STUDIES ON PLANT BIODIVERSITY AND ECOSYSTEM FUNCTION IN SACRED GROVES OF MEGHALAYA

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I, Mr. Krishna Upadhaya, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any University/Institute.

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CONTENTS

CHAPTER 1

INTRODUCTION

The term 'Biological diversity' draws together concepts that had preoccupied Ecologists and Geneticists for some time prior to 1980's. The concept of biodiversity was introduced by Lovejoy (1980) to express the number of species present in a community. Norse and McManus (1980) included genetic diversity and ecological diversity and Norse *et al* (1986) further expanded the usage of the term 'biological diversity' to include genetic (within species), species (species numbers) and ecological (community) diversity.

The contracted form – 'biodiversity', was coined by Walter G. Rosen in 1985 (cf. Wilson 1988). But the notion of the term was brought to the attention of scientists and others by Wilson (1988). The term was clearly defined in the Earth Summit (1992) at Rio De Janeiro, Brazil, which closely mirrors the concept of Norse *et al* (1986).

"Biological diversity means the variability among living organisms from all sources including, *inter*, *alia*, terrestrial, marine and other aquatic systems and the ecological complexes of which they are part, this include diversity within species, between species and of ecosystem" (UNEP, 1992 cf. Harper and Hawksworth 1995).

Biodiversity is by no means evenly distributed on the earth; some areas are very rich in overall diversity than the others. Biodiversity is high in warm and wet areas and low in drier and cooler areas. Diversity decreases with the increase in altitude and latitude. The tropical rain forests are non-seasonal ecosystems with high species diversity of both plants and animals, their structure is very complex and they are relatively stable (Richards 1986). Their stability is only in a relative sense and they are subjected to short-term changes due to natural and man-made causes. Even the least disturbed tropical rain forest consists of both seral and climax tree species, and is characterised by patchwork of gap, building and mature phases. They are the richest diversity areas on the earth containing more than 50% of the plant species, out of the estimated 3,00,000 flowering plants (Myers 2000). It is estimated that the tropical moist forest occupies an area of 1510 million ha, within which lowland rain forest covers 715 million ha (Whitmore 1998).

One of the severe and unlike any environmental threats is the accelerating and potentially catastrophic loss of biotic diversity. In the tropics the most important cause of biodiversity loss is shifting cultivation and logging for timber based industries. The overall global loss of all tropical moist forests during 1981-1990 was estimated to be 13.1x 10^6 ha year $^{-1}$ or 0.9% (FAO cf. Whitmore 1998). Therefore, conservation of biodiversity has attained immense importance in the recent time. From conservation point of view, a promising approach is to identify areas, which harbour far greater concentration of biodiversity then others and exhibit high level of endemisms and at the same time most severely threatened. This has led to identify priorities or species- rich areas on the earth (Myers 1988,1990). These areas are referred to as '*Hotspots*' of biodiversity. Myers *et al* (2000) identified 25 hotspots supporting 44% of all vascular plants in just 1.4% of land surface of the earth. Out of the 25 hotspots, 15 are predominantly tropical forests, which largely mean developing countries where threats are greatest and conservation resources are scarcest.

Species richness, their dispersion, density and dominance in relation to the co-existing species are major determinants of community structure. According to Richards (1996) the structure and function of forest ecosystem is primarily determined by the plant component than any other living component of the system. The species composition of communities express their relationships to one another as well as to their physical environment than dominance or any other community characteristics. Therefore, Whittaker (1975) emphasized that classification and interpretation of communities should be based on their floristic composition. Clement (1916) viewed community as a 'super organisms' with successional development from pioneer stage to relatively stable climax stage. Tansley (1935) pointed that in a community certain populations are independent as they can establish themselves well in other communities while others are strongly dependent. Gleason (1926) claimed that community depends for its existence on its particular environment, which changes constantly in space and time. The individualistic concept of Gleason (1926) provides a framework for examining plant community in greater detail as a dynamic unit.

Biodiversity renders several environmental services also known as ecosystem services including regulation of climate, biogeochemical cycles, hydrological functions, soil protection, crop pollination, pest control, recreation and ecotourism (Myers 1996). In recent years, the effect of biodiversity on ecosystem processes has received much greater attention because of growing concern that loss of biodiversity may impair ecosystem functioning (Ehrlich and Wilson 1991, Schulze and Mooney 1994, Vitousek *et al* 1997, Chapin *et al* 1997). With the current rate of species extinction there is growing interest in determining how the loss of biodiversity might alter the rates of ecological processes like productivity, decomposition, elemental cycling etc. that are vital to the functioning of the ecosystems. Several studies have provided clear evidence that biological communities do indeed regulate ecological processes (Naeem *et al* 1994, Tilman *et al* 1996, 1997, Hooper and Vitousek 1997, Mc Grady-Steed *et al* 1997, Wardle *et al* 1997, Symstad *et al* 1998), but these studies have often reached very different conclusions about the contribution that species diversity itself makes to ecosystem functioning.

The classification of species into functional groups has been suggested as a way to simplify the examination of species effects on ecosystem properties and of the effect of global change on species interactions (Korner cf. Schulze and

Mooney 1994). Functional groups' are defined as groups of species with similar response to a given factor (Gitay and Noble 1997). Within an ecosystem plants can be divided into groups with common features according to quality criteria such as life form, over all size, rooting depth, symbiotic associations, fire resistance, spatial distribution of plants and plants organs etc., (Lavorel *et al* 1997, Korner 1994). Functional grouping of components of vegetation have been done by earlier workers on the basis of morphological (Raunkiaer 1934), physiological (Ellenberg 1974, Kinzel 1983) and physio-morphotype characteristic (Turesson 1930, Pisek 1965, Schulze and Hall 1982). Functional groups have been identified in response to disturbance on the basis of extensive sets of traits. Life form has been considered to have largest effect because this trait is correlated with other functionally important traits such as plant size (Lavorel *et al* 1997).

Forest clearance not only destroys community organization and causes biodiversity loss, it results in exposure of topsoil leading to increased erosion and decrease in total soil organic matter (SOM). The carbon loss from the system is gradual and is not easily detectable. One of the current models of SOM dynamics divides SOM into three fractions with different turnover rates; the active (0.14 yr), slow (5 yrs) and passive (150 yrs) fractions (Parton *et al* 1989). The active fraction with short turnover time appears to contain primarily living soil microbial biomass and microbial products.

Information on changes in microbial biomass following vegetation removal is valuable not only because it provides information on slower, less easily detectable SOM changes but also because microbial biomass contributes to soil fertility (Henrot and Robertson 1994). The change in microbial biomass carbon after conversion of virgin rain forest to pasture in an Amazonian soil has been reported by Luizao *et al* (1992). Microbial biomass carbon accounts for 3.5–5.3% of the total carbon in Amazonian Pastures and forests, (Luizao *et al* 1992), 0.27–5.0% in cultivated soils (Anderson and Domsch 1986) and 1.8- 2.9% in forests soils (Vance *et al* 1987). It acts as medium through which all organic material that enters the soil must pass (Jenkinson 1977).

Bolton *et al* (1993) demonstrated that plant cover determines the amount and activity of the soil microorganisms. Root biomass and aboveground plant biomass are considered to be the main source of SOM and the latter is highly correlated with microbial biomass (Schnurer *et al* 1985). Srivastava and Singh (1991) reported that the conversion of dry tropical forest into savanna resulted in a decrease in the amount of plant biomass leading to decrease in soil nutrients and microbial biomass. The effect of disturbance such as tree cutting and shifting cultivation in the humid tropical forest causes depletion of soil nutrients by lowering microbial biomass and microbial activity (Arunachalam *et al* 1999).

Microbial biomass can provide one of the most satisfactory estimates of the effect of disturbances. Though the soil biomass measurements are not uniform across systems and is highly debatable, relative biomass change over time should be sufficient for predicting the ecosystem recovery after disturbance. The microbial biomass measurement may provide the information needed for ecosystem level monitoring of disturbances and recovery (Smith and Paul 1990).

Nitrogen and Phosphorus are the two most important limiting nutrients in soils. A major challenge to ecologists and land managers is to increase agricultural and forest productivity, which is largely dependent on the availability of these two essential macronutrients. The availability of N and P in soil is largely controlled by biologically mediated processes such as mineralization and immobilization.

Mineralization is a process of nutrient release from the organically bound materials into inorganic or plants-available forms. Mineralization of organic soil N is therefore, fundamentally linked with forest productivity and attention is being shifted from static measures of N- availability to more dynamic measures of N release (Keeney 1980).

Many studies have reported increased loss of N and other elements from forest ecosystem following tree felling. Recognition of the effects of disturbance on elemental cycling and loss in terrestrial ecosystems has increased in recent years. This emphasizes the continuation of a longstanding concern among forest scientists over the possibility that forest clearing causes nutrient losses, which could affect the long-term productivity of a site (Likens *et al* 1970). To characterize the degree of homeostasis in forest biogeochemical cycles, elemental losses following disturbance have been used and has been suggested as a useful measures of ecosystem-level stability (Bormann and Likens 1979).

In the north-eastern India the state of Meghalaya having an area of 22429 sq. km and is botanically rich and interesting area which has attracted the attention of a large number of taxonomists in the past. The state has about 15,769 sq. km of tropical and subtropical forest cover, of which only 11% is under the control of the state government and the rest belongs to the people (Tiwari *et al* 1999).

The rich floristic diversity of the state is confined mainly to moist tropical and humid subtropical forests, which are exposed to various types of forces leading to their destruction. The major factors responsible for deterioration of forest wealth are shifting cultivation or *jhum*, forest fire, over exploitation of medicinal and ornamental plants, encroachment for developmental activities and permanent agriculture. The state lost 845 sq. km of forest cover during 1987-1997 and 24 sq. km during 1997-1999 (FSI 1987, 1997, 1999). Therefore, the biological diversity of the state is preserved mainly in the Biosphere reserves, Wildlife sanctuaries and National parks and forests protected by the different tribes of the state. All three major tribes of the state - Khasi, Jaintia and Garo, have an age-old tradition of preserving small patches of old growth forests as a part of their culture and religious beliefs. These are popularly known as '*sacred groves*'. These are forest communities and composed of large number of endemic and rare taxa of the region and harbour a good number of medicinal and other plants of economic importance. The sacred grove gives a glimpse of the virgin climax vegetation that might have covered the hills and valleys in the past (Kanjilal *et al* 1934-40). About 79 sacred groves covering an area of about 1,00,00 ha has been reported by Tiwari *et al* (1999) from Meghalaya. The vegetation of these groves varies from tropical moist deciduous to sub-tropical wet hill broad leaved forest (Champion and Seth 1968).

Loss in forest cover and destruction of climax tropical and humid subtropical forests are of major concern for plant diversity conservation. Even the sacred forests, which were protected for centuries, are being encroached upon for various reasons, causing destruction of the complex community organization and loss of plant diversity. Therefore, the present study was undertaken in the two well preserved sacred groves and their mildly disturbed portion in Jaintia Hills of Meghalaya with an objective to assess floristic richness, study community structure and to evaluate the effect of disturbance on phyto diversity certain ecological processes within the ecosystem.

The major objectives of the study were as follows:

i) To study the plant biodiversity status of the sacred groves.

ii) To analyse the structural organization of the sacred grove communities.

iii) To assess the effect of cultural disturbance in the grove on plant diversity, certain soil biological process such as temporal and spatial dynamics of microbial biomass carbon and N mineralization.

CHAPTER II

REVIEW OF LITERATURE

The tropical rain forests covers an area of 7% of the land surface and are among the most species-rich vegetation in the world (Richards 1996, Gentry 1982, Whitmore *et al* 1985, Gentry 1988). They harbour more than 50% of the total plant species of the world (WCMC 1992) and are characterized by complex community organization and high productivity. Besides, sustaining local environment through soil and water conservation, they also influence regional and global climate. Biodiversity not only provide direct economic benefits to human beings but plays important role in ecosystem function and stability.

It has been estimated that every hour 2-5 species are being lost from the tropical forests alone. This amounts to a loss of 16m populations per year or 1800 populations per hour (Singh 2002). Biodiversity is by no means evenly distributed on earth, and could comprise 5 to more than 50 million species. It increases from the poles to the equator and from high elevations to low elevations. Diversity is greater on continents than on islands, and rather low in habitats with extreme environmental conditions such as deserts, hot spring etc. Even at regional and ecosystem levels biodiversity is not uniformly distributed. There are some areas that are very rich in overall diversity and endemism than the other. Furthermore, many of the richest areas of the world happen to be under the most severe threat.

From conservation point of view a promising approach for the study of biodiversity is to identify '*hotspots*' or areas which harbour far greater concentration of species than others and exhibit high levels of endemism and at the same time most severely threatened. Myers (1998) used plants as indicators for biodiversity and initially identified 10 tropical rain forests hotspots, which has been increased to 25 (Myers *et al* 2000). These hotspots accounts for 20% of the global plant diversity in just 0.5% of the land area. The tropical Andes ranks first among the hotspots with 20,000 endemic plant species followed by Mediterranean Basin (13,000 endemic species). In the Indian subcontinent the two hotspots, the Indo-Burma harbours about 7000 and the Western Ghats and Srilanka provides shelter to 2182 endemic species.

The highest number of tree (> 10 cm dbh) species (307) was recorded for a 1 ha plot of terra firme tropical rain forest by Valencia *et al* (1994). Gentry (1988) recorded 283 species (>10 cm dbh) from a 1 ha plot of a forest near Iquatos, Peru and Gentry (1990) in Cocha Cashu recorded 201 species from 1 ha plot. These findings only reflect the magnitude of species richness in the tropics.

The economic development of many developing countries of the world is closely linked with the exploitation of tropical forests, which has led to faster rate of deforestation and the loss of biological diversity. The effect of human activities on species diversity is an issue that has attracted the attention of ecologist from both theoretical and applied standpoints (Stapanian *et al* 1997). The accelerating and potentially catastrophic loss of biodiversity is unlike other environmental threats because it is irreversible. Human impacts were once very restricted in time and space, therefore, deforested clearings usually regenerated. However, the impact on tropical rain forests has change in pace and time leading to biodiversity loss. The most important cause of biodiversity loss in the tropics is shifting cultivation and logging for timber based industries (Richards 1996). The growing concern of the benefits and at the same time the fast depletion of biodiversity has necessitated a speedy inventory and monitoring of diversity at all levels.

Biodiversity is usually expressed as species richness or number of species in a given area. Species area curve has been widely used by early ecologist to identify the minimum area of a plant community, its application for estimating the number of species for a given area or for estimating species loss as a function of habitat loss, has gained momentum only in recent years (Singh 2002). A number of formulae, indices and models to explain various aspects of species richness in a community have been devised by ecologists. Fisher *et al* (1943), Shannon and Weaver (1949), Simpson (1949), Pielou (1975), Wilson (1984), Magurran (1988), and Smith (1986) have interpreted different formulae and indices of diversity and suggested appropriate tools for different situations. The most widely and accepted tool for measuring diversity is the Shannon and Wiener's (1963) index commonly known as Shannon's Index of general diversity. Simpson's (1949) successfully formulated an index known as Simpson's index of dominance. This index shows a high preponderance towards the most abundant species in the sample. Thus the value of Simpson's index increases as the index of general diversity decreases (Magurran 1988). Whittaker (1972, 1977) used α (alpha) and β (beta) diversity to measure species richness of a community or habitat and diversity between habitats or communities respectively. Jaccard (1912) and Sorensen (1948) derived formulae to measure similarity between habitats or communities based on species composition and are qualitative in nature. The quantitative approach to the measurement of similarity between the habitats or communities was worked out by Morisita- Horn (Morisita 1959, Horn 1966, Walda 1981, 1983 and Magurran 1988). The methods outlined by the above authors have been widely used for the study of plant diversity.

A number of studies on plant diversity have been carried out in the tropics and subtropics. Gentry (1988), Phillips *et al* (1994), Felfili (1995), Johnston and Gillman (1995), Liberman *et al* (1996), Kellman *et al* (1998) and Wilson et al (1996) are some of the prominent workers who made significant contribution to the study of plant diversity. Hubbell and Foster (1983) carried out an exhaustive survey of 50 ha permanent plot in Borro Colarado Island, Panama. Similarly a 50 ha plot was surveyed by Manokaran *et al* (1992) and Sukumar *et al* (1992) in Malayasia and South India. Ayyapan and Parthasarathy (1999) studied 30 ha permanent plot in Western Ghats of India. Ashton *et al* (1972), Proctor *et al* (1988), Turner (1996), Shin-ichiro Aiba (1999), Min Cao (1997), Fang Cao (1997) and Sahunula and Dhanmononda (1995) have contributed to the understanding of biodiversity in the tropical and subtropical Asia.

In India, Parathasarathy and Karthikeyan (1997), Sukumar *et al* (1992), Visalakshi (1995), Singh *et al* (1995), Ganesh *et al* (1996), Joshi *et al* (1997), Ganeshieh *et al* (1997), Elouard (1997) Kadavul and Parthasarathy (1999) and Jamir (2000) have contributed to the understanding of the plant diversity in different parts of the country.

The understanding of the effect of human activities on species diversity has emerged as an important issue for many ecologists. There are two views regarding the effect of disturbance on species diversity. One hypothesis is that ecosystems with greater species diversity are more resilient to environmental disturbance and some species would compensate for those members of the community that are reduced or eliminated by the disturbance (Pimm 1984, Ehrlich and Wilson 1991, Lawton and Brown 1993). Contrary to this view Connell (1978) proposed that the tree species diversity in rainforest would be greatest where disturbances are moderate in intensity and frequency. Similar was the opinion of Collins (1995) who argued that species richness should be highest at intermediate frequencies of disturbance when condition favours competitive species and those that tolerate disturbance.

The damage caused to the trees may be natural or human induced. These damages may evidently lead to the formation of gaps of different sizes and shapes in the forest canopy. Such openings alter the microclimate and microsite heterogeneity significantly so much so that it may effect community dynamics (Orians 1982, Nunez Farfan and Dirzo 1988 and Mc Carthy and Facelli 1990), and play important role in maintaining species diversity in the forest. In course of time, the gaps are colonized by a variety of plant species making the forest a mosaic of plant communities representing different developmental stages of the forest (Whitmore 1975, Oldeman 1978, Sarukhan *et al* 1985).

Inventories of natural population of tropical trees by girth or diameter classes are numerous. In natural rain forests there are many more young individuals than mature trees in the majority of species and in the population as a whole (Richards 1996). The diameter class distribution also reflects the height distribution to some extent and gives some indication of the vertical structure of the forest. There are striking differences between the size class distribution of shade intolerant (light demanding) and shade tolerant tree species. The population structure also reflects the regeneration potential of the forests. Jamir (2000) and Upadhaya *et al* (2002) have also reported the preponderance of trees in the lower dbh (5-15 cm) class from the sacred groves of Jaintia hills in Meghalaya.

The dispersion pattern of trees in the community is an important structural parameter. In all rain forests the trees are unevenly, but usually not randomly spaced. This applies to individuals of one species as well as the tree population as a whole and seems to be due to various causes, some intrinsic to the trees themselves and some influenced by environmental. Poore (1968), Ashton (1969), Herwitz (1981) have shown by pattern analysis that in the mixed forest, although the dispersion pattern of some species do not depart significantly from random, many are clumped to various degrees. Regular patterns are rare and are found sometimes in peat swamp forests. Clumping of individuals of the same species may be due to opportunity or chance. When numerous saplings are able to grow in large gaps, it is often clearly related to the dispersal mechanisms of the species.

Several hypotheses have been put forward to explain the cause of species diversity in communities. There are two different broad views. One group of theories (equilibrium theories) considers the environment as stable and recognizes intra and inter specific competition as the determinants of species diversity. The importance of competitive abilities of the species for co-existence has been stressed in this theory. Species though they survive in a particular environment, they are able to avoid or reduce competition from other species by finding its own niche (Grime 1979, Tilman 1982). Another group of theories (non equilibrium theory) focuses on the spatial and temporal instability of the environment (Huston 1979) that creates regeneration niches for species (Grubb 1977).

Biodiversity and ecosystem function

The relationship between biodiversity and ecosystem functioning has emerged as a major scientific issue today. Loreau (2000) provided an overview that on short-term biodiversity affects the magnitude of ecosystem processes such as primary productivity and nutrient retention and in the long-term contributes to the stability and maintenance of ecosystem process in the face of perturbation. In many recent studies of biodiversity functional characteristics of the species are given prominence. Thus the concepts of ecological function, functional group and functional diversity have come into existence (Tilman *et al* 1997, Hooper and Vitousek 1997).

The ecosystem level effect of an individual species is essential to examine the interaction between biological diversity and ecosystem function. Vitousek and Hooper (cf. Schulze and Mooney 1994) suggested that individual species are significant; otherwise, it is unlikely to detect the much more subtle and complex effects of species diversity. Korner (cf. Schulze and Mooney 1994) suggested the classification of species into functional groups to simplify the effects of global change on species interaction. Functional grouping of vegetation components by various criteria such as phytosociological association, life form, overall morphology, position in the canopy, structure of organs such as leaves or roots and their physiological characteristics is well known (Schulze 1982). Grime (1998) suggested that the relationship between plant diversity and ecosystem properties could be explored by classifying component species into three categories- dominants, subordinates and transients.

Wardle *et al* (1997) made extensive study of ecosystem properties on 50 relatively pristine forested islands of varied size and plant biodiversity. The ecosystem properties like higher microbial biomass, high litter quality, and more rapid rates of litter decomposition and nitrogen mineralization coincided with lower botanical diversity and the earlier successional state of the vegetation on larger areas. Tilman *et al* (1997) demonstrated that that all species in a system are not equal. The loss or addition of species with certain functional traits may have a great impact, and others have little impact, on a particular ecosystem process, but different processes are likely to be affected by different species and functional groups. Hooper and Vitousek (1997) pointed that the functional group composition can have a large effect on ecosystem processes than does functional group alone. He also emphasized that all species or functional group grown alone as well as in more diverse combinations should be investigated to understand the mechanisms of diversity effects on ecosystem processes. However, in natural communities such experiments are often difficult to conduct and the investigation of overall composition or diversity in ecosystem processes seems to be more important rather than investigating the effect of functional groups.

Microbial biomass Carbon.

Soil microorganisms play crucial role in functioning of ecosystem by affecting plant–available nutrients and soil structural stability (Paul and Clark 1989). They constitute a reservoir of nutrients and participate in nutrient cycling (Smith and Paul 1990). A number of studies on measurement of microbial C, N and P in different natural and disturbed ecosystems have shown that the soil microbial biomass contains liable pools of carbon and mineral nutrients (Anderson and Domsch 1980, Smith and Paul 1990, Von Lutzow *et al* 1992, Wardle 1992, Diaz-Ravina *et al* 1993) which are liberated after their death. Their role in the cycling of C, N and P is well established and is influenced by forest management (Ohtonen *et al* 1992, Bauhus and Barthel 1995) and increases proportionally with forest productivity (Myrold *et al* 1989).

Bolton *et al* (1993) demonstrated that plant cover determined the amount and activity of soil microorganisms at the perennial shrub-step site. The removal of plant cover in forest ecosystem due to disturbance reduces complexity in community structure and adversely influences some important ecosystem functions such as productivity and nutrient cycling. Disturbance in forest often causes accelerated soil erosion and soil compaction, as a consequence of which most of the essential nutrients are lost from the site, textural condition deteriorates and revegetation of these nutrient-poor sites becomes difficult (Borman and Likens 1981).

Studies in tropical forest ecosystem (Luizao *et al* 1992, Henrot and Robertson 1994) have established that microbial diversity and its biomass decrease as a result of disturbance. Srivastava and Singh (1991) reported that the conversion of forest into savanna resulted in a decrease in the amount of plant biomass resulting in the reduction in organic C that finally led to the decrease in the amount of microbial biomass in soil. Results of Arunachalam *et al* (1999) show that the disturbances such as tree cutting, shifting cultivation, artificial plantation causes depletion of soil nutrients thereby lowering the microbial biomass and microbial activity in the degraded sites than in the mature forest. While most studies have reported that the conversion of forest to other land uses results in the decrease in soil C (Veldkamp 1994, Van Dam *et al* 1997), several studies have found an increase in soil carbon following conversion of forest to other land use (Lugo and Brown 1993, Fischer *et al* 1994, Neill *et al* 1997).

The microbial biomass is affected by a number of factors such as moisture, carbon, nutrients, temperature and pH. Seasons influence microbial number (Diaz Ravina *et al* 1993) and mass (Granatstein *et al* 1987, Lynch and Panting 1981) either directly by inducing their responses changes in soil or indirectly by influencing plant metabolism. In tropical forest soils the peak microbial biomass has been reported during winter (Luizao *et al* 1992, Maithani *et al* 1996) when temperature is unfavourable for their activity. On the contrary, during rainy season, when warm and humid condition prevails, their biomass–C is low but activity is at its peak, thereby indicating fast turnover of MBC during this season. In temperate forest soils peak microbial biomass has been reported during summer and winter (Diaz – Ravina *et al* 1993). Microbial biomass is also influenced by rainfall and pH (Brookes *et al* 1986, Sarathchandra *et al* 1989, Kaiser *et al* 1992, Baath *et al* 1995). The percentage of active microbes may be affected by soil texture. It is assumed that due to difference in pore size distribution a higher proportion of microbes are physically protected in small pores in loams and clays than in sandy soils (Hassink *et al* 1993). Due to this protection the grazing intensity on the microbes by the soil fauna is low in clays than in sandy soils. It has been hypothesized that the grazing intensity in the sandy soils keeps the microbial population in a more active state.

Soil moisture content is another important factor, which regulates the decomposition of litter and fine roots and thus affects microbial biomass in soil. The drying and rewetting processes are cyclic over the seasonal pattern and soils are usually dry during winter when the plant and microbial growth is hampered due to unfavourable conditions (Singh *et al* 1989). On the other hand, microbial growth and activity is favoured due to rewetting of soil during rainy season, and therefore, there could be a greater release of microbial nutrients, which are readily absorbed by the plants due to vegetation growth during the rainy season.

Microbial biomass C ranges between 60-2000 $\mu g\ g^{-1}$ in various tropical forests (Singh *et al* 1989, Luizao *et al* 1992, Henrot and Robertson 1994), while in the temperate forests it ranges between 132-800 $\mu g\ g^{-1}$ (Diaz – Ravina *et al* 1995). Arunachalam *et al* (1999) reported 811- 1684 $\mu g\ g^{-1}$microbial biomass C from Jhum fallow and sacred groves in northeast India. The contribution of microbial biomass C to the total soil organic - C ranges between 1.5-5.3% in tropical forest soils (Theng *et al* 1989, Luizao *et al* 1992) and 1.8-2.9% for temperate forests soils (Vance *et al* 1987). Maithani (1996) reported a range of 0.92-1.74% from the subtropical broad-leaved forest ecosystem undergoing recovery in northeast India.

Nitrogen Mineralization

N-mineralization is the rate at which mineral N becomes available in the soil for uptake by plants through decomposition of organic matter and has been shown to be an important factor limiting production in non-fertilized forest ecosystems (Nadelhoffer *et al* 1984, Pastor *et al* 1984). The breakdown of organically combined nitrogen in the soil is a central part of the nitrogen cycle and results in the provision of inorganic nitrogen in the form that is most readily assimilated by the plants. The immediate product of nitrogen mineralization is usually ammonia, (ammonium ion) generated by the process of ammonification, which in turn may be converted to nitrate by the process of nitrification with the help of suitable microorganisms.

A number of studies carried out within tropical forests, including lowland forests have shown that N-mineralization and nitrification are substantially more rapid in most lowland tropical forests than the in temperate or boreal forests (Ellenberg 1977, Robertson 1984). Many chemical and biological tests have been used for many years in an attempt to predict the N supplying capacity of soils but a satisfactory method of predicting N-mineralization continues to elude investigators (Burket and Dick 1998). A better knowledge of the mechanisms and indicators of

N-mineralization in soil is essential to improve N-use efficiency and lessen environmental impacts on agricultural production.

In situ N-mineralization in forest soil was first studied by Lamee (1967). Subsequently a number of studies were carried out in mature forests of different productivity status (Adams and Attiwill 1986, Raison *et al* 1987), in forests along a gradient of N-availability (Aber *et al* 1985, Nadelhoffer *et al* 1984), along a successional gradient (Lamb 1980, Maithaini *et al* 1996) and forests subjected to disturbance (Vitousek and Denslow 1986). These studies have shown that N-mineralization in mature forests ranges from 10kg/ha/yr in cool temperate forests to 800 kg/ha/yr in tropical forests.

The species composition affects the release of nutrients and at the same time the soil fertility also has a major impact on plant community composition (Van Der Krift and Berendse 2001). Most studies have shown that the effects of dominant plant species can be as important as abiotic factors in controlling ecosystem fertility (Berendse 1990, Wedin and Tilman 1990, Van Vuuren *et al* 1992). Such differences are likely to have important consequences for soil organic matter dynamics and nutrient mineralization where plant species composition changes during succession. Some authors have reported that changes in N supply have important effects on species replacement (Chapin 1980, Berendse 1983, Wedin and Tilman 1990, Olff *et al* 1994) and the species replacement during succession might also have major effects on N cycle (Van Der Krift and Berendse

2001). Effect of plant species on soil nitrogen mineralization is available from grassland (Van Der Krift 2001, Wedin and Tilman 1990). However such studies are limited from forests as manipulating different species in combinations is often a major problem.

The effects of disturbance on elemental cycling and nutrient loss in forest ecosystems have been a matter of long standing concern among the forests Scientists. Element losses following disturbance have been used to characterize the degree of homeostasis in forest biogeochemical cycles (Borman and Likens 1979) and is considered as a useful measure of ecosystem level stability. The impact of disturbance on N-mineralization is important because high disturbance may reduce the ability of plants to take up mineralized N, removal of canopy can increase the rate of N mineralization by increasing soil temperature and moisture, by increasing the frequency and intensity of dry and rewetting cycle on the forest floor (Campbell *et al* 1973, Van Gestel *et al* 1991), by increasing the availability of substrate for mineralization (Rice 1979) and by decreasing resource competition between heterotrophs and mycorrhizae (Gadgil and Gadgil 1975). However, the amount of the N-mineralized varies among sites and depends on the extent to which plant N uptake is decreased, the amount of increase in the rate of mineralization (Vitousek 1981) and the rate of mineralization prior to disturbance.

Fluctuations in N-mineralization and nitrification have been largely attributed to seasonal variation in temperature and moisture content (Swift *et al*

1979, Sierra 1997). A low rate of N-mineralization during winter reflects low temperature. The rise of temperature during spring increases microbial activity and enables more inorganic N to be released (Sierra 1997). The decrease in net soil N transformation rate with increasing altitude indicates that temperature primarily controlled the transformation rate irrespective of substrate (Kitayama *et al* 1998). The rainfall (Zak and Grigal 1991) governs seasonality in N-mineralization. Soil moisture content limits N mineralization in dry tropical forests (Singh *et al* 1991), in Scotish highlands (Morecroft *et al* 1992) and in Taiga forests (Clein and Schimel 1995).

Since forests soils are usually low in plant available ammonium and nitrate and such ecosystems do not receive large fertilizer inputs, mineralization plays a key role in influencing forest productivity. The differences in N-mineralization and nitrification is not simply a function of the net plant biomass production but are probably also due to differences in biomass turnover rates (Aerts *et al* 1992, Schlapfer and Ryser 1996) and litter decomposability (Berendse *et al* 1989). Release of nutrients from forest floor is regulated by the chemical composition of the litter (Berg and Staof 1980) and environmental conditions (Meentemeyer 1978). The litter decay depends upon the availability of carbohydrate that can be utilized by microorganisms (Gilmour *et al* 1985) and factors such as species and age of substrate could be expected to affect this availability.

It has been shown that the vegetation present on a given site influences the availability and cycling of the nutrients. The specific influence of vegetation, in isolation from other factors such as climate, soil, time and topography (Jenny 1980, Van Cleve *et al* 1991) is difficult to assess as similar vegetation is found at other places. The studies in old growth forests revealed that N-mineralization and nitrification are species specific (Alban 1969 and Turner *et al* 1993). They showed that nitrification and nitrate concentration in soil differed due to tree species growing on it indicating species-specific effect on ammonium and nitrate production and uptake within the forest type.

Sacred forests

The sacred forests or sacred groves have been reported from many parts of Africa, Asia, Europe and Australia (cf. Ramakrishnan *et al* 1998). These are plant communities that have persisted through ages depending upon the history, traditional beliefs and culture of the tribes. The size of the sacred grove may vary from a single tree, to forest patches of varied size, or the entire landscape.

In India sacred forests are found in the states of Bihar, Karnataka, Kerela, Madhya Pradesh, Maharastra, Meghalaya, Orissia and Rajasthan. Gadgil and Vartak (1976) have classified the sacred groves of India into four important regions, they are the Western Ghats, Aravalli Hills, Central India and Khasi and Jaintia Hills of the north-east India. Chandrashekara and Sankar (1998) reported that the sacred grove covers an area of 0.05% of the total forest area and harbours about 20% of the total flowering plants of the Kerela state. Sinha and Maikhuri (1998) reported seven sacred groves from Garhwal Himalaya.

Seventy-nine sacred groves have been reported in the state of Meghalaya by Tiwari *et al* (1999). Their size vary from 0.1 ha to more than 100 ha. These are rich in floral and faunal diversity and have attracted the attention of many earlier botanists such as Hooker (1854), Brandis (1897), Kanjilal *et al* (1934), Hajra (1975) who were interested in enumerating the flora of the region. Ecological studies on the sacred groves of the state are confined to the Khasi hills. Khiewtam and Ramakrishnan (1993) studied the ecosystem function of the sacred grove at Cherrapunjee. Barik *et al* (1992), Rao *et al* (1997) have studied community characteristics, microenvironmental variability in gaps and understory and natural regeneration of trees in the Mawphlang sacred groves of Meghalaya. Recently, Jamir (2000) has prepared an inventory of plants from three sacred groves in Jowai and studied the population behaviour of dominant tree species.

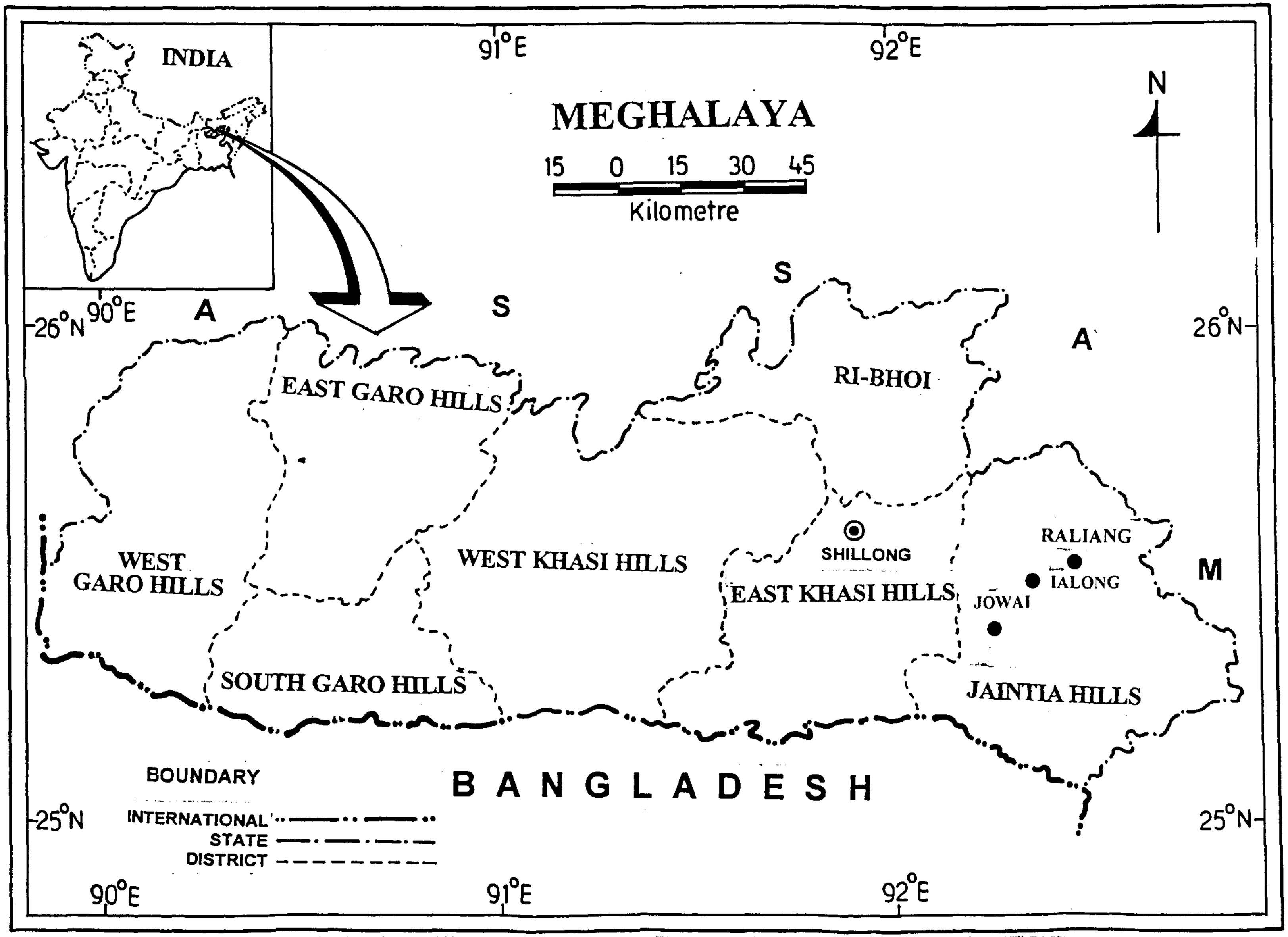
The literature reviewed in the foregoing pages clearly indicates that plant diversity studies in the sacred groves of northeast India are limited. The present study was undertaken to assess the plant diversity status of the two well preserved sacred groves in Jaintia hills of Meghalaya, hither to unexplored from this point of view. The effect of biodiversity on ecosystem processes is a subject of great interest that has attracted the attention of a large number of ecologists. Most of the studies conducted so far are from the grasslands and small plants grown in different combinations. To assess the impact of diversity on ecosystem processes in forest communities is a difficult task. Therefore an attempt has been made to study how disturbance induced the change in plant diversity and other community parameters may affect certain ecosystem processes like microbial biomass-C dynamics and N-mineralization in the sacred groves.

CHAPTER III

STUDY SITE AND METHODOLOGY

Study Sites

The study was conducted at Ialong and Raliang sacred groves in Jaintia hills district of Meghalaya in northeast India. The Ialong sacred grove is located about 8 km east (latitude 25^0 28' N, longitude 92^0 16' E, altitude 1350m asl), and the Raliang sacred grove (latitude 25^0 30' N and longitude 92^0 28'E, altitude of 1300m asl) is located 28 km of the Jowai town the headquarter of Jaintia hills district (Map1). The Ialong and Raliang sacred groves are called '*Khloo blai*' (religious forest) and '*Khloo Lyngdoh* or *Khloo Poh Lyngdoh*' (forest taken care by the *Lyngdoh* or preist) respectively. These groves are well protected for a long time on account of the strong religious beliefs of the Jaintia tribe and represent the climax vegetation of the area. A portion of each of the two sacred groves covering an area of 20 and 30 ha is well protected while another portion (30-40 ha) was open for the people residing in nearby village to meet timber and fuel wood requirements. Grazing is allowed in the periphery of the disturbed part of the sacred groves where herbaceous growth is burnt annually during the winter season. However, the intensity of disturbance and fire is not enough to cause



Map.1. Showing the location of Ialong and Raliang sacred groves in Jaintia hills of Meghalaya

serious damage to the forest, which appears quite dense due to abundant tree regrowth (Photographs 1 and 2).

Geology

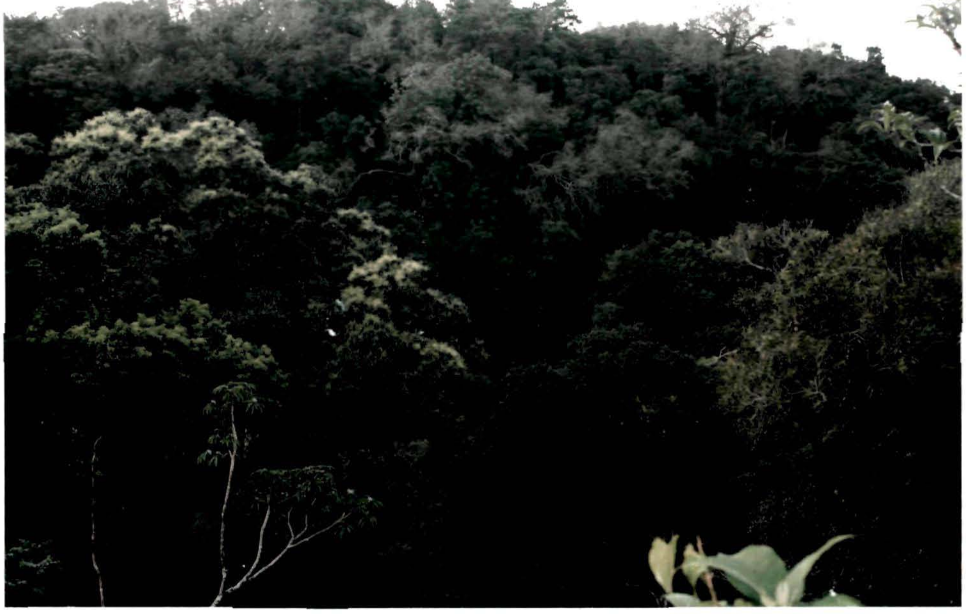
Jaintia hills are the oldest part of a chain of hills forming the southern boundary of Brahmaputra valley. The plateau of Jaintia hills are predominantly composed of metamorphic rocks consisting of a thick series of quartizites and schists with intrusions of granites, laterites and perodites and embedded bands of argillites. The southern and southeastern regions are composed of Jaintia series, consisting of Pre-Tertiary and Tertiary rocks of limestones lying almost horizontally. The northern part is composed of Cretaceous rocks. A large part of the Jaintia hills is characterized by presence of hard sandstone, soft loose sands, hard conglomerates, sandstones, sandy shales and sandy clays (Ahmad 1993).

Climate

The climate of the area is monsoonic with alternate wet and dry seasons. The wet period extends from April to October followed by a dry period from November to March. During wet seasons monthly rainfall ranged from a maximum of 1854mm in June 2000 to a minimum of 229mm in April 2000. During the dry period rainfall is low. The annual rainfall was 6456mm during 2000. Relative humidity exhibited marked seasonal variation with a peak during June-July and a through fall in January-February and was closely related to the rainfall pattern. The mean monthly temperature varied from a maximum of 26^0C in June –July 2000 to a minimum of 5^0C in January 2000 (Fig. 3.1).

Photographs 1. A view of undisturbed stands of Ialong (A) and Raliang (B) sacred groves in Jaintia hills of Meghalaya

A



B

Photographs 2. A view of mildly disturbed stands of Ialong (A) and Raliang (B) sacred groves in Jaintia hills of Meghalaya


A


B

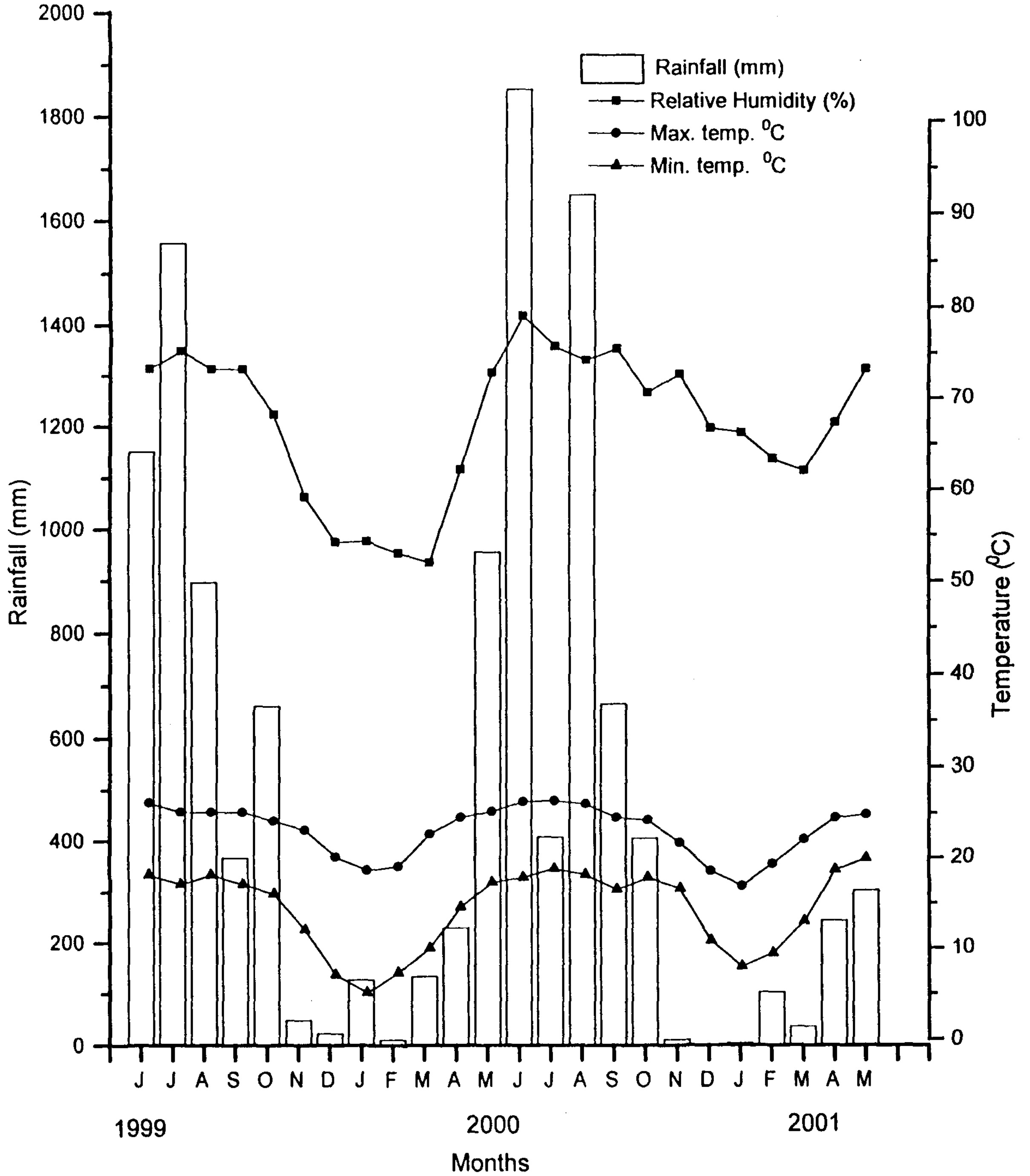


Fig.3.1. Mean monthly rainfall (mm), relative humidity (%), mean maximum and minimum temperatures (^{0}C) at Jowai during the period (1999-2001)

Soil

Texture

The texture of the upper soil layer (0-10cm) varied from loamy sand to sandy loam while that of the sub soil layer (10-20cm) it was loamy sand in undisturbed stand (Isg) and mildly disturbed stand (Imd) of Ialong and loamy and sandy loam in the undisturbed stand (Rsg) and mildly disturbed stand (Rmd) of Raliang respectively (Table 3.1).

Soil moisture content

The soil moisture content varied significantly ($P < 0.01$) between the sites, soil depths and seasons. In all four stands the surface layer (0-10cm) had higher moisture content than the subsurface soil layer (10-20cm). Seasonal fluctuation in moisture content was very prominent; the values were high during the warm-wet season and low during the dry-cold season. The soil in undisturbed stand of both the sacred groves had higher moisture content than the mildly disturbed stand (Fig. 3. 2).

Soil temperature.

The soil temperature varied significantly ($P < 0.01$) between sites, months and depths. It was high during June-July and low during January and February at all sites. The temperature was slightly high in the surface layer (0-10cm) then the subsurface soil layer (10-20cm) and in the mildly disturbed stand than the undisturbed stand both at Ialong and Raliang (Fig. 3. 3)

Table 3.1. Soil texture at the study sites.

Forest stand	Depths (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
Isg	0-10	84.36 ± 0.02	11.09 ± 0.05	4.55 ± 0.05	Loamy sand
	10-20	81.36 ± 0.71	11.59 ± 0.71	7.02 ± 0.00	Loamy sand
Rsg	0-10	58.76 ± 0.72	24.79 ± 0.90	16.45 ± 0.92	Sandy loam
	10-20	37.52 ± 1.01	35.76 ± 0.71	26.72 ± 0.71	Loamy
Imd	0-10	84.38 ± 1.59	11.08 ±1.59	4.54 ± 0.00	Loamy sand
	10-20	77.64 ±0.89	14.37 ± 1.79	7.98 ± 0.90	Loamy sand
Rmd	0-10	81.19 ± 1.22	12.73 ± 1.09	6.07 ± 0.88	Loamy sand
	10-20	73.19 ± 0.86	13.64 ± 1.79	13.17 ± 1.19	Sandy loam

(± SEM, n=3).

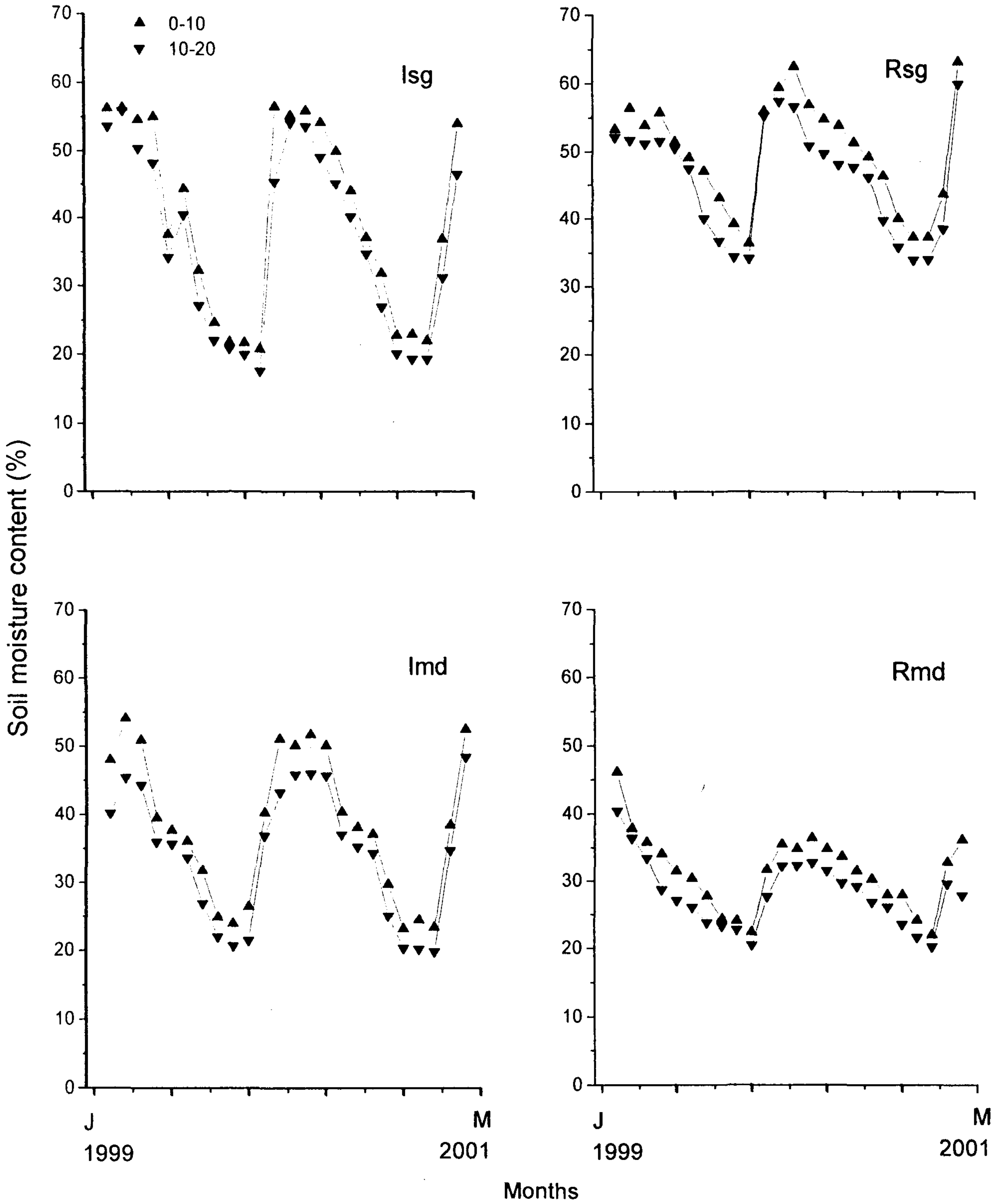


Fig. 3.2. Mean monthly soil moisture content (%) in undisturbed (Isg, Rsg) and mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

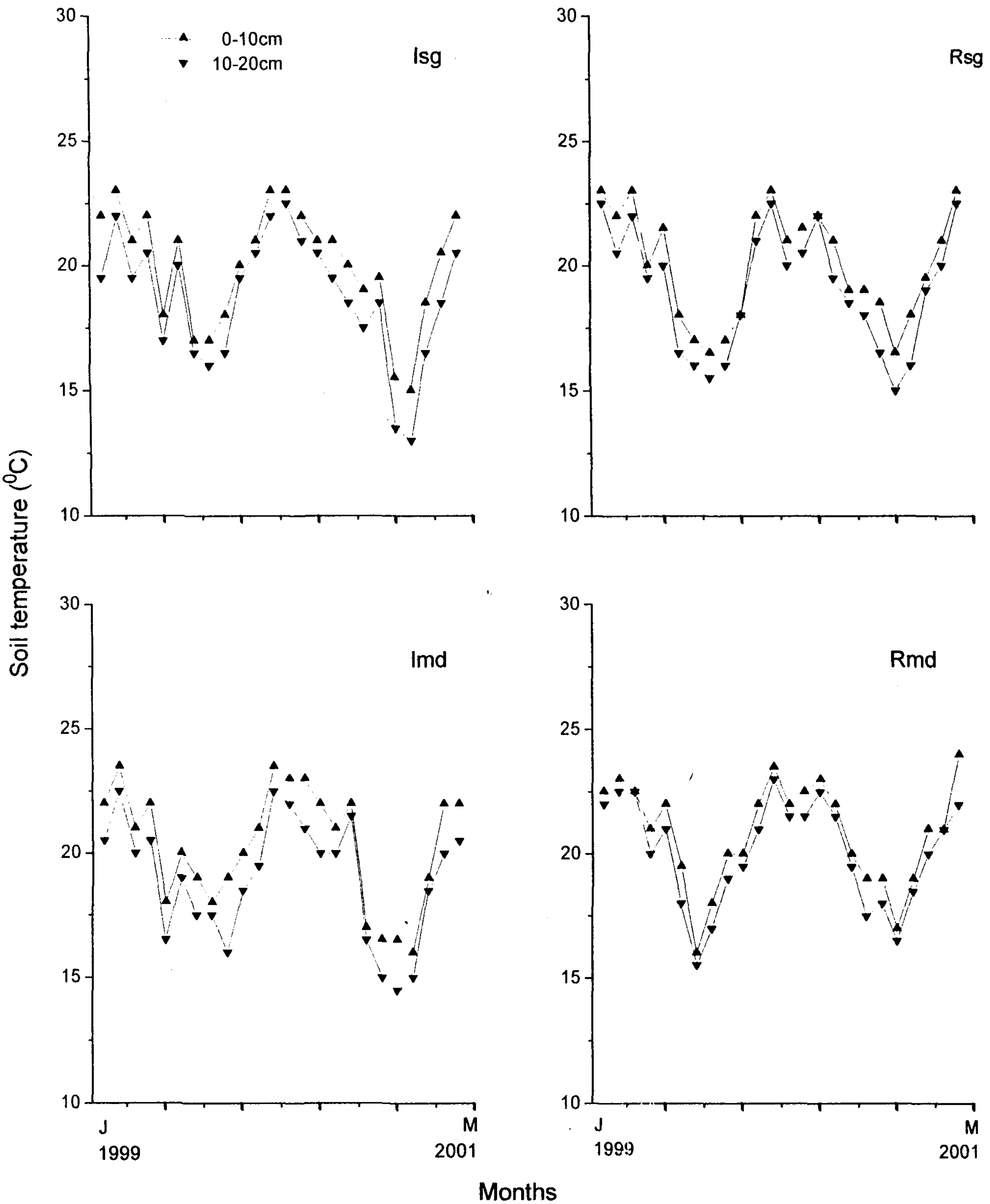


Fig. 3.3. Mean monthly soil temperature (^{0}C) in the undisturbed (Isg, Rsg) and mildly disturbed (Imd, Rmd) stands at Ialong and Raliang.

pH

The soils were acidic in nature and the mean value ranged from a minimum of 4.80 (Rsg) to a maximum of 5.25 (Imd). The pH exhibited a marked seasonal change (significant at $P < 0.01$) in all four stands. The pH showed a sharp decline during rainy season followed by a steep rise during winter season. The surface soil was less acidic than the subsurface layer (Fig. 3.4).

Soil organic carbon (SOC)

Soil organic carbon (SOC) content showed significant ($P<0.01$) difference between sites and depths. In the surface soil layer (0-10cm) the difference between sites was significant ($P<0.01$) but the variation between seasons was not significant. SOC was generally low during rainy season and high during autumn. The undisturbed stands had higher SOC than the mildly disturbed stand in both the sacred groves (Table 3. 2).

Total Kjeldahl Nitrogen (TKN)

Seasonal variation in TKN was not marked, but the difference between soil depths and sites was distinct. The surface layer (0-10cm) had higher TKN concentration than the sub surface layer (10-20cm). Similarly the undisturbed stands of both the sacred groves soils had higher TKN concentration than the mildly disturbed stands (Table 3. 3).

Available soil Phosphorous

The concentration of available soil-P varied significantly ($P< 0.01$) between sites, depths and seasons. In all the stands the concentration was high during rainy

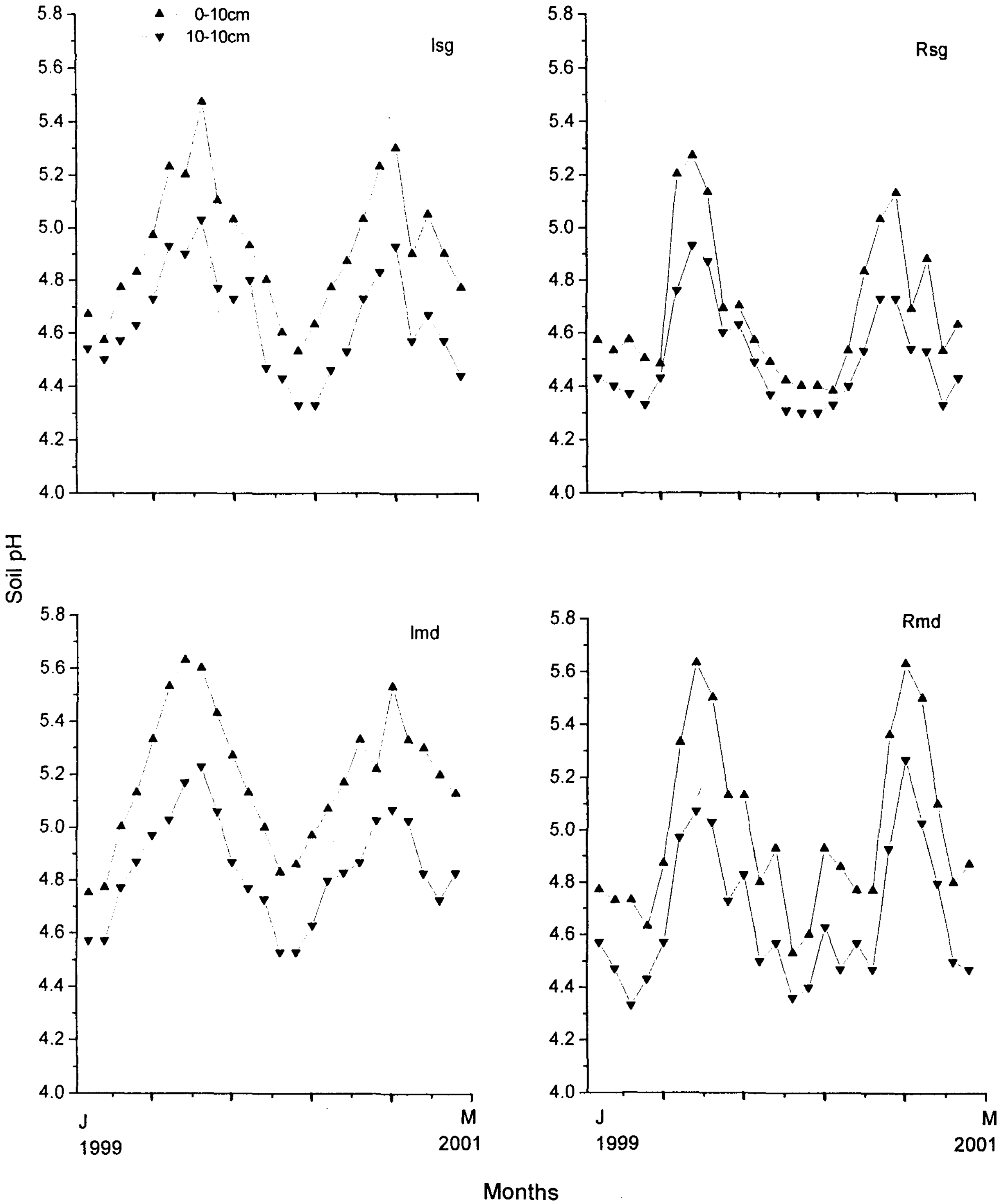


Fig. 3.4. Mean monthly soil pH in the undisturbed (Isg, Rsg) and mildly disturbed (Imd, Rmd) stands at Ialong and Raliang.

Table 3. 2. Seasonal variation in soil organic carbon (%) content at the study sites.

Forest stands	Depths (cm)	R	A	W	S	Mean	R	A	W	S	Mean
Isg	0-10	4.58 ± 0.037	4.99 ± 0.036	4.94 ± 0.072	4.90 ± 0.01	**4.85**	4.58 ± 0.036	5.05 ± 0.052	5.03 ± 0.006	4.95 ± 0.01	**4.90**
	10-20	4.26 ± 0.046	4.29 ± 0.04	4.26± 0.027	4.42 ± 0.05	**4.30**	4.16± 0.026	4.49± 0.07	4.36 ± 0.014	4.39 ± 0.01	**4.35**
Rsg	0-10	4.56 ± 0.065	5.01 ± 0.076	4.88 ± 0.08	5.06 ± 0.017	**4.88**	4.64 ± 0.088	5.02 ± 0.064	5.11 ± 0.02	5.03 ± 0.04	**4.95**
	10-20	4.14 ± 0.016	4.21 ± 0.06	4.28 ± 0.03	4.56 ± 0.006	**4.30**	4.16 ± 0.049	4.18 ± 0.05	4.49 ± 0.05	4.35 ± 0.01	**4.30**
Imd	0-10	4.03 ± 0.068	4.19 ± 0.024	4.11± 0.01	4.22 ± 0.02	**4.14**	4.73 ± 0.023	4.28 ± 0.017	4.25 ± 0.014	4.22 ± 0.02	**4.37**
	10-20	3.14 ± 0.032	3.48 ± 0.08	3.18 ± 0.04	3.73 ± 0.006	**3.38**	3.1 ± 0.04	3.69 ± 0.046	3.62 ± 0.02	3.46 ± 0.031	**3.47**
Rmd	0-10	4.14 ± 0.013	4.37 ± 0.04	4.09 ± 0.017	4.17 ± 0.036	**4.19**	4.16 ± 0.049	4.71 ± 0.016	4.35± 0.01	4.24 ± 0.028	**4.37**
	10-20	2.98 ± 0.06	3.91± 0.01	3.22± 0.075	2.87± 0.042	**3.24**	3.03± 0.066	4.06± 0.01	3.82± 0.14	3.72 ± 0.26	**3.66**

(± SEM, n=3)
R- rainy (June, July and Aug.)
A- autumn (Sept., Oct. and Nov.)
W- winter (Dec., Jan. and Feb.)
S- spring (Mar., Apr. and May).

Table 3. 3. Seasonal variation in TKN (%)content of the soil at the study sites.

Forest stands	Depths (cm)	R	A	W	S	Mean	R	A	W	S	Mean
Isg	0-10	0.46± 0.003	0.45± 0.005	0.43± 0.003	0.46± 0.008	**0.45**	0.48± 0.01	0.47± 0.017	0.42± 0.005	0.42± 0.003	**0.45**
	10-20	0.31± 0.003	0.31± 0.003	0.37± 0.006	0.38± 0.005	**0.34**	0.34± 0.011	0.35± 0.012	0.38± 0.006	0.38± 0.17	**0.36**
Rsg	0-10	0.48 ± 0.005	0.46 ± 0	0.43± 0.003	0.43± 0	**0.45**	0.51± 0.017	0.54± 0.023	0.43± 0.006	0.44± 0.01	**0.48**
	10-20	0.38± 0.003	0.33± 0.003	0.38± 0.006	0.40± 0.008	**0.37**	0.38± 0.026	0.48± 0.003	0.40± 0.006	0.39± 0.006	**0.41**
Imd	0-10	0.34± 0.006	0.36± 0.012	0.38± 0.005	0.38± 0.005	**0.37**	0.37± 0.003	0.38± 0.012	0.38± 0.01	0.37± 0.013	**0.38**
	10-20	0.28± 0.003	0.30± 0.003	0.31± 0.005	0.32± 0.01	**0.30**	0.30± 0.01	0.34± 0.008	0.32± 0.006	0.30± 0.012	**0.32**
Rmd	0-10	0.31± 0.003	0.42± 0.005	0.36± 0.003	0.36± 0.005	**0.36**	0.36± 0.011	0.40± 0.008	0.38± 0.012	0.38± 0.005	**0.38**
	10-20	0.29± 0.003	0.27± 0.005	0.29± 0.008	0.32± 0.005	**0.29**	0.29± 0.01	0.35± 0.008	0.30± 0.005	0.29± 0.014	**0.31**

(± SEM, n=3)
R- rainy (June, July and Aug.)
A- autumn (Sept., Oct. and Nov.)
W- winter (Dec., Jan. and Feb.)
S- *spring (Mar., Apr. and May).*

Table 3.4. Seasonal variations in available phosphorous ($\mu g\ g^{-1}$) content of the soil in the study site.

Forest stands	Depths (cm)	R	A	W	S	Mean	R	A	W	S	Mean
Isg	0-10	16.13	13.73	10.6	11.46	**12.98**	18.4	17.26	12.4	13.34	**15.35**
		±0.13	±0.93	±0.8	±0.73		±1.03	±0.27	±0.2	±1.13	
	10-20	12.4	9.26	8.06	8.8	**9.63**	15.86	14.67	9.26	10.66	**12.61**
		±0.2	±0.26	±0.33	±0.2		±0.27	±0.94	±0.26	±0.77	
Rsg	0-10	17.53	19.53	13.53	9.26	**14.96**	21.2	20.8	15.86	13.73	**17.89**
		±0.27	±0.86	±1.04	±0.26		±0.20	±0.20	±0.26	±1.87	
	10-20	16.0	16.13	9.26	7.86	**12.31**	17.53	16.6	10.33	8.80	**13.31**
		±0.23	±0.13	±0.26	±0.26		±0.23	±0.20	±0.96	±0.20	
Imd	0-10	12.4	12.4	8.6	9.53	**10.73**	15.8	15.73	10.66	14.8	**14.24**
		±0.2	±0.2	±0.2	±0.26		±0.13	±0.13	±0.77	±1.01	
	10-20	9.26	9.53	6.73	8.13	**8.41**	10.73	9.53	8.6 0	11.46	**10.08**
		±0.26	±0.26	±0.86	±0.26		±0.73	±0.26	±0.2	±0.73	
Rmd	0-10	13.46	14.67	9.53	9.26	**11.73**	15.73	14.66	10.6	11.4	**13.09**
		±1.09	±0.93	±0.26	±0.26		±0.13	±0.93	±0.80	±0.80	
	10-20	9.26	9.26	7.86	8.13	**8.63**	10.53	10.6	8.6	8.13	**9.46**
		±0.26	±0.26	±0.26	±0.27		±0.73	±0.8	±0.2	±0.27	

(± SEM, n=3)
R- rainy (June, July and Aug.)
A- autumn (Sept., Oct. and Nov.)
W- winter (Dec., Jan. and Feb.)
S- spring (Mar., Apr. and May).

season and low during winter. The surface layer had higher concentration than the subsurface layer. Soils in the undisturbed sacred grove stands had higher available phosphorous than the disturbed stands (Table 3.4).

Litter quality

The litter quality of dominant tree species, which is known to have an adverse affect on nutrient cycling, declined in the mildly disturbed stands of both the sacred groves (Table 3.5).

Table 3.5. Litter quality of dominant tree species at the study sites.

Stands	N (%)	P (%)	K (%)
Isg	1.99 ± 0.03	0.07 ± 0.001	1.75 ± 0.01
Imd	1.49 ± 0.02	0.05 ± 0.001	1.27 ± 0.06
Rsg	1.73 ± 0.02	0.07 ± 0.002	1.38 ± 0.01
Rmd	1.51 ± 0.05	0.06 ± 0.003	1.07 ± 0.01

±SEM (n=3)

Vegetation

According to Champion and Seth (1968) the climax vegetation of the area can be grouped under subtropical wet hill forest. This broad categorization however, sometimes appears to be inadequate in dealing with the plant communities in small area because of variation in local environment and botanical composition. Balakrishnan (1981-83) divided the vegetation of Jaintia hills into two broad categories and four vegetation zones on the basis of altitude and annual rainfall respectively.

i) Tropical evergreen zone (altitude 100-1200m, annual rainfall 300-500cm): The forests in this zone are characterised by the presence of species like *Terminalia bellirica*, *Gynocardia odorata*, *Elaeocarpus rugosus*, *Castanopsis armata*, *Spondias pinnata*, *Ficus racemosa*, etc.

ii) Tropical semievergreen zone (altitude 100-1200m, rainfall 150-300cm): The dominant species in this zone includes *Elaeocarpus floribundus*, *Dillenia* spp, *Lithocarpus fenestrata*, *Micromelum integerrimum*, *Garcinia lancifolia*, etc.

iii) Subtropical evergreen zone (altitude 1200-1800m, rainfall 300-500cm): The dominant tree species in this zone are *Castanopsis tribuloides*, *Lithocarpus elagans*, *Engelhardtia spicata*, *Ficus elastica*, *Mangletia insignis*, *Evodia trichotoma* etc.

iv) Subtropical semievergreen zone (altitude 1200-1800m, rainfall 150-300 cm): Predominant tree species in the forest of this zone are *Castanopsis indica*, *Elaeocarpus floribunda*, *Albizzia chinensis*, *Ficus altissima*, *Pyrularia edulies*, *Dyconia indica* etc.

Since majority of the tree species in the canopy and subcanopy layers at Ialong and Raliang are evergreen, the vegetation of the sacred groves may be termed as subtropical evergreen forest. The common evergreen trees found in the sacred groves are *Cinnamomum glanduliferum*, *Neolitsea cassia*, *Persea odoratissima*, *Syzygium tetragonum*, etc. The deciduous elements included *Engelhardia spicata*, *Acer laevigatum*, *Ficus* spp., *Spondias axallaries*, *Mangletia* sp., *Dyconia indica* etc. The shrub layer was quite thick and composed of *Boehmeria platyphylla, Brynea retusa, Erythroxylon kunthianum, Gonionthalamus sesquipedalis, Psychotria spp., Ardisia griffithii, Sarcandra glabra,* etc. The ground vegetation is dominated by *Impatiens* spp., *Polygonum* spp., *Ophiopogon* sp., *Globba clarkei, Hedychium* spp., *Costos specious* etc. Ferns and Selaginellas are common on the forest floor. The tree trunks and branches are covered with profuse growth of mosses, ferns and epiphytes. Woody climbers and twiners are abundant. In the community forests of both the groves invasive weeds like *Lantana camera, Artimesia* sp. and *Eupatorium* sp. were also present.

Methodology

Soil analysis

Soil samples were collected from two depths (0-10cm and 10-20cm) at ten randomly located points in each of the four stands at monthly and seasonal intervals using an iron soil corer (6.5cm diameter and 30cm height). The samples were mixed for each depth and site separately to obtain a composite sample. Soil texture was determined by hydrometer method (Kanwar and Chopra 1967). Soil moisture content was determined gravimetrically by taking 10g of fresh unsieved soil and the result expressed on oven-dry weight basis. pH was determined by a digital pH meter taking 1:2.5 suspension of soil and distilled water (Anderson and Ingram 1993). Carbon by rapid titration method (Walkley and Black 1934). Total Kjeldahl Nitrogen (TKN) was analysed by Semi-micro kjeldahl digestion method and available Phosphorus by Molybdenum Blue method (Allen *et al* 1974).

Plant diversity inventory

For plant diversity studies extensive survey was carried out in the two sacred groves during June 1999-June 2001. Specimens were collected and identified with the help of Flora of Jowai (Balakrishnan 1981-1983), Forest flora of Meghalaya (Haridasan and Rao 1985-1987), Flora of Assam (Kanjilal *et al* 1934-1940), Flora of Nongpoh and its vicinity (Joseph 1982) and Flora of British India (Hooker 1872-1897). Wherever necessary, the herbaria at Botany Department, NEHU and Botanical Survey of India, North-Eastern Circle, Shillong were consulted for correct identification of the specimens. List of endangered, rare and endemic plants was prepared using available literature (Deb 1958, Balakrishnan 1981-83, Rao and Haridasan 1983, Das and Deori 1983, Haridasan and Rao 1985-1987, Kumar 1991, Samant *et al* 1998, Khan *et al* 1997, Kataki 1983, Chauhan 1983). The nomenclature of the species follows the regional flora.

Community studies

Structural analysis of pant community was carried out on the basis of the following measures:

Species richness and floristic similarity

Total number of species recorded in the undisturbed and disturbed stands of the groves was taken as species richness.

Floristic similarity between the stands was studied by computing Sorensen's index of similarity (Sorensen 1948) = 2c/ a+b x 100

Where, a = Number of species at site a

b = Number of species at site b

c = Number of species common to stand a and stand b.

Frequency, density, abundance, basal cover and IVI

A total of 50 quadrats of 10m x 10m size were randomly laid in both the stands of Ialong and Raliang sacred groves for woody species ($\geq$ 5 cm dbh). For the study of shrubs and herbs 30 quadrats each of 5m x 5m and 1m x 1m size were laid. Frequency, density, basal cover, abundance and importance value Index (IVI) of the species were calculated according to Misra (1968) and Muller-Dombois and Ellengberg (1974).

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats of occurance of a species}}{\text{Number of quadrats studied}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats studied}}$$

Basal Cover ($m^2\ ha^{-1}$) = Density x Average tree basal area.

$$\text{Abundance} = \frac{\text{Number of individuals of a species}}{\text{Number of quadrats of occurance of the species.}}$$

IVI= Relative frequency + Relative density + Relative basal area (for trees).

IVI= Relative frequency + Relative density (for shrubs and herbs)

Whitford's index (Whitford 1948) was used to study the horizontal distribution pattern of species in the community

Whitford's index = Abundance / Frequency

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

Species diversity and dominance

Simpson index of dominance (D) (Simpson 1949) was calculated as

$$D = \sum (ni/N)^2$$

Where, ni = number of individuals of ith species.

N = total number of individuals of all the species.

Shannon and Wiener index of diversity (Shannon and Wiener 1963) was calculated using proportional number of species.

$$H^{-} = - \sum pi \ln pi$$

Where, pi = proportion number of ith species in the number of all the species.

Microbial biomass carbon (MBC)

MBC was determined in soils of all four stands during one annual cycle from June 2000 to May 2001. Soils samples were collected from two soil depths (0-10cm and 10-20cm) at monthly interval. The data were then pooled together to present seasonally. At each sampling date ten samples were collected using soil corer (6.5cm diameter and 30cm height) for each of the four stands. The samples were sealed in polythene bags in field and brought to laboratory. They were bulked depth wise to obtain composite samples for each site. They were sieved through 2mm-mesh screen to remove stones, roots and plant debris and used in field moist condition for the determination of microbial biomass carbon.

MBC was determined by chloroform extraction method (Vance *et al* 1987). Six sub samples of 10g ± 0.01 each were drawn from each composite samples, three of them was fumigated by saturating with 10-ml (alcohol free) liquid chloroform and kept for 24 hours. After fumigation, chloroform was removed from the samples by evaporation. Both fumigated and non-fumigated samples were then extracted with 50ml of 0.5 M K_2SO_4 by shaking for 30 minutes. The extracts were filtered through Whatman filter paper No. 42. The filtrates of fumigated and non-fumigated soils collected were used for determination of microbial biomass carbon.

The organic C in the extracts of fumigated and non-fumigated soil samples was determined by digesting 4ml filtered extract with 0.00667 M $K_2Cr_2O_7$ (1ml) and 5ml of H_2SO_4 (98% acid) for 30 minutes. The digested sample was titrated with acidified ferrous ammonium sulphate solution using 0.3ml (3-4 drops) of indicator (O-phenolpthaline monohydrate and ferrous sulphate hexahydrate). The MBC was calculated according to (Vance *et al* 1987)

$$MBC = 2.64\ E_C$$

Where, E_C is the difference between the amount of organic C extracted from the K_2SO_4 extract of fumigated and non-fumigated soils, both expressed as μg C g^{-1} dry soil, and 2.64 is the relationship between biomass C as measured by fumigation incubation method and amount of C extracted by 0.5 M K_2SO_4 after chloroform treatment.

Nitrogen mineralization

Nitrogen mineralization was studied *in situ* on monthly basis during one annual cycle from June 2000 to May 2001 using buried bags technique (Eno 1960). At each sampling date soils were collected from two soil depths (0-10cm, 10-20cm) using a steel corer (6.5cm diameter) at five randomly located points in each of the four stands. At each sampling point two samples were drawn from each depth. One of the pair was sealed into sterilized polyethylene bags after removing roots and larger organic debris, and inserted in to its respective depth. The other pair was brought to the laboratory, bulked depth wise and sieved through a 2mm mesh screen. Initial moisture content (SMC) and NH_4^+-N and NO_3^--N concentration was determined within 24 hours following the method outlined by Allen *et al* (1974). The buried bags were retrieved after one month and soil samples were analysed for final NH_4^+-N and NO_3^--N concentrations. Ammonification and nitrification rates were calculated based on the changes in ammonium and nitrate N concentrations by subtracting the initial concentration from their respective final concentration. Net nitrogen mineralization was calculated as the sum of changes in the extractable ammonium– N and nitrate– N over one month period.

Statistical analysis

The field and laboratory data were statistically analysed using two, three way ANOVA (fixed model effect) in order to acertain the effect of season, soil depth and stands on MBC, ammonification and net mineralization. Relationships between community parameters and environmental variables and soil processes were studied by computing correlation coeffection and linear regression equation wherever necessary following Zar (1974).

CHAPTER IV

PLANT DIVERSITY IN THE SACRED GROVES

In-depth study of plant biodiversity status of sacred groves in India is scanty. Chandrashekara and Sankar (1998) reported that 18% of the total species of Ollur Kavu, S.N.Puram Kavu and Iringole Kavu sacred groves of Kerela are endemic. Swamy *et al* (1998) recorded 54 woody species in seven sacred groves of Tamilnadu. Ecological studies in the sacred groves of Meghalaya have been carried out by Bhooj and Ramakrishnan (1981), Barik *et al* (1992), Khiewtam and Ramakrishnan (1993), Rao *et al* (1997) and Jamir (2000). The most extensively studied sacred grove in Meghalaya is located at Mawphlang in the East Khasi hills district of the state. It harbours 392 vascular plants including pteridophytes (Hajra 1975). Floristic survey of 56 sacred groves of the state was carried by Tiwari *et al* (1999). The study documented 514 species representing 340 genera and 131 families, including 50 rare and endangered species from these groves. Khan *et al* (1997) reported that out of an estimated 1236 endemic species in the state 90 are restricted to the sacred groves. In the Jaintia hills, the groves are relatively well protected and represent the climax vegetation of the area in almost intact state. Recently, Jamir (2000) has reported 395 vascular plants that include 51 endemic and 31 rare species from the three sacred groves of Jaintia hills near Jowai town.

In the present study besides enumerating plant diversity of the Ialong and Raliang sacred groves, attempt has been made to evaluate the impact of anthropogenic disturbance on the floristic diversity by studying their mildly disturbed stands, which is used by nearby villagers for the collection of fuelwood and cattle grazing. Apart from this biotic interference there is annual burning in the periphery of the community forest for new shoots to develop for grazing by cattle.

Results and Discussion

Floristic composition

A total of 410 (5 unidentified) flowering plants were recorded in Ialong and Raliang sacred groves (Table 4.1). This is about 27% and 13% respectively of the total flowering plants reported from Jaintia hills (Balakrishnan 1981-1983) and Meghalaya (Khan *et al* 1997). Three gymnosperms namely, *Pinus kesiya*, *Gnetum montanum* and *Podocarpus neriifolia* and twenty-four pteridophytes including *Cyathea* sp. were also recorded in the present study. The floristic composition showed affinity with the flora of peninsular India on the one hand, and provided evidence of discontinuous distribution of taxa like *Eurya japonica*, *Helicia nilagirica*, *Munronia pinnata*, *Schefflera wallichiana* etc, on the other (Table 4.2). There were several tropical, temperate, Sino-Himalayan, Burma-Malaysian, Malayan and to a lesser extent peninsular Indian elements in the groves.

Besides, there were taxa belonging to pritimive families like Annonaceae, Ranunculaceae, Piperaceae, Menispermaceae, Caryophyllaceae, Lauraceae,

Table 4.1. Plant diversity in the two sacred groves of Jaintia hills, Meghalaya (The species are arranged in alphabetic order)

I. Trees (>8m height)

Sl. No	Name of species	Family	Ialong		Raliang	
			Sg	Md	Sg	Md
1	*Acer laevigatum* Wall.	Aceraceae	+	+	+	+
2	*Acer oblongum* Wall.	Aceraceae	-	-	+	+
3	*Actinodaphne obovata* (Nees) Bl.	Lauraceae	-	-	+	+
4	*Alangium chinense* (Lour.) Harms	Coronaceae	+	+	+	+
5	*Albizia chinensis* (Osb.) Merr.	Mimosaceae	-	+	-	-
6	*Alseodaphne petiolaris* Hk.f.	Lauraceae	+	-	+	+
7	*Antidesma bunius* (L.) Spreng.	Euphorbiaceae	+	-	+	-
8	*Beilschmiedia assamica* Meissn.	Lauraceae	-	+	+	+
9	*Beilschmiedia roxburghiana* Nees	Lauraceae	+	-	-	-
10	*Betula alnoides* Buch.-Ham. ex D.Don.	Betulaceae	+	+	+	+
11	*Caryota urens* Linn.	Arecaceae	+	-	+	+
12	*Castanopsis indica* (Roxb.) DC.	Fagaceae	+	+	+	+
13	*Castanopsis purpurella* (Miq.) Balak.	Fagaceae	+	+	+	+
14	*Castanopsis tribuloides* (Sm.) DC.	Fagaceae	+	+	+	+
15	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet.	Lauraceae	+	+	+	+
16	*Cinnamomum glanduliferum* (Wall.) Meissn.	Lauraceae	+	+	-	+
17	*Cinnamomum glaucescens* (Nees) Meissn.	Lauraceae	-	-	+	-
18	*Cinnamomum tamala* Fr. Nees	Lauraceae	-	-	+	+
19	*Citrus latipes* (Swingle) Tanaka	Rutaceae	+	+	+	-
20	*Cryptocarya floribunda* Nees.	Lauraceae	-	-	+	+
21	*Diospyros kaki* Thunb.	Ebenaceae	+	+	+	+
22	*Docynia indica* (Wall) Decne	Rosaceae	+	+	-	-
23	*Drimycarpus racemosus* (Roxb.) Hk.f.	Anacardiaceae	+	-	+	+
24	*Dysoxylum gobara* (Buch.-Ham.) Merr.	Meliaceae	-	-	+	+
25	*Elaeocarpus lancifolius* Roxb.	Elaeocarpaceae	-	-	+	-
26	*Elaeocarpus sikkimensis* Mast.	Elaeocarpaceae	-	-	+	+
27	*Engelhardtia spicata* Bl.	Juglandaceae	+	+	+	+
28	*Erythrina arborescens* Roxb.	Fabaceae	+	+	-	-
29	*Eurya acuminata* DC.	Theaceae	+	+	+	+
30	*Evodia trichotoma* (Lour.) Planch.	Rutaceae	-	+	-	+
31	*Ficus altissima* Bl.	Moraceae	+	+	+	+
32	*Ficus concinna* Miq.	Moraceae	+	+	-	-
33	*Ficus mclelandi* var. *rhododendrifolia* Corn.	Moraceae	+	+	-	-
34	*Ficus nerifolia* J.E.Sm.	Moraceae	+	+	+	-
35	*Ficus virens* Ait.	Moraceae	+	+	+	+
36	*Ficus* sp.	Moraceae	-	+	-	-
37	*Garcinia morella* Desr.	Clusiaceae	+	-	-	-
38	*Garcinia tinctoria* (DC.) W.F.Wight	Clusiaceae	+	-	+	-
39	*Glochidion lanceolarium* (Roxb.) Voight.	Euphorbiaceae	-	+	-	+
40	*Helicia nilagirica* Bedd.	Proteaceae	+	+	+	+
41	*Ilex embelioides* Hook.f.	Aquifoliaceae	-	-	+	+

42	*Knema angustifolia* (Roxb.) Warb.	Myristicaceae	-	-	+	+
43	*Lindera latifolia* Hk.f.	Lauraceae	+	+	+	+
44	*Lindera nacusua* (D.Don.) Merr.	Lauraceae	+	+	+	-
45	*Lindera reticulata* Benth.	Lauraceae	-	-	+	+
46	*Lithocarpus elagens* (Bl.) Hatus ex Soep.	Fagaceae	+	-	+	+
47	*Lithocarpus fenestratus* (Roxb.) Rehder.	Fagaceae	+	+	+	+
48	*Lithocarpus* sp	Fagaceae	+	+	+	+
49	*Litsea citrata* Bl.	Lauraceae	-	+	-	+
50	*Litsea semicarpifolia* (Nees) Hook.f.	Lauraceae	-	-	+	+
51	*Macaranga denticulata* Muell.-Arg.	Euphorbiaceae	+	+	+	+
52	*Macropanax dispermus* (Bl) O.Ktz.	Araliaceae	+	-	+	+
53	*Manglietia insignis* (Wall) Bl.	Magnoliaceae	+	-	+	+
54	*Melia azedarach* Linn.	Meliaceae	-	-	+	-
55	*Michelia doltsopa* DC.	Magnoliaceae	-	-	+	-
56	*Myrica esculenta* Buch.-Ham. ex D.Don	Myricaceae	+	+	+	+
57	*Myrsine semiserrata* Wall.	Myrsinaceae	+	+	+	+
58	*Neolitsea cassia* (Linn) Koster.	Lauraceae	-	-	+	+
59	*Ostodes paniculata* Bl.	Euphorbiaceae	-	-	+	+
60	*Persea bombycina* (King ex Hk.f.) Koster.	Lauraceae	+	+	+	+
61	*Persea duthiei* (King ex Hk.f.) Koster.	Lauraceae	+	-	-	-
62	*Persea gamblei* (King ex Hk.f.) Koster.	Lauraceae	-	-	+	-
63	*Persea odoratissima* (Nees) Koster.	Lauraceae	+	+	+	+
64	*Persea parviflora* (Meissn.) Haridasan et Rao	Lauraceae	-	+	+	+
65	*Pinus kesiya* Royle. ex Gordon.	Pinaceae	+	+	-	+
66	*Pithecellobium monadelphum* (Roxb.) Koster.	Mimosaceae	+	+	+	+
67	*Podocarpus neriifolia* D.Don.	Podocarpaceae	-	-	+	-
68	*Prunus acuminata* (Wall.) Dietr.	Rosaceae	-	+	+	+
69	*Prunus jenkinsii* Hook.f.	Rosaceae	+	+	+	+
70	*Pseudostreblus indica* Bureau.	Moraceae	+	-	-	-
71	*Pyrus pashia* D.Don	Rosaceae	-	+	-	-
72	*Quercus griffithii* Hk.f.&Th ex DC.	Fagaceae	+	-	-	-
73	*Quercus serrata* Thunb.	Fagaceae	+	+	-	-
74	*Rhododendron arboreum* Sm.	Ericaceae	+	+	-	-
75	*Rhus acuminata* DC.	Anacardiaceae	+	+	+	+
76	*Rhus hookerii* Sahni & Bahd.	Anacardiaceae	-	+	-	+
77	*Sapindus rarak* DC.	Sapindaceae	-	-	+	+
78	*Sarcosperma griffithii* Clarke	Sapotaceae	-	-	+	+
79	*Schefflera elata* (Buch-Ham) Harms	Araliaceae	+	-	-	+
80	*Schefflera hypoleuca* (Kurz) Harms	Araliaceae	+	+	+	+
81	*Schima khasiana* Dyer.	Theaceae	-	-	+	+
82	*Schima wallichii* (DC.) Korth	Theaceae	+	+	+	+
83	*Spondias axillaris* Roxb.	Anacardiaceae	-	+	+	+
84	*Sterculia hamiltonii* (O.Ktze.) Adelb.	Sterculiaceae	-	-	+	-
85	*Syzygium tetragonum* (Wt.) Kurz	Myrtaceae	+	+	+	+
86	*Vaccinium spirengelii* (G.Don) Rehd.	Vacciniaceae	+	+	-	-
87	*Viburnum simonsii* Hk.f. & Th.	Caprifoliaceae	-	+	-	-

II. Small tree or large shrubs (< 8m)

1	*Antidesma diandrum* (Roxb) Roth	Euphorbiaceae	+	-	-	-
2	*Antidesma khasianum* Hk.f.	Euphorbiaceae	+	-	-	-
3	*Aralia thomsonii* Seem	Araliaceae	+	+	-	+
4	*Brassiopsis glomerulata* (Bl.) Regal	Araliaceae	-	+	-	+
5	*Calophyllum polyanthum* Choisy	Clusiaceae	+	-	+	+
6	*Camellia caudata* Wall.	Theaceae	+	+	-	-
7	*Camellia caduca* Cl.ex Brandis	Theaceae	-	+	-	-
8	*Capparis acutifolia* Sweet	Capparaceae	-	-	+	+
9	*Cinnamomum pauciflorum* Nees	Lauraceae	+	-	+	+
10	*Clerodendrum bracteatum* Wall. ex Walp	Verbenaceae	+	+	+	+
11	*Coffea khasiana* Hook.f.	Rubiaceae	+	+	+	+
12	*Corylopsis himalayana* Griff.	Hamamelidaceae	+	+	+	+
13	*Croton oblongus* Burm.f.	Euphorbiaceae	+	+	+	-
14	*Cyathea sp*	Cyatheaceae	-	+	+	-
15	*Desmos longiflorus* (Roxb.) Safford	Annonaceae	-	-	+	-
16	*Erythroxylum kunthianum* Wall. ex Kurz.	Erythroxylaceae	+	+	+	+
17	*Euonymus attenuatus* Laws.	Celastraceae	-	-	+	+
18	*Euonymus lawsonii* Clarke & Prain	Celastraceae	-	-	+	-
19	*Eurya japonica* Thunb.	Theaceae	+	+	-	-
20	*Eurya cerasifolia* (D.Don) Kobuski	Theaceae	+	+	-	-
21	*Ficus elmeri* Govt.	Moraceae	+	+	-	-
22	*Ficus hirta var. roxburghii* (Mig.) King	Moraceae	+	+	+	+
23	*Itea chinensis* Hook.f.	Iteaceae	-	-	+	+
24	*Itea macrophylla* Wall.	Iteaceae	+	-	-	+
25	*Ixora subsessilis* G.Don	Rubiaceae	+	+	+	+
26	*Leucosceptrum canum* Smith	Lamiaceae	-	+	-	-
27	*Ligustrum robustum* (Roxb.) Bl.	Oleaceae	+	+	+	+
28	*Litsea salicifolia* (Roxb. ex Nees) Hk.f.	Lauraceae	-	-	+	+
29	*Litsea sebifera* Pers.	Lauraceae	-	-	+	+
30	*Lindera caudata* Benth.	Lauraceae	+	+	+	+
31	*Lyonia ovalifolia* var. *ovalifolia* (Wall.) Drude	Ericaceae	+	+	-	+
32	*Maesa indica* (Roxb.) Wall.	Myrsinaceae	+	+	+	+
33	*Meyna spinosa* Link.	Rubiaceae	+	+	-	+
34	*Micromelum integerrimum* (Roxb.) Roem.	Rutaceae	-	-	+	+
35	*Microtropis discolor* (Wall.) Arn.	Celastraceae	+	+	-	-
36	*Paramignya micrantha* Kurz	Rutaceae	-	-	+	+
37	*Phoebe lanceolata* (Nees)	Lauraceae	+	+	+	+
38	*Picrasma* sp.	Simaroubaceae	+	-	-	-
39	*Pittosporum podocarpum* Gagnep.	Pittosporaceae	-	-	+	+
40	*Pouzolzia frondosa* (D.Don) O.Ktze.	Urticaceae	+	-	-	-
41	*Pseudobrassaiopsis hispida* (Seem) R.N.Ban.	Araliaceae	+	-	-	-
42	*Pyrularia edulis* A. DC	Santalaceae	+	+	-	+
43	*Randia griffithii* Hk.f.	Rubiaceae	+	+	-	+
44	*Rhus javanica* Linn.	Anacardiaceae	-	+	+	+
45	*Sarcococca pruiniformis* Lindl.	Buxaceae	+	+	+	+
46	*Saurauia punduana* Wall.	Saurauiaceae	+	+	-	+
47	*Styrax serrulatum* Roxb.	Styracaceae	+	+	+	+
48	*Styrax hookerii* Cl	Styracaceae	+	+	-	-

49	*Symplocos pyrifolia* Wall. ex G.Don	Symplocaceae	-	-	+	+
50	*Symplocos crataegoides* D.Don	Symplocaceae	-	+	+	+
51	*Symplocos spicata* Roxb.	Symplocaceae	+	+	+	+
52	*Viburnum foetidum* Wall.	Caprifoliaceae	+	+	+	+
53	*Wendlandia wallichii* W.& A.Prodr.	Rubiaceae	+	+	+	+
54	*Zanthoxylum acanthopodium* DC.	Rutaceae	+	+	-	-

III. Shrubs

1	*Achyranthes aspera* L.	Amaranthaceae	+	+	+	+
2	*Ardisia griffithii* Cl.	Myrsinaceae	+	+	+	+
3	*Artemisia nilagirica* (Clarke) Pamp.	Asteraceae	-	+	-	+
4	*Boehmeria platyphylla* D.Don	Urticaceae	+	+	+	+
5	*Boehmeria sidaefolia* Wedd.	Urticaceae	+	+	+	+
6	*Breynia retusa* (Dennst) Alst.	Euphorbiaceae	+	+	+	+
7	*Bridelia* sp.	Euphorbiaceae	-	-	+	+
8	*Brucea mollis* Wall. ex Kurz.	Simaroubaceae	-	-	+	+
9	*Callicarpa psilocalyx* Clarke	Verbenaceae	-	+	-	-
10	*Callicarpa rubella* Lindl.	Verbenaceae	+	+	+	+
11	*Cassia floribunda* Cav.	Fabaceae	-	+	-	-
12	*Clerodendrum lasiocephalum* Clarke	Verbenaceae	-	-	+	+
13	*Clerodendrum wallichii* Merr.	Verbenaceae	-	-	+	+
14	*Crotalaria anagyroides* HBK.	Fabaceae	-	+	-	+
15	*Datura stramonium* Linn.	Solanaceae	-	+	-	-
16	*Desmodium floribundum* (D.Don) G..Don	Fabaceae	+	+	+	+
17	*Desmodium heterocarpon* (Linn.) DC.	Fabaceae	+	+	+	+
18	*Eupatorium adenophorum* Spreng.	Asteraceae	-	+	-	+
19	*Ficus clavata* Wall ex Miq.	Moraceae	+	+	+	+
20	*Ficus fulva* Reinwdt	Moraceae	-	+	+	+
21	*Ficus gasperriniana* Miq.	Moraceae	+	+	+	+
22	*Flemingia macrophylla* (Willd.) Prain	Fabaceae	-	+	+	+
23	*Girardinia palmata* (Forsk) Gaud.	Urticaceae	-	+	-	-
24	*Goldfussia glabrata* (Nees) Balakr.	Acanthaceae	-	+	-	-
25	*Gomphostemma parviflorum* Wall. ex Benth.	Lamiaceae	+	+	+	+
26	*Goniothalamus sesquipedalis* (Wall.) Hk.f.&Th.	Annonaceae	+	+	+	+
27	*Inula cappa* (D.Don) DC. Prodr.	Asteraceae	+	+	-	-
28	*Lantana camara* Linn.	Verbenaceae	-	+	-	+
29	*Lasianthus lucidus* Bl.	Rubiaceae	+	+	+	+
30	*Lasianthus sikkimensis* Hook.f.	Rubiaceae	+	+	+	+
31	*Mahonia pycnophylla* (Fedde) Takeda	Berberidaceae	-	+	-	-
32	*Melastoma nepalensis* Lodd.	Melastomataceae	-	+	+	+
33	*Munronia pinnata* (Wall.) Harms.	Meliaceae	-	-	+	+
34	*Mussaenda roxburghii* Hk.f.	Rubiaceae	-	+	-	+
35	*Neillia thyrsiflora* D.Don	Rosaceae	+	+	-	+
36	*Phlogacanthus pubinervius* T.Anders.	Acanthaceae	+	+	+	+
37	*Phyllanthus sp*	Euphorbiaceae	-	+	-	-
38	*Plectranthus striatus* Benth.	Lamiaceae	+	+	+	+
39	*Prinsepia utilis* Royle	Rosaceae	+	+	+	+
40	*Pseuderanthemum indicum* A.M.&J.M.Cowan	Acanthaceae	-	+	+	-

41	*Psychotria curviflora* Wall.	Rubiaceae	+	+	+	+
42	*Psychotria erratica* Hook.f.	Rubiaceae	+	+	+	+
43	*Rauvolfia densiflora* (Wall.) Benth. ex Hk.f.	Apocynaceae	+	+	+	+
44	*Rhynchotecum ellipticum* (Wall ex Dietr)A.DC	Gesneriaceae	+	+	+	+
45	*Rhynchotechum vestitum* Wall. ex Cl.	Gesneriaceae	+	+	+	+
46	*Sarcandra glabra* (Thunb.) Nakai	Chloranthaceae	+	+	+	+
47	*Senecio cappa* Buch.-Ham. ex D.Don	Asteraceae	+	+	+	+
48	*Sida rhombifolia* Linn.	Malvaceae	-	+	-	+
49	*Smilax myrtillus* DC.	Smilacaceae	+	-	+	-
50	*Solanum aculeatissimum* Jacq.	Solanaceae	+	+	+	+
51	*Sympagia monadelpha* (Nees) Bremek.	Acanthaceae	-	+	-	-
52	*Teucrium quadrifarium* Buch-Ham	Lamiaceae	+	+	+	+
53	*Triumfetta tomentosa* Bojer	Tiliaceae	+	+	+	+
54	*Urena lobata* Linn.	Malvaceae	+	+	+	+

IV. Scandent shrub

1	*Alyxia fascicularis* Benth.	Apocynaceae	-	-	+	+
2	*Capparis* sp.	Capparaceae	-	-	+	-
3	*Celastrus stylosus* Wall.	Celastraceae	-	+	-	-
4	*Embelia subcoriacea* (Clarks) Mez.	Myrsinaceae	+	+	-	+
5	*Eleagnus pyriformis* Hook.f.	Eleagnaceae	-	+	+	+
6	*Embelia parviflora* DC.	Myrsinaceae	-	-	+	+
7	*Embelia vestita* Roxb.	Myrsinaceae	+	+	+	+
8	*Euonymus theifolius* Wall. ex Laws.	Celestraceae	+	+	+	+
9	*Jasminum dispermum* Wall.	Oleaceae	+	+	+	+
10	*Jasminum lanceolaria* Roxb.	Oleaceae	-	+	+	+
11	*Jasminum nepalense* Spreng.	Oleaceae	+	+	+	+
12	*Lygodium flexuosum* (Linn.)Sw.	Lygodiaceae	+	-	+	+
13	*Polygonum molle* D.Don	Polygonaceae	+	+	+	+
14	*Polygonum perfoliatum* Linn.	Polygonaceae	-	+	+	+
15	*Rubus alceifolius* Poir.	Rosaceae	+	+	+	+
16	*Rubus assamensis* Focke	Rosaceae	+	+	+	+
17	*Rubus ellipticus* Smith	Rosaceae	+	+	+	+
18	*Rubus khasianus* Cordat.	Rosaceae	+	+	+	+
19	*Smilax aspera* L.	Smilacaceae	+	+	+	+
20	*Smilax lanceiofolia* Roxb.	Smilacaceae	+	+	+	+
21	*Smilax perfoliata* Lour.	Smilacaceae	-	+	+	+
22	*Toddalia asiatica* (Linn.) Lamk.	Rutaceae	+	+	+	+
23	*Tupidanthus calyptratus* Hk.f. &Th.	Araliaceae	+	-	+	+
24	*Zanthoxylum oxyphyllum* Edgew.	Rutaceae	+	+	+	+

V. Climbers

1	*Acacia pennata* (Linn.) Willd.	Mimosaceae	-	+	+	+
2	*Cayratia japonica* (Thunb.) Gagnep.	Vitaceae	+	+	+	+
3	*Cissampelos pareira* Linn.	Menispermaceae	-	-	+	+
4	*Cissus repens* Lamk.	Vitaceae	-	-	+	+
5	*Clematis buchaniana* DC.	Rananculaceae	-	+	+	+

6	*Cyclea bicristata* (Griff.) Diels.	Menispermaceae	+	+	+	+
7	*Dioscorea bulbifera* Linn.	Dioscoreaceae	+	+	+	+
8	*Dioscorea kamoonesis* Kunth	Dioscoreaceae	+	+	+	+
9	*Entada phaseoloides* (Linn.) Merr.	Mimosaceae	-	-	+	+
10	*Fissistigma verrucosum* (Hk.f.&Th) Merr.	Annonaceae	+	-	+	+
11	*Gnetum montanum* Mg.F.	Gnetaceae	-	-	+	+
12	*Hedera nepalensis* K.Koch.	Araliaceae	+	+	+	+
13	*Hedyotis scandens* D.Don	Rubiaceae	+	+	+	+
14	*Heterostemma alatum* Wt.	Asclepiadaceae	-	-	+	+
15	*Hodgsonia macrocarpa* (Bl.) Cogn..	Cucurbitaceae	+	+	+	+
16	*Holboellia latifolia* Wall.	Lardizabalaceae	-	-	-	+
17	*Melodinus khasianus* Hk.f.	Apocynaceae	+	-	+	-
18	*Melodinus monogynus* Roxb.	Apocynaceae	+	-	+	+
19	*Millettia cinerea* Benth.	Fabaceae	-	-	+	+
20	*Paederia foetida* Linn.	Rubiaceae	+	+	+	+
21	*Passiflora edulies* Sims.	Passifloraceae	-	+	+	+
22	*Passiflora nepalensis* Wall.	Passifloraceae	+	+	+	+
23	*Passiflora stipulata* Aubl.	Passifloraceae	-	+	-	-
24	*Pericampylus glaucus* (Lamk.) Merr.	Menispermaceae	+	+	+	+
25	*Piper griffithii* C.DC	Piperaceae	+	+	+	-
26	*Piper mellesua* D.Don	Piperaceae	+	+	+	+
27	*Piper peepuloides* Roxb.	Piperaceae	+	-	+	+
28	*Rourea minor* (Gaert.) Leenh.	Connaraceae	+	+	+	+
29	*Rubia cordifolia* Linn.	Rubiaceae	+	+	-	-
30	*Shuteria vestita* W. & A.	Fabaceae	+	+	+	-
31	*Stephania glandulifera* Miers.	Menispermaceae	+	+	+	+
32	*Tetrastigma leucostaphylum* (Dennst.) Balakr.	Vitaceae	-	-	+	+
33	*Tetrastigma serrulatum* (Roxb.)Planch.	Vitaceae	-	+	-	-
34	*Trichosanthes bracteata* (Lamk.) Voigt.	Cucurbitaceae	-	-	+	-
35	*Tricosanthes himalensis* Clarke	Cucurbitaceae	-	-	+	+
36	*Trichosanthes wallichiana* (Ser) Wt.	Cucurbitaceae	-	+	-	-
37	*Vitis heyneana* Roem. & Schult.	Vitaceae	-	-	+	+

VI. Epiphytes

1	*Aerides multiflora* Roxb.	Orchidaceae	-	-	+	-
2	*Aeschynanthes parasiticus* (Roxb.) Wall	Gesneriaceae	+	-	+	-
3	*Aeschynanthes sikkimensis* (Clarke) Stapf.	Gesneriaceae	+	+	+	+
4	*Aeschynanthes superba* Clarke	Gesneriaceae	-	-	+	-
5	*Agapetes auriculata* Hk.f.	Vacciniaceae	+	-	+	-
6	*Agapetes variegata* (Roxb) G.Don	Vacciniaceae	+	+	+	+
7	*Agrostaphyllum brevipes* King & Pantl.	Orchidaceae	+	+	+	+
8	*Asplenium phyllitides D.Don*	Aspleniaceae	+	+	+	+
9	*Bulbophyllum affine* Lindl.	Orchidaceae	-	-	+	-
10	*Bulbophyllum griffithii* (Lindl.) Reichb.f.	Orchidaceae	+	-	-	-
11	*Bulbophyllum gymnopus* Hk.f.	Orchidaceae	+	+	+	+
12	*Coelogyne stricta* (Don) schltr.	Orchidaceae	+	+	+	-
13	*Coelogyne suaveolens* (Lindl.) Hk.f.	Orchidaceae	-	-	+	-
14	*Cryptochilus sanguinea* Wall.	Orchidaceae	+	-	-	-
15	*Crypsinus hastata* (Thunb) Copel.	Polypodiaceae	+	+	+	+

16	*Cymbidium* sp.	Orchidaceae	-	-	-	+
17	*Dendrobium chrysanthum* Lindl..	Orchidaceae	+	+	+	-
18	*Dendrobium devonianum* Paxt.	Orchidaceae	+	+	+	+
19	*Dendrobium nobile* Lindl.	Orchidaceae	+	-	+	+
20	*Dendrobium ochreaceum* Lindl.	Orchidaceae	-	-	+	-
21	*Dendrobium williamsonii* Day & Reichb.f.	Orchidaceae	+	+	+	-
22	*Euonymus frigidus* Wall.	Celastraceae	-	-	+	-
23	*Helixanthera ligustrina* (Wall.) Danser	Loranthaceae	+	-	-	-
24	*Hoya lanceolata* Wall.	Asclepiadaceae	-	-	+	-
25	*Hoya purviflora* Wight.	Asclepiadaceae	+	-	+	-
26	*Hoya* sp.	Asclepiadaceae	-	-	+	-
27	*Lepidogrammitis rostrata (Hook.) Ching*	Polypodiaceae	+	+	+	+
28	*Loranthus umbellifer* Schult.	Loranthaceae	+	-	-	-
29	*Luisia inconspicua* (Hk.f.) King & Prantl.	Orchidaceae	+	+	-	-
30	*Luisia psyche* Reichb.	Orchidaceae	+	+	+	+
31	*Lycopodium setaceum* Buch.-Ham.	Lycopodiaceae	-	-	+	-
32	*Lysionotus serratus* D.Don	Gesneriaceae	+	-	+	-
33	*Microsorum superficiale* (D.Don)Ching	Polypodiaceae	+	+	+	+
34	*Oberonia iridifolia* Lindl.	Orchidaceae	+	+	+	+
35	*Pholiodata imbricata* Hook.	Orchidaceae	+	+	+	+
36	*Pholiodata undulata* Lindl.	Orchidaceae	+	+	+	+
37	*Pleione maculata* (Smith) D.Don.	Orchidaceae	+	-	+	+
38	*Pleione praecox* (Smith) D.Don	Orchidaceae	-	-	+	-
39	*Pothos scandens* Linn.	Araceae	+	+	+	+
40	*Pyrrosia heteractis* (Mett ex Kuhn) Ching	Polypodiaceae	+	+	+	+
41	*Rhaphidophora calophyllum* Schott.	Araceae	+	+	+	+
42	*Rhaphidophora decursiva* (Roxb.) Schott.	Araceae	+	+	+	+
43	*Schefflera venulosa* (W.&A.) Harms.	Araliaceae	+	-	+	-
44	*Tainia viridifusca* (Hook.) Benth.	Orchidaceae	-	-	+	+
45	*Vaccinium vacciniaceum* (Roxb.) Sleum.	Ericaceae	+	-	-	-
46	*Viscum monoicum* Roxb. ex DC.	Loranthaceae	-	-	+	-

VII. Herbs

1	*Aeginetia indica* Linn.	Orobanchaceae	+	+	-	+
2	*Achyrospermum wallichianum* (Benth.) Hk.f.	Lamiaceae	+	+	-	-
3	*Ageratum conyzoides* Linn.	Asteraceae	-	+	-	-
4	*Ainsliaea latifolia* (D.Don) Sch.	Asteraceae	-	+	-	-
5	*Anaphalis adnata* DC.	Asteraceae	-	+	-	+
6	*Anaphalis contorta* (D. Don) Hk.f.	Asteraceae	-	+	-	+
7	*Anemone rivularis* Ham.	Ranunculaceae	-	+	-	+
8	*Anoectochilous roxburghii* (Wall.) Lindl.	Orchidaceae	+	-	+	+
9	*Anotis wightiana* Hk.f.	Rubiaceae	-	-	+	+
10	*Arisaema consanguineum* Schott.	Araceae	+	+	+	+
11	*Arisaema tortuosum* (Wall.) Schott.	Araceae	+	+	+	+
12	*Arundinella nepalensis* Trin.	Poaceae	+	+	+	+
13	*Asparagus filicinus* Buch.-Ham.	Liliaceae	-	-	+	+
14	*Asplenium cheilosorum* Kuntze	Aspleniaceae	+	+	+	+
15	*Asplenium unilaterale* Lamk.	Aspleniaceae	+	+	+	+
16	*Athyriopsis japonica* (Thunb.)Ching	Athyriaceae	+	+	+	+

17	*Athyrium drepanopterum (Kuntze)A.Brown*	Athyriaceae	+	+	+	+
18	*Balanophora dioica* R. Br.	Balanophoraceae	+	-	+	-
19	*Begonia palmata* D.Don	Begoniaceae	+	+	+	+
20	*Begonia* sp.	Begoniaceae	+	+	+	+
21	*Bidens pilosa* (Bl.) Sherff	Asteraceae	-	+	-	+
22	*Blumea hieraciifolia* (D.Don) DC.	Asteraceae	-	+	-	-
23	*Borreria articularis* (L.f) F.N.Williams	Rubiaceae	+	+	+	+
24	*Calanthe clavata* Lindl.	Orchidaceae	+	-	-	-
25	*Cardamine hirsuta* Linn.	Brassicaceae	-	+	-	-
26	*Carex filicina* Nees.	Cyperaceae	+	+	+	+
27	*Centella asiatica* (Linn.) Urban	Apiaceae	-	+	-	+
28	*Chirita oblongifolia* (Roxb.) Sinclair	Gesneriaceae	-	-	+	+
29	*Cirsium involucratum* DC.	Asteraceae	-	+	-	+
30	*Colosasia esculanta* (Linn.) Schott	Araceae	+	+	+	+
31	*Commelina paludosca* Bl.	Commelinaceae	+	+	+	+
32	*Costus speciosus* (Koenig.) Smith	Zingiberaceae	+	+	+	+
33	*Crassocephalum crepidioides* (Benth.) Moore	Asteraceae	+	+	+	+
34	*Cyanotis vaga* (Lour.) J.A.&J.H.Schult.	Commelianaceae	+	+	+	+
35	*Cyperus flavidus* Retz.	Cyperaceae	+	+	+	+
36	*Cyperus kyllingia* Endl.	Cyperaceae	+	+	+	+
37	*Cyperus pilosus* Vahl	Cyperaceae	+	+	+	+
38	*Dianella ensata* (Thunb.) R.J.Handerson	Liliaceae	+	+	+	+
39	*Dichanthium coricosum* (L.) A.Camus	Poaceae	+	+	+	+
40	*Dicranopteris linearis* (Burm.f)Underwood	Gleicheniaceae	-	+	-	+
41	*Dicrocephala bicolor* (Roth) Schltdl.	Asteraceae	-	-	-	+
42	*Digitaria ciliaris* (Retz.) Koel.	Poaceae	+	+	+	+
43	*Dipteris wallichii* (R.Br.) Moore	Dipteridaceae	-	-	+	+
44	*Disporum cantoniense* (Lour.) Merr.	Liliaceae	+	+	+	+
45	*Drosera peltata* Smith	Droseraceae	-	+	-	-
46	*Drymaria cordata* (Linn.) Roem. & Schult.	Caryophyllaceae	+	+	+	+
47	*Elatostema dissectum* Wedd.	Urticaceae	-	-	+	-
48	*Elatostemma hookerianum* Wedd.	Urticaceae	+	+	+	+
49	*Elatostemma sessile* Forst.	Urticaceae	-	-	+	-
50	*Elsholtzia blanda* (Benth.) Benth.	Lamiaceae	+	+	-	-
51	*Elsholtzia strobilifera* (Benth.) Benth	Lamiaceae	+	+	-	-
52	*Emilia sonchifolia* (Linn.) DC.	Asteraceae	+	+	+	+
53	*Eragrostis gangetica* (Roxb.) Steud.	Poaceae	+	+	+	+
54	*Eragrostis unioloides* (Retz.) Steud.	Poaceae	+	+	+	+
55	*Eriosaema himalaicum* Ohashi	Fabaceae	-	+	-	-
56	*Equisetum ramosissimum* Desf.	Equisetaceae	-	+	-	-
57	*Floscopa scandens* Lour.	Commelinaceae	-	-	+	+
58	*Forrestia mollissima* (Bl.) Kds.	Commelinaceae	+	-	-	-
59	*Galinsoga parviflora* Cav.	Asteraceae	+	+	+	+
60	*Geranium nepalense* Sweet	Geraniaceae	-	+	-	+
61	*Gerbera piloselloides* (Linn.) Cass.	Asteraceae	-	+	-	-
62	*Globba clarkii* Baker.	Zingiberaceae	+	+	+	+
63	*Gnaphalium pensylvanicum* Willd.	Asteraceae	-	+	-	+
64	*Gomphostemma nutans* Hook.f.	Lamiaceae	+	-	-	-
65	*Gomphostemma velutinum* Benth.	Lamiaceae	-	-	+	+
66	*Gynura cusimbusa* (D.Don) S. Moore	Asteraceae	+	+	-	-
67	*Habenaria stenostachya* (Lindl.) Benth.	Orchidaceae	+	+	-	+

68	*Hedychium coccineum* Smith	Zingiberaceae	+	+	+	+
69	*Hedychium coronarium* Koen	Zingiberaceae	+	+	+	+
70	*Hedychium ellepticum* Smith	Zingiberaceae	+	+	+	+
71	*Hedychium stenopetalum* Lodd.	Zingiberaceae	+	+	+	+
72	*Hedyotis tenelliflora* Bl.	Rubiaceae	+	+	+	+
73	*Hedyotis uncinella* Hook.& Arn.	Rubiaceae	+	+	+	+
74	*Hydrocotyle javanica* Thunb.	Apiaceae	+	+	+	+
75	*Hypericum elodeoides* Choisy	Hypericaceae	+	+	-	-
76	*Impatiens benthamii* V.Steenis	Balsaminaceae	+	+	+	+
77	*Impatiens chinensis* Linn.	Balsaminaceae	+	+	+	+
78	*Impatiens drepanophora* Hook.f.	Balsaminaceae	+	-	-	-
79	*Impatiens juripa* Hk.f. & Th.	Balsaminaceae	+	-	-	-
80	*Impatiens khasiana* Hk.f.	Balsaminaceae	+	+	+	+
81	*Impatiens laevigata* Hook.f. & Th	Balsaminaceae	-	-	+	+
82	*Imperata cylindrica* (Linn) P.Beauv.	Poaceae	+	+	+	+
83	*Isachne himalaica* Hook.f.	Poaceae	+	+	+	+
84	*Kaulina pteropus* (Blume) Nayar	Polypodiaceae	+	+	+	+
85	*Leucas ciliata* Benth.	Lamiaceae	+	+	-	+
86	*Linderbergia muraria* (Roxb.) Bruhl	Scrophulariaceae	+	+	-	-
87	*Lobelia angulata* Forst.	Campanulaceae	-	+	-	-
88	*Lophatherum gracile* Brongn.	Poaceae	+	+	+	+
89	*Lycopodium cernum* Linn.	Lycopodiaceae	-	+	-	+
90	*Malaxis latifolia* Sm.	Orchidaceae	+	+	+	+
91	*Microsorum membranaceum* (D.Don)Ching	Polypodiaceae	+	-	-	-
92	*Murdannia gigantea* (Vahl.) Bruck.	Commelinaceae	+	+	+	+
93	*Murdannia nudiflora* (Linn.) Brenan	Commelinaceae	+	+	+	+
94	*Neocheiropteris normalis* (D.Don) Togawa	Polypodiaceae	-	-	+	-
95	*Ophiopogon parviflorus* (Hk.f.) Hara	Liliaceae	+	+	+	+
96	*Ophiorrhiza mungos* L	Rubiaceae	-	-	+	+
97	*Ophiorrhiza nutans* Clarke	Rubiaceae	+	+	+	+
98	*Osbeckia capitata* Benth.	Melastomataceae	-	+	-	-
99	*Oxalis corniculata* L.	Oxalidaceae	+	+	+	+
100	*Panicum brevifolium* L.	Poaceae	+	+	+	+
101	*Peliosanthes bakerii* Hk.f.	Liliaceae	-	-	+	-
102	*Peperomia reflexa* A.Dietr.	Piperaceae	+	-	+	+
103	*Phrynium placentarium* (Lour.) Merr.	Maranthaceae	-	+	-	-
104	*Phyllanthus urinaria* L.	Euphorbiaceae	-	+	-	+
105	*Phytolacca acinosa* Roxb.	Phytolaccaceae	-	-	-	+
106	*Pilea umbrosa* Wedd.	Urticaceae	+	+	+	-
107	*Plantago erosa* Wall.	Plantaginaceae	+	+	+	+
108	*Pogostemon strigosus* (Benth.) Benth.	Lamiaceae	+	+	-	-
109	*Polygonum barbata* L	Polygonaceae	-	+	-	-
110	*Polygonum capitatum* D.Don	Polygonaceae	+	+	+	+
111	*Polygonum dibotrys* D.Don	Polygonaceae	+	+	-	+
112	*Polygonum viscosum* D.Don	Polygonaceae	-	-	+	+
113	*Polystichum aculeatum* (Linn.) Roth	Aspidiaceae	+	+	+	+
114	*Polyura geminata* Hook.f.	Rubiaceae	-	-	+	+
115	*Potentilla fulgens* Wall.	Rosaceae	-	+	-	-
116	*Pouzolzia hirta* (Bl.) Hassk.	Urticaceae	+	+	+	+
117	*Pronephrium nudatam* (Roxb.) Holttum	Thelypteridaceae	-	-	+	-
118	*Pteris quadriaurita* Retz.	Pteridaceae	+	+	+	+

119	*Ranunculus cantoniensis* DC.	Ranunculaceae	+	-	-	-
120	*Scutelleria discolor* Benth.	Lamiaceae	+	+	+	+
121	*Selaginella semicordata* (Wall ex. Hk.Et Grev.) Spring	Selaginellaceae	+	+	+	+
122	*Selaginella willdenovii* (Desu.) Baker	Selaginellaceae	+	+	+	+
123	*Smithia ciliata* Royle	Fabaceae	+	+	+	+
124	*Solanum myriacanthum* Dunal.	Solanaceae	+	+	+	+
125	*Sonerila khasiana* Clarke	Melastomataceae	+	+	-	-
126	*Spilanthes paniculata* DC.	Asteraceae	+	+	+	+
127	*Spiranthes sinense* (Pers.) Ames	Orchidaceae	+	+	-	-
128	*Strobalanthes* sp.	Acanthaceae	-	-	-	+
129	*Torenia diffusa* D.Don	Scrophulariaceae	+	+	+	+
130	*Viola palmaris* Ging.	Violaceae	+	+	-	-
131	*Viola sikkimensis* W.Becker	Violaceae	+	+	+	+
132	*Zingiber rubens* Roxb.	Zingeberaceae	+	+	+	+

Table 4.2. Species of different climatic zones and botanical regions present in Ialong and Raliang sacred groves.

Tropical species	*Lithocarpus fenestrata*, *Sarcosperma griffithii*, *Todallia asiatica* and *Cyathea sp.* etc.
Temperate species	*Rhododendron arboreum*, *Pinus kesiya*, *Ilex* sp., *Clematis* sp. and *Ranunculus* sp. etc
Sino-Himalayan species	*Corylopsis* sp., *Mahonia*, *Mangletia* , *Camellia*, *Eurya* sp., and *Anemone* sp. etc.
Burmese-Malayan species	*Vaccinium* sp., *Engelhardtia spicata*, *Cinnamomum* sp., *Pittosporum* sp., *Litsea* sp., *Lasianthus* sp., *Gonionthalamus sesquipedalis*, *Balanophora dioca*, *Neillia thyrsiflora* and many Zingiberaceae etc.
Peninsular-India species	*Eurya japonica*, *Helecia nilagirica*, *Munronia pinnata*, *Schefflera wallichiana* etc.

Sources: Puri (1960), Rao (1974) and Balakrishnan (1981- 83).

Table 4.3. Primitive flowering plants recorded in Ialong and Raliang sacred groves.

Plant species	Family	Distribution
Manglietia sp.	Magnoliaceae	Eastern Himalayas.
Michelia sp.	Magnoliaceae	Temperate Himalayas and North-east India
Sarcandra glabra	Chloranthaceae	Indo-Malaya, North-east and southern India.
Corylopsis himalayana	Hamamelidaceae	North-east India
Myrica esculenta	Myricaceae	Himalaya, Burma, Indo-china, West and South China, Malayasia.
Houttuynia cordata	Saururaceae	Himalaya, Khasi hills, Manipur, Thailand, Indo-China.
Betula alnoides	Betulaceae	Temperate and subtropical Himalayas.

Sources: Takhtajan (1969), Rao and Hajra (1986), Balakrishnan (1981- 83).

Myricaceae, Lardizabalaceae and primitive genera like *Sarcandra*, *Corylopsis* and *Myrica* in the groves (Table 4.3). This observation further supports the view of Takhtajan (1969) who opined that eastern Himalayas including Assam and Upper Burma and from Yunnan to Fiji Island show high concentration of primitive angiosperms.

Family and Genera

Out of 115 families recorded, 99 were angiospermic, three belonged to gymnosperm and 13 to pteridophyte. Jamir (2000) has reported 96 angiospermic families from three sacred groves and Balakrishnan (1981-83) has reported 165 families from the vegetation of the entire Jaintia hills. Orchidaceae was the dominant family with 27 species followed by Lauraceae (24 species) and Rubiaceae (20 species). Forty-seven families were mono-specific and 17 were bi-specific (Table 4.4).

Earlier workers (Balakrishnan 1981-83, Jamir 2000) have also reported dominance of Orchidaceae both in the sacred groves as well as in the flora of Jaintia hills. Numerous orchids are found in the forests of Southeast Asia and tropical America. The Malay Peninsula alone has about 800 species of orchids, the majority of which are epiphytes (Holttum 1957). Even in Africa, the epiphytic orchids form the largest group in the Nimba Mountains (Johansson 1974). Abundance of macro-epiphytes, as observed at the present study site is a characteristic of montane and subtropical as well as tropical rain forests where atmosphere is usually permanently moist.

Table 4.4. Family-wise distribution of genera and species in the two sacred groves.

Sl. no	Family	Ialong		Raliang		Total	
		Genera	Species	Genera	Species	Genera	Species
	Angiosperms						
1	Acanthaceae	4	4	3	3	5	5
2	Aceraceae	1	1	1	2	1	2
3	Amaranthaceae	1	1	1	1	1	1
4	Anacardiaceae	3	5	3	5	3	5
5	Annonaceae	2	2	3	3	3	3
6	Apiaceae	2	2	2	2	2	2
7	Apocynaceae	2	3	3	4	3	4
8	Aquifoliaceae	-	-	1	1	1	1
9	Araceae	4	6	4	6	5	6
10	Araliaceae	7	9	6	8	7	9
11	Arecaceae	1	1	1	1	1	1
12	Asclepiadaceae	1	1	2	4	2	4
13	Asteraceae	15	16	12	12	18	19
14	Balanophoraceae	1	1	1	1	1	1
15	Balsaminaceae	1	5	1	4	1	6
16	Begoniaceae	1	2	1	2	1	2
17	Berberidaceae	1	1	-	-	1	1
18	Betulaceae	1	1	1	1	1	1
19	Brassicaceae	1	1	-	-	1	1
20	Campanulaceae	1	1	1	1	1	1
21	Capparaceae	-	-	1	2	1	2
22	Caprifoliaceae	1	2	1	1	1	2
23	Caryophylaceae	1	1	1	1	1	1
24	Celastraceae	3	3	1	4	3	6
25	Chloranthaceae	1	1	1	1	1	1
26	Clusiaceae	2	3	2	2	2	3
27	Commelinaceae	4	5	4	5	5	6
28	Connaraceae	1	1	1	1	1	1
29	Coranaceae	1	1	1	1	1	1
30	Cucurbitaceae	2	2	2	3	2	4
31	Cyperaceae	2	4	2	4	2	4
32	Dioscoreaceae	1	2	1	2	1	2
33	Droseraceae	1	1	-	-	1	1
34	Ebenaceae	1	1	1	1	1	1
35	Eleagnaceae	1	1	1	1	1	1
36	Elaeocarpaceae	-	-	1	2	1	2
37	Ericaceae	3	3	1	1	3	3
38	Erythroxylaceae	1	1	1	1	1	1
39	Euphorbiaceae	6	9	6	6	7	10
40	Fabaceae	8	9	5	7	10	11
41	Fagaceae	3	8	2	6	3	8
42	Geraniaceae	1	1	1	1	1	1
43	Gesneriaceae	3	5	4	7	4	7
44	Hamamelidaceae	1	1	1	1	1	1

45	Hypericaceae	1	1	-	-	1	1
46	Iteaceae	1	1	1	2	1	2
47	Juglandaceae	1	1	1	1	1	1
48	Lamiaceae	9	11	5	6	10	13
49	Lardizabalaceae	-	-	1	1	1	1
50	Lauraceae	7	15	10	23	10	24
51	Liliaceae	3	3	5	5	5	5
52	Loranthaceae	2	2	1	1	3	3
53	Magnoliaceae	1	1	2	2	2	2
54	Malvaceae	2	2	2	2	2	2
55	Maranthaceae	1	1	-	-	1	1
56	Melastomataceae	3	3	1	1	3	3
57	Meliaceae	-	-	3	3	3	3
58	Menispermaceae	3	3	4	4	4	4
59	Mimosaceae	3	3	3	3	4	4
60	Moraceae	2	12	1	7	2	12
61	Myricaceae	1	1	1	1	1	1
62	Myristicaceae	-	-	1	1	1	1
63	Myrsinaceae	4	5	4	6	4	6
64	Myrtaceae	1	1	1	1	1	1
65	Oleaceae	2	4	2	4	2	4
66	Orchidaceae	14	20	14	22	18	27
67	Orabancaceae	1	1	1	1	1	1
68	Oxalidaceae	1	1	1	1	1	1
69	Passifloraceae	1	3	1	2	1	3
70	Phytolaccaceae	-	-	1	1	1	1
71	Piperaceae	2	4	2	4	2	4
72	Pittosporaceae	-	-	1	1	1	1
73	Plantiganaceae	1	1	1	1	1	1
74	Poaceae	8	9	8	9	8	9
75	Polygonaceae	1	5	1	5	1	6
76	Proteaceae	1	1	1	1	1	1
77	Ranunculaceae	3	3	2	2	3	3
78	Rosaceae	7	11	4	8	7	11
79	Rubiaceae	13	17	14	19	15	20
80	Rutaceae	4	5	6	6	6	7
81	Santalaceae	1	1	1	1	1	1
82	Sapindaceae	-	-	1	1	1	1
83	Sapotaceae	-	-	1	1	1	1
84	Saurauiaceae	1	1	1	1	1	1
85	Scrophulariaceae	2	2	1	1	2	2
86	Simaroubaceae	1	1	1	1	2	2
87	Smilacaceae	1	4	1	4	1	4
88	Solanaceae	2	3	1	2	2	4
89	Sterculariaceae	-	-	1	1	1	1
90	Styracaceae	1	2	1	1	1	2
91	Symplocaceae	1	2	1	3	1	3
92	Theaceae	3	6	2	3	3	7
93	Tiliaceae	1	1	1	1	1	1
94	Urticaceae	5	6	4	7	5	9

95	Vaccinaceae	2	3	1	2	2	3
96	Verbenaceae	3	4	3	5	3	6
97	Violaceae	1	2	1	1	1	2
98	Vitaceae	2	2	4	4	4	4
99	Zingeberaceae	4	7	3	7	4	7
	Gymnosperms						
100	Gnetaceae	-	-	1	1	1	1
101	Pinaceae	1	1	1	1	1	1
102	Podocarpaceae	-	-	1	1	1	1
	Pteridophytes						
103	Aspleniaceae	1	3	1	3	1	3
104	Aspideaceae	1	1	1	1	1	1
105	Athyriaceae	2	2	2	2	2	2
106	Cyatheaceae	1	1	-	-	1	1
107	Dipteridaceae	-	-	1	1	1	1
108	Equisetaceae	1	1	-	-	1	1
109	Gleicheniaceae	1	1	1	1	1	1
110	Lycopodiaceae	1	1	1	2	1	2
111	Lygodiaceae	1	1	1	1	1	1
112	Polypodiaceae	5	6	6	6	6	7
113	Pteridaceae	1	1	1	1	1	1
114	Selaginellaceae	1	2	1	2	1	2
115	Thelypteridaceae	-	-	1	1	1	1

Table 4.5. Endemic (E) and rare (R) plant species found in Ialong (1) and Raliang (2) sacred groves.

Sl. No.	Plant species	Family	Habit	Status	Forest stands
1	*Acer laevigatum* Wall.	Aceraceae	Tree	E, R	1,2
2	*Acer oblongum* Wall.	Aceraceae	Tree	R	2
3	*Aeschynanthes parasiticus* (Roxb.) Wall.	Gesneriaceae	Epiphytic	E	1
4	*Aeschynanthes sikkimensis* (Clarke) Stapf.	Gesneriaceae	Epiphytic	E, R	1,2
5	*Aeschynanthes superba* Clarke.	Gesneriaceae	Epiphytic	E	2
6	*Aralia thomsonii* Seem	Araliaceae	Small tree	E	1
7	*Ardisia griffithii* Cl.	Myrsinaceae	Shrubs	E	1,2
8	*Balanophora dioica* Royle	Balanophoraceae	Parasitic	R	1,2
9	*Boehmeria sidaefolia* Wedd.	Rubiaceae	Shrubs	E	1,2
10	*Bruceae mollis* Wall. ex Kurz.	Simaroubaceae	Shrub	R	2
11	*Bulbophyllum griffithii* (Lindl.) Reiclb	Orchidaceae	Epiphytic	E, R	1
12	*Callicarpa psilocalyx* Clarke	Verbenaceae	Shrubs	E, R	1
13	*Camellia caduca* Cl. ex Brandis	Theaceae	Small tree	E	1
14	*Capparis acutifolia* Sweet	Capparaceae	Small tree	E	2
15	*Cinnamomum pauciflorum* Nees	Lauraceae	Small tree	E, R	2
16	*Citrus latipes* (Swingle) Tanaka	Rutaceae	Small tree	E, R	1,2
17	*Croton oblongus* Burm.f.	Euphorbiaceae	Small tree	R	1,2
18	*Cyathea* sp.	Cyatheaceae	Small tree	R	1
19	*Dendrobium densiflorum* Wall.	Orchidaceae	Epiphytic	R	1,2
20	*Dendrobium devonianum* Paxt.	Orchidaceae	Epiphytic	R	1,2
21	*Dendrobium nobile* Lindl.	Orchidaceae	Epiphytic	R	1,2
22	*Dipteris wallichii* (R.Br.) Moore	Dipteridaceae	Shrubs	R	2
23	*Drimycarpus racemosus* (Roxb.)Hook.f.	Anacardiaceae	Tree	E	1,2
24	*Drosera peltata* Smith	Droseraceae	Herbs	R	1
25	*Embelia vestita* Roxb.	Myrsinaceae	Climber	R	1
26	*Erythroxylum kunthianum* Wall. ex Kurz	Erythroxylaceae	Shrubs	E	1,2
27	*Euonymus lawsonii* Clarke & Prain	Celastraceae	Shrubs	E	2
28	*Ficus concinna* Miq.	Moraceae	Tree	R	1
29	*Ficus subincisa* Buch.-Ham. ex J.E.SH	Moraceae	Shrub	R	1,2
30	*Fissistigma verrucosum* (Hk.f.&Th) Merr.	Annonaceae	Climber	E, R	1,2
31	*Goldfussia glabrata* (Nees) Balakr.	Acanthaceae	Shrubs	E	1
32	*Hedera nepalensis* K.Koch	Araliaceae	Climber	E, R	1,2
33	*Ilex embeloides* Hook.f.	Aquifoliaceae	Tree	E, R	2
34	*Impatiens khasiana* Hook.f.& Th	Balsaminaceae	Herb	E	1,2
35	*Impatiens laevigatum* Hook.f.& Th	Balsaminaceae	Herb	E	2
36	*Ixora subsessilis* G.Don	Rubiaceae	Small tree	E	1,2
37	*Leucosceptrum canum* Smith	Lamiaceae	Small tree	R	1
38	*Lindera latifolia* Hook.f.	Lauraceae	Tree	E, R	1,2
39	*Luisia inconspicua* (Hook.f)King & Pantl.	Orchidaceae	Epiphytic	E	1
40	*Mahonia pycnophylla* (Fedde) Takeda	Berberidaceae	Shrubs	E	1
41	*Melodinus monogynus* Roxb.	Apocynaceae	Climber	R	1,2
42	*Munronia pinnata* (Wall.) Harms.	Meliaceae	Shrubs	R	2
43	*Manglietia insignis* Bl.	Magnoliaceae	Tree	R	1,2
44	*Neillia thyrsiflora* D.Don	Rosaceae	Shrubs	E	1,2
45	*Osbeckia capitata* Benth.	Melastomataceae	Herb	E	1

46	*Paramignya micrantha* Kurz	Rutaceae	Small tree	E	2
47	*Persea parviflora* (Meissn).Haridasan et Rao	Lauraceae	Tree	E	1,2
48	*Piper griffithii* C.DC.	Piperaceae	Climber	E	1,2
49	*Piper peepuloides* Roxb.	Piperaceae	Climber	E	2
50	*Pleione maculata* (Lindl.) Lindl.	Orchidaceae	Epiphytic	R	2
51	*Pleione praecox* (Lindl.) Lindl.	Orchidaceae	Epiphytic	R	2
52	*Podocarpus neriifolia* D.Don	Podocarpaceae	Tree	R	2
53	*Pseudobrassaiopsis hispida* (Seem.) R.N.Ban	Araliaceae	Small tree	R	1
54	*Pyrularia edulis* A.DC.	Santalaceae	Small tree	R	1,2
55	*Pogostemon strigosus* (Benth.) Benth.	Lamiaceae	Herb	E	1
56	*Prunus jenkinsii* Hook.f.	Rosaceae	Tree	E	1,2
57	*Rhaphidophora calophyllum* Schott.	Araceae	Epiphytic	E	1,2
58	*Rhaphidophora decursiva* (Roxb.) Schott.	Araceae	Epiphytic	E	1,2
59	*Rhus hookerii* Sahni & Bahd.	Anacardiaceae	Tree	R	2
60	*Rubus assamensis* Focke	Rosaceae	Scandent	E	1,2
61	*Rubus khasianus* Cordat	Rosaceae	Scandent	E	1,2
62	*Sarcosperma griffithii* Clarke	Sapotaceae	Tree	R	2
63	*Schima khasiana* Dyer.	Theaceae	Tree	E, R	2
64	*Smilax myrtillus* DC.	Smilacaceae	Shrubs	E	1,2
65	*Sonerila khasiana* Clarke	Melostomataceae	Herb	E, R	1
66	*Styrax hookerii* Cl.	Styracaceae	Small tree	R	1
67	*Sympagis monodelpha* (Nees) Bremek.	Acanthaceae	Shrubs	E	1
68	*Tupidanthus calyptratus* Hk.f. & Th.	Araliaceae	Small tree	E, R	1,2
69	*Vaccinium vacciniaceum* (Roxb.) Sleum.	Vacciniaceae	Epiphytic	E	1
70	*Viburnum simonsii* Hk.f. & Th.	Caprifoliaceae	Tree	E	1

individuals of such species is probably kept low by a combination of unfavourable regeneration conditions, and lack of appropriate habitat or both (Hubbell 1979).

A list of 38 such species based on their rarity status in Meghalaya is given in Table 4.5. Two rare fern namely, *Dipteris wallichii* and *Cyathea* sp. (Photographs1) were found at the present study sites and *Ilex embeloides*, *Styrax hookerii* and *Fissistigma verrucosum* (as shown in Photographs 1) were collected after several decades. Some species of ornamental value such as *Dendrobium* and *Pleione* which are becoming rare due to over-exploitation, while others like *Podocarpus nerifolia*, *Cyathea* sp. and *Balanophora dioca* (Photographs 1), which are becoming rare due to habitat alteration were also recorded.

Effect of disturbance

Though not much variation was seen in species composition in different life forms due to disturbance, but shrubs and herbs diversity increased where as the epiphytes showed a decrease (Table 4.6). There was a slight change in family dominance also eg. Asteraceae, Rubiaceae, Rosaceae and Verbenaceae showed an increase while Orchidaceae showed a decrease with disturbance. Some weedy species such as *Lantana camara*, *Eupatorium* sp, *Artemisia* sp., *Bidens pilosa* and *Polygonum* sp. were absent in the undisturbed stands of the sacred groves and present only in the mildly disturbed stands.

Photographs 1. ***Balanophora dioica*** **(A), a rare and** ***Fissistigma verrucosum*** **(B) an endemic species present in Ialong and Raliang sacred groves.**


A


B

Photographs 1. Two rare ferns *Cyathea* sp. (A) and *Dipteris wallichii* (B) present in Ialong and Raliang sacred groves.


A


B

A total of 303 genera were recorded from the two sacred groves. *Ficus* was the largest genus with 11 species followed by *Impatiens* and *Dendrobium* with 6 and 5 species, respectively.

Endemic species

A list of endemic species found in the two sacred groves is given in Table 4.5. These may not necessarily be endemic only to Meghalaya, but to the entire northeastern region and the eastern Himalayas. Takhtajan (1988) while describing the flora of the Khasi hills concluded that it is most richly saturated by eastern Asiatic elements, and is one of the most important centers of survival of the Tertiary flora of eastern Asia. The geological antiquity of the Khasi hills, the taxanomic composition of the flora and its richness and peculiarity indicate that long before glacial times, these mountains already constituted an important part of the area where the nucleus of the flora of the eastern Asiatic flora originated. The flora of the Shillong plateau, including the Khasi and Jaintia hills, is considerably rich with high level of endemism. The sacred groves, the remnant of climax forest of the area, are still the abodes of a large number of endemic taxa as is evident by presence of 45 endemic species in the two groves under the present study as well as 51 species in other three groves of Jaintia hills (Jamir 2000). Some of the endemic species like *Acer laevigatum*, *Aeschynanthes superba*, *Citrus latipes*, etc are rare in Meghalaya.

Rare species

The species represented by very small number of individuals or populations, which are at risk in an area, may be considered as rare species. The number of

Table 4.6. Summary of the floristic composition in the four stands.

Life form	**Ialong**		**Raliang**	
	Undisturbed	Mildly disturbed	Undisturbed	Mildly disturbed
Number of trees	90	86	96	95
Number of shrubs	31	48	38	43
Number of scandent shrubs	16	19	22	22
Number of climbers	20	22	32	29
Number of epiphytes	33	21	39	29
Number of herbs	90	104	84	95
Total	**280**	**300**	**311**	**305**

CHAPTER V

COMMUNITY STRUCTURE

Apart from floristic composition, quantitative measures such as frequency, density, abundance and dominance have been widely used to describe the structure and dynamics of plant community. Tree dispersion pattern as well as density-diameter distribution of trees which contribute to the structural characteristic of the forests, have been studied in tropical rain forest by Okuda *et al* 1997 and Richards (1996). The quantification of plant diversity studies carried out in the tropics has emphasized mainly on tree species. The smaller woody plants, climbers, and herbs are rarely included, which contribute greatly to the total species richness of the forest. In some studies (Gentry and Dodson 1987, Smith 1970, Hall and Swaine 1981, Poulsen and Pendry 1995, Annaselvam and Parthasarathy 1999) attempts have been made to quantify the species diversity of the ground vegetation.

The effect of disturbance by human activities on species diversity is an issue that has attracted the attention of a number of ecologists (Hurd *et al* 1971, McNaughton 1977, 1985, Tilman 1988, Frank and McNaughton 1991, Tilman and Downing 1994). Connell (1978) and Collins (1995) argued that richness should be highest at intermediate frequencies of disturbances when condition favours competitive species and those that tolerate disturbance. Thus, the intensity and frequency of disturbance are important determinants of plant diversity.

In the present study structure of sacred forest community has been analysed by measuring following parameters.

Stratification

Four distinct layers viz. canopy (>15 m height), sub-canopy (8 to15 m), under canopy (<8m) and ground vegetation (upto 2m height) which included shrubs and herbs could be recognised in both the sacred groves. At lalong the average tree height in the canopy layer was 18 m, which was composed of *Acer laevigatum, Alseodaphne petiolaris, Betula alnoides, Persea odoratissima, Syzygium tetragonum* etc. All together there were 22 tree species in this layer. The subcanopy layer was composed of 27 species. *Alangium chinensis, Citrus latipes, Ficus nerifolia,* were common species in this layer. The undercanopy had 28 species. *Erythroxylum kunthianum, Coffea khasiana, Microtropis discolor* were most frequent in this layer. The canopy layer of Raliang sacred grove with 29 species was richer than lalong. *Actinodaphne obovata, Sarcosperma griffithii, Prunus jenkensii,* were dominant canopy trees. The subcanopy was composed of 26 species. *Dysoxylon gobara, Macropanax dispermus, Helicia nilagirica* and *Pithecellobium monadelphum* were dominant species in this stratum. The under canopy with 18 species was composed mainly of *Capparis acutifolia, Ixora subsessilis, Sarcococca pruniformis.* The shrubs layer was dominated by *Brynea retusa, Psychotria erratica, Euonymus theifolius, Boehmeria sidaefolia* etc. The herbs layer consisted of *Isachne himalaica* and zingiberaceae species.

Vegetation stratification in the mildly disturbed stands were similar to the undisturbed stands of both the groves, but the former showed higher species richness in the tree component of < 8m height and ground vegetation in comparision to its respective undisturbed stands.

Woody components ($\geq$ 5cm dbh)

Species – area relationship

The species area curves for woody species ($\geq$5cm dbh) in the undisturbed stands and their respective mildly disturbed stands of the sacred groves have been shown in the Fig. 5.1. As expected the species number increased with the increase in area in all the stands. The curves reached almost at asymptote level between 0.4 to 0.5 ha where about 80% to 90% of the total species content in a given stand could be recorded.

Species richness

A total of 159 woody species ($\geq$ 5cm dbh) (including 4 unidentified species) were identified from all four stands. There were 115 species at Ialong and 113 species at Raliang, out of which about 80% species were common to both sites. The species richness of the mildly disturbed stands (92, 93 species) was higher than the undisturbed stands, which have 80 and 82 species (Table 5.1).

The number of species per unit area or species density in the community was examined by measuring number of tree species in 100m^2 plots to study the distribution pattern of species richness (Fig. 5.2). The species density per 100 m^2 ranged from 3 to 15 in the undisturbed and 5-16 in the mildly disturbed stands. However, a closer look of data reveals that about 25-40% of the plots had 1-5 species, 50% plots had 6-10 species and rest had 11-15 species in the undisturbed stands. But

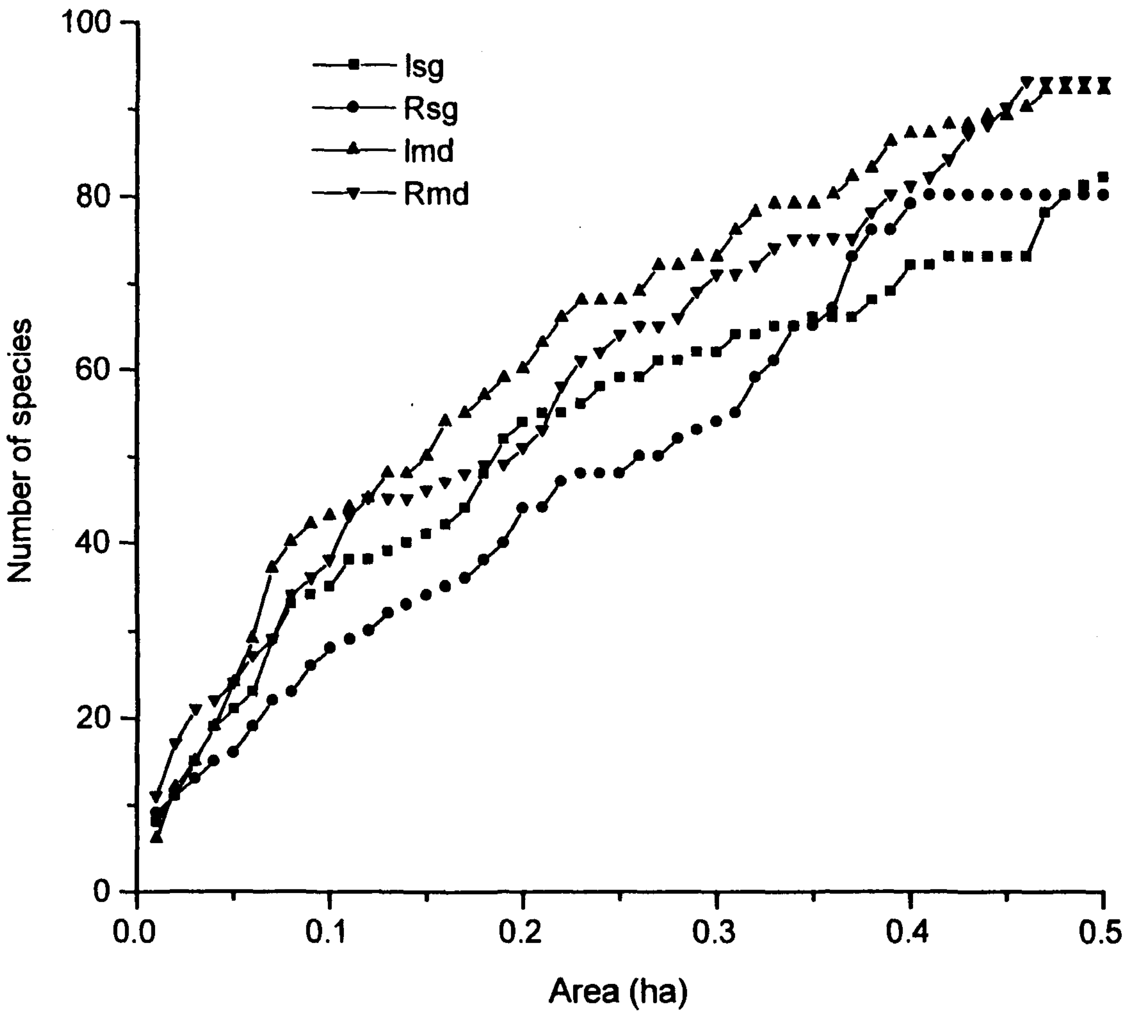


Fig. 5.1. Species-area curve for woody species (≥5cm dbh) in the undisturbed (Isg, Rsg) and mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

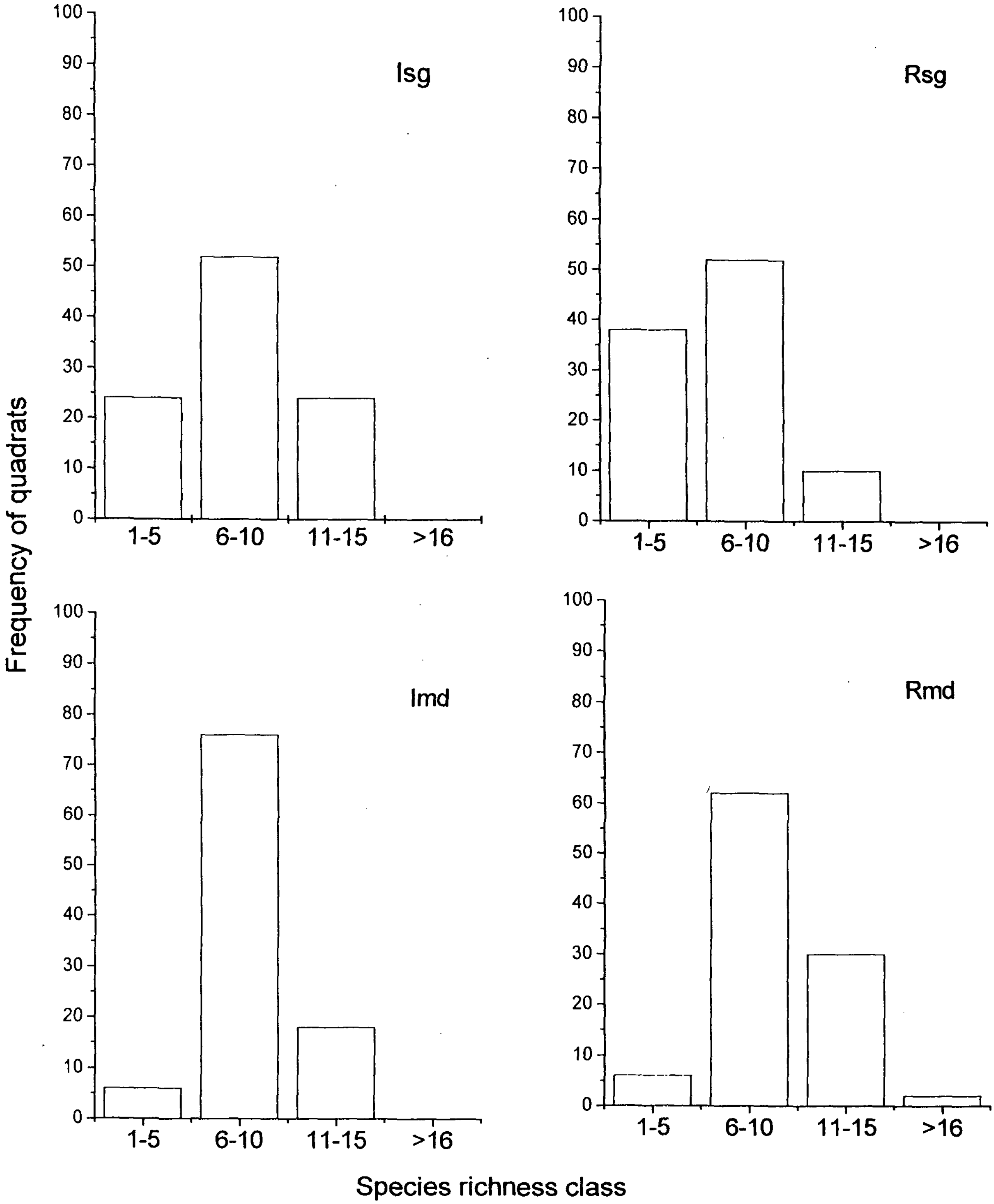


Fig. 5.2. Species richness per quadrat ($100m^2$) in the undisturbed (Isg,Rsg) and mildly disturbed (Imd, Rmd) stands at Ialong and Raliang.

in the mildly disturbed forest frequency of plots having 6-10 species showed an increase of 60% to 75% and those having 1-5 species declined to about 5%.

Table 5.1. Diversity and community characteristics of woody species (≥ 5cm dbh) at Ialong and Raliang.

Variables	**Ialong**		**Raliang**	
	Isg	**Imd**	**Rsg**	**Rmd**
Area sampled (ha)	0.5	0.5	0.5	0.5
Density ha^{-1}	1476	1340	938	1308
Species richness	82	92	80	93
Number of families	39	39	41	46
Number of genera	59	69	62	71
Basal area m^2 ha^{-1}	57.46	49.64	71.44	36.52
Shannon diversity index	3.42	3.78	3.55	3.87
Pielou evenness index	0.53	0.61	0.56	0.61
Simpson dominance index	0.067	0.047	0.052	0.034

In all stands majority of the species were represented by young individuals (5-15cm dbh). The species richness decreased with the increase in dbh class, except in case of mature trees (>66cm dbh) (Fig.5.3). In both the mildly disturbed stands the species richness was more in the first two classes (5-15 and 16-25cm) but decreased sharply in the higher dbh classes, particularly in Rmd.

Family composition

The identified species belonged to 63 plant families (4 unidentified and grouped as unidentified). Overall species richness can be predominantly attributed to Lauraceae with 24 species followed by Araliaceae and Moraceae (9 species each). Euphorbiaceae and Fagaceae had 8 species each, Theaceae (7), Rutaceae (6),

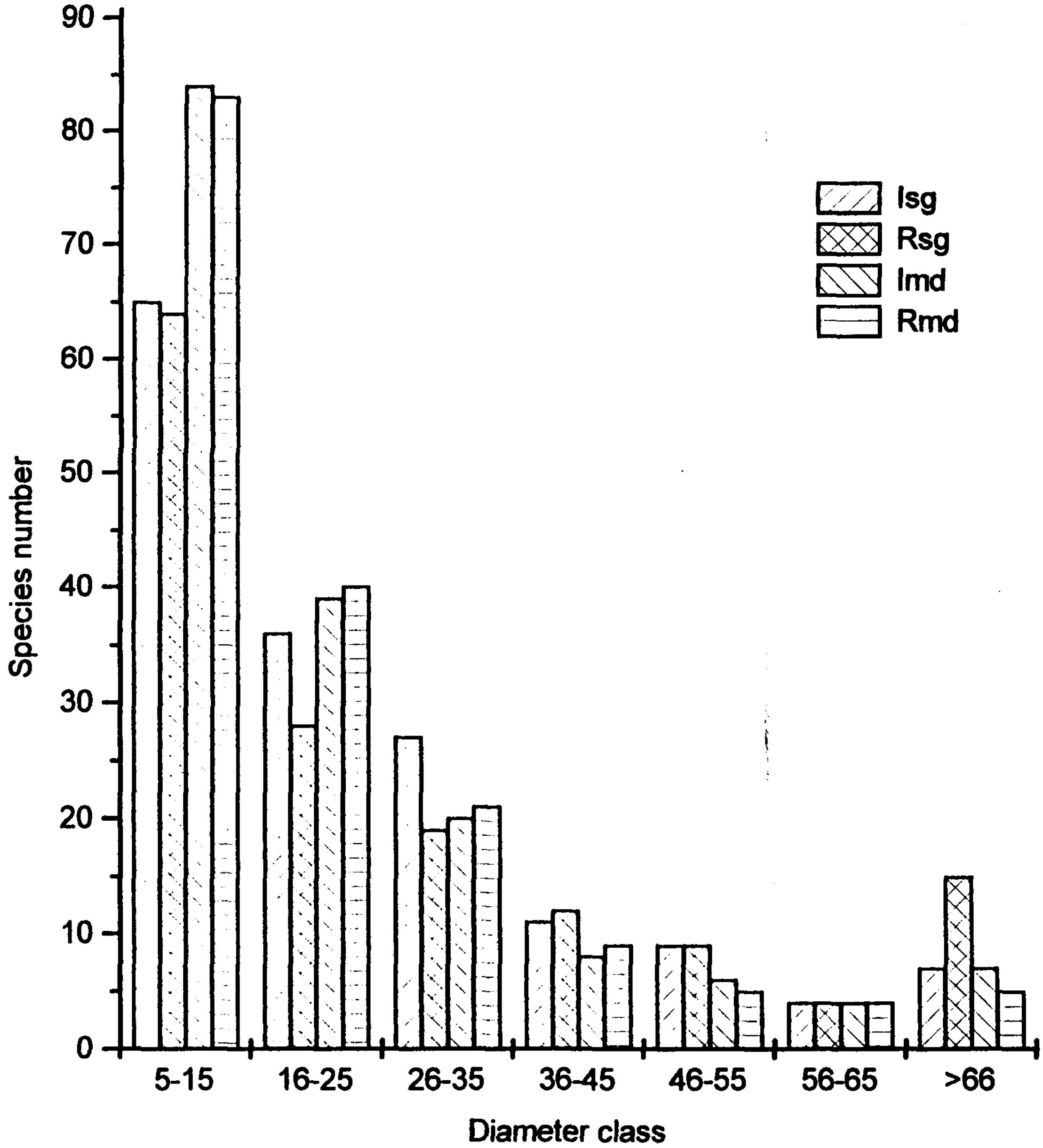


Fig. 5. 3. Species richness in different diameter classes in the undisturbed (Isg, Rsg) and mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

Anacardiaceae, Myrsinaceae and Rubiaceae (5), Rosaceae (4), Clusiaceae and Symplocaceae (3). Thirteen families were bi-specific and thirty-three were mono-specific. Arecaceae was the only monocot family represented by *Caryota urens* whereas, there were two gymnospermic families namely, Pinaceae and Podocarpaceae represented by *Pinus kesiya* and *Podocarpus neriifolia* respectively. Stand wise distribution of species in different family is shown in the figure (5.4a – 5.4b)

Species – stem relationship

The relationship between the number of species and the number of individuals is shown in the Fig. 5.5. In all stands majority of the species was represented by few individuals whereas, few species had relatively large population density. In the undisturbed stands about 35% (28-29) of the species were represented by one individual each and 12-17% (10-14) species were represented by two stems each. While in the mildly disturbed stands 25% of the species were represented by one individual each and 17% by two stems each.

Frequency

In both Ialong and Raliang undisturbed stands 87-91% of the tree species belonged to Raunkiaer's frequency class A, and the rest were distributed in B, C and D classes; Class E was completely absent (Fig 5.6). In both the mildly disturbed stands the proportion of the species in frequency class A declined to about 80%, while it increased in B and C classes. *Coffea khasiana*, *Microtropis discolor*, *Syzygium tetragonum*, and *Helicia nilagirica* in Isg and *Sarcosperma griffithii*, *Actinodaphne obovata* and *Prunus jenkensii* in Rsg were the most frequently found species.

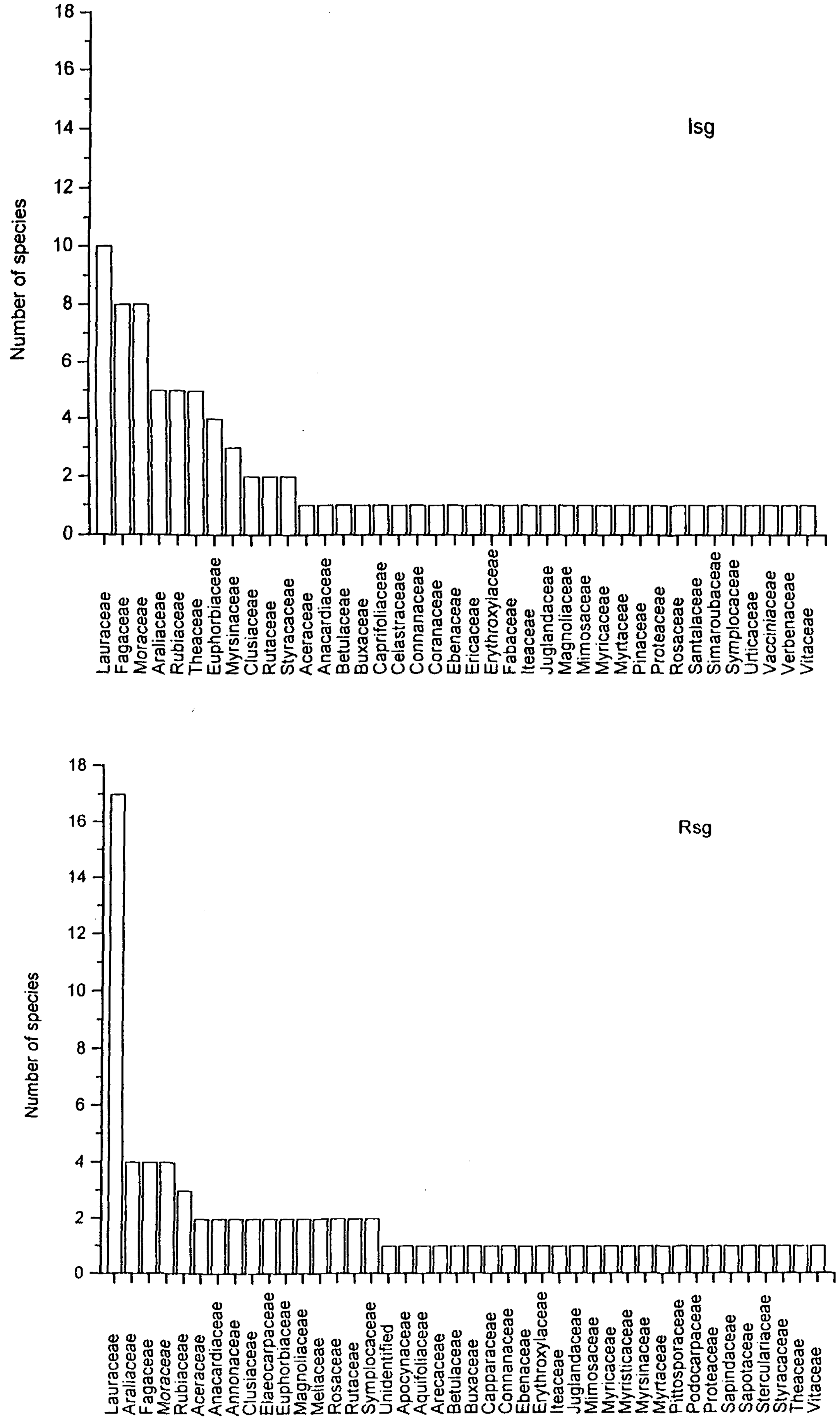


Fig.5.4a. Family-wise distribution of woody species in undisturbed stands (Isg, Rsg) at Ialong and Raliang.

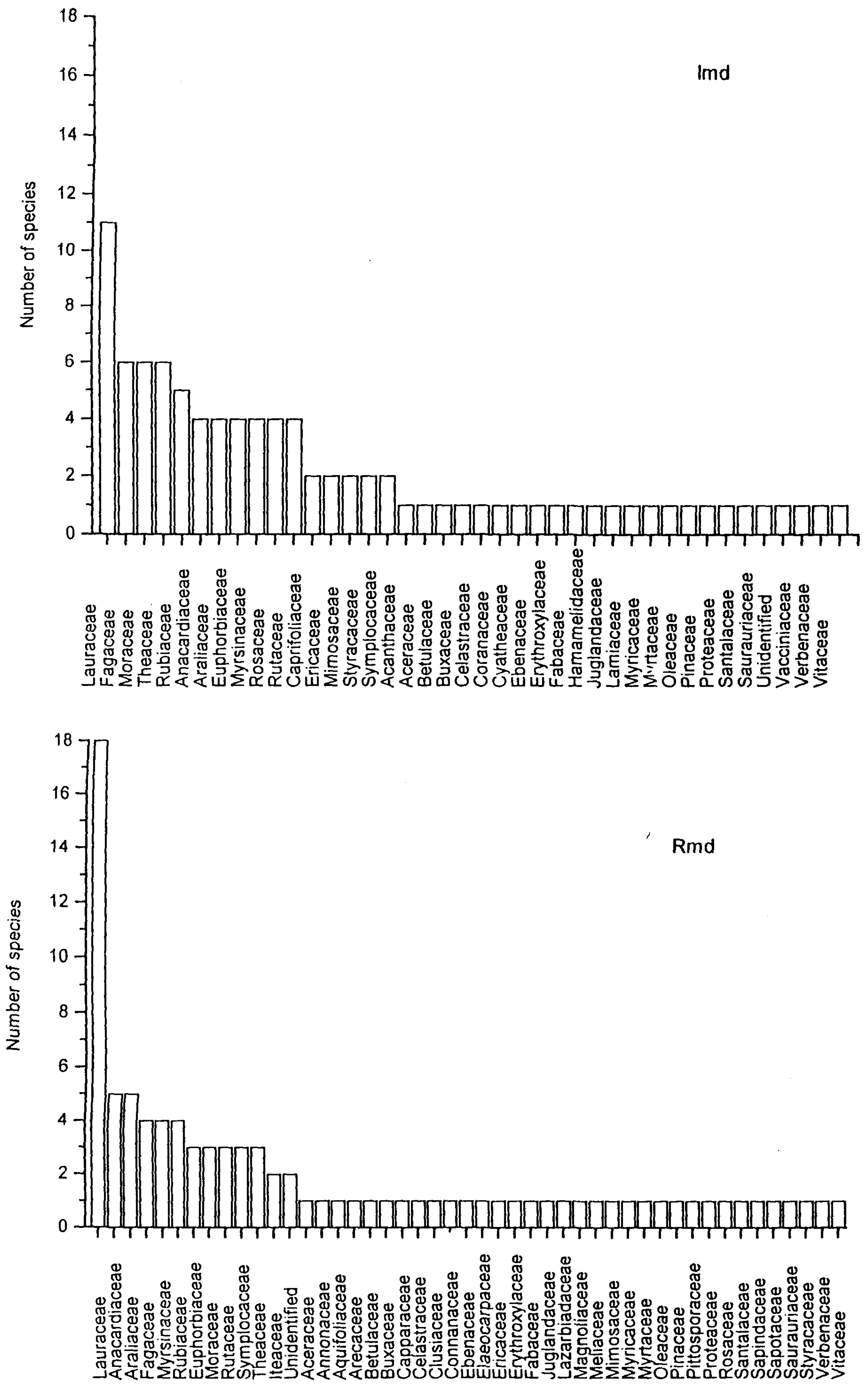


Fig. 5.4b. Family-wise distribution of woody species in mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

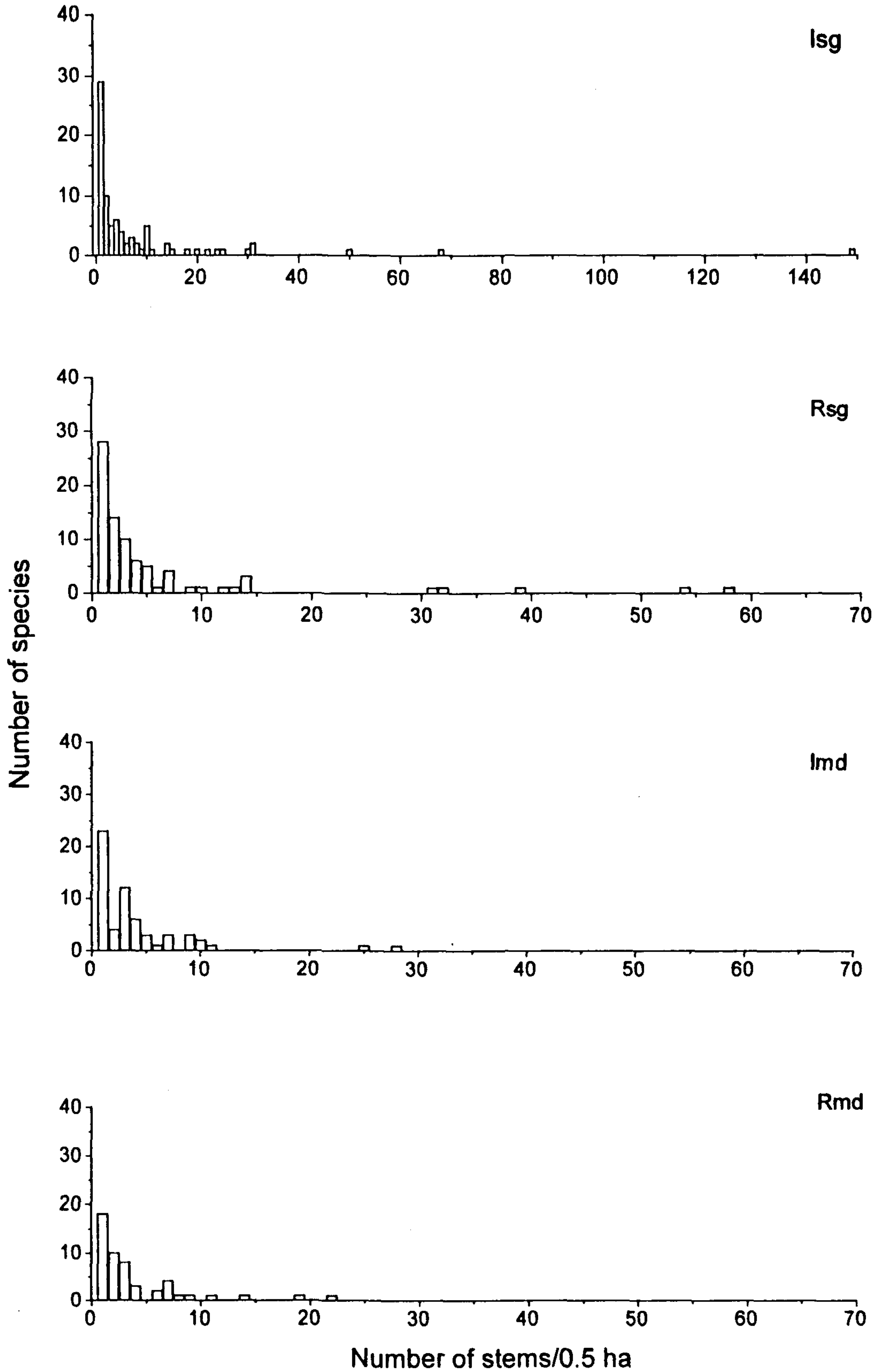


Fig. 5.5. Species - stem relationship of woody species in the undisturbed (Isg, Rsg) and mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

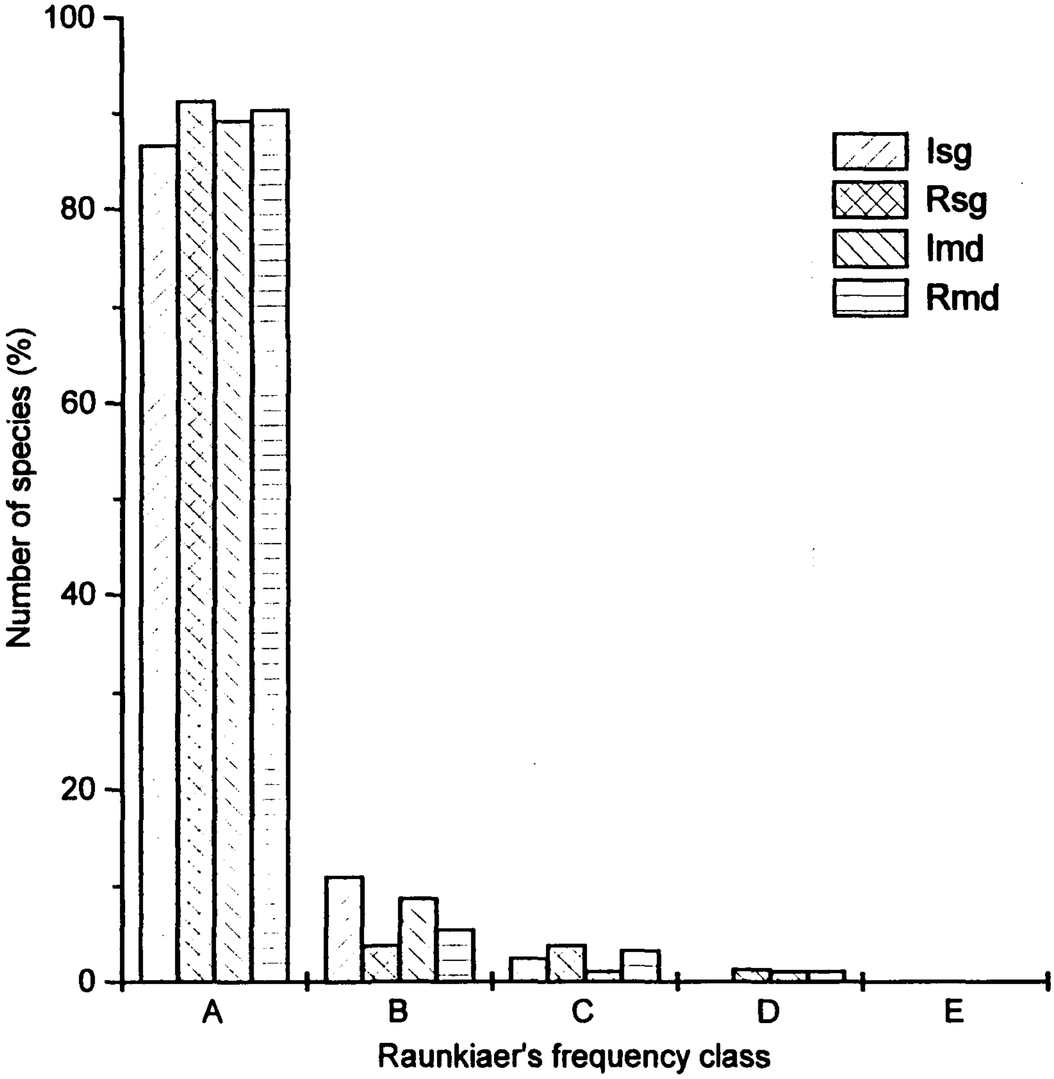


Fig. 5.6. Distribution of woody species in different frequency classes in the undisturbed (Isg, Rsg) and mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

Similarly, *Castanopsis purpurella* was the most frequent species in the mildly disturbed stands of both the groves (Table 5.2a-5.2d).

Density

The stand density at the four sites ranged from 938 to 1476 stems ha^{-1} with a mean value of 1155 stems ha^{-1}. In Isg, *Microtropis discolor* had the highest density (298 stems ha^{-1}) followed by *Camellia caudata* (136 stems ha^{-1}) (Table 5.2a). They together accounted for 29% of tree density in the forest. In Rsg, *Sarcosperma griffithii* had the highest density (116 stems ha^{-1}) followed by *Actinodaphne obovata* (108 stems ha^{-1}). Together they constituted about 23% of the stand density (Table 5.2b). *Castanopsis purpurella* was the most abundant species in the mildly disturbed stands of both the groves (Table 5.2c, 5.2d).

The distribution of density in different dbh classes (Fig. 5.7) shows that about 74% and 54% of the total stems in the undisturbed stands of Ialong and Raliang respectively were in 5-15cm dbh class. Only 2-5% of the trees had > 66cm dbh. In the mildly disturbed stands of both the groves 50-67% of the stem density was constituted by 5-15cm dbh class. Stem density in >66cm dbh class accounted for only 2% of the stand density.

Basal cover

The basal cover in the four stands varied from a minimum of 36.52 m^2ha^{-1} in Rmd to a maximum of 71.44 m^2ha^{-1} in Rsg (Table 5.1). Both the undisturbed stands had comparatively higher tree basal cover than the mildly disturbed stands. Despite that density of young trees (5-15cm dbh) was very high, their basal cover was much

Table 5.2 a. Frequency (%), density (plant ha^{-1}) and IVI of woody species ($\geq$ 5cm dbh) in undisturbed stand at Ialong.

Plant species	Family	Frequency	Density	IVI
Canopy layer (> 15m height)				
Acer laevigatum Wall.	Aceraceae	4	6	1.48
Alseodaphne petiolaris Hk.f.	Lauraceae	2	6	1.85
Betula alnoides Buch.-Ham. ex D.Don	Betulaceae	12	12	16.13
Castanopsis indica A. DC.	Fagaceae	10	10	2.44
Castanopsis purpurella (Miq) Balakr.	Fagaceae	36	62	14.56
Castanopsis tribuloides (Sm.) DC.	Fagaceae	20	30	12.9
Cinnamomum bejolghota (Buch.-Ham.) Sweet.	Lauraceae	2	2	0.58
Cinnamomum glanduliferum (Wall.) Meissn.	Lauraceae	16	16	5.79
Engelhardtia spicata Leschn. ex Bl.	Juglandaceae	28	40	18.34
Ficus altissima Bl.	Moraceae	6	8	7.40
Ficus virens Ait.	Moraceae	4	4	6.58
Garcinia tinctoria (DC.) W.F.Wight	Clusiaceae	2	2	0.53
Lithocarpus elagans (Bl.) Hatus ex Soep.	Fagaceae	20	28	3.46
Lithocarpus fenestrata (Roxb.) Rehder.	Fagaceae	10	12	2.45
Lithocarpus sp.	Fagaceae	6	8	5.55
Persea odoratissima (Nees) Koster.	Lauraceae	14	18	6.06
Pinus kesiya Royle ex. G.Don	Pinaceae	2	2	1.19
Prunus jenkinsii Hook.f.	Rosaceae	14	20	4.06
Pseudostreblus indica Bureau	Moraceae	16	48	14.2
Quercus serrata Thunb.	Fagaceae	2	2	0.65
Schima wallichii (DC.) Korth.	Theaceae	14	20	3.84
Syzygium tetragonum (Wt.) Kurz	Myrtaceae	38	60	12.55
Sub canopy layer (8-15m height)				
Alangium chinensis (Lour.) Harms	Coranaceae	14	16	4.08
Antidesma bunius (Linn.) Spreng.	Euphorbiaceae	2	2	0.40
Bielschmedia roxburghiana Nees	Lauraceae	2	2	0.47
Citrus latipes (Swingle) Tanaka	Rutaceae	8	8	1.78
Diospyros kaki Thunb.	Ebenaceae	6	8	1.40
Erythrina arborescens Roxb.	Fabaceae	2	2	0.40
Eurya acuminata DC.	Theaceae	2	4	0.56
Ficus concinna Miq.	Moraceae	2	2	0.55
Ficus mclelandi var. *rhododendrifolia* Corn.	Moraceae	2	2	0.68
Ficus nerifolia J.E.Sm.	Moraceae	2	2	0.43
Garcinia morella Desr.	Clusiaceae	2	6	1.22
Helicia nilagirica Bedd.	Proteaceae	38	62	9.76
Lindera latifolia Hook.f.	Lauraceae	16	28	4.50
Lindera nacusua (D.Don) Merr.	Lauraceae	2	2	0.40
Macropanax dispermus (Bl.) O.Ktz.	Araliaceae	2	2	0.40
Manglietia insignis (Wall.) Bl.	Magnoliaceae	2	2	0.40
Myrica esculenta Buch.-Ham. ex D.Don	Myricaceae	6	6	2.85
Myrsine semiserrata Wall.	Myrsinaceae	10	14	2.37
Persea bombycina (King ex Hk.f.) Koster.	Lauraceae	2	4	.73
Persea duthiei (Hook.f.) Koster.	Lauraceae	2	4	1.03
Pithecellobium monadelphum (Roxb.) Koster.	Mimosaceae	34	50	9.18
Quercus griffithii Hk.f. &Th ex DC.	Fagaceae	2	2	0.73
Rhododendron arboreum Sm.	Ericaceae	2	2	0.55
Rhus acuminata DC.	Anacardiaceae	28	36	8.73
Schefflera elata (Buch.-Ham.) Harms	Araliaceae	4	4	0.89
Schefflera hypoleuca (Kurz) Harms	Araliaceae	22	22	4.63
Vaccinium sprengelii (G.Don) Rehd.	Vacciniaceae	2	4	0.66

Under canopy (<8m height)				
Antidesma diandrum (Roxb.) Roth	Euphorbiaceae	2	2	0.40
Antidesma khasianum Hk.f.	Euphorbiaceae	2	2	0.40
Camellia caudata Wall.	Theaceae	30	136	13.86
Clerodendrum bracteatum Wall. ex Walp.	Verbenaceae	2	2	0.40
Coffea khasiana Hook.f.	Rubiaceae	54	100	13.96
Croton oblongus Burm.f.	Euphorbiaceae	4	4	0.85
Erythroxylum kunthianum Wall ex. Kurz.	Erythroxylaceae	2	2	0.40
Eurya cerasifolia (D.Don) Kobuski	Theaceae	10	14	2.11
Eurya japonica Thunb.	Theaceae	2	2	0.40
Ficus elmerii Merr.	Moraceae	2	2	0.40
Ficus hirta var. *roxburghii* (Miq.) King	Moraceae	8	8	1.56
Itea macrophylla Wall.	Iteaceae	2	2	0.47
Ixora subsessilis G.Don.	Rubiaceae	2	2	0.70
Maesa indica (Roxb.) Wall.	Myrsinaceae	2	2	0.40
Meyna spinosa Link.	Rubiaceae	4	4	0.79
Microtropis discolor (Wall.) Arn.	Celastraceae	58	298	29.49
Phoebe lanceolata (Nees) Nees	Lauraceae	16	20	3.79
Picrasma sp.	Simroubaceae	6	8	1.31
Pouzolzia frondosa var. fulgens (Wedd.) Balakr.	Urticaceae	2	2	0.42
Pseudobrassaiopsis hispida (Seem.) R.N.Ban.	Araliaceae	4	4	0.78
Pyrularia edulis A. DC	Santalaceae	14	20	3.62
Randia griffithii Hook.f.	Rubiaceae	2	2	0.40
Sarcococca pruniformis Lindl.	Buxaceae	10	10	2.22
Styrax serrulatum Roxb.	Styracaceae	8	10	1.71
Styrax hookerii Cl.	Styracaceae	2	2	0.40
Symplocos spicata Roxb	Symplocaceae	8	10	1.96
Viburnum foetidum Wall.	Caprifoliaceae	2	2	0.40
Wendlandia wallichii W. & A.	Rubiaceae	10	20	3.22
Liana				
Embelia subcoriaceous (Clarke) Mez.	Myrsinaceae	4	4	0.77
Rourea minor (Gaert.) Leenh.	Connanaceae	24	44	6.22
Schefflera wallichiana (W. & A.) Harms	Araliaceae	2	2	0.40
Tetrastigma serullatum (Roxb.) Planch.	Vitaceae	12	14	2.49
Todallia asiatica (Linn.) Lamk.	Rutaceae	4	6	0.93
Total			**1476**	**300**

Table 5.2b. Frequency (%), density (plant ha^{-1}) and IVI of woody species ($\geq$ 5cm dbh) in undisturbed stand at Raliang.

Plant species	Family	Frequency	Density	IVI
Canopy layer (>15m height)				
Acer laevigatum Wall.	Aceraceae	16	26	11.41
Acer oblongum Wall.	Aceraceae	2	2	0.68
Actinodaphne obovata (Nees) Bl.	Lauraceae	50	108	25.59
Alseodaphne petiolaris Hk.f.	Lauraceae	6	6	1.79
Betula alnoides Buch.-Ham. ex D.Don	Betulaceae	2	4	2.39
Castanopsis purpurella (Miq.) Balak.	Fagaceae	8	14	6.58
Cinnamomum bejolghota (Buch.-Ham.) Sweet.	Lauraceae	2	2	2.02
Cinnamomum glaucescens (Nees) Meissn.	Lauraceae	2	2	3.40
Cryptocarya floribunda Nees.	Lauraceae	6	6	2.05
Drymicarpus racemosus (Roxb.) Hk.f.	Anacardiaceae	18	20	5.38
Elaeocarpus sikkimensis Mast.	Elaeocarpaceae	2	2	0.59
Engelhardtia spicata Leschn. ex Bl.	Juglandaceae	6	8	4.81
Ficus altissima Bl.	Moraceae	4	4	12.92
Ficus virens Ait.	Moraceae	8	10	16.08
Garcinia tinctoria (DC.) W.F.Wight	Clusiaceae	4	4	1.27
Knema angustifolia (Roxb.) Warb.	Myristicaceae	22	28	7.72
Lithocarpus elagans (Bl.) Hatus ex Soep.	Fagaceae	14	14	7.89
Lithocarpus fenestrata (Roxb.) Rehder.	Fagaceae	2	2	0.53
Lithocarpus sp.	Fagaceae	2	2	0.52
Michelia doltsopa DC.	Magnoliaceae	2	2	3.90
Neolitsea cassia (Linn.) Koster.	Lauraceae	32	64	16.47
Persea gamblei (King ex Hk.f.) Koster.	Lauraceae	4	4	1.82
Persea odoratissima (Nees) Koster.	Lauraceae	6	10	3.76
Podocarpus neriifolia D.Don	Podocarpaceae	2	2	1.01
Prunus jenkinsii Hook.f.	Rosaceae	48	78	19.97
Sarcosperma griffithii Cl.	Sapotaceae	72	116	36.88
Schima wallichii (DC.) Korth.	Theaceae	4	4	1.50
Spondias axallaris Roxb.	Anacardiaceae	2	2	2.26
Syzygium tetragonum (Wt) Kurz	Myrtaceae	12	14	3.74
Sub canopy layer (8-15m height)				
Antidesma bunius (L.) spreng.	Euphorbiaceae	2	2	0.52
Bielschmedia assamica Meissn.	Lauraceae	8	8	2.23
Caryota urens Linn.	Arecaceae	8	8	2.23
Cinnamomum tamala Fr. Nees	Lauraceae	4	4	1.05
Citrus latipes (Swingle) Tanaka	Rutaceae	6	6	1.56
Diospyros kaki Thunb..	Ebenaceae	2	2	0.62
Dysoxylum gobara (Buch.-Ham.) Merr.	Meliaceae	42	62	14.07
Elaeocarpus lancifolius Roxb.	Elaeocarpaceae	2	2	0.55
Ficus nerifolia J.E.Sm.	Moraceae	2	2	0.52
Helicia nilagirica Bedd.	Proteaceae	10	28	5.23
Ilex embeloides Hook.f.	Aquifoliaceae	2	4	0.75
Lindera latifolia Hook.f.	Lauraceae	8	10	2.45
Lindera reticulata Benth.	Lauraceae	8	8	3.16
Litsea semicarpifolia (Nees) Hook.f.	Lauraceae	8	10	2.47
Macaranga denticulata Muell.-Arg.	Euphorbiaceae	4	4	1.47
Macropanax dispermus (Bl.) O.Ktz.	Araliaceae	20	24	6.05
Manglietia insignis (Wall.) Bl.	Magnoliaceae	6	8	2.87
Melia azedarach Linn.	Meliaceae	2	2	0.52
Myrica esculenta Buch.-Ham. ex D.Don	Myricaceae	2	2	0.55

Myrsine semiserrata Wall.	Myrsinaceae	2	2	0.52
Persea bombycina (King ex Hk.f.) Koster.	Lauraceae	2	2	0.52
Persea parviflora (Meissn.) Haridasan et Rao	Lauraceae	4	4	1.27
Pithecellobium monadelphum (Roxb.) Koster.	Mimosaceae	16	18	4.44
Prunus acuminata (Wall.) Dietr.	Rosaceae	4	6	1.26
Sapindus rarak DC.	Sapindaceae	2	2	0.52
Schefflera hypoleuca (Kurz) Harms	Araliaceae	4	4	1.05
Under canopy (<8m height)				
Calophyllum polyanthum Choisy	Clusiaceae	2	2	0.52
Capparis acutifolia Sw.	Capparaceae	24	28	6.92
Coffea khasiana Hook.f.	Rubiaceae	4	4	1.04
Desmos longiflorus (Roxb.) Safford.	Annonaceae	6	6	1.60
Erythroxylum kunthianum Wall. ex Kurz.	Erythroxylaceae	2	2	0.52
Ficus hirta var. *roxburghii* (Miq.) King	Moraceae	4	4	1.05
Itea chinensis Hook.f.	Iteaceae	2	2	0.52
Ixora subsessilis G.Don.	Rubiaceae	10	10	3.23
Litsea salicifolia (Roxb. ex Nees) Hook.f.	Lauraceae	2	2	0.52
Paramignya micrantha Kurz.	Rutaceae	6	6	1.56
Phoebe lanceolata (Nees) Nees	Lauraceae	2	2	0.52
Pittosporum podocarpum Gagnep.	Pittosporaceae	6	6	1.65
Sarcococca pruniformis Lindl.	Buxaceae	2	8	1.47
Stercularia hamiltonii (O.Ktz.) Adelb.	Sterculariaceae	4	6	1.38
Styrax serrulatum Roxb.	Styracaceae	6	6	1.62
Symplocos pyrifolia Wall. ex G.Don.	Symplocaceae	6	6	1.66
Symplocos spicata Roxb	Symplocaceae	2	2	0.52
Wendlandia wallichii W. & A.	Rubiaceae	4	4	1.05
Liana				
Fissistigma verrucosum (Hook.f. & Th.) Merr.	Annonaceae	10	14	3.09
Melodinus monogynous Roxb.	Apocynaceae	2	2	0.52
Rourea minor (Gaertn.) Leenh.	Connanaceae	10	12	2.92
Schefflera venulosa (W. & A.) Harms	Araliaceae	2	2	0.52
Tetrastigma leucostaphylum (Dennest.)Balak.	Vitaceae	2	2	0.53
Tupidanthus calyptratus Hook.f. & Th.	Araliaceae	4	4	1.17
Unidentified sp.	-	2	2	0.52
Total			**938**	**300**

Table 5.2 c. Frequency (%), density (plant ha^{-1}) and IVI of woody species (≥ 5cm dbh) in mildly disturbed stand at Ialong.

Plant species	Family	Frequency	Density	IVI
Canopy layer (>15m height)				
Acer laevigatum Wall.	Aceraceae	2	2	0.46
Albizia chinensis (Osb.) Merr.	Mimosaceae	12	16	3.79
Betula alnoides Buch. -Ham. ex D.Don	Betulaceae	4	12	1.52
Castanopsis indica A.DC.	Fagaceae	4	8	1.58
Castanopsis purpurella (Miq.) Balak.	Fagaceae	74	224	42.17
Castanopsis tribuloides (Sm.) DC.	Fagaceae	24	28	6.09
Cinnamomum bejolghota (Buch.-Ham.) Sweet	Lauraceae	2	2	1.93
Cinnamomum glanduliferum (Wall.) Meissn.	Lauraceae	20	28	8.49
Engelhardtia spicata Leschn. ex Bl.	Juglandaceae	36	56	20.74
Evodia tricotoma (Lour.) Planch.	Rutaceae	10	10	2.42
Ficus sp.	Moraceae	2	2	12.71
Ficus virens Ait.	Moraceae	4	4	12.57

Lithocarpus elegans (Bl.) Hatus ex Soep.	Fagaceae	12	12	2.48
Lithocarpus fenestratus (Roxb.) Rehder.	Fagaceae	4	6	0.96
Persea odoratissima (Nees) Koster.	Lauraceae	14	14	4.28
Pinus kesiya Royle ex. G.Don	Pinaceae	6	6	1.72
Prunus jenkensii Hk.f.	Rosaceae	2	4	0.56
***Schima wallichii* (DC.) Korth.**	**Theaceae**	**42**	**88**	**17.49**
Spondias axillaris Roxb.	Anacardiaceae	4	8	1.26
Syzygium tetragonum (Wt.) Kurz	Myrtaceae	18	22	7.10
Subcanopy layer (8-15m height)				
Alangium chinense (Lour.) Harms	Coranaceae	4	6	1.26
Bielschmedia assamica Meissn.	Lauraceae	12	16	4.56
Citrus latipes (Swingle) Tanaka	Rutaceae	16	52	8.80
Diospyros kaki Thunb.	Ebenaceae	24	32	6.29
Docynia indica (Wall.) Decne	Rosaceae	6	6	2.98
Erythrina arborescens Roxb.	Fabaceae	2	4	0.58
Eurya acuminata DC.	Theaceae	2	2	0.40
Ficus concinna Miq.	Moraceae	2	2	0.84
Ficus nerifolia J.E.Sm.	Moraceae	2	2	0.53
Glochidion lanceolarium (Roxb.) Voigt	Euphorbiaceae	6	10	1.58
Helicia nilagirica Bedd.	Proteaceae	22	32	6.07
Lindera latifolia Hook.f.	Lauraceae	30	48	8.01
Lindera nacusua (D.Don) Merr.	Lauraceae	8	8	1.65
Litsea citrata Bl.	Lauraceae	2	4	0.63
Macaranga denticulata Mull.-Arg.	Euphorbiaceae	4	4	0.90
Myrica esculenta Buch.-Ham. ex D.Don	Myricaceae	22	26	6.14
Myrsine semiserrata Wall.	Myrsinaceae	4	4	0.78
Persea bombycina (King ex Hk.f.) Koster.	Lauraceae	12	14	3.10
Persea parviflora (Meissn.) Haridasan et Rao	Lauraceae	2	2	0.45
Pithecellobium monadelphum (Roxb.) Koster.	Mimosaceae	14	30	4.37
Prunus acuminata (Wall.) Dietr.	Rosaceae	2	4	0.65
Quercus griffithii Hk.f. & Th. ex DC.	Fagaceae	2	6	1.33
Rhododendron arboreum Sm.	Ericaceae	6	8	1.60
Rhus acuminata DC.	Anacardiaceae	36	50	10.90
Schefflera hypoleuca (Kurz) Harms	Araliaceae	14	18	3.17
Vaccinium sprengelii (G.Don) Rehd.	Vaccinaceae	4	4	0.88
Viburnum simonsii Hk.f. & Th.	Caprifoliaceae	8	12	2.13
Undercanopy (< 8m height)				
Aralia thomsonii Seem	Araliaceae	2	2	0.39
Ardisia griffithii Cl.	Myrsinaceae	2	2	0.40
Brassaiopsis glomerulata (Bl.) Regel	Araliaceae	2	2	0.40
Camellia caudata Wall.	Theaceae	24	48	6.80
Camellia caduca Cl.ex Brandis	Theaceae	16	26	4.04
Clerodendrum bracteatum Wall.ex Walp.	Verbenaceae	8	8	1.57
Coffea khasiana Hk.f.	Rubiaceae	20	26	4.49
Corylopsis himalayana Griff.	Hamamelidaceae	6	8	1.36
Croton oblongus Burm.f.	Euphorbiaceae	2	2	0.40
Cyathea sp.	Cyatheaceae	6	10	1.81
Erythroxylum kunthianum Wall.ex Kurz	Erythroxylaceae	4	4	0.79
Eurya cerasifolia (D.Don) Kobuski	Theaceae	4	6	0.98
Eurya japonica Thunb.	Theaceae	2	2	0.39
Ficus elmeri Merr.	Moraceae	4	4	0.94
Ficus hirta var. *roxburghii* (Mig.) King	Moraceae	2	2	0.39
Ixora subsessilis G.Don	Rubiaceae	2	2	0.39
Leucosceptrum canum Sm.	Lamiaceae	6	6	1.21
Ligustrum robustum (Roxb.) Bl.	Oleaceae	6	8	1.42
Lindera caudata Benth.	Lauraceae	8	8	1.63

Lyonia ovalifolia (Wall.) Drude	Ericaceae	12	22	3.48
Maesa indica (Roxb.) Wall.	Myrsinaceae	14	14	2.76
Meyna spinosa Link	Rubiaceae	20	28	5.80
Microtropis discolor (Wall.) Arn.	Celastraceae	2	2	0.41
Phlogacanthus thyrsiflorus (Roxb.) Nees	Acanthaceae	10	12	2.19
Phoebe lanceolata (Nees) Nees	Lauraceae	2	2	0.39
Phyllanthus sp.	Euphorbiaceae	4	4	0.81
Pyrularia edulis A.DC.	Santalaceae	12	14	2.81
Pyrus pashia D.Don	Rosaceae	8	8	2.06
Randia griffithii Hk.f.	Rubiaceae	4	4	0.80
Rhus hookerii Sahni & Bahad.	Anacardiaceae	2	2	0.39
Rhus javanica Linn.	Anacardiaceae	4	6	0.97
Sarcococca pruniformis Lindl.	Buxaceae	12	18	3.19
Saurauia nepaulensis DC.	Saurauiaceae	10	16	2.53
Styrax hookerii Cl.	Styracaceae	6	6	1.20
Styrax serrulatum Roxb.	Styracaceae	2	2	0.39
Symplocos crataegoides D.Don	Symplocaceae	4	4	0.83
Symplocos spicata Roxb.	Symplocaceae	6	6	1.25
Unidentified sp.	Unidentified	4	4	0.86
Viburnum foetidum Wall.	Caprifoliaceae	10	10	1.97
Wendlandia wallichii W. & A.	Rubiaceae	8	10	1.86
Zanthoxylum acanthopodium DC.	Rutaceae	2	2	0.40
Liana				
Embelia vestita Roxb.	Myrsinaceae	2	2	0.39
Tetrastigma serrulatum (Roxb.) Planch	Vitaceae	2	2	0.39
Toddalia asiatica (Linn.) Lamk	Rutaceae	4	4	0.80
Tupidanthus calyptratus Hook.f. & Th.	Vitaceae	2	2	0.39
Total			**1340**	**300**

Table 5.2d. Frequency (%), density (plant ha^{-1}) and IVI of woody species ($\geq$ 5cm dbh) in mildly disturbed stand at Raliang.

Plant species	Family	Frequency	Density	IVI
Canopy layer (>15m height)				
Acer laevigatum Wall.	Aceraceae	16	20	11.13
Actinodaphne obovata (Nees) Bl.	Lauraceae	2	2	0.43
Alseodaphne petiolaris Hk.f.	Lauraceae	2	2	0.80
Betula alnoides Buch.-Ham. ex D.Don.	Betulaceae	4	4	0.90
Castanopsis purpurella (Miq.) Balak	Fagaceae	64	130	33.81
Cinnamomum bejolghota (Buch.-Ham.) Sweet	Lauraceae	2	2	0.39
Cinnamomum glanduliferum (Wall.) Meissn.	Lauraceae	10	10	2.02
Drimycarpus racemosus (Roxb.) Hk.f.	Anacardiaceae	8	8	4.17
Elaeocarpus sikkimensis Mast.	Elaeocarpaceae	16	18	6.91
Engelhardtia spicata Leschn. ex Bl.	Juglandaceae	18	24	7.07
Evodia trichotoma (Lour.) Planch.	Rutaceae	4	4	1.23
Ficus altissima Bl.	Moraceae	2	2	0.53
Ficus virens Ait.	Moraceae	6	6	1.79
Lithocarpus elegans (Bl.) Hatus ex Soep.	Fagaceae	52	82	20.65
Lithocarpus fenestrata (Roxb.) Rehder.	Fagaceae	2	2	0.42
Lithocarpus sp.	Fagaceae	4	8	1.57
Neolitsea cassia (Linn.) Koster.	Lauraceae	10	12	3.49
Persea odoratissima (Nees) Koster.	Lauraceae	10	10	2.46
Pinus kesiya Royle ex Gordon	Pinaceae	4	4	1.21

Prunus jenkinsii Hook.f.	Rosaceae	16	18	5.35
Sarcosperma griffithii Cl.	Sapotaceae	32	44	10.48
Schima khasiana Dyer.	Theaceae	4	8	8.55
Schima wallichii (DC.) Korth.	Theaceae	32	66	12.88
Spondias axillaris Roxb.	Anacardiaceae	10	10	5.89
Syzygium tetragonum (Wt.) Kurz	Myrtaceae	8	12	2.52
Subcanopy (8-15m height)				
Bielschmedia assamica Meissn.	Lauraceae	2	2	0.60
Caryota urens Linn.	Araceae	2	2	0.40
Cinnamomum tamala Fr. Nees	Lauraceae	6	6	1.17
Diospyros kaki Thunb.	Ebenaceae	8	10	1.94
Dysoxylum gobara (Buch.-Ham.) Merr.	Meliaceae	16	26	4.12
Eurya acuminata DC.	Theaceae	4	4	0.82
Glochidion lanceolarium (Roxb.) Voigt	Euphorbiaceae	18	28	5.0
Helicia nilagirica Bedd.	Proteaceae	48	76	16.35
Ilex embeloides Hk.f.	Aquifoliaceae	2	4	0.77
Lindera latifolia Hk.f.	Lauraceae	12	18	3.17
Lindera reticulata Benth.	Lauraceae	4	6	1.27
Litsea citrata Bl.	Lauraceae	14	16	3.81
Litsea semicarpifolia (Nees) Hook.f.	Lauraceae	4	4	0.89
Macaranga denticulata Muell.-Arg.	Euphorbiaceae	10	12	2.12
Macropanax dispermus (Bl.) O.Ktz.	Araliaceae	16	16	4.41
Manglietia insignis (Wall.) Bl.	Magnoliaceae	2	6	0.97
Myrica esculenta Buch.-Ham. ex D.Don	Myricaceae	18	32	5.62
Myrsine semiserrata Wall.	Myrsinaceae	4	4	0.78
Ostodes paniculata Bl.	Euphorbiaceae	4	4	0.78
Persea bombycina (King ex Hk.f.) Koster.	Lauraceae	2	2	0.47
Persea parviflora (Meissn.) Haridasan et Rao	Lauraceae	10	12	2.76
Pithecellobium monadelphum (Roxb.) Koster.	Mimosaceae	28	40	7.07
Rhus acuminata DC.	Anacardiaceae	28	38	8.69
Sapindus rarak DC.	Sapindaceae	6	6	1.18
Schefflera elata (Buch.-Ham.) Harms	Araliaceae	2	2	0.50
Schefflera hypoleuca (Kurz.) Harms	Araliaceae	20	28	4.85
Undercanopy (<8m height)				
Ardisia griffithii Cl.	Myrsinaceae	2	2	0.40
Brassaiopsis glomerulata (Bl.) Regel	Araliaceae	2	2	0.41
Calophyllum polyanthum Choisy	Clusiaceae	2	2	0.43
Capparis acutifolia Sw.	Capparadaceae	2	6	0.72
Clerodendrum bracteatum Wall.ex Walp.	Verbenaceae	12	12	2.33
Coffea khasiana Hk.f.	Rubiaceae	6	6	1.14
Erythroxylum kunthianum Wall.ex Kurz	Erythroxylaceae	2	2	0.38
Euonymus attenuatus Laws.	Celastraceae	10	10	2.10
Ficus hirta var. *roxburghii* (Miq.) King	Moraceae	6	6	1.18
Itea chinensis Hk.f.	Iteaceae	2	2	0.38
Itea macrophylla Wall.	Iteaceae	18	34	5.48
Ixora subsessilis G.Don	Rubiaceae	2	2	0.38
Ligustrum robustum (Roxb.) Bl.	Oleaceae	10	10	1.97
Lindera caudata Benth.	Lauraceae	6	6	1.18
Litsea salicifolia (Roxb.ex Nees) Hk.f.	Lauraceae	2	2	0.39
Litsea sebifera Pers.	Lauraceae	4	6	1.22
Lyonia ovalifolia (Wall.) Drude	Ericaceae	14	18	3.91
Maesa indica (Roxb.) Wall.	Myrsinaceae	4	4	0.78
Meyna spinosa Link	Rubiaceae	4	4	0.87
Micromelum integerrimum (Roxb.) Wt.& Arn.	Rutaceae	16	16	3.20
Paramigyna micrantha Kurz	Rutaceae	6	8	1.32
Phoebe lanceolata (Nees) Nees	Lauraceae	4	4	0.96

Pittosporum podocarpum Gagn.	Pittosporaceae	4	4	0.89
Pyrularia edulis A.DC.	Santalaceae	2	2	0.42
Rhus hookerii Sahani & Bahad.	Anacardiaceae	4	4	0.86
Rhus javanica Linn.	Anacardiaceae	4	4	0.84
Sarcococca pruniformis Lindl.	Buxaceae	16	22	3.88
Saurauia nepaulensis DC.	Saurauiaceae	4	6	0.96
Styrax serrulatum Roxb.	Styracaceae	48	88	13.68
Symplocos crataegoides D.Don	Symplocaceae	6	6	1.16
Symplocos pyrifolia Wall. ex G.Don	Symplocaceae	12	12	2.50
Symplocos spicata Roxb.	Symplocaceae	2	2	0.40
Unidentified sp.	Unidentified	2	2	0.80
Wendlandia wallichii W.&A.	Rubiaceae	22	30	6.53
Liana				
Embelia subcoriacea (Cl.) Mez.	Myrsinaceae	2	2	0.38
Fissistigma verrucosum (Hk.f.&Th.) Merr.	Annonaceae	6	14	1.98
Holboellia latifolia Wall.	Lardizarbalaceae	2	2	0.40
Millettia cinerea Benth.	Fabaceae	4	4	0.79
Rourea minor (Gaert.) Leenh.	Connanaceae	16	20	3.64
Tetrastigma leucostaphylum (Dennst.) Balak.	Vitaceae	4	4	0.82
Tupidanthus calyptratus Hk.f.& Th.	Araliaceae	2	2	0.39
Unidentified Liana	Unidentified	2	2	0.40
Total			**1308**	**300**

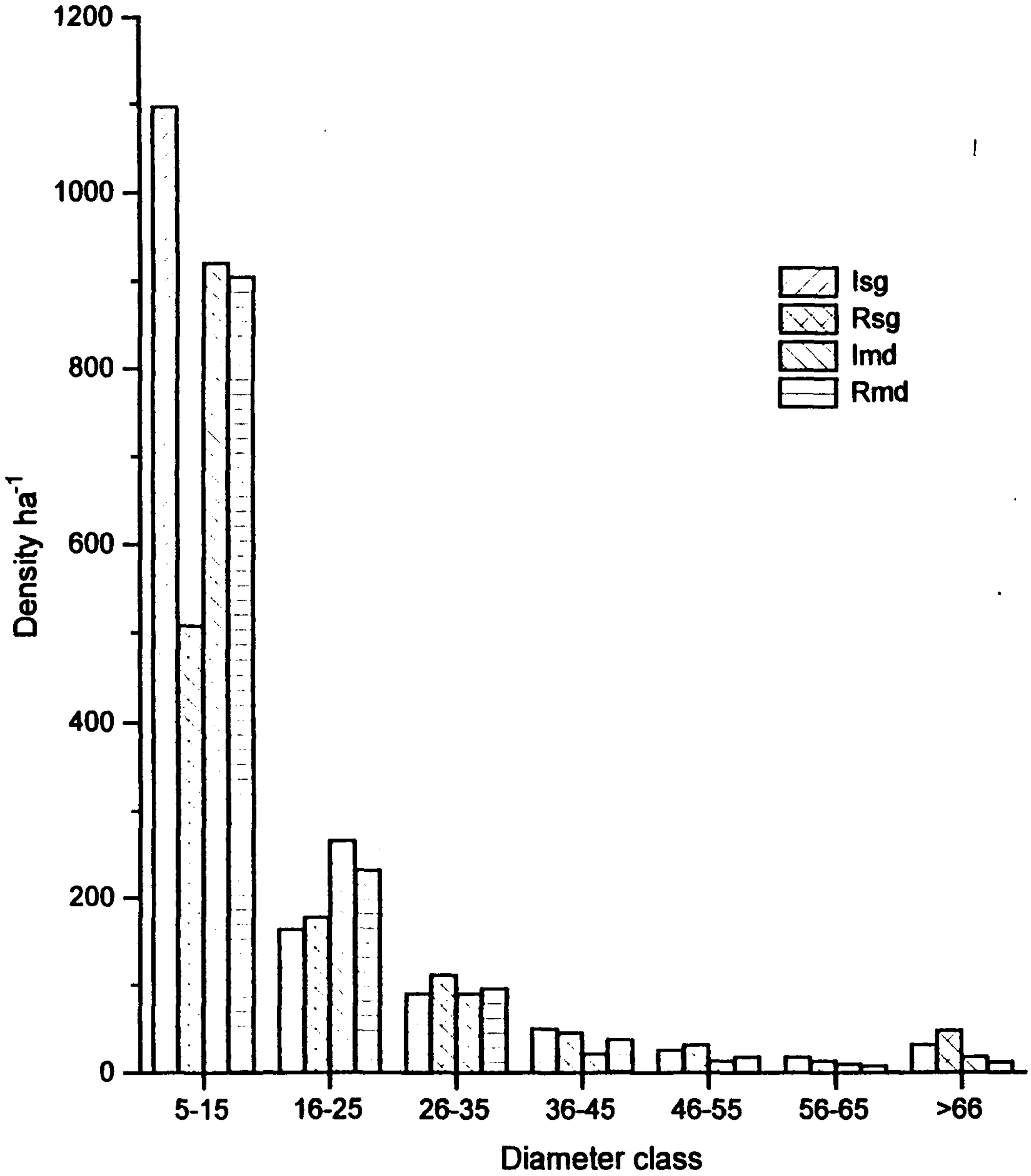


Fig. 5.7. Density - diameter distribution of woody species in the undisturbed (Isg,Rsg) and mildly disturbed stands (Imd,Rmd) at Ialong and Raliang.

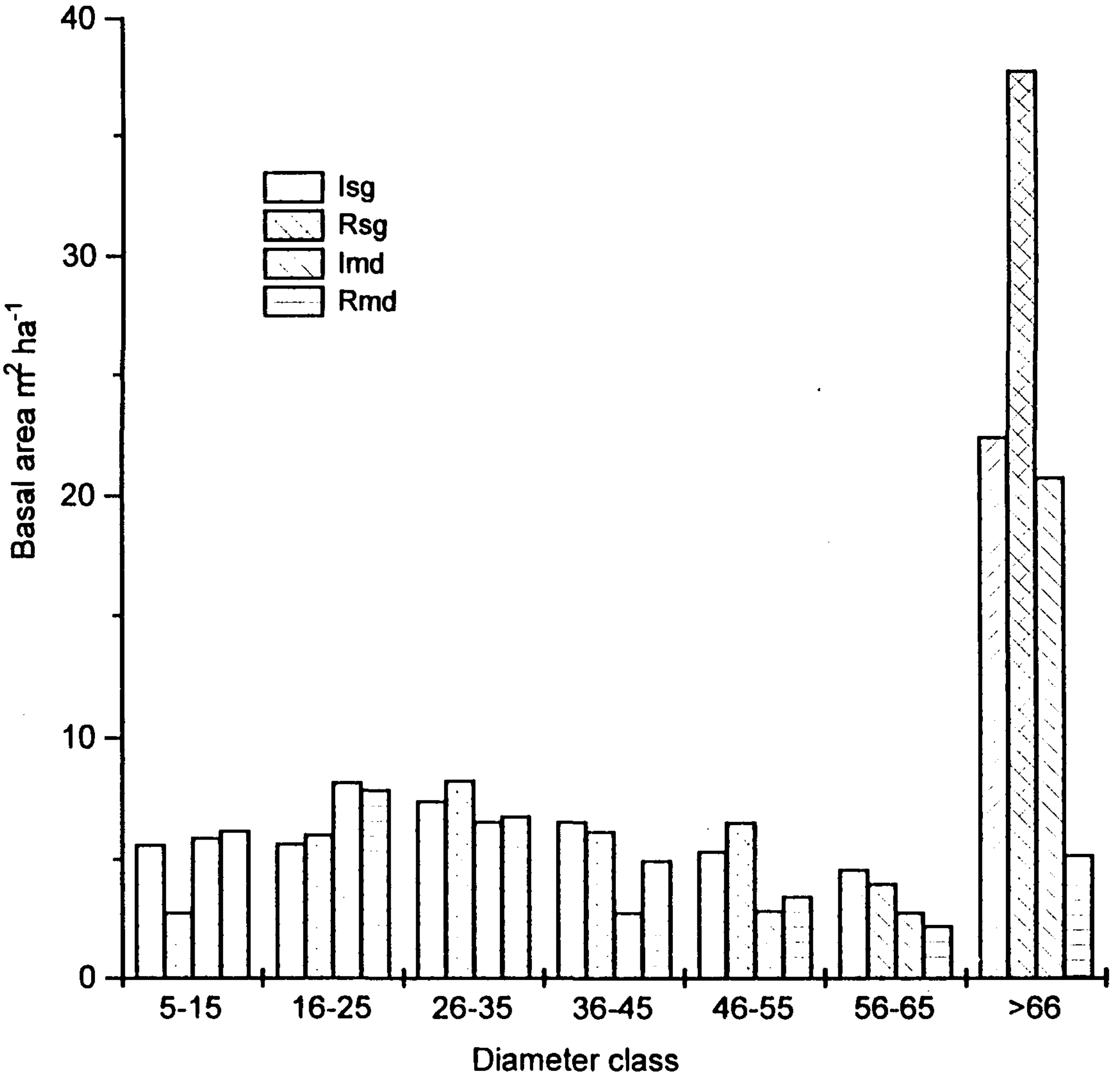


Fig. 5.8. Distribution of basal area in different diameter classes in the undisturbed (Isg, Rsg) and mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

lower than that of the mature trees (Fig 5.8). However, in Rmd the contribution of basal area by intermediate dbh classes was comparatively higher than that of higher dbh (> 66cm dbh) class.

Horizontal distribution pattern

Majority of the species (85-93%) showed contagious distribution pattern in all stands. A small percentage (6-15%) was randomly distributed. Regular dispersion was seen only in case of *Sarcosperma griffithii* in Rsg (Table 5.3).

Dominance distribution Pattern

The dominance distribution curve showed high equitability and low dominance in all four stands (Fig. 5.9). *Microtropis discolor* and *Engelhardtia spicata* in Isg and *Sarcosperma griffithii* and *Actinodaphne obovata* in Rsg were dominant and codominant species respectively. However, in both the mildly disturbed stands *Castanopsis purpurella* was the dominant species.

Table 5.3. Distribution pattern of woody species in the undisturbed and mildly disturbed stands at Ialong and Raliang.

Stands	Number of species (% of the total)		
	Regular	Random	Contagious
Isg	-	8 (10)	74 (90)
Rsg	1 (1)	5 (6)	74 (93)
Imd	-	9 (15)	51(85)
Rmd	-	7 (8)	86 (92)

- indicates absence.

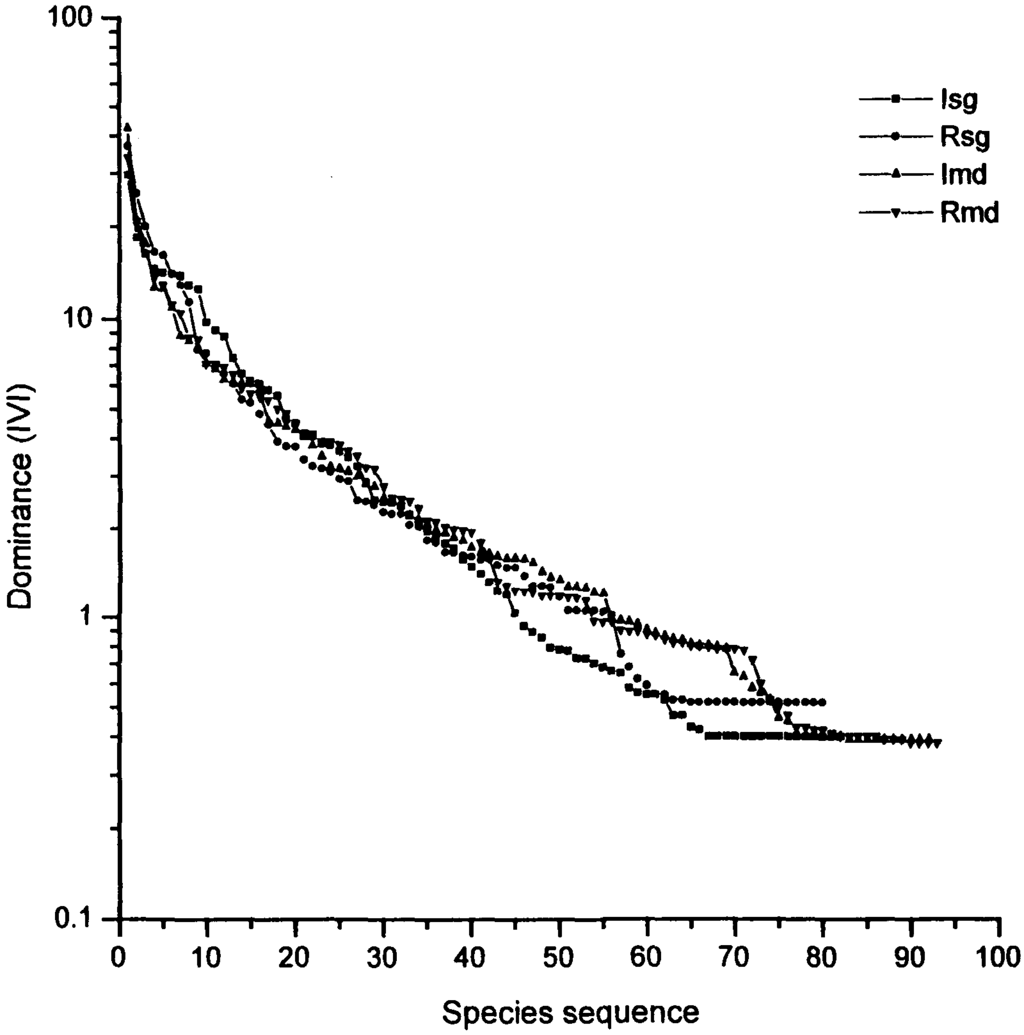


Fig. 5.9. Dominance -diversity curve of woody species in the undisturbed (Isg, Rsg) and mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

Diversity and Dominance

Shannon and Wiener's diversity index for trees worked out using proportional density as well as Pielou's eveness index increased from the undisturbed stands ($\bar{H}$ = 3.42 and 3.55, E = 0.53 and 0.56) to the mildly disturbed stands ($\bar{H}$ = 3.78 and 3.87, E = 0.61) at Ialong and Raliang. A reverse trend was seen in case of Simpson's dominance index, which decreased with the increase in diversity index (Table 5.1).

Shrub and Herb components

Species richness

A total of 89 shrub species belonging to 69 genera was identified in 120 plots (5 x 5 m quadrats) from all four stands. Standwise species richness is given in Table 5.4. Mildly disturbed stands had higher species richness (59-61) than the undisturbed stands (46 – 49). For herbs a total of 91 species belonging to 72 genera and 39 families, was identified in 120 (1x1m) plots examined in all four stands. As observed in the case of trees and shrubs the species richness of herbs also increased from the protected stands to the mildly disturbed stands.

Family composition

There were a total of 42 families of shrubs out of which Rosaceae and Rubiaceae, each with 6 species, was the dominant family followed by Myrsinaceae and Fabaceae (5 species each) and Asteraceae and Verbenaceae with (4 species each). Twenty families were monospecific. Similarly, out of the 39 herbaceous families encountered in the study site, Rubiaceae and Lamiaceae were the dominant families with 8 species each followed by Zingiberaceae with 7 species. Stand wise distribution of shrub and herb species is shown in the figure (5.10 a, b; 5.10 c, d).

Table 5. 4. Diversity and community characteristics of shrub and herb species at Ialong and Raliang.

Shrub	Ialong		Raliang	
	Isg	Imd	Rsg	Rmd
Area sampled (m^2)	750	750	750	750
Density ha^{-1}	6427	10680	8067	11040
Species richness	49	61	46	59
Number of families	30	32	28	31
Number of genera	39	44	37	43
Shannon diversity index	3.40	3.76	3.04	3.72
Pielou evenness index	0.61	0.63	0.55	0.63
Simpson dominance index	0.048	0.029	0.078	0.031
Herb				
Area sampled (m^2)	30	30	30	30
Density ($100m^2$)	2470	2077	1607	1887
Species richness	52	56	45	51
Number of families	23	30	20	28
Number of genera	43	50	39	46
Shannon diversity index	3.26	3.59	3.30	3.45
Pielou evenness index	0.57	0.62	0.60	0.61
Simpson dominance index	0.067	0.036	0.049	0.043

Frequency

Majority of (78-88%) shrub species had < 20% frequency in both the undisturbed stands at Ialong and Raliang. The rest were distributed in B, C and D classes. The proportion of species in Class A declined to 69-81% in the mildly

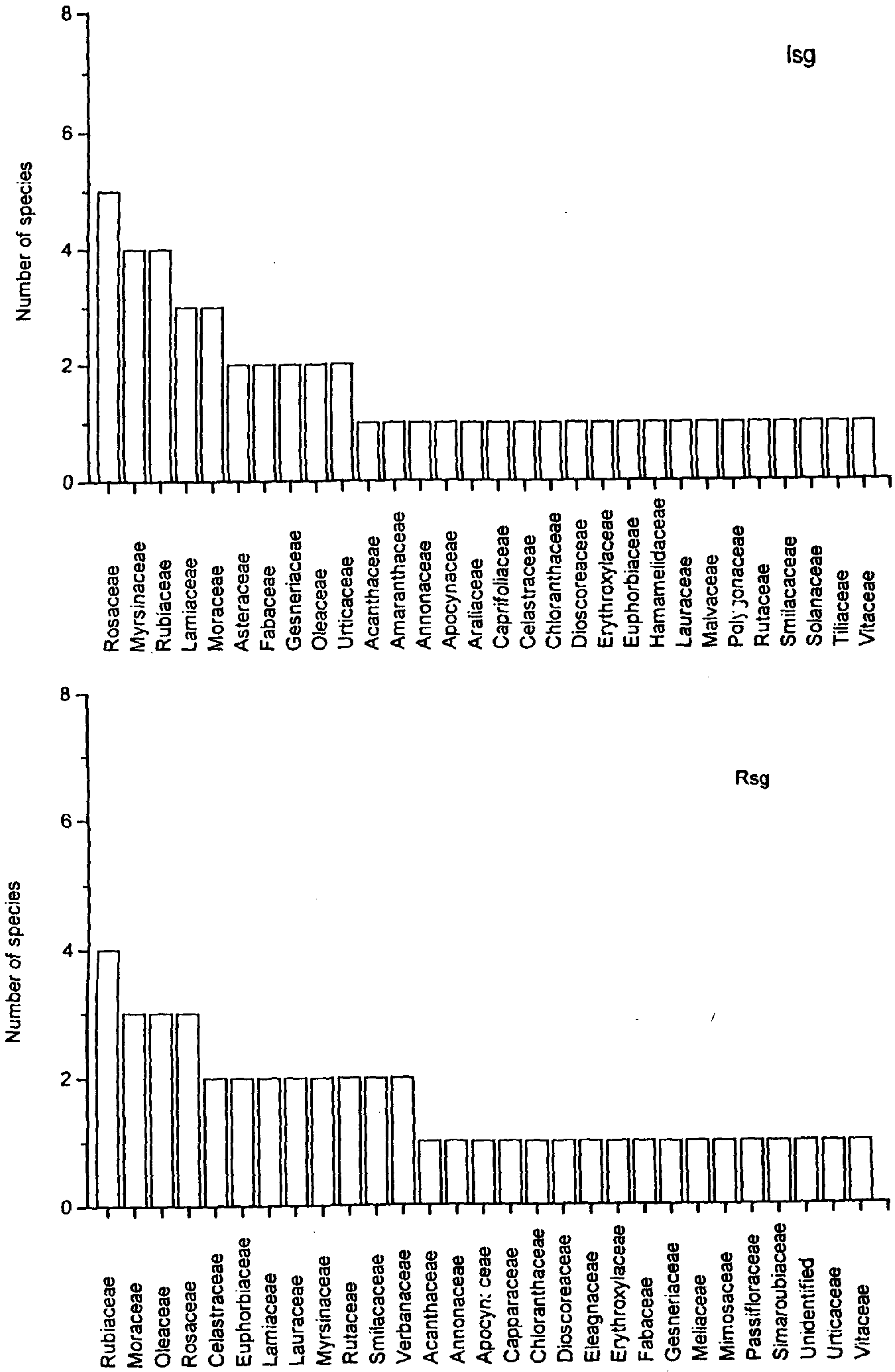


Fig.5.10a. Family-wise distribution of shrub species in undisturbed stands (Isg, Rsg) at Ialong and Raliang.

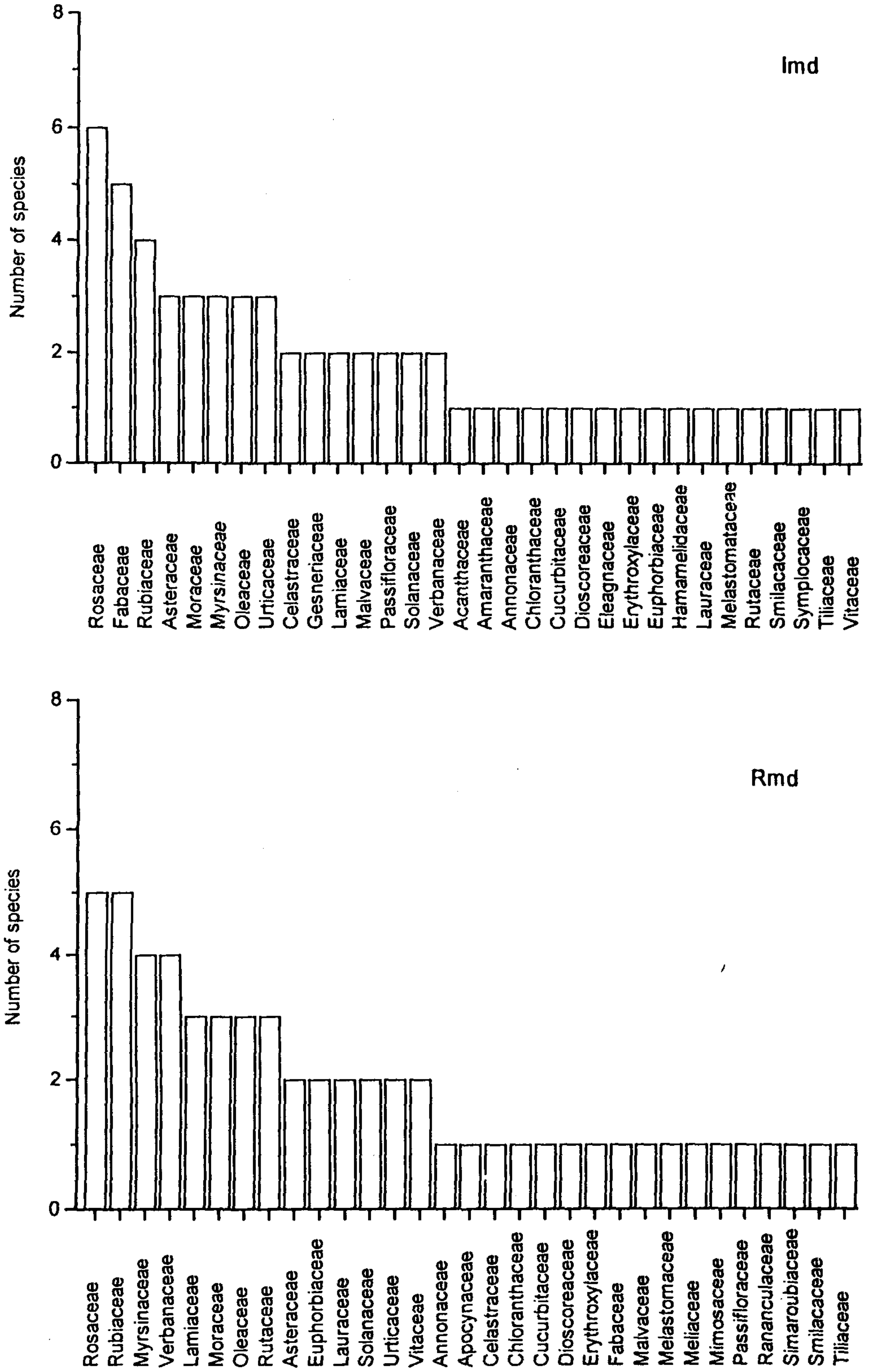


Fig. 5.10b. Family-wise distribution of shrub species in the mildly disturbed stands (Imd,Rmd) at Ialong and Raliang.

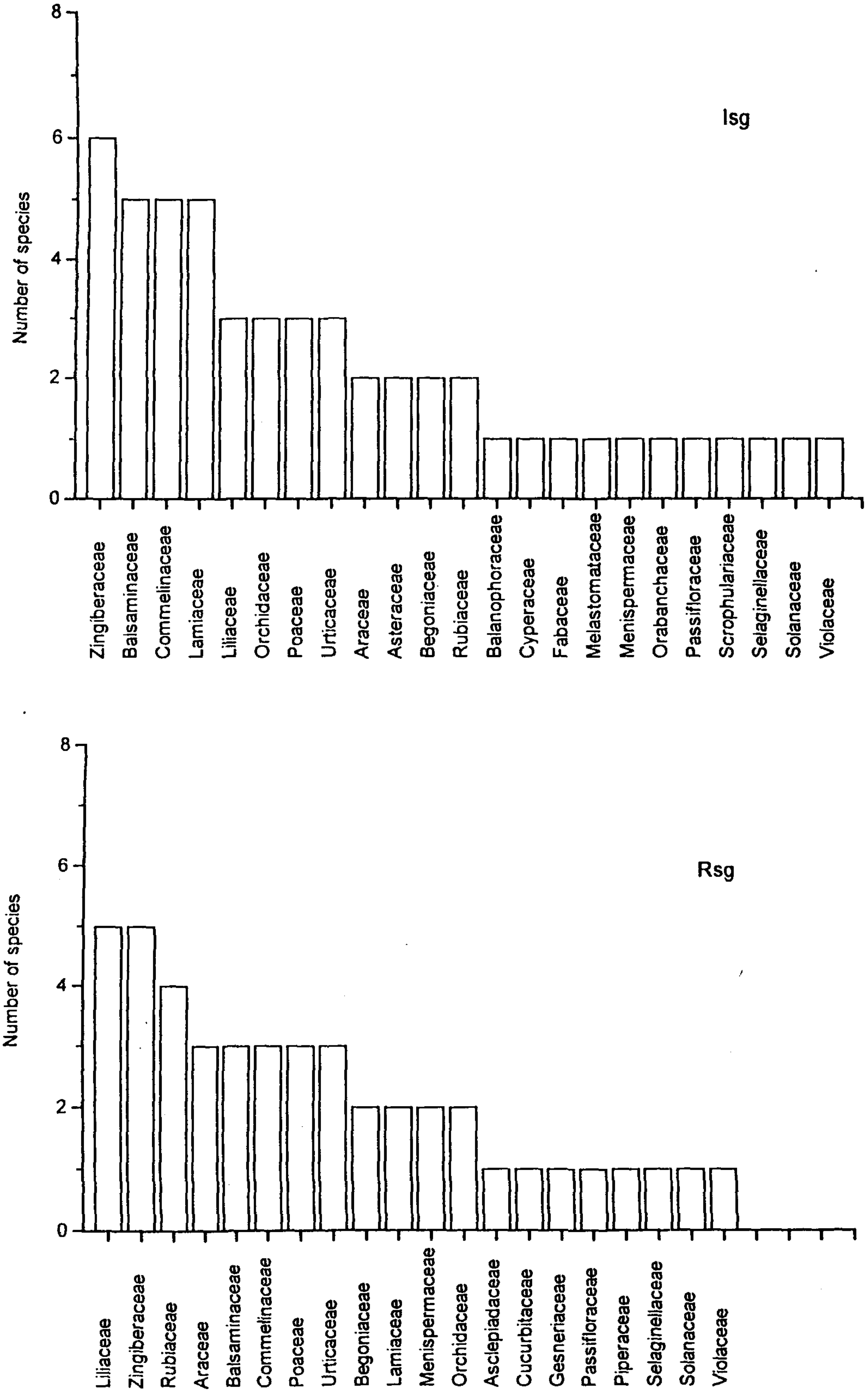


Fig. 5.10c. Family-wise distribution of herb in undisturbed stands (Isg, Rsg) at Ialong and Raliang.

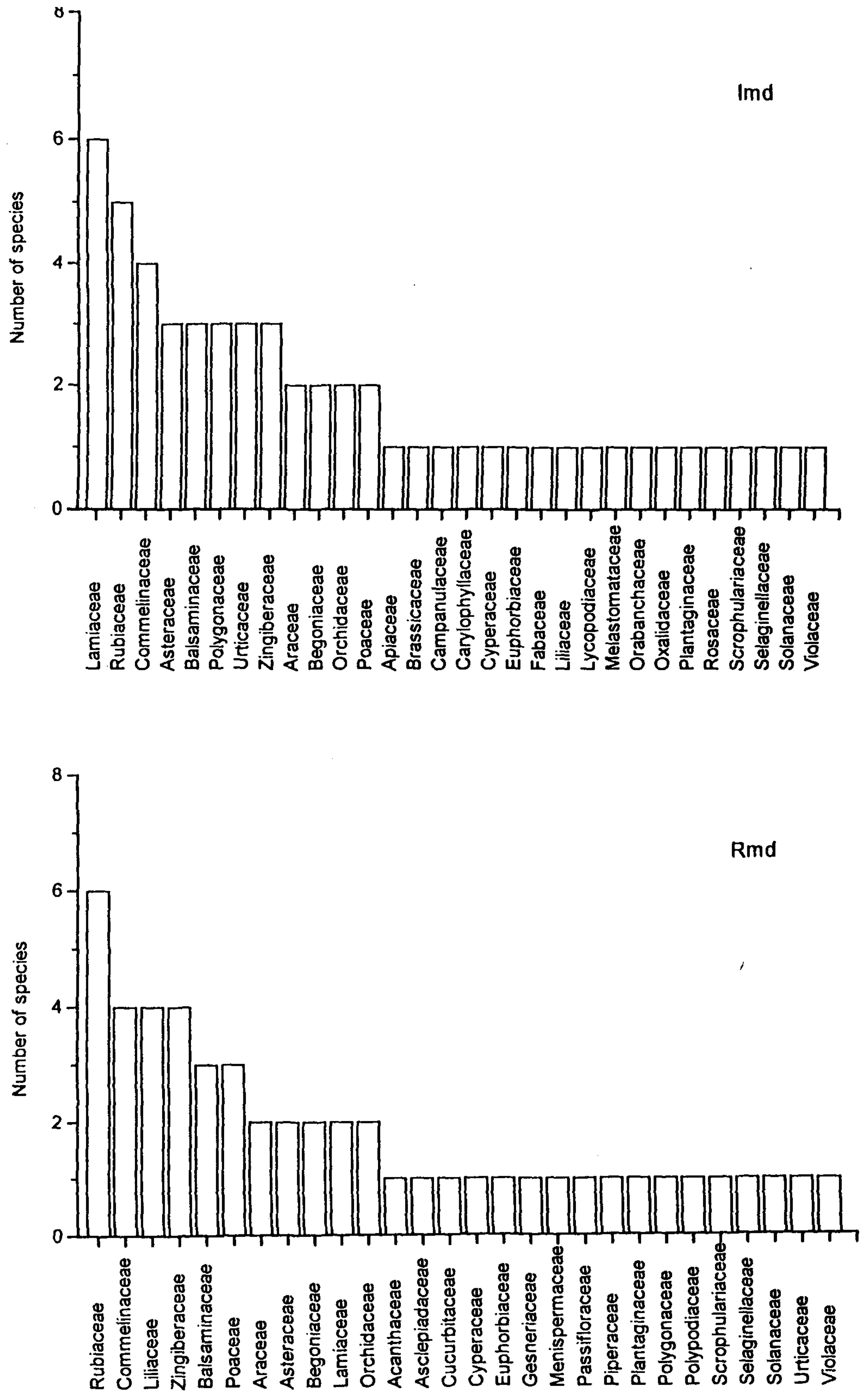


Fig. 5.10d. Family-wise distribution of herb species in mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

disturbed stands. Class E was completely absent in all the stands (Fig. 5.11). *Psychotria erratica* in Isg, *Euonymus theifolius*, *Lasianthus sikkimensis* and *Paramigyna micrantha* in Rsg, *Boehmeria sidaefolia* and *Brynea retusa*, in Imd, and *Rubus alceofolious* and *Sarcandra glabra* in Rmd had higher frequency than the other species (Table 5.5a - 5.5d).

The distribution of herbaceous species in different frequency classes was slightly different from those observed in case of tree and shrub species. In all the stands 94 -100% of the species had <20% frequency. The frequency classes D and E were completely absent (Fig. 5.11). *Globba clarkeii* in Isg and Rsg and *Isachne himalaica* in Imd and Rmd were the most frequently encountered herbaceous species (Table 5.6 a -5.6 d).

Density

The shrub density in the four stands ranged from a minimum of 6427 to 11040 individual ha^{-1}. The undisturbed stands had lower shrub density than their corresponding mildly disturbed stands (Table 5.5 a – 5.5 d). In terms of density *Sarcandra glabra* had the maximum number of individuals (853 stems ha^{-1}) in Isg and *Euonymus theifolius* (1347 stems ha^{-1}) in Rsg whereas, *Brynea retusa* with 573-800 stems ha^{-1} ranked as the most abundant species in both the mildly disturbed stands.

The mean herb density was 2470, 1607, 2077 and 1887 individual $100m^2$ in Isg, Rsg, Imd and Rmd respectively. In Isg, *Globba clarkeii*, *Selaginella* sp. and in Rsg, *Isachne himalaica* and *Globba clarkeii* had the highest number of individuals,

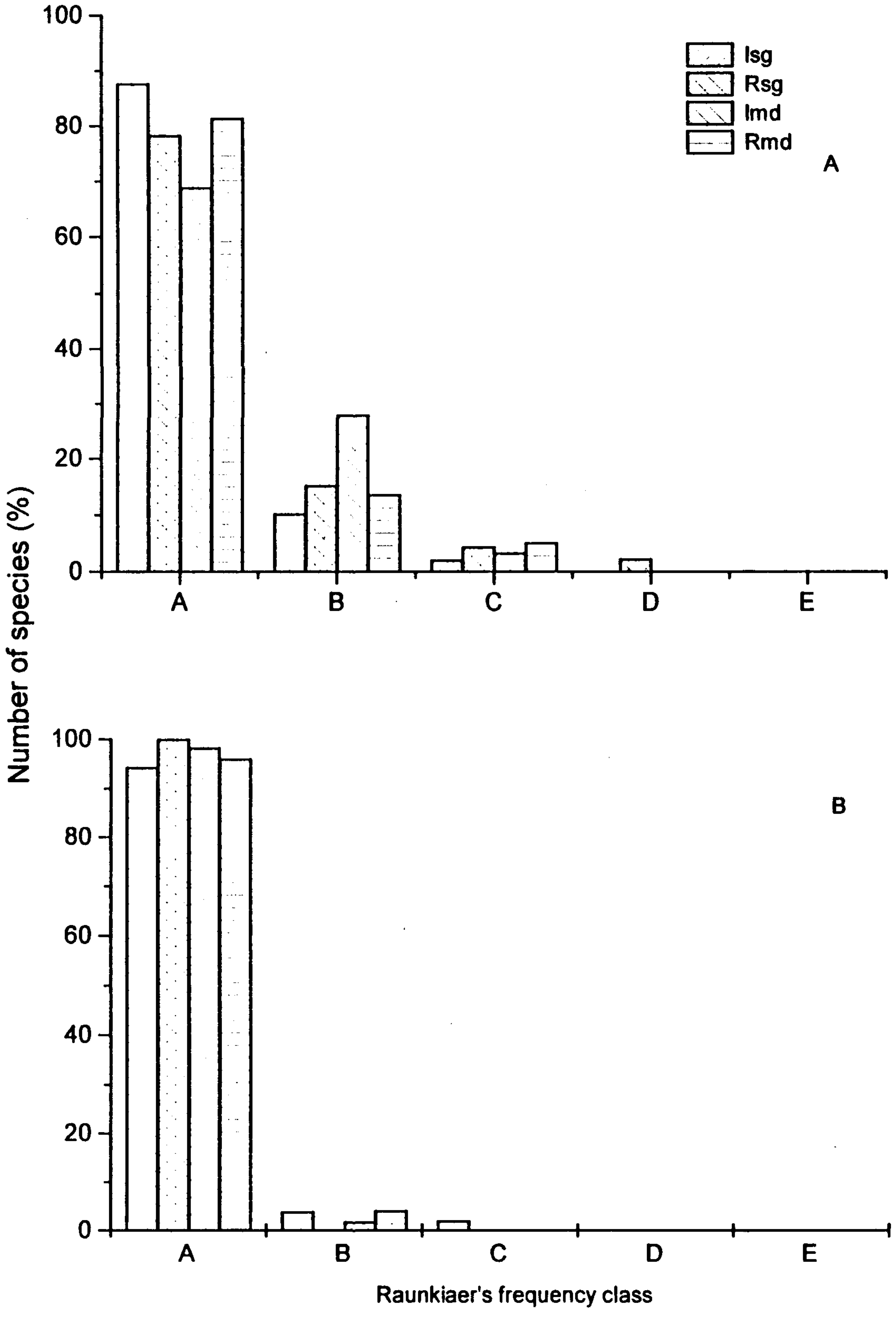


Fig. 5.11. Distribution of shrub (A) and herb (B) species in the undisturbed (Isg, Rsg) and mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

Table 5.5 a. Frequency (%), density (plant ha^{-1}) and IVI of shrub species in undisturbed stand at Ialong.

Name of species	Family	Frequency	Density	IVI
Achyranthes aspera Linn.	Amaranthaceae	16.67	160	4.96
Aralia thomsonii Seem.	Araliaceae	3.33	13	0.70
Ardisia griffithii Clarke	Myrsinaceae	6.67	27	1.40
Boehmeria platyphylla D.Don	Urticaceae	3.33	40	1.12
Boehmeria sidaefolia Wedd.	Urticaceae	6.67	80	2.23
Breynia retusa (Dennst.) Alst.	Euphorbiaceae	20.00	173	5.67
Corylopsis himalayana Griff.	Hamamelidaceae	10.00	53	2.31
Cayratia japonica (Thunb.) Gagnep.	Vitaceae	13.33	133	4.05
Desmodium heterocarpom (Linn.) DC.	Fabaceae	3.33	27	0.91
Dioscorea kamoonensis Kunth	Dioscoreaceae	16.67	120	4.34
Embelia subcoriaceae (Clarke) Mez.	Myrsinaceae	6.67	27	1.40
Embelia vestita Roxb.	Myrsinaceae	10.00	67	2.52
Erythroxylum kunthianum Kurz.	Erythroxylaceae	16.67	93	3.93
Euonymus theifolius Wall. ex Laws	Celastraceae	10.00	67	2.52
Ficus clavata Wall. ex Miq	Moraceae	6.67	40	1.61
Ficus fulva Bl.	Moraceae	6.67	27	1.40
Ficus gasparrinia Miq.	Moraceae	6.67	67	2.03
Gomphostemma parviflorum Benth	Lamiaceae	13.33	80	3.22
Goniothalamus sesquipedalis (Wall.) Hk.f.& Th.	Annonaceae	10.00	80	2.73
Inula cappa (D.Don) DC.	Asteraceae	16.67	120	4.34
Jasminum dispermum Wall.	Oleaceae	10.00	67	2.52
Jasminum nepalense Spreng.	Oleaceae	10.00	40	2.11
Lasianthus lucidus Bl.	Rubiaceae	20.00	120	4.84
Lasianthus sikkimensis Hook.f.	Rubiaceae	40.00	427	12.58
Lindera caudata (Nees) Hook.f.	Lauraceae	3.33	13	0.70
Maesa indica (Roxb.) Wall.	Myrsinaceae	20.00	147	5.25
Neillia thyrsiflora D.Don.	Rosaceae	3.33	27	0.91
Phlogacanthus pubinervis T.And.	Acanthaceae	6.67	40	1.61
Plectranthus striatus Benth.	Lamiaceae	20.00	200	6.08
Polygonum molle D.Don	Polygonaceae	26.67	267	8.11
Prinsepia utilis Royle	Rosaceae	16.67	93	3.93
Psychotria curviflora Wall.	Rubiaceae	33.33	200	8.06
Psychotria erratica Hook.f.	Rubiaceae	46.67	453	13.98
Rhynchotechum ellipticum (Dietr.) A.DC.	Gesneriaceae	23.33	547	11.97
Rhynchotechum vestitum Clarke	Gesneriaceae	10.00	107	3.14
Rauvolfia densiflora (Wall.) Hook.f.	Apocynaceae	13.33	93	3.43
Rubus ellipticus Smith	Rosaceae	16.67	213	5.79
Rubus assamensis Focke	Rosaceae	6.67	40	1.61
Rubus khasianus Cordat	Rosaceae	6.67	40	1.61
Sarcandra glabra (Thunb.) Nakai	Chloranthaceae	40.00	853	19.22
Senecio cappa D.Don	Asteraceae	13.33	200	5.09
Shuteria vestita W. & A.	Fabaceae	13.33	133	4.05
Smilax myrtillus DC.	Smilacaceae	13.33	227	5.51
Solanum aculeatissimum Jacq.	Solanaceae	16.67	107	4.13
Teucrium quadrifarium Buch.-Ham.	Lamiaceae	3.33	13	0.70
Triumfetta tomentosa Bojer	Tiliaceae	6.67	53	1.82
Urena lobata Linn.	Malvaceae	3.33	27	0.91
Viburnum foetidum Wall.	Caprifoliaceae	13.33	120	3.85
Zanthoxylum oxyphyllum Edgew.	Rutaceae	13.33	67	3.02
Total			**6427**	**200**

Table 5.5 b. Frequency (%), density (plant ha^{-1}) and IVI of shrub species in undisturbed stand at Raliang.

Name of species	Family	Frequency	Density	IVI
Acacia pennata (Linn.) Willd.	Mimosaceae	6.67	53	1.60
Boehmeria platyphylla D.Don	Urticaceae	10.00	107	2.80
Bridelia sp.	Euphorbiaceae	10.00	40	2.00
Brucea mollis Kurz	Simaroubaceae	16.67	187	4.80
Breynia retusa (Dennst.) Alst.	Euphorbiaceae	20.00	187	5.30
Capparis sp.	Capparaceae	3.33	13	0.70
Cinnamomum pauciflorum Nees	Lauraceae	3.33	13	0.70
Clerodendrum lasiocephalum Clarke	Verbenaceae	6.67	40	1.50
Clerodendrum wallichii Merr.	Verbenaceae	33.33	360	9.40
Dioscorea koomensis Kunth	Dioscoreaceae	6.67	27	1.30
Elaeagnus pyriformis Hook. f.	Elaeagnaceae	10.00	53	2.10
Embelia parviflora DC.	Myrsinaceae	30.00	373	9.00
Erythroxylum kunthianum Kurz	Erythroxylaceae	6.67	80	2.00
Euonymus lawsonii Clarke & Prain	Celastraceae	3.33	27	0.80
Euonymus theifolius Wall ex Laws	Celastraceae	56.67	1347	25.00
Ficus clavata Wall. ex Miq	Moraceae	3.33	13	0.70
Ficus fulva Bl.	Moraceae	6.67	27	1.30
Ficus gasparrina Miq.	Moraceae	6.67	67	1.80
Flemingia macrophylla (Willd.) Prain	Fabaceae	3.33	53	1.20
Gomphostemma parviflorum Benth.	Lamiaceae	3.33	27	0.80
Goniothalamus sesquipedalis Hk.f. & Th.	Annonaceae	13.33	267	5.30
Jasminum lanceolarium Roxb.	Oleaceae	3.33	13	0.70
Jasminum dispermum Wall.	Oleaceae	26.67	333	8.10
Jasminum nepalense Spreng.	Oleaceae	23.33	173	5.60
Lasianthus lucidus Bl.	Rubiaceae	36.67	293	9.00
Lasianthus sikkimensis Hook.f.	Rubiaceae	56.67	720	17.30
Lindera caudata (Nees) Hook.f.	Lauraceae	6.67	27	1.30
Maesa indica (Roxb.) Wall.	Myrsinaceae	6.67	40	1.50
Munronia pinnata (Wall.) Harms	Meliaceae	36.67	413	10.50
Paramignya micrantha Kurz	Rutaceae	70.00	1293	26.30
Passiflora edulis Sims.	Passifloraceae	3.33	13	0.70
Plectranthus striatus Benth.	Lamiaceae	6.67	80	2.00
Prinsepia utilis Royle	Rosaceae	10.00	80	2.50
Pseuderanthemum indicum (Nees) A.M.&J.M.Cowan	Acanthaceae	6.67	53	1.60
Psychotria curviflora Wall.	Rubiaceae	20.00	160	4.90
Psychotria erratica Hook.f.	Rubiaceae	6.67	67	1.80
Rhynchotechum ellipticum (Dietr.) A.DC.	Gesneriaceae	6.67	253	4.10
Rauvolfia densiflora (Wall.) Hook.f.	Apocynaceae	10.00	53	2.10
Rubus alceifolius Poir.	Rosaceae	3.33	13	0.70
Rubus khasianus Cordat	Rosaceae	3.33	27	0.80
Sarcarandra glabra (Thunb.) Nakai	Chloranthaceae	23.33	213	6.10
Smilax ferox Kunth	Smilacaceae	10.00	67	2.30
Smilax perfoliata Lour.	Smilacaceae	20.00	213	5.60
Unidentified sp.	Unidentified	10.00	40	2.00
Vitis heyneana Roem. & Schult.	Vitaceae	3.33	13	0.70
Zanthoxylum oxyphyllum Edgew.	Rutaceae	10.00	53	2.10
Total			**8067**	**200**

Table 5.5c. Frequency (%), density (plant ha-1) and IVI of shrub species in mildly disturbed stand at Ialong.

Name of species	Family	Frequency	Density	IVI
Achyranthes aspera Linn.	Amaranthaceae	26.67	253	4.90
Ardisia griffithii Clarke	Myrsinaceae	10.00	67	1.57
Artemisia nilagirica (Clarke) Pamp.	Asteraceae	16.67	680	7.94
Boehmeria platyphylla D.Don	Urticaceae	40.00	440	7.91
Boehmeria sidaefolia Wedd.	Urticaceae	43.33	360	7.47
Breynia retusa (Dennst.) Alst.	Euphorbiaceae	60.00	573	11.02
Cayratia japonica (Thunb.) Gagnep.	Vitaceae	6.67	40	1.01
Corylopsis himalayana Griff.	Hamamelidaceae	13.33	67	1.89
Cassia floribunda Cav.	Fabaceae	13.33	187	3.01
Celastrus stylosus Wall.	Celastraceae	3.33	13	0.44
Clerodendrum bracteatum Walp.	Verbenaceae	23.33	147	3.58
Desmodium heterocarpum (Linn.) DC.	Fabaceae	10.00	67	1.57
Dioscorea kamoonensis Kunth	Dioscoreaceae	6.67	27	0.88
Elaeagnus pyriformis Hook.f.	Elaeagnaceae	6.67	27	0.88
Embelia subcoriacea (Clarks) Mez	Myrsinaceae	3.33	13	0.44
Erythroxylon kunthianum Kurz	Erythroxylaceae	30.00	333	5.96
Euonymus theifolius Wall ex Laws	Celastraceae	20.00	160	3.39
Eupatorium adenophorum Spreng.	Asteraceae	23.33	280	4.83
Ficus clavata Wall. Ex Miq.	Moraceae	6.67	40	1.01
Ficus fulva Bl.	Moraceae	6.67	27	0.88
Ficus gasparriniana Miq.	Moraceae	10.00	147	2.32
Flemingia macrophylla (Willd.) Prain	Fabaceae	16.67	160	3.08
Girardinia palmata (Forsk.) Gaud.	Urticaceae	36.67	560	8.71
Goniothalamus sequipedalis (Wall.) HK.f.&Th.	Annonaceae	13.33	320	4.26
Hedyotis scandens D.Don	Rubiaceae	23.33	320	5.20
Jasminum dispermum Wall.	Oleaceae	10.00	53	1.45
Jasminum lanceolarium Roxb.	Oleaceae	6.67	40	1.01
Jasminum nepalense Spreng.	Oleaceae	26.67	133	3.77
Lantana camara Linn.	Verbenaceae	26.67	413	6.39
Lasianthus sikkimensis Hook.f.	Rubiaceae	10.00	107	1.95
Lindera caudata (Nees) Hook.f.	Lauraceae	3.33	27	0.57
Melastoma nepalensis Lodd.	Melastomataceae	10.00	227	3.07
Maesa indica (Roxb.) Wall.	Myrsinaceae	20.00	120	3.02
Neillia thyrsiflora D.Don	Rosaceae	30.00	280	5.46
Passiflora edulis Sims.	Passifloraceae	10.00	53	1.45
Passiflora stipulata Aubl.	Passifloraceae	3.33	27	0.57
Phlogacanthus pubinervis T.And.	Acanthaceae	13.33	93	2.14
Plectranthus striatus Benth.	Lamiaceae	40.00	520	8.65
Prinsepia utilis Royle	Rosaceae	3.33	13	0.44
Prioptropis cytisoides (Roxb.) W. & A.	Fabaceae	16.67	120	2.70
Psychotria curviflora Wall.	Rubiaceae	30.00	267	5.34
Psychotria erratica Hook.f.	Rubiaceae	26.67	187	4.27
Rhynchotechum ellipticum (Dietr) A.DC.	Gesneriaceae	3.33	93	1.19
Rhynchotechum vestitum Clarke	Gesneriaceae	20.00	213	3.89
Rubus ellipticus Smith	Rosaceae	3.33	13	0.44
Rubus alceifolius Poir.	Rosaceae	23.33	213	4.21
Rubus assamensis Focke	Rosaceae	20.00	187	3.64
Rubus khasianus Cordat	Rosaceae	13.33	107	2.26
Sarcandra glabra (Thunb.) Nakai	Chloranthaceae	20.00	213	3.89
Shuteria vestita W. & A.	Fabaceae	6.67	53	1.13
Senecio cappa D.Don	Asteraceae	30.00	240	5.09

Sida rhomboidifolia Linn.	Malvaceae	13.33	107	2.26
Smilax perfoliata Lour.	Smilacaceae	13.33	133	2.51
Solanum aculeatissimum Jacq.	Solanaceae	23.33	200	4.08
Solanum khasianum Clarke	Solanaceae	20.00	133	3.14
Symplocos crataegoides D.Don	Symplocaceae	6.67	40	1.01
Teucrium quadrifarium Buch.-Ham.	Lamiaceae	40.00	307	6.66
Trichosanthes wallichiana (Ser.) Wt.	Cucurbitaceae	3.33	27	0.57
Triumfetta tomentosa Bojer	Tiliaceae	6.67	80	1.38
Urena lobata Linn.	Malvaceae	20.00	240	4.14
Zanthoxylum oxyphyllum Edgew.	Rutaceae	13.33	93	2.14
Total			**10680**	**200**

Table 5.5d. Frequency (%), density (plant ha^{-1}) and IVI of shrub species in mildly disturbed stand at Raliang.

Name of species	Family	Frequency	Density	IVI
Acacia pennata (Linn.) Willd.	Mimosaceae	40.00	373	7.59
Ardisia griffithii Clarke	Myrsinaceae	10.00	107	2.02
Boehmeria platyphylla D.Don	Urticaceae	20.00	360	5.37
Boehmeria sidaefolia Wedd.	Urticaceae	16.67	200	3.57
Bridelia sp.	Euphorbiaceae	3.33	13	0.47
Brucea mollis Kurz	Simaroubaceae	6.67	80	1.42
Breynia retusa (Dennst.) Alst.	Euphorbiaceae	56.67	800	13.21
Cayratia japonica (Thunb.) Gagnep.	Vitaceae	6.67	53	1.18
Cinnamomum pauciflorum Nees	Lauraceae	16.67	93	2.60
Clematis buchaniana DC.	Ranunculaceae	6.67	27	0.94
Clerodendrum bracteatum Walp.	Verbenaceae	26.67	267	5.22
Clerodendrum lasiocephalum Clarke	Verbenaceae	10.00	133	2.26
Clerodendron wallichii Merr	Verbenaceae	13.33	93	2.25
Dioscorea kamoonensis Kunth	Dioscoreaceae	10.00	107	2.02
Embelia parviflora DC.	Myrsinaceae	10.00	107	2.02
Embelia subcoriaceae (Clarke) Mez.	Myrsinaceae	3.33	13	0.47
Erythroxylum kunthianum Kurz	Erythroxylaceae	36.67	320	6.76
Euonymus theifolius Laws.	Celastraceae	6.67	80	1.43
Eupatorium adenophorum Spreng.	Asteraceae	13.33	240	3.58
Ficus clavata Wall. ex Miq	Moraceae	3.33	27	0.59
Ficus fulva Bl.	Moraceae	3.33	27	0.59
Ficus gasparriniana Miq.	Moraceae	16.67	133	2.96
Flemingia macrophylla (Willd.) Prain	Fabaceae	20.00	413	5.85
Gomphostemma parviflorum Benth.	Lamiaceae	40.00	560	9.28
Goniothalamus sequipedalis (Wall.) Hk.f.&Th.	Annonaceae	10.00	200	2.86
Hodgsonia macrocarpa Bl.	Cucurbitaceae	3.33	13	2.47
Jasminum dispermum Wall.	Oleaceae	10.00	187	2.74
Jasminum lanceolarium Roxb.	Oleaceae	16.67	107	2.72
Jasminum nepalense Spreng.	Oleaceae	16.67	160	3.20
Lantana camara Linn.	Verbenaceae	20.00	200	3.92
Lasianthus lucidus Bl.	Rubiaceae	13.33	160	2.85
Lasianthus sikkimensis Hook.f.	Rubiaceae	10.00	120	2.14
Lindera caudata (Nees) Hook.f.	Lauraceae	13.33	80	2.13
Melastoma nepalense Lodd.	Melastomataceae	10.00	133	2.26
Maesa indica (Roxb.) Wall.	Myrsinaceae	13.33	80	2.13
Munronia pinnata (Wall.) Harms	Meliaceae	13.33	160	2.85
Mussaenda roxburghii Hk.f.	Rubiaceae	3.33	13	0.47

Paramignya micrantha Kurz	Rutaceae	20.00	213	4.04
Passiflora edulis L.	Passifloraceae	3.33	13	0.47
Plectranthus striatus Benth.	Lamiaceae	30.00	507	7.75
Prinsepia utilis Royle	Rosaceae	6.67	67	1.31
Psychotria curviflora Wall.	Rubiaceae	20.00	213	4.04
Psychotria erratica Hook.f.	Rubiaceae	13.33	200	3.22
Rauvolfia densiflora (Wall.) Hook.f.	Apocynaceae	40.00	520	8.92
Rubus ellipticus Smith	Rosaceae	3.33	40	0.71
Rubus alceifolius Poir.	Rosaceae	43.33	427	8.43
Rubus assamensis Focke	Rosaceae	10.00	213	2.98
Rubus khasianus Cordat	Rosaceae	20.00	227	4.16
Sacaranda glabra (Thunb.) Nakai	Chloranthaceae	46.67	720	11.43
Senecio cappa D.Don	Asteraceae	10.00	107	2.02
Smilax perfoliata Lour.	Smilacaceae	26.67	213	4.74
Solanum aculeatissimum Jacq.	Solanaceae	13.33	120	2.49
Solanum khasianum Clarke	Solanaceae	10.00	80	1.78
Teucrium quadrifarium Buch.-Ham.	Lamiaceae	16.67	333	4.77
Toddalia asiatica (Linn.) Lamk.	Rutaceae	10.00	40	1.41
Triumfetta tomentosa Bojer	Tiliaceae	6.67	93	1.55
Urena lobata Linn.	Malvaceae	16.67	213	3.69
Vitis heyneana Roem. & Schult.	Vitaceae	10.00	53	1.54
Zanthoxylum oxyphyllum Edgew.	Rutaceae	23.33	187	4.15
Total			**11040**	**200**

Table 5.6a. Frequency (%), density (plant 100m^2) and IVI of herb species in undisturbed stand at Ialong.

Name of species	Family	Frequency	Density	IVI
Achyrospermum wallichianum (Benth.) Hk.f.	Lamiaceae	6.67	50	3.70
Aeginetia indica Linn.	Orobancaceae	3.33	7	1.11
Anoectochilus roxburghii (Wall.) Lindl.	Orchidaceae	3.33	10	1.25
Arisaema consanguineum Schott.	Araceae	6.67	10	2.09
Arisaema tortuosum (Wall.) Schott.	Araceae	6.67	7	1.95
Balanophora dioica R.Br.	Balanophoraceae	3.33	27	1.92
Begonia palmata D.Don	Begoniaceae	6.67	27	2.76
Begonia sp	Begoniaceae	3.33	57	3.13
Calanthe clavata Lindl.	Orchidaceae	3.33	107	5.16
Carex filicinia Nees	Cyperaceae	6.67	10	2.09
Commelina paludosa Bl.	Commelinaceae	10.00	37	4.01
Costus speciosus (Koenig) Smith	Zingiberaceae	3.33	7	1.11
Cyanotis vaga (Lour) J.A.& J.H.Schult	Commelinaceae	10.00	37	4.01
Cyclea bicristata (Griff.) Diels	Menispermaceae	3.33	3	0.98
Dianella ensata (Thunb.) R.J.Henderson	Liliaceae	10.00	13	3.06
Disporum cantoniense (Lour.) Merr.	Liliaceae	6.67	17	2.36
Elatostemma hookerianum Wedd.	Urticaceae	10.00	107	6.84
Elsholtzia strobilifera (Benth) Benth	Lamiaceae	3.33	40	2.46
Forrestica mollissima (Bl.) Kds.	Commelinaceae	13.33	117	8.08
Globba clarkei Baker	Zingiberaceae	43.33	460	29.55
Gomphostemma nutans Hook.f.	Lamiaceae	3.33	137	6.37
Gynura cusimbusa (D.Don) S. Moore	Asteraceae	3.33	3	0.98
Hedychium coccineum Smith	Zingiberaceae	3.33	3	0.98
Hedychium ellipiticum Smith	Zingiberaceae	3.33	7	1.11
Hedychium gracile Roxb.	Zingiberaceae	6.67	57	3.97
Impatiens benthamii V. Steenis	Balsaminaceae	10.00	53	4.68
Impatiens chinensis Linn.	Balsaminaceae	3.33	27	1.92
Impatiens drepanophora Hook.f.	Balsaminaceae	3.33	23	1.78
Impatiens juripa Hk.f. & Th	Balsaminaceae	3.33	10	1.24
Impatiens khasiana Hk.f.	Balsaminaceae	13.33	33	4.71
Isachne himalaica Hook.f.	Poaceae	33.33	200	16.50
Lophatherum gracile Brongn.	Poaceae	6.67	50	3.70
Malaxis latifolia Sm.	Orchidaceae	3.33	17	1.52
Murdannia gigantea (Vahl.) Bruck.	Commelinaceae	6.67	13	2.22
Murdannia nudiflora (Linn.) Brenan	Commelinaceae	6.67	13	2.22
Ophiopogon parviflorus (Hk.f.) Hara	Liliaceae	6.67	10	2.09
Ophiorrhiza nutans Clarke	Rubiaceae	6.67	27	2.76
Paederia foetida Linn.	Rubiaceae	6.67	7	1.95
Panicum brevifolium Linn.	Poaceae	13.33	73	6.33
Passiflora nepalensis Wall.	Passifloraceae	6.67	10	2.09
Pilea umbrosa Wedd.	Urticaceae	3.33	50	2.86
Pogostemon striogsus (Benth.) Benth.	Lamiaceae	3.33	10	1.25
Pouzolzia hirta (Bl.) Hassk.	Urticaceae	3.33	27	1.92
Scutellaria discolor Benth.	Lamiaceae	3.33	27	1.92
Selaginella sp.	Selaginellaceae	36.67	237	18.83
Smithia ciliata Royle	Fabaceae	3.33	40	2.46
Solanum myriacanthum Dunal.	Solanaceae	3.33	10	1.25

Sonerila khasiana Clarke	Melastomataceae	6.67	50	3.70
Spilanthus paniculata DC.	Asteraceae	3.33	33	2.19
Torenia diffusa D.Don	Scrophulariaceae	3.33	7	1.11
Viola sikkimensis W.Becker	Violaceae	3.33	13	1.38
Zingiber rubens Roxb.	Zingiberaceae	10.00	47	4.41
Total			**2470**	**200**

Table 5.6b. Frequency (%), density (plant $100m^2$) and IVI of herb species in undisturbed stand at Raliang.

Name of species	Family	Frequency	Density	IVI
Anoectochilus roxburghii (Wall.) Lindl.	Orchidaceae	10.00	10	3.60
Anotis wightiana Hk.f.	Rubiaceae	6.67	17	3.00
Arisaema consanguineum Schott.	Araceae	10.00	17	4.00
Arisaema tortuosum (Wall.) Schott.	Araceae	6.67	10	2.60
Asparagus filicinus Buch.-Ham.	Liliaceae	10.00	13	3.80
Begonia palmata D.Don	Begoniaceae	3.33	17	2.00
Begonia sp.	Begoniaceae	3.33	17	2.00
Chirita oblongifolia (Roxb.) Sinclair	Gesneriaceae	3.33	7	1.40
Colosacia esculanta (Linn.) Schott	Araceae	3.33	3	1.20
Costus speciosus (Koenig) Smith	Zingiberaceae	6.67	13	2.80
Cyanotis vaga (Lour) J.A.&J.H.Schult.	Commelianaceae	6.67	33	4.00
Cyclea bicristata (Griff.) Diels	Menispermaceae	6.67	10	2.60
Dianella ensata (Thunb.) R.J.Henderson	Liliaceae	3.33	3	1.20
Disporum cantoniense (Lour.) Merr.	Liliaceae	3.33	7	1.40
Elatostemma disectum Wedd.	Urticaceae	6.67	60	5.70
Elatostemma hookerianum Wedd.	Urticaceae	6.67	70	6.30
Floscopa scandens Lour.	Commelinaceae	10.00	50	6.10
Globba clarkei Baker	Zingiberaceae	20.00	130	14.00
Gomphostemma velutinum Benth.	Lamiaceae	3.33	23	2.40
Hedychium ellipticum Smith	Zingiberaceae	3.33	3	1.20
Hedychium gracile Roxb.	Zingiberaceae	3.33	7	1.40
Heterostemma alatum Wt.	Asclepiadaceae	16.67	27	6.60
Impatiens benthamii V.Steenis	Balsaminaceae	13.33	60	7.70
Impatiens khasiana HK.f.	Balsaminaceae	3.33	10	1.60
Impatiens laevigata Hook.f.	Balsaminaceae	6.67	83	7.10
Isachne himalaica Hook.f.	Poaceae	20.00	167	16.30
Lophotherum gracile Brongn.	Poaceae	20.00	70	10.20
Malaxis latifolia Sm.	Orchidaceae	10.00	20	4.20
Murdannia gigantea (Vahl) Bruck.	Commelinaceae	6.67	17	3.00
Ophiopogon parviflorus (Hk.f.) Hara	Liliaceae	3.33	7	1.40
Ophiorrhiza mungos Linn.	Rubiaceae	13.33	117	11.20
Paederia foetida Linn.	Rubiaceae	3.33	7	1.40
Panicum brevifolium Linn.	Poaceae	6.67	43	4.70
Passiflora nepalensis Wall.	Passifloraceae	3.33	7	1.40
Peliosanthes bakeri Hook.f.	Liliaceae	6.67	100	8.20
Pericampylus glaucus (Lamk.) Merr.	Menispermaceae	3.33	3	1.20
Pilea umbrosa Wedd.	Urticaceae	6.67	83	7.10
Piper peepuloides Roxb.	Piperaceae	3.33	7	1.40

Polyura geminata Hook.f.	Rubiaceae	6.67	63	5.90
Scutellaria discolor Benth.	Lamiaceae	10.00	33	5.00
Selaginella sp.	Selaginellaceae	16.67	97	10.90
Solanum myriacanthum Dunal.	Solanaceae	6.67	10	2.60
Trichosanthes himalensis Clarke	Cucurbitaceae	3.33	3	1.20
Viola sikkimensis W.Becker	Violaceae	3.33	10	1.60
Zingiber rubens Roxb.	Zingiberaceae	10.00	433	5.60
Total			**1607**	**200**

Table 5.6c. Frequency (%), density (plant 100m²) and IVI of herb species in mildly disturbed stand at Ialong.

Name of species	Family	Frequency	Density	IVI
Achyrospermum wallichianum (Benth.) Hk.f.	Lamiaceae	3.33	7	1.10
Aeginetia indica Linn.	Orabancaceae	3.33	7	1.10
Arisaema consanguineum Schott.	Araceae	6.67	33	3.20
Begonia palmata D.Don	Begoniaceae	6.67	40	3.50
Begonia sp.	Begoniaceae	3.33	20	1.80
Borreria articularis (L.f.) F.N. Williams	Rubiaceae	3.33	13	1.40
Cardamine hirsuta Linn.	Brassicaceae	3.33	10	1.30
Carex filicinia Nees.	Cyperaceae	3.33	3	1.00
Colocasia esculenta (Linn.) Schott	Araceae	3.33	3	1.00
Commelina paludosa Bl.	Commelinaceae	10.00	30	3.80
Costus speciosus (Koenig) Smith	Zingiberaceae	6.67	7	1.90
Crassocephalum crepidioides (Benth.) Moore	Asteraceae	6.67	10	2.10
Cyanotis vaga (Lour) J.A.&J.H.Schult.	Commelinaceae	20.00	107	9.90
Drymaria cordata (Linn.) Roem & Schult.	Caryophyllaceae	6.67	117	7.20
Elatostemma hookerianum Wedd.	Urticaceae	6.67	40	3.50
Elsholtzia blanda (Benth.) Benth.	Lamiaceae	6.67	13	2.20
Elsholtzia strobilifera (Benth.) Benth.	Lamiaceae	3.33	47	3.00
Forrestia mollissima (Bl.) Kds.	Commelinaceae	6.67	37	3.40
Galinsoga parviflora Cav.	Asteraceae	13.33	113	8.70
Globba clarkei Baker	Zingiberaceae	16.67	97	8.70
Gynura cusimbusa (D.Don) S. Moore	Asteraceae	3.33	3	1.00
Hedychium sp.	Zingiberaceae	3.33	13	1.40
Hedyotis tenelliflora Bl.	Rubiaceae	6.67	63	4.60
Hedyotis uncinella Hook. & Arn.	Rubiaceae	3.33	17	1.60
Hydrocotyle javanica Thunb.	Apiaceae	6.67	27	2.90
Impatiens benthamii V.Steenis	Balsaminaceae	16.67	93	8.50
Impatiens chinensis Linn.	Balsaminaceae	13.33	83	7.20
Impatiens khasiana Hk.f.	Balsaminaceae	6.67	17	2.40
Isachne himalaica Hook.f.	Poaceae	36.67	170	17.00
Leucus ciliata Benth.	Lamiaceae	6.67	10	2.10
Lophotherum gracile Brongn.	Poaceae	20.00	93	9.30
Lycopodium sp.	Lycopodiaceae	3.33	7	1.10
Malaxis latifolia Sm.	Orchidaceae	3.33	17	1.60
Murdannia gigantae (Vahl.) Bruck.	Commelinaceae	10.00	17	3.20
Ophiophogon parviflorus (Hk.f.) Hara	Liliaceae	6.67	7	1.90
Ophiorrhiza nutans Clarke	Rubiaceae	3.33	13	1.40

Oxalis corniculata Linn.	Oxalidaceae	6.67	13	2.20
Paederia foetida Linn.	Rubiaceae	3.33	7	1.10
Phyllanthus urinaria Linn.	Euphorbiaceae	3.33	7	1.10
Pilea umbrosa Wedd.	Urticaceae	10.00	60	5.30
Plantago erosa Wall.	Plantaginaceae	3.33	10	1.30
Pogostemon strigosus (Benth.) Benth.	Lamiaceae	3.33	27	2.10
Polygonum barbatum Linn.	Polygonaceae	10.00	43	4.50
Polygonum capitatum D.Don	Polygonaceae	6.67	37	3.40
Polygonum dibotrys D.Don	Polygonaceae	3.33	60	3.70
Potentilla fulgens Wall.	Rosaceae	3.33	13	1.40
Pouzolzia hirta (Bl.) Hassk.	Urticaceae	6.67	27	2.90
Pratia begoniifolia (Wall.) Lindl.	Campanulaceae	10.00	30	3.80
Scutellaria discolor Benth.	Lamiaceae	13.33	40	5.10
Selaginella sp.	Selaginellaceae	13.33	97	7.90
Smithia ciliata Royle	Fabaceae	6.67	43	3.70
Solanum myriacanthum Dunal.	Solanaceae	3.33	7	1.10
Sonerilla khasiana Clarke	Melastomataceae	3.33	20	1.80
Spilanthes sinense (Pers.) Ames	Orchidaceae	6.67	113	7.10
Torenia diffusa D.Don	Scrophulariaceae	3.33	10	1.30
Viola sikkimensis W.Becker	Violaceae	6.67	10	2.10
Total			**2077**	**200**

Table 5.6d. Frequency (%), density (plant 100m²) and IVI of herb species in mildly disturbed stand at Raliang.

Name of species	Family	Frequency	Density	IVI
Anoectochilus roxburghii (Wall.) Lindl.	Orchidaceae	3.33	3	0.90
Arisaema consanguineum Schott	Araceae	13.33	20	4.00
Arisaema tortuosum (Wall.) Schott.	Araceae	16.67	33	5.40
Asparagus filicinus Buch.-Ham.	Liliaceae	10.00	13	2.90
Begonia palmata D.Don	Begoniaceae	6.67	40	3.60
Begonia sp.	Begoniaceae	6.67	30	3.00
Carex filicinia Nees.	Cyperaceae	6.67	7	1.80
Chiritia oblongifolia (Roxb.) Sinclair	Gesneriaceae	6.67	13	2.20
Commelina paludosa Bl.	Commelinaceae	6.67	23	2.70
Costus speciosus (Koenig) Smith	Zingiberaceae	16.67	30	5.20
Cyanotis vaga (Lour.) J.A.&J.H.Schult.	Commelinaceae	13.33	70	6.60
Cyclea bicristata (Griff) Diels.	Menispermaceae	6.67	7	1.80
Dianella ensata (Thunb.) R.J.Henderson	Liliaceae	3.33	3	0.90
Disporum cantoniensis (Lour.) Merr.	Liliaceae	6.67	20	2.50
Fern sp.	Polypodiaceae	3.33	7	1.10
Floscopa scandens Lour.	Commelinaceae	3.33	13	1.40
Galinsoga parviflora Cav.	Asteraceae	6.67	50	4.10
Globba clarkei Baker	Zingiberaceae	16.67	93	8.60
Gomphostemma velutinum Benth.	Lamiaceae	6.67	10	2.00
Hedychium stenopetalum Lodd.	Zingiberaceae	3.33	7	1.10
Hedyotis tenelliflora Bl.	Rubiaceae	3.33	67	4.30
Hedyotis uncinella Hk. & Arn.	Rubiaceae	6.67	23	2.70
Heterostemma alatum Wt.	Asclepiadaceae	13.33	23	4.20
Impatiens benthamii V.Steenis	Balsaminaceae	26.67	123	12.40

Impatiens chinensis Linn.	Balsaminaceae	10.00	57	5.20
Impatiens laevigata Hook.f.	Balsaminaceae	6.67	20	2.50
Isachne himalaica Hook.f.	Poaceae	30.00	217	18.10
Lophatherum gracile Brongn.	Poaceae	20.00	107	10.00
Malaxis latifolia Sm.	Orchidaceae	10.00	33	4.00
Murdannia gigantae (Vahl.) Bruck.	Commelinaceae	13.33	30	4.50
Ophiopogon purviflorus (Hk.f.) Hara	Liliaceae	3.33	3	0.90
Ophiorrhiza mungos Linn.	Rubiaceae	6.67	40	3.60
Ophiorrhiza nutans Clarke	Rubiaceae	6.67	20	2.50
Paederia foetida Linn.	Rubiaceae	3.33	3	0.90
Panicum brevifolium Linn.	Poaceae	13.33	87	7.50
Passiflora nepalensis Wall.	Passifloraceae	13.33	30	4.50
Phyllanthus urinaria Linn.	Euphorbiaceae	3.33	3	0.90
Piper peepuloides Roxb.	Piperaceae	3.33	7	1.10
Plantago erosa Wall.	Plantaginaceae	3.33	7	1.10
Polygonum viscosum D.Don	Polygonaceae	6.67	20	2.50
Polyura geminata Hook.f.	Rubiaceae	6.67	57	4.50
Pouzolzia hirta (Bl) Hassk.	Urticaceae	3.33	17	1.60
Scutellaria discolor Benth.	Lamiaceae	20.00	77	8.40
Selaginella sp.	Selaginellaceae	13.33	123	9.50
Solanum myriacanthum Dunal.	Solanaceae	3.33	7	1.10
Spilanthus paniculata DC.	Asteraceae	6.67	30	3.00
Strobilanthes Sp.	Acanthaceae	10.00	97	7.30
Torenia diffusa D.Don	Scrophulariaceae	3.33	7	1.10
Tricosanthes himalensis Clarke	Cucurbitaceae	10.00	10	2.70
Viola sikkimensis W.Becker	Violaceae	6.67	10	2.00
Zingiber rubens Roxb.	Zingiberaceae	6.67	40	3.60
Total			**1887**	**200**

whereas in both the mildly disturbed stands *Isachne himalaica* ranked as the most abundant species (Table 5.6 a – 5.6 d).

Horizontal distribution pattern

The spatial distribution pattern of shrub species was similar to that of woody species ($\geq$5cm dbh). In all the stands 93-100% of the species showed contagious distribution pattern and only 2-7% showed random dispersion. Regular dispersion was completely absent. However, the dispersion pattern observed in case of herbaceous species was entirely different. All the species were contagiously distributed; regular and random distribution was absent (Table 5.7).

Table 5.7. Distribution pattern of shrub and herb species in the four stands.

Shrub	Number of species (% of the total)		
	Regular	Random	Contagious
Isg	-	2 (4)	47 (96)
Rsg	-	1 (2)	45 (98)
Imd	-	4 (7)	57 (93)
Rmd	-	-	59 (100)
Herb			
Isg	-	-	52 (100)
Rsg	-	-	45 (100)
Imd	-	-	56 (100)
Rmd	-	-	51 (100)

Dominance distribution pattern

The dominance distribution pattern for shrub and herb species was similar to that of woody species. It fitted a lognormal distribution with high equability and low dominance (Fig. 5.12).

Diversity and dominance

Shannon diversity index and Pielou eveness index for shrub and herb species was higher in the mildly disturbed stands as compared to undisturbed stands. However, the dominance index showed a reverse trend with higher values in the undisturbed stands (Table 5.4).

Similarity Index

The two undisturbed stands of the sacred groves were more similar to their respective mildly disturbed stands than themselves. The shrub and herb components showed higher similarity than that of the tree component (Table 5.8).

Table 5.8. Index of similarity between trees, shrubs and herbs in the four stands.

Stands	Trees	Shrubs	Herbs
Isg and Imd	67.82	70.90	64.81
Isg and Rsg	48.18	52.63	61.86
Rsg and Rmd	69.36	74.29	72.92

Discussion

The tropical rain forests, which are characterized by highly complex community organization, have five to six strata (Whitmore 1975, Richards 1996). The

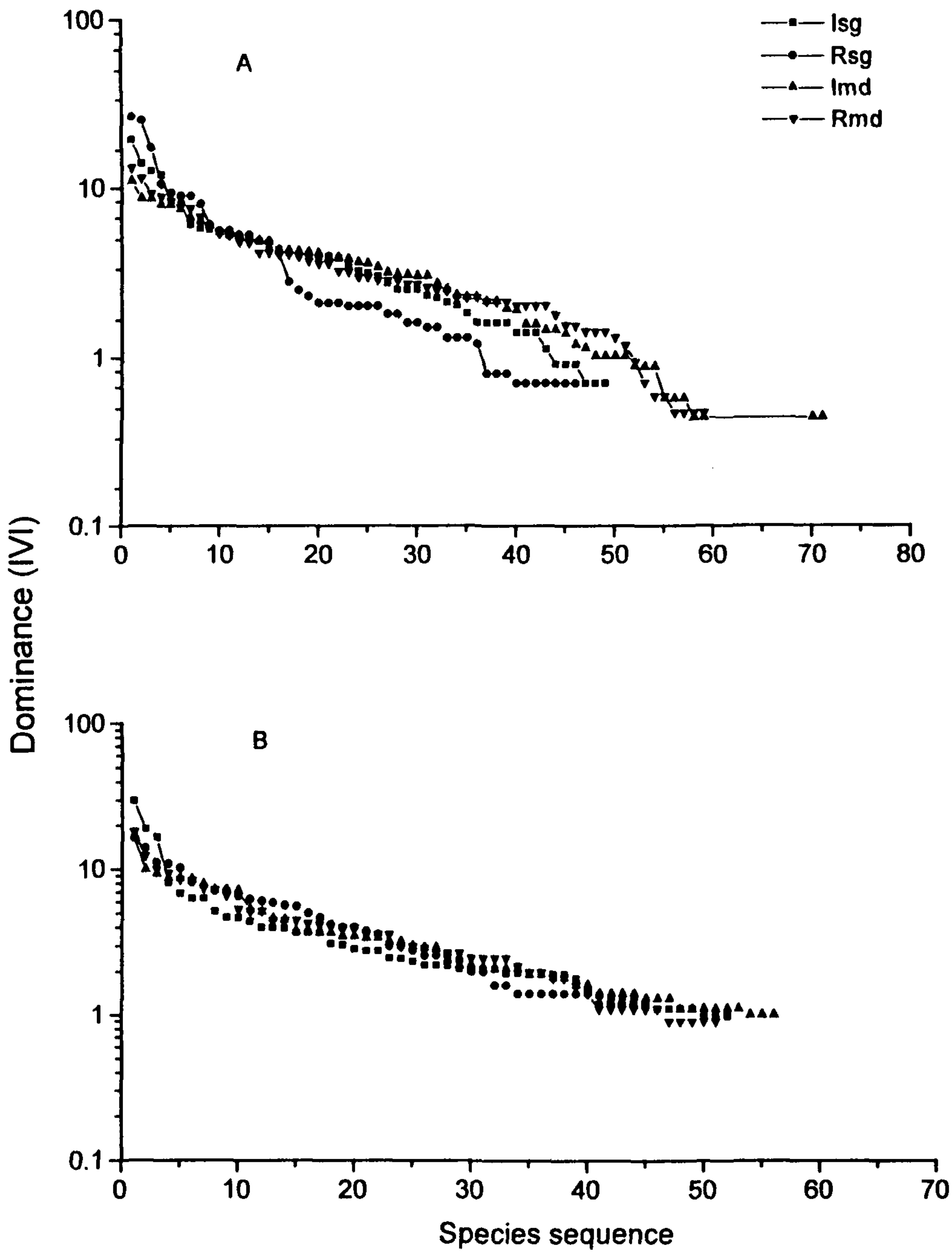


Fig. 5.12. Dominance diversity curve of shrub (A) and herb (B) species in the undisturbed (Isg, Rsg) and mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

top or the A strata is composed of emergent trees. The B and C stratum represents a continious canopy layer often with no distinction between the two (Ashton and Hall 1992, Richards 1996). In the sacred groves the emergent trees were absent and its A and B layer can be compared to the B and C layer of the tropical rain forests. The average tree height is comparable to the height of B strata of the tropical forests at Moraballi and Sarawak (Richards 1996). However, in terms of species composition, diverse plant forms, stratification (4-5 layers) and average tree height of the overstory (15-25m) it resembles more with the subtropical evergreen broad-leaved forests of South China (Box 1995 and Min Coa 1996). The shorter tree height is often linked with nutrient poor soil conditions and dry climate (Whitmore 1975, Sahanula 1995 and Visalakshi 1995). In the present case neither the climate is dry nor the soil fertility appears to be low, therefore, it may be presumed that shorter tree height may be related to altitude (Whitmore 1975, Grubb 1977, Aiba and Kitayama 1999).

It has been argued by several workers (cf. Brown 1981) that productivity of the system and structural complexity or heterogeneity determines species richness in the community. Others (Putman 1994) have argued that neither environmental productivity nor structural complexities seem sufficient of their own to explain the observed pattern of species richness. Slobodkin and Sanders (1969) opined that species richness of any community is a function of severity, variability and predictability of environment in which it develops. Therefore, diversity is seen to increase as environment become more favourable and more predictable (Putman 1994). Although it is difficult to explain the causes of high species richness in the sacred grove communities with the available data, it seems that favourable climatic condition of the area and protection over a long period of time have played major role in making the community highly complex and species-rich. In this respect they are similar to tropical forests at Luquillo Mountains in Puerto Rico (Weaver and Murphy 1990), Papua, New Guinea (Edwards1977, Edwards and Grubb 1977) and Yanamono, Peru (Gentry 1988).

The forests in which only one tree species constitutes 50-80% of the canopy trees have been considered as low-diversity forests (Connell and Lowman 1989). On the basis of this criterion, the sacred groves may be regarded as high-diversity forest since about 28% of the tree species were present in the canopy layer. The intensity of disturbance was less in the disturbed stands at Ialong and Raliang; it indicates that disturbance of mild intensity results in the increase of species richness. Disturbance is widely believed to be one of the main factors influencing variations in species diversity (Conell 1978, Huston 1994, Noss 1996). Intermediate intensity of disturbance favours the coexistence of competitive species as well as disturbance–tolerant species thereby increasing species richness. This seems to be the main reason for high species richness of the mildly disturbed stands, which was similar to the protected sacred forest in respect to other community attributes. Disturbance often leds to the creation of treefall gaps with varied microenvironmental conditions which favours many light demanding species to germinate.

Spatial distribution of species richness was not uniform in the forest; rather the groves were mosaic of low and high diversity patches. This seems to be the result of the combined effect of non-extreme stable environmental conditions and gap phase dynamics within the forest (Whittaker 1972).

Since majority of the species were contagiously distributed and frequency class A was dominant in all the stands, the forest may be termed as highly heterogeneous and patchy in terms of species distribution. Poore (1968), Ashton (1969), and Herwitz (1981) have described tropical rain forests as highly patchy community primarily due to gap-phase dynamics. Clumping of individuals of the same species is often clearly related to gap formation and dispersal mechanism of the species. Armesto *et al* (1986) compared the dispersion pattern of trees in tropical and temperate climates in different parts of the world and concluded that clumping was characteristic of forest in which formation of canopy gaps was the chief source of disturbance. Hubbell (1979) in dry tropical forest observed that all species were either clumped or randomly dispersed, with rare species more clumped than common species. Whitmore (1990) has also reported patchy distribution of ground flora in most of the tropical rain forests.

The tree species represented by one or two individuals in each stands have been considered as rare species and they constituted about 42% to 52% of the total species. Number of individuals of such species are probably kept low by a combination of unfavourable regeneration conditions, lack of appropriate habitat, or both (Hubbell 1979). In this respect also the sacred groves are similar to tropical forests, which are known to possess large number of rare tree species. For example, Paijmans (1970), Thorington *et al.* (1982), and Parthasarathy and Karthikeyan (1997) reported that 50% species in New Guinea, 40% in Barro Colorado Island, Panama, and 47% in the Western Ghats forests respectively were rare.

Abundance of young individuals in both the groves, a characteristic feature of vegetation on moist and infertile soil (Coomes and Grubb, 2000) indicates slow rate of seedling and sapling growth in the understorey, relatively low rate of seedling mortality. It may also be due to tree-fall gaps having varied microenvironmental variability (Rao *et al* 1997), which might have favoured the tree species having different regeneration requirements (Phillips *et al* 1994). The preponderance of young individuals in the mature forest has also been reported from Brazalian Amazon (Campbell *et al* 1992), Costa Rica (Nadkarni *et al* 1995) and Western Ghats (Parthasarathy 2001).

The basal cover (ranging from 36.52 m^2 ha^{-1} and 71.44 m^2 ha^{-1}) in both lalong and Raliang is close to other tropical forests such as equatorial forest (10-45 m^2 ha^{-1}) in Kango Island, Zaire (Mosango 1991), tropical rain forest (78 m^2 ha^{-1}) in Amazonia (Campbell *et al* 1992), lower montane forest (62 m^2 ha^{-1}) in Costa Rica (Nidkarni *et al* 1995), evergreen forest (55-94 m^2 ha^{-1}) of Kalakad in Western Ghats (Parthasarathy *et al* 1992), and in dry evergreen forest (32.8 m^2 ha^{-1}) of Puthupet, South India (Parthasarathy and Sethi 1997).

The dominance-distribution curve showed a lognormal distribution. A logarithimic or broken-stick distribution reflect that the community is primarily ordered in respect of one dominating factor, while lognormal distribution represents a more complex community, ordered by a multiplicity of interaction (May1975). The latter appears to be true for the sacred grove communities under study.

CHAPTER VI

SOIL BIOLOGICAL PROCESSES IN SACRED GROVES

The changes in vegetation composition can produce substantial changes in carbon and nitrogen dynamics and may accelerate or constrain future changes in ecosystem structure and function (Chapin 1993, Hooper and Vitousek 1997, Tilman *et al* 1997). The removal of tree biomass and changes in the land use in the long–term may lead to decline in soil organic matter which is of crucial importance for maintaining the fertility of highly weathered tropical soils and for ensuring sustainability of agricultural systems developed on these soils (Henrot and Robertson 1994). Microbial biomass is an important source of soil organic carbon and inorganic mineral nutrients. Their role in nutrient cycling is well established both in mature and degraded forest ecosystems (Smith and Paul 1990, Fenn *et al* 1993, Arunachalum *et al* 1999). Wolters and Joergensen (1991), Wardle (1992), Bauhus and Khanna (1994) and Beek *et al* (1995) have reported that the quantity and composition of microbial biomass is sensitive to changes in the soil chemical and physical environment. It is influenced by temperature, moisture content, clay content and pH of the soil both in natural and disturbed ecosystems (Carter 1986, Kaiser *et al* 1992, Gestel *et al* 1993, Hassink *et al* 1993). Seasonal changes in atmospheric condition may also influence microbial number (Diaz-Ravina *et al* 1993) and mass (Granatstein *et al* 1987, Lynch and Panting 1981).

Soil microbial biomass is also affected by forest management practices (Ohtonan *et al* 1992, Bauhus and Barthel 1995, Pietikainen and Fritze 1995) and it increases proportionately with forest productivity (Myrold *et al* 1989) and forest age (Hale *et al* 1999).

Nitrogen mineralization is of crucial importance in natural forest ecosystems, where N has been reported to be a limiting nutrient for plant growth. The species composition and primary productivity of terrestrial ecosystems are strongly affected by the rates at which N is supplied to the plants (Chapin 1980, Berendse 1983, Wedin and Tilman 1990, Olff *et al* 1994). In the forest ecosystem the supply of N is influenced by litter quality, its input and decay rate (Verchot *et al* 2001). Since mineralization of organic soil N is fundamentally linked with forest productivity, attention is shifting from static measures of N-availability to more dynamic measures of N-release (Keeney 1980). In part, this emphasis represents the continuation of a long-standing concern among forest scientists over the possibility that forest clearing causes nutrient losses that could affect the long-term productivity of a site. Element losses following disturbance have also been used to characterize the degree of homeostasis in forest biogeochemical cycle and have been suggested as a useful measure of ecosystem-level stability (Borman and Likens 1979).

In the state of Meghalaya degradation of natural forests is a wide spread phenomenon, so much so that the sacred groves which were protected through ages, are also being encroached upon by the indigenous tribes themselves for their timber and fuel wood needs. In this chapter data on seasonal dynamics of microbial biomass carbon and N-mineralization rate in the undisturbed and mildly disturbed stands of the sacred groves have been presented and an attempt has been made to assess the impact of disturbance on these two functional attributes of the edaphic complex.

Results

Microbial biomass Carbon (MBC)

The MBC showed significant ($P < 0.01$) monthly variation in all four stands; the values were low during rainy season and high during winter (Fig. 6.1). In the undisturbed stands the minimum value of 446.9 $\mu g\ g^{-1}$ was recorded in the month of July and maximum (1205.6 $\mu g\ g^{-1}$) in January. In the mildly disturbed stands the value ranged from a minimum of 292.51 $\mu g\ g^{-1}$ in August to a maximum of 809.6 $\mu g\ g^{-1}$ during the month of February. The values were significantly ($P < 0.01$) lower in the mildly disturbed stands than the undisturbed stands of both the sacred groves.

A significant ($P < 0.01$) depth wise variation was seen both in the undisturbed as well as in the mildly disturbed stands of the sacred groves (Table 6.1). In the surface soil (0-10cm) layer of the undisturbed stands, the value ranged from a minimum of 446.93 $\mu g\ g^{-1}$ to a maximum of 1205.6 $\mu g\ g^{-1}$ in Rsg. In the subsurface (10-20cm) layer it varied between 419.76 $\mu g\ g^{-1}$ in Rsg to 809.6 $\mu g\ g^{-1}$

in Isg. In the mildly disturbed stands, it varied between 292.51 and 809.6 μg g^{-1} in the topsoil layer and 283.98 to 699.60 μg g^{-1} in the subsurface layer.

The percentage contribution of MBC to the total soil organic carbon content was higher in the undisturbed stands than the mildly disturbed stands (Table 6.2). Similarly, its contribution in the topsoil layer (0-10cm) was higher than the subsoil layer, except in the case of Rmd where the contribution was higher in the subsurface layer (Table 6.2). It also exhibited a marked seasonal trend with peak contribution during winter season and minimum share during rainy season at both the depths in almost all stands.

Ammonium- nitrogen (NH_4^+-N)

NH_4^+-N was the dominant form of inorganic nitrogen in soils of all stands. It varied significantly ($P < 0.01$) between stands, months and soil depths. The undisturbed stands soils had significantly higher NH_4^+-N than the mildly disturbed stands. In the former it ranged between 11.04–19.51 μg g^{-1} and 9.34-17.56 μg g^{-1} in the surface and subsurface soil layers, respectively. Whereas, in the mildly disturbed stands the corresponding values for the two soil layers were 4.75 –11.14 μg g^{-1} and 3.89 – 9.68 μg g^{-1} (Fig. 6.2).

A marked seasonal trend was also seen in all stands. NH_4^+-N concentration, which was at its minimum level during rainy season in both the soil depths, gradually increased and attained the peak during winter (Table 6.3).

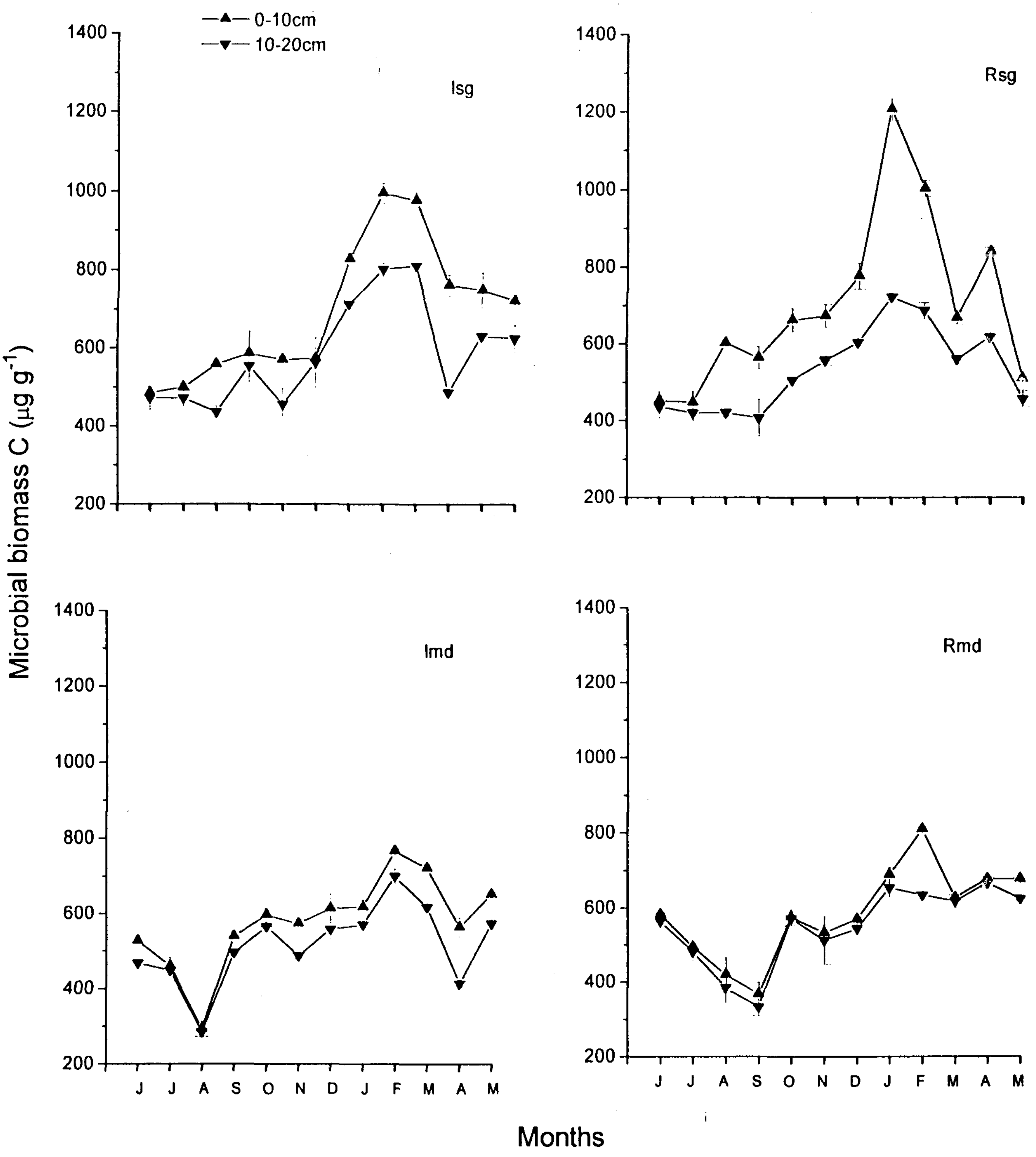


Fig.6.1. Monthly variation in microbial biomass carbon in the undisturbed (Isg, Rsg) and mildly disturbed (Imd, Rmd) stands at Ialong and Raliang sacred groves (vertical lines represent SEM)

Table 6. 1. Three way Analysis of variance to study the effects of stand, soil depth and month on microbial biomass carbon (MBC), ammonification, nitrification and net–N mineralization rate in the four stands.

Source of variation	df	F ratio			
		MBC	Ammonification	Nitrification	Net N mineralization
Stands	3	8.85**	15.87**	0.12 ns	8.18**
Months	11	19.91**	36.66**	50.01**	57.82**
Depths	1	1.47**	12.41**	47.36**	33.09**
Stands x months	33	1.36**	1.71**	0.86 ns	2.46**
Stands x depths	3	3.06*	3.00*	'1.71 ns	5.57**
Months x depths	11	4.40**	10.34**	39.71**	51.88**
Stands x months x depths	33	1.05**	1.46**	1.11 ns	0.40 ns

Significant at * P < 0.05, ** P < 0.01, ns- not significant.

Table 6.2. Mean MBC (μg g^{-1}) and its contribution (%) to total soil organic carbon (SOC) content in the undisturbed and mildly disturbed stands at Ialong and Raliang in Jaintia hills, Meghalaya.

Stands	Depths (cm)	Rainy	Autumn	Winter	Spring
Isg	0-10	489.87 ± 31.76 (1.07)	577.87 ± 48.89 (1.14)	932.80 ± 37.85 (1.85)	745.07 ± 41.69 (1.51)
	10-20	457.60 ± 30.48 (1.10)	522.13 ± 67.56 (1.16)	774.40 ± 24.50 (1.78)	591.07 ± 42.65 (1.34)
Rsg	0-10	501.60 ± 38.11 (1.08)	630.67±42.76 (1.26)	997.33 ± 71.60 (1.95)	674.67 ± 51.14 (1.34)
	10-20	425.33± 28.67 (1.02)	489.87± 54.80 (1.17)	668.80 ± 25.28 (1.48)	542.67 ± 30.20 (1.25)
Imd	0-10	425.33 ± 43.21 (1.06)	572 ± 21.56 (1.34)	662.93 ± 42.08 (1.56)	642.40 ± 31.42 (1.52)
	10-20	396 ± 28.52 (1.04)	510.4 ± 13.91 (1.38)	589.60 ± 26.76 (1.56)	536.80 ± 34.08 (1.38)
Rmd	0-10	489.87 ± 42.91 (1.18)	492.8 ± 46.15 (1.04)	686.40 ± 39.35 (1.58)	660.00 ± 11.64 (1.49)
	10-20	478.13 ± 47.48 (1.21)	469.33± 65.82 (1.16)	607.20 ± 28.52 (1.59)	639.47±20.06 (1.62)

(±SEM, n=9)

The values in parentheses are the percent contribution of MBC to total SOC content.

The soil organic carbon (SOC) data is presented in Chapter III, Table 3.2.

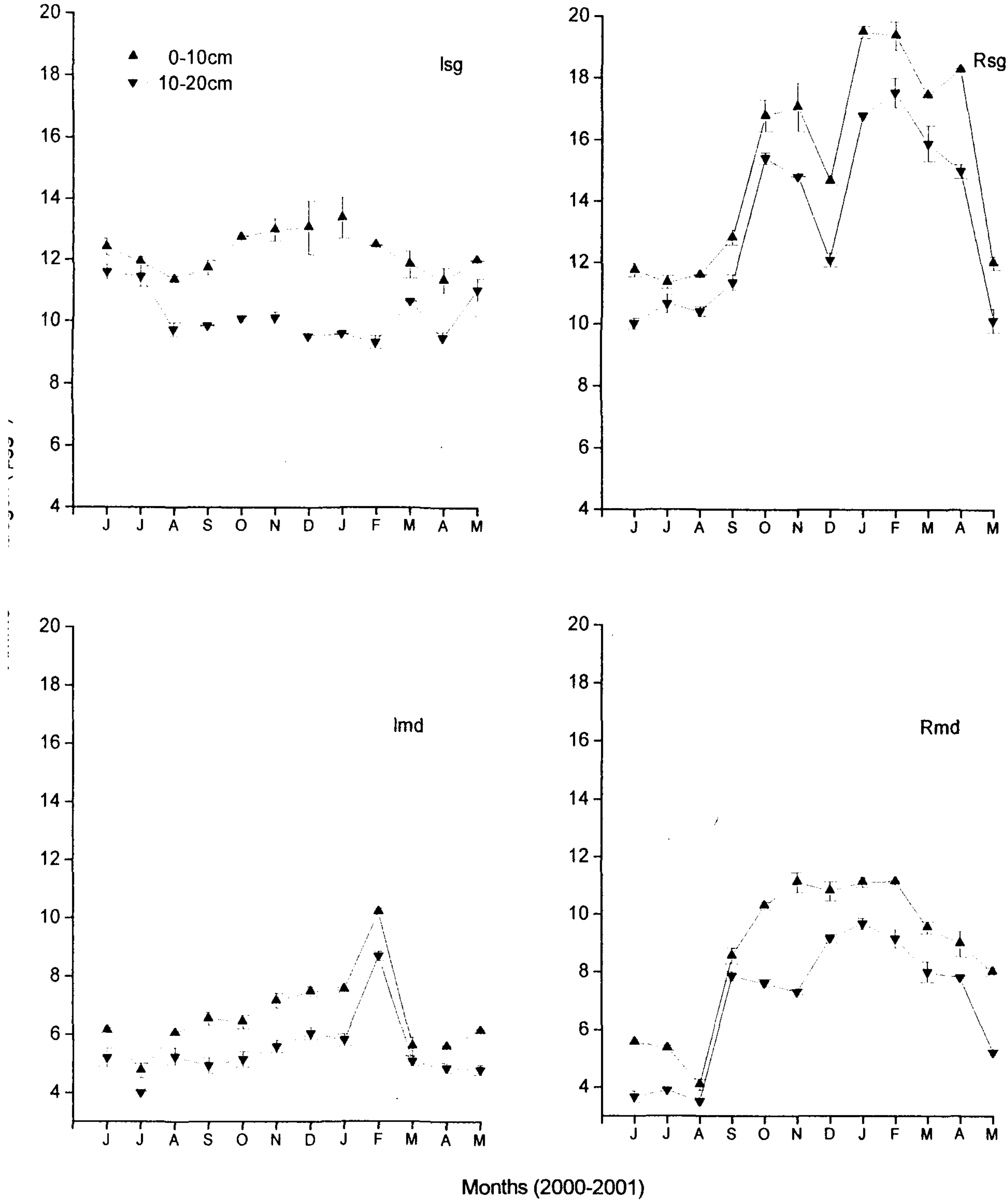


Fig. 6.2. Monthly variation in ammonium-N concentration in the undisturbed (Isg, Rsg) and mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

Table 6.3. Seasonal variations in mean NH_4^+- N (µg g^{-1}), NO_3^--N (µg g^{-1}) and total inorganic nitrogen (µg g^{-1}) concentration in soils of undisturbed and mildly disturbed stands.

Stands	Depths	Rainy			Autumn			Winter			Spring		
	(cm)	NH_4	NO_3	Total	NH_4	NO_3	Total	NH_4	NO_3	Total	NH_4	NO_3	Total
Isg	0-10	11.90	5.24	16.75	12.49	6.34	18.83	12.98	8.87	21.85	11.74	5.73	17.47
		±4.59	±2.03	±6.29	±4.67	±2.40	±7.07	±4.76	±3.48	±8.23	±4.55	±2.16	±6.71
	10-20	10.81	4.02	14.84	10.02	5.36	15.38	9.48	7.16	16.64	10.40	5.08	15.48
		±4.25	±1.72	±5.97	±3.88	±2.11	±5.99	±3.67	±2.40	±6.07	±4.16	±2.02	±6.18
Rsg	0-10	11.56	7.98	19.54	15.56	9.71	25.27	17.86	13.59	31.45	15.92	10.34	26.26
		±4.45	±3.13	±7.58	±6.05	±3.81	±9.86	±6.72	±5.32	±12.03	±5.71	±3.93	±9.62
	10-20	10.02	6.80±	16.82	13.86	7.76±	21.61	15.49	10.30	25.79	13.68	7.50	21.18
		±3.84	2.50	±6.33	±5.06	2.94	±8.00	±5.56	±4.03	±9.59	±5.11	±2.92	±8.02
Imd	0-10	5.64	4.15	9.80	6.72	5.57	12.29	8.41	6.27	14.68	5.77	5.46	11.23
		±2.37	±1.59	±3.96	±2.63	±2.14	±4.47	±3.40	±2.33	±5.73	±2.29	±2.05	±4.33
	10-20	4.81	3.22	8.03	5.22	4.52	9.75	6.85	5.21	12.06	4.90	4.46	9.36
		±2.06	±1.25	±3.31	±2.14	±1.67	±3.80	±2.84	±2.04	±4.88	±1.93	±1.53	±3.47
Rmd	0-10	5.01	4.11	9.71	9.99	7.86	17.85	11.03	9.63	20.66	8.85	7.30	16.15
		±1.94	±1.57	±3.51	±3.68	±2.63	±6.32	±4.29	±3.72	±8.01	±3.37	±2.81	±6.18
	10-20	3.69	3.23	6.92	7.60	6.15	13.75	9.33	7.75	17.08	7.01	5.64	12.66
		±1.36	±1.27	±2.63	±2.83	±2.29	±5.12	±3.53	±3.36	±6.87	±2.59	±1.82	±4.41

± SEM (n=9)

Nitrate nitrogen (NO_3^--N)

NO_3^--N concentration was significantly ($P< 0.01$) lower than the NH_4^+-N at all sites and depths. Its monthly trend was similar to that of NH_4^+-N with higher values in the undisturbed stands than the mildly disturbed stands (Fig. 6.3). The mean concentration of NH_4^+-N was about two times higher in the undisturbed stand than the disturbed stands of both the groves. The difference in the NO_3^--N concentration between the undisturbed and mildly disturbed stands was not prominent. However, its concentration was higher in the Rsg than other sites.

Total inorganic soil N (NH_4^+-N + NO_3^--N) pool was larger in the undisturbed stands of both the groves than their corresponding disturbed stands. Its concentration was invariably higher (significant at $P < 0.01$) in the surface layer than the subsurface layer (Table 6.3).

Mean values of NH_4^+-N and NO_3^--N and total inorganic N contents furnished in Table 6.4 reveals that NH_4^+- N constituted the dominant fraction of the total inorganic N in the undisturbed as well as in the mildly disturbed stands, though the proportion was higher in the former (55% - 65%) than the latter (35-45 NH_4^+-N%). Total inorganic N content in the undisturbed stands soils was markedly higher than the mildly disturbed stands. However, the values in Rsg and its mildly disturbed stand (Rmd) were higher than their counterparts at Ialong.

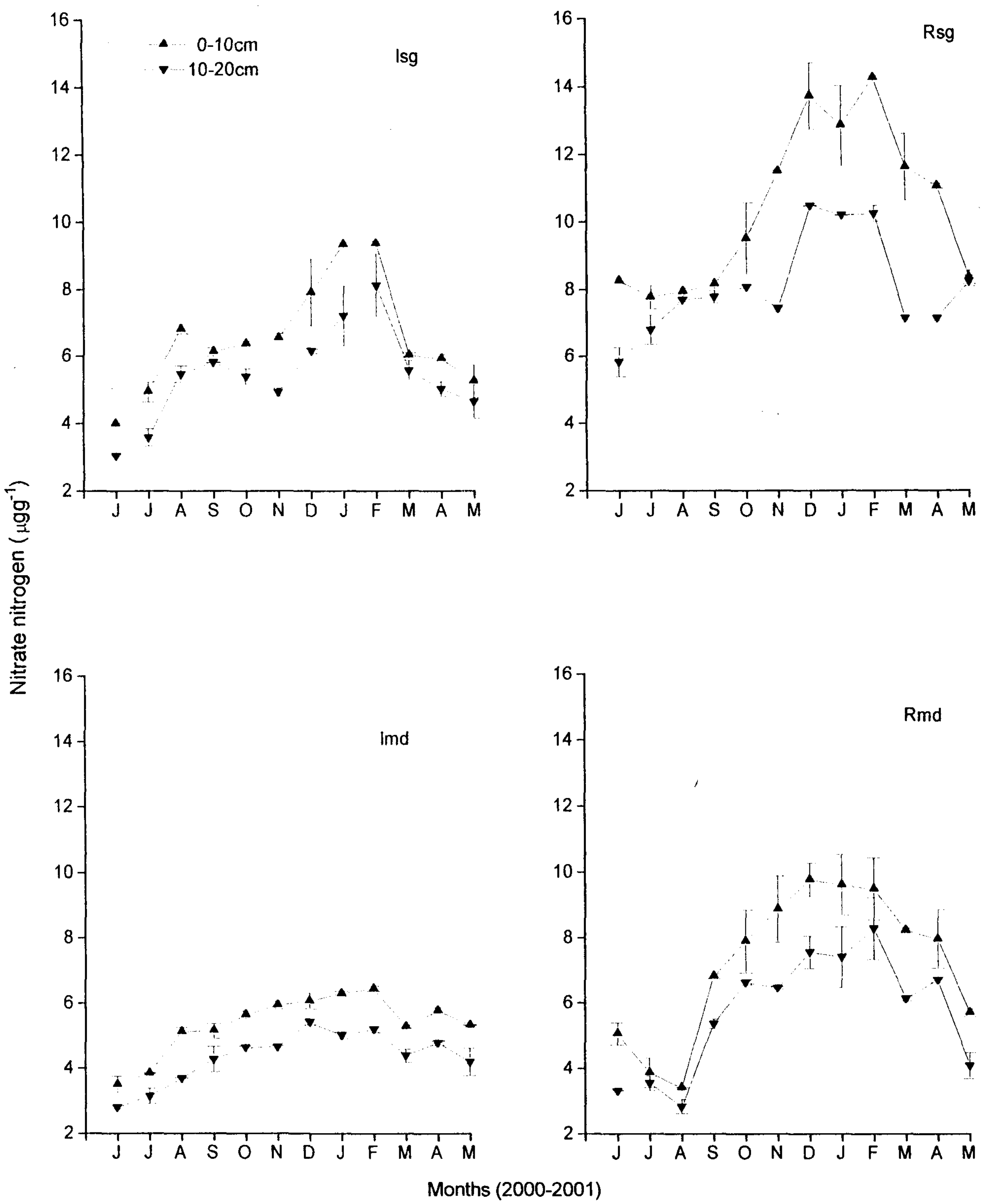


Fig. 6.3. Monthly variation in nitrate-N concentration in the undisturbed (Isg, Rsg) and mildly disturbed stands (Imd, Rmd) at Ialong and Raliang.

N- mineralization

Ammonification

Ammonification rate varied significantly (P< 0.01) between seasons, sites and depths (Table 6.1). The rate was at its peak during June–July, thereafter it declined to its minimum level in January in all the stands (Fig. 6.4). In the surface soil layer the rate varied from a minimum of 5.42 μg $g^{-1}month^{-1}$ to a maximum of 8.31 μg $g^{-1}month^{-1}$. The corresponding values for the subsurface soil layer were 4.59 μg $g^{-1}month^{-1}$ to 6.68 μg $g^{-1}month^{-1}$. The undisturbed stands soils showed significantly higher ammonification rate than the mildly disturbed stands.

Nitrification

The nitrification rate varied significantly (P< 0.01) due to soil depth and season, but the difference between the forest stands was not significant. The seasonal variation in nitrification rate at the two soil depths was similar to that of ammonification except that the subsurface layer showed higher value during winter season in Rmd (Fig. 6 5). However, in the surface layer mean nitrification rate (6.01 μg $g^{-1}month^{-1}$) in Imd stand was higher than the other three stands (Table 6.4).

Net N-mineralization

A marked seasonal variation was observed in net mineralization rate in all the stands. The peak was noticed during rainy season, followed by a sharp decline during winter season (Table 6.5). The peak rate (31.27 μg $g^{-1}month^{-1}$) was

Table 6. 4. **Average inorganic-N pool (μg g^{-1}) and N-mineralization rate (μg $g^{-1}month^{-1}$) in the undisturbed and mildly disturbed stands.**

Sites	Depths (cm)	Concentration (μg g^{-1})			Net rate (μg g^{-1})		
		NH_4^+-N	NO_3^--N	Total Inorganic N	Ammonification	Nitrification	Mineralization
Isg	0-10	12.27 (65)	6.55 (35)	18.82	8.31 (59)	5.82 (41)	14.13
	10-20	10.20 (65)	5.40 (35)	15.60	6.31 (57)	4.75 (43)	11.06
Rsg	0-10	15.22 (59)	10.40 (41)	25.62	7.92 (58)	5.84 (42)	13.76
	10-20	13.26 (62)	8.09 (38)	21.35	6.68 (60)	4.47 (40)	11.15
Imd	0-10	6.64 (55)	5.36 (45)	12.00	5.43 (47)	6.01 (53)	11.44
	10-20	5.45 (56)	4.35 (44)	9.80	4.59 (50)	4.61 (50)	9.20
Rmd	0-10	8.72 (55)	7.22 (45)	15.94	6.09 (51)	5.77 (49)	11.86
	10-20	6.91 (55)	5.69 (45)	12.60	4.93 (52)	4.62 (48)	9.55

The values in the parentheses are the percentages of the total inorganic N content.

Table 6. 5. Seasonal variation in ammonification (Amn), nitrification (Nit) and Net N mineralization (Tot.) rate (μg $g^{-1}month^{-1}$) in undisturbed and mildly disturbed stands at Ialong and Raliang.

Sites	Depths	Rainy			Autumn			Winter			Spring		
	(cm)	Amn.	Nit.	Tot.	Amn.	Nit.	Tot.	Amn.	Nit.	Tot.	Amn.	Nit.	Tot.
Isg	0-10	16.57	11.50	28.07	7.61	5.77	13.38	2.16	1.73	3.89	6.90	4.26	11.03
		±5.64	±4.80	±10.44	±3.38	±2.25	±5.59	±0.98	±0.94	±1.86	±2.68	±1.80	±4.48
	10-20	13.96	10.76	24.74	4.68	4.48	9.16	1.79	1.47	3.26	4.80	2.31	7.12
		±5.09	±4.19	±9.28	±1.78	±1.31	±3.09	±0.85	±1.07	±1.85	±1.48	±0.66	±2.13
Rsg	0-10	15.15	11.51	26.66	9.00	6.26	15.26	1.61	2.02	3.63	5.92	3.57	9.49
		±5.53	±4.54	±10.06	±3.38	±2.18	±5.57	±0.29	±1.23	±1.46	±2.57	±1.37	±3.92
	10-20	13.88	9.07	22.95	7.11	4.57	11.68	1.01	1.32	2.33	4.74	2.90	7.64
		±5.37	±3.62	±8.99	±2.97	±2.09	±5.06	±0.58	±0.84	±1.42	±1.48	±0.83	±2.31
Imd	0-10	9.05	11.03	20.08	3.49	4.13	7.62	1.65	1.53	3.18	7.52	7.34	14.86
		±3.42	±4.24	±7.65	±1.28	±1.29	±2.56	±0.82	±0.56	±1.28	±2.95	±2.71	±5.66
	10-20	7.40	9.47	16.88	3.40	3.17	6.57	1.19	0.80	1.98	6.38	4.98	11.36
		±2.82	±3.44	±6.25	±1.26	±1.47	±2.72	±0.42	±0.34	±0.76	±2.42	±1.70	±4.12
Rmd	0-10	10.33	11.34	21.67	6.57	5.51	12.08	1.41	0.83	2.24	6.07	5.41	11.48
		±3.74	±4.54	±8.22	±2.70	±2.51	±5.20	±0.54	±0.59	±1.13	±2.38	±2.13	±4.50
	10-20	9.48	10.18	19.66	4.64	3.66	8.30	0.85	1.0	1.84	4.74	3.66	8.40
		±3.74	±3.84	±7.58	±2.05	±1.46	±3.51	±0.32	±0.57	±0.83	±1.90	±1.58	±3.44

± SEM (n=9)

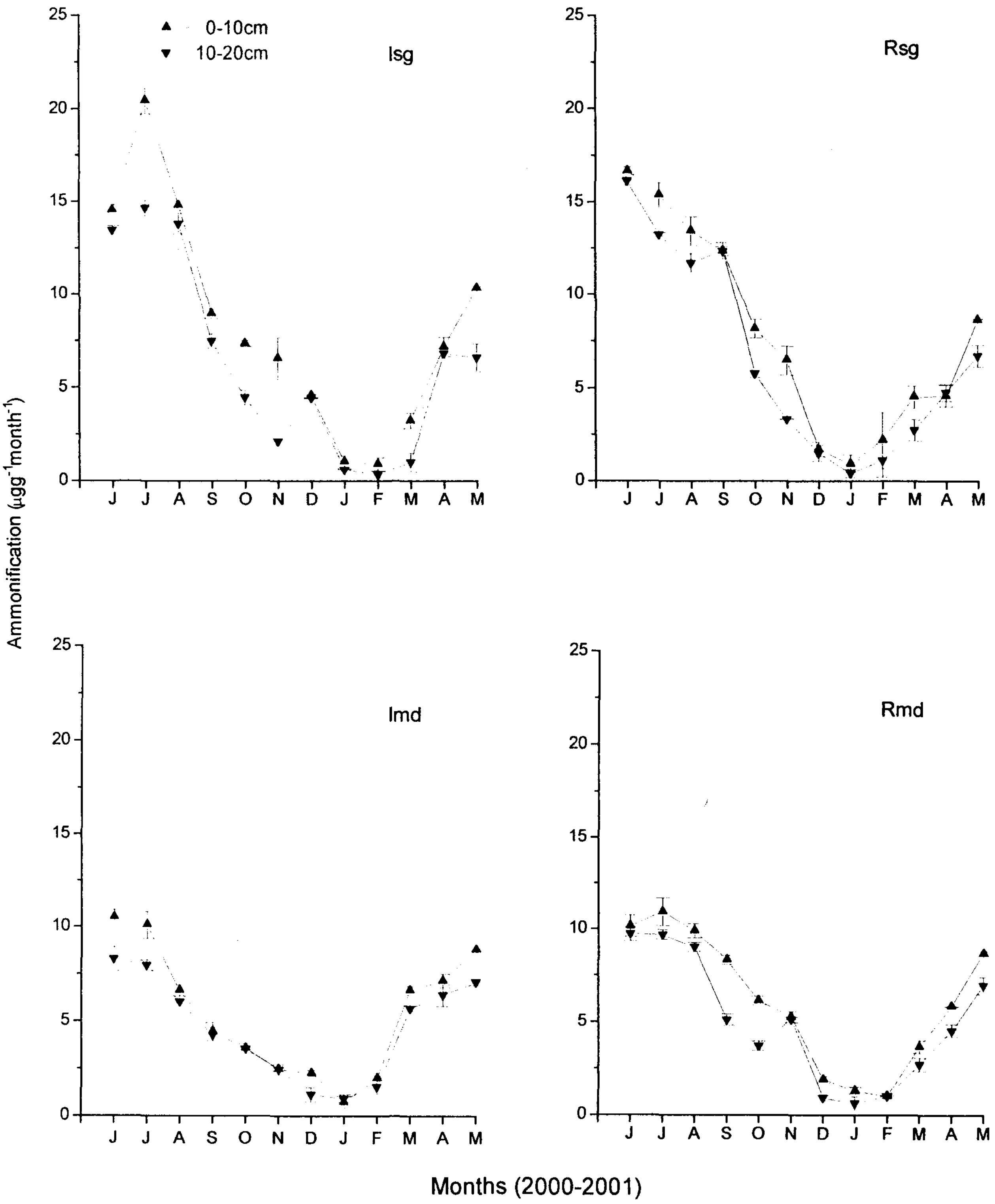


Fig. 6.4. Ammonification rate ($\mu gg^{-1}month^{-1}$) in the undisturbed (Isg, Rsg) and mildly disturbed (Imd, Rmd) stands at Ialong and Raliang.

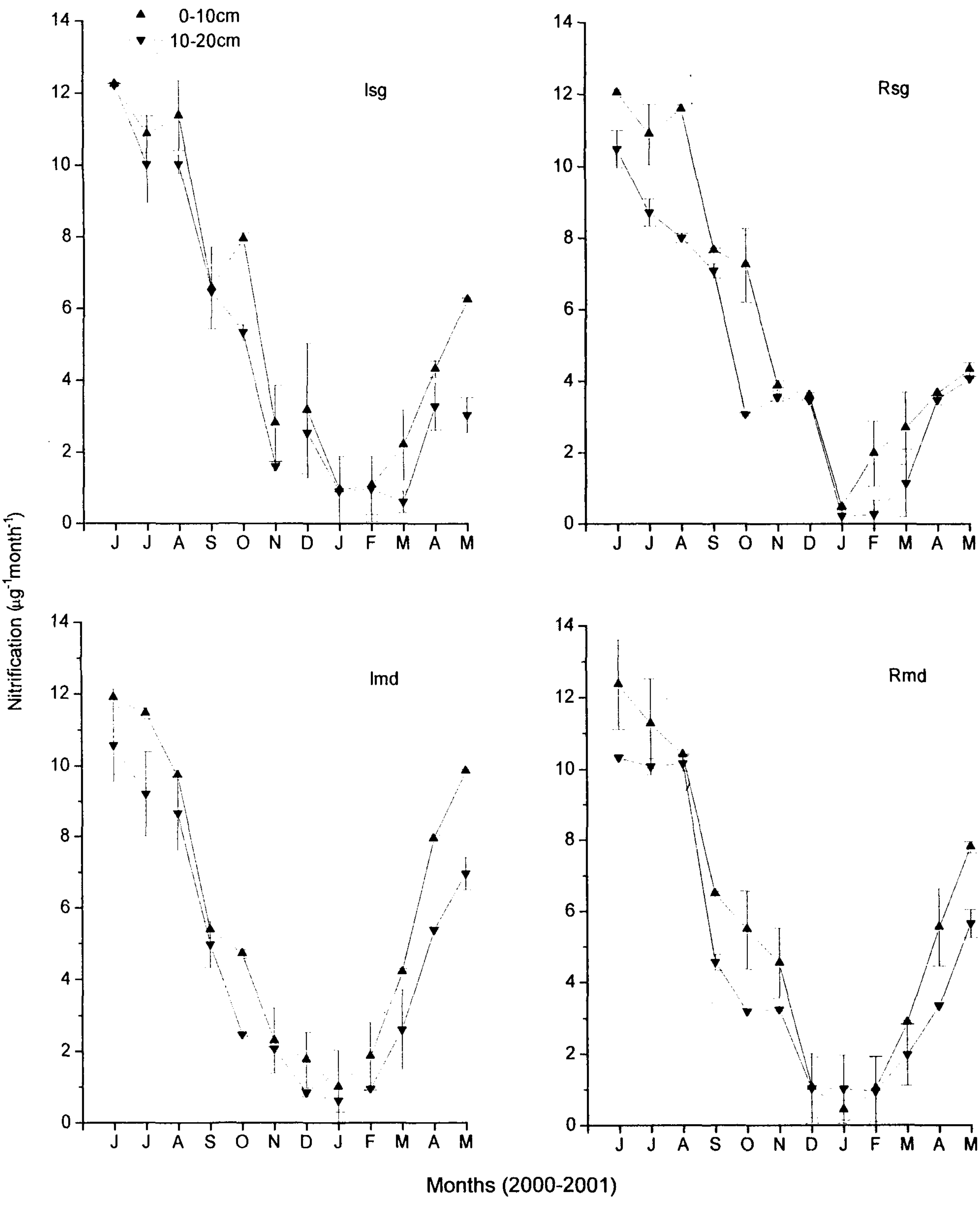


Fig. 6.5. Nitrification rate ($\mu g g^{-1} month^{-1}$) in the undsiturbed (Isg, Rsg) and mildly disturbed (Imd, Rmd) stands at Ialong and Raliang.

recorded in the topsoil layer of Isg while the lowest rate (0.42 μg $g^{-1}month^{-1}$) was obtained in Rmd (Fig. 6.6). ANOVA of the results showed that mineralization rate was significantly (P <0.01) higher in the undisturbed stands than the mildly disturbed stands. Similarly, the surface soil layer exhibited significantly higher (P< 0.01) rate than the subsurface layer.

The mean annual N- mineralization rate in the surface soil layer was 13.76 μg $g^{-1}month^{-1}$ in Rsg and 14.14 in Isg μg $g^{-1}month^{-1}$. The corresponding values for the sub surface layer (10-20cm) were 11.06 and 11.15 μg $g^{-1}month^{-1}$. In the disturbed stands the rate varied from 11.44 to 11.86 μg $g^{-1}month^{-1}$ and 9.20 to 9.55 μg $g^{-1}month^{-1}$ in the surface and sub surface layers respectively (Table 6.4).

Discussion

The seasonal variation in MBC observed in the present study is slightly different from those reported for tropical deciduous forests, savanna and temperate pastures where peak values for microbial nutrients were observed during early spring and summer (Sarathchandra *et al* 1989, Singh *et al* 1989, Srivastava 1992, Diaz-Ravina *et al* 1995). Studies on soils in forest, croplands, mine spoils and grazed and protected savanna in India have demonstrated that the storage of C, N and P in microbial biomass was significantly higher during dry summer and low during the rainy season at each habitat (Raghubanshi 1992, Srivastava 1992, Srivastava and Singh 1988). Singh *et al* (1989) have reported a reciprocal relationship between the plant growth rates that are highest during the wet period

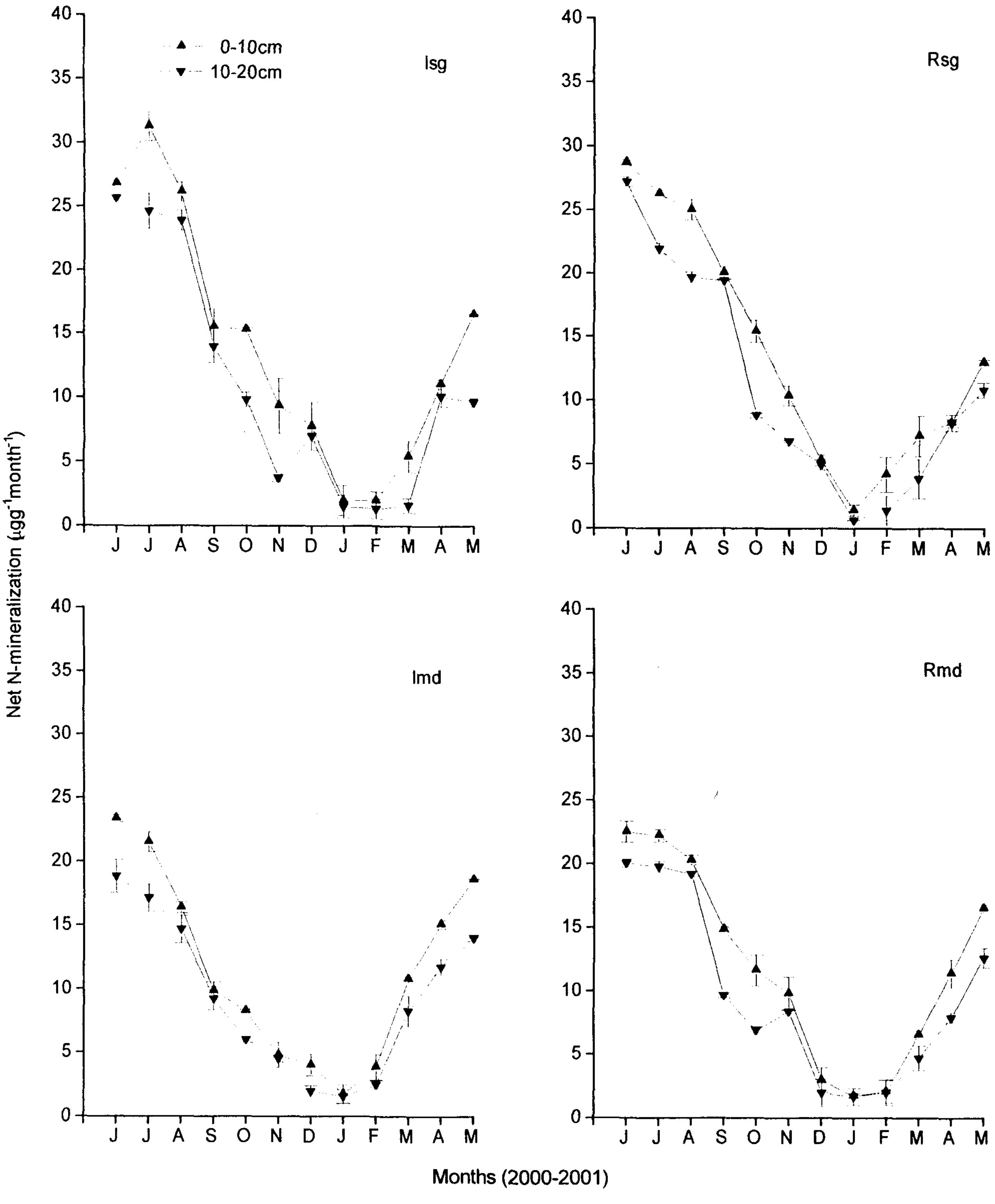


Fig. 6.6. Net N-mineralization ($\mu gg^{-1} month^{-1}$) in the undisturbed (Isg, Rsg) and mildly disturbed (Imd, Rmd) stands at Ialong and Raliang.

and microbial biomass, which is highest in the dry period. The drop in microbial biomass in the beginning of the rainy season was attributed to lysis, while maintenance of low biomass during the wet season was attributed to the greater microbiovory (Singh *et al* 1989, Raghubanshi *et al* 1990). In a spurce forest soil, Von Lutzow *et al* (1992) recorded highest biomass values in autumn and spring and lowest in summer. The seasonal variation in microbial biomass C observed in the present study is similar to that reported by Arunachalam *et al* (1999) in subtropical semievergreen forest undergoing recovery after disturbance. During cool dry winter when plant uptake of nutrients is greatly reduced on account of the death of majority of annuals and dormant growth phase of perennial species, nutrient are either immobilized in microbial biomass or accumulates in the soil. On the contrary during warm wet period when conditions for lysis and microbiovory seem to be more favourable, MBC was at its minimum level, thereby adding the nutrients in soil. This coincides with the period of active vegetation growth of majority of plants in the community. Since the forest floor is covered with a dense network of fine roots, there is every likely hood that nutrients released on account of lysis of soil microbes and or from other sources are quickly absorbed by the plants, reducing the runoff and leaching losses.

The concentration of microbial biomass C reported for various temperate and tropical forest soils (Vance *et al* 1987, Henrot and Robertson 1994, Diaz-Ravina *et al* 1995) vary widely between 61 μg $g^{-1}$and 2000 μg g^{-1}. The higher MBC in the protected stands as compared to the unprotected stands could be the result of greater input of organic matter and nutrients through litter and fine roots, which might have favoured the growth of microbial population and accumulation of microbial biomass. Arunachalam *et al* (1996) and Marion and Black (1988), has obtained similar results and attributed it to an increase in organic matter content in older forest stands owing to the greater accumulation of plant derived organic matter and microbial products. Diaz-Ravina *et al* (1988) have reported that soil with low organic C usually has less microbial biomass and vice versa. Low soil organic matter content in the disturbed stands could well explain the low MBC.

The contribution of MBC to SOC in the four stands (1.02 % to 1.95%) obtained in this study is low compared to other tropical forests 1.53% to 5.3% (Theng *et al* 1989, Luizao *et al*, 1992), tropical dry deciduous forest, 1.6% to 3.6%, (Srivastava and Singh 1989) but close to the Pinewood and Oakwood forests, 0.5% to 2%, (Diaz-Ravina *et al* 1995) and temperate forests soils, 1.8-2.9%, (Vance *et al* 1987).

The relationship between MBC and soil properties was studied by computing coeffection of correlation. It showed a positive correlation with soil moisture content (SMC), soil organic C, TKN and available P (Table 6.6) and a negative correlation with soil temperature (significant at $P< 0.01$). With species richness it showed a negative correlation ($Y = a151.0342 - 0.1006X$, $r^2 = 0.977$, $P<0.05$). MBC was also influenced by soil nutrient status as is evident by significant positive correlations with soil organic C, N and available P.

Disturbance also seems to have played a role. The decrease in basal cover (13.61 and 48.88%), TKN (12 to 15%), SOC (15 to 21%) and available P (14 to 24%) in the mildly disturbed stands could have led to the lower MBC as compared to the undisturbed stands of the sacred groves.

The low soil NH_4^+-N and NO_3^--N during rainy season may be due to greater demand by vegetation which grow vigorously during this period of the year (Singh *et al* 1989, Arunachalam *et al* 1996). Higher leaching losses could be another reason for low NH_4^+-N and NO_3^--N level in the soil during this season. Higher NH_4^+-N and NO_3^--N during dry winter season may be attributed to low uptake by plants coupled with low leaching and runoff losses. It has been suggested by Birch (1958) that during dry season soil starts drying up due to evaporation, which facilitates the upward movement of nitrate and release of free ammonia and amino acids from the drying soils. These factors together might have led to the accumulation of inorganic–N in the soil during dry winter season.

Table 6.6. Correlation coeffection (r) between MBC (μg g^{-1}) in two soil depths with soil characteristics.

Depths (cm)	Soil properties				
	Temp.[a]	Moisture (%)[a]	SOC (%)[b]	TKN (%)[b]	Available P (μg g-1)[b]
0-10	- 0.401**	0.164 ns	0.505*	0.506*	0.798*
10-20	- 0.361**	0.315*	0.793*	0.792*	0.514*

* Significant at < 0.05, ** Significant at < 0.01, ns = not significant.
a = (n=46): soil temperature and soil moisture
b = (n=14) : SOC (soil organic carbon), TKN (total kjeldahl nitrogen) and available P (Phosphorous).

Predominance of ammonium ion in soil has also been reported by Maithani *et al* (1998) from subtropical broadleaved forest undergoing recovery after disturbance in north-east India and Verchot *et al* (2001) from temperate forests in eastern New York state.

N-mineralization pattern

The nitrification rate found in the present study (0.42-12.36 $\mu g\ g^{-1} month^{-1}$) is lower than those (0.5-23 $\mu g\ g^{-1} month^{-1}$) reported by Singh *et al* (1991) from a disturbed dry tropical savanna. Low rate of nitrification in the presence of adequate ammonium ions found in all the stands, is similar to the results reported by Robertson and Vitousek (1981), Ellenberg (1977) and Maithani *et al* (1998). The low rate of nitrate production has been attributed to allelochemic inhibition by organic compounds in soil or plant extracts (Montangnini *et al* 1986, Rice and Pancholy 1972). However, 7-11% increase in rate of nitrification in the community forests could be the low acidic nature of the soil that might have facilitated the growth and activity of autotrophic nitrifiers in soils. The undisturbed sacred groves the high SOC would supply readily available C sources to soil microbes resulting in increased rate of inter-N cycling. However, due to excessive heterotrophic immobilization, that reduces N-availability to nitrifying organisms leading to low activity of nitrifiers population (Adams and Attiwill 1986). This possibly could be the reason for relatively low N-mineralization in soil.

The relationship of N-mineralization rate with two climatic variables (rainfall and air temperature) and five edaphic variables was ascertained through correlation coefficient. It was positively correlated with rainfall, air temperature, soil temperature, and soil moisture content and available phosphorous (Table 6.7). Apart from these variables, it also showed positive correlation with MBC.

Seasonality in N-mineralization has been reported to be controlled by soil moisture level in dry tropical savanna (Singh *et al* 1991), Scottish highlands (Morecroft *et al* 1992), tiaga forests (Clein and Schimel 1995) and subtropical humid forest of north-east India (Maithani *et al* 1998). Rewetting of dry soil increases N-mineralization (Birch 1958, Sorensen 1974). This is evident by significant positive correlations between N-mineralization and rainfall and soil moisture content. Relatively higher ambient and soil temperature during wet-summer period might have facilitated the bacterial and fungal population growth resulting in an increase in N mineralization (Maithani *et al* 1998) as is evident by its positive correlations between MBC on the one hand and air and soil temperatures on the other. Menaut *et al* (1985) have also found that in slightly acidic soils, the high stock of nutrients is rapidly released during the wet season.

Table 6.7. Correlation coefficient (r) between mean N-mineralization rate ($\mu g\ g^{-1} month^{-1}$) and climate and soil variables.

	Climatic variables		Edaphic variables			
Soil depths (cm)	Rainfall (mm)[a]	Air temp. (^0C)[a]	Temp. (^0C)[a]	Moisture (%)[a]	P ($\mu g\ g^{-1}$)[b]	MBC ($\mu g\ g^{-1}$)[a]
0-10	0.534**	0.656**	0.589**	0.538**	0.513*	0.339*
10-20	0.612**	0.693**	0.538**	0.502**	0.460	0.343*

* Significant at < 0.05, ** Significant at < 0.01.

In the present study the result discussed indicates that due to disturbance the soil physico-chemical properties are altered which reduces the MBC and N-mineralization rate. N-mineralization showed a close association with MBC indicating that the latter is a microbe-mediated process. Differences in N cycling between stands are strongly linked to the quality of organic matter in the soils.

CHAPTER VII

GENERAL DISCUSSION

The rich plant diversity of the state of Meghalaya is preserved mainly in protected areas such as Biosphere Reserve, National Park, Wild Life Sanctuaries and the Sacred Groves. The sacred groves though cover a very small area as compared to the other protected forests; they have a unique diversity of varied life-forms. A striking feature of the sacred grove flora is the concentration of primitive angiospermous taxa, tropical and temperate elements, Sino-Himalayan and Burma – Malayan species and rare and endemic species within a small area.

A total of 410 angiosperms, 3 gymnosperms and 24 pteridophytes representing 115 families were recorded in the present study of two sacred groves viz. Ialong and Raliang in Jaintia hills. Angiosperms were the dominant group with 99 families followed by pteridophytes with 13 families and gymnosperms with three families viz., Gnetaceae, Pinaceae and Podocarpaceae. Among angiosperms, Orchidaceae was the dominant family. Balakrishnan (1981-83) and Jamir (2000) have also reported the dominance of Orchidaceae in the flora of Jaintia hills as well as in the sacred groves of Jaintia hills.

Highest concentration of epiphytic flora is believed to occur in the mid montane forests (Sugden 1979, Benzig 1983) where some precipitation occurs even in the driest period and relative humidity is high during most part of the year.

Dominance of epiphytic orchids (ca. 80%) and presence of epiphytic ferns as well as thick growth of mosses on tree trunks branches and even on the leaves contributed to the high species richness of the epiphytic flora in the two sacred groves. This could be attributed to high rainfall spreading over 8 months and high relative humidity (≅ 70%) prevailing during most part of the year.

The sacred groves were similar to the humid tropical and subtropical forests (Kumar 1984, Balakrishnan 1981-83, Valencia *et al* 1994) owing to the presence of large number of multi-species genera in the community. The species rich forests are generally rich in family composition also, as is evident by the presence of 115 families in the two groves. The Eastern Himalayas including the northeastern India has a high concentration of endemic plant with 5,000 species (Olson *et al.* 1998) indicating that the region is an important center where the Tertiary flora of Asiatic elements has survived (Taktajan 1988).

The vegetation of sacred groves resembles the tropical lower montane rain forest (Whitmore 1998) where canopy tree height ranges between 15m and 33m and may be compared with that of southwest China (Min Cao 1996) and Moraballi Creek, Guyana (Davis and Richards 1934). The height of the canopy trees in the sacred groves is lower than the average canopy tree height in the rain forest of Queensland, Australia (Unwin 1989), some tropical mixed dipterocarp forest at Borneo (Ashton 1992). Relatively shorter height of the canopy trees in the sacred groves as compared to tropical rain forests (Richards 1996) cannot be attributed to dry climate and low soil fertility as discussed by Whitmore (1975) and Visalakshi

(1995). This appears to be related more to the altitude as suggested by Whitmore (1975), Grubb (1977) and Lieberman *et al* (1996).

The comparison of species richness between different forest types in the tropics is often difficult because of variations in area sampled and differences in the dbh taken by different workers to define tree species. Campbell *et al* (1986,1992), Parthasarathy *et al* (1992), Proctor *et al* (1988), Kadavul and Parthasarathy (1999) have enumerated all species > 10 cm dbh in 3, 3, 1, 0.04, and 4 ha respectively, while Nadkarni *et al* (1995), Weaver and Murphy (1990) and Johnston and Gillman (1995) have described species having >2cm, > 4cm and > 5cm dbh in 4, 0.4, and 4 ha respectively. In spite of the above variations, species richness of the sacred groves appears to be higher than the tropical rain forests studied by Nadkarni *et al* (1995) and Weaver and Murphy (1990). The species richness recorded in the present study is higher than those reported by previous worker in the state of Meghalaya (Rao 1992, Barik 1992, and Singh 1980). However, it is lower than the forests in Amazonian Equator (Valencia *et al* 1994), Tropical America (Gentry 1988, Phillips *et al* 1994) and South East Asia (Nicholson 1965, Proctor 1983) that are exceptionally rich in species diversity.

The mildly disturbed stands of both the sacred groves had higher species richness than the undisturbed stands. Mild disturbance in the form of selective felling of trees, annual fire and grazing often create gaps in closed–canopy forest and favours colonization of secondary species like *Pinus kesiya, Leucoseptrum canum, Lyonia ovalifolia,* etc. Connell (1978) and Collins (1995) concluded that species diversity should be highest at intermediate frequency of disturbance when conditions favours coexistence of competitive species and those that tolerate disturbance.

The density of woody species recorded in the present study (938 –1476 plants ha^{-1}) is similar to those reported from Amozonia (1420-1720 plants ha^{-1}, Campbell *et al* 1986, 1992), Gunung Silam (1596 plants ha^{-1} Proctor *et al* 1988,) and sacred groves of Jaintia hills (1176- 1496 plants ha^{-1} Jamir 2000). The tree basal cover obtained in the present study (36.5 m^2ha^{-1} to 71.4m^2ha^{-1}) is close to the values obtained from Amazonia (28-68 m^2ha^{-1} and 78 m^2ha^{-1}, Campbell 1986, 1992), Gunung Silam, Malaysia (26.7 m^2ha^{-1}, Proctor *et al* 1988) Luquillo mountains, Puerto Rico (40 m^2ha^{-1}, Weaver and Murphy 1990) and Monteuverde, Costa Rica (40 m^2ha^{-1}, Nadkarni *et al* 1995) tropical rain forests. These values indicate clearly that the vegetation of sacred groves in Jaintia hills of Meghalaya is similar to the tropical rain forests found in other parts of the world. The comparatively lower tree basal cover in the mildly disturbed stands of both the groves may be attributed to selective felling of trees of high dbh classes for timber.

The density-diameter distribution of the woody species in the sacred groves yielded a reverse J-shaped curve, which is a characteristic feature of ancient climax tropical forests (White 1980, Sarukhan 1985, Whitmore 1975). Presence of large number of individuals of the understory and overstory species in small diameter class (5-15 cm dbh) was responsible for the reverse J-shaped curve. The preponderance of individuals in lower dbh class suggested that tree regeneration was fairly good in the sacred groves. Similar results have also been obtained by Kadavul and Parthasarathy (1999), Nadrarni *et al* (1995) and Campbell *et al* (1992) from the tropical forests.

Log normal distribution pattern of dominance among the species (trees, shrubs and herbs) is a characteristic feature of a complex community (May 1975) and is an indicator of the community of stable environment, whereas the logarithmic curve characterize the communities of unstable system (Stenseth 1979). Ugland and Gray (1982) concluded that a lognormal distribution is a characteristic of the system at equilibrium state that is influenced by multiplicity of factors. The lognormal type of dominance-distribution pattern observed in the present study suggest the stable and complex community and is the result of prolong protection and existence of favourable environmental condition for a long period of time. The dominance distribution curve did not change appreciably in the disturbed stand of both the groves, indicating the low intensity of disturbance in the stand open for use by local villagers and their cattle.

There was a marked increase in species richness and species diversity, and decrease in species dominance in the disturbed stands of both the sacred groves following disturbance. The composition of functional groups in the community such as evergreen, deciduous, shade tolerant and shade intolerant species also changed as a result of disturbance. Associated with these changes, there was a sharp decrease in tree basal cover in the disturbed stands. The change in species composition also influenced the quality of litter, which is one of the major pathways of nutrient transfer to the soil in forest ecosystem. This is clearly evident from the low concentration of N, P and K in the leaf litter of dominant tree species in the disturbed stands of the forest. Change in the species composition and reduction in vegetation cover due to removal of trees not only exposes the topsoil, but also leads to changes in its physico-chemical and biological properties.

Soil microorganisms are of great importance for plant growth and maintenance of the ecosystem functions, since they constitute the liable pool of C and mineral nutrients (Smith and Paul 1990, Wardle 1992, Diaz-Raviana *et al* 1993), which are liberated after their death. Significantly higher microbial biomass C in the protected stands than the mildly disturbed stands of both the sacred grove could be due to higher detrital accumulation on the forest floor and larger microbial population (Maithani *et al* 1996). Greater tree basal cover and high species dominance in the undisturbed stands might have also contributed indirectly to greater microbial biomass carbon (MBC) in the soil system through higher litter production.

Peak MBC during winter and low during rainy season in all the stands was related to seasonal changes in temperature and rainfall. During winter when the decomposition rate is low due to low temperature, nutrients are immobilized in to the dormant microbial cells leading to higher MBC during this season. During warm-rainy season fast turnover of microbial biomass was responsible for low MBC. High microbial activity and fast turnover of microbial biomass was in turn responsible for rapid decomposition rate and increased rate of nutrient release in the soil during this period. The low MBC during rainy season could also be due to lysis of cells and increase in microbiovory (Singh *et al* 1989, Raghuvanshi *et al* 1990). MBC was also influenced by soil organic C and nutrient status as is evident by a significant positive correlations with soil organic C, TKN and available–P.

Higher microbial biomass led to greater nitrogen mineralization rate in the undisturbed and mildly disturbed stands of the sacred groves. The amount of inorganic-N (ammonium + nitrate) and N-mineralization rate (ammonification + nitrification) showed a seasonal trend in all stands. The ammonium and nitrate nitrogen concentration was maximum during winter and minimum during rainy season. The low level of inorganic–N recorded during rainy season may be attributed to higher uptake by plants. Leaching and denitrification could be another reason for low values during rainy season. On the contrary, high concentration of inorganic nitrogen during dry winter season may be due to low uptake by plants and upward transport of previously present nitrogen or recently mineralized nitrogen in the subsoil due to evaporation (Birch 1958).

N-mineralization rate peaked during rainy season when temperature and soil conditions were favourable for growth of both plants as well as soil microbes and low during winter when growth in majority of plants enter into dormant phase and microbial activity slows down due to low atmospheric temperature and low soil moisture level.

SUMMARY

The present study was conducted at Ialong (*Khloo Blai*) and Raliang (*Khloo lyngdoh* or *Khloo Poh Lyngdoh*) sacred groves in Jaintia hills district of Meghalaya, northeast India during the period June 1999 and May 2001. They are the remnants of the subtropical evergreen climax forest of the area. One portion (ca. 20 - 30 ha) of both the sacred groves was well protected whereas, another portion (30 - 40 ha) was open to use by the people of the nearby village for fuel wood collection, timber and cattle grazing and therefore was mildly disturbed. The periphery of the disturbed portion of the sacred grove burned during dry winter to obtain good forage for the cattle in the ensuing rainy spell. Both the undisturbed as well as disturbed stands of the sacred groves were studied to assess plant diversity, analyse community structure and determine soil properties including temporal and spatial dynamics of microbial biomass C and N-mineralization. Attempts also were made to assess the impact of disturbance on plant diversity and soil biological processes in the sacred grove ecosystems.

Plant diversity

There were 280 species of vascular plants in Ialong and 311 species in Raliang undisturbed stands whereas, their corresponding mildly disturbed stands had 300 and 305 species respectively. Altogether there were 437 species, 303 genera and 115 families. *Ficus* was the largest genus with 11 species followed by *Impatiens* and *Dendrobium* with 6 and 5 species each respectively. Out of the 115 families, 99 belong to angiosperm, 3 to gymnosperms and 24 to pteridophytes. Orchidaceae was the dominant family with 27 species followed by Lauraceae (24 species) and Rubiaceae (20 species). Forty-seven families had one species each and 17 families were bispecific. The sacred groves flora was characterized by the presence of species belonging to primitive families and genera. At the same time, large number of tropical, temperate, Sino-Himalayan, Burmese-Malayan and to a lesser extent the Peninsular-India elements were also present in the sacred groves. They together made sacred grove flora very rich in species.

The sacred groves had 45 endemic species. Some endemic species recorded includes *Acer laevigatum*, *Citrus latipes*, *Ilex embeloides Drymicarpus racemosus* and *Tupidanthus calyptratus*. There were 38 rare species, out of which 13 were endemic. Species like *Fissistigma verrucosum, Ilex embeloides* and *Styrax hookerii* were collected after few decades. About 45 species of medicinal plant, used by the local people were also recorded. The important among them are *Achyranthes aspera*, *Houttuynia cordata*, *Plantago erosa*, *Pouzolzia hirta, Alstonia scholaris*, *Centella asiatica*, *Costus speciosus* and *Oxalis corniculata*.

The community was composed of plants of varied life forms, which were distributed in four strata. The canopy and subcanopy layers were composed of 39 and 45 species respectively and they form somewhat a continuous cover. Large number of small trees or large shrubs (60 species) constituted the undercanopy layer. The small shrubs with 89 species and 91 herbaceous species, especially in the mildly disturbed stands, constituted the most species-rich layer in the community. The species richness of woody ($\geq$ 5cm dbh), shrub and herb components increased in the disturbed stands of both the groves following disturbance (Table 1).

The communities were a mosaic of low and high diversity patches of woody species. About 42-52% of the woody species in each stand were represented by one or two individuals. Majority of woody (85-92%), shrub (93-100%) and herb (100%) species were contiguously distributed in the forest. As a result the forest was highly heterogeneous and patchy in species distribution.

The species diversity index ($\bar{H}$) of woody, shrub and herb species increased in the disturbed stands of both the groves, while the dominance index (D) showed a reverse trend (Table 1). The similarity between the botanical composition of the two sacred groves was relatively less (48-62%) than between undisturbed and disturbed stands (65-73%) of a given grove.

The density of woody species varied from a minimum of 938 individuals ha^{-1} in Raliang undisturbed stand to a maximum of 1476 in Ialong undisturbed stand. The shrubs density ranged from 6427 individuals ha^{-1} to 11040 individuals ha^{-1} and the herbs density ranged from 1607 to 2470 per $100m^2$ between the four stands. The density-diameter distribution pattern showed preponderance of young (5-15cm dbh class) individuals in all stands. In the undisturbed and mildly disturbed stands of the sacred groves 54-74% and 50-67% of the total stem density, respectively were represented by young individuals (5-15cm dbh class).

The individuals in the highest dbh class (>66) were only 2-5% of the stand density in all stands. The basal cover-diameter distribution showed a reverse trend.

The dominance distribution pattern was similar in all four stands. It fitted a lognormal distribution curve showing high equitability and low dominance in the community. Shannon and Wiener's diversity index worked out using proportional number did not vary much between the stands. Pielou's evenness index also showed high degree of equitability in all stands.

Soil properties

Soil moisture content (SMC) was significantly higher in the protected stand than the disturbed stand of the two sacred groves. Soil temperature and pH was however, slightly higher in the disturbed stands. Soil organic-C (SOC), TKN, and available phosphorous all showed significantly higher values in the undisturbed stands than the disturbed stands where 15-21%, 12-15% and 14-24% decline was recorded in SOC, TKN and available-P, respectively (Table 1).

Microbial biomass Carbon

The seasonal dynamics of microbial biomass carbon (MBC) was studied for a period of one year. It showed that MBC concentration was significantly ($P < 0.01$) higher during winter season and lower during rainy season. Similarly, the surface soil layer (0-10cm) had significantly ($P<0.01$) higher MBC than the subsurface layer (10-20cm). The undisturbed stands had significantly ($P<0.01$) higher MBC than the disturbed stands. The percentage contribution of MBC to the total soil organic - C pool varied between 1.02 % in rainy and 1.95 % in

Table.1.Structural and functional changes in vegetation and soil of sacred forest ecosystem following anthropogenic disturbances

	Parameters	Undisturbed Stand	Mildly disturbed stand	(% Change)
I.	**Community structure**			
	Species richness			
	Tree	Low	High	12-16
	Shrub	Low	High	24-28
	Herb	Low	High	7-13
	Density			
	Tree (ha^{-1})	High (I)	Low	9
		Low (R)	High	39
	Shrub (ha^{-1})	Low	High	37-66
	Herb ($100m^2$)	High (I)	Low	17
		Low (R)	High	13
	Tree basal cover (m^2 ha^{-1})	High	Low	14-48
	Diversity index (H^-)			
	Tree	Low	High	9
	Shrub	Low	High	10-22
	Herb	Low	High	5-10
	Dominance (D)			
	Tree	High	Low	30-35
	Shrub	High	Low	39-60
	Herb	High	Low	12-46
II.	**Functional groups**			
	Number of evergreen trees	High (I)	Low	7
		Low (R)	High	8
	Number of deciduous trees	Low	High	50-90
	Number of shade intolerant trees	Low	High	13-18
	Number of shade tolerant trees	High	Low	0-10
	N, P, K concentration in litter of dominant trees	High	Low	13-27
III.	**Soil properties**			
a.	**Physical**			
	SMC (%)	High	Low	5-38
b.	**Chemical**			
	pH	Low	High	5
	TKN (%)	High	Low	12-15
	SOC (%)	High	Low	15-20
	Available P ($\mu g\ g^{-1}$)	High	Low	14-24
	NH_4- N ($\mu g\ g^{-1}$)	High	Low	45-46
	NO_3- N ($\mu g\ g^{-1}$)	High	Low	18-30
	Inorganic – N ($\mu g\ g^{-1}$)	High	Low	37-39
c.	**Biological**			
	MBC ($\mu g\ g^{-1}$)	High	Low	8-15
	Ammonification ($\mu g\ g^{-1}\ month^{-1}$)	High	Low	25-31
	Nitrification ($\mu g\ g^{-1}\ month^{-1}$)	Low	High	< 1
	N-mineralization ($\mu g\ g^{-1}\ month^{-1}$)	High	Low	14-18

I=Ialong, R=Raliang.

winter season. MBC was positively correlated with moisture, organic-C, TKN and available-P contents of the soil and negatively correlated with soil temperature.

Nitrogen mineralization

N-availability and its mineralization were studied for a period of one year. The mean concentration of NH_4^+-N and NO_3^--N was significantly higher ($P<0.01$) in the undisturbed stands than the disturbed stands. There was about 45% reduction in NH_4^+-N and 18-30% reduction in NO_3^--N in the disturbed stands (Table 1). The total soil inorganic-N (NH_4^+-N + NO_3^--N) concentration was maximum during winter and minimum during rainy season in all stands. Ammonium nitrogen was the dominant form with (55-65%) of inorganic-N in all stands. Ammonification, nitrification and net-mineralization rates were higher during rainy season and low during winter season. The concentration of NH_4^+-N and NO_3^--N and ammonification, nitrification and N-mineralization rates were significantly higher in the upper soil layer (0-10cm) than the lower soil layer (10-20cm). N-mineralization rate was positively correlated with rainfall, air temperature, soil moisture content, available-P and MBC.

Thus the findings of the present study clearly reveals that the sacred groves located in Jaintia hills are extremely rich in plant diversity. Disturbance of mild intensity in these groves led to an increase in diversity and decrease in dominance of species in the community. These changes were associated with decrease in moisture content, organic-C, N and P contents, MBC and N-mineralization rate in soils of mildly disturbed stands.

REFERENCES

Aber JD, Melillo JM, Nadelhoffer KJ, McClaugherty CA and Pastor J (1985). Fine root turnover in forest ecosystems in relation to quantity and form of nitrogen availability: a comparison of two methods. Oecologica (Berlin) 66: 317-321.

Adams MA and Attiwill PM (1986). Nutrient cycling and nitrogen mineralization in eucalypt forest of Southeastern Australia. II. Indices of nitrogen mineralization. Plant Soil 92: 341-362.

Aerts R, Bakker C and De Caluwe H (1992). Root turnover as determinant of the cycling of C, N and P in a dry heath-land ecosystem. Biogeochemistry 15: 175-190.

Ahmad A (1993). Geological mapping, Meghalaya. An overview. In, Records of Geological Survey of India. Government of India. Vol. 126, part 4, 19

Aiba Shin- Ichiro and Kitayama Kancehiro (1999). Structure, composition and species diversity in al altitude-substrate matrix of rain forest tree communities on Mount Kinabalu, Borneo. Plant Ecology 40: 139-157.

Akira Itoh (1995). Effect of forest floor environment and germination and seedling establishment of two Borean rain forest emergent species. Journal of Tropical Ecology 11: 517-527.

Alban DH (1969). The influence of Western hemlock and Western red Cedar on soil properties. Soil Science Society of American Journal 46: 853-861.

Allen SE, Grimshaw HM, Parkinson JA and Quarmby C (1974). Analysis of ecological materials. Blackwell Scientific Publications Oxford.

Anderson JPE and Domsch KH (1986). Carbon link between microbial biomass and soil organic matter. In: Perspectives in Microbial Ecology (Megusar E and Gantan M eds.) Malinska knijiga, Ljubljana, pp. 467-474.

Anderson JPE and Domsch KH (1980). Quantities of plant nutrients in microbial biomass of selected soils. Soil Science 130: 211-216.

Anderson JM and Ingram JS (1993). Tropical Soil Biology and Fertility. A hand book of methods, 2nd edition, CAB International. Wallingford, UK.

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

Armesto JJ, Mitchell JD and Villogram C (1986) A comparison of spatial patterns of trees in tropical and temperate forests. Biotropica 18: 1–11.

Arunachalam A (1996). The role of litter and fine roots in organic matter and nutrient dynamics during recovery of degraded subtropical forest ecosystems. PhD thesis, NEHU, Shillong.

Arunachalam K, Arunachalam A and Melkania NP (1999). Influence of soil properties on microbial populations, activity and biomass in humid subtropical mountainous ecosystems of India. Biology and Fertility of Soils 30: 217-223.

Ashton PS (1969).Speciation among tropical forest trees: some deductions in the light of recent evidence. Biological Journal of Linnaean Society London 1: 155–96

Ashton PS and Hall Pamela (1992). Comparision of structure among mixed dipterocarp forest of north western Borneo. Journal of Ecology 80: 459-481.

Ashton PMS, Gunatilleke CVS and Gunatilleke IAUN (1995). Seedling survival and growth of four Shorea species in a Sri Lankan rain forest. Journal of Tropical Ecology 11: 263-279.

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

Balakrishnan NP (1981–1983) Flora of Jowai and vicinity, Meghalaya, 2 vols. BSI, Howrah.

Barik SK (1992). Ecology of tree regeneration along a disturbance gradient in subtropical wet hill forest of Meghalaya. PhD thesis, NEHU, Shillong.

Barik SK, Pandey HN, Tripathi RS and Rao P (1992) Microenvironmental variability and Species diversity in treefall gaps in a sub-tropical broad leaved forest. Vegetatio 103: 31-40.

Bauhus J and Barthel R (1995). Mechanisms for carbon and nutrient release and retention within beech forest gaps. II. The role of soil microbial biomass. Plant and Soil 168-169, 585-592.

Bauhus J and Khanna PK (1994). Carbon and nitrogen turnover in two acid forest soils of southeast Australia as affected by phosphorous addition and drying and rewetting. Biology and Fertility of Soils 17: 212-218.

Beck T, Capriel P, Borchert H and Brandhuber R (1995). Die mikrabielle biomass in landwirtschaftlich genutzten Bolden.2. Mitteilung: Beziehungen der biomass Zu chemischen and physikaloschen bodeneigenschaften. Agribiological Research 48: 74-82.

Benzing DH (1983). Vascular epiphytes : a survey with special reference to their interactions with other organisms. In: Sulton SL, Whitmore TC and Chadwick AC (eds.) Tropical rain forest, Ecology and management. Blackwell Scientific publications, Oxford,,pp. 11-23.

Berendse F (1983). Interspecific competition and niche differentiation between *Anthoxanthum odoratum* and *Plantago lanceolata* in a natural hayfield. Journal of Ecology 71: 379-390.

Berendse F, Bobbink R and Rouwenhorst G (1989). A comparative study on nutrient cycling in wet heathland ecosystems. II. Litter decomposition and nutrient mineralization. Oecologia 78: 338-348.

Berendse F (1990). Organic matter accumulation and nitrogen mineralization during secondary succession in heathland ecosystems. Journal of Ecology 78: 413-427.

Berg B and Stoff H (1980). Decomposition rate and chemical changes of Scots pine needle litter II. Influence of chemical composition. In: structure and function of Northern Coniferous Forests – An ecosystem study (Perrson T ed.) Ecological Bulletins, Stockholm Vol.32, pp. 313-390.

Boohj R and Ramakrishnan PS (1981). Phenology of trees in sub-tropical evergreen mountain forest in north-east India. Geo-Eco Trop 5: 189-209.

Birch HF (1958). The effect of soil drying on humus decomposition and nitrogen availability. Plant Soil 12: 81-96.

Bolton Jr.H, Smith JJ and Link SO (1993). Soil microbial biomass and activity of a disturbed and undisturbed shrub-steppe ecosystem. Soil Biology and Biochemistry 25:545-552.

Bormann FH and Likens GE (1979). Pattern and Process in a Forest Ecosystem, Springer, New York, Pp 253.

Bormann FH and Likens GE (1981). Pattern and Process in a Forest Ecosystem, Springer, New York.

Box EO (1995). Climatic relations of the forest of East and South-East Asia. In: Box *et al* (eds.) Vegetation Science in Forestry. Kluwer Academic Publishers, Dordrech, Netherlands, pp 23-35.

Brandis D (1897). Indian Forestry Working. Oriental Institute, UK.

Brookes PC, Heijnen CE, McGrath SP and Vance ED (1986). Soil microbial biomass estimates in soil contaminated with metals. Soil Biology and Biochemistry 18(4): 383-388.

Brown JH (1981). Two decades of homage to Santa Roselia: towards a general theory of diversity. American Zoologist 21: 877-888.

Burket JZ and Dick RP (1988). Microbial and soil parameters in relation to N-mineralization in soils of diverse genesis under differing management systems. Biology and Fertility of Soils 27: 430-438.

Campbell CA, Beiderbeck VO and Warden FG (1973). Influence of simulated fall and spring conditions on the soil system. III. Effect of method of simulating spring temperatures on ammonification, nitrification and microbial populations. Proceeding of Soil Science Society America 37: 382-386.

Campbell DG, Daly DC, Prance GT and Maciel UN (1986). Quantitative ecological inventory of terre firme and Varzea tropical forest on the Rio Xingu, Brazalian Amazon. Brittonia (New York) 38: 369- 93.

Campbell DG, Stone JL and Rosas A Jr. (1992) A comparision of the phytosociology and dynamics of three flood plain (Varzae) forests of known ages, Rio Jurua, Western Brazalian Amazon. Botonical Journal of Linnaean Society 108: 213-237.

Carter MR (1986). Microbial biomass as an index for tillage induced changes in soil biological properties. Soil and tillage Research 7: 29-40.

Champion HG and Seth SK (1968) A revised survey of forest types of India. Govt. of India Press, Delhi.

Chandrashekara UM and Sankar S (1998) Ecology and management of sacred groves in Kerala, India. Forest Ecology and Management 112: 165-177.

Chauhan AS (1983). Dwindling taxa of Meghalaya In: An assessment of Threatened plants of India (eds.) Jain SK and Rao RR. Botanical Survey of India Howrah pp. 142-145.

Chao WL, Gan KD and Chao CC (1993). Nitrifying and nitrifying potential of tropical and subtropical soils. Biology and Fertility of Soils 15: 87-90.

Chapin FS (1980). The mineral nutrition of wild plants. Annu. Rev. Ecol. Syst. 11:233-260.

Chapin III FS, Walker BH, Hobbs RJ, Hooper DU, Lawton H, Sala H and Tilman D (1997). Biotic control over the functioning of ecosystems. Science 277: 500-503.

Clein JS and Schimel JP (1995). Nitrogen turnover and availability during succession from Alder to Popular in Alaskan Taiga Forests. Soil Biology and Biochemistry 27: 743-752.

Clements FE (ed.) (1916). Plant succession. Carnegie, Wash. Publ. pp 242.

Collins SI, Glenn SM and Gibson DJ (1995). Experimental analysis of intermediate disturbance and initial floristic composition: decoupling cause and effect. Ecology 76: 486-492.

Connell JH (1978). Diversity in tropical rain forest and coral reefs. Science 199: 1302-1310.

Connell JH and Lowman MD (1989) Low-diversity tropical rain forests: Some possible mechanisms for their existence. The American Naturalist 134: 89–119

Das S and Deori NC (1983). A census of endemic orchids of northeast India. In: An assessment of Threatened plants of India (eds.) Jain SK and Rao RR. Botanical survey of India, Howrah pp. 104-109.

Davis TAW and Richards PW (1933-34). The vegetation of Moraballi Creek, British Guian; an ecological study of a limited area of tropical rain forest. I, II. Journal of Ecology 21: 350-84, 22:106-55.

Deb DB (1958). Endemisms and outside influence on the flora of Manipur. Journal of Bombay Natural History Society 55: 313-317.

Diaz-Ravina M, Carballas T and Acea MJ (1988). Microbial biomass and metabolic activity in four acid soils. Soil Biology and Biochemistry 20: 817-823.

Diaz-Ravina M, Acea MJ and Carballas T (1993). Microbial biomass and its contribution to nutrient concentration in forest soils. Soil Biology and Biochemistry 25: 25-31.

Diaz-Ravina M, Acea MJ and Carballas T (1995). Seasonal changes in microbial biomass and nutrient flush in forest soils. Biology and Fertility of Soil 19: 220-226.

Edwards PJ (1977). Studies in montane rain forest in New Guinea.II. The production and disappearance of litter. Journal of Ecology 65: 971–1022

Edwards PJ and Grubb PJ (1977). Studies of mineral cycling in a montane rain forest in New Guinea.I. The distribution of organic matter in the vegetation and soil. Journal of Ecology 65: 943–969

Ehrlich PR and Wilson EO (1991). Biodiversity studies; science and policy. Science 253: 758-762.

Ellenberg H (1974). Zeigerwerte der Gefasspflanzen Mitteleuropas. Ser Geobot 9: 55-97.

Ellenberg H (1977). Stickstoff als standortsfaktor, inbesondes fur mitteleuropaische pflanzenges ellschaften. Oecologica Plantarum 12: 1-22.

Eluoard CJP, Pascal RP, Ramesh BR, Haullier F, Durand M, Anavajy S, Moravie MA and Carpentier CG (1997). Monitoring the structure and dynamics of moist evergreen forest in the Western Ghats. (Kodagh district, Karnataka, India). Tropical Ecology 38(2): 193-217.

Eno CF (1960). Nitrate production in the field by incubating the soil in polyethylene bags. Soil Science Society of America proc. 24: 277-279.

Felfili JM (1995). Diversity, structure and dynamics of a gallery forest in central Brazil. Vegetatio 117: 1-15.

Fenn ME, Poth MA, Dunn PH and Barro SC (1993). Microbial N and biomass, respiration and N-mineralization in soil beneath two chaparral species along a fire –induced age gradient. Soil Biology and Biochemistry 25: 457-466.

Fisher MJ, Rao IM, Zyarza MA, Lascano CE, Sanz JI, Thomas RJ, Vera RR (1994). Carbon storage by introduced deep – rooted grasses in South America savannas. Nature 371: 236-238.

Fisher RA, Corbet AS and Williams CB (1934). The relationship between the number of species and the number of individuals in a random sample of an animal population. Journal of Animal Ecology 12: 42-58.

Frank DA and McNaughton SJ (1991). Stability increases with diversity in plant communities : empirical evidence from the 1998 Yellow stone Drought. Oikos 62: 360-362.

FSI (1987). The State of Forest Report. Government of India, Forest survey of India, Dehradun.

FSI (1997). The State of Forest Report. Government of India, Forest survey of India, Dehradun.

FSI (1999). The State of Forest Report. Government of India, Forest survey of India, Dehradun.

Gadgil R and Gadgil PD (1975). Suppression of litter decomposition by mycorrhizal roots of *Pinus radiata*. Nz. J. For. Sci. 5: 33 - 41.

Gadgil R and Vartak VD (1976). The sacred groves of Western Ghats in India. Economic Botany 30: 152-160.

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

Ganashaiah KN, Shaanker RV and Bawa KS (1997). Diversity of species assemblages of Islands: Predictions and their test using tree species composition of Shola fragments. Current Science 73(2): 188-194.

Gentry AH (1982). Patterns of neotropical plant species diversity. Evolutionary Biology 15:1-84.

Gentry AH (1988) Tree species richness of upper Amazon forests. Proceedings of National Academy of Sciences, USA 85: 156–159

Gentry AH and Dodson C (1987). Contribution of nontrees to species richness of a tropical rain forest. Biotropica 19: 149-156.

Gestel MV, Merckx R and Vlassok K. 1993. Microbial biomass and activity in soils with fluctuating water contents. Geoderma 56: 617-626.

Gilmour JT, Clark MD and Sigua GC (1985). Estimating net nitrogen mineralization from carbon dioxide evolution. Soil Science Society of America Journal 49: 1398-1402.

Gitay H and Nobel IR (1997). What are functional types and how should we seek them? In: Smith TM, Shugart HH, Woodward EI (Eds.) Vegetational functional types: Their relevance to ecosystem properties and global change. Cambridge University Press, Cambridge Pp.3-19.

Gleason HA (1926). The individualistic concept of the plant association. Bull. Torr. Bot. Club 53: 7-26.

Granatstein DM, Bezdicek DF, Cochran VL, Elliott LF, Hammel J (1987). Long term tillage and rotation effects on soil microbial biomass, carbon and nitrogen. Soil Biology and Biochemistry 5: 265-270.

Grime JP (1979). Plant Strategies and Vegetation Process. Wiley, Chichester.

Grime JP (1998). Benefits of plant diversity to ecosystem: immediate filter and founder effects. Journal of Ecology 86: 902-910.

Grubb PJ (1977). The maintenance of species-richness in plant communities: the importance of the regeneration niche. Biological Rev.52: 107-145.

Hajra PK (1975) Law lyngdoh or Sacred groves at Mawphlang, Visitor's guide, Government of Meghalaya, Shillong.

Hall JB and Swaine MD (1981). Distribution and ecology of vascular plants in a tropical rain forest. The Hauge.

Haridasan K and Rao RR (1985–1987) Forest flora of Meghalaya. 2 vols. Bishen Singh Mahendrapal *Singh. DehraDun, India.*

Harper JL and Hawksworth DL (1995). In (eds.) Hawksworth Dl, Biodiversity measurement and estimation, Oxford.

Hassink J (1993). Relationships between the amount and the activity of the microbial biomass in Dutch grassland soils: comparison of the FI method and the SIR method. Soil Biology and Biochemistry 25: 533-538.

Henrot J and Robertson GP (1994). Vegetation removal in two soils of the humid subtropics: Effect of microbial biomass. Soil Biology and Biochemistry 26: 111-116.

Herwitz SR (1981) Regeneration of selected tropical tree species in Corcovado National Park, Costa Rica. University California Publication in Geography 24, Berkeley, California.

Holttum, RE (1957). A revised flora of Malaya, Vol 1. Orchids of Malaya. 2nd edition, Govt. Print. Off. Singapore.

Hooker JD (1872–1897) Flora of British India Vols. 1–7. London.

Hooker JD (1854). Himalayan Journals Vol. I-II. London.

Hooper D and Vitousek PM (1997). The effects of plant composition and diversity on ecosystem processes. Science 277: 1302-1305.

Horn H (1966). The measurement of overlap in comparative ecological studies. American Naturalist 100:419-424.

Hubbell SP (1979) Tree dispersion, abundance and diversity in a tropical dry forest. Science 203: 1299–1309.

Hubbell SP and Foster RB (1983). Diversity of canopy trees in a neotropical forest and implications for conservation pp. 25-41. In: Sutton SL, Whitmore TC and Chadwick AC (eds.) The Tropical Rain Forest: Ecology and Management.

Hurd LE, Mellinger MV, Wolf LL and McNaughton SJ (1971). Stability and diversity at three trophic levels in terrestrial systems. Science 173: 1134-1136.

Huston M (1979). A general hypothesis of plant species diversity. American Naturalists 113: 81-101.

Huston MA (1994). Biological diversity: the coexistence of species on changing landscapes. Cambridge University Press, Cambridge, UK.

Jaccard P (1912). The distribution of the flora of the Alpine zone New Phytol., 11:37-50. Smith, Benjamin, Wilson, J.Baston., 1996; A consumer's guide to evenness indices Oikos 76: 70-82.

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

Jenkinson DS (1977). The soil biomass. New Zealand Soil News 25: 213-218.

Jenny (1980). The Soil Resource. Springer- Verlag. New York.

Johansson D (1974) Ecology of vascular epiphytes in West African rain forest. Acta Phytogeography Suecica 59: 1-129.

Johnston M and Gillman M (1995). Tree population studies in low-diversity forests, Guyana. I. Floristic composition and stand structure. Biodiversity and Conservation 4: 339-362.

Joseph J (1982). Flora of Nongpoh and vicinity. Forest department, Government of Meghalaya.

Joshi NV, Suresh HS and Prabhakar R (1997). Hierarchical partition of tree diversity across spatial scales. A case study from Nilgiri Biosphere Reserves, Southern India. International Journal of Environmental Science 23: 185-196.

Kadavul K and Parthasarathy N (1999). Structure and composition of woody species in tropical semievergreen forest of Kalrayan hills, Eastern Ghats, India. Tropical Ecology 40(2): 247-60.

Kaiser EA, Muller T, Roergensen RG, Insam H and Heinemeyer O (1992). Evolution of methods to estimate the soil microbial biomass and the relationship with soil texture and organic matter. Soil Biology and Biochemistry 24: 675-683.

Kanjilal VN, Kanjilal PC, Das A, De RN and Bor NL (1934–1940) Flora of Assam 5 vols. Govt. Press, Shillong.

Kanwar JS and Chopra SL (1967) Practical Agricultural Chemistry. S Chand and Co., New Delhi.

Kataki SK (1983). Some rare plants in Khasi and Jaintia hills of Meghalaya. In: An assessment of Threatened plants of India (eds.) Jain SK and Rao RR. Botanical survey of India Howrah pp. 104-109.

Kellman M, Tackaberry R and Rigg L (1998). Structure and function in two tropical gallery forest communities: implications for forest conservation in fragmented systems. Journal of Applied Ecology 35: 195-206.

Keeney D (1980). Prediction of soil nitrogen availability in forest ecosystem: a literature review .Forest Science 26: 156-171.

Kinzel H (1983). Influence of limestone, silicates and soil pH on vegetation. In: Lang OL, Nobel PS, Osmond CB, Ziegler H (eds.) Encyclopedia of plant physiology 12: physiological plant ecology III. Springer, Berlin Heidelberg, New York pp. 201-244.

Kitayama K, Aiba Shin-Ichiro, Noreen M-L and Ohsawa M (1998). Soil N-mineralization rates of rainforest in a matrix of elevations and geological substrates on Mount Kinabalu, Bornea. Ecological Research 13: 301-312.

Khan ML, Shaily M and Bawa KS (1997) Effectiveness of the protected area network in biodiversity conservation, a case study of Meghalaya state. Biodiversity and Conservation 6: 853-868.

Khiewtam RS and Ramakrishnan PS (1993) Litter and fine root dynamics of relic sacred grove forest of Cherrapunjee in northeastern India. Forest Ecology and Management. 60: 327-344.

Korner Ch (1994). Scaling from species to vegetation: the usefulness of functional groups. In: Biodiversity and ecosystem function.(eds).Schultze ED and Mooney AH, Springer-Verlag, Berlin, Heidelberg Pp. 117-140.

Kumar Y (1984). Studies on the flora of Balphakram Wildlife Sanctuary, Garo Hills, Meghalaya. PhD thesis, NEHU, Shillong.

Kumar Y (1991). Floristic studies on Balphakram Wild life Sanctury in Meghalaya – Rare, endemic or threatened flora. Journal of Meghalaya Science Society 11-12: 33-48.

Lamb D (1980). Soil nitrogen mineralization in the forest floor of stands of *Pinus radiata* on different soils. Journal of Ecology 63: 615-625.

Lamee G (1967). Investigations sur la mineralization de tazote et son evolution annuelle dans des humus forestifers in situ. Oecologia Planta 2: 285-334.

Lavorel S, McIntyre S, Landsberg J and Forbes TDA (1997). Plant functional classifications: from general functional groups to specific groups of response to disturbance. Trends in Ecology and Evolution 12: 474-478.

Liberman D, Liberman M, Peralta R and Hartshom GS (1996). Tropical forest structure and composition on a large-scale altitudinal gradient in Costa Rica. Journal of Ecology 84: 137-152.

Likens GE, Bormann FH, Johnson NM, Fisher DW and Pierce RS (1970). Effects of forest cutting and herbicide treatment on nutrient budgets in Hubbard Brook Watershed-ecosystem. Ecological Monographs 40: 23-47..

Loreau M (2000). Biodiversity and ecosystem functioning: recent theoretical advances. Oikos 91: 3-17.

Lovejoy TE (1980). Changes in biological diversity. In: G.O. Barney (ed.) The global 2000 report to the president: Vol.2. (The Technical Report) pp. 327-332. Harmendworth, Penguin Books.

Lawton JH and Brown VK (1993). Redundancy in ecosystems. In: Ed. Schulzt and Mooney HA, Biodiversity and ecosystem function. Springler Verlag. Berlin. pp 255-270.

Lugo AE, Brown S (1993). Management of tropical soils as sinks or sources of atmospheric carbon. Plant and Soil 149: 27-41.

Luizao RCC, Bonde TA and Rosswell T (1992). Seasonal variation of soil microbial biomass- the effect of clear felling in a tropical rain forest and establishment of pasture in the central Amazon. Soil Biology and Biochemistry 24: 805-813.

Lynch JM and Panting LM (1981). Measurement of microbial biomass in intact cores of soil. Microbial Ecology 7: 229-234.

Magurran A (1988). Ecological Diversity and its Measurement. Princeton University Press, New Jersey.

Maithani K, Tripathi RS, Arunachalam A and Pandey HN (1996). Seasonal dynamics of microbial C, N and P during regrowth of a disturbed subtropical humid forest in north-east India. Applied Soil Ecology 4: 31-37.

Maithani K, Arunachalam A, Tripathi RS and Pandey HN (1998). Influence of leaf litter quality on N-mineralization in soils of subtropical humid forest regrowths. Biology and Fertility of Soils 27: 44-50.

Manokaran N, La Frankie JV, Kochumman KM, Quah ES, Klahn J, Ashton PS and Hubbell SP (1992). Stand table and distribution of species in the 50 ha reserve plot at Pasoh Forest Reserve. Forest Research Institute of Malaysia, Research data I Kepong, Malaysia.

Marion GM and Black CH (1988). Potentially available nitrogen and phosphorous along a Chaparral fire cycle chronosequence. Soil Science Society American Journal 52: 1155-1162.

May RM (1975). Patterns of species abundance and diversity. In: Evolution of Communities (eds. ML Cody and JM Diamond), Belknap, Harward: 81–120.

McCarthy BC and Facelli JM (1990). Microdisturbance in old fields and forests, implication for woody seedling establishment. Oikos 58: 55-60.

McGrady-Steed J, Harris P and Morin P (1997). Biodiversity regulates ecosystem predictability. Nature 390: 162-165.

McNaughton SJ (1977). Diversity and stability of ecological communities; a comment on the role of empiricism in ecology. American Naturalists.111: 515-525.

McNaughton SJ (1985). Ecology of a grazing system; the serengeti. Ecological monograph.55: 259-294.

Menaut JC, Barbault R, Lavell P, and Lepaze M (1985). African savanna: biological systems of humification and mineralization. In Ecology and management of the World's savvanas (Tothill JC and Mott JJ Eds.). The Australian Academy of Sciences,,Canberra.

Meentemeyer V (1978). Macroclimate and lignin control of litter decomposition rates. Ecology 59: 465-472.

Min Cao, and Zhang Jianhou (1997). Tree species diversity of tropical forest vegetation in Xishuangbanna, SW China. Biodiversity and Conservation 6: 995-1006.

Min Cao, Zhang Jianhou, Feng Zhili, Deng Jimu and Deng Xiaobao (1996). Tree species composition of a seasonal rain forest in Xishuangbanna, South West China. Tropical Ecology 37(2): 183-192.

Misra R (1968). Ecology workbook. Oxford & IBH Publishing Co., Calcutta.

Montangnini F, Haines B, Boring L and Swank W (1986). Nitrification potential in early successional black locust and mixed hardwood forest stands in the Southern Applachains, USA. Biogeochemistry 2: 197-210.

Morecroft MD, Marrs RH and Woodward FI (1992). Altitudinal and seasonal trend in soil nitrogen mineralization rate in Scottish highlands. Journal of Ecology 30: 49-56.

Morisita M (1959). Measuring of interspecific association and similarity between communities. Mem. Fac. Sci. Kyushu Univ. Ser. E (Biol)3: 65-80.

Mosango M (1991). Contribution 'Al' etude botanique biogeochemique de I ecosystem forest region equatoriale (IFBe Kongalo, Zaire). Belgian Journal of Botany 124: 167–194.

Muller Dombois D and Ellenberg H (1974). Aims and methods of vegetation analysis. John Wiley and Sons, New York.

Myers N (1990). The biodiversity challenge: expanded hotspots analysis. The Environmentalist 10: 243-256.

Myers N (1988). Tropical forests: Much more than stock of wood. Journal of tropical Environmentalists 10(4): 243-255.

Myers N, Mittermiler RA, Mittermiler CG, Gustava AB, Da Foseca and Kent J (2000). Biodiversity hotspots for conservation priorities. Nature 403: 853-858.

Myrold DD, Matson PA and Peterson DL (1989). Relationship between soil microbial properties and above ground stand characteristics of coniferous forests in Oregon. Biochemistry 8: 265-281.

Nadelhoffer KJ, Aber JD and Melillo JM (1984). Seasonal patterns of ammonium and nitrate uptake in nine temperate forest ecosystems. Plant Soil 80: 321-335.

Nadkarni NM, Matelson TJ and Haber WA (1995). Structural characteristics and floristic composition of neotropical cloud forest, Monteverde, Costa Rica. Journal of Tropical Ecology 11: 482–495.

Naeem S, Thomson LJ, Lawler SP, Lawton JH, Woodfin RM (1994). Declining biodiversity can alter the performance of ecosystems. Nature 368: 734-737.

Neill C and Melillo JM, Steudles PA, Lerri CC, de Moraces JFL, Piccolo MC and Brito M (1997). Soil carbon and nitrogen stocks following forest clearing for pasture in the southwestern Brazalian Amazon, Ecological Applications 7: 1216-1225.

Nicholson DI (1965). A study of vargin forest near Sardakan North Borneo. In Proceeding Symposium on Ecological Research in Humid Tropics Vegetation UNESCO, pp. 67-87.

Norse EA and McManus RE (1980). Ecology and living resources biological diversity. IN Environmental quality 1980. The eleventh annual report of the council on Environment Quality, pp. 31-80. Washington DC. Council on Environment Quality.

Norse EA, Rosenbaum KL, Wilcave DS, Wilcox BA, Romme WH, Johnston DW and Stout ML (1986). Conserving biological diversity in our national forests, Washington DC, The wilderness society.

Noss RS (1996). Conservation of biodiversity at land-scape scale. In: (eds.) Szaro RC and Johnston DW Biodiversity in managed landscapes: theory and practice. Oxford, New York, USA pp. 574-589.

Nunez-Farfan J and Dirzo R (1988). Within-gap heterogeneity and seedling performance in a Mexican tropical forest Oikos 51: 274-284.

Ohtonen R, Munson R and Brand D (1992). Soil microbial community response to silvicultural intervention in coniferous plantation ecosystems. Ecological Applications 2: 363-375.

Okuda, Toshinori, Kachi, Naoki, Yap, Son Kheong, Manokaran,N (1997). Tree distribution pattern and fate of juvenile in a lowland tropical rain forest- implication for regeneration and maintenance of species diversity. Plant Ecology 131: 155-171.

Oldeman RAA (1978). Architecture and energy exchange of dicotyledonous trees in the forest. In: Thomlinson PB and Zimmerman MH (eds.), Tropical trees as living systems. Cambridge University Press, Cambridge, Eangland.

Olff H, Berendese F and de Visser W (1994). Changes in N-mineralization, tissue nutrient concentrations and biomass compartmentation after cessation of fertilizer application to mown grassland. Journal of Ecology 82: 611-620.

Olson MD, Dinerstein E, Mittermeier RA, Myers N, Thomsen JB and Fonseca GAB da (1998). Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. Conservation Biology 12: 516–520.

Orions GH (1982). The influence of tree falls in tropical forests on tree species richness. Tropical Ecology.23: 255-279.

Paijams K (1970). An analysis of four tropical rain forest sites in New Guinea. Journal of Ecology 58:77-101.

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

Parthasarathy N and Karthikeyan R (1997). Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandal Coast, South India. Biodiversity and Conservation 6: 1063-1083.

Parthasarathy N, Kindal V and Praveen KL (1992). Plant species diversity and human impacts in the tropical wet evergreen forest of southern Western Ghats. In: Indo-French workshop on tropical forest ecosystem: natural functioning and anthropogenic impact 26-27 Nov. French Institute, Pondicherry.

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

Parton WJ, Sanford Rl, Sanchez PA and Stewart JWA (1989). Modelling soil organic matter dynamics in tropical soils. In: Dynamics of soil organic matter in tropical ecosystems, (Coleman DC, Oades JM and Uehara G eds.), Hawaii, USA.

Pastor J, Aber JD, McClaugherty CA, Melillo JM (1984). Above ground production and N and P cycling along a nitrogen mineralization gradient on Blackhawk Island, Wisconsin. Ecology 65: 256-268.

Paul EA and Clark FE (1989). Soil microbiology and biochemistry. Academic Press, San Diego.

Phillips Ol, Hall R, Gentry Ar, Sawyer SA and Vazquez R (1994). Dynamics and species richness of tropical forests. Proceedings of the National Academy of Sciences, USA, 91: 2805-2809.

Pielou EC (1975). Ecological diversity. John Wiley and Sons Inc. New York.

Pimm SL (1984). The complexity and stability of ecosystems. Nature. 307: 312-326.

Pisek A (1956). Der Wasserhaushalt der meso- und Hygrophytes. In: Ruhland W (ed.) Handbuch der Pflanzenphysiologie, Vol.3. Springer Berlin Gattingen, Heidelberg pp. 825-853.

Pietikainen J and Fritze H (1995). Clear cutting and prescribed burning in coniferous forest: comparision of effects on soil fungal and fatal microbial biomass, respiration activity and nitrification. Soil Biology and Biochemistry 27: 101-109.

Poore MED (1968). Studies in Malaysian rain forest. I. The forest on Triassic sediments in Jengka forest reserve. Journal of Ecology 56: 143–196

Poulsen AD and Pendry CA (1995). Inventories of ground herbs at three altitudes on Bukit Belalong, Brunei, Borneo. Biodiversity and conservation 4: 745-757.

Proctor J, Lee YE, Langley AM, Munro WRC and Nelson T (1988). Ecological studies of Gunung Silam, a small ultrabasic mountain in Sabah, Malayasia I. Environment, Forest structure and Floristic. Journal of Ecology 76: 320-340.

Proctor J, Anderson JM, Chai P and Vallack HW (1983). Ecological studies in four contrasting lowland forest in Gunung Malu national park. Sarawak. 1. Forest environment, structure and floristic. Journal of Ecology 71: 237-260.

Puri GS (1960). Indian Forest Ecology, Oxford Book and Sty. Co., New Delhi.

Putman RJ (1994). Community Ecology. Chapman and Hall, London.

Ragubanshi AS and Singh H (1992). Microbial management for restorating soil fertility. In Restoration of degraded land: Concepts and strategies (Singh JS ed.) Rastogi publications, Merrut, India. pp. 50-63.

Raison RJ, Connell MJ, Khanna PK (1987). Methodology for studying fluxes of soil mineral N in situ. Soil Biology and Biochemistry 19: 521-530.

Ramakrishnan PS, Saxena KG and Chandrashekara UM (1998). Conserving the sacred for biodiversity management. Oxford and IBH publication Co Pvt Ltd, New Delhi.

Rao AS (1974). The vegetation and phytogeography of Assam-Burma. In Mani MS (ed.). Ecology and Biogeography in India, Hague 204–205.

Rao P (1992). Ecology of gap phase regeneration in a subtropical broadleaved climax forest of Meghalaya. PhD thesis, NEHU, Shillong.

Rao P, Barik SK, Pandey HN and Tripathi RS (1997). Tree seed germination and seedling eastablishment in tree fall gaps and understorey in a sub-tropical forest of north east India. Australian Journal of Ecology 22: 136-145.

Rao RR and Hajra PK (1986). Floristic diversity of Eastern Himalaya – in a conservation perspective. Proceeding of Indian Academic Sciences 103-125.

Rao RR and Haridasan K (1983). Threatened plants of Meghalaya – A plea for conservation. In : An assessment of Threatened plants of India (eds.) Jain SK and Rao RR. Botanical Survey of India Howrah, pp. 94-103.

Raunkiaer C (1934). The life-form of plants and statistical plant geography. Toranl.H. Gilbart-Cartes. Oxford University Press.

Rice EL (1979). Allelopathy: an update. Bot. Rev. 45: 15-109.

Rice EL and Pancholy SK (1972). Inhibition of nitrification by climax ecosystems. American Journal of Botany 59: 1033-1040.

Richards PW (1986). The nature of tropical forest ecosystems. In Nicholas Polunin (ed.); 'Ecosystem theory and application'. A John Wiley International Publication, pp. 131-171.

Richards PW (1996). Tropical rain forest, an ecological study 2nd ed. Cambridge university press, Cambridge, UK.

Robertson GP (1984). Nitrification and nitrogen mineralization in a lowland rainforest succession in Costa Rica, Central America, Oecologia 61: 99-104.

Sahunalu P and Dhanmanonda P (1995). Structure and dynamics of dry dipterocarp forest, Sakaerat, North Eastern Thialand, In: E.O.Box et al (eds.) Vegetation Science in Forestry, Kluwer Academic Publication pp. 465-494.

Samant SS, Dhar U and Palni, LMS (1998). Medicinal plants of Indian Himalaya, Diversity distributional potential values. Gyan odyog Prakashan, Nainital.

Saratchandra SV, Perrott KW and Littler RA (1989). Soil microbial biomass: Influence of simulated temperature changes on size activity and nutrient content. Soil Biology and Biochemistry 21: 987-993.

Sarukhan, Piners JD and Maotinez-Ramos M (1985). Plant demography: A community-level interpretation. In James White (ed.), Studies on plant demography, Academic press Inc. (London) Ltd.

Schlapfer B and Ryser P (1996). Leaf and root turnover of three ecologically contrasting grass species in relation to their performance along a productivity gradient. Oikos 75: 398-406.

Schnurer J, Clarhalm M and Rosswall T (1985). Microbial biomass and activity in agricultural soils with different organic matter contents. Soil Biology and Biochemistry 17: 611-618.

Schulze ED (1982). Plant life forms and their carbon, water and nutrient relations. In Lange OL, Nobel PS, Osmond CB, Ziegler H (eds.) Physiological plant ecology II. Springer, Berlin Heidelberg, New York, pp. 615-676.

Schulze E-D and Hall AE (1982). Stomatal responses, water loss and CO_2 assimilation rates of plants in contrasting environments. In: Lang OL, Nobell PS, Osmond CB, Ziegler H (eds.) Encyclopedia of plant physiology new series, 12B, physiological plant ecology H, Springer, Berlin Heidelberg, New York. Pp. 181-230.

Schulze E-D and Mooney HA (1994). Eds. Biodiversity and ecosystem function. Springer-Verlag, Berlin Heidelberg.

Shannon and Weaver (1949). The mathematical theory of communication. University of Ilinois press, Urbana.

Shannon CE and Wiener W (1963). The mathematical theory of communication, University of Illinios press (Urbana), pp.177.

Sierra J (1997). Temperature and soil moisture dependence of N-mineralization in intact soil cores. Soil Biology and Biochemistry 29: 1557-1563.

Simpson EH (1949). Measurement of diversity. Nature 163: 688.

Singh J (1980). Studies on structural and functional aspects of two subtropical humid forest types of Meghalaya. PhD. Thesis, NEHU, Shillong.

Singh JS (2002). The biodiversity crises: A multifaceted review. Current Science 82: 638-647.

Singh JS, Raguvanshi AS, Singh RS and Srivastava SC (1989). Microbial biomass acts as a source of plant nutrients in dry tropical forest and savanna. Nature 399:449-500.

Singh JS, Raguvanshi AS, Singh RS and Srivastava SC (1991). Microbial C, N and P in dry tropical savanna: Effect of burning and grazing. Journal of Applied Ecology 28: 869-878.

Sinha B and Maikhuri RK (1998). Conservation through 'Socio-cultural-religious practice' in Gahrwal Himalaya: A case study of Hariyal sacred site. In: Ramakrishnan PS, Chandrashakara UM and Shankar S (eds.) Conserving the sacred for biodiversity management. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.

Slobodkin LB and Sanders HL (1969). On the contribution of environmental predictability to species diversity. Brookhaven Symposia in Biology 22: 82–95.

Smith DM (1986). The practice of silviculture. John Wiley and Sons, New York, USA.

Smith RF (1970). The vegetation structure of a Puerto Rican rain forest before and after short term gamma irradiation Pp 103-140 in Odum H (ed) A tropical rain forest. US Atomic Energy Commission, Tennessee, Oak Ridge.

Smith JL and Paul EA (1990) The significance of soil microbial biomass estimations. In: Soil Biochemistry (Bollag JM and Stotzy ed.), Marcel Dekker Inc, New York, pp. 357-396.

Sorenson J (1948). A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. Detkong. Dauske Vidrnsk.Selsk.Biol. Skn.5 (4): 1-34.

Sorenson LH (1974). Rate of decomposition of organic matter in soils as influenced by repeated air drying-rewetting and repeated additions of organic matter. Soil Biology and Biochemistry 6: 287-292.

Srivastava SC (1992). Influence of soil properties on microbial C, N and P in dry tropical ecosystems. Biology and Fertility of Soils 13: 178-180.

Srivastava SC and Singh JS (1988). Carbon and phosphorous in the soil biomass of some tropical soils of India. Soil Biology and Biochemistry 20: 743-747.

Srivastava SC and Singh JS (1989). Effect of cultivation on microbial biomass C and N of dry tropical forest soil. Biology and Fertility of soils 8: 343-348.

Srivastava SC and Singh JS (1991). Microbial C, N and P in dry tropical forests soils: Effects of alternate land uses and nutrient flux. Soil Biology and Biochemistry 23: 117-124.

Stapanian MA, Cassell DL, Cline SP (1997). Regional patterns of local diversity of trees: associations with anthropogenic disturbance. Forest Ecology and Management 93: 33-44.

Stenseth NC (1979). Where have all the species gone? On the nature of extinction and Red Queen hypothesis. Oikos 33: 196-227.

Sugden AM and Robins RJ (1979). Aspects of the ecologyof vascular epiphytes in Columbian cloud forest. 1. The distribution of the epiphytic flora. Biotropica 11: 173-188.

Sukumar R, Dattaraja HS, Suresh HS, Radakrishnan J, Vasudev R, Nirmala S and Joshi NV (1992). Long term monitoring of vegetation in a tropical deciduous forest in Madumalai, Southern India. Current Science 62: 608-616.

Swamy PS, Sundarpandian SM and Chandrasekaharan S (1998). Sacred groves of Tamilnadu. In: Ramakrishnan PS, Saxena KG and Chandrashekhara UM 1998. (eds) Conserving the Sacred for Biodiversity Management, Oxford and IBH Publishing Co. New Delhi.

Swift MJ, Heal OW and Anderson JM (1979). Decomposition in terrestrial ecosystems, Vol.5, University of California Press, Berkeley.

Symstad A, Tilman D, Willson J and Knops J (1998). Species loss and ecosystem functioning: effect of species identity and community composition. Oikos 81: 389-397.

Takhtajan A (1969). Flowering plants, Origin and dispersal, Edinburg.

Taktajan A (1988). Floristic regions of the world. Bishen Singh Mahandra Pal Singh, Dehradun. 71-78.

Tansley AG (1935). The use and abuse of vegetational concepts and terms. Ecology 16: 284-307.

Theng BKG, Tata KR and Sollins P (1989). Constituents of organic matter in temperate and tropical soils. In: Dynamics of soil organic matter in tropical Ecosystems (Coleman DC, Oades JM and Uehara eds.), University of Hawaii Press, Honolula, Pp. 5-32.

Thorington Jr. R.W, Tannenbaum A Tarak and Rudran R (1982). Distribution of trees on Borro Colorado Island: A five hectare sample. In: Leign EG, Rand Jr.AS and Windsor DM (Eds.) The ecology of tropical forest – seasonal rhythms and long-term changes. Smithsonian Institution Press, Washington, DC.

Tilman D (1982). Resource competition and community structure. Princeton University Press, Princeton.

Tilman D (1988). Plant stratagies and the dynamics and structure of plant communities. Princeton University Press, Princton. pp. 360.

Tilman D and Downing JA (1994). Biodiversity and stability in grasslands. Nature.367: 363-365.

Tilman D, Knops J, Wedin D, Reich P, Ritchie M and Siemann E (1997). The influence of functional diversity and composition on ecosystem processes. Science 227: 1300-1302.

Tilman D, Wedin D, Knops J (1996). Productivity and sustainability influenced by biodiversity in grassland ecosystems. Nature 379: 718-720.

Tiwari B K, Barik S K and Tripathi R S (1999). Sacred forest of Meghalaya. Biological and cultural diversity. Reginol center, National Afforestation and Eco-Development Board, NEHU, Shillong.

Turesson G (1930). The selective effect of climate upon the plant species. Herediates 14: 99-152.

Turner DP, Sollins P, Leuking M and Rudd N (1993). Availability and uptake of inorganic nitrogen in a mixed old growth coniferous forest. Plant and Soil 14: 163-174.

Ugland KI and Gray JJ (1982). Log normal distribution and the concept of community equilibrium. Oikos 39: 171-178.

UNEP (United Nations Environment Programme1992). Convention of biological diversity June 1992. Nairobi: United Nations Environment Programme Environmental Law and Institutions Programme Activity Center.

Unwin GL (1989). Structure and composition of the abrupt rain forest boundary in the Herberton Highland, North Queensland. Australian Journal of Botany 37: 418-427.

Upadhaya K, Law PS, Pandey HN, Tripathi RS. (2002). Tree diversity in sacred groves of Meghalaya, north-east India. Biodiversity and Conservation, (in Press).

Valencia R, Balslev H Pazy Mino C G (1994). High tree alpha diversity in Amazonia Ecuador . Biodiversity and Conservation 3: 21-28.

Vance ED, Brookes PC and Jenkinson DS (1987). Microbial biomass measurements in forest soils: The use of chloroform fumigation-incubation method for strongly acid soils. Soii Biology and Biochemistry 19: 697-702.

Van Cleve K, Chapin FS III, Dyrness CT, Viereck LA (1991). Elemental cycling in taiga forests: state factor control. Bioscience 41: 78-88.

Van Dam D, Veldkamp E and Bremen N (1997). Soil organic carbon dynamics: variability with depth in forested soils under pasture in Costa Rica. Biogeochemistry 39: 343-375.

Van Der Krift, Tanka AJ and Berendse Frank (2001). The effect of plant species on soil nitrogen mineralization. Journal of Ecology 89: 55-561.

Van Gestel M, Ladd JN and Amato M (1991). Carbon and nitrogen mineralization from two soils of contrasting texture and microaggregate stability: Influence of sequential fumigation, drying and storage. Soil Biology and Biochemistry 23: 313-322.

Van Vauren MMI, Aerts R, Berendse F and Devisser W (1992). Nitrogen mineralization in heathland ecosystem dominated by different plant species. Biogeochemistry 16: 151-166.

Veldkamp E (1994). Organic Carbon turn over in three tropical soils under pasture after deforeststion. Soil Science Society of America Journal 58: 175-180.

Verchot LV, Holmes Z, Mulon L, Groffman PM, Lovett GM (2001). Gross Vrs net rates of N mineralization and nitrification as indicators of functional differences between forest types. Soil Biology and Biochemistry 33: 1889-1901.

Visalakshi, N (1995). Vegetation analysis of two tropical dry evergreen forests in Southern India. Tropical Ecology 36: 117-127.

Vitousek PM (1981). Clear cutting and nitrogen cycling. In: Nitrogen cycling in terrestrial ecosystems: Processess, ecosystem strategies and management implications (Clark FE and Rosswall TH ed.) Ecological Bulletin 33, Swedish Natural Science Research Council, Stockholm, Sweden.

Vitousek PM, Aber J, Howarth RW, Likens GE, Matson PA, Schindler DW, Schlesinger WH and Tilman GD (1997) Human alteration of the global nitrogen cycle: Causes and Consequences, Issues in Ecology No. 1.

Von Lutzow, Zelles L, Scheunert I and Ottow JCG (1992). Seasonal effect of liming, irrigation and acid precipitation on microbial biomass N in a spruce (Picea abies L) forest soil. Biology and Fertility of Soils 13: 130-134.

Walkey A and Black IA (1934). An examination of the jet jareff method for determining soil organic matter and proposed modification of the chromic acid filtration method. Soil Science 37:29-38.

Wardle DA (1992). A comparative assessment of factors which influence microbial biomass carbon and nitrogen levels in soil. Biological Reviews 67: 321-356.

Wardle DA, Zackrisson O, Hornberg G and Gallet C (1997). The influence of island area on ecosystem properties. Science 277: 1296-1299.

WCMC (1992). Global biodiversity strategy (ed.) Groombridge B. World Conservation and monitoring Centre. Chapman and Hall. London.

Weaver PL and Murphy PG (1990). Forest structure and productivity in Puerto Rico's Luquillo mountains. Biotropica 22: 69–82.

Wedin DA and Tilman D (1990). Species effects on nitrogen cycling: a test with perennial grasses. Oecologia 84: 433-441.

Whitford PB (1948). Distribution of woodland plants in relation to succession and clonal growth. Ecology 30: 199–208

Whitmore TC (1975). Tropical rain forest of the Far east. Oxford University press. Oxford.

Whitmore TC (1990). An introduction to tropical rain forest. Oxford.

Whitmore TC (1998). An introduction to Tropical Rain Forests, 2nd. eds. Oxford University Press, Oxford.

Whittaker RH (1972). Evolution and measurement of species diversity. Taxon 21: 213–251.

Whittaker, RH (1975). Communities and Ecosystems. Mac Millan Publishing Co. Inc. New York.

Whittaker RH (1977). Evolution of species diversity in land communities. In. Evolutionary Biology Vol.10 (eds.) Hecht MK, Steere Wc and Wallace B. Plenum, New York pp. 1-67.

White J (1980). Demographic factors in population of plants. In: Otto T Solbring (ed.), Demography and evolution in plant population. Botanical monographs, Blackwell scientific publication, Oxford, Vol. 15.

Wilson EO (1988). (Ed.). Biodiversity, Washington, DC. National Academy Press.

Wilson J, Bastow, Wells, Terry CE, Trueman Ian.C, Jones, Grant, Atkinson MD, Crawley MJ, Dodal ME, Silvertown J (1996). Are there assembly rules for plant species abundance? An investigation in relation to soil resources and successional trends. Journal of Ecology 84: 527-538.

Wolda H (1981). Similarity indices, sample size and diversity. Oecologia 50: 296-302.

Wolda H (1983). Diversity, diversity indices and tropical coackroachés. Oecologia 58: 290-298.

Wolters V and Joergensen RG (1991). Microbial carbon turn over in beech forest soils at different stages of acidification. Soil Biology and Biochemistry 23: 897-902.

Zak DR and Grigal DF (1991). Nitrogen cycling in upland and wetland ecosystems of east-central Minnesota. Oecologia 88: 189-196.

Zar JH (1974). Biostastical analysis, 2nd edn. Prentice Hall, Englewood cliff, New Jersey.

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Tree diversity in sacred groves of the Jaintia hills in Meghalaya, northeast India

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Abstract. Biodiversity of woody species was investigated in Ialong and Raliang sacred groves of the Jaintia hills in Meghalaya, northeast India. These groves represent the climax subtropical broad-leaved forest of the area. A total of 738 individuals belonging to 82 species, 59 genera and 39 families was identified in a 0.5 ha plot of the Ialong sacred grove, whereas the same area in the Raliang sacred grove had 469 individuals of 80 species, 62 genera and 41 families. About 32% species were common to both groves. Lauraceae, with 10–17 species, was the dominant family. The canopy and subcanopy strata were respectively composed of 28 and 33% of the total tree species in the forest. The number of species as well as stem density were greater for the trees of lower dbh (5–15 cm) class compared to the higher (> 66 cm) dbh class. The majority of the species showed a contagious distribution pattern and low frequency. The basal area varied from 57.4 to 71.4 m^2 ha^{-1}. Species richness within the forest varied from 3 to 15 per 100 m^2 in Ialong and 3 to 12 per 100 m^2 in Raliang. The dominance–distribution curves showed high equitability and low dominance in both groves.

Introduction

The humid tropical forests in the eastern Himalayas and northeast India, which harbour about 5000 endemic species, are very rich in plant wealth (Olson et al. 1998). Species richness of these forests has been recognized by taxonomists like Hooker (1872–1897), Kanjilal et al. (1934–1940), Rao and Panigrahi (1961), Rao (1969, 1970, 1974, 1977) and Balakrishnan (1981–1983), who carried out botanical explorations in different parts of northeast India. Recently, various studies have been carried out to quantify plant diversity and to understand the ecology of forest communities of the region (Khan et al. 1987; Khiewtam and Ramakrishnan 1993; Rao et al. 1997; Jamir 2000). Several researchers (Pascal and Pelissier 1996; Parthasarathy and Karthikeyan 1997; Ayyappan and Parthasarathy 1999; Parthasarathy 2001) have studied floristic diversity in the humid tropical forests of the Western Ghats of India, another biodiversity-rich area in the Indian subcontinent.

The Meghalaya state (25°02′ to 26°10′ N latitude and 89°45′ to 92°45′ E longitude) in northeast India, comprising the Khasi, Jaintia and Garo hills, covers an area of 22 429 km^2. The moist tropical and humid subtropical forests found in the state are rich in plant diversity. About 3128 flowering plants, including endemic, rare and primitive taxa have been reported from the state by Khan et al. (1997). The

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indigenous tribes of the state have an age-old tradition of preserving small patches of old growth forests as a part of their culture and religious beliefs. These forests, popularly known as sacred groves, are biodiversity-rich communities, which provide refuge for a large number of endemic and rare plant taxa of the region. In India, several studies have been made on the vegetation structure, composition and ecology of the sacred groves of Meghalaya (Barik et al. 1992; Khiewtam and Ramakrishnan 1993; Rao et al. 1997; Jamir 2000) and some other parts of India (cf. Chandrashekara and Sankar 1998; Ramakrishnan et al. 1998). This paper deals with the diversity of woody species (trees and lianas) and the structure of the two sacred groves located in the Jaintia hills of Meghalaya.

Study site

The study was conducted in Ialong and Raliang sacred groves in the Jaintia Hills, the eastern district of Meghalaya. These groves are remnants of subtropical broad-leaved forest (Champion and Seth 1968), which presumably is the climax vegetation of the area. The important tree species that constituted the forest canopy were *Engelhardia spicata*, *Ficus* sp., *Castanopsis purpurella*, *Syzygium tetragonum*, *Sarcosperma griffithii*, *Prunus jenkensii* and *Neolitsea cassia*. These groves have been protected since time immemorial by the *Jaintia* tribe due to their strong religious beliefs. The Ialong sacred grove is located about 8 km east of Jowai town at an altitude of 1350 m a.s.l. (latitude 25°28′ N and longitude 92°25′ E), while the Raliang sacred grove is 28 km away from Jowai town in the northeast direction (altitude 1300 m a.s.l., latitude 25°30′ N, longitude 92°18′ E). The Ialong sacred grove is spread over an area of about 30 ha on a steep hill slope (20° to > 60°), while the Raliang sacred grove covers an area of 20 ha on a gently sloping (10–25°) hill.

The climate of the area is monsoonic with distinct alternate wet and dry seasons. The wet season extends from April to October, followed by a dry period from November to March. During the wet season monthly rainfall ranges from 131 to 1557 mm, while in the dry period it is usually < 50 mm per month. The annual rainfall was 6539 mm during the study period (1999–2000). Relative humidity also exhibited marked seasonal variation and was closely related to precipitation. The mean monthly temperature varied from a maximum of 26 °C in the month of April to a minimum of 5 °C in January (Figure 1).

The soil of the sacred groves was loamy (Raliang) to loamy sand (Ialong) and acidic (pH 4.5–4.62).

Methods

Vegetation sampling was done during 1999–2000 by randomly laying 50 quadrats of 100 m^2 in each of the two groves. All woody species (≥ 5 cm dbh) in each quadrat were tagged and measured. They were identified with the help of the Flora of Jowai (Balakrishnan 1981–1983), the Forest Flora of Meghalaya (Haridasan and

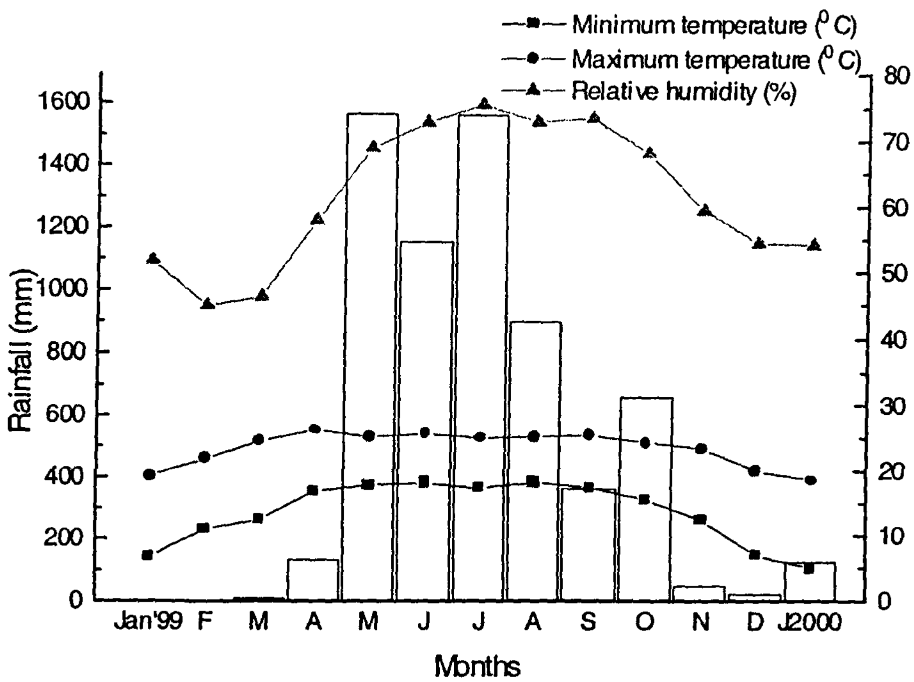

Figure 1. Monthly mean temperature (max and min), relative humidity and rainfall at Jowai during January 1999 and 2000.

Rao 1985–1987) and the Flora of Assam (Kanjilal et al. 1934–1940). The Herbaria of Botanical Survey of India, Eastern Circle, Shillong and Botany Department, NEHU, Shillong, were consulted for correct identification of plant specimens. The nomenclature of species follows the regional flora.

Frequency, density, dominance and importance value index (IVI) of all woody species were determined according to Misra (1968) and Muller and Ellenberg (1974). The Whitford index was used to study dispersion patterns (Whitford 1948). Shannon's diversity index (H^{-}) and Simpson's dominance index (λ) were calculated according to Magurran (1988). Species richness was studied on the basis of number of species per 100 m^2 area.

Results

Species–area curve

The species–area curves for the two sacred groves were very similar. After a gradual increase in the species number with increase in area, they reached an asymptote at 0.35–0.4 ha. About 80% of the species were found in a 0.35 ha area, while 88–99% of the species were encountered in 0.4 ha (Figure 2).

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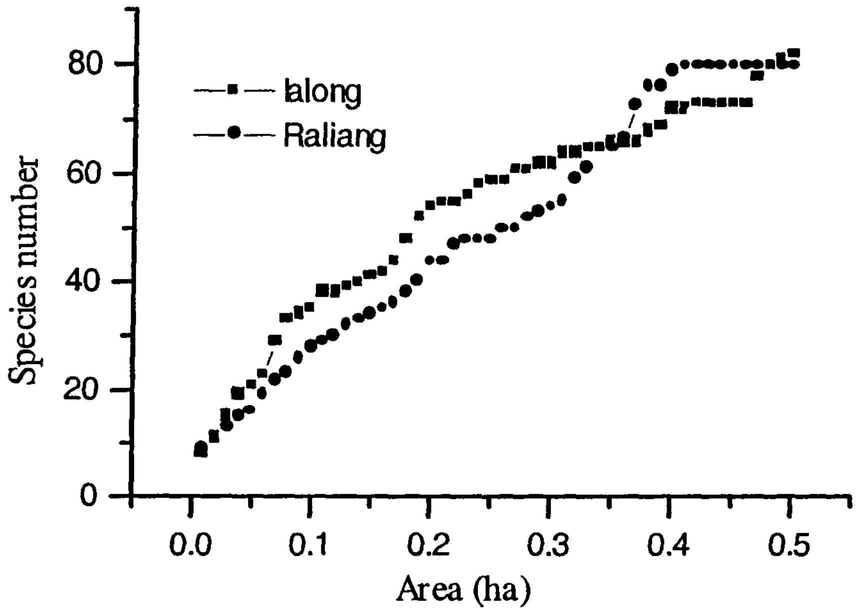

Figure 2. Species–area curves of the two sacred groves in the Jaintia hills.

Species composition and their distribution pattern

A total of 123 woody species was identified in a 1 ha area of the two sacred groves (Table 1). This included two gymnosperms, viz. *Pinus kesiya* in Ialong and *Podocarpus neriifolia* in Raliang sacred grove. In both groves, trees were distributed in three distinct strata, namely canopy (> 15 m height), subcanopy (8–15 m height) and under canopy (< 8 m height). The canopy layer was composed of *Acer laevigatum*, *Betula alnoides*, *Castanopsis* sp., *Cinnamomum* sp., *Ficus altissima* and *F. virens*, while *Antidesma bunius*, *Diospyros kaki*, *Pithecellobium monodelphum*, *Helicia nilagirica*, and *Schefflera hypoleuca* constituted subcanopy stratum. *Coffea khasiana*, *Erythroxylon kunthianum*, *F. hirta*, *Microtropis discolor*, *Sarcococca pruniformis* and *Wendlandia wallichii* formed the under canopy layer. The subcanopy, with 40 species, was the most species-rich layer in both sacred groves. Species richness (number of species per 100 m^2 area) clearly indicated that both the communities were a mosaic of high- and low-diversity patches (Figure 3A).

A total of 82 species belonging to 59 genera and 39 families and 80 species belonging to 62 genera of 41 families were identified in 0.5 ha plots in the Ialong and Raliang sacred groves, respectively. About 32% of the species were common to both groves. Lauraceae with 10 species, Fagaceae and Moraceae (eight species each), Araliaceae, Rubiaceae and Theaceae (five species each), Euphorbiaceae (four species) and Myrsinaceae (three species) were well represented in the Ialong sacred grove. Three families, Clusiaceae, Rutaceae and Styracaceae, were represented by two species each, whereas 28 families were monospecific. Similarly, in the Raliang

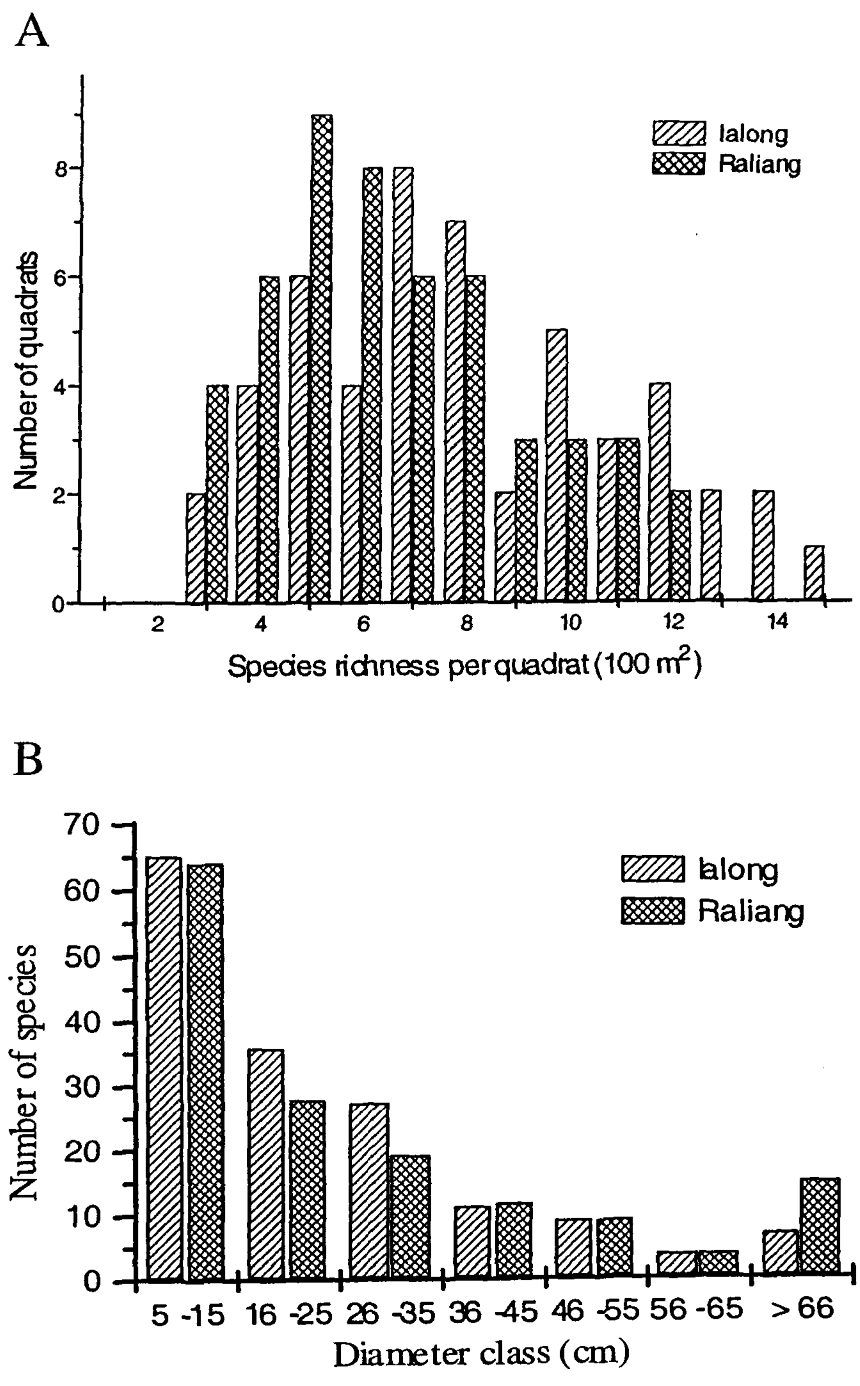

Figure 3. (A) Spatial distribution of species richness in the two sacred groves. (B) Distribution of species in different diameter classes in the two sacred groves.

Table 1. Frequency (%), density (number of plants per ha) and IVI of woody species (≥ 5 cm dbh) in Ialong and Raliang sacred groves.

Plant species	Family	Ialong			Raliang		
		Frequency	Density	IVI	Frequency	Density	IVI
Canopy layer (15 m height)							
Acer laevigatum Wall.	Aceraceae	4	6	1.48	16	26	11.41
A. oblongum Wall.	Aceraceae	–	–	–	2	2	0.68
Actinodaphne obovata (Nees) Kosterm	Lauraceae	–	–	–	50	108	25.59
Alseodaphne petiolaris Hk.f.	Lauraceae	2	6	1.85	6	6	1.79
Betula alnoides Buch-Ham	Betulaceae	12	12	16.13	2	4	2.39
Castanopsis indica (Roxb) DC	Fagaceae	10	10	2.44	–	–	–
C. purpurella (Miq.) Balakr.	Fagaceae	36	62	14.56	8	14	6.58
C. tribuloides (Sm.) DC	Fagaceae	20	30	12.9	–	–	–
Cinnamomum bejolghota (Buch.-Ham.) Sweet.	Lauraceae	2	2	0.58	2	2	2.02
Ci. glanduliferum (Wall.) Meissn.	Lauraceae	16	16	5.79	–	–	–
Ci. glaucescens (Nees) Meissn.	Lauraceae	–	–	–	2	2	3.40
Cryptocarya floribunda Nees	Lauraceae	–	–	–	6	6	2.05
Drymicarpus racemosus (Roxb) Hk.f.	Anacardiaceae	–	–	–	18	20	5.38
Elaeocarpus sikkimensis Mast.	Elaeocarpaceae	–	–	–	2	2	0.59
Engelhartia spicata Bl.	Juglandaceae	28	40	18.34	6	8	4.81
Ficus altissima Bl.	Moraceae	6	8	7.40	4	4	12.92
F. virens Ait.	Moraceae	4	4	6.58	8	10	16.08
Garcinia tinctoria (DC.) W.F. Wight	Clusiaceae	2	2	0.53	4	4	1.27
Knema angustifolia (Roxb.) Warb.	Myristicaceae	–	–	–	22	28	7.72
Lithocarpus elagans Soepadmo	Fagaceae	20	28	3.46	14	14	7.89
L. fenestrata (Roxb) Rehder	Fagaceae	10	12	2.45	2	2	0.53
Lithocarpus sp.	Fagaceae	6	8	5.55	2	2	0.52
Michelia doltsopa DC.	Magnoliaceae	–	–	–	2	2	3.90
Neolitsea cassia (L.) Kosterm.	Lauraceae	–	–	–	32	64	16.47
Persea gamblei (King ex Hk.f.) Kosterm.	Lauraceae	–	–	–	4	4	1.82
Pe. odoratissima (Nees) Kosterm.	Lauraceae	14	18	6.06	6	10	3.76
Pinus kesiya Royle ex. G. Don	Pinaceae	2	2	1.19	–	–	–
Podocarpus neriifolia D. Don	Podocarpaceae	–	–	–	2	2	1.01
Prunus jenkinsii Hook. f.	Rosaceae	14	20	4.06	48	78	19.97
Pseudostreblus indica Bureau	Moraceae	16	48	14.2	–	–	–
Quercus serrata Thunb.	Fagaceae	2	2	0.65	–	–	–
Sarcosperma griffithii Clarke	Sapotaceae	–	–	–	72	116	36.88
Schima wallichii Dyer	Theaceae	14	20	3.84	4	4	1.50
Spondias axillaris Roxb.	Anacardiaceae	–	–	–	2	2	2.26
Syzygium tetragonum (Wt.) Kurz	Myrtaceae	38	60	12.55	12	14	3.74
Subcanopy layer (8–15 m height)							
Alangium chinensis (Lour) Harms	Cornaceae	14	16	4.08	–	–	–
Antidesma bunius (L.) Spreng.	Euphorbiaceae	2	2	0.4	2	2	0.52
Beilschmiedia assamica Meissn	Lauraceae	–	–	–	8	8	2.23
B. roxburghiana Nees	Lauraceae	2	2	0.47	–	–	–
Caryota urens Linn.	Arecaceae	–	–	–	8	8	2.23
Ci. tamala (Spreng.) Nees & Eberm	Lauraceae	–	–	–	4	4	1.05
Citrus latipes (Swingle) Tanaka	Rutaceae	8	8	1.78	6	6	1.56
Diospyros kaki L.f.	Ebenaceae	6	8	1.40	2	2	0.62
Dysoxylon gobara (Buch.-Ham.) Merr.	Meliaceae	–	–	–	42	62	14.07
El. lancifolius Roxb.	Elaeocarpaceae	–	–	–	2	2	0.55

Table 1. (continued)

Plant species	Family	Ialong			Raliang		
		Frequency	Density	IVI	Frequency	Density	IVI
Erythrina arborescens Roxb.	Fabaceae	2	2	0.40	–	–	–
Eurya acuminata DC.	Theaceae	2	4	0.56	–	–	–
F. concinna Meq.	Moraceae	2	2	0.55	–	–	–
F. mclelandi var. *rhododendrifolia* Corn.	Moraceae	2	2	0.68	–	–	–
F. nerifolia J. E. Sm.	Moraceae	2	2	0.43	2	2	0.52
G. morella Desr.	Clusiaceae	2	6	1.22	–	–	–
Helecia nilagirica Bedd.	Proteaceae	38	62	9.76	10	28	5.23
Ilex embeloides Hook. f.	Aqualifoliaceae	–	–	–	2	4	0.75
Lindera latifolia Hook. f.	Lauraceae	16	28	4.5	8	10	2.45
Li. nagusa (D. Don) Merr.	Lauraceae	2	2	0.40	–	–	–
Li. reticulata Benth.	Lauraceae	–	–	–	8	8	3.16
Litsea semicarpifolia (Nees) Hook. f.	Lauraceae	–	–	–	8	10	2.47
Macaranga denticulata (Bl.) Muell-Arg.	Euphorbiaceae	–	–	–	4	4	1.47
Macropanax dispermus (Bl.) O. Ktze	Araliaceae	2	2	0.40	20	24	6.05
Manglietia insignis (Wall) Bl.	Magnoliaceae	2	2	0.40	6	8	2.87
Melia azedarach Linn.	Meliaceae	–	–	–	2	2	0.52
Myrica esculanta Buch.-Ham. ex D. Don	Myricaceae	6	6	2.85	2	2	0.55
Myrsine semiserrata Wall.	Myrsinaceae	10	14	2.37	2	2	0.52
Pe. bombocyania (King ex Hk. f.) Kosterm.	Lauraceae	2	4	0.73	2	2	0.52
Pe. duthiei (Hook. f.) Kosterm.	Lauraceae	2	4	1.03	–	–	–
Pe. parviflora Meissn.	Lauraceae	–	–	–	4	4	1.27
Pithecellobium monadelphum (Roxb.) Kosterm.	Mimosaceae	34	50	9.18	16	18	4.44
P. acuminata (Wall) Dietr.	Rosaceae	–	–	–	4	6	1.26
Q. griffithii Hk. f. & Th ex DC.	Fagaceae	2	2	0.73	–	–	–
Rhododendron arboreaum Sm.	Ericaceae	2	2	0.55	–	–	–
Rhus acuminata DC.	Anacardiaceae	28	36	8.73	–	–	–
Sapindus rarak DC.	Sapindaceae	–	–	–	2	2	0.52
Schefflera elata (Buch.-Ham.) Harms	Araliaceae	4	4	0.89	–	–	–
Sc. Hypoleuca (Kurz) Harms	Araliaceae	22	22	4.63	4	4	1.05
Vaccinium sprengelii (G. Don) Rehd.	Vacciniaceae	2	4	0.66	–	–	–
Under canopy (< 8 m height)							
Ant. khasiana Hk. f.	Euphorbiaceae	2	2	0.40	–	–	–
Calophyllum polyanthium Choisy	Clusiaceae	–	–	–	2	2	0.52
Camellia caudata Wall.	Theaceae	30	136	13.86	–	–	–
Capparis acutifolia Sweet	Capparaceae	–	–	–	24	28	6.92
Clerodendron bracteatum Walp.	Verbenaceae	2	2	0.40	–	–	–
Coffea khasiana Hook. f.	Rubiaceae	54	100	13.96	4	4	1.04
Croton oblongus Burm. f	Euphorbiaceae	4	4	0.85	–	–	–
Desmos longiflorus (Roxb.) Safford	Annonaceae	–	–	–	6	6	1.60
Erythroxylon kunthianum Kurz.	Erythroxylaceae	2	2	0.40	2	2	0.52
Eu. cerasifolia (D. Don) Kobuski	Theaceae	10	14	2.11	–	–	–
Eu. japonica Thunb	Theaceae	2	2	0.40	–	–	–
F. elmerii Merr.	Moraceae	2	2	0.40	–	–	–
F. hirta var. *roxburghii* (Mig) King	Moraceae	8	8	1.56	4	4	1.05
Itea chinensis Hook. & Arn.	Iteaceae	–	–	–	2	2	0.52
I. macrophylla Wall.	Iteaceace	2	2	0.47	–	–	–
Ixora subsessilis G. Don.	Rubiaceae	2	2	0.70	10	10	3.23
Li. salicifolia (Nees) Hook. f.	Lauraceae	–	–	–	2	2	0.52

Table 1. (continued)

Plant species	Family	Ialong			Raliang		
		Frequency	Density	IVI	Frequency	Density	IVI
Maesa indica (Roxb.) Wall.	Myrsinaceae	2	2	0.40	–	–	–
Mynea spinosa Link.	Rubiaceae	4	4	0.79	–	–	–
Microtropis discolor (Wall.) Arn.	Celastraceae	58	298	29.49	–	–	–
Ant. diandrum (Roxb.) Roth	Euphorbiaceae	2	2	0.40	–	–	–
Paramignya micrantha Kurz	Rutaceae	–	–	–	6	6	1.56
Phoebe lanceolata (Nees) Nees	Lauraceae	16	20	3.79	2	2	0.52
Picresema sp.	Simaroubaceae	6	8	1.31	–	–	–
Pittosporum podocarpum Gagnep.	Pittosporaceae	–	–	–	6	6	1.65
Pouzolzia frondosa var. fulgens (Wedd.) Balakr.	Urticaceae	2	2	0.42	–	–	–
Pseudobrassiopsis hispida (Seem.) R. N. Ban.	Araliaceae	4	4	0.78	–	–	–
Pyrularia edulis (Wall.) DC.	Santalaceae	14	20	3.62	–	–	–
Randia griffithii Hook. f.	Rubiaceae	2	2	0.40	–	–	–
Sarcococca pruniformis Lindl.	Buxaceae	10	10	2.22	2	8	1.47
Stercularia hamiltonii (O. Ktze.) Adelb.	Sterculiaceae	–	–	–	4	6	1.38
Styrax serrulatum Roxb.	Styracaceae	8	10	1.71	6	6	1.62
St. hookerii Cl.	Styracaceae	2	2	0.40	–	–	–
Symplocos pyrifolia G. Don.	Symplocaceae	–	–	–	6	6	1.66
Sy. spicata Roxb	Symplocaceae	8	10	1.96	2	2	0.52
Viburnum foetidum Wall.	Caprifoliaceae	2	2	0.40	–	–	–
Wendlandia wallichii W. & A. Prodr.	Rubiaceae	10	20	3.22	4	4	1.05
Lianas							
Embelia subcoriaceous (Clarke). Mez.	Myrsinaceae	4	4	0.77	–	–	–
Fissistigma verrucosum (Hook. f. & Th.) Merr	Annonaceae	–	–	–	10	14	3.09
Melodinus monogynous Roxb.	Apocynaceae	–	–	–	2	2	0.52
Rourea minor (Gaertn.) Leenh.	Connaraceae	24	44	6.22	10	12	2.92
Sc. venulosa (W. & A.) Harms	Araliaceae	–	–	–	2	2	0.52
Sc. wallichiana (W. & A.) Harms	Araliaceae	2	2	0.40	–	–	–
Tetrastigma leucostaphylum (Dennst.) Balakr.	Vitaceae	–	–	–	2	2	0.53
T. serullatum (Roxb.) Planch.	Vitaceae	12	14	2.49	–	–	–
Todallia asiatica (L.) Lamk.	Rutaceae	4	6	0.93	–	–	–
Tupidanthus calyptratus Hook. f. & Thoms.	Araliaceae	–	–	–	4	4	1.17
Unidentified sp.	–	–	–	–	2	2	0.52
Total			1476	300		938	300

sacred grove, Lauraceae with 17 species was the dominant family followed by *Araliaceae, Fagaceae and Moraceae (four species each)* and Rubiaceae (three species). Eleven families had two species each and 25 families were represented by only one species.

In both groves, the majority of species (65) were represented by young individuals (5–15 cm dbh) and species richness decreased with increase in dbh class, except in the case of mature trees beyond 66 cm dbh (Figure 3B). In both groves 87–91% of the species belonged to Raunkiaer's frequency class A and the rest were distributed in the B, C and D classes; class E was completely absent (Table 2). Similarly, the majority of species (90–92%) showed a contagious distribution pattern and only 6–10% of the species were randomly distributed in the forest (Table 3). Regular dispersion was seen only in case of *S. griffithii.*

Table 2. Percentage distribution of species in Raunkiaer's frequency classes in the two sacred groves.

Sacred grove	Raunkiaer's frequency class				
	A	B	C	D	E
Ialong	86.6	11.0	2.4	–	–
Raliang	91.2	3.8	3.8	1.2	–

Table 3. Percentage of species showing a different dispersion pattern (based on Whitford's index) in the two sacred groves.

Sacred grove	Whitford's index		
	Regular	Random	Contagious
Ialong	–	9.8	90.2
Raliang	1.2	6.3	92.5

Density and basal cover

Distribution of density in different dbh classes is shown in Figure 4. In Ialong and Raliang, 74% and 54%, respectively of the stems were in the 5–15 cm dbh class and only 2–5% of the individuals were present in the > 66 cm dbh class. The tree density varied from 938 to 1476 ha^{-1} in the two groves (Table 4). In Ialong, 738 individuals encountered in a 0.5 ha area belonged to as many as 82 species. Most of these species (48%) were represented by one or two stems. *Microtropis discolor* had the maximum number of individuals (149 stems), followed by *Camellia caudata* with 68 stems (Figure 5). These species together constituted 29% of the tree density in the forest. In Raliang 469 individuals belonging to 80 species were present in a 0.5 ha area. One or two stems represented 53% of the species. *S. griffithii* had the highest number (58 stems), followed by *Actinodaphne obovata*, which had 54 stems. Together they constituted about 23% of the stand density. In both sacred groves, the density of young trees (5–15 cm dbh) was much greater compared to the mature trees (> 66 cm dbh). However, despite this, the basal cover of young trees was much lower than that of mature trees (2.72 versus 37.78 m^2 ha^{-1}; Figure 6).

Dominance distribution pattern

The dominance distribution yielded log-normal curves showing a high equitability and low dominance in both groves (Figure 7). *Microtropis discolor* (IVI = 29.49) and *E. spicata* (IVI = 18.34) in Ialong and *S. griffithii* (IVI = 36.88) and *Ac. obovata* (IVI = 25.59) in Raliang were dominant and co-dominant species, respectively (Table 1).

Discussion

It has been argued by several workers (cf. Brown 1981) that the productivity of the

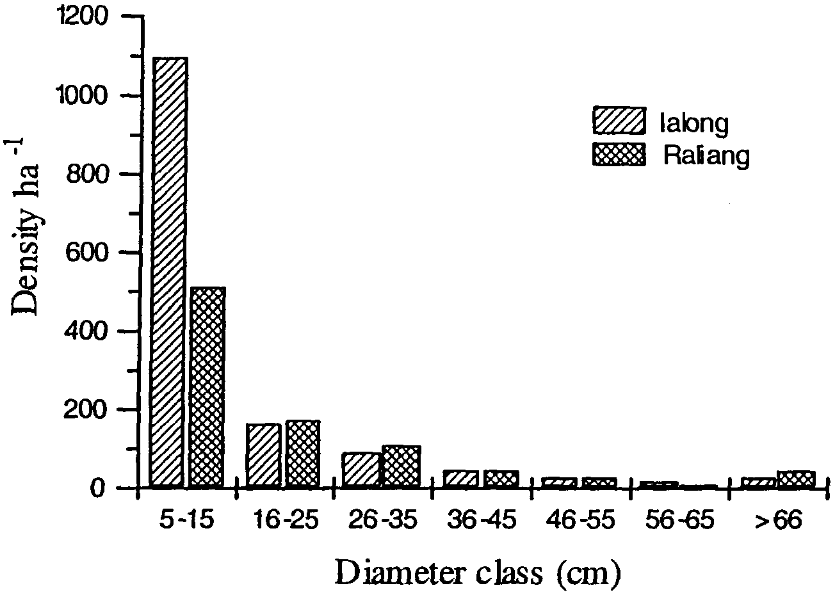

Figure 4. Distribution of density in different diameter classes in the two sacred groves.

system and structural complexity or heterogeneity determine species richness in the community. Others have argued that neither ecosystem productivity nor structural complexities seem sufficient on their own to explain the observed pattern of species richness (Putman 1994). Slobodkin and Sanders (1969) opined that species richness of any community is a function of severity, variability and predictability of the environment in which it develops. Therefore, diversity tends to increase as the environment becomes more favourable and more predictable (Putman 1994). In the present case it is difficult to pinpoint the exact causes of high species richness in the sacred groves with the available data, but it seems that the favourable climatic conditions of the area and protection over a long period of time have played a major role in making these forest patches highly complex and species-rich. In this respect they are similar to tropical forests at Luquillo Mountains in Puerto Rico (Weaver and Murphy 1990), Papua, New Guinea (Edwards 1977; Edwards and Grubb 1977), and Yanamono, Peru (Gentry 1988). Forests in which only one tree species constitutes 50–80% of the canopy have been considered as low-diversity forests (Connell and Lowman 1989). On the basis of this criterion, the sacred groves may be regarded as high-diversity forest since ca. 28% of the tree species were present in the canopy layer.

Spatial distribution of species richness was not uniform in the forest; rather, both groves were a mosaic of low- and high-diversity patches. This seems to be the result of the combined effect of non-extreme stable environmental conditions and gap-phase dynamics within the forest (Whittaker 1972).

Since the majority of the species was contagiously distributed and frequency class A was dominant, both groves were highly heterogeneous and patchy in terms of

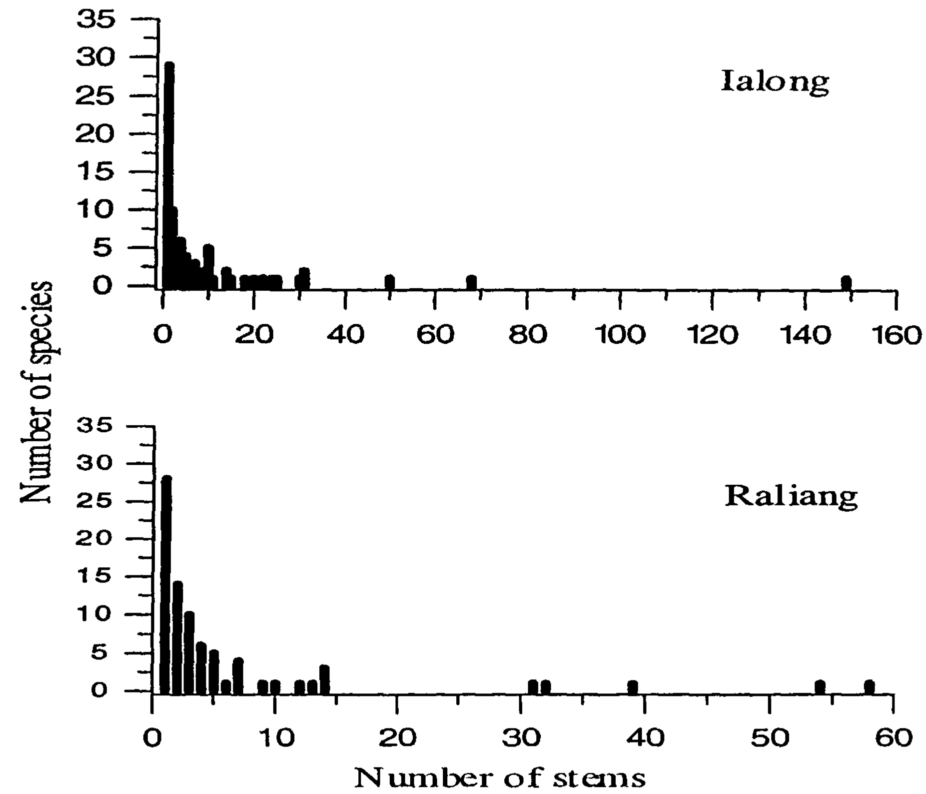

Figure 5. Species–stem relationship in a 0.5 ha area of the two sacred groves.

species distribution. Poore (1968), Ashton (1969) and Herwitz (1981) have described tropical rain forests as highly patchy communities, primarily due to gap-phase dynamics. Clumping of individuals of the same species is often clearly related to gap formation and a dispersal mechanism of the species. Armesto et al. (1986) compared the dispersion pattern of trees in tropical and temperate climates in different parts of the world and concluded that clumping was characteristic of forest in which formation of canopy gaps was the chief source of disturbance. Hubbell (1979), in dry tropical forest, observed that all species were either clumped or randomly dispersed, with rare species more clumped than common species.

The species represented by one or two individuals in the study plot have been considered as rare species. The number of individuals of such species is probably kept low by a combination of unfavourable regeneration conditions, lack of appropriate habitat, or both (Hubbell 1979). Based on this criterion, 48–53% of species may be termed as rare in the two groves. In this respect too, the two sacred groves are similar to tropical forests, which are known to possess large numbers of rare tree species. For example, Paijmans (1970), Thorington et al. (1982) and Parthasarathy and Karthikeyan (1997) reported that 50% of species in New Guinea,

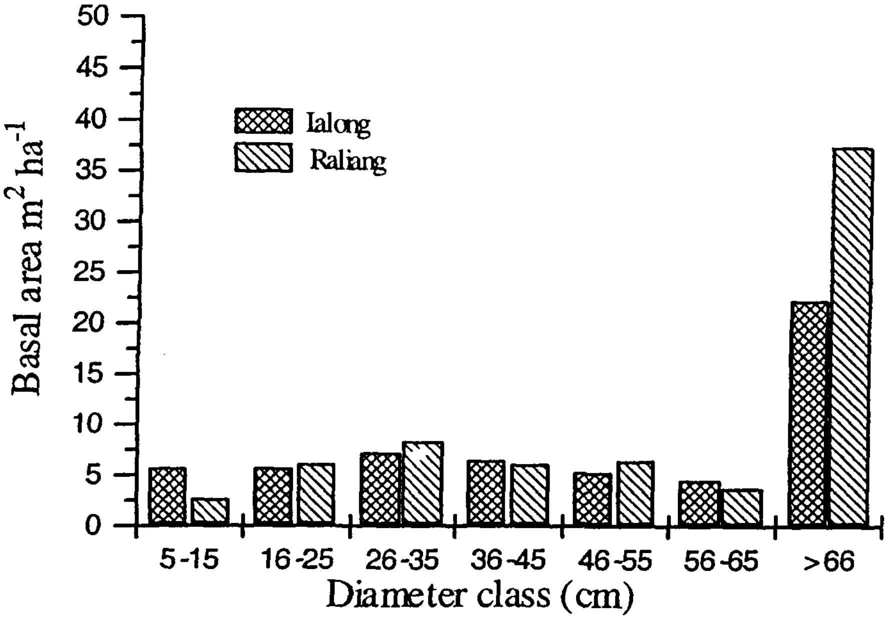

Figure 6. Distribution of basal area in different diameter classes in the two sacred groves.

Table 4. Density, basal area, dominance, diversity and evenness indices of woody species in two sacred groves in the Jaintia Hills, Meghalaya.

Variable	Ialong	Raliang
Density (ha^{-1})	1476	938
Basal area ($m^2 ha^{-1}$)	57.46	71.44
Shannon's diversity index	3.42	3.55
Pielou's evenness index	0.53	0.56
Simpson's dominance index	0.067	0.052

40% in Barro Colorado Island, Panama, and 47% in the Western Ghats forests were rare.

Abundance of young individuals in both groves, a characteristic feature of vegetation on moist and infertile soil (Coomes and Grubb 2000), indicates a slow rate of seedling and sapling growth in the understorey and a relatively low rate of seedling mortality. This may also be due to tree-fall gaps having a varied microenvironmental variability (Rao et al. 1997), which might have favoured the tree species having different regeneration requirements (Phillips et al. 1994). The preponderance of young individuals in the mature forest has also been reported from the Brazilian Amazon (Campbell et al. 1992), Costa Rica (Nadkarni et al. 1995) and the Western Ghats (Parthasarathy 2001).

The basal cover (57.46 and 77.44 $m^2 ha^{-1}$) in both the sacred groves is close to that of other tropical forests, such as equatorial forest (10–45 $m^2 ha^{-1}$) in Kongo Island, Zaire (Mosango 1991), tropical rain forest (78 m^2 ha^{-1}) in Amazonia

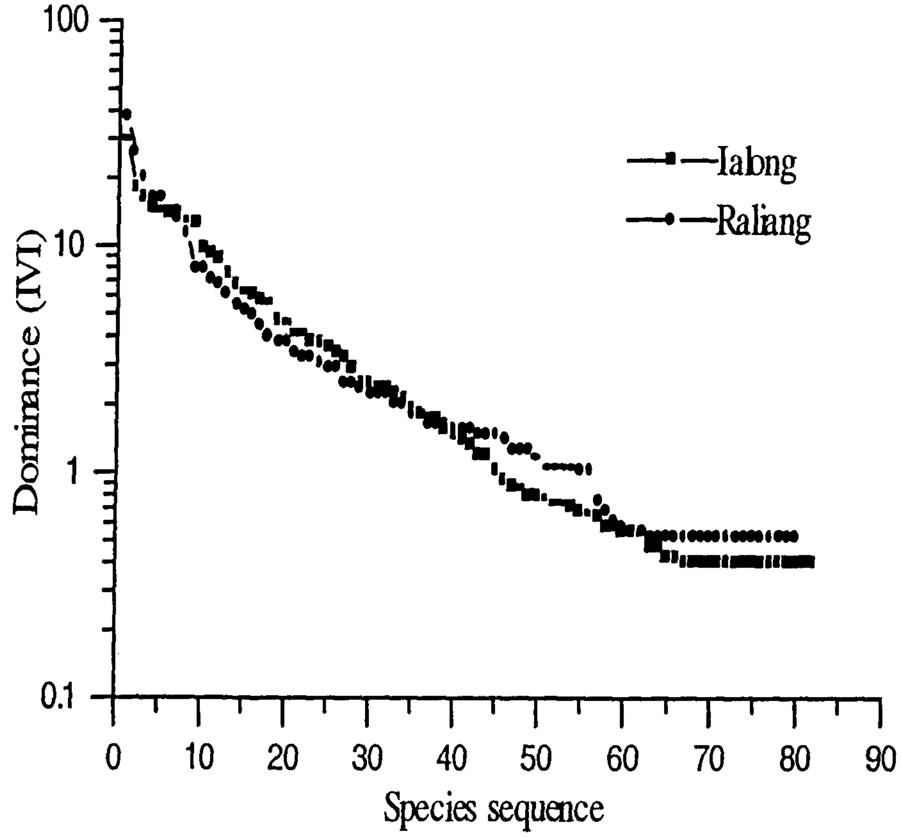

Figure 7. Dominance–diversity curves of woody species in the two sacred groves.

(Campbell et al. 1992), lower montane forest (62 m^2 ha^{-1}) in Costa Rica (Nadkarni et al. 1995), evergreen forest (55.3–78.3 $m^2 ha^{-1}$) around Sengattheri in the Western Ghats (Parthasarathy 2001), and in the dry evergreen forest (32.8 m^2 ha^{-1}) of Puthupet, South India (Parthasarathy and Sethi 1997).

The dominance–distribution curve showed a log-normal distribution. A logarithmic or broken-stick distribution reflects that the community is primarily ordered with respect to one dominating factor, while a log-normal distribution represents a more complex community, ordered by a multiplicity of interactions (May 1975). The latter appears to be the case for the sacred groves under study.

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References

Armesto J.J., Mitchell J.D. and Villogram C. 1986. A comparison of spatial patterns of trees in tropical and temperate forests. Biotropica 18: 1–11.

Ashton P.S. 1969. Speciation among tropical forest trees: some deductions in the light of recent evidence. Biological Journal of the Linnaean Society London 1: 155–196.

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

Balakrishnan N.P. 1981–1983. Flora of Jowai and Vicinity, Meghalaya, 2 Vols. BSI, Howrah, India.

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

Brown J.H. 1981. Two decades of homage to Santa Roselia: towards a general theory of diversity. American Zoologist 21: 877–888.

Campbell D.G., Stone J.L. and Rosas A. Jr. 1992. A comparision of the phytosociology and dynamics of three flood plain (Varzae) forests of known ages, Rio Jurua, Western Brazalian Amazon. Botanical Journal of the Linnaean Society 108: 213–237.

Champion H.G. and Seth S.K. 1968. A Revised Survey of Forest Types of India. Government of India Press, Delhi, India.

Chandrashekara U.M. and Sankar S. 1998. Ecology and management of sacred groves in Kerala, India. Forest Ecology and Management 112: 165–177.

Connell J.H. and Lowman M.D. 1989. Low-diversity tropical rain forests: some possible mechanisms for their existence. The American Naturalist 134: 89–119.

Coomes D.A. and Grubb P.J. 2000. Impacts of root competition in forests and woodlands: a theoretical framework and review of experiments. Ecological Monographs 70: 171–207.

Edwards P.J. 1977. Studies in montane rain forest in New Guinea. II. The production and disappearance of litter. Journal of Ecology 65: 971–1022.

Edwards P.J. and Grubb P.J. 1977. Studies of mineral cycling in a montane rain forest in New Guinea. I. The distribution of organic matter in the vegetation and soil. Journal of Ecology 65: 943–969.

Gentry H.A. 1988. Tree species richness of upper Amazon forests. Proceedings of the National Academy of Sciences USA 85: 156–159.

Haridasan K. and Rao R.R. 1985–1987. Forest Flora of Meghalaya, 2 Vols. Bishen Singh Mahendrapal Singh, DehraDun, India.

Herwitz S.R. 1981. Regeneration of selected tropical tree species in Corcovado National Park, Costa Rica. Publication in Geography 24. University of California, Berkeley, California.

Hooker J.D. 1872–1897. Flora of British India. Vols. 1–7. ■■Author please provide the name of the publisher. Thank you.■■, London.

Hubbell S.P. 1979. Tree dispersion, abundance and diversity in a tropical dry forest. Science 203: 1299–1309.

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

Kanjilal V.N., Kanjilal P.C., Das A., De R.N. and Bor N.L. 1934–1940. Flora of Assam, 5 Vols. Government Press, Shillong, India.

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

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

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

Magurran A. 1988. Ecological Diversity and its Measurement. Princeton University Press, Princeton, New Jersey.

May R.M. 1975. Patterns of species abundance and diversity. In: Cody M.L. and Diamond J.M. (eds), Evolution of Communities. Belknap Press, Harvard, Massachusetts, pp. 81–120.

Misra R. 1968. Ecology Work Book. Oxford & IBH Publishing Co., Calcutta, India.

Mosango M. 1991. Contribution 'AI' etude botanique biogeochemique de I ecosystem forest region equatoriale (IFBe Kongalo, Zaire). Belgian Journal of Botany 124: 167–194.

Muller D.D. and Ellenberg H. 1974. Aims and Methods of Vegetation Analysis. John Wiley and Sons, New York.

Nadkarni N.M., Matelson T.J. and Haber W.A. 1995. Structural characteristics and floristic composition of neotropical cloud forest, Monteverde, Costa Rica. Journal of Tropical Ecology 11: 482–495.

Olson M.D., Dinerstein E., Mittermeier R.A., Myers N., Thomsen J.B. and da Fonseca G.A.B. 1998. Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. Conservation Biology 12: 516–520.

Paijmans K. 1970. An analysis of four tropical rain forest sites in New Guinea. Journal of Ecology 58: 77–101.

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

Parthasarathy N. and Karthikeyan R. 1997. Plant biodiversity inventory and conservation of two tropical dry evergreen forests on the Coromandal Coast, South India. Biodiversity and Conservation 6: 1063–1083.

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

Pascal J.P. and Pelissier R. 1996. Structure and floristic composition of a tropical rain forest in south-west India. Journal of Tropical Ecology 12: 191–214.

Phillips O.L., Hall P., Gentry A.H., Sawyer S.A. and Vasquez R. 1994. Dynamics and species richness of tropical rain forest. Proceedings of the National Academy of Science USA 91: 2805–2809.

Poore M.E.D. 1968. Studies in Malaysian rain forest. I. The forest on Trassic sediments in Jengka forest reserve. Journal of Ecology 56: 143–196.

Putman R.J. 1994. Community Ecology. Chapman & Hall, London.

Ramakrishnan P.S., Saxena K.G. and Chandrashekara U.M. 1998. Conserving the Sacred for Biodiversity Management. Oxford and IBH publication Co Pvt Ltd, New Delhi, India.

Rao A.S. 1969. Orchids of Khasi and Jaintia Hills. Bulletin of Botanical Survey of India 11: 115–123.

Rao A.S. 1970. A sketch of the flora of north-eastern India, particularly Assam and Meghalaya. In: ■■Please provide the name of the editor(s), if possible. Thank you.■■ (ed.), Souveneir 40th session of Central Board of Irrigation and Power, Shillong. ■■Please provide the details of the publishers, if possible. Thank you.■■, pp. 85–90.

Rao A.S. 1974. The vegetation and phytogeography of Assam–Burma. In: Mani M.S. (ed.), Ecology and Biogeography in India. W. Junk, The Hague, the Netherlands, pp. 204–205.

Rao A.S. 1977. Floristic studies in north-eastern India (Old Assam Region). Bulletin Botanical Survey of India 19: 56–60.

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

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

Slobodkin L.B. and Sanders H.L. 1969. On the contribution of environmental predictability to species diversity. Brookhaven Symposia in Biology 22: 82–95.

Thorington R.W. Jr., Tannenbaum B., Tarak A. and Rudran R. 1982. Distribution of trees on Barro Colorado Island: a five hectare sample. In: Leigh E.G., Rand A.S. Jr. and Windror D.M. (eds), The Ecology of Tropical Forest – Seasonal Rhythms and Long-term Changes. Smithsonian Institution Press, Washington, DC.

Weaver P.L. and Murphy P.G. 1990. Forest structure and productivity in Puerto Rico's Luquillo mountains. Biotropica 22: 69–82.

Whitford P.B. 1948. Distribution of woodland plants in relation to succession and clonal growth. Ecology 30: 199–208.

Whittaker R.H. 1972. Evolution and measurement of species diversity. Taxon 21: 213–251.