall.f.	Convolvulaceae	C	Angiosperms
Merremia vitifolia (Burm.f.) Hall.f.	Convolvulaceae	C	Angiosperms
Mikania micrantha Kunth.	Asteraceae	C	Angiosperms
Milletia pachycarpa Benth.	Fabaceae	C	Angiosperms
Mimosa himalayana Gamble	Mimosaceae	C	Angiosperms
Momordica dioica Roxb. ex Willd.	Cucurbitaceae	C	Angiosperms
Mucuna bracteata DC.	Fabaceae	C	Angiosperms

Plant species	Family	Habit	Division
Mucuna imbricata DC.	Fabaceae	C	Angiosperms
Mucuna pruriens (L.) DC.	Fabaceae	C	Angiosperms
Mukia maderaspatana (L.) M.Roem.	Cucurbitaceae	C	Angiosperms
Naravelia zeylanica DC.	Ranunculaceae	C	Angiosperms
Paederia scandens (Lour) Merr.	Rubiaceae	C	Angiosperms
Pericampylus glaucus (Lamk.) Merr.	Menispermaceae	C	Angiosperms
Phanera khasiana (Baker) Thoth.	Caesalpiniaceae	C	Angiosperms
Phanera nervosa Benth.	Caesalpiniaceae	C	Angiosperms
Premna scandens Roxb.	Verbenaceae	C	Angiosperms
Pueraria phasioloides (Roxb.) Benth.	Fabaceae	C	Angiosperms
Pueraria wallichii DC.	Fabaceae	C	Angiosperms
Raphidophora decursiva Schott.	Araceae	C	Angiosperms
Raphidophora lancifolia Schott.	Araceae	C	Angiosperms
Rhynchosia viscosa DC.	Fabaceae	C	Angiosperms
Rubus khasianus Cordot.	Rosaceae	C	Angiosperms
Rubus rosifolius Sm.	Rosaceae	C	Angiosperms
Rubus rugosus Sm.	Rosaceae	C	Angiosperms
Sabia lanceolata Colebr.	Sabiaceae	C	Angiosperms
Schefflera venulosa Harms.	Araliaceae	C	Angiosperms
Senecio scandens Buch.-Ham ex D.Don	Asteraceae	C	Angiosperms
Smilax aspera L.	Smilacaceae	C	Angiosperms
Smilax macrophylla Roxb.	Smilacaceae	C	Angiosperms
Smilax sp	Smilacaceae	C	Angiosperms
Smilax zeylanica L.	Smilacaceae	C	Angiosperms
Solena heterophylla Lour.	Cucurbitaceae	C	Angiosperms
Sphenodesma pentandra Jacq.	Verbenaceae	C	Angiosperms
Stephania glandulifera Miers.	Menispermaceae	C	Angiosperms
Stephania japonica (Thunb.) Miers.	Menispermaceae	C	Angiosperms
Strychnos quintuplinervis A.W.Hill	Loganiaceae	C	Angiosperms
Strychnos wallichiana Benth.	Loganiaceae	C	Angiosperms
Tellosma pallida (Roxb.) Craib.	Asclepiadaceae	C	Angiosperms
Tetracera sarmentosa (L.) Vahl.	Dilleniaceae	C	Angiosperms
Tetrastigma leucostaphylum (Dennst.) Balak.	Vitaceae	C	Angiosperms
Tetrastigma obovatum (Laws) Gagnep	Vitaceae	C	Angiosperms
Tetrastigma rumicispermum (Laws.) Plantch.	Vitaceae	C	Angiosperms
Tetrastigma serrulatum (Roxb.) Planch.	Vitaceae	C	Angiosperms
Tetrastigma thomsonianum Planch.	Vitaceae	C	Angiosperms
Thladiantha colorata Cogn.	Cucurbitaceae	C	Angiosperms

Plant species	Family	Habit	Division
Thunbergia coccinea Wall.	Acanthaceae	C	Angiosperms
Thunbergia grandiflora Roxb.	Acanthaceae	C	Angiosperms
Tiliacora acuminata (Lamk.) Hk.f. &Th.	Menispermaceae	C	Angiosperms
Tinospora cordifolia Miers.	Menispermaceae	C	Angiosperms
Tinospora sinensis (Lour.) Merr.	Menispermaceae	C	Angiosperms
Toddalia asiatica (L.) Lamk.	Rutaceae	C	Angiosperms
Trichosanthes tricuspidata Lour.	Cucurbitaceae	C	Angiosperms
Uncaria macrophyllus Wall.	Rubiaceae	C	Angiosperms
Uncaria sessilifructus Roxb.	Rubiaceae	C	Angiosperms
Uvaria lurida Hk.f.&Th.	Annonaceae	C	Angiosperms
Vallaris solanacea (Roxb.) O.Ktz.	Apocynaceae	C	Angiosperms
Ventilago madraspatana Gaertn.	Rhamnaceae	C	Angiosperms
Zanthoxylum khasianum Hk.f.	Rutaceae	C	Angiosperms
Zizyphus oenoplia (L.) Mill.	Rhamnaceae	C	Angiosperms
Adiantum caudatum L.	Adiantaceae	F	Pteridophytes
Adiantum lunulatum Burm.f.	Adiantaceae	F	Pteridophytes
Aglaomorpha coronans (Wall. ex Mett.) Copel.	Polypodiaceae	F	Pteridophytes
Angiopteris evecta (G.Forst.) Hoffm.	Angiopteridaceae	F	Pteridophytes
Arthromeris lehmanni (Mett.) Ching	Polypodiaceae	F	Pteridophytes
Arthromeris wallichana (Spreng.) Ching	Polypodiaceae	F	Pteridophytes
Blechnum orientale L.	Blechnaceae	F	Pteridophytes
Cheilanthes farinosa (Forsk.) Kaulf.	Sinopteridaceae	F	Pteridophytes
Colysis hemionitidea Presl.	Polypodiaceae	F	Pteridophytes
Coniogramme spp.	Hemionitidaceae	F	Pteridophytes
Cyathea spp.	Cyatheaceae	F	Pteridophytes
Cyclosorus megaphylla	Thelypteridaceae	F	Pteridophytes
Dichranopteris liniaris Holtum	Gleicheniaceae	F	Pteridophytes
Diplazium esculentum (Retz.) Sw.	Athyriaceae	F	Pteridophytes
Drymoglossum heterophyllum (L.) Trimen.	Polypodiaceae	F	Pteridophytes
Lemmaphyllum spp.	Polypodiaceae	F	Pteridophytes
Lepisorus soridus (C.Chr.) Ching.	Polypodiaceae	F	Pteridophytes
Leptochilus nitidum	Polypodiaceae	F	Pteridophytes
Lycopodium spp.	Lycopodiaceae	F	Pteridophytes
Microsorum normale (Roxb.) Copel	Polypodiaceae	F	Pteridophytes
Nephrolepis cordifolia (L.) C.Presl.	Oleandraceae	F	Pteridophytes
Onychium saliculosum (Desv.) C.Chr.	Cryptogrammataceae	F	Pteridophytes
Plagiogyria communis Ching.	Plagiogyriaceae	F	Pteridophytes
Pleopeltis excavatus	Polypodiaceae	F	Pteridophytes

Plant species	Family	Habit	Division
Polypodium argutum (Wall. ex Hooker) Ching	Polypodiaceae	F	Pteridophytes
Pteris biaurita L.	Pteridaceae	F	Pteridophytes
Pteris spp.	Pteridaceae	F	Pteridophytes
Pyrossia spp.	Polypodiaceae	F	Pteridophytes
Selaginella spp.	Selaginellaceae	F	Pteridophytes
Apluda mutica Hack.	Poaceae	G	Angiosperms
Arundo donax L.	Poaceae	G	Angiosperms
Brachiaria distachya Stapf.	Poaceae	G	Angiosperms
Capillipedium assimile (Steud.) A.Camus	Poaceae	G	Angiosperms
Chrysopogon serrulatus Trin.	Poaceae	G	Angiosperms
Cynodon dactylon Pers.	Poaceae	G	Angiosperms
Cyrtococcum accrescens Stapf.	Poaceae	G	Angiosperms
Cyrtococcum oxyphyllum Stapf.	Poaceae	G	Angiosperms
Dactyloctenium aegyptium Willd.	Poaceae	G	Angiosperms
Digitaria setigera R.&S.	Poaceae	G	Angiosperms
Digitaria stricta Roth.	Poaceae	G	Angiosperms
Eleusine coracana Gaertn.	Poaceae	G	Angiosperms
Eleusine indica Gaertn.	Poaceae	G	Angiosperms
Eragrostiella bifaria (Vahl.) Bor.	Poaceae	G	Angiosperms
Eragrostis atrovirens Lange.	Poaceae	G	Angiosperms
Eragrostis pilosa Beauv.	Poaceae	G	Angiosperms
Eragrostis tenella R.&S.	Poaceae	G	Angiosperms
Eragrostis unioloides Nees.	Poaceae	G	Angiosperms
Eulaliopsis binata (Retz.) C.E. Hubbard	Poaceae	G	Angiosperms
Hackelochloa granularis (L.) O.Ktze.	Poaceae	G	Angiosperms
Imperata cylindrica (L.) Raeus.	Poaceae	G	Angiosperms
Oplismenus burmanii Beauv.	Poaceae	G	Angiosperms
Oplismenus compositus Beauv.	Poaceae	G	Angiosperms
Panicum auritum Presl.	Poaceae	G	Angiosperms
Panicum notatum Retz.	Poaceae	G	Angiosperms
Paspalidium flavidum (Retz.) A.Camus	Poaceae	G	Angiosperms
Paspalum conjugatum Berg.	Poaceae	G	Angiosperms
Paspalum scorbiculatum L.	Poaceae	G	Angiosperms
Saccharum arundinaceum Retz.	Poaceae	G	Angiosperms
Saccharum munja Roxb.	Poaceae	G	Angiosperms
Saccharum spontaneum L.	Poaceae	G	Angiosperms
Sacharum benghalensis Ham.	Poaceae	G	Angiosperms
Setaria glauca Beauv.	Poaceae	G	Angiosperms

Plant species	Family	Habit	Division
Setaria paniculifera (Steud.) Fourn.	Poaceae	G	Angiosperms
Setaria verticillata (L.) P.Beauv.	Poaceae	G	Angiosperms
Sporobolus diander Beauv.	Poaceae	G	Angiosperms
Sporobolus indicus var. purpureosuffusus (Ohwi) Koyama	Poaceae	G	Angiosperms
Themeda quadrivalvis (L.) O.Kuntze.	Poaceae	G	Angiosperms
Themeda villosa (Poir.) A.Camus	Poaceae	G	Angiosperms
Thysanolaena maxima (Roxb.) O.Kuntze	Poaceae	G	Angiosperms
Abelmoschus moschatus Medik.	Malvaceae	H	Angiosperms
Abrus fruticulosus W.&A.	Fabaceae	H	Angiosperms
Acalypha ciliata Forsk.	Euphorbiaceae	H	Angiosperms
Achyranthes aspera L.	Amaranthaceae	H	Angiosperms
Achyranthes bidentata Bl.	Amaranthaceae	H	Angiosperms
Acorus calamus L.	Araceae	H	Angiosperms
Aerides spp.	Orchidaceae	H	Angiosperms
Aerva spp.	Amaranthaceae	H	Angiosperms
Aeschynomene indica L.	Fabaceae	H	Angiosperms
Ageratum conyzoides L.	Asteraceae	H	Angiosperms
Ajuga bracteosa Wall.	Lamiaceae	H	Angiosperms
Alternanthera pungens HBK	Amaranthaceae	H	Angiosperms
Alternanthera sessilis Br.	Amaranthaceae	H	Angiosperms
Amaranthus spinosus L	Amaranthaceae	H	Angiosperms
Amaranthus viridis L.	Amaranthaceae	H	Angiosperms
Anaphalis adnata Wall. ex DC.	Asteraceae	H	Angiosperms
Anisomeles indica (L.) O.Ktze.	Lamiaceae	H	Angiosperms
Anisomeles ovata R.Br.	Lamiaceae	H	Angiosperms
Argemone mexicana L.	Papaveraceae	H	Angiosperms
Aristolochia spp.	Aristolochiaceae	H	Angiosperms
Aristolochia tagala Cham.	Aristolochiaceae	H	Angiosperms
Asclepias curassavica L.	Asclepiadaceae	H	Angiosperms
Bacopa procumbens (Mill.) Green	Scrophulariaceae	H	Angiosperms
Barleria cristata L.	Acanthaceae	H	Angiosperms
Begonia picta Sm.	Begoniaceae	H	Angiosperms
Begonia rubro-vinea Hook.	Begoniaceae	H	Angiosperms
Begonia spp.	Begoniaceae	H	Angiosperms
Bidens bitternata Merrill. &Scheriff.	Asteraceae	H	Angiosperms
Bidens pilosa L.	Asteraceae	H	Angiosperms
Blumea densiflora DC.	Asteraceae	H	Angiosperms
Blumea lacera DC.	Asteraceae	H	Angiosperms

Plant species	Family	Habit	Division
Blumea lacera var. blumei DC.	Asteraceae	H	Angiosperms
Blumea oxyodonta DC.	Asteraceae	H	Angiosperms
Blumea procera DC.	Asteraceae	H	Angiosperms
Blumea riparia DC.	Asteraceae	H	Angiosperms
Blumeopsis flava (DC) Gagnep.	Asteraceae	H	Angiosperms
Boerhavia diffusa L.	Nyctaginaceae	H	Angiosperms
Borreria articularis (L.f.) F.N.Will.	Rubiaceae	H	Angiosperms
Borreria pusila (Wall.) DC.	Rubiaceae	H	Angiosperms
Borreria pusila DC.	Rubiaceae	H	Angiosperms
Bryophyllum calycinum Salisb.	Crassulaceae	H	Angiosperms
Cannabis sativa L.	Cannabinaceae	H	Angiosperms
Carex spp.	Cyperaceae	H	Angiosperms
Carex spp.	Cyperaceae	H	Angiosperms
Cassia occidentalis L.	Caesalpiniaceae	H	Angiosperms
Cassia tora L.	Caesalpiniaceae	H	Angiosperms
Catheranthus roseus (L.) G.Don.	Apocynaceae	H	Angiosperms
Celosia argentea L.	Amaranthaceae	H	Angiosperms
Centella asiatica (L.) Urban.	Apiaceae	H	Angiosperms
Chenopodium ambrosioides L.	Chenopodiaceae	H	Angiosperms
Chenopodium murale L.	Chenopodiaceae	H	Angiosperms
Chirita hamosa R.Br.	Gesneriaceae	H	Angiosperms
Circium involucratum DC. var. horridum (Hk.f.) Balak.	Asteraceae	H	Angiosperms
Cissampelos pareira L.	Menispermaceae	H	Angiosperms
Cissus discolor Bl.	Vitaceae	H	Angiosperms
Coelogyne spp.	Orchidaceae	H	Angiosperms
Colocasia spp.	Araceae	H	Angiosperms
Commelina benghalensis L.	Commelinaceae	H	Angiosperms
Commelina longifolia Spreng.	Commelinaceae	H	Angiosperms
Commelina suffruticosa Bl.	Commelinaceae	H	Angiosperms
Corchorus acutangulus Lamk.	Tiliaceae	H	Angiosperms
Costus speciosus Sm.	Zingiberaceae	H	Angiosperms
Cotula hemisphaerica Wall.	Asteraceae	H	Angiosperms
Crassocephalum crepidioides (Benth.) Moore	Asteraceae	H	Angiosperms
Crotalaria juncea L.	Fabaceae	H	Angiosperms
Crotalaria sericea Retz.	Fabaceae	H	Angiosperms
Crotalaria sessiliflora L.	Fabaceae	H	Angiosperms
Curcuma psuedomontana Grah.	Zingiberaceae	H	Angiosperms
Curcuma spp.	Zingiberaceae	H	Angiosperms

Plant species	Family	Habit	Division
Curcuma zedoaria Roxb.	Zingiberaceae	H	Angiosperms
Cuscuta reflexa Roxb.	Cuscutaceae	H	Angiosperms
Cyanotis cristata Sch.f.	Commelinaceae	H	Angiosperms
Cyclea bicristata (Griff.) Diels.	Menispermaceae	H	Angiosperms
Cyperus compressus L.	Cyperaceae	H	Angiosperms
Cyperus kyllingia Endl.	Cyperaceae	H	Angiosperms
Cyperus triceps Endl.	Cyperaceae	H	Angiosperms
Deeringia amaranthoides (Lamk.) Merril.	Amaranthaceae	H	Angiosperms
Dendrobium aphyllum (Roxb.) Fischer.	Orchidaceae	H	Angiosperms
Dendrobium spp.	Orchidaceae	H	Angiosperms
Desmodium gangeticum DC.	Fabaceae	H	Angiosperms
Desmodium gyrans DC.	Fabaceae	H	Angiosperms
Desmodium pulchellum (L.) Benth.	Fabaceae	H	Angiosperms
Desmodium spp.	Fabaceae	H	Angiosperms
Desmodium triflorum DC.	Fabaceae	H	Angiosperms
Desmodium velutinum (Willd.) DC.	Fabaceae	H	Angiosperms
Dicliptera bupleuroides Nees.	Acanthaceae	H	Angiosperms
Duchesnea indica (Andr.) Focke.	Rosaceae	H	Angiosperms
Eclipta prostrata L.	Asteraceae	H	Angiosperms
Elephantopus scaber L.	Asteraceae	H	Angiosperms
Elsholtzia flava Benth.	Lamiaceae	H	Angiosperms
Emilia sonchifolia (L.) DC.	Asteraceae	H	Angiosperms
Epilobium spp.	Onagraceae	H	Angiosperms
Erigeron bonariensis L.	Asteraceae	H	Angiosperms
Erigeron karvinskianus DC.	Asteraceae	H	Angiosperms
Eupatorium adenophorum Spreng.	Asteraceae	H	Angiosperms
Eupatorium odoratum L.	Asteraceae	H	Angiosperms
Euphorbia hirta L.	Euphorbiaceae	H	Angiosperms
Euphorbia prostrata Orteg.	Euphorbiaceae	H	Angiosperms
Evolvulus nummularius L.	Convolvulaceae	H	Angiosperms
Fimbristylis dichotoma Vahl.	Cyperaceae	H	Angiosperms
Galinsoga parviflora Cav.	Asteraceae	H	Angiosperms
Galium elegans Wall.	Rubiaceae	H	Angiosperms
Gnaphalium polycaulon Pers.	Asteraceae	H	Angiosperms
Gomphrena globosa L.	Amaranthaceae	H	Angiosperms
Hedychium coronarium Koen.	Zingiberaceae	H	Angiosperms
Hedychium spp.	Zingiberaceae	H	Angiosperms
Hedychium spicatum Ham.	Zingiberaceae	H	Angiosperms

Plant species	Family	Habit	Division
Hedyotis corymbosa (L.) Lamk.	Rubiaceae	H	Angiosperms
Hedyotis scandens D.Don	Rubiaceae	H	Angiosperms
Heliotropium supinum L.	Boraginaceae	H	Angiosperms
Horsfieldia amygdalina (Wall.) Warb.	Myristicaceae	H	Angiosperms
Horsfieldia kingii (Hk.f.) Warb.	Myristicaceae	H	Angiosperms
Hydrocotyle sybthorpioides Lamk.	Apiaceae	H	Angiosperms
Hygrophila auriculata (Sch.) Heine	Acanthaceae	H	Angiosperms
Impatiens chinensis L.	Balsaminaceae	H	Angiosperms
Indigofera linifolia Retz.	Fabaceae	H	Angiosperms
Ipomoea alba L.	Convolvulaceae	H	Angiosperms
Ipomoea batatas (L.) Lamk.	Convolvulaceae	H	Angiosperms
Ipomoea nil (L.) Roth.	Convolvulaceae	H	Angiosperms
Ipomoea pes-tigridis L.	Convolvulaceae	H	Angiosperms
Ipomoea purpurea (L.) Roth.	Convolvulaceae	H	Angiosperms
Ipomoea quamoclit L.	Convolvulaceae	H	Angiosperms
Knoxia spp.	Rubiaceae	H	Angiosperms
Lepidagathis cristata Willd.	Acanthaceae	H	Angiosperms
Lepidagathis incurva D.Don.	Acanthaceae	H	Angiosperms
Leucas aspera Spreng.	Lamiaceae	H	Angiosperms
Leucas cephalotes Spreng.	Lamiaceae	H	Angiosperms
Leucas mollissima Wall.	Lamiaceae	H	Angiosperms
Lindenbergia indica (L.) O.Ktze.	Scrophulariaceae	H	
Lindernia ciliaris (Colsm.) Penn.	Scrophulariaceae	H	Angiosperms
Lindernia cordifolia (Colsm.) Merr.	Scrophulariaceae	H	
Lobelia nicotianifolia R.&S.	Lobeliaceae	H	Angiosperms
Ludwigia octovalvis (Jacq.) Raven.	Onagraceae	H	Angiosperms
Martynia annua L.	Martyniaceae	H	Angiosperms
Mimosa pudica L.	Mimosaceae	H	Angiosperms
Mosla dianthera Maxim.	Lamiaceae	H	Angiosperms
Murdannia nudiflora (L.) Brenan.	Commelinaceae	H	Angiosperms
Musa superba Roxb.	Musaceae	H	Angiosperms
Neanotis oxyphylla (G.Don.) Hk.f.	Rubiaceae	H	Angiosperms
Nelsonia canescens Nees.	Acanthaceae	H	Angiosperms
Nelumbo nucifera L.	Nymphaeaceae	H	Angiosperms
Nepeta spp.	Lamiaceae	H	Angiosperms
Nicotiana tabacum L.	Solanaceae	H	Angiosperms
Oberonia spp.	Orchidaceae	H	Angiosperms
Oxalis corniculata L.	Oxalidaceae	H	Angiosperms

Plant species	Family	Habit	Division
Oxalis debilis H.B.K. var. corymbosa (DC.) Lourt.	Oxalidaceae	H	Angiosperms
Parthenium hysterophorus L.	Asteraceae	H	Angiosperms
Phyla nudiflora (L.) Green.	Verbenaceae	H	Angiosperms
Phyllanthus retusus Dennst.	Euphorbiaceae	H	Angiosperms
Phyllanthus spp.	Euphorbiaceae	H	Angiosperms
Phyllanthus urinaria L.	Euphorbiaceae	H	Angiosperms
Physalis minima L.	Solanaceae	H	Angiosperms
Pilea spp.	Urticaceae	H	Angiosperms
Pimpinella Spp.	Apiaceae	H	Angiosperms
Piper griffithii DC.	Piperaceae	H	Angiosperms
Piper mullesua D.Don.	Piperaceae	H	Angiosperms
Piper nigrum L.	Piperaceae	H	Angiosperms
Piper pedicellosum Wall.	Piperaceae	H	Angiosperms
Piper peepuloides Roxb.	Piperaceae	H	Angiosperms
Plantago erosa Wall.	Plantaginaceae	H	Angiosperms
Plantago major L.	Plantaginaceae	H	Angiosperms
Plantago spp.	Plantaginaceae	H	Angiosperms
Polygala glomerata Lour.	Polygalaceae	H	Angiosperms
Polygala persicariaefolia DC.	Polygalaceae	H	Angiosperms
Polygala sibirica L.	Polygalaceae	H	Angiosperms
Polygonum spp.	Polygonaceae	H	Angiosperms
Polygonum barbatum L.	Polygonaceae	H	Angiosperms
Polygonum chinense L.	Polygonaceae	H	Angiosperms
Polygonum hydropiper L.	Polygonaceae	H	Angiosperms
Polygonum runcinatum Ham.	Polygonaceae	H	Angiosperms
Portulaca grandiflora Hook.	Portulacaceae	H	Angiosperms
Portulaca pilosa L.	Portulacaceae	H	Angiosperms
Pothos scandens L.	Araceae	H	Angiosperms
Pothos spp.	Araceae	H	Angiosperms
Pouzolzia pentandra Benn.	Urticaceae	H	Angiosperms
Pseudognaphalium leuteo-album Gillard.&Burtt.	Asteraceae	H	Angiosperms
Ranunculus arvensis L.	Ranunculaceae	H	Angiosperms
Ranunculus sceleratus L	Ranunculaceae	H	Angiosperms
Rhynchoglossum obliquum Bl.	Gesneriaceae	H	Angiosperms
Richardsonia pilosa H.B. &K.	Rubiaceae	H	Angiosperms
Rubia cordifolia L.	Rubiaceae	H	Angiosperms
Ruellia tweediana (Nees.) Griseb.	Acanthaceae	H	Angiosperms
Rumex nepalensis Spreng	Polygonaceae	H	Angiosperms

Plant species	Family	Habit	Division
Rungia pectinata Nees.	Acanthaceae	H	Angiosperms
Rungia repens Nees.	Acanthaceae	H	Angiosperms
Scoparia dulcis L.	Scrophulariaceae	H	Angiosperms
Siegesbeckia orientalis L.	Asteraceae	H	Angiosperms
Silene alba (Mill.) Krause	Caryophyllaceae	H	Angiosperms
Smithia blanda Wall.	Fabaceae	H	Angiosperms
Solanum nigrum L.	Solanaceae	H	Angiosperms
Solanum surattense Burm.f.	Solanaceae	H	Angiosperms
Sonchus asper (L.) Hill	Asteraceae	H	Angiosperms
Sonchus oleraceus L.	Asteraceae	H	Angiosperms
Spilanthes acmella Jacq.	Asteraceae	H	Angiosperms
Synedrella nodiflora (Lour.) Gaert.	Asteraceae	H	Angiosperms
Thalictrum spp.	Ranunculaceae	H	Angiosperms
Tribulus terrestris L.	Zygophyllaceae	H	Angiosperms
Tridax procumbens L.	Asteraceae	H	Angiosperms
Uraria crinita Desv.	Fabaceae	H	Angiosperms
Utricularia striatula Sm.	Utriculariaceae	H	Angiosperms
Vernonia cinerea (L.) Less.	Asteraceae	H	Angiosperms
Viola betonicifolia Sm.	Violaceae	H	Angiosperms
Viola serpens Wall.	Violaceae	H	Angiosperms
Youngia japonica (L.) DC.	Asteraceae	H	Angiosperms
Zingiber officinale Rosc.	Zingiberaceae	H	Angiosperms
Zingiber spp.	Zingiberaceae	H	Angiosperms
Abroma angusta Linn.f.	Sterculiaceae	S	Angiosperms
Adhathoda zeylanica Medik.	Acanthaceae	S	Angiosperms
Aeschmanthera gossypina Nees	Acanthaceae	S	Angiosperms
Aeschynanthus grandiflora Spreng.	Gesneriaceae	S	Angiosperms
Aeschynanthus superba Cl.	Gesneriaceae	S	Angiosperms
Agapetes variegata G.Don.	Vacciniaceae	S	Angiosperms
Allophyllus distachys Radlk.	Sapindaceae	S	Angiosperms
Allophyllus villosus Bl.	Sapindaceae	S	Angiosperms
Amblyanthus glandulosus (Roxb.) D.C.	Myrsinaceae	S	Angiosperms
Antidesma acidum Retz.	Euphorbiaceae	S	Angiosperms
Antidesma acuminatum Wall	Euphorbiaceae	S	Angiosperms
Aralia armata Seem.	Araliaceae	S	Angiosperms
Aralia dasyphylla Miq.	Araliaceae	S	Angiosperms
Aralia spp.	Araliaceae	S	Angiosperms
Ardisia crispa (Thunb.) DC.	Myrsinaceae	S	Angiosperms

Plant species	Family	Habit	Division
Ardisia griffithii Cl.	Myrsinaceae	S	Angiosperms
Ardisia pedunculosa Wall.	Myrsinaceae	S	Angiosperms
Ardisia spp.	Myrsinaceae	S	Angiosperms
Ardisia thomsonii (Cl.) Mez.	Myrsinaceae	S	Angiosperms
Artemisia nilagirica (Cl.) Pamp.	Asteraceae	S	Angiosperms
Artemisia parviflora Roxb.	Asteraceae	S	Angiosperms
Artemisia spp.	Asteraceae	S	Angiosperms
Baliospermum calycinum Muell.-Arg.	Euphorbiaceae	S	Angiosperms
Boehmeria glomerulifera Miq.	Urticaceae	S	Angiosperms
Boehmeria platyphylla D.Don.	Urticaceae	S	Angiosperms
Boehmeria spp.	Urticaceae	S	Angiosperms
Breynia retusa (Dennst) Alst.	Euphorbiaceae	S	Angiosperms
Bridelia stipularis Bl.	Euphorbiaceae	S	Angiosperms
Buddleja asiatica Lour.	Buddlejaceae	S	Angiosperms
Callicarpa macrophylla Vahl.	Verbenaceae	S	Angiosperms
Callicarpa rubella Lindl.	Verbenaceae	S	Angiosperms
Calotropis gigantea (L.) Dryand	Asclepiadaceae	S	Angiosperms
Canthium angustifolium Roxb.	Rubiaceae	S	Angiosperms
Canthium parviflorum Roxb.	Rubiaceae	S	Angiosperms
Capparis acutifolia Sw.	Capparidaceae	S	Angiosperms
Capparis assamica Hk.f. & Th.	Capparidaceae	S	Angiosperms
Caryopteris wallichiana Schau.	Verbenaceae	S	Angiosperms
Cassia alata L.	Caesalpiniaceae	S	Angiosperms
Cestrum nocturnum L.	Solanaceae	S	Angiosperms
Chasalia ophioxyloides (Wall.) Craib.	Rubiaceae	S	Angiosperms
Chloranthus elatior R.Br.	Chloranthaceae	S	Angiosperms
Citrus hystrix DC.	Rutaceae	S	Angiosperms
Citrus spp.	Rutaceae	S	Angiosperms
Clausena heptaphylla W.&A.	Rutaceae	S	Angiosperms
Clematis gouriana DC.	Ranunculaceae	S	Angiosperms
Clematis laureiriana DC.	Ranunculaceae	S	Angiosperms
Clerodendrum bracteatum Wall. ex Walp.	Verbenaceae	S	Angiosperms
Clerodendrum colebrookianum Walp.	Verbenaceae	S	Angiosperms
Clerodendrum serratum (L.) Moon.	Verbenaceae	S	Angiosperms
Clerodendrum viscosum Vent.	Verbenaceae	S	Angiosperms
Clerodendrum wallichii Merr.	Verbenaceae	S	Angiosperms
Coffea bengalensis Roxb.	Rubiaceae	S	Angiosperms
Combretum acuminatum Roxb.	Combretaceae	S	Angiosperms

Plant species	Family	Habit	Division
Combretum flagocarpum Cl.	Combretaceae	S	Angiosperms
Combretum roxburghii Spreng.	Combretaceae	S	Angiosperms
Crotalaria alata Ham.	Fabaceae	S	Angiosperms
Croton caudatus Geisel.	Euphorbiaceae	S	Angiosperms
Croton spp.	Euphorbiaceae	S	Angiosperms
Cudrania cochinchinensis (Lour) Kudo-Mas.	Moraceae	S	Angiosperms
Cudrania fruticosa Wt. ex Kurz.	Moraceae	S	Angiosperms
Dalbergia mimosoides Franch.	Fabaceae	S	Angiosperms
Dalbergia pinnata (Lour.) Prain.	Fabaceae	S	Angiosperms
Daphne involucrata Wall.	Thymeliaceae	S	Angiosperms
Datura stramonium L.	Solanaceae	S	Angiosperms
Dendrocnide sinuata (Bl.) Chew.	Urticaceae	S	Angiosperms
Dendrophthoe falcata (L.f.) Etting.	Loranthaceae	S	Angiosperms
Desmodium heterocarpon (L.) DC.	Fabaceae	S	Angiosperms
Desmodium laxiflorum DC.	Fabaceae	S	Angiosperms
Desmodium motorium DC.	Fabaceae	S	Angiosperms
Desmodium triquetrum (L.) DC.	Fabaceae	S	Angiosperms
Didymosperma nana H.Wdl.&DC.	Arecaceae	S	Angiosperms
Diflugosa colorata (Nees.) Bremek.	Acanthaceae	S	Angiosperms
Dracaena elliptica Thunb.	Dracaenaceae	S	Angiosperms
Dracaena spicata Roxb.	Dracaenaceae	S	Angiosperms
Elaeagnus conferta Roxb.	Elaeagnaceae	S	Angiosperms
Elsholtzia blanda Benth.	Lamiaceae	S	Angiosperms
Embelia floribunda Wall.	Myrsinaceae	S	Angiosperms
Embelia ribes Burm.f.	Myrsinaceae	S	Angiosperms
Embelia spp.	Myrsinaceae	S	Angiosperms
Eranthemum pulchellum Andr.	Acanthaceae	S	Angiosperms
Euonymus theifolius Wall. ex Laws.	Celastraceae	S	Angiosperms
Euphorbia royleana Boiss	Euphorbiaceae	S	Angiosperms
Eurya japonica Thunb.	Theaceae	S	Angiosperms
Ficus crininervia Miq.	Moraceae	S	Angiosperms
Ficus foveolata Wall. ex Miq.	Moraceae	S	Angiosperms
Ficus sarmentosa Ham. ex J.E. SH.	Moraceae	S	Angiosperms
Ficus scandens Roxb.	Moraceae	S	Angiosperms
Ficus squamosa Roxb.	Moraceae	S	Angiosperms
Ficus subulata Bl.	Moraceae	S	Angiosperms
Ficus urophylla Wall. ex King.	Moraceae	S	Angiosperms
Flacourtia indica (Hk.f.) Warb.	Flacourtiaceae	S	Angiosperms

Plant species	Family	Habit	Division
Flacourtia jangomas (Lour.) Rae.	Flacourtiaceae	S	Angiosperms
Flemingia latifolia Benth.	Fabaceae	S	Angiosperms
Flemingia macrophylla (Willd.) Prain.	Fabaceae	S	Angiosperms
Flemingia strobilifera (L.) R.Br.	Fabaceae	S	Angiosperms
Gaultheria fragrantissima Wall.	Ericaceae	S	Angiosperms
Girardinia palmata (Forsk.) Gaud.	Urticaceae	S	Angiosperms
Glycosmis pentaphylla Hk.f.	Rutaceae	S	Angiosperms
Goldfussia echinata Haridasan et Rao	Acanthaceae	S	Angiosperms
Goniothalamus sesquipedalis (Wall.) Hk.f.&Th.	Annonaceae	S	Angiosperms
Grewia abutilifolia Vent. ex Juss.	Tiliaceae	S	Angiosperms
Grewia hirsuta Vahl.	Tiliaceae	S	Angiosperms
Grewia sapida Roxb.	Tiliaceae	S	Angiosperms
Grewia spp.	Tiliaceae	S	Angiosperms
Grewia spp.	Tiliaceae	S	Angiosperms
Hedyotis uncinella Hk.f. & Arn.	Rubiaceae	S	Angiosperms
Helixanthera ligustrina (Wall.) Dans.	Loranthaceae	S	Angiosperms
Hibiscus rosa-sinensis L.	Malvaceae	S	Angiosperms
Hibiscus surattensis L.	Malvaceae	S	Angiosperms
Himalrandia tetrasperma (Roxb.) Yam.	Rubiaceae	S	Angiosperms
Hiptage accuminata Wall. ex Hk.f.	Malpighiaceae	S	Angiosperms
Hiptage bengalensis (L.) Kurz.	Malpighiaceae	S	Angiosperms
Holmskioldia sanguinea Retz.	Verbenaceae	S	Angiosperms
Homonoia riparia Lour.	Euphorbiaceae	S	Angiosperms
Hoya fusca Wall.	Asclepiadaceae	S	Angiosperms
Hoya lanceolata Wall. ex D.Don.	Asclepiadaceae	S	Angiosperms
Hoya lobbii Hk.f.	Asclepiadaceae	S	Angiosperms
Hypericum uralum Buch.-Ham. ex D.Don.	Hypericaceae	S	Angiosperms
Hyptis suaveolens (L.) Poit.	Lamiaceae	S	Angiosperms
Indigofera atropurpurea Ham.	Fabaceae	S	Angiosperms
Indigofera dosua Ham.	Fabaceae	S	Angiosperms
Indigofera pulchella Roxb.	Fabaceae	S	Angiosperms
Inula cappa (Buch.-Ham. ex D.Don.) DC.	Asteraceae	S	Angiosperms
Inula eupatorioides DC.	Asteraceae	S	Angiosperms
Ipomoea fistulosa Mart. ex Choisy	Convolvulaceae	S	Angiosperms
Ixora acuminata Roxb.	Rubiaceae	S	Angiosperms
Ixora nigricans W.&A.	Rubiaceae	S	Angiosperms
Jasminum amplexicaule Buch.-Ham. ex G.Don.	Oleaceae	S	Angiosperms
Jasminum humile L.	Oleaceae	S	Angiosperms

Plant species	Family	Habit	Division
Jasminum lanceolaria Roxb.	Oleaceae	S	Angiosperms
Jasminum multiflorum (Burm.f.) Andrews	Oleaceae	S	Angiosperms
Jasminum nervosum Lour.	Oleaceae	S	Angiosperms
Jasminum subglandulosum Kurz.	Oleaceae	S	Angiosperms
Jatropha curcas L.	Euphorbiaceae	S	Angiosperms
Lantana camara L.	Verbenaceae	S	Angiosperms
Lantana indica Roxb.	Verbenaceae	S	Angiosperms
Lasianthus biermanii King. ex Hk.f.	Rubiaceae	S	Angiosperms
Lasianthus lucidus Bl.	Rubiaceae	S	Angiosperms
Lasianthus tubiferus Hk.f.	Rubiaceae	S	Angiosperms
Leea alata Edgew.	Leeaceae	S	Angiosperms
Leea asiatica (L.) Ridsdale	Leeaceae	S	Angiosperms
Leea crispa L.	Leeaceae	S	Angiosperms
Leea crispa L.	Leeaceae	S	Angiosperms
Lepidagathis hyalina Nees.	Acanthaceae	S	Angiosperms
Loranthus gracilifolius Schult.	Loranthaceae	S	Angiosperms
Loranthus scurrula L.	Loranthaceae	S	Angiosperms
Macrosolan cochinchinensis (Lour.) Van Tiegh.	Loranthaceae	S	Angiosperms
Maesa montana DC.	Myrsinaceae	S	Angiosperms
Maoutia puya Wedd.	Urticaceae	S	Angiosperms
Maytenus hookeri Loes.	Celastraceae	S	Angiosperms
Melastoma malabathricum L.	Melastomataceae	S	Angiosperms
Morinda augustifolia Roxb.	Rubiaceae	S	Angiosperms
Morinda umbellata L.	Rubiaceae	S	Angiosperms
Munronia pinnata (Wall.) Harms.	Meliaceae	S	Angiosperms
Murraya koenigii (L.) Spreng.	Rutaceae	S	Angiosperms
Mussaenda corymbosa Roxb.	Rubiaceae	S	Angiosperms
Mussaenda roxburghii Hk.f.	Rubiaceae	S	Angiosperms
Mycetia longifolia (Wall.) O.Kuntze	Rubiaceae	S	Angiosperms
Nepenthes khasiana Hk.f.	Nepenthaceae	S	Angiosperms
Osbeckia nutans Triana	Melastomataceae	S	Angiosperms
Osbeckia rostrata D.Don	Melastomataceae	S	Angiosperms
Oxyspora cernua (Roxb.) Triana	Melastomataceae	S	Angiosperms
Paramignya micrantha Kurz.	Rutaceae	S	Angiosperms
Paramignya scandens (Griff.) Craib.	Rutaceae	S	Angiosperms
Pavetta tomentosa Roxb. ex Sm.	Rubiaceae	S	Angiosperms
Phlogacanthus thyrsiflorus (Roxb.) Nees	Acanthaceae	S	Angiosperms
Phlogacanthus tubiflorus Nees.	Acanthaceae	S	Angiosperms

Plant species	Family	Habit	Division
Phoenix acaulis Ham.	Arecaceae	S	Angiosperms
Phyllanthus glaucus Wall. ex Muell.-Arg.	Euphorbiaceae	S	Angiosperms
Plectranthus ternifolius D.Don.	Lamiaceae	S	Angiosperms
Pogostemon amaranthoides Benth.	Lamiaceae	S	Angiosperms
Pogostemon benghalensis (Burm.f.) Kuntze	Lamiaceae	S	Angiosperms
Pogostemon parviflorus Benth.	Lamiaceae	S	Angiosperms
Pouzolzia sanguinea Merr.	Urticaceae	S	Angiosperms
Pseudaechmanthera glutinosa (Nees.) Bremek.	Acanthaceae	S	Angiosperms
Pseuderanthemum indicum A.M.&J.M. Cowan	Acanthaceae	S	Angiosperms
Psychotria denticulata Wall.	Rubiaceae	S	Angiosperms
Psychotria erratica Hk.f.	Rubiaceae	S	Angiosperms
Psychotria monticola Kurz.	Rubiaceae	S	Angiosperms
Psychotria spp.	Rubiaceae	S	Angiosperms
Psychotria symplicifolia Kurz.	Rubiaceae	S	Angiosperms
Pteracanthus griffithianus Bremek.	Acanthaceae	S	Angiosperms
Randia longiflora Lamk.	Rubiaceae	S	Angiosperms
Randia spinosa (Thunb.) Poir.	Rubiaceae	S	Angiosperms
Ricinus communis L..	Euphorbiaceae	S	Angiosperms
Rivea hypocrateriformis Choisy	Convolvulaceae	S	Angiosperms
Rivea ornata Chois.	Convolvulaceae	S	Angiosperms
Rosa clinophylla Thory	Rosaceae	S	Angiosperms
Rosa moschata Herrn.	Rosaceae	S	Angiosperms
Rotula aquatica Lour.	Ehretiaceae	S	Angiosperms
Rubus alceifolius Poir.	Rosaceae	S	Angiosperms
Rubus ellipticus Sm.	Rosaceae	S	Angiosperms
Rubus hexagynus Roxb.	Rosaceae	S	Angiosperms
Rubus niveus Thunb.	Rosaceae	S	Angiosperms
Rubus spp.	Rosaceae	S	Angiosperms
Sarcococca saligna (D.Don.) Muell.-Arg.	Buxaceae	S	Angiosperms
Schefflera sp	Araliaceae	S	Angiosperms
Securinega virosa (Roxb. ex Willd.) Baill.	Euphorbiaceae	S	Angiosperms
Sida acuta Burm.f.	Malvaceae	S	Angiosperms
Sida rhombifolia L.	Malvaceae	S	Angiosperms
Solanum erianthum D.Don	Solanaceae	S	Angiosperms
Solanum myriacanthum Dunal	Solanaceae	S	Angiosperms
Solanum torvum Sw.	Solanaceae	S	Angiosperms
Solanum violaceum Ort.	Solanaceae	S	Angiosperms
Stachytarpheta dichotoma Vahl.	Verbenaceae	S	Angiosperms

Plant species	Family	Habit	Division
Stachytarpheta jamaicensis (L.) Vahl.	Verbenaceae	S	Angiosperms
Stixis suaveolens (Roxb.) Bail.	Capparidaceae	S	Angiosperms
Strobilanthes neilgherrensis T.Anders	Acanthaceae	S	Angiosperms
Syzygium cuneatum (Duthie) Balak.	Myrtaceae	S	Angiosperms
Tabernaemontana divaricata (L.) R.Br.	Apocynaceae	S	Angiosperms
Taxillus vestitus (Wall.) Dans.	Loranthaceae	S	Angiosperms
Tephrosia candida (Roxb.) DC.	Fabaceae	S	Angiosperms
Tephrosia purpurea Pers.	Fabaceae	S	Angiosperms
Tithonia diversifolia A.Gray.	Asteraceae	S	Angiosperms
Tournefortia viridiflora Wall.	Boraginaceae	S	Angiosperms
Trachelospermum lucidum (D.Don.) H.Sch.	Apocynaceae	S	Angiosperms
Trigonostemon semperflorens (Roxb.|) Muell.-Arg.	Euphorbiaceae	S	Angiosperms
Triumfetta pilosa Roth.	Tiliaceae	S	Angiosperms
Triumfetta rhomboidea Jacq.	Tiliaceae	S	Angiosperms
Triumfetta tomentosa Bojer.	Tiliaceae	S	Angiosperms
Tupidanthus calyptratus Hk.f.&Th.	Araliaceae	S	Angiosperms
Uraria picata Desv.	Fabaceae	S	Angiosperms
Urena lobata L.	Malvaceae	S	Angiosperms
Urtica dioica L.	Urticaceae	S	Angiosperms
Urtica parviflora Roxb.	Urticaceae	S	Angiosperms
Vaccinium dunalianum Wt.	Vacciniaceae	S	Angiosperms
Vaccinium vacciniaceum (Roxb.) Sleum.	Vacciniaceae	S	Angiosperms
Vemonia scandens DC.	Asteraceae	S	Angiosperms
Viscum nepalense Spreng.	Loranthaceae	S	Angiosperms
Wallichia densiflora Mart.	Arecaceae	S	Angiosperms
Zizyphus mauritiana Lamk.	Rhamnaceae	S	Angiosperms
Arundinaria hirsuta Munro	Bambusaceae	SB	Angiosperms
Bambusa arundinacea Willd.	Bambusaceae	SB	Angiosperms
Bambusa balcooa Roxb.	Bambusaceae	SB	Angiosperms
Bambusa nutans Wall.	Bambusaceae	SB	Angiosperms
Bambusa pallida Munro	Bambusaceae	SB	Angiosperms
Bambusa tulda Roxb.	Bambusaceae	SB	Angiosperms
Bambusa vulgaris Schrad.	Bambusaceae	SB	Angiosperms
Cephalostachyum latifolium Munro.	Bambusaceae	SB	Angiosperms
Dendrocalamus hamiltonii Nees. et Am. ex Munro	Bambusaceae	SB	Angiosperms
Dendrocalamus strictus Nees.	Bambusaceae	SB	Angiosperms
Melocanna baccifera Skeels	Bambusaceae	SB	Angiosperms
Schizostachyum capitatum (Munro) Majumdar	Bambusaceae	SB	Angiosperms

Plant species	Family	Habit	Division
Schizostachyum dullooa (Gamble) Majumdar	Bambusaceae	SB	Angiosperms
Calamus erectus Roxb.	Arecaceae	SC	Angiosperms
Calamus erectus var macrocarpa Roxb.	Arecaceae	SC	Angiosperms
Calamus floribundus Griff.	Arecaceae	SC	Angiosperms
Calamus gracilis Roxb.	Arecaceae	SC	Angiosperms
Calamus spp.	Arecaceae	SC	Angiosperms
Calamus spp.	Arecaceae	SC	Angiosperms
Daemonorops jenkinsianus Mart.	Arecaceae	SC	Angiosperms
Derris cuneifolia Benth.	Fabaceae	SC	Angiosperms

APPENDIX 5.1

LIST OF TREE SPECIES INTERVIEWED FOR THEIR KEY ECOLOGICAL FUNCTIONS (AS WILDLIFE FOOD) AND KEY CULTURAL FUNCTIONS (UTILISATION OF TREE SPECIES BY NATIVE PEOPLE)

S. No.	Botanical name	Common name
1	*Abrus precatorius*	Kitma/sabong
2	*Acronychia pedunculata*	Bolmapu
3	*Actinodaphne augustifolia*	Boljalik
4	*Actinodaphne obovata*	Dodikimsong
5	*Aesculus assamica*	Bolribu/renot
6	*Ailanthus integrifolia*	Chandana
7	*Alangium chinense*	Rengokmi
8	*Albizia chinensis*	Bolphu
9	*Albizia lebbek*	Shishu
10	*Albizia odoratissima*	Khilbe
11	*Albizia stipulata*	Bolapu
12	*Alstonia scholaris*	Sokchon
13	*Anthocephalus chinensis*	Kadam
14	*Aphanamixis polystachya*	Bolapal/bolsampal
15	*Aporusa dioica*	Chamolja/Chamsia
16	*Aquilaria agallocha*	Agalbol
17	*Aristolochia tagala*	Terimu
18	*Artocarpus chama*	Chrum/bolsrem
19	*Artocarpus gomezianus*	Armu/arimu
20	*Bauhinia malabarica*	Bakbakil/megongtak
21	*Bauhinia stipularis*	Megong
22	*Betula alnoides*	Gakkal
23	*Bischoffia javanica*	Udari/udim
24	*Bombax ceiba*	Bolchhu
25	*Bridelia monoica*	Kasi dupret
26	*Bridelia retusa*	Kasi
27	*Bursera serrata*	Ambilatong/tekring
28	*Callicarpa arborea*	Makanchi/kimbal
29	*Calophyllum polyanthum*	Bolmendu
30	*Canarium strictum*	Dongkhreng/dongram
31	*Careya arborea*	Gambil/dambil
32	*Casearia graveolens*	Mangjotra
33	*Cassia fistula*	Sinaru
34	*Castanopsis hystrix*	Chako chiring
35	*Castanopsis purpurella*	Chako

S. No.	Botanical name	Common name
36	*Celtis tetranda*	Bolgitchak
37	*Cinnamomum bejolghota*	Teja bifa
38	*Cinnamomum glaucescens*	Gansari
39	*Cinnamomum tamala*	Tejpatta
40	*Croton caudatus*	Bolmisak
41	*Croton joufera*	Matmi
42	*Cryptocarya andersonii*	Bolong bolanchi/boljadong/boldujong
43	*Cynometra polyandra*	Rongrip
44	*Dalbergia paniculata*	Bolmendu
45	*Derris robusta*	Bolkakharu
46	*Dillenia indica*	Tediki
47	*Dillenia pentagyna*	Agatchi
48	*Diospyros embryopteris*	Gap
49	*Drimycarpus racemosus*	Babari
50	*Duabunga grandiflora*	Achim/bolchhim
51	*Elaeocarpus aristatus*	Dura agong/gangma
52	*Elaeocarpus rugosus*	Ankisipak
53	*Emblica officinalis*	Ambre
54	*Erythrina stricta*	Mandal
55	*Eurya accuminata*	Chamisi
56	*Ficus foveolata*	Goerangsang
57	*Ficus heterophylla*	Sakap
58	*Ficus hispida*	Sakapak
59	*Ficus infectoria*	Sewla
60	*Ficus lamponga*	Bolmitap
61	*Ficus semicordata*	Aminsep
62	*Ficus subulata*	Tewak
63	*Firmiana colorata*	Bokta
64	*Flacourtia jangomas*	Darichik
65	*Garcinia kydia*	Dengaduti
66	*Garcinia lancifolia*	Tesaru
67	*Garcinia tinctoria*	Aruwak
68	*Garuga pinnata*	Chigambil
69	*Glochidion spharogynum*	Boljagro
70	*Glochidion velutinum*	Bolchiring
71	*Glycosmis arborea*	Jalwai
72	*Gmelina arborea*	Gambari
73	*Grewia microcos*	Bolsubret/damsuri
74	*Gynocardia odorat*	Bolibu
75	*Haldina cordifolia*	Sandang
76	*Heteropanax fragrans*	Mugasalgro

S. No.	Botanical name	Common name
77	*Hibiscus macrophyllus*	Mao
78	*Hodgsonia macrocarpa*	Tebe
79	*Holarrhena antidysenterica*	Bolgolmatra/matalwe/bolmatra
80	*Ilex embelioides*	Bolchhenda
81	*Ilex umbellulata*	Boltajong
82	*Kaeya floribunda*	Bolong
83	*Knema linifolia*	Bolanchi
84	*Kydia calycina*	Boldubok
85	*Lagerstroemia parviflora*	Sidai
86	*Lagerstroemia speciosa*	Ajakari/bolasari
87	*Lannea coromandelica*	Chigampa
88	*Lannea grandis*	Bole agru/jiga/dome
89	*Lepisanthes rubiginosa*	Gawigran
90	*Ligustrum robustum*	Bolgreng
91	*Lithocarpus elegans*	Simok
92	*Litsea monopelata*	Bolbet
93	*Litsea sebifera*	Laham/boldukaki
94	*Macaranga denticulata*	Bolajak/chhagro
95	*Macaranga indica*	Rimikgital
96	*Maesa sarmentosa*	Mangritchok
97	*Mallotus roxbughianus*	Boltatu
98	*Mallotus tetracoccus*	Matchmikong
99	*Mangifera indica*	Thegatchu
100	*Mangifera sylvatica*	Thegatchu
101	*Meliosma simplicifolia*	Babari jaksram
102	*Mesua ferrea*	Khimde
103	*Michelia champaca*	Champa
104	*Micromelum integerrimum*	Aburispil
105	*Morinda augustifolia*	Chegong
106	*Neocinnamomum caudatum*	Chammejam
107	*Oreocnoide integrifolia*	Dingsning/kilkira
108	*Oroxylum indicum*	Kiring
109	*Ostodes paniculata*	Karekgran
110	*Parapentapanax subcordatum*	Samibrek
111	*Persea villosa*	Nameaga
112	*Pithecellobium heterophyllum*	Bolmangal/mangal
113	*Pithecellobium monodelphum*	Boldaru
114	*Podocarpus neerifolia*	Durama shillongkit
115	*Polaquium polyanthum*	Solwa
116	*Polyalthia simiarum*	Bolgisim

S. No.	Botanical name	Common name
117	*Premna latifolia*	Dokimi
118	*Pterigota alata*	Charapak
119	*Pterospermum acerifolium*	Adingok
120	*Pterospermum lancifolium*	Laisa/adambit
121	*Randia uliginosa*	Agrenda/agreng
122	*Rhus accuminata*	Bolmising/bolmicheng
123	*Rhus succedanea*	Bolkhat-thi
124	*Sapium baccatum*	Changsim/cherasu
125	*Sapium euginiaefolium*	Agong
126	*Saurauia nepaulensis*	Adambak
127	*Schefflera venulosa*	Jengjil
128	*Schima wallichii*	Boldak
129	*Shorea robusta*	Bolsal
130	*Sterculia colorata*	Senksu/waljem
131	*Sterculia villosa*	Olmak
132	*Syzygium balsameum*	Tebrong
133	*Syzygium cumini*	Chambu
134	*Syzygium operculatum*	Chambu sirsang
135	*Tectona grandis*	Segun/teak
136	*Terminalia bellirica*	Churi/cherore
137	*Terminalia citrina*	Artak
138	*Tetrameles nudiflora*	Bolbok/awek
139	*Toddalia asiatica*	Nache makkal
140	*Toona ciliata*	Bolbret
141	*Trema orientalis*	Pakram
142	*Trewia nudiflora*	Bolkha/bolklap
143	*Ulmus lancifolia*	Wakru/bolsue
144	*Vitex glabrata*	Bandikuri
145	*Vitex peduncularis*	Rangri
146	*Vitex pubescens*	Bhodia
147	*Walsura arborea*	Khrenti/kranchi
148	*Walsura tubularis*	Bolkingrak
149	*Wendlandia excelsa*	Garadek
150	*Xylosma longifolium*	Palwang

APPENDIX 5.2

A FEW BIRD SPECIES FROM BALPAKRAM NATIONAL PARK AND SURROUNDINGS

(MANOJ AND JAYAPAL, PERSONAL COMMUNICATION, 1996)

Asterisk indicates that species is included in bird habitat relationship analysis

S. No.	Common Name	*Species*	Family
1	Darter	*Anhinga rufa*	Phalacrocoracidae
2	Pond Heron	*Ardeola grayii*	Ardiedae
3	Little Egret	*Egretta garzetta*	Ardiedae
4	Cattle Egret	*Bubulcus ibis*	Ardiedae
5	Common Teal	*Anas crecca*	Anatidae
6	Lesser Whistling Teal	*Dendrocygna javanica*	Anatidae
7	Common Merganser	*Mergus merganser*	Anatidae
8	* Sparrow Hawk	*Accipiter nisus*	Accipitridae
9	* Crested surpent eagle	*Spilornis cheela*	Accipitridae
10	* Buzzard spp	*Buteo spp*	Accipitridae
11	* Blackcrested Baza	*Aviceda leuphotes*	Accipitridae
12	* Short-Toed Eagle	*Circaetus gallicus*	Accipitridae
13	Crested Hawk Eagle	*Spizaetus cirrhatus*	Accipitridae
14	Bonnelli's Hawk Eagle	*Hieraaetus fasciatus*	Accipitridae
15	Black winged Kite	*Elanus caeruleus*	Accipitridae
16	Shikra (?)	*Accipiter badius*	Accipitridae
17	Black Eagle	*Ictinaetus malayensis*	Accipitridae
18	* Oriental hobby	*Falco severus*	Falconidae
19	* Kestrel Falco	*Falco tinnunculus*	Falconidae
20	* Lesser Kestrel	*Falco naumannii*	Falconidae
21	* Red Jungle Fowl	*Gallus gallus*	Phasianidae
22	* Kaleej Pheasant	*Lophura leucomelana*	Phasianidae
23	* Peacock Pheasant	*Polyplectron bicalcaratum*	Phasianidae
24	White breasted waterhen	*Amaurornis phoenicurus*	Rallidae
25	* Thickbilled green pigeon	*Treron curvirostra*	Columbidae
26	* Rufous turtle dove	*Streptopelia orientalis*	Columbidae
27	* Emerald dove	*Chalcophaps indica*	Columbidae
28	Red turtle dove	*Streptopelia tranquebarica*	Columbidae
29	Spotted dove	*Streptopelia chinensis*	Columbidae
30	* Lorikeet	*Loriculus vernalis*	Psittacidae

S. No.	Common Name	Species	Family
31	Red breasted parakeet	*Psittacula alexandri*	Psittacidae
32	* Indian cuckoo	*Cuculus micropterus*	Coculidae
33	* Common hawk cuckoo	*Cuculus varius*	Coculidae
34	Emerald cuckoo	*Chalcites maculatus*	Coculidae
35	* Drongo cuckoo	*Surniculus lugubris*	Coculidae
36	Pied crested cuckoo	*Clamator jacobinus*	Coculidae
37	* Coucal	*Centropus sinensis*	Coculidae
38	Lesser coucal	*Centropus bengalensis*	Coculidae
39	* Large green billed malkoha	*Rhopodytes tristis*	Coculidae
40	Barred owlet	*Glaucidium cuculoides*	Strigidae
41	* Longtailed nightjar	*Caprimulgus macrurus*	Caprimulgidae
42	* Red headed trogon	*Harpactes erythrocephalus*	Trogonidae
43	* Palm swift	*Cypsiurus parvus*	Apodidae
44	* Himalayan swiftlet	*Collocalia brevirostris*	Apodidae
45	* Whitebreasted kingfisher	*Halcyon smyrnensis*	Alcedinidae
46	Himalayan pied kingfisher	*Ceryle lugubris*	Alcedinidae
47	Blyth's /great blue kingfisher	*Alcedo hercules*	Alcedinidae
48	Common kingfisher	*Alcedo atthis*	Alcedinidae
49	Hoopoe	*Upupa epops*	Upupidae
50	* Chestnut headed bee-eater	*Merops leschenaultii*	Meropidae
51	Green bee-eater	*Merops orientalis*	Meropidae
52	Blue bearded bee-eater	*Nyctyornis athertoni*	Meropidae
53	* Indian roller	*Coracias benghalensis*	Coracidae
54	* Indian pied hornbill	*Anthracoceros coronatus*	Bucreotidae
55	Great pied hornbill	*Buceros bicornis*	Bucreotidae
56	* Great hill barbet	*Megalaima virens*	Capitonidae
57	* Large green barbet	*Megalaima zeylonica*	Capitonidae
58	Lineated barbet	*Megalaima lineata*	Capitonidae
59	* Bluethroated barbet	*Megalaima asiatica*	Capitonidae
60	Blue eared barbet	*Megalaima australis*	Capitonidae
61	Crimson breasted barbet	*Megalaima haemacephala*	Capitonidae
62	* Speckled piculet	*Picumnus innominatus*	Picidae
63	* Rufous piculet	*Sasia ochrasia*	Picidae
64	* Rufous woodpecker	*Micropternus brachyurus*	Picidae
65	Blacknaped green woodpecker	*Picus canus*	Picidae
66	Golden backed three-toed woodpecker	*Dinopium shorii*	Picidae

S. No.	Common Name	*Species*	Family
67	Larger goldenbacked woodpecker	*Chrysocolaptes lucidus*	Picidae
68	Falvous breasted pied woodpecker	*Dendrocopos macei*	Picidae
69	Greycrowned pygmy woodpecker	*Dendrocopos canicapillus*	Picidae
70	Large yellow naped woodpecker	*Picus flavinucha*	Picidae
71	Small yellow naped woodpecker	*Picus chlorolophus*	Picidae
72	Redeared bay wood pecker	*Blyrthipicus pyrrhotis*	Picidae
73	* Longtailed broadbill	*Psarisomus lunatus dalhousiae*	**Eurylamidae**
74	* Golden oriole	*Oriolus oriolus*	Oriolidae
75	Blacknaped oriole	*Oriolus chinensis*	Oriolidae
76	* Maroon oriole	*Oriolus trailii*	Oriolidae
77	* Blackheaded oriole	*Oriolus xanthornus*	Oriolidae
78	* Swallow	*Hirundo rustica*	Hirundinidae
79	* Sand Martin	*Riparia riparia*	Hirundinidae
80	* Greybacked shrike	*Lanius tephronotus*	Laniidae
81	* Rufousbacked shrike	*Lanius schach tricolor*	Laniidae
82	* Brown shrike	*Lanius cristatus*	Laniidae
83	* Grey drongo	*Dicrurus leucophaeus*	Dicruridae
84	Black drongo	*Dicrurus adsimilis*	Dicruridae
85	* Bronzed drongo	*Dicrurus aeneus*	Dicruridae
86	* Lesser rackettailed drongo	*Dicrurus remifer*	Dicruridae
87	* Greater rackettailed drongo	*Dicrurus paradiseus*	Dicruridae
88	Haircrested drongo	*Dicrurus hottentottus*	Dicruridae
89	* Ashy swallow shrike	*Artamus fuscus*	Artamide
90	* Hill myna	*Gracula religiosa*	Sturnidae
91	* Greyheaded myna	*Sturnus malabaricus*	Sturnidae
92	Brahminy myna	*Sturnus pagodarum*	Sturnidae
93	Pied myna	*Sturnus contra*	Sturnidae
94	Jungle myna	*Acridotheres fuscus*	Sturnidae
95	Common myna	*Acridotheres tristis*	Sturnidae
96	Jungle crow	*Corvus macrorhynchos*	Corvidae
97	Green magpie	*Cissa chinensis*	Corvidae
98	Indian tree pie	*Dendrocitta vagabunda*	Corvidae
99	Himalayan tree pie	*Dendrocitta formosae*	Corvidae
100	* Pied flycatcher shrike	*Hemipus picatus*	Campephagidae
101	* Large wood shrike	*Tephrodornis virgatus*	Campephagidae
102	* Large cuckoo shrike	*Coracina novaehollandie*	Campephagidae

S. No.	Common Name	Species	Family
103	* Smaller grey cuckoo shrike	*Coracina melaschistos*	Campephagidae
104	* Scarlet minivet	*Pericrocotus flammeus*	Campephagidae
105	* Longtailed minivet	*Pericrocotus ethologus*	Campephagidae
106	* Small minivet	*Pericrocotus cinnamomeus*	Campephagidae
107	* Common iora	*Aegithinia tiphia*	Irenidae
108	* Goldfronted chloropsis	*Chloropsis aurifrons*	Irenidae
109	* Orange bellied chloropsis	*Chloropsis hardwickii*	Irenidae
110	* Goldmantled chloropsis	*Chloropsis cochinchinensis*	Irenidae
111	* Fairy bluebird	Irene puella	Irenidae
112	* Finchbilled bulbul	*Spizixos canifrons*	Pycnonotidae
113	* Blackheaded yellow bulbul	*Pycnonotus melanicterus*	Pycnonotidae
114	* Red whiskered bulbul	*Pycnonotus jocosus*	Pycnonotidae
115	* Red vented bulbul	*Pycnonotus cafer*	Pycnonotidae
116	* Olive bulbul	*Hypsipetes viridiscens*	Pycnonotidae
117	Rufous bellied bulbul (?)	*Hypsipetes mclellandi*	Pycnonotidae
118	* Black bulbul	*Hypsipetes madagascariensis*	Pycnonotidae
119	* Brown eared bulbul	*Hypsipetes flavalus*	Pycnonotidae
120	* Whitethroated bulbul	*Criniger flaveolus*	Pycnonotidae
121	* Spotted babbler	*Stachyris ruficeps*	Muscicapidae
122	* Slatyheaded scimitar babbler	*Pomatorhinus horsfieldii*	Muscicapidae
123	* Redfronted babbler	*Pallorneum ruficeps*	Muscicapidae
124	* Blackchinned babbler ?	*Stachyris pyrrhops*	Muscicapidae
125	Jungle babbler	*Turdoides striatus*	Muscicapidae
126	* yellow breasted babbler	*Macronous gularis*	Muscicapidae
127	* Redcapped babbler	*Timalia pileata*	Muscicapidae
128	* Necklace laughing thrush	*Garrulax moniliger*	Muscicapidae
129	* Blackgorgetted laughing trush	*Garrulax pectoralis*	Muscicapidae
130	Whitcrested laughing thrush	*Garrulax leucolophus*	Muscicapidae
131	* Nepal babbler	*Alcippe nipalensis*	Muscicapidae
132	* Blackcapped sibia	*Heterophasia capistrata*	Muscicapidae
133	Chestnutbacked sibia	*Heterophasia annectens*	Muscicapidae
134	Black redstart	*Phoenicurus ochrurus*	Muscicapidae
135	Plumbeous redstart	*Rhyacornis fuliginosus*	Muscicapidae
136	Whitecapped redstart	*Chaimorornis leucocephalus*	Muscicapidae
137	Stone chat	*Saxicola torquata*	Muscicapidae
138	Magpie robin	*Copsychus saularis*	Muscicapidae

S. No.	Common Name	Species	Family
139	Shama	*Copsychus malabaricus*	Muscicapidae
140	* Little pied flycatcher	*Ficedula westermanni*	Muscicapidae
141	* Redbreasted flycatcher	*Ficedula parva*	Muscicapidae
142	* Pygmy blue flycatcher	*Muscicapella hodgsonii*	Muscicapidae
143	* Bluethroated flycatcher	*Cyornis rubeculoides*	Muscicapidae
144	* Greyheaded flycatcher	*Culicicapa ceylonensis*	Muscicapidae
145	* Whitethroated fantail flycatcher	*Rhipidura albicollis*	Muscicapidae
146	* Blacknaped blue flycatcher	*Hypothymis azurea*	Muscicapidae
147	* Blyth's reed wabbler	*Acrocephalus dumetorum*	Muscicapidae
148	* Dull green leaf warbler	*Phylloscopus trochiloides*	Muscicapidae
149	* Yellow browed leaf warbler	*Phylloscopus inornatus*	Muscicapidae
150	* Large billed leaf warbler	*Phylloscopus magnirostris*	Muscicapidae
151	* Large crowned leaf warbler	*Phylloscopus coronatus*	Muscicapidae
152	* Grey headed flycatcher warbler	*Seicercus xanthoschistos*	Muscicapidae
153	* Allied flycatcher wabler	*Seicercus affinis*	Muscicapidae
154	Blackbacked forktail	*Enicurus immaculatus*	Muscicapidae
155	Little forktail	*Enicurus scouleri*	Muscicapidae
156	Leschenault's forktail	*Enicurus leshnaultii*	Muscicapidae
157	Blue whistling thrush	*Myophonus caeruleus*	Muscicapidae
158	Blue rock thrush	*Monticola solitarius*	Muscicapidae
159	Orange headed ground thrush	*Zoothera citrina*	Muscicapidae
160	Large brownthrush	*Zoothera monticola*	Muscicapidae
161	* Dark grey bush chat	*Saxicola ferrea*	Muscicapidae
162	* Franklin's wren warbler	*Prinia hodgsoni*	Muscicapidae
163	Ashy wren wabler	*Prinia socialis*	Muscicapidae
164	Plain wren wabler	*Prinia subflava*	Muscicapidae
165	Black-necked tailorbird	*Orthotomus atrogularis*	Muscicapidae
166	* Sultat tit	*Melanochlora sultanea*	Paridae
167	Velvet fronted nuthatch	*Sitta frontalis*	Sittidae
168	* Indian tree pipit	*Anthus hodgsoni*	Motacillidae
169	White wagtail	*Motacilla alba*	Motacillidae
170	Forest wagtail	*Motacilla indica*	Motacillidae
171	* Scarlet backed flowerpecker	*Dicaeum cruentatum*	Dicaedae
172	* Rubycheek	*Anthreptessingalensis*	Nectariniidae
173	* Purple sunbird	*Nectarinia asiatica*	Nectariniidae
174	* Nepal yellowbacked sunbird	*Aethopyga nipalensis*	Nectariniidae

S. No.	Common Name	Species	Family
175	* Yellow backed sunbird	*Aethopyga siparaja*	Nectariniidae
176	* Little spider hunter	*Arachnothera longirostris*	Nectariniidae
177	* Streaked spider hunter	*Arachnothera magna*	Nectariniidae
178	* Blackbreasted sunbird	*Aethopyga saturata*	Nectariniidae
179	* White-eye	*Zosterops palpebrosus*	Zosteropidae
180	* Tree sparrow	*Passer montanus*	Ploceidae
181	* House sparrow	*Passer domesticus*	Ploceidae
182	* Whitebacked munia	*Lonchura striata*	Ploceidae
183	* spotted munia	*Lonchura punctulata*	Ploceidae
184	Chestnut bunting	*Emberiza rutila*	Emberizidae

APPENDIX 5.3

WHR MATRIX – DATA DICTIONARY

(MATHUR *et al.*, 2002)

Scientific name (cite source)

Vernacular name

Taxonomic class

A – amphibian
R – reptile
B – bird
M - mammal

Legal status

As denoted in Wildlife Protection Act: SI, SII, SIII, SIV, SV
As denoted in CITES: AI, AII, AIII

Conservation status (IUCN categories)

CE – critically endangered
EN – endangered
VU – vulnerable
LR – lower risk
DD – data deficient, might be one of above
[blank] – none of above

Residency status

P - Permanent (year-round) resident
C - Country-wide migrant
S - State-wide migrant
V – vagrant / incidental

Abundance / distribution status

A – abundant and well-distributed throughout its range within the CA
B – fairly abundant but more patchily distributed with gaps
C – disjunct population patches
D – disjunct patches of small local populations at risk of local extirpation
E – extremely patchy with high risk of overall extirpation

Conflict with humans

K - Direct killing of humans
H - Human injuries
C - Crop depredation
P - Destruction of property
L - Livestock depredation

Conservation area

A – ACA (Anaimalai Conservation Area)
G – GCA (Garo Hills Conservation Area)
S – SCA (Satpura Conservation Area)
T – TCA (Terai Conservation Area)

Ecosystem types (C-S)

Code the ecosystem types as follows:
2 = Closely associated (provides critical resources for survival and reproduction)
1 = Associated (occurs but not critical)
0 = Absent
blank = does not occur in conservation area

Champion and Seth Forest Types of India (to the group level)

Tropical moist evergreen forest
Tropical semi-evergreen forest (GCA, TCA)
Tropical moist deciduous forest (GCA, TCA)
Shola type of mixed evergreen forest (GCA)
Alluvial sal – kamrup alluvial sal forests
Foot hill and plateau sal – eastern hill sal
East Himalayan moist deciduous forests
Assam alluvial plain semi evergreen forests (GCA)
Secondary moist bamboo brakes
Riparian fringing forests

Other, non-CS types including plantations

Wet grassland habitat on hill plateaus (ACA, GCA)
Extensive bamboo areas (GCA)
Wet, tall grasslands interspersed with woodland and swamps (TCA)
Rivers (by name, TCA, ACA & GCA)
Sal plantations (100 yrs old; GCA)
Young *jhum* (<10 yrs; GCA)
Middle *jhum* (10-20 yrs; GCA)
Old *jhum* (>20 yrs; GCA)

Trophic category

He- Herbivore
Fr - Frugivore
Ca - Carnivore (consumes animals other than insects)
In - Insectivore
Om - Omnivore (as general habit)
Cn - Carrion

Habitat elements/substrates
(As per the discussion of habitat elements in the Proposed National Working Plan Code)

Habitat elements of biotic origin (special habitats)

A. Snags
B. Snag recruits (dying trees, live trees with dead portions)
C. Hollow trees, chimney trees (living or dead)
D. Tree cavities (natural or created)
E. Large old trees (living)
F. Trees with fluting boles and buttresses
G. Down wood
H. Litter and duff layers
I. Lianas
J. Fruit-bearing trees and shrubs
K. Epiphyte patches

Habitat elements of geomorphic origin

L. Cliffs, talus, and ledges
M. Caves
N. Overhangs
O. Dens (existing burrows dug by animals)
P. Sheet rocks
Q. Large bouldery aggregates
R. Sandy banks and sand spits
S. Salt licks (exposed mineral soils)
T. Earth cuttings
U. Additional / other (specify)

Structural stage

Early stage
Mid stage
Late stage
Old-growth stage

Key ecological functions

A. Pollination vector
B. Disperser of plant propagules, fruits, seeds, etc.
C. Primary tree cavity excavator
D. Primary ground burrow excavator
E. Creator of paths or runways (terrestrial or arboreal)
F. Soil digging
G. Soil compaction, trampling
H. Other (specify)

Sensitivity to anthropogenic disturbance

A. Fire (human-set ground fires)
B. Livestock grazing
C. Marking, thinning of immature trees, and legal felling of mature trees or bamboo harvesting
D. Loss of snags, hollow trees
E. Clearing of undergrowth
F. Cutting of climbers
G. Extraction of NTFPs
H. Fuelwood gathering
I. Lopping
J. Tourism and recreation
K. Collection of plant samples for education purposes
L. Religious visits / pilgrimages
M. Poaching (illegal hunting)
N. Legal hunting
O. Roads and vehicle traffic
P. *Jhum*
Q. Illicit timber and bamboo harvest / extraction
R. Construction activities in general
S. Impoundments
T. Draining of wetlands
U. Removing of riparian vegetation
V. Pesticides and chemicals
W. Harrowing of wild grasslands
X. Plantations in grassy blanks
Y. Sand mining
Z. Introducing exotic vegetation
AA. Rock climbing
BB. Fishing
CC. Cannabis growing
DD. Encroachment on forests

APPENDIX 7.1

KEY ENVIRONMENTAL CORRELATES FOR ALL SPECIES IN THE SPECIES-ENVIRONMENT RELATIONS (SER) MODEL DATABASE

The numbered codes in this classification correspond to codes denoted for each species in the SER Model (Morrison *et al.*, 1998).

1 Vegetation elements

- 1.1 cover types (Society of American Forests, Society of Range Management, ICBEMP)
- 1.2 structural stages
  - 1.2.1 SAF stages
  - 1.2.2 SRM stages
  - 1.2.3 CRB stages
  - 1.2.4 Other stages used to denote plant response
    - 1.2.4.1 regeneration cut
    - 1.2.4.2 selectively logged
    - 1.2.4.3 thinned
    - 1.2.4.4 patch clearcut
    - 1.2.4.5 shelterwood
    - 1.2.4.6 overstory removal
- 1.3 forest or woodland vegetation substrates
  - 1.3.1 down wood (includes coarse woody debris, "CWD")
    - 1.3.1.1 down wood in riparian zone
  - 1.3.2 snags (entire tree dead)
    - 1.3.2.1 bark piles at base of snag
  - 1.3.3 mistletoe brooms
  - 1.3.4 litter
  - 1.3.5 duff
  - 1.3.6 shrubs
  - 1.3.7 fruits/seeds/mast
    - 1.3.7.1 seed caching
  - 1.3.8 dead parts of live trees
  - 1.3.9 moss
  - 1.3.10 trees
    - 1.3.10.1 exfoliating bark
  - 1.3.11 flowers
  - 1.3.12 lichens
  - 1.3.13 bark
  - 1.3.14 forbs (grass)
  - 1.3.15 cactus
  - 1.3.16 fungi
  - 1.3.17 roots, tubers, underground plant parts
  - 1.3.18 peatlands
- 1.4 herbaceous vegetation elements or substrates
  - 1.4.1 herbaceous vegetation cover

1.4.1.1 aquatic submergent vegetation
1.4.2 fruits/seeds
1.4.3 moss
1.4.4 cactus
1.4.5 flowers
1.4.6 shrubs
1.4.7 fungi
1.4.8 forbs
1.4.9 bulbs/tubers
1.4.10 cryptogammic crusts
1.5 diversity of vegetation cover types
1.6 edges
1.6.1 openings
1.6.2 meadows
1.7 mycorrhizal associations

2 Biological (non-vegetation) elements

2.1 presence of prey species (including small mammals, insects, birds, other spp.)
2.1.1 carrion
2.2 presence of predators
2.2.1 absence of predator
2.3 presence of exotic species
2.3.1 exotic plants
2.3.2 exotic animals
2.4 insect irruption areas
2.4.1 mountain pine beetle
2.4.2 spruce budworm
2.4.3 gypsy moth
2.5 presence of burrows or presence of burrowing mammals
2.6 grazing
2.6.1 direct effects (trample, consumed)
2.6.2 indirect effects (habitat degredation)
2.6.3 seasonality of grazing
2.7 presence of beaver or muskrat ponds or lodges
2.8 presence of nesting structures
2.8.1 cavities
2.8.2 platforms
2.9 presence of other species
2.9.1 positive or neutral effect
2.9.2 negative effect
2.10 forest pathogens
2.11 colonial nester

3 Non-vegetation terrestrial substrates

- 3.1 rocks
  - 3.1.1 gravel
- 3.2 soils
  - 3.2.1 soil class
  - 3.2.2 soil depth
  - 3.2.3 soil texture
    - 3.2.3.1 sand/dunes
    - 3.2.3.2 soil suitable for burrowing vertebrates
    - 3.2.3.3 soil suitable for burrowing invertebrates
  - 3.2.4 soil pH
  - 3.2.5 soil temperature
  - 3.2.6 soil moisture
  - 3.2.7 soil chemistry
  - 3.2.8 soil organic matter
- 3.3 lithic (rock) substrates
  - 3.3.1 lithic series or types (including lithic formations such as Jefferson limestone)
    - 3.3.1.1 granite
    - 3.3.1.2 basalt
    - 3.3.1.3 rhyolite
    - 3.3.1.4 sedimentary and metamorphic (fine grained rock), including limestone
    - 3.3.1.5 calcareous rock
    - 3.3.1.6 serpentine
    - 3.3.1.7 sand (sandstone)
    - 3.3.1.8 clay (alluvium)
    - 3.3.1.9 glacial till and landslides
    - 3.3.1.10 playa (alkaline, saline)
    - 3.3.1.11 tuff (volcanic ash)
    - 3.3.1.12 metal rich
    - 3.3.1.13 pumice
  - 3.3.2 avalanche chute
  - 3.3.3 cliff
  - 3.3.4 talus
  - 3.3.5 boulder, large rocks
  - 3.3.6 cave
  - 3.3.7 rock outcrops/crevices
  - 3.3.8 lava flows
  - 3.3.9 [blank]
  - 3.3.10 lava tubes
  - 3.3.11 canyons
  - 3.3.12 barren ground
  - 3.3.13 rugged terrain
  - 3.3.14 rocky ridges
  - 3.3.15 ravine
  - 3.3.16 cirque or basins (also see entry 5.7 below)
- 3.4 snow
  - 3.4.1 snow depth (winter)

- 3.4.2 glaciers, snow fields
- 3.5 water characteristics
  - 3.5.1 dissolved oxygen
  - 3.5.2 water depth
  - 3.5.3 dissolved solids
  - 3.5.4 water pH
  - 3.5.5 water temperature
  - 3.5.6 water velocity
  - 3.5.7 water turbidity
- 3.6 forages above tree canopy

4 Riparian and aquatic bodies

- 4.1 rivers
  - 4.1.1 riverine wetlands
  - 4.1.2 oxbows
- 4.2 streams (permanent or seasonal)
  - 4.2.1 intermittant
  - 4.2.2 rocks in streams
- 4.3 seeps or springs (including warm seeps or springs)
- 4.4 exposed mudflats, sand bars
- 4.5 sand bars, unconsolidated shore
- 4.6 gravel bars
- 4.7 shallow water
- 4.8 lakes or reservoirs (lacustrine)
  - 4.8.1 lakes with submergent vegetation
  - 4.8.2 lakes with floating mats
  - 4.8.3 lakes with silt or mud bottom
  - 4.8.4 lakes with emergent vegetation
  - 4.8.5 alkaline lake beds
- 4.9 ponds (permanent or seasonal)
  - 4.9.1 ponds with submergent vegetation
  - 4.9.2 ponds with floating mats
  - 4.9.3 ponds with silt or mud bottoms
  - 4.9.4 ponds with emergent vegetation
- 4.10 wetlands, marshes, or wet meadows (palustrine)
  - 4.10.1 bulbs or tubers in wetlands, marshes, or wet meadows
  - 4.10.2 Phragmites
- 4.11 bogs or fens
- 4.12 swamps
- 4.13 islands
- 4.14 waterfalls
- 4.15 hyporheic zone
- 4.16 irrigation ditches
- 4.17 ephemeral pools
- 4.18 deciduous riparian, including willow and cottonwood
- 4.19 vernal or seasonal flooding or flood plains
- 4.20 bottomlands
- 4.21 water table

5 Topographic or physiographic elements

5.1 elevation
5.2 slope
5.3 aspect
5.4 slope position
5.5 ridge tops
5.6 plateau
5.7 convex or concave basin (also see entry 3.3.16 above)
5.8 flat
5.9 mima

6 Climate

6.1 precipitation (amount, pattern, seasonality)
6.2 Mediterranean influence (dry summers)
6.3 maritime influence (higher humidity and more moisture)
6.4 temperature
6.5 humidity
6.6 wind

7 Fire

- 7.1 recency
  - 7.1.1 recent fire
  - 7.1.2 old fire
- 7.2 effects of fire suppression activities
  - 7.2.1 positive effect
  - 7.2.2 negative effect
  - 7.2.3 neutral effect
- 7.3 fire frequency
  - 7.3.1 positive effect
  - 7.3.2 negative effect
  - 7.3.3 neutral effect
- 7.4 fire intensity
  - 7.4.1 overstory lethal
    - 7.4.1.1 positive effect
    - 7.4.1.2 negative effect
    - 7.4.1.3 neutral effect
  - 7.4.2 overstory non-lethal
    - 7.4.2.1 positive effect
    - 7.4.2.2 negative effect
    - 7.4.2.3 neutral effect
- 7.5 prescribed fire
  - 7.5.1 spring prescribed fire
    - 7.5.1.1 positive effect

7.5.1.2 negative effect
7.5.1.3 neutral effect
7.5.2 late summer or fall prescribed fire
7.5.2.1 positive effect
7.5.2.2 negative effect
7.5.2.3 neutral effect
7.6 historic fire suppression
7.6.1 positive effect
7.6.2 negative effect
7.6.3 neutral effect

8 Human disturbance elements

8.1 recreation areas and activities (including dispersed camping areas)
8.1.1 positive effect
8.1.2 negative effect
8.2 roads or trails
8.2.1 positive effect
8.2.2 negative effect
8.3 residential development
8.3.1 positive effect
8.3.2 negative effect
8.4 buildings
8.4.1 positive effect
8.4.2 negative effect
8.5 bridges
8.5.1 positive effect
8.5.2 negative effect
8.6 tunnels (for mines, see above under Non-vegetation terrestrial substrates)
8.6.1 positive effect
8.6.2 negative effect
8.7 agriculture and croplands
8.7.1 positive effect
8.7.2 negative effect
8.8 livestock (disease)
8.8.1 positive effect
8.8.2 negative effect
8.9 mines and mining activities
8.9.1 positive effect
8.9.2 negative effect
8.9.3 neutral effect
8.10 harvest (including legal hunting, legal trapping, and illegal poaching of animals)
8.10.1 positive effect
8.10.2 negative effect
8.11 fences
8.11.1 positive effect
8.11.2 negative effect

- 8.12 bird feeders
    - 8.12.1 positive effect
    - 8.12.2 negative effect
- 8.13 winter recreation
    - 8.13.1 positive effect
    - 8.13.2 negative effect
- 8.14 garbage
    - 8.14.1 positive effect
    - 8.14.2 negative effect
- 8.15 logging
    - 8.15.1 positive effect
    - 8.15.2 negative effect
- 8.16 nest box
    - 8.16.1 positive effect
    - 8.16.2 negative effect
- 8.17 perch structures
    - 8.17.1 positive effect
    - 8.17.2 negative effect
- 8.18 platforms
    - 8.18.1 positive effect
    - 8.18.2 negative effect
- 8.19 guzzlers
    - 8.19.1 positive effect
    - 8.19.2 negative effect
- 8.20 pesticide use
- 8.21 exotic plant effects
    - 8.21.1 direct displacement
    - 8.21.2 indirect competition
    - 8.21.3 inhibit recruitment
    - 8.21.4 habitat structure change
- 8.22 livestock grazing strategies
    - 8.22.1 season-long
        - 8.22.1.1 positive effect
        - 8.22.1.2 negative effect
        - 8.22.1.3 neutral effect
    - 8.22.2 spring grazing
        - 8.22.2.1 positive effect
        - 8.22.2.2 negative effect
        - 8.22.2.3 neutral effect
    - 8.22.3 summer grazing
        - 8.22.3.1 positive effect
        - 8.22.3.2 negative effect
        - 8.22.3.3 neutral effect
    - 8.22.4 fall grazing
        - 8.22.4.1 positive effect
        - 8.22.4.2 negative effect
        - 8.22.4.3 neutral effect

9 Barriers to movement

9.1 forest management (clearcuts)
9.2 canopy closure
9.3 agriculture

10 Natural disturbance -- floods, scouring, openings in forests

APPENDIX 7.2

KEY ECOLOGICAL FUNCTIONS MATRIX

The purpose of building a database of Key Ecological Functions of vertebrates is to provide a consistent framework from which to consider the ecological roles of wildlife in the management of populations, habitats, and ecosystems. A related purpose is to provide a means of posing working hypotheses of the ecological roles of wildlife and effects of management actions on those roles (MARCOT AND HEYDEN, 2001).

1. Trophic relationships

1.1 heterotrophic consumer

1.1.1 primary consumer (herbivore) (also see below under Herbivory)

1.1.1.1 foliovore (leaf-eater)

1.1.1.2 spermivore (seed-eater)

1.1.1.3 browser (leaf, stem eater)

1.1.1.4 grazer (grass, forb eater)

1.1.1.5 frugivore (fruit-eater)

1.1.1.6 sap feeder

1.1.1.7 root feeders

1.1.1.8 nectivore (nectar feeder)

1.1.1.9 fungivore (fungus feeder)

1.1.1.10 flower/bud/catkin feeder

1.1.1.11 aquatic herbivore

1.1.1.12 feeds in water on decomposing benthic substrate

1.1.1.13 bark/cambium/bole feeder

1.1.2 secondary consumer (primary predator or primary carnivore)

1.1.2.1 invertebrate eater

1.1.2.1.1 terrestrial invertebrates

1.1.2.1.2 aquatic macroinvertebrates

1.1.2.1.3 freshwater or marine zooplankton

1.1.2.2 vertebrate eater (consumer or predator of herbivorous vertebrates)

1.1.2.2.1 piscivorous (fish eater)

1.1.2.3 ovivorous (egg eater)

1.1.3 tertiary consumer (secondary predator or secondary carnivore)

1.1.4 carrion feeder

1.1.5 cannibalistic

1.1.6 coprophagous (feeds on fecal material)

1.1.7 feeds on human garbage/refuse

1.1.7.1 aquatic (e.g. offal and bycatch of fishing boats)

1.1.7.2 terrestrial (e.g. landfills)

1.2 prey relationships

1.2.1 prey for secondary or tertiary consumer (primary or secondary predator)

2. Aids in physical transfer of substances for nutrient cycling (C,N,P, etc.)

3. Organismal relationships

3.1 controls or depresses insect population peaks

3.2 controls terrestrial vertebrate populations (through predation or displacement)

3.3 pollination vector

3.4 transportation of viable seeds, spores, plants or animals

3.4.1 disperses fungi

3.4.2 disperses lichens

3.4.3 disperses bryophtes, including mosses

3.4.4 disperses insects and other invertebrates

3.4.5 disperses seeds/fruits (through ingestion or caching)

3.4.6 disperses vascular plants

3.5 creates feeding, roosting, denning, or nesting opportunities for other organisms

3.5.1 creates feeding opportunities (other than direct prey relations)

3.5.1.1 creates sapwells in trees

3.5.2 creates roosting, denning, or nesting opportunities

3.6 primary creation of structures (possibly used by other organisms)

3.6.1 aerial structures

3.6.2 ground structures

3.6.3 aquatic structures

3.7 user of structures created by other species

3.7.1 aerial structures

3.7.2 ground structures

3.7.3 aquatic structures

3.8 nest parasite

3.8.1 interspecies parasite

3.8.2 common interspecific host

3.9 primary cavity excavator in snags or live trees

3.10 secondary cavity user

3.11 primary burrow excavator (fossorial or underground burrows)

3.11.1 creates large burrows (rabbit-sized or larger)

3.11.2 creates small burrows (less than rabbit-sized)

3.12 uses burrows dug by other species (secondary burrow user)

3.13 creates runways (possibly used by other species)

3.14 uses runways created by other species)

3.15 pirates food from other species

3.16 interspecific hybridization

4. Carrier, transmitter, or reservoir of vertebrate diseases

4.1 diseases that affect humans

4.2 diseases that affect domestic animals

4.3 diseases that affect other wildlife species

5. Soil relationships

5.1 physically affects (improves) soil structure, aeration (typically by digging)

5.2 physically affects (degrades) soil structure, aeration (typically by trampling)

6. Wood structure relationships (either living or dead wood)

6.1 physically fragments down wood

6.2 physically fragments standing wood

7. Water relationships

7.1 impounds water by creating diversions or dams

7.2 creates ponds or wetlands through wallowing

8. Vegetation structure and composition relationships

8.1 creates standing dead trees (snags)

8.2 herbivory on trees or shrubs that may alter vegetation structure and composition (browsers)

8.3 herbivory on grasses or forbs that may alter vegetation structure and composition (grazers)

APPENDIX 7.3

CLASSIFICATION OF KEY CULTURAL FUNCTIONS OF PLANTS AND ANIMALS
(BRUCE G. MARCOT, PERSONAL COMMUNICATION)

August 7, 2000
*** draft ***
Bruce Marcot, David Johnson, and Eva Greda

1) **food/dietary (subsistence) use**
   a) food source
      i) oil
      ii) salt
      iii) herbs/spices
      iv) vegetables and fruits
         (1) native species
         (2) introduced species (including agriculture)
      v) fish
         (1) native species
         (2) introduced species (including hatcheries)
      vi) meats
         (1) native species
         (2) introduced species
      vii) alcohol (fermented)
   b) food-holding use
      i) baskets
      ii) containers
      iii) implements
   c) food preparation
      i) mats for fish preparation
      ii) leaves used for cleaning food
      iii) preservatives
   d) food for livestock or domesticated animals

2) **medicinal**
   a) treatment of systemic disease
      i) taken internally
      ii) applied externally
   b) treatment of injury or pain
      i) taken internally
      ii) applied externally
   c) treatment for pregnancy/labor
   d) treatment for dental conditions
   e) antitode for poisoning or insect bite
   f) personal hygeine

3) religious/ceremonial

- a) poisons
- b) Christmas trees and wreaths
- c) drugs
- d) burials
  - i) grave markers
- e) headdresses
- f) personal relations
- g) practice of witchcraft
- h) protection from witchcraft
- i) totemic symbols or rituals
- j) religious ceremonial adornment
- k) political or national symbol

4) clothing

5) ornaments

- a) floral uses
  - i) lichens
  - ii) mosses
  - iii) flowers
  - iv) branches
- b) jewelry
- c) personal adornment
  - i) tattoo

6) garden or landscape plants

7) musical instruments

8) paint/dyes

9) tools

- a) preparing food
- b) building structures
- c) creating clothing
  - i) needles
  - ii) thread
- d) food acquisition
  - i) snares, nets, traps
  - ii) creation of forage (for luring ungulates, as with use of fire)
  - iii) animal baits
  - iv) fishing
    - (1) poisons
    - (2) floats
    - (3) nets
    - (4) fishhooks
  - v) hunting game
    - (1) darts
- e) knives, cutting tools

f) rope, twine, string, binding materials
g) wood gathering
   i) wedges for splitting logs

10) **transportation**
   a) watercraft/ships
      i) tools for creating or maintaining watercraft
         (1) glues
         (2) bailer
      ii) materials forming the body of watercraft
      iii) paddles
   b) aircraft
   c) railroads (ties, cars)
   d) roadways (e.g., for bridges)
   e) snowshoes
   f) snowskis

11) **bedding**

12) **insecticide or repellent**

13) **light source**
   a) oil

14) **heat source**
   a) fuelwood/firewood
   b) other fuels

15) **recreation**
   a) games
   b) wildlife observation
      i) bird-watching
      ii) whale-watching
      iii) elk viewing
   c) festivals
   d) sport fishing
   e) sport hunting
   f) sport trapping

16) **weapons**
   a) ceremonial weapons
      i) clubs
   b) firearms
      i) gun stocks
   c) bows & arrows
   d) harpoons for whaling and sealing

17) **artwork (medium or materials)**

18) **lubricants**
   a) oils

19) **cosmetics**

20) **myths and legends**

21) **trade**

- a) barter (used as currency)
- b) economic export
- c) commercial use
  - i) trapping
  - ii) hunting
  - iii) fishing
  - iv) gathering plants (nontimber)

22) **furniture**

23) **handbags/carrying packs**

24) **smoking/tobbaco**

25) **wood resources**
- a) lumber and timber
- b) wood chip
- c) veneer

26) **pest or varmint species**
- a) predators
- b) crop depredation
  - i) agriculture
  - ii) forestry
  - iii) orchards
  - iv) gardens
- c) introduced/exotic plants
- d) introduced/exotic animals

27) **pets**
- a) native species
- b) introduced species

APPENDIX 7.4

Examples of Key Cultural Functions of Plants and Animals in Garo Hills

Examples of key cultural functions of plants and animals used by Garo people in the Garo Hills of western Meghalaya for religious rites and rituals (source: Sangma 1993). Species common or scientific names are included as mentioned by Sangma (1993). We identified the scientific name of some species by cross-referencing Garo names given by Sangma (1993) to descriptions of common or scientific names given in Nengminza (1996). Species not identifiable to scientific specific epithet are listed here only with their Garo names *[G.]* and descriptions (Marcot *et al.* in press).

Plants

Used in religious rites and rituals:

- Dum Attiakola *[G.]*, a large variety of banana plant – used to counteract evil-minded folk medicine practitioner; a flower bud is carefully extracted while it is still about two and a half cubits inside the bole, and the evil-minded adept is severely beaten with it
- *Macropanax undulatum*, a small tree -- used as above
- *Cynadon dactylong*, doob grass -- a circle of which is dried out by use of a potent herb while reciting the name of the evil-minded adept and his place of residence; as the doob grass wilts and dries, the victim's body suffers and dies
- *Aquilaria agaklocha*, aloe wood – used on which to scribe specific chants and spells
- *Adenanthere pavoniva*, red sandal-wood – used as a pen for writing down chants and spells, the ink of which is devised from several ingredients including the juice of the plants *Aega marmelos* and *Ocymum sanctum* (black basil)
- *Macaranga indica*, boltotu shrub – used in a ritual to heal one's wandering soul
- *Entada scandens*, sue or gila plant – fruit or seed used to emotionally startle an adept or shaman
- *Colocasis indica*, kochu – chewed by an adept or shaman during a ritual of reciting chants and spells
- *Spatholobus roxburghii*, maari (a common climber) – used to startle certain kinds of evil adepts; also the juice of which is smeared on a stool, bench, or chair to prevent an evil adept from sitting.
- Also used to frighten evil adepts are seeds of *Erythna suberosa* (mandal tree), *Clerodendron infortunatum*, and *Acacia concina*; the fruit of gila *Entada scandens*; and the odors of onion, garlic, and panat *Ocymum canum*. To kill an adept or shaman, he is secretly given a concoction of the bark of maari, the roots of Gnengsi *[G.]* a small perennial grass with razor-sharp blades, the leaves of panat, and garlic. A nocturnal adept can be caught and killed at

night by their long hair tangling in thorny branches of the kangkani tree *Marjorca indica* or in the thorny shoots of *Mezoneurum cucullatum*. Sangma (1993) lists many other plant species used against evil adepts or shamans.

Used for medicines:

Sangma (1993:184-190) lists many plant species used in Garo folk medicine for healing or for killing. Garo folk medicine is intricately tied with religious rituals and rites. A few examples follow.

- *Ocymum sanctum*, black tulsi – a leafy branch is used to sprinkle water over an ailing person while reciting a specific chant
- Plants used in transformation rituals – Under specific spells, the plucked leaves of tarai bamboos or water bamboos *Malocanna bamboosoides* are said to be transformed into fresh lasso fishes. A folded rind of the banana plant is said to be turned into a Calbasu or kaila fish. A tuber of lokra *Xanthium strumarius* or a globous root of a large kind of banana plant is said to be turned into a living pig.
- Bon Harangjhora *[G.]*, a parasitic plant – used as a salve to mend broken bones.
- *Cratoeva eoxburghii*, jongsia tree – leafy branch held in the right hand of an adept or shaman who utters a secret chant to cure leprosy. However, to cause virulence in offending persons living in distant places, the adept keeps a piece of duringkap *Cryptolepis buchananii* wedged in the bark of the wakru tree *Engel hardiaspicata* while reciting secret chants.

Animals

Used in religious rites and rituals:

- Lizard – A *chuar* is an otherworldly being that appears as a luminous flying lizard. The initiate can transform into a *chuar* and then be able to attract ripe foodgrains from other people's cultivations.
- Flying squirrel – A *bakwan* or *matwan* is an otherworldly being that appears as a grey winsome flying squirrel, which can attract worldly riches and material goods.
- Bat – A *rakasi* is an otherworldly being that appears as a bat. Usually invisible, it can appear luminous in flight and as an extraordinarily keen and clear-headed person who is able to garner great riches and material goods.
- Pigs, mice, owls – Used to thwart and kill evil spirits and malicious otherworldly beings.

Used for medicines:

Arboreal animals:

- tree squirrel *Myhaepus congaing Bengalensis*
- rarek or lajjbatibander *[G.]* "an ape-like arboreal animal which covers its face with both hands on seeing human beings"

- Marsi *[G.]*, "a reddish-yellow flying chameleon-like creature, which lives in deep woods," possibly draco of flying lizard *Draco dussumieri*
- flying squirrel *Petaurista* sp.

Terrestrial mammals:

- great Indian onehorned rhinoceros *Rhinoceros unicornis* (horn and bile of which are considered to be of medicinal value)
- Chinese pangolin *Manis pentadactyla* (scales and liver used for medicines)
- jackal *Canis aureus* ("the bone and horn, if any, which looks like a small red hook, is of medicinal value;" sic., as jackals lack "horns" per se)

Birds:

- Dosildura *[G.]*, "a rare myna-like bird with red glistening head," possibly scarlet finch *Haematospiza sipahi* (leg-bone is of medicinal value)
- Baya weaver *Ploceus philippinus* (liver and bones of medicinal value)
- Chamchora *[G.]*, "a small agile bird, which used to make nests inside rof or dwelling-houses" (flesn and bones used to cure impotency)
- fire-tailed sunbird *Aethopyga ignicauda* (fat and bones of medicinal value)
- hornbill, species not specified (fat is of medicinal value)
- black-rumped flameback (=lesser goldenbacked woodpecker) *Dinopium benghalense* (bones are of medicinal value)

Reptiles:

- Chipu Chinnong or Chipu Gra *[G.]*, "a small reddish-yellow snake," possibly monocellate cobra *Naja kaouthis* (Chipu gram means cobra) ("breaks itself to pieces when one lifts up a stick to beat it but loosened pieces of which rejoin themselves again and crawl away, when left alone; the first piece, which moves first of itself to rejoin the broken pieces, is considered to be of great medicinal value;" bile is considered of medicinal value)
- lizard, unidentified species (Matpu *[G.]*, "iguana;" there is no iguana in India) (fat is used to restore atrophied male genitals)
- Wakkime *[G.]*, listed by Sangma as reptile but possibly an invertebrate, "a rare scorpion-like creature, which usually dwells under massive rocks, the flesh of which posseses magical virtues"

Fish:

- electric eel *Electrophorus electricus* (flesh and bones used in preparing a healing medicine)
- puffer *Tetraodon cutcutia* (flesh used as medicine)
- gar, unidentified species of family Lepisosteidae (head used to cure chronic vertigo)
- zebra fish *Brachydanio rerio* (flesh used in preparation of nutritive pills)
- *Cyrenus robita*, no common name (fat is of great nutritive value)

Insects:

- cicada, unidentified species of family Tibicinidae (of all flying insects has greatest medicinal and magical value; eggs are considered to be antidotal against possibility of drowning)

APPENDIX 7.5

POTENTIAL DEMONSTRATION PROJECTS

Potential demonstration projects for the ~~the~~ Garo Hills in western Meghalaya. These are potential projects that could be implemented as small demonstrations to illustrate specific measures and approaches for conserving old forest or important wildlife habitats in GCA (Marcot *et al.*, in press).

BACKGROUND

The Garo Hills Conservation Area (GCA) assessment may result in identifying forest biodiversity conservation needs for the area. These needs can be expanded into tests in demonstration areas within the GCA. This document presents ideas on three possible demonstration areas for the GCA following the current project.

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DEMONSTRATION AREA THEMES

Three potential themes for demonstration area for the GCA are: (1) Additions to protected areas, (2) Protection of primary forests and mature forests in wildlife corridor habitat areas, and (3) Provision of elements of older secondary forests as wildlife habitat and for biodiversity conservation in heavily *jhummed* areas.

For each of these three themes, a small portion of the GCA can be selected to demonstrate how results from the overall GCA Assessment can be used at finer scales. Each theme focuses on a very different environmental condition and management focus within the GCA, with the overall aim of contributing to long-term conservation of wildlife habitat and biodiversity within the area as a whole.

GCA DEMONSTRATION I THEME: ADDITIONS TO PROTECTED AREAS AS BUFFERS

Objective: The objective is to demonstrate how to select specific sites for adding onto existing protected areas, including national parks, reserved forests, and wildlife sanctuaries. Additions can be peripheral to the existing boundaries and can be part of a buffer boundary system..

Problem: The existing protected areas of GCA do not seem to be established according to biosphere reserve designs with sanctum sanctorum core areas and surrounding partial-use buffer areas. Older forests adjacent to existing protected areas are being incurred for *jhum* cultivation and resource extraction with no specific guidelines to ensure the integrity of the protected areas.

Demonstration tasks: Identify, through the vegetation mapping of GCA, areas of older forest adjacent or very near to existing protected area boundaries. Identify such areas that are also undergoing undue incursion for *jhum* agriculture, and where habitat values for wildlife conservation are high. Then, allocate selected, specific forest sites as the start of an additional buffer area around the protected area. Identify the set of activities that can continue or be permitted within the site that would also provide for the older-forest habitat conditions, such as selected nontimber forest product use.

Products: The following products may result from this activity: [1] a map of older-forest zones adjacent to existing protected area boundaries that may serve as buffer areas; [2] a set of management guidelines for activities permissible within such buffer areas that would protect habitat values; [3] a list of habitat and wildlife values that would be conserved over time by institution of this approach. A further product might include a list of other priority areas for possible consideration.

GCA DEMONSTRATION II THEME: CONSERVATION OF PRIMARY AND MATURE FORESTS AND KEY HABITAT ELEMENTS FOR WILDLIFE CORRIDORS

Objective: This objective pertains to maintaining forest habitat conditions in specific areas as migration and movement corridors for wildlife. As well, specific forest use activities by local peoples may be identifed as compatible with provision of corridor habitats.

Problem: More and more, the intensity of forest use is increasing in areas traditionally used as corridors by wildlife, especially elephant and other large species associated with older forest conditions such as dense tall tree canopies. If continued at the present pattern and pace, this will doubtless lead to further conflicts, including elephant-man altercations. Loss of wildlife corridor habitat also will lead to isolation of wildlife populations into smaller, disconnected centres. Such smaller wildlife population "islands" then have far higher risk of local extinction from many types of events. Also, linkages of specific habitat elements across the landscape can help maintain viability of many types of wildlife.

Demonstration tasks: A demonstration project focused on conserving primary and mature forests and key habitat elements for wildlife corridors would first identify areas that currently serve as wildlife movement corridors, and, second, provide specific guidelines for the kinds of resource use activities by local peoples that would be compatible with maintaining the habitat values of such coridor areas for wildlife. Wildlife included in this task are principally elephant, and also other species associated with older forest conditions, such as hoolock, slow loris, other arboreal species of primates and squirrels, and other species of older forest conditions.

Products: [1] A general map of known or suspected wildlife corridors in the Garo Hills; [2] a specific map of particular sites that contribute to one of the corridors for the demonstration activity; [3] a list of the habitat conditions to provide within the corridor, such as forest canopy contiguity and density, occurrence of snags or down wood, occurrence of specific forage and food types and sources, and corridor width and area; and [4] a list of forest resource-use activities that are compatible with maintaining these habitat conditions. Compatible forest resource-activities may specify the type, intensity, and frequency of extraction of nontimber forest products, the desirability or undesirability of man-set fires, the level of grazing, and other actions and uses.

As with the Demonstration I objectives, above, the aim is to help provide for rationale and compatible human use of forest resources, not to blindly exclude all uses and incursions which would be unnecessary and impossible to accomplish.

GCA DEMONSTRATION III THEME: PROVISION OF OLDER SECONDARY FOREST HABITAT ELEMENTS IN HEAVILY *JHUMMED* AREAS

Objective: The objective of this theme is to provide for selected elements of forest habitat conditions within heavily *jhummed* landscapes to help conserve forest-associated wildlife with a minimal impact on agriculture.

Problem: Accelerated use of forest land in the Garo Hills for *jhum* agriculture has led to a severe shortage of old forest habitats and specific elements of old forests. Such forest habitat elements include large mature trees, local canopy clumps of older trees, standing dead trees, down trees, and key fruit- and seed-bearing shrubs and trees as wildlife food sources, all of which are used by many species of wildlife species. The loss of such habitat elements has meant that a large portion of the forest wildlife fauna has been severely reduced or eliminated from large areas of the Garo Hills. In turn, this makes conservation of such wildlife populations only within the few protected areas of the region difficult to impossible.

Demonstration tasks: A demonstration project can entail identifying a few specific forest plots within heavily *jhummed* landscapes; listing the set of forest habitat elements for conservation focus; developing operating guidelines for *jhum* activities that would help protect or create such habitat elements; carrying out such activities in a few selected sites; and monitoring results.

Illustrating the potential for permanent plot agroforestry is an important part of this theme. Accomplishing this will entail selecting specific demonstration sites which can be developed for intensive and ongoing agricultural and timber tree interplanting. The demonstration site may entail terracing to nelp stave off soil erosion, ease access for site and crop management, and ease interim treatment activities. The purpose is to demonstrate alternatives to the short-cycle *jhum* activities that will permit some *jhum* sites to lay fallow for longer than 8-10 years by which some mature forest conditions as habitat for wildlife can regenerate.

Products: Products for this demonstration theme can include: [1] a list of the habitat elements and associated wildlife species; [2] *jhum* operating guidelines or activities to protect or create the habitat elements, such as extending the *jhum* fallow period; [3] an evaluation of the efficacy of the operations and how well they provide for the habitat elements in the field. Monitoring may include evaluating economic and ecological results, including agricultural crop production, tree and timber crop growth, and reduction in soil erosion and retention of productive soils.