THESIS

FOREST DYNAMICS ALONG AN ALTITUDINAL GRADIENT IN DOI INTHANON NATIONAL PARK, NORTHERN THAILAND

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THESIS

FOREST DYNAMICS ALONG AN ALTITUDINAL GRADIENT IN DOI INTHANON NATIONAL PARK, NORTHERN THAILAND

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A Thesis Submitted in Partial Fulfilment of
the Requirements for the Degree of
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Chomphu Boonrodklab 2007: Forest Dynamics Along an Altitudinal Gradient in Doi Inthanon National Park, Northern Thailand. Master of Science (Forestry), Major Field: Silviculture, Department of Silviculture. Thesis Advisor: Mr. Sakhan Teejuntuk, Ph.D. 94 pages.

The purpose of this research was to study forest dynamics along an altitudinal gradient in Doi Inthanon National Park, northern Thailand by emphasizing on the community structure, aboveground biomass and population change during 1999-2006. The results showed that the total of 289 species, 150 genera and 69 families were found in five forest types, DDF, MDF, PDF, POF and HEF. The mean DBH, density and basal area were found to increase with the rising altitude. HEF was found to have largest basal area, density and aboveground biomass while POF, PDF, MDF and DDF had less in all these values respectively. The cluster analysis classified all these 5 forest types floristically into three forest zones and could be clustered into six forest community groups. Various species diversity indices indicated the significant difference among forest groups, being lowest in group I and highest in group IV and group V. Richness indices also showed the similar trend, while evenness indices indicated no significant difference among groups except for the evenness index E_1 which were highest in group V and VI, moderately high in group III and IV and lowest in group I and II. Changes in tree populations during the 7 years period were found to be different in six groups, resulting from tree death and replacement by new recruits. The absolute growth rate was different between groups and it was found that group II was higher than other groups. The relative growth rate in group II was higher than other groups, however depending on successful establishment and survival of the component species of the stands. Group III had the largest density than in other groups and group V had the lowest. In spite of the large gain and loss of individuals, all groups gained in net basal area coverage, about 0.34-7.81 m^2/ha during the 7 years period. The aboveground biomass gain in all groups were in the range of 2.69-54.95 ton/ha, by which group II had the lowest and group III had the highest gain. The most remarkable tree death were *Aporosa villosa* and *Wendlandia tinctoria* in group III, *Tectona grandis* and *Xylia xylocarpa var. kerii* in group II, *Litsea dubele* and *Myrsinese miserrata* in group IV, V and VI. Group III had recruitment involved *Aporosa villosa*, *Lithocarpus elegans* and *Castanopsis acuminatissima* as the abundant species. Group II found *Tectona grandis* and *Xylia xylocarpa var.kerii*, which are relatively common species in this group whereas group IV, V and VI are found *Castanopsis diversifolia*, *Cryptocarya dencifolia* and *Rapanea yunnanensis* as the most potential species recruited in the groups respectively besides several unidentified species.

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Student's signature Thesis Advisor's signature

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FOREST DYNAMICS ALONG AN ALTITUDINAL GRADIENT IN DOI INTHANON NATIONAL PARK, NORTHERN THAILAND

INTRODUCTION

The imposing Doi Inthanon, located in Chiang Mai province, is the highest point in the country, and is often dubbed 'The Roof of Thailand'. In Doi Inthanon National Park there are also several lesser summits to explore. The forest of the national park is one of the country's most important heritages. Forest types include moist evergreen forest, pine forest and mixed deciduous forest composing of species with economic value including teak and mountain pine. Past work had mostly emphasized and qualitatively described the forest structure and species composition in general and biomass. The continuous land use pressure and vegetation degradation in Doi Inthanon have awakened interest in the study of forest tree species diversity and their biomass production. Assessing the total aboveground biomass, defined as biomass when expressed as dry weight per unit area, is a useful way of quantifying the amount of resource available for traditional uses, either total biomass or by components. The biomass of each forest component varies with the forest type.

Quantification of biomass is useful for estimating amounts of available forest resources, such as food, fuel, fodder and fiber (Brown, 1997). Forest biomass data can also be used to understand changes in forest structure resulting from succession or in differentiating between forest types. An important use of biomass density (dry mass/unit area) in recent years has been to track carbon cycling between the atmosphere and the terrestrial biosphere, related to global climate change (Cairns *et al.*, 2000). Biomass change represents the potential for carbon (~ 50 % of dry weight biomass) emission to the atmosphere when forests are degraded or replaced through processes of deforestation and biomass burning. Conversely, growth results in accumulation of biomass and represents atmospheric CO_2-C sequestration in the terrestrial biosphere. Thus, forest biomass may act as either a souce or sink for greenhouse gases. Developing global carbon markets, specified in the Kyoto protocol for climate change, require accurate and reliable methods to quantify these sources and sinks.

Although structure of forest, aboveground biomass and dynamic of some tropical forests have been reported by several researchers but less document is found at Doi Inthanon National park. This thesis is emphasized about structure of forest, aboveground biomass and dynamic in 1999-2006 because these knowledge are useful for management and conservation of Doi Inthanon forest.

OBJECTIVES

1. To analyse the ecological data on the community structure of forest based on quantitative and qualitative investigation.

2. To estimate the aboveground biomass and compare to other sites.

3. To study the forest dynamics during 1999 - 2006.

LITERATURE REVIEW

Biomass in Forest Ecosystem

Biomass is the dry mass of living organisms and dead organic matter contained in a defined area, usually unit one square meter or a hectare (g m^{-2} or kg ha^{-1}, respectively). In some instances, biomass is reported in its C or energy equivalent (i.e., g C m^{-2} or cal m^{-2}), a necessary tool for understanding the flow of C (or energy) within ecosystems. In forest ecosystems, biomass is located in 5 major pools: 1) the above- and belowground tissues of over- and understory plants, 2) woody debris consisting of dead, fallen tree stems, 3) forest floor, 4) mineral soil, and 5) the tissues of heterotrophic organisms (decomposers and consumers). Although biomass in woody debris, forest floor, and mineral soil are composed of dead organic matter, it is convention to consider these compartments when discussing the distribution of biomass within forest or other terrestrial ecosystems (Barnes *et al*. 1998).

The total biomass of the forest community in tropical wet seasonal rain forest was 360.9 t/ha and its allocation in different layers as: tree layer 352.5t/ha (accounts for 97.69%), shrub layer 4.7 t/ha (1.31%) liana 3.1t/ha (0.86%) and herb layer 0.5t/ha (0.14%) (Shanmughavel *et al*., 2001).

The biomass in accumulation model

Based on measured and projected changes in total biomass, Bormann and Liken (1979) proposed a biomass accumulation model of forest ecosystem development after clear-cutting. This model is divided into four phases of development: Regeneration, a period of one or two decades during which the ecosystem loses total biomass despite accumulation of living biomass; Aggradation, a period of more than a century when the ecosystem accumulates total biomass reaching a peak at the end of the phase; Transition, a variable length of time during which total biomass declines; and the Steady State, when total biomass fluctuates about a mean.

Dynamics of ecosystem

It is well known that forests considered as ecosystems exhibit significant changes over time. An understanding of these dynamics processes are important both from scientific and management perspectives. One component of these, the prediction of growth and yield of forests has received the greatest attention in the past. However, there are several other equally important aspects concerned with dynamics of forests like long term effects of environmental pollution, successional changes in forests, dynamics, stability and resilience of both natural and artificial ecosystems etc. These different application purposes require widely different modeling approaches.

Any dynamics process is shaped by the characteristic time-scale of its components. In forests they range from minutes (stomatal processes) to hours (diurnal cycle, increment), to years (tree growth and senescence), to decades (forest succession) and to centuries (forest response to climatic change). The model purpose determines which of these time-scales will be emphasized. This usually requires an aggregated description of processes having different time-scales, but the level of aggregation will depend on the degree of behavioural validity required.

The traditional method of gathering data to study forest dynamics at a macro level is to lay out permanent sample plots and make periodical observations. More recently, remote sensing through satellites and other means has offered grater scope for gathering accurate historical data on forests efficiently. (Jayaraman, 2000)

Forest types

The forests of Doi Inthanon National Park are comprised of the following types (Smitinand, 1977):

1. Moist Evergreen Forest

The upper Moist Evergreen Forests occupy the slopes of 600-900 m. altitude and are also two-storied. The upper story is represented by a great proportion of oaks and chestnuts (*Quercus, Lithocarpus* and *Castanopsis*) interspersed with *Magnolia, Michelia, Syzygium, Pentace, Dipterocarpus costatus, D. grandiflorus, Myristica, Canarium* and *Podocarpus*.

2. Dry or Semi-evergreen Forest

This type of forest is scattered all country along the depressions on the peneplain, along the valleys of low hill ranges of about 500 m. elevation or forming galleries along streams and rivulets. The annual precipitation is between 1000-2000 mm. The upper story consists of *Antisoptera costata*, *Dipterocarpus alatus*, *D. Turbinatus*, *Hopea odorata*, *H. Ferrea*, *Shorea thorelii*, *Alstonia scholaris*, *Pterocymbium tinctorium*, *Tetrameles nudiflora*, *Afzelia xylocarpa*, *Ailanthus triphysa*, *Ulmus lanceifolius*, *Antiaris toxicaria*, *Lagerstroemia ovalifolia* and *Acrocarpus fraxinifolius*.

3. Hill evergreen Forest

Hill Evergreen Forest occurs in the upper elevations from 1000 m upwards and appears discontinuously all over the country, with a larger percentage in the northwestern Highland. This type of forest is also known as Temperate Evergreen Forest or Lower Montane Forest by some authors. The forest is two storied and dominated by the oaks, chestnuts, laurels, magnolias, teas and rhododendrons; gymnospermous elements are also present, such as *Podocarpus, Dacrydium, Cephalotaxus, Gnetum* and *Cycas*. The soil is either red granitic, brown-black calcareous or yellow-brown sandy. The humidity is very high as explained by the moss-clad trees: the precipitation is 1500-2000 mm annually.

4. Coniferous Forest

This type of forest is scattered in small pockets in the Northwest Highland and the Khorat Plateau of about 200-1300 m elevation, where poor acid soil occurs. The soil is either grayish sandy, or brownish gravelly and sometimes lateritic. The annual rainfall is about 1000-1500 mm. The forest is 3-storied and is rather open in nature in certain localities where forest fire is concurrent, the forest grades into a savanna. The upper story is composed of *Pinus kesiya* and *P. merkusii*, in certain localities where lateric soil is evident, *Dipterocarpus obtusifolius* and *D. tuberculatus* also come into from a Pinus-Dipterocarpus association.

5. The Deciduous Forest

Along the dry belt of the country, where precipitation is low (under 1000 mm.) the climate is more seasonal and the soil is either sandy or gravelly loam and sometimes lateritic. The vegetation here is classified as deciduous and tree species shed their leaves during the dry season. Trees growing in this forest type tend to develop growth or annual rings. The height of predominant trees is comparatively lower (20-25 m.) than that of the evergreen forest. This forest is more or less subject to ground fire during the dry season.

Deciduous forests can be sub-divided into three main categories: Mixed Deciduous Forest, Dry Deciduous Dipterocarp Forest and Savanna Forest.

5.1 Mixed Deciduous Forest

This type of forest is composed of all deciduous species in a good proportion but in certain localities a species such as teak (*Tectona grandis*) may become predominant and the area would generally be called a Teak forest for convenience.

5.2 Moist Upper Mixed Deciduous Forest

This type of forest occurs between the elevations of 300-600 m altitude and is 3 stories in profile. The soil in this forest is usually loamy, either calcareous or granitic. The upper story consists of *Tectona grandis*, *Lagerstroemia tomentosa*, *Terminalia alata*, *T. Calamansanai*, *T.bellirica*, *Afzelia xylocarpa*, *Xylia kerrii*, *Bombax insigne*, *Pterocarpus macrocarpus*, *Dalbergia cultrata*, *D.oliveri*, *Adina cordifloia*, *Gmelina arborea*, *Anogeissus acuminata*, *Millettia leucantha*, *Albizia lebbeck*, *A. Procera*, *A.lebbekiodes*, *A. Chinensis*, *Acacia leucophloea*, *Adenanthera pavonina* and *Dillenia pentagyna*.

5.3 Dry Upper Mixed Deciduous Forest

Along the ridges at the elevations of 300-500 m altitude the vegetation becomes more open due to the evaporation, exposure, surface erosion and the leaching of organic components from the soil. The forest is also three stories. The soil is either sandy loam or lateritic. The ground flora is frequently destroyed by fire. This type of forest especially when constantly disturbed by human beings, will degrade into a bamboo sward which sometimes cover quite an extensive area. The main bamboo species are *Bambusa arundinacea* and *Thyrsostachys siamensis*.

5.4 Lower Mixed Deciduous Forest

This forest type occurs on low-lying country at 50-300 m altitude in the dry zone where the soil is either sandy loam or lateritic. The forest is three-storied. The absence of teak (*Tectona grandis*) from the upper story is a distinct characteristic, differentiating the Lower from the Upper Mixed Deciduous Forest.

6. Dry Deciduous Dipterocarp Forest

On the undulating peneplain and ridges where the soil is either sandy or lateritic and subjected to extreme leaching erosion and annual burning the vegetation is markedly changed into a subclimax type. The predominant species belong to the

Dipterocarpaceae. The forest is rather open and can be considered as two-storied (Smitinand, 1977).

Teejuntuk *et al.* (2003) studied in Doi Inthanon National Park and classified plant from altitudinal gradient into 5 groups:

Group I: *Shorea siamensis, Canarium subulatum, Shorea obtusa*

This group included five dry dipterocarp forest stands located between 450 and 720 m asl. *Shorea siamensis* is the dominant species in every stand. Stands and subgroup A are represented by other co-dominant species such as *Canarium subulatum*, *Lannea coromandelica, Terminalia triptera, Cratoxylum formosum*, and some other minor species. In sub group B, there are *Shorea obtus*a, *Canthium parvifolium, Dalbergia dongnaiensis* and a few more underrepresented species. The most obvious characteristics of this group are an open canopy, low density, and the small diameter and short stature of most trees. These stands have a conspicuous layer of graminoid, dwarf bamboo, or other undergrowth.

Group II: *Tectona grandis, Xylia xylocarpa, Lagerstroemia calyculata, Millettia leucantha*

This group can be further divided into two sub-groups, one with *Tectona grandis* as the dominant species, the other without its presence. The canopy strata of this forest are evenly mixed among almost all the deciduous tree species, lacking any single-species dominance. One of the sub-groups, which features *Tectona grandis* and *Xylia kerrii* as the dominant tree species, mixed with other species such as *Millettia leucantha, Dalbergia oliveri, Strychnos nux-vomica* and *Grewia eriocarpa*.

Group III: *Pinus kesiya, Dipterocarpus tuberculatus, Aporusa villosa, Wendlandia tinctoria, Schima wallichii, Helicia nilagirica*

Pinus kesiya is the dominant species in this group and the main canopy tree species. The stands having *Pinus kesiya* as a dominant tree can be classified into two sub-groups: 1) those also including *Dipterocarpus tuberculatus*, *Quercus ramsbottomii* and 2) those also including *Schima wallichii*, *Aporusa villosa*, and *Wendlandia tinctoria.* Sub-group 1 occurs in habitats drier than sub-group 2. During the dry season, soils of this sub-group are often very dry, and therefore, some species shed their leaves. Normally this group is restricted to upper slopes or on mountain ridges at altitudes between 850 and 1,150 m asl.

Group IV: *Schima wallichii, Castanopsis ferox, Castanopsis tribuloides, Helicia nilagirica*

This group is represented by three stands located between 1,340 and 1,440 m asl. Stands of this group is characterized by a tall and closed canopy. Canopy trees of this group are those belonging to the family Fagaceae, such as *Castanopsis ferox* and *Castanopsis tribuloides*, well mixed with *Schima wallichii*. Those species with lower statures, especially *Helicia nilagirica, Ternstroemia gymnanthera, Syzygium angkae and Wendlandia tinctoria*, are the main co-dominant trees.

Group V: *Mastixia euonymoides, Castanopsis calathiformis, Drypetes indica*

This group is located between 1,650 and 1,710 m asl. The essential characteristics of these stands are high density and a tall, closed canopy. In stands on the lower and middle slope, *Mastixia euonymoides* is the dominant canopy tree mixed with other species such as *Manglietia garrettii*, *Lithocarpus aggregatus* and *Calophyllum polyanthum*. In the sub-canopy layer, *Drypetes indica*, *Mallotus khasianus, Ostodes paniculata* are abundant. In contrast, in stands on the upper slopes *Castanopsis calathiformis* is dominant, mixed with *Quercus lenticellata*, *Tarenna disperma*, and

Lindera metacafaena. This group may be considered a cloud forest and mosses grow abundantly on tree trunks.

Group VI: *Neolitsea pallens, Actinodaphne henryi, Rapanea yunnanensis*

This group occurs at the highest altitudes in Doi Inthanon National Park, located between 2,220 and 2,320 m asl. The characteristics of the canopy layer are the same as those of group V, however the dominant trees are different. In this case, *Neolitsea pallens*, *Castanopsis ferox* and *Quercus lenticellata* are the main canopy trees mixed with *Rapanea yunnanensis, Symplocos longifolia* in the sub-canopy.

Quantitative characteristics

1. Density

Density is the count of the number of individuals of a particular species per unit area (Goldsmith and Harrison, 1976 ; Kershaw and Looney, 1985 ; Mueller-Dombois and Ellenberg, 1974 and Barbour *et al*., 1980). It is usually to count the number of individuals within a series of randomly distributed quadrats, calculating the average number of individuals relative to the quadrat used, from the total sample (Kershaw, 1964 ; Kershaw and Looney, 1985). It is equal to the number of square units of the total area divided by the individuals. Relative density is the density of one species as a percent of total plant density (Barbour *et al*., 1980).

2. Frequency

The frequency of a species is defined as the chance of finding a species in a particular trail samples (Goldsmith and Harrison, 1976 ; Kershaw and Looney, 1985). The measure is obtained very simply by noting whether a species is present or not in a series of randomly placed quadrats (Kershaw and Looney, 1985). It is obtained by using quadrats and expressed as the number thrown or, more often, as a percentage (Goldsmith and Harrison, 1976). Frequency relates to the number of times a species occurred in a given number of repeatedly placed small sample plots. Relative frequency is the frequency of one species as a percentage of total frequency (Babour *et al*., 1980).

3. Dominance

In several-layered tree and shrub communities the degree of dominance of a species is given by its share in the different layers of the vegetation. The relative abundance of the different species may indicate whether each single species has any influence on the system.

Relative dominance is the cover of a particular species as a percentage of total plant cover (Mueller-Dombois and Ellenberg, 1974), however, canopy cover of trees is assumed to correlate with trunk cross-sectional area (basal area, BA) or with trunk diameter at breast height (DBH) (Barbour *et al*., 1980).

4. Importance value index

Importance value index (IVI) of any species in a community can be between 0-300. It defines as the sum of relative dominance, relative density and relative frequency (Curtis and McIntosh, 1951). This index presents ecological success of the abundant species. Importance value index will provide an indication of the dominant species in forest.

5. Species diversity

The Shannon index (H') has probably been the most widely used index in community ecology. It is based on information theory (Shannon and Wiener, 1949) and is a measure of the average degree of “uncertainly” in predicting to what species and individuals chosen at random from a collection of S species and N individuals will belong. This average uncertainty increases as the number of species increases and as the distribution of individuals among the species becomes even. Thus, H' has two properties that have made it a popular measure of species diversity: $H^{'} = 0$ if and only if there is one species in the sample, and $H^{'}$ is maximum only when all S species are represented by the same number of individuals, that is a perfectly even distribution of abundances (Ludwig and Reynolds, 1988).

Simpson's index, which varies from 0 to 1, gives the probability that two individuals drawn at random from a population belong to the same species, then the diversity of the community sample is low. The simpson's index applies only to finite communities where all of the members have been counted i.e., $n = N$, where n is the total number of individuals in the sample and N is the total individuals in the population. Since this usually work with infinite populations where it is impossible to count all members, Simpson (1949) developed an unbiased estimator (λ) for sampling from a infinite population.

These diversity numbers, which are in units of number of species, measure what Hill calls the effective number of species present in a sample. This effective number of species is a measure of the degree to which proporational abundances are distributed among the species. Explicitly, N_0 is the number of all species in the sample (regardless of their abundances), N_2 is the number of vary abundant species, and N_1 measures the number of abundant species in the sample. (N_1 will always be intermediate between N_0 and N_2.) In other words, the effective number of species is a measure of the number of species in the sample where each species is weighted by its abundance (Ludwig and Reynolds, 1988).

As evenness index should be independent of the numberof species in the sample. Intuitively, it would seem reasonable that, regardless of the number of species present, an evenness index should not change. J' is strongly affected by species richness; the addition of one rare species to a sample that contains only a few species (low S) greatly changes the value of E_1. This sensitivity is illustrated where a species represented by only one individual is added to a sample containing three well-represented species. E_2 and E_3 and like E_1, are very sensitivity is illustrated, where a species represented by only one individual is added to a sample containing three well-respented species. E_2 and E_3, like E_1, are very sentitive to species richness. In contrast, E_4 and E_5 are relatively unaffected by species richness.

Forest community classification

Clustering method is the ways to classify all objects into different groups, or more precisely, the partitioning of a data set into subsets (clusters), so that the data in each subset (ideally) share some common traits - often proximity according to some defined distance measures. Data clustering is a common technique for statistical data analysis, which is used in many fields, including machine learning, data mining, pattern recognition, image analysis and bioinformatics.

Data clustering algorithms can be hierarchical or partitional. Hierarchical algorithms find successive clusters using previously established clusters, whereas partitional algorithms determine all clusters at once. Hierarchical algorithms can be agglomerative ("bottom-up") or divisive ("top-down"). Agglomerative algorithms begin with each element as a separate cluster and merge them into successively larger clusters. Divisive algorithms begin with the whole set and proceed to divide it into successively smaller clusters. The traditional representation of this hierarchy is a tree (called a dendrogram), with individual elements at one end and a single cluster containing every element at the other. Agglomerative algorithms begin at the top of the tree, whereas divisive algorithms begin at the bottom (Prinzie and Poel, 2006).

In the fields of plant and animal ecology, clustering is used to describe and to make spatial and temporal comparisons of communities (assemblages) of organisms in heterogeneous environments; it is also used in plant systematics to generate artificial phylogenies or clusters of organisms (individuals) at the species, genus or higher level that share a number of attributes.

Study Site

1. Doi Inthanon National Park

Doi Inthanon National Park, Chiang Mai Province is one of the first 14 national parks established, because of their high diversity of vegetation designed for conservation and recreation purposes. It is located at 31st km. of Chomthong - Inthanon road. Tambol Banlang, Chomthong District, Chiang Mai Province. Doi Inthanon is located 50 km south-southwest of Chiang Mai City. An area of 482.4 km^2 around the summit has been designated a national park (National Park Wildlife and Plant Conservation Department, 2006). The national park made up of a series of mountains along the range toward from north to south known as Thanontongchai. The highest of the national park is 2,565 meter, which is the highest point of Thailand. The national park contains many mountains of different series and heights, when one views from the surrounding plains the range looks like a series of rising and falling waves. Throughout the national park, the different altitudes create both plant and animal more diversity.

The study area is located on the middle slope (18°24´N to 18°40´N latitude and 98 °24´E to 98°45´ E longtitude of Doi Inthanon, Chiang Mai Province, northern Thailand as shown in Figure 1.

2. Topography and climate

According to Pendelton's reconnaissance geological map, Doi Inthanon is a huge granite massive, underlain by three major rock types found in the highlands of Thailand (Pendelton, 1962). From Ban Mae Hoi, in the eastern part of the park, to Pha Mawn, in the central part of the park, it traverses the band of gneiss that connects in the northwest with Doi Suthep National Park. This parent material produces the Sithammarat coarse sandy loams which Pendelton (1962) described as miserably poor and of little agricultural value. At Pha Mawn, there is a narrow pocket of clastic sediments, the Kanchanaburi series consisting of shales, siliceous sandstone and in

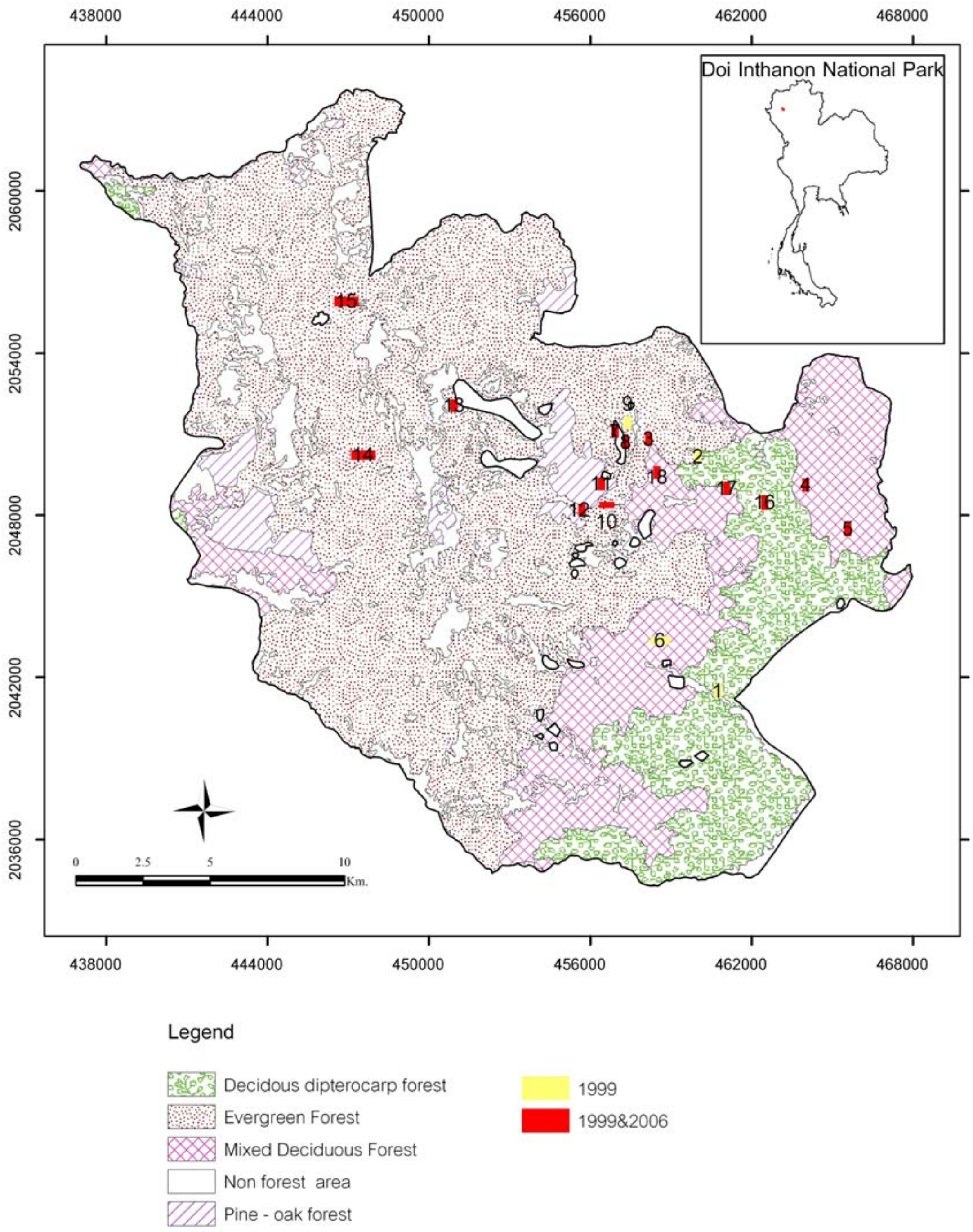

Figure 1 Vegetation map and location of study plots in Doi Inthanon National Park.

places, quartzites and slates. These parent materials produce poor soils, shallow and stony and of scant agricultural value. Doi Inthanon itself is a granitic massive generally giving rise to the Kuantan sandy loams of shallow coarse and stony soils.

Doi Inthanon has a typical monsoon climate characterized by the alternation of dry and rainy seasons. The rainy season usually starts from May to October. The rain is brought by the humid southwest winds blowing across the Indian Ocean. According to weather recoreded at the Royal Project Doi Inthanon Station (1300 m altitude) from 1993 to 1999, the mean annual rainfall is 1908 mm, of which 88 % falls in the six months of the rainy season. The monthly rainfall from December to February is less than 10 mm in normal years. The monthly mean of the daily maximum temperatures ranges from 22.7°c in December to 28.9 °c in April and that of the daily minimum temperatures ranges from 11.4 °c in January to 18.6 °c in May.

Rainfall and humidity clearly increased according to the altitude. The summit of Doi Inthanon (2,565 m a.s.l.) is often covered with clouds, even in the dry season. At the weather station on the summit, the mean annual rainfall from 1982 to 1999 reached to 2,279 mm. The monthly mean of the daily maximum temperatures ranges from 17.3 °c in August to 21.4 °c in April and that of the daily minimum temperatures ranges from 2.9 °c in December to 10.2 °c in August (Hara *et al*., 2003).

MATERIALS AND METHODS

Field Data Collection

According to vegetation map, Doi Inthanon National Park has five forest types, including deciduous dipterocarp forest, mixed deciduous forest, pine-dipterocarp forest, pine-oak forest and hill evergreen forest. Nine sample plots in three sites of each forest type were delineated at three slope positions: upper, middle and lower. Plots were deliberately selected by varying in altitude in order to represent the entire altitudinal gradient of the study area. The sampling locations were selected in five forest types: deciduous dipterocarp forest (DDF), mixed deciduous forest (MDF), pine-dipterocarp forest (PDF), pine-oak forest (POF) and hill evergreen forest (HEF). The dry evergreen forest, which occupied less than 1 percent of the total area was omitted. These were a total of forty five sample plots (Figure 1) and field work was conducted in November 1999. The plots in 5 forest types were composed of HEF (E1, E2, E3, E4, E5, E6, E7, E8 and E9), POF (D1, D2, D3, D4, D5, D6, D7, D8 and D9), PDF (C1, C2, C3, C4, ,C5, C6, C7, C8 and C9), MDF (B1, B2, B3, B4, B5, B6, B7, B8 and B9) and DDF (A1, A2, A3, A4, A5, A6, A7, A8 and A9). In 2006, the data were collected again and new plots were established in the DDF and MDF, totally thirty nine plots. The plots were composed of HEF (E1, E2, E3, E4, E5, E6, E7, E8 and E9), POF (D1, D2, D3, D4, D5, D6, D7, D8 and D9), PDF (C1, C2, C4, C5 and C6), MDF (B1, B2, B3, B4, B10, B11 and B12) and DDF (A7, A8, A9, A10, A11, A12, A13, A14 and A15).

Each sample plot (0.16 ha or 40x40 m^2) was divided into sixteen 10x10 m^2 quadrats using a surveying instrument set (field compass and measuring tape) (Figure 2). In every quadrat, all living trees with a diameter at breast height (DBH) equal or exceeding 4.5 cm were measured with a diameter tape and as far as possible identified to species. Plant specimens were collected and dried for identification at the Royal Forest Department Herbarium, Bangkok. Altitude, slope and aspect were determined using an altimeter and pocket compass. The important value index of species, relative dominance, relative density, relative frequency, structure, diversity, basal area and biomass were analysed in each of the thirty nine sample stands and entered into a database for further study.

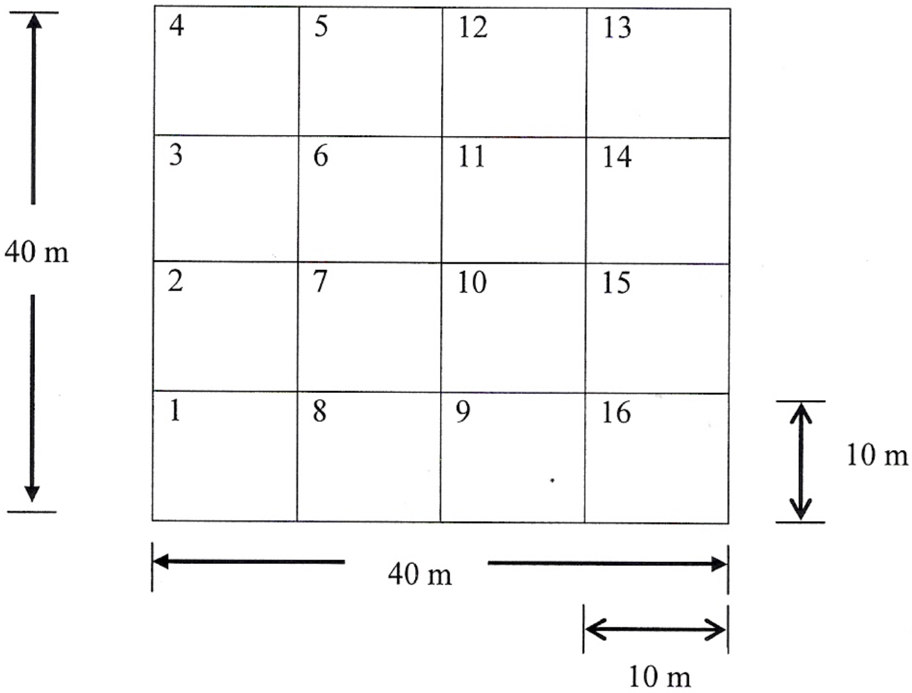

Figure 2 Permanent 0.16 ha plot (40x40 m^2) and numbering labels show the number of subplots, trees were studied in all subplots of 10x10 m^2

2. Data analysis

2.1 Structural characteristics

The studies were carried out by adopting the quantitative ecological methods as follows:

2.1.1 The importance value index (IVI)

The importance value index (IVI) of each species in each plot was determined as:

$$\text{IVI} = \%\text{ relative density} + \%\text{ relative frequency} + \%\text{ relative dominance} \quad (1)$$

Where,

$$\%\text{ relative density} = \frac{\text{density of species i}}{\text{Total tree density}} \times 100 \quad (2)$$

$$\%\text{ relative frequency} = \frac{\text{frequency of species i}}{\text{Total frequency of all species}} \times 100 \quad (3)$$

$$\%\text{ relative dominance} = \frac{\text{total basal area of species i}}{\text{Total basal area of all species}} \times 100 \quad (4)$$

i = 1, 2, 3, 4,….,S

S = total number of species

The relative density was determined from all standing trees of DBH larger than 4.5 cm in the whole plot of 40x40 m^2. The relative frequency was determined for sixteen (10x10 m^2) subplots set by regularly subdividing the 40x40 m^2 plot. The relative dominance was obtained from the basal area at breast height, calculated as $\pi D^2/4$, of each tree in the whole plot.

2.2.2 The number of dominant species was also determinated by Ohsawa' s formula (Ohsawa, 1984) as follow:

$$d = \frac{1}{s\left[\sum_{i \in T} \left(x_i - x'\right)^2 + \sum_{j \in u} x_j^2\right]} \quad (5)$$

Where x_i = actual percent share (IVI is adopted) of the top species (T), i.e. in the top dominant in the one-dominant model, or the two top dominant model.

x' = ideal percent share (IVI is adopted) of the top species

x_j = percent share of the remaining species (U)

s = number of species

d = deviation between actual IVI and the expected percent share of the corresponding co-dominant-number model

2.2.3 Species diversity indices

1. The Shannon-Wiener index of species diversity, H′ (Shannon and Wiener, 1949) was adopted as:

$$H'(s) = -\sum_{i=1}^{S} pi \log_2 pi \quad (6)$$

Where, p_i = proportion of number of individuals of species i to the total number of individuals of all species (i=1,2,…,s)

s = total number of species in the sample area

$\log_2$ = base 2 logarithm

2. The Fisher's index of species diversity (α) (Fisher *et al*., 1943);

$$N = \frac{\alpha X}{1-X} \quad (7)$$

$$\alpha = \frac{N(1-X)}{X} \quad (8)$$

$$S = -\alpha \ln(1-X) \quad (9)$$

N = number of individuals in the same area

α = the Fisher's index of species diversity

S = number of species

X = constant value (calculated from trail and error method) from(9)/(7) or

$$\frac{S}{N} = [(\frac{1-X}{X})][-\ln(1-X)] \quad (10)$$

ln = natural logarithm

3. The Simpson's index of species diversity (D) (Simpson, 1949; Pielou, 1969);

$$D = -\sum_{i=1}^{S} \frac{[Ni(Ni-1)]}{[N(N-1)]} \quad (11)$$

Where, N_i = total number of individuals of species i
N = total number of individuals of all species
D = Simpson's index of species diversity

4. The richness index in forms of richness index 1 (R_1 of Margalef, 1958) and richness index 2 (R_2) or Menhinick's index (Menhinick, 1964) were used:

$$R_1 = \frac{(S-1)}{\ln(N)} \quad (12)$$

$$R_2 = \frac{S}{\sqrt{N}} \quad (13)$$

Where, S = total number of species
N = total number of individuals of all species
ln = natural logarithm

5. The evenness index was calculated as:

5.1 Evenness index 1 (E_1) which is the most common evenness index used by ecologists was calculated as:

$$E_1 = \frac{H'}{\ln(S)} = \frac{\ln(N_1)}{\ln(N_0)} \tag{14}$$

5.2 Evenness index 2 (E_2). Sheldon (1969) proposed an exponential form of E_1 as an evenness index:

$$E_2 = \frac{e^{H'}}{S} = \frac{N_1}{N_0} \tag{15}$$

5.3 Evenness index 3 (E_3). This is with the minimum subtracted, it become the evenness proposed by Heip (1974):

$$E_3 = \frac{e^{H'} - 1}{S - 1} = \frac{N_1 - 1}{N_0 - 1} \tag{16}$$

5.4 Evenness index 4 (E_4). Hill (1973) proposed the ratio of N_2 to N_1 as an index of evenness:

$$E_4 = \frac{1/\lambda}{e^{H'}} = \frac{N_2}{N_1} \tag{17}$$

5.5 Evenness index 5 (E_5). was calculated as:

$$E_5 = \frac{(1-\lambda) - 1}{e^{H'} - 1} = \frac{N_2 - 1}{N_1 - 1} \tag{18}$$

Where,	E	=	species evenness
	H'	=	Shannon-Weiner index of species diversity
	S	=	total number of species
	ln	=	natural logarithm
	N_1	=	$e^{H'}$
	N_2	=	$1/D$ (D = Simpson's index)

6. Hill (1973) 's diversity numbers were obtained from:

$$\text{Number 0: } N_0 = S \tag{19}$$

$$\text{Number 1: } N_1 = e^{H'} \tag{20}$$

$$\text{Number 2: } N_2 = 1/D \tag{21}$$

Where	S	=	the total number of species,
	H'	=	Shannon-Weiner index
	D	=	Simpson's index

2.2 Aboveground biomass estimation

The trunk and branch biomass (W_C) were estimated by using the allometric relation proposed by Ogawa *et al*.(1961) for hardwood trees of the hill evergreen forest and deciduous forest in Doi Inthanon as follows:

$$W_C = 0.06851\,(D^2H)^{0.8396} \tag{22}$$

$$W_L = 0.04518\,(D^2H)^{0.6230} \tag{23}$$

$$W_T = W_C + W_L \tag{24}$$

where, D = diameter at breast height (cm)

H = tree height (m)

W_C = aboveground weight of a tree trunk and branch (kg)

W_L = aboveground weight of a tree leaf (kg)

W_T = total aboveground biomass (kg)

For hardwood trees of the dipterocarp forest in Doi Inthanon, equestions of Ogino *et al*. (1967) were applied as follows:

$$W_s = 189\ (D^2H)^{0.902} \qquad (25)$$

$$W_B = 0.12\ (W_S)^{1.204} \qquad (26)$$

$$1/W_L = (11.4/\ (W_S)^{0.09}) + 0.172 \qquad (27)$$

$$W_T = W_S + W_L + W_B \qquad (28)$$

where, D = diameter at breast height (m)

H = tree height (m)

W_S = aboveground weight of a tree trunk (kg)

W_B = aboveground weight of a tree branch (kg)

W_L = aboveground weight of a tree leaf (kg)

W_T = total aboveground biomass (kg)

Kajornsrichon *et al*. (1988)'s equestions were used to study the biomass of *Pinus kesiya* as fallows:

$$\log W_S = -1.6693 + 0.9814 \log (D^2H) \qquad (29)$$

$$\log W_B = -4.8060 + 1.4561 \log (D^2H) \qquad (30)$$

$$\log W_L = -3.5245 + 1.03138 \log (D^2H) \qquad (31)$$

$$\log W_T = -1.8833 + 1.0412 \log (D^2H) \qquad (32)$$

where, D = diameter at breast height (cm)

H = tree height (m)

W_S = aboveground weight of a tree trunk (kg)

W_B = aboveground weight of a tree branch (kg)

W_L = aboveground weight of a tree leaf (kg)

W_T = total aboveground biomass (kg)

2.3 Height

The actual height of tree in the closed canopy is very difficult to measure. In this case, the relationships between DBH and H (D-H curve) were derived by using data from tree height measurement in 2006 and estimate height of another tree from DBH (using D-H curve). Ogawa (1969) and Kira and Ogawa (1971) found that D-H curve are important parameters in forest community structure because the aboveground parts have closed relationships with biomass of the forest. Ogawa presented this relationships by hyperbolic equastion:

$$\frac{1}{H} = \frac{1}{aD^h} + \frac{1}{H^*} \qquad (33)$$

Where a and h are constant values in stand and H* is constant value represent the upper limit value of H value (asymptote H if $D \rightarrow \infty$), h value will be more than 1 in sun tree but equals to 1 in stabilized climax community or shade-tolarant trees. For estimating a and H*, following fomulas are used:

$$A = \frac{\sum y \sum w^2 - \sum w \sum yw}{\sum y^2 \sum w^2 - \left(\sum yw\right)^2} \qquad (34)$$

$$B = \frac{\sum y^2 \sum w - \sum y \sum yw}{\sum y^2 \sum w^2 - \left(\sum yw\right)^2} \qquad (35)$$

where, A = 1/H* ; H* = 1/A

B = 1/a ; a = 1/B

D = Diameter at breast height (cm.)

y = H (Height in 2006 (m))

w = y/D

$$\frac{1}{H} = \frac{1}{aD^h} + \frac{1}{H^*} \qquad (36)$$

Where h = 1

$$\frac{1}{H} = \frac{1}{aD} + \frac{1}{H^*} \qquad (37)$$

The values of A and B in (34) and (35) were then replaced into (37) to estimate the height of forest in all plots in 1999.

2.4 Basal Area

$$BA = \frac{\pi d_i^2}{4} \qquad (38)$$

Where, Basal Area (BA) = the total basal area of tree i

d_i = diameter at breast height (dbh) for tree i

2.3 Community dynamics

2.3.1 Mortality rate

The mortality rate was calculated in terms of number of dead tree, % of dead tree, and also used the mortality rate in terms of (λ) as:

$$\lambda = \frac{\ln N_{t2} - \ln N_{t1}}{t_2 - t_1} \quad (39)$$

Where, N_t = the number of individuals in the first measurement

N_{t2} = the number of individuals surviving in the second measurement

t_1 and t_2 = the period between t_1 and t_2

2.3.2 Growth rate

Growth increment of all living individuals (DBH≥ 4.5 cm) in each plot were studied in two ways, absolute growth rate and relative growth rate, defined as follows;

$$\Delta D = \frac{D_2 - D_1}{t_2 - t_1} \quad (40)$$

Where, ΔD = the absolute growth rate of DBH

D_1 = the DBH of the first measurement

D_2 = the DBH of the second measurement

t_1 and t_2 = the period between t_1 and t_2

2.3.3. Relative growth rate (RGR)

$$RGR = \frac{\ln D_2 - \ln D_1}{t_2 - t_1} \quad (41)$$

where, RGR = the relative growth rate of DBH

D_1 = the DBH of the first measurement

D_2 = the DBH of the second measurement

t_1 and t_2 = the period between t_1 and t_2

ln = the natural logarithm

2.4 Cluster analysis

Cluster analysis (CA) is a classification technique for placing similar entities or objects into groups or “clusters”. The cluster analysis models used to place similar samples into clusters, which are arranged in a hierarchical treelike structure called a dendrogram. The vegetation data were subsequently analyzed by using cluster analysis (CA) . The PC-OR program was applied to analyze the data in terms of mutivariate technique. The species abundance matrix consisting of the parceled important value index (IVIs) of the species having IVI value more than 2.0 in all of stands were included. This matrix were standardized by an equation, $Xij = (Pij)^{0.2}$ before entering into analysis procedure. The same vegetation data set was used again for analyzing by the cluter analysis (CA).

RESULTS AND DISCUSSION

1. Community structure

1.1 Stand composition

In 2006, the studied tree community were composed of 39 plots and investigated in 5 types of forests: Dry Dipterocarp Forest (DDF, A7-A9 and new plots A10-A15), Mixed Deciduous Forest (MDF, B1-B4 and new plots B10-B12), Pine Dipterocarp Forest (PDF C1, C2, C4, C5 and C6) Pine-Oak Forest (POF, D1-D9), and Hill Evergreen Forest (HEF, E1-E9). In total 39 plots of this study found 289 tree species, 150 genera and 69 families. The HEF had the highest species than others which was comprised of 144 species, 86 genera and 48 families, while the plant species in POF, PDF, MDF, DDF were found 95 species, 62 genera and 38 families, 70 species, 49 genera and 29 families, 75 species, 49 genera and 24 families and 70 species 51 genera and 25 families, respectively (Table 1). Number of species indicated that DDF was lower than other forests.

Pengklai (1996) reported that plant species diversity in Doi Inthanon were 97 families, 317 genera, 2,500 species for dicotyledon plants, therefore the results of this study were approximates to be 71.13 % of total families, 47.32 % of total genera and 11.56 % of all species from the record studied by Pengklai (1996) because this study included only trees having DBH equal to and over 4.5 cm. in which small-sized trees, shrubs and other life-forms were not enumerated.

Table 1 Summary of the study plots in Doi Inthanon National Park, trees of DBH ≥ 4.5 cm are enumerated.

Forest Type	Number of Plots	Elevation (m asl)	Number of families	Number of genera	Number of species
DDF	9	450-990	25	51	70
MDF	7	490-730	24	49	75
PDF	5	980-1,100	29	49	70
POF	9	1,020-1,180	38	62	95
HEF	9	1,340-2,320	48	86	144

1.2 Density

Density varied by many factors such as tree size, site conditions and human effects. Generally, large tree size has density lower than small tree size in climax community. The forest divided by type as shown in Table 2 and Figure 3 found that DDF had low density in 450-730 m asl because these sites had fire disturbance and young trees were been mostly disappeared. In 730-930 m asl the density increased because in this altitude range has many young trees. Density of trees in 990 m asl altitude had decreased because from 490-600 m asl it has many large tree size in the plot. Density values in DDF ranged from 170-590 stem/ha (Sukwong and Dhamanittakul, 1977; Bunyavejchewin, 1983b). In MDF (Figure 3), density increased except in 600-620 m asl where it decreased because in this altitude trees are sparse. The density in MDF had 171 stem/ha (Marod *et al*., 1999) that the result of this study shown higher density. The density of trees in PDF, POF and HEF (Figure 3) were found to have no clear correlation with altitude. POF (Table 2) had the highest density because they are young forest succession. The tree density of Doi Inthanon forests showed a close value to the seccondary DDF at Somdet, Kalasin (Kanzaki *et al*., 1991), DDF at Sakaerat (Sahunalu and Dhanmanonda, 1995), the DDF in Northern and Northeastern region of Thailand (Bunyavejchewin, 1983 a), Hill Evergreen Forest at Huay Nam Dang (Suksomut, 1987), Hill Evergreen Forest, and Pine Forest at Phu Kradung (Pothitan, 1999) as is shown in Table 3. In long term, tree density will decrease because of the fact that nutrient and light competition within stands will cause death and create some of suppressed tree, the low density forest will become mature phase finally.

Table 2 Density, basal area, DBH and aboveground biomass of tree in forest stand in Doi Inthanon National Park.

Forest types	Density (No/ha)	Basal area (%)	Average DBH (cm)	Aboveground biomass (ton/ha)		
				w_C	w_L	w_T
Dry Dipterocarp Forest						
Max.	1962	0.31	13.21	135.23	0.20	135.37
Mean	1027	0.16	11.46	57.92	0.11	58.03
Min.	568	0.06	10.05	14.62	0.06	14.68
S.D. (±)	533	0.10	1.00	43.6	0.05	43.64
Mixed Deciduous Forest						
Max.	856	0.25	21.6	66.72	5.55	72.26
Mean	522	0.14	14.54	45.77	3.91	49.63
Min.	237	0.07	9.98	22.82	2.07	24.89
S.D. (±)	223	0.70	3.69	15.35	1.25	16.56
Pine-Dipterocarp Forest						
Max.	2143	0.64	20.04	256.03	3.20	261.41
Mean	1275	0.40	14.18	172.81	1.72	175.59
Min.	712	0.29	10.07	147.49	0.96	148.84
S.D. (±)	543	0.14	4.01	46.75	0.88	48.21
Pine-Oak Forest						
Max.	2437	0.47	19.86	270.89	10.68	284.73
Mean	1426	0.39	14.26	187.54	8.27	197.21
Min.	906	0.34	11.00	141.23	6.45	149.15
S.D. (±)	517	0.40	2.99	39.98	1.31	41.56
Hill Evergreen Forest						
Max.	1881	0.90	21.74	284.75	16.48	300.93
Mean	1353	0.60	15.86	180.58	12.38	192.96
Min.	856	0.39	11.91	110.10	8.47	119.66
S.D. (±)	346	0.18	2.96	63.72	3.12	66.57

w_C = aboveground biomass of trunk and branch

w_L = aboveground biomass of leaf

w_T = total aboveground biomass

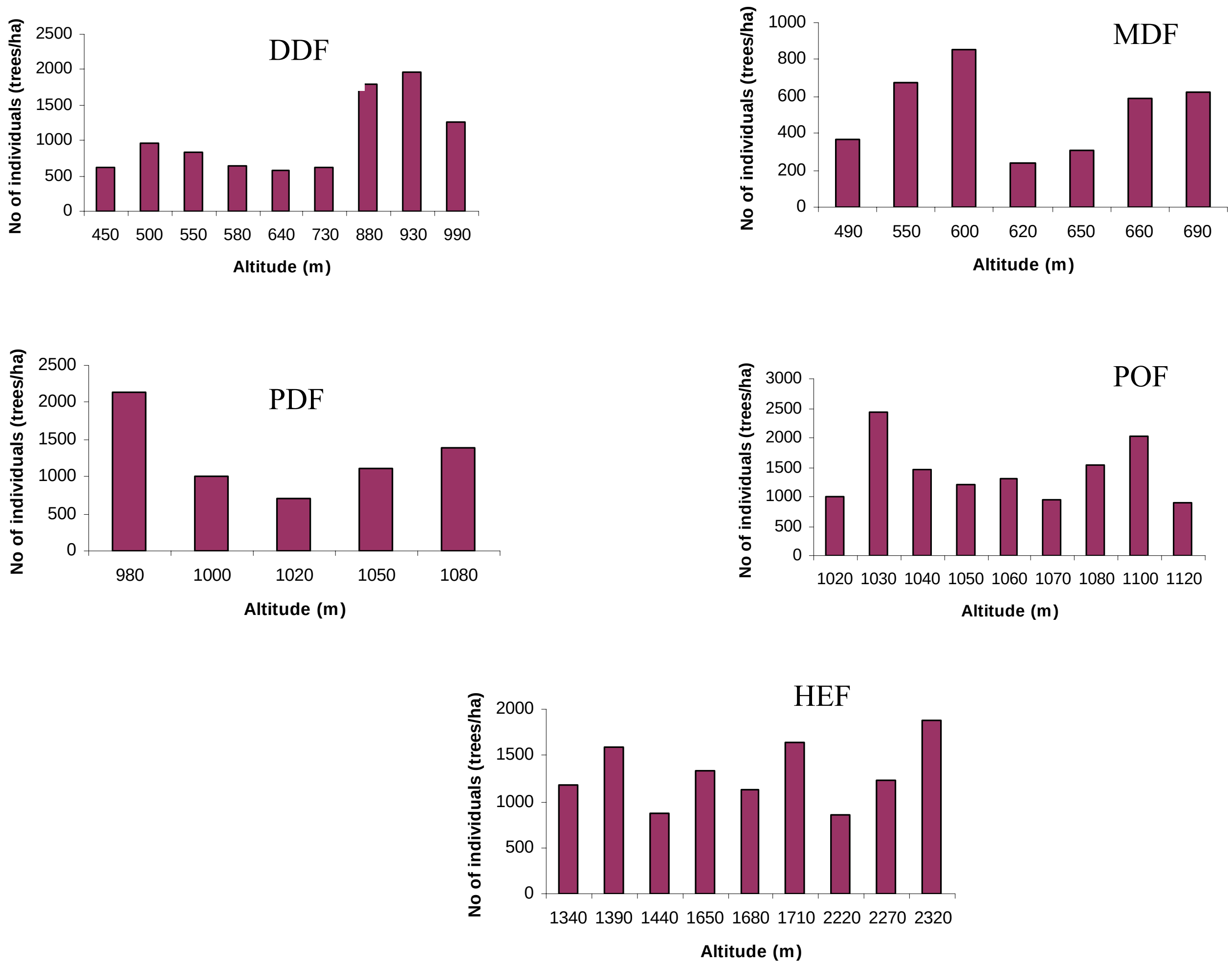

Figure 3 Distributional patterns of density in each forest type along an altitudinal gradients in Doi Inthanon National Park.

Table 3 Tree density and basal area of some forest types in Thailand, only trees with DBH ≥ 4.5 cm are included.

Forest plot	Tree density (no/ha)	Basal area (%)	Referance
Secondary DDF, Somdet	1,444	0.069	Kanzaki *et al*. (1991)
DDF, Somdet			
4 Sub-communities DDF, Sakaerat	688±51	0.152±0.023	Sahunalu and Dhanmanonda (1995)
Fire –protected DDF, somdet, Kalasin	316	0.327	Kanzaki *et al*. (1991)
Dry dipterocarp forest Northern and Northeastern region of Thailand			
1) *S. obtusa* type	417±144	0.167±0.056	Bunyavejchewin (1983a)
2) *D. Tuberculatus-S. obtusa* type	470±78	0.239±0.081	
DDF at Pingkong, Chiang Mai	1,488	0.147	Ogawa *et al*. (1961)
Mixed deciduous forest, Mae Moh, Lampang	765±353	0.078±0.026	Ratchareon (1996)
Mixed deciduous forest around Thailand			
1) *Tectona grandis* type	326±123	0.384 ±0.105	Bunyavejchewin (1983b)
2) *Lagerstroemia calyculata* type	360±118	0.331 ±0.143	
Hill evergreen forest, Huay Nam Dang, Chiang Mai	521	0.365	Suksomut (1994)
Hill evergreen forest, Phu Kradung	2,170	0.3239	Pothitan (1999)
Pine forest, Phu Kradung	77	0.1101	Pothitan (1999)

1.3 DBH and basal area

Average DBH and basal area classified by forest type are shown in Table 2 and Figure 4. In DDF, the total basal area increased in 730-990 m asl altitude but in low altitude of 450-640 m asl it had a close value because this forest type had many suppress and intermediate trees and moreover soil fertility and moisture are usually low. Total basal area in DDF displayed an increasing trend with altitude as similarly to the result of the study by Sungpalee (2002). The total basal area in MDF was found to be increased in 490-550 m asl and this range had the highest. In 550-650 m asl the total basal had decreased. In PDF, it was found that total basal area were decreased in 980-1,080 m asl probably because in PDF is composed of some species belonging to Dipterocarp forest. The Dipterocarp Forest was not found in a higher altitude and trees were mostly suppress and intermediate. The total basal area in POF was found to be moderately high along all range of the altitude because soil and climate may be more favourable for Pinus and Oak that were the dominant species in this type. The HEF had the highest total basal area while PDF, POF, MDF, DDF had low values respectively. In 1,340-1,440 m asl, it was found that total basal area were similarly low probably because they had highest suppress and intermediate trees. In 1,440-1650 m asl they had increased but over 1,650 m asl the total basal area had both decreased and increased patterens because in high altitude it always had high moisture, but litter had low decomposition rate due to low temperature by which these factors might cause trees to grow slowly. The MDF, PDF, POF and HEF were not the same as for DDF. The altitude will not affect to total basal area because basal area was calculated from DBH therefore, when DBH increased the basal area would show the same trend. The co-occurrence of low basal area per individual, as well as longer drought period or sometimes a sporadic disturbance by humans as a usual case for most forests of deciduous types or located in lower altitude where closed to human settlement (e.g. forest fire, tree cutting and firewood extraction) may be the main factors affecting species composition and the physiognomy of these forest stands.

The basal area of forest in Doi Inthanon showed the different trend from the secondary DDF at somdet, Kalasin (Kanzaki *et al*., 1991), DDF at Sakaerat (Sahunalu and Dhanmanonda, 1995), the DDF in Northern and Northeastern region of Thailand (Bunyavejchewin, 1983 a), Hill Evergreen Forest at Huay Nam Dang (Suksomut, 1987), Hill Evergreen Forest, and Pine Forest at Phu Kradung (Pothitan, 1999) as is shown in Table 3.

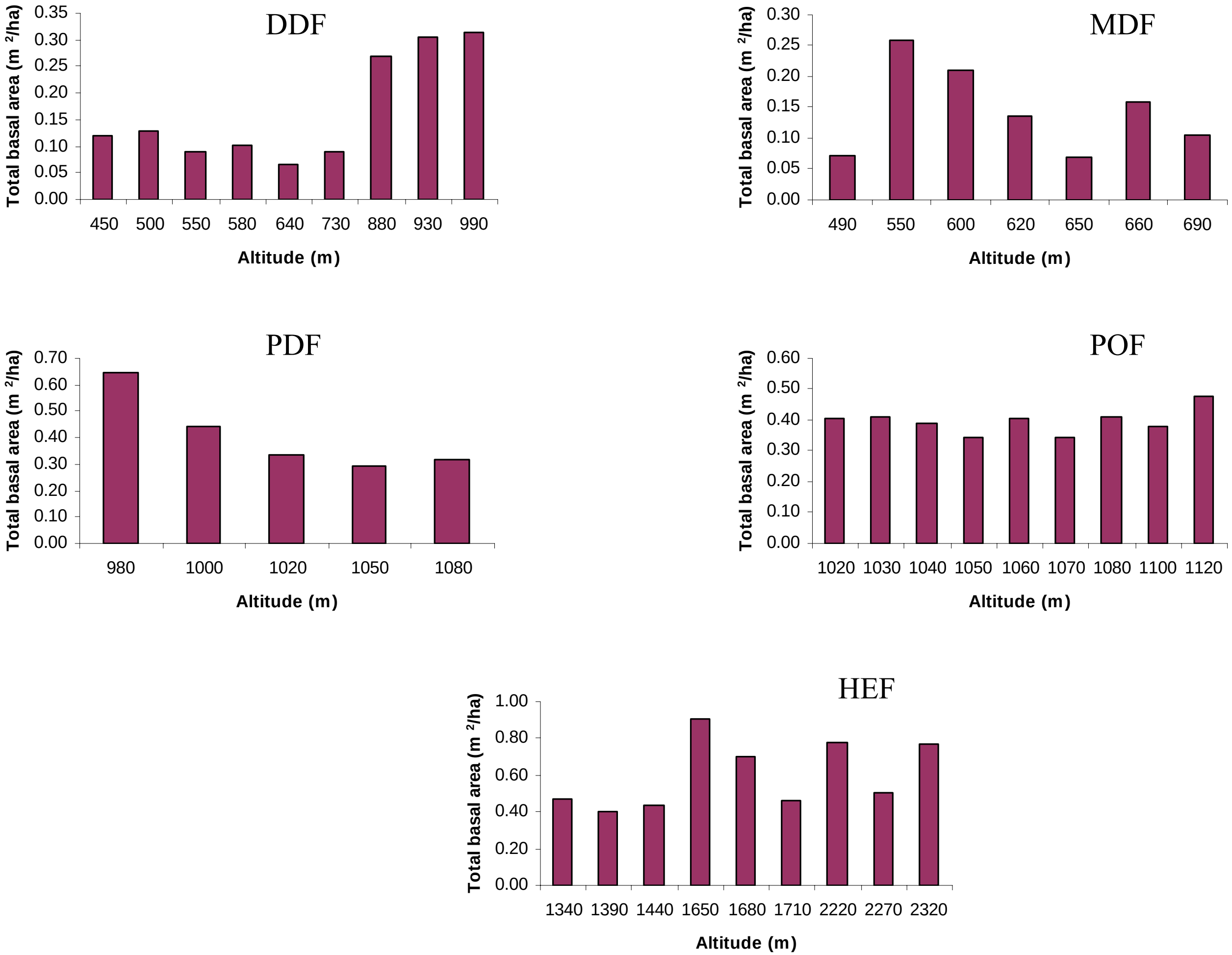

Figure 4 Distributional patterns of basal area in each forest type along an altitudinal gradient in Doi Inthanon National Park.

1.4 Dominant species

The importance value index (IVI) was studied from the summation of relative density, relative frequency and relative dominance. The forest community in Doi Inthanon had different dominant species in each type as shown by IVI value of each species in Appendix Table1-5 as classified by plots. The average IVI more than 10 is the criterion for class tying the dominant species. *Dipterocarpus tuberculatus*, *Shorea obtusa* and *Shorea siamensis* were the dominant species in DDF. Sungpalee (2002) studied DDF in Doi Inthanon found that *Shorea obtusa* and *Shorea siamensis* had IVI decreased with high attitude but *Dipterocarpus tuberculatus* had high IVI when altitude was higher than 850 m asl. *Tectona grandis* in MDF was the dominant species in the forest and found with *Xylia xylocarpa var. kerrii* but where *Tectona grandis* was absence, the dominant species were represented by *Millettia leucantha, Canarium subulatum*, *Zizyphus oenoplia*, *Vitex pinnata*, *Hymenodictyon excelsum*, *Grewia eriocarpa* and *Terminalia floribunda*. Ogawa *et al*. (1961); Smitinand (1977); found that *Tectona grandis,Pterocarpus macrocarpus, Afzelia xylocarpa, Xylia xylocarpa var. kerrii, Lagerstroemia calyculata*, *Terminalia* spp. and *Vitex peduncularis* are the dominant species in MDF. *Tectona grandis* is usually the most important species although it can be absent from the MDF. In PDF, it was found that *Pinus kesiya* had the highest IVI value. *Dipterocarpus tuberculatus* was the second species that distributed in high altitude of DDF. Sungpalee (2002) found that IVI of *Dipterocarpus tuberculatus* in high altitude had decreased. Other species in PDF such as *Aporusa villosa*, *Quercus ramsbottomii*, *Wendlandia tinctoria* were dominant. *Pinus kesiya*, *Schima wallichii, Castanopsis ferox*, *Aporusa villosa* and *Wendlandia tinctoria* were the dominant sprcies in POF type. Moreover, *Mastixia euonymoides, Drypetes indica, Castanopsis calathiformis*, *Mangleitia garrettii, Drypetes indica, Actinodaphne henryi, Castanopsis ferox, Neolitsea pallens* were the dominant species of HEF. Hara *et al*. (2002) studied tropical montane forest in Doi Inthanon National Park found that *Mastixia euonymoides* followed by *Quercus eumorpha*, *Manglietia garretii* and *Calophyllum polyanthum* are the dominant species.

1.5 Aboveground biomass

Aboveground biomass was estimated by using DBH and height of trees where height was calculated from D-H relationship. Aboveground biomass was estimated by the formulas proposed by Ogawa *et al*. (1961) for hill evergreen and deciduous forests, Ogino *et al*. (1967) for dipterocarp forest and Kajornsrichon *et al*. (1988) for *Pinus kesiya*. The aboveground biomass are shown in Table 2 and Figure 5 as classified by forest type. Aboveground biomass in DDF was found to have close values in 450-730 m asl and increased beyond the altitude of 730-990 m asl. Aboveground biomass in DDF had the lowest because on low altitude (450-730 m asl), soil is always low in moisture and fertility, fire and human disturbance are frequent. In MDF aboveground biomass had the higest value in 600 m asl but 650-690 m asl, these values decreased because soil is always dry, more erosive and easily washed by surface runoff and associated with wildfire. PDF had aboveground biomass highest in altitude 1,000 m asl but 1,020-1,080 m asl these values were closely lowered because this forest soil showed highly weathering process and displayed the highest clay content as well as the reddish soil color. In POF, it was found that aboveground biomass were similarly low in 1,030-1,100 m asl because soil is the same as in PDF but higher in organic matter on the top of soil profile than in PDF. Aboveground biomass of HEF in the altitude range between 1,340-1,440 m asl are found to be similarly low due to the abundant large suppress and intermediate trees. In 1,650 m asl, HEF showed the higest aboveground biomass. Along the altitude higher than 1,650 m asl, aboveground biomass of HEF were fluctuated because trees in these altitudes were mostly the co-dominant and suppress, under low temperature, litter decomposition is rather slow and soil properties are closely related to amount of organic matter causing the favourable soil properties such as high porosity, field moisture content and water holding capacity (Teejuntuk, 2003). While in MDF, PDF, POF and HEF, it was found that aboveground biomass tendency did not relate with altitude. The aboveground biomass was found to be related to D-H relationship, by which D and H are high, aboveground biomass will be high. HEF showed the highest total aboveground biomass, while MDF showed the lowest.

Table 4 shows the total aboveground biomass in various forest types of Thailand. The total biomass of DDF in Kalasin (Kanzaki *et al*., 1991), in Namprom (Nilroung, 1968) and Ping Kong (Handechanon, 1990) were higher than in the DDF of Doi Inthanon, while the aboveground biomass in Hill Evergreen Forest in Doi Inthanon, was higher than in Phu Kradung (Pothitan, 1999). The total aboveground biomass was different because of site, climate, soil, fire and human where they showed strong and clear effects in DDF and MDF.

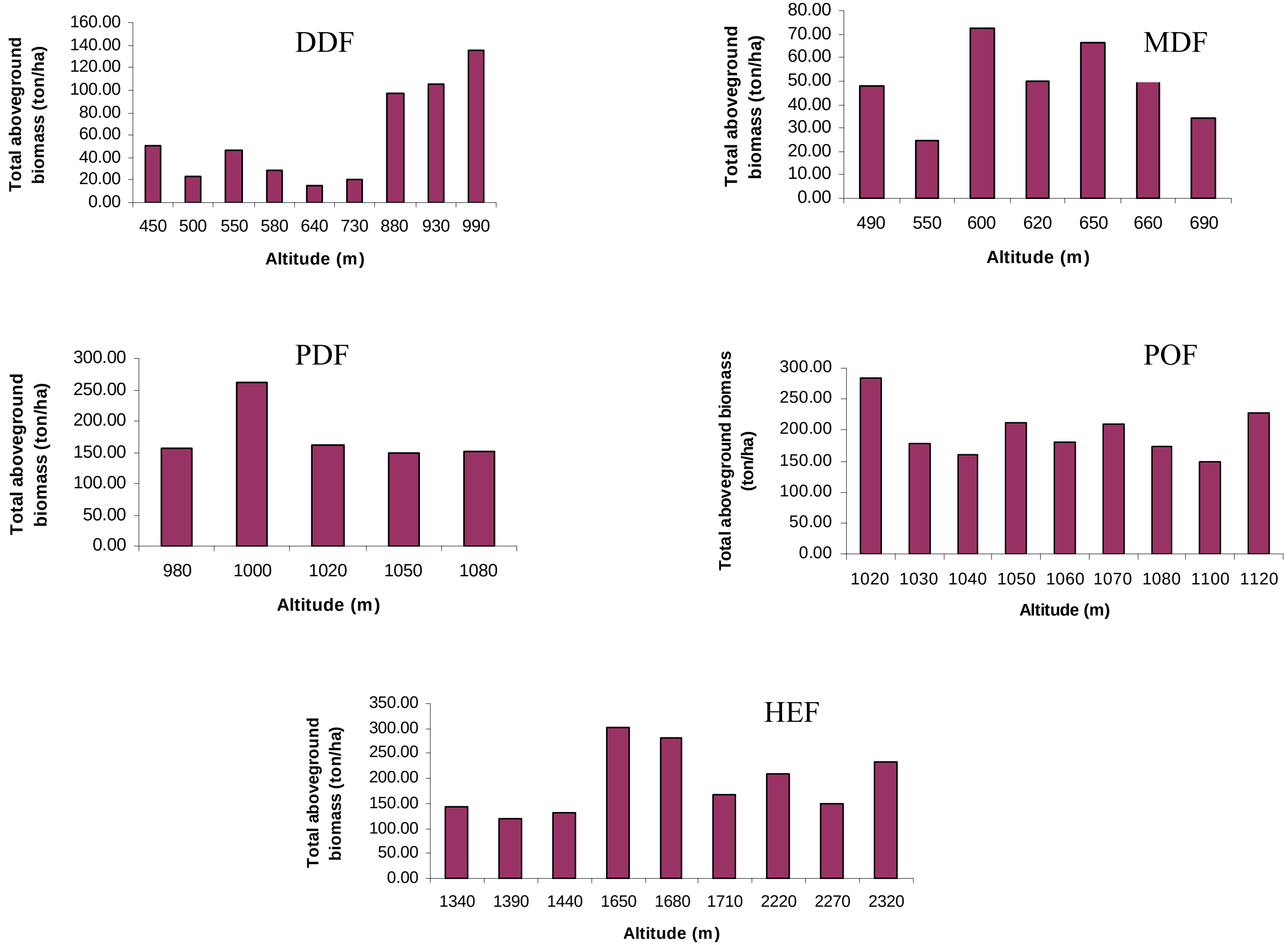

Figure 5 Distributional patterns of biomass in each forest type along an altitudinal gradient in Doi Inthanon National Park.

Table 4 Aboveground biomass of various forest types in Thailand.

Forest types	Location	Total aboveground biomass (ton/ha)	Reference
DDF			
Secondary DDF, Somdet	Kalasin	15.9	Kanzaki *et al*. (1991)
DDF at Namprom Basin	Chaiyaphum	61.8-144.0	Nilroung (1986)
DDF at Ping Kong	Chiang Mai	149.56	Handechanon (1990)
MDF			
MDF, Ping Kong	Chiang Mai	49.60	Ogawa *et al*. (1961)
MDF	Lampang	57.50	Ogawa *et al*. (1961)
Yang stand	Prachaup Khiri Khan	304.93	Wacharinrat *et al*. (1999)
DEF			
DEF, Sakaerat	Nakhon Ratchasima	283.81	Kanzaki *et al*. (1988)
DEF, Namprom basin	Chaiyaphum	281.668	Handechanon (1990)
MEF			
MEF, Khao Kitchakoot	Chantha Buri	437.85	Srigongpan (2000)
HEF			
HEF, Phu kadung	Loei	153.33	Pothitan (1999)

2 Forest Community Classification

Cluster analysis demonstrated that the 39 forest stands in Doi Inthanon National Park could be classified into six forest groups along the altitudinal gradient by correlation’s distance (Figure 6). The cluster analysis found that they were composed of three forest zones: lowland (group I and II), transition (group III and IV) and montane (group V and VI) zone, where group I was DDF, group II was MDF, group III were DDF, POF and PDF, and group IV, V, VI were HEF and brief descriptions of their species composition are as follows:

Group I: *Shorea siamensis*

This group included two dry dipterocarp forest stands located between 450 and 720 m asl. (A10 and A11). *Shorea siamensis* were the dominant species in both stands. The most obvious characteristics of this group are an open canopy, low density and the small tree.

Group II: *Tectona grandis*, *Xylia xylocarpa var.kerrii*, *Millettia leucantha*, *Canarium subulatum*

This group included seven mixed deciduous forest stands located between 490 and 730 m asl. (B1, B2, B3, B4, B10, B11 and B12). These group could be further divided into two sub-groups as with and without *Tectona grandis* as the dominant species.The first sub-group was mainly dominanted by *Tectona grandis* and *Xylia xylocarpa var*. *kerrii* and represented in the stands B1, B2 and B3. The second sub-group species were represented by stands B4, B10, B11 and B12 which *Tectona grandis* was absent. The dominant species represented by *Millettia leucantha*, *Canarium subulatum*, *Zizyphus oenoplia*, *Vitex pinnata*, *Hymenodictyon excelsum*, *Grewia eriocarpa* and *Terminalia floribunda*. This group was clearly associated with bamboo in every stand.

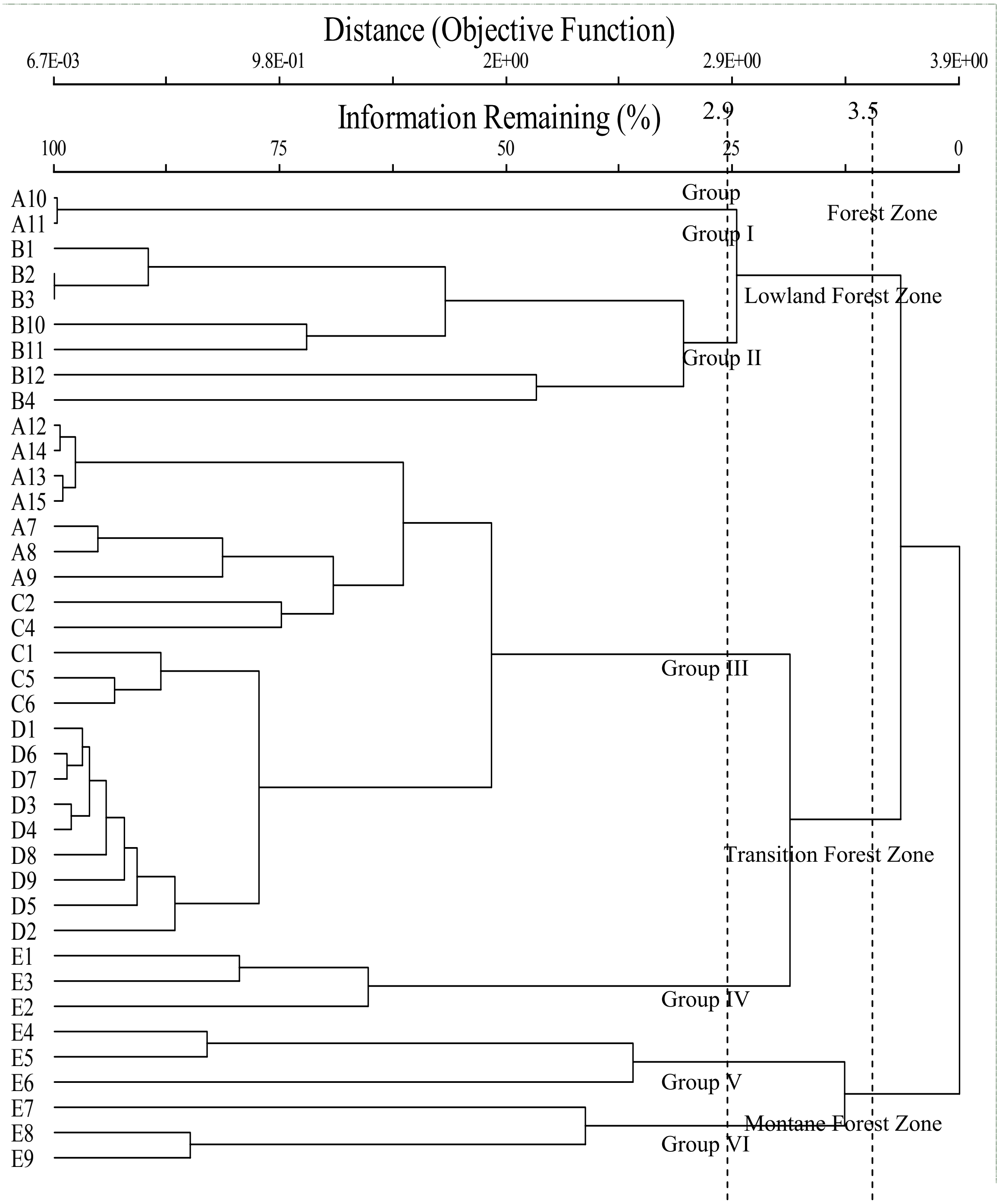

Figure 6 Dendrogram obtained by cluster analysis based on correlation 's distance using importance value index.

Group III: *Pinus kesiya*, *Quercus ramsbottomii*, *Dipterocarpus tuberculatus*, *Schima wallichii, Shorea obtusa*

This group included twenty-one stands in the pine-oak forest, pine dipterocarp and dry dipterocarp forest stands located between 450 and 1,100 m asl. *Pinus kesiya* is the dominant species in this group and occupies mainly on the canopy. The stands having *Pinus kesiya* as adominant tree could be classified into two sub-groups: 1) those also including *Dipterocarpus tuberculatus*, *Shorea siamensis*, *Quercus ramsbottomii*, *Aporusa villosa* and *Wendlandia tinctoria* (C1, C2, C4, C5 and C6) and 2) also including *Schima wallichii*, *Lithocarpus elegans*, *Helicia nilagirica*, *Aporusa villosa*, *Wendlandia tinctoria*, *Tristanopsis burmanica* and *Tristania rufescens* (D1-D9). The fomer sub-group occured in the drier habitats than the latter sub-group. During the dry season soil properties in this sub-group were often very dry and, some of the species shed their leaves. Furthermore stand A7-A9 were clearly associated with the forest sub-group 1 because there were many similar tree species in other stands of this group which were dominanted by *Quercus ramsbottomii*, *Dipterocarpus tuberculatus*, *Q. kerrii*, *Anneslea fragrans*, *Symplocos sp*. and *Shorea obtusa*. *Shorea obtusa* and *Dipterocarpus tuberculatus* were dominant species in A12, A13, A14 and A15 stands.

Group IV: *Schima wallichii*, *Syzygium angkae*, *Castanopsis tribuloides*, *C. ferox*, *Helicia nilagirica*

This group was represented by three stands located between 1,340 and 1,440 m asl (E1, E2 and E3). This group was characterized by tall tree and closed canopy was found. The canopy trees of this group were those belonging to the family Fagaceae such as *Castanopsis tribuloides*, *C. ferox*, *C. diversifolia*, *Lithocarpus triboides* and *L. dealbatus* and mixed with *Schima wallichii*. The co-dominant species were *Helicia nilagirica*, *Syzygium angkae*, *Styrax benzoides* and *Eurya acuminata*.

Group V: *Mastixia euonymoides; Manlietia garrettii*, *Drypetes indica*, *Ostodes paniculata*, *Castanopsis calathiformis*

This group occured between 1,650-1,710 m asl. The main characteristics of this group were high tree density and crown canopies were also tall and close. The dominant species were *Mastixia euonymoides, Manlietia garrettii*, *Drypetes indica* and *Calophyllum polyanthum*. The co-dominant were *Mallotus khasianus* and *Ostodes paniculata*. In contrast, in the stands on the upper slopes (E6), *Castanopsis calathiformis* and *Quercus lenticellata* were the dominant species.

Group VI: *Actinodaphne henryi*, *Castanopsis ferox*, *Neolitsea pallen*

This group was found at the highest altitudes in Doi Inthanon National Park located between 2,220 and 2,320 m asl. The *Actinodaphne henryi*, *Castanopsis ferox*, *Neolitsea pallens* were the main canopy tree mixed with *Litsea dubele*, *Quercus lenticellata*, *Rapanea yunnanensis*, *Beilshmiedia roxberghiana* in the sub canopy.

Ecological studies on forest communities in Doi Inthanon were firstly begun by Ogwa *et al*. (1961). They classified the forest in Doi Inthanon into five forest types; (1) tall deciduous, (2) savana, (3) evergreen gallery, (4) subtropical evergreen forest and (5) temperate evergreen forest. Robbins and Smitinand (1966) studied forest communities in the same area as Ogawa *et al*. (1961) and subsequently replaced the forest type names as (1) mixed deciduous forest, (2) dry dipterocarp forest, (3) tropical evergreen forest, (4) ecotone and (5) hill evergreen forest. Faculty of Forestry (1992) reported six forest types in the area together with the vegetation map and area cover distribution of each forest types as 54.06, 0.98, 1.58, 12.83, 20.77 and 4.77% for hill evergreen forest, dry evergreen forest, pine-oak forest, mixed deciduous forest, deciduous dipterocarp forest and pine deciduous dipterocarp forest respectively.

Santisuk (1988) recognized two vegetation zones by altitude in the mountains of northern Thailand: lowland (0-1,000 m) and mountain (>1,000 m). He recognized two vegetation types in the montane zone: Upper Montane Forest and Lower Montane Forest.

The boundary between the two forest types is gradual but lies around 1,800 m in altitude. Ohsawa (1993) recognized three vegetation zones by altitude in the tropical mountains of Asia: lowland (0-1,000 m), lower montane (1,000-2,500 m) and upper montane (>2,500 m). According to both classifications, our research plot is located in the lower montane zone, where lauro-fagaceous forest is predominant.

2.1 Dominant species in group

The d value of each species in each group is shown in Table 5. IVI was used for determining minimum d value (Ohsawa's fomula). The forest community in Doi Inthanon had different dominant species in groups (Table 5). *Shorea siamensis* was the dominat species in group I (DDF). *Tectona grandis, Xylia xylocarpa, Canarium subulatum, Grewia eriocarpa, Terminalia floribunda* etc. were the dominant species in Group II (MDF). *Quercus ramsbottomii, Dipterocarpus tuberculatus, Pinus kesiya, Aporusa villosa* etc. were the dominant species in group III (DDF, POF and PDF). *Schima wallichii*, *Castanopsis ferox* etc. were the dominant species in group IV (HEF). Group V (HEF), *Mastixia euonymoides, Castanopsis calathiformis, Mangleitia garrettii, Drypetes indica* etc. were the dominant species. Group VI (HEF), *Actinodaphne henryi, Castanopsis ferox, Neolitsea pallens* etc. were the dominant species. The dominant species in these groups were the same as reported by Teejuntuk (2003) in Doi Inthanon.

Table 5 Dominant species in each group in 2006 classified by Ohsawa's formula.

Group	Plot	Dominant Species	d (Ohsawa's formula)
I	A10	*Shorea siamensis*	331.84
	A11	*Shorea siamensis*	358.23
II	B1	*Tectona grandis*	525.91
		Millettia leucantha	312.15
		Xylia xylocarpa var. kerrii	306.97
	B2	*Tectona grandis*	1087.57
	B3	*Tectona grandis*	517.42
		Xylia xylocarpa var. kerrii	196.06
	B4	*Canarium subulatum*	419.86
		Millettia leucantha	197.68
		Zizyphus oenoplia	137.65
		Vitex pinnata	111.04
	B10	*Grewia eriocarpa*	249.80
		Xylia xylocarpa var. kerrii	77.94
	B11	*Xylia xylocarpa var. kerrii*	149.99
	B12	*Terminalia floribunda*	384.23
		Vitex pinnata	201.68
III	A7	*Quercus ramsbottomii*	231.66
		Dipterocarpus tuberculatus	101.66
	A8	*Dipterocarpus tuberculatus*	397.52
		Quercus ramsbottomii	219.39
	A9	*Dipterocarpus tuberculatus*	120.68
		Quercus kerrii	65.27
		Anneslea fragrans	58.19
		Symplocos sp.	57.08
	A12	*Shorea obtusa*	364.49
		Dipterocarpus tuberculatus	246.39
	A13	*Dipterocarpus tuberculatus*	1829.17
		Shorea obtusa	1486.22
	A14	*Shorea obtusa*	745.68
	A15	*Shorea obtusa*	989.85
		Dipterocarpus tuberculatus	560.31
	C1	*Pinus kesiya*	128.08
		Dipterocarpus tuberculatus	95.43

Table 5 (Continued)

Group	Plot	Dominant Species	d (Ohsawa's formula)
III (Continued)	C2	*Pinus kesiya*	254.55
		Shorea siamensis	122.54
		Quercus ramsbottomii	78.59
		Aporusa villosa	58.95
		Wendlandia tinctoria	54.74
	C4	*Wendlandia tinctoria*	184.71
		Quercus ramsbottomii	119.39
		Aporosa villosa	102.22
		Dipterocarpus tuberculatus	101.20
	C5	*Dipterocarpus tuberculatus*	470.54
		Pinus kesiya	235.20
	C6	*Pinus kesiya*	149.89
		Aporosa villosa	64.03
		Dipterocarpus tuberculatus	61.81
	D1	*Pinus kesiya*	81.62
		Schima wallichii	69.12
	D2	*Pinus kesiya*	226.78
		Lithocarpus elegans	144.04
		Helicia nilagirica	129.90
	D3	*Pinus kesiya*	164.86
	D4	*Pinus kesiya*	82.41
	D5	*Pinus kesiya*	209.56
		Aporusa villosa	122.54
		Wendlandia tinctoria	94.51
		Lithocarpus elegans	86.45
		Tristaniopsis burmanica	81.84
	D6	*Pinus kesiya*	163.21
		Aporusa villosa	108.97
	D7	*Pinus kesiya*	141.86
		Aporusa villosa	59.84
	D8	*Pinus kesiya*	142.49
		Lithocarpus elegans	104.80
		Schima Wallichii	92.70
	D9	*Pinus kesiya*	214.43
		Aporusa villosa	197.35
		Tristania rufescens	193.30

Table 5 (Continued)

Group	Plot	Dominant Species	d (Ohsawa's formula)
IV	E1	*Schima wallichii*	133.48
		Syzygium angkae	77.45
		Castanopsis tribuloides	56.10
	E2	*Castanopsis ferox*	154.89
		Helicia nilagirica	66.93
		Schima wallichii	49.32
	E3	*Schima wallichii*	252.30
		Castanopsis tribuloides	117.37
		Styrax benzoides	78.11
		Lithocarpus triboides	65.26
		Eurya acuminata	58.92
		Castanopsis diversifolia	55.02
		Lithocarpus dealbatus	54.91
V	E4	*Mastixia euonymoides*	107.73
		Mangleitia garrettii	24.18
		Drypetes indica	8.98
	E5	*Drypetes indica*	257.84
		Calophyllum polyanthum	128.89
		Cryptocarya dencifolia	89.74
		Ostodes paniculata	70.53
		Mallotus khasianus	59.68
		Mastixia euonymoides	52.61
		Aidia yunnanensis	47.59
	E6	*Castanopsis calathiformis*	117.67
		Quercus lenticellata	65.13
VI	E7	*Actinodaphne henryi*	351.00
		Litsea dubele	259.50
		Beilschmiedia roxberghiana	250.54
	E8	*Castanopsis ferox*	356.12
		Litsea dubele	183.85
		Quercus lenticellata	149.41
	E9	*Neolitsea pallens*	293.05
		Castanopsis ferox	163.03
		Rapanea yunnanensis	128.08

2.2 Species diversity

The forest communities in Doi Inthanon National Park varied greatly in species composition as shown by the classification above. The number of species, richness, diversity and evenness indices of each group are shown in the Table 6. Diversity indices of all stands as determined by N1 (7.01-22.27), N2 (4.16-16.49) and H′ (1.94-3.09) indicated that group I has significantly lower diversity than the other groups followed by N1, N2 and H′. According to the result, several tree species had limiting site preference. Disturbance is also important factor in determining the success or failure of forest establishment and growth in this forest zone. Forest fire, which occurs almost every year, may cause accelerated soil erosion during the early rainy season. H′ increase along the altitudinal gradient as same as the results studied by Pendry and Proctor (1996), Wilson *et al*. (1990) and Sundarapandian and Swamy (2000). Moreover, Fisher's index was 3.62-11.88 and this index is associated with other indices. This index of group IV (11.88) is the highest diversity and decreases in groups V, III, VI, II and I. The Simpson's index is between 0.11-0.91 as shown by group IV (0.91) with the highest value followed by groups V, I, II, III and VI. According to results, it was found that soil moisture content availability during the dry season and less disturbance are probably the main cause of the greater species diversity in transitional and montane forest zones, with diversity of tree species increasing up to montane zone. Diversity tends to decrease again at above montane zone, probably due to the decreasing of temperature with a rising in altitude. Richness values (R1, R2 are between 3.16-7.17 and 1.49-2.80, respectively) and their trends were closely related to diversity indices. Therefore, R1 of group I clearly showed the lowest value but R2 of group VI showed the lowest richness index and increased of R1 and R2 by groups II, VI, III, IV and V. Above montane zone they tended to decrease particularly Shannon-Wiener's, Hill's and Fisher's diversity indices as well as richness indices (Table 6). Evenness values, such as E1 (0.7-0.84) indicated that forest stands of all group are significantly different, while E2, E3, E4 and E5 demonstrated non significant difference among all groups. Evenness indices did not vary much along the altitudinal gradient.

This study found that richness and evenness indices had increasing trend along the altitudinal gradient except group VI but Gracia, *et al*. (2007) studied overall shrub richness and diversity have shown no significant change with aspect and only a small decrease with elevation, which agreed with the tendency found by Theurillat and Gusisan (2001) for species richness to decrease with elevation, which is in close correlation with the decrease of mean air temperature. However, the understory vegetation of the Massis de I'Orri has shown strong patterns of spatial variability, with drastic changes in understory composition relative to elevation and aspect. Thus, individual species cover shows large variations according to aspect and elevation. As in other studies (Olivero and Hix, 1998; Sternerg and Shoshany, 2001), analysis of individual species confirmed that aspect was the most important variable determining species distribution. Small and McCarthy (2002) found that elevation has influenced the cover of many of the understory species considered.

In additional, Shimwell (1971) reported that species diversity of community in initial succession stage was low and it will increase when succession reaches to a significant level. From this reason, species diversity can be used as an indicator of stability of community. Sahunalu (1998) also confirmed that DDF will slowly increase its species depending upon the density increasing. In the initial stage, there are slow increase of the number of species and they will rapidly increase in the middle stage and reach to dynamic equilibrium at the final stage.

Table 6 Community characteristics (mean) classified by cluster analysis. (N1, N2 = Hill's diversity indices, H′ = Shannon-Wiener's index, D = Simpson's index, α = Fisher's index, R1,R2 = Margalef & Menhinick's richness indices, E1, E3, E5 = Pielou's evenness indices). For the comparison among groups the nonparametric rank test was employed (Kruskal-Wallis' method at $p < 0.05$). ns indicates non-significantly difference

Zone	Lowland forest zone		Transition forest zone		Montane forest zone	
Group	I	II	III	IV	V	VI
plots/ area (ha)	2/0.32	7/1.12	21/3.36	3/0.48	3/0.48	3/0.48
Diversity indices :						
No	$16.00±1.41^{b}$	$18.571±6.8^{b}$	$27.38±10.52^{ab}$	$38.67±5.86^{a}$	$38.67±2.08^{a}$	$21.33±3.05^{b}$
N1	$7.01±0.17^{c}$	$9.72±4.52^{bc}$	$13.77±5.29^{abc}$	$18.15±3.53^{ab}$	$22.27±3.75^{a}$	$12.13±1.97^{bc}$
N2	$4.16±0.35^{b}$	$7.06±4.22^{ab}$	$9.75±398^{ab}$	$12.52±5.92^{a}$	$16.49±6.87^{a}$	$9.73±2.91^{ab}$
H′	$1.94±0.02^{b}$	$2.15±0.60^{ab}$	$2.58±0.46^{a}$	$2.88±0.19^{a}$	$3.09±0.17^{a}$	$2.48±0.16^{ab}$
D	$0.24±0.02^{ab}$	$0.21±0.16^{ab}$	$0.12±0.66^{b}$	$0.91±0.34^{a}$	$0.70±0.03^{a}$	$0.11±0.03^{b}$
α	$3.62±0.41^{bc}$	$4.56±2.23^{bc}$	$7.65±3.71^{b}$	$11.88±2.48^{a}$	$11.83±0.91^{a}$	$5.40±1.15^{b}$
Richness indices :						
R1	$3.16±0.52^{b}$	$4.05±1.39^{ab}$	$4.98±1.89^{ab}$	$7.17±0.77^{a}$	$6.99±0.16^{a}$	$3.82±0.32^{b}$
R2	$1.50±0.38^{b}$	$2.13±0.70^{ab}$	$1.94±0.69^{ab}$	$2.80±0.16^{a}$	$2.62±0.11^{a}$	$1.49±0.09^{b}$
Evenness indices :						
E1	$0.70±0.01^{b}$	$0.74±0.14^{b}$	$0.78±0.04^{ab}$	$0.79±0.08^{ab}$	$0.84±0.06^{a}$	$0.81±0.07^{a}$
E2	$0.44±0.28^{ns}$	$0.51±0.15^{ns}$	$0.51±0.67^{ns}$	$0.49±0.17^{ns}$	$0.58±0.13^{ns}$	$0.58±0.12^{ns}$
E3	$0.40±0.03^{ns}$	$0.47±0.16^{ns}$	$0.49±0.06^{ns}$	$0.47±0.18^{ns}$	$0.57±0.13^{ns}$	$0.56±0.13^{ns}$
E4	$0.59±0.06^{ns}$	$0.70±0.13^{ns}$	$0.72±0.08^{ns}$	$0.67±0.18^{ns}$	$0.71±0.20^{ns}$	$0.79±0.13^{ns}$
E5	$0.53±0.07^{ns}$	$0.65±0.17^{ns}$	$0.68±0.09^{ns}$	$0.65±0.19^{ns}$	$0.70±0.21^{ns}$	$0.77±0.15^{ns}$

3 Dynamics

3.1 Density

The records of tree density during 1999 and 2006 in the same stands of all forest groups enabled computation of net changes in numbers of tree populations of each group, as shown in (Table 7). Group VI, indicated the smallest gains but greatest losses resulting from the largest number of dead and least number of causing the net change during this 7 years period to be 94 trees/ha disappeared from the group. Group III showed remarkable largest gain moderately loss by dead trees being 132 trees/ha making from the new recruits of 175 trees/ha but the net change to be relatively large gain of 43 trees/ha. Although both groups were composed of almost the same stand density initially in 1999 (1426 vs 1427 trees/ha). Group II showed the similar trend of net change as group VI that tree density gain was lesser than tree density loss, but net tree density loss was only 15 trees/ha. The other three groups (Group III, IV and V) indicated all net gain in tree density by different values as the results of different larger number of recruited trees than loss by dead trees.

The motarity rates (λ) in the five groups were in the range of 0.47-3.56 % /yr and were highest in group II and lowest in group V. The highest (3.56 % /yr) in group II indicates the sensitivity of trees in the group to various distriburbance factors causing tree death and showing the poorest regeneration and most instability in stand maintenance, as compared to other forest groups. The mortality rate in group V was the lowest (0.47 % /yr) probably because the site had high co-dominant and dominant trees which were considered to be strong resistant to the eliminative factors. Sahunalu and Dhanmanonda (1995) studied the motarity rates at Sakaerat in four stands of DDF found about 1.2-2.2 % /yr, which are within the range values this studied and they suggested to be because of frequent fire and drought of the site.

Table 7 Community parameters (mean) and their changes in the 5 groups as classified by cluster analysis. Group I is omitted due to the incomplete data collection from the same stands in both years.

Group	II			III			IV			V			VI		
Year	1999		2006	1999		2006	1999		2006	1999		2006	1999		2006
Parameter															
Density (No/ha)	480		465	1426		1469	1150		1233	1529		1556	1427		1333
Loss		106			132			63			50			154	
Gain		91			175			146			77			60	
Net change (7 yrs)		-15			+43			+83			+27			-94	
Mortality rate (%/yr)		3.56			1.39			0.80			0.47			1.63	
DBH (cm)	15.51		14.00	14.97		17.00	16.86		18.00	16.79		18.00	17.93		19.00
ΔD (cm/yr)		0.22			0.29			0.16			0.17			0.15	
RGR(mm/mm yr)		0.15			0.18			0.09			0.10			0.08	
Basal area (m2/ha)	11.83		11.79	35.95		38.16	40.38		43.53	64.10		68.75	68.58		68.22
Loss		0.38			5.60			0.34			2.76			1.64	
Gain		0.34			7.81			3.49			7.41			1.28	
Net change (7 yrs)		-0.04			+2.21			+3.15			+4.65			-0.36	
Biomass (ton/ha)	46.01		43.32	430.32		485.27	114.06		131.87	225.36		249.08	197.93		184.53
Loss		13.88			20.85			18.62			15.81			49.61	
Gain		11.19			75.80			36.43			39.53			36.21	
Net change (7 yrs)		-2.69			+54.95			+17.81			+23.72			-13.40	

Loss = No of tree death

Gain = No of tree recruited

3.2 Growth of trees in different group

During the seven years period of 1999-2006, the number of dead and recruited trees were examined. There were no data in group I because the plots set in 1999 could not be found in 2006. The mean DBH in 2006 were higher than 1999 in group III, IV, V and VI except group II because trees in 2006 were disturbed by fire and human and some dominants trees were cut and dead. The remaining trees were mostly the co-dominant, causing the mean DBH of trees in 2006 to be slightly lower than in 1999.

The absolute growth rate is net growth per period. The absolute growth rate (ΔD) in group III was the highest because mean DBH of trees in 1999 in group III was lowest but mean DBH in 2006 was rather high. Mean DBH in 2006 in almost all groups were relatively higher than in 1999 except group II therefore absolute growth rate (ΔD) of these groups were similarly moderate and varied between 0.15 to 0.17 cm/yr. The absolute growth rate (ΔD) was then lowest in group II and become negative because mean DBH in 2006 was reduced stighlty due to many large trees died during this period.

The largest increment and relative growth rate were found in group III because this group had high dominant and co-do minant trees as well as some tree species such as *Pinus kesiya* which is a fast growing tree was predominated in the group. It is generally believed that the growth of group IV and V are relatively slow because low temperature and litters on top soil was less decomposed. In contrast, group II indicated the negative relative growth rate in which trees belonging to Dipterocarpaceae were dominant and generally have slow growth rate. Moreover, the deciduous character of most trees in this groups, with a relatively long leafless period, is another factor responsible for the slow growth.

3.3 Basal area

Change in basal area at breast height of the six groups were computed from the standing trees, dead trees (loss) and new recruits (gain), as shown in Table 7. The basal area increased in the three groups (group III, IV and V) with some variation between groups and decreased in two groups (group II and VI). The large gain in group III (7.81 m^2/ha) from the initial basal area, was larger than in the other two groups, This is because the surviving trees had more rapid growth than in other groups in addition to the large number of trees gained from the recruited trees in this group. The loss and gain in basal area in group II were lower than other groups followed by group VI but losses were over gains in both groups resulting in negative net change during the 7 years period.

3.4 Aboveground biomass

Change in aboveground biomass of the six groups was computed from the standing trees, dead trees and new recruits, as shown in Table 7. The net changes in the aboveground biomass showed the increasing values in these groups and the decreasing values in two groups. The largest gain was found in group III (54.95 ton/ha) during the 7 years period. The loss of aboveground biomass was highest in group VI because it had suppress and intermediate trees and the site was located in a relatively low temperature that might cause the growth of trees to be less. Group II had the low loss and gain by which loss was over gain, causing the net change to be negative as the same as in group VI, probably because sometimes severe drought occurred and the surviving trees had slow or growth than in other groups. The loss and gain in aboveground biomass among groups were different, but altitude in this area was not clearly affect much on the loss and gain as compared to the number of tree recruited and the relative growth rate of the surviving trees in the groups.

3.5 Number of species death and recruited

Number of tree species and individuals with DBH ≥ 4.5 cm death and recruited during 1999-2006 were summarized by group in Table 8 and 9. The highest number of tree species loss due to death and gain by new tree recruited in group III were probably because this group is composed of DDF, PDF and POF and these forest types are composed of various tree species that are sensitive to disturbance by several factors and some of dominant tree species are fast growing and having good regerneration potential.

Aporosa villosa and *Wendlandia tinctoria* were the two most dying species in group III (shown in Table 8). It was found that *Tectona grandis* and *Xylia xylocarpa var. kerii* were largely dying in group II. *Lithocarpus elegans* and *Shima wallichii* were in group IV, *Castanopsis calathiformis* and *Acer laurinum* were in group V. *Litsea dubele* and *Myrsinese miserrata* were found to be abundant dead species in group VI. Tree death may be due to several factors. In the present study, tree competition is considered to be one of the major causes. This is particularly true for forest group III, IV, V and VI, where tree density in these groups were higher than in group II.

Table 8 Number of trees dying (no/ha) in each group during 1999-2006 in the five groups of Doi Inthanon National Park, Chiangmai, Thailand.

Species	Group				
	II	III	IV	V	VI
Acer laurinum	-	-	-	4	2
Actinodaphne henryi	-	-	-	-	2
Aidia yunnanensis	-	-	-	2	-
Albizia chinensis	-	1	-	-	-
Albizia odoratissima	-	-	-	-	-
Anneslea fragrans	-	3	-	-	-
Anogeisus acuminata	2	-	-	-	-
Antidesma ghaesembilla	-	1	-	-	-
Aporusa villosa	-	24	-	-	-
Archidendron clypearia	-	-	2	-	-
Ardisia rubro-glandulosa	-	-	-	-	2
Artocarpus chaplasha	-	-	2	-	-
Bauhinia variegata	3	-	-	-	-
Beilschmiedia globularia	-	-	-	-	8
Bridelia retusa	-	-	-	-	-
Buchanania lanzan	-	1	-	-	-
Callicarpa arborea	2	-	-	-	-
Camellia oleifera	-	-	-	2	-
Canarium subulatum	2	-	-	-	-
Capparis sabiifolia	-	-	-	2	-
Cassia fistula	2	-	-	-	-
Castanopsis acuminatissima	-	-	-	-	2
Castanopsis argyrophylla	-	2	-	-	-
Castanopsis armata	-	1	-	-	-
Castanopsis calathiformis	-	-	2	17	-
Castanopsis cerebrina	-	1	-	-	-
Castanopsis ferox	-	-	10	-	8
Castanopsis roxkii	-	-	2	-	-
Castanopsis sp.1	-	-	-	-	-
Castanopsis tribuloides	-	1	2	-	-
Chionanthus ramiflorus	-	-	-	-	6
Cordia dichotoma	2	-	-	-	-
Craibiodendron stellatum	-	3	-	-	-
Cratoxylum cochinchinensis	-	-	-	-	-
Cratoxylum formosum	2	-	-	-	-
Dalbergia cultrata	-	-	-	-	-
Dalbergia dongnaiensis	-	-	-	-	-
Dalbergia floribunda	-	-	-	-	-
Dalbergia rimosa	-	1	-	-	-
Dalbergia velutina	-	-	-	-	-

Table 8 (Continued)

Species	Group				
	II	III	IV	V	VI
Dillenia parviflora	-	-	-	-	-
Dipterocarpus tuberculatus	-	9	-	-	-
Drypetes indica	-	-	-	2	-
Engelhardtia serrata	-	-	-	-	-
Engelhardtia spicata	-	-	-	-	-
Eurya acuminata	-	1	-	-	-
Eurya nitida	-	-	2	-	-
Gardenia sootepensis	-	-	-	-	-
Glochidion sp.	-	-	2	-	-
Glochidion sphaerogynum	-	1	-	-	-
Gluta usitata	-	2	-	-	-
Gordonia dalglieshiana	-	1	-	-	-
Grewia eriocarpa	11	1	-	-	-
Helicia attenuata	-	-	-	-	2
Helicia formosana var.oblane	-	-	-	-	8
Helicia nilagirica	-	4	2	-	-
Ilex triflora	-	-	-	2	2
Ilex umbellulata	-	-	-	-	-
Lagerstroemia calyculata	3	-	-	-	-
Lagerstroemia villosa	2	-	-	-	-
Lannea coromandelica	-	-	-	-	-
Lindera metacafaena	-	-	-	2	-
Lindera sp.	-	-	-	2	-
Lithocarpus aggregatus	-	-	-	-	17
Lithocarpus annamensis	-	1	-	-	-
Lithocarpus ceriferus	-	-	2	-	-
Lithocarpus dealbatus	-	-	2	-	-
Lithocarpus elegans	-	7	6	-	-
Lithocarpus polystachyus	-	1	-	-	-
Lithocarpus thomsnii	-	-	-	-	2
Litsea beusekomii	-	-	-	4	-
Litsea dubele	-	-	-	-	21
Mallotus khasianus	-	-	-	4	-
Millettia brandisiana	2	-	-	-	-
Millettia leucantha	2	-	-	-	-
Myrsine semiserrata	-	-	-	-	21
Neolitsea pallens	-	-	-	-	19
Parenaria camelliflora	-	-	-	-	2
Phoebe lanceolata	-	-	-	2	-
Phoebe sp.	-	-	-	-	-
Phyllanthus emblica	-	1	-	-	-
Pinus kesiya	-	8	-	-	-

Table 8 (Continued)

Species	Group				
	II	III	IV	V	VI
Premna latifolia	-	-	2	-	-
Quercus indica	-	-	-	-	-
Quercus kerrii	-	3	-	-	-
Quercus lenticellata	-	-	-	-	6
Quercus ramsbottomii	-	4	-	-	-
Rapanea yunnanensis	-	-	-	-	6
Rhus chinensis	-	1	2	-	-
Saurauia napaulensis	-	-	4	-	-
Schima wallichii	-	1	6	-	-
Shorea obtusa	-	2	-	-	-
Shorea siamensis	-	-	-	-	-
Sterculia rubiginosa	-	-	-	-	-
Stereospermum neuranthum	-	-	2	-	-
Strychnos nux-vomica	5	-	-	-	-
Styrax benzoides	-	1	4	-	-
Symplocos cochinchinensis	-	-	2	2	-
Symplocos longifolia	-	-	-	-	1-
Symplocos macrophylla	-	-	2	-	-
Symplocos racemosa	-	-	-	-	-
Symplocos sp.	-	2	-	-	-
Syzygium albiforum	-	-	-	-	-
Syzygium angkae	-	-	-	-	4
Syzygium siamensis	-	1	-	-	-
Tectona grandis	36	-	-	-	-
Terminalia chebula	-	-	-	-	-
Terminalia triptera	5	-	-	-	-
Tristania rufescens	-	4	-	-	-
Tristaniopsis burmanica	-	3	-	-	-
Unidentified	-	-	-	2	-
Vaccinium sprengelii	-	1-	-	-	2
Vaccinium whitmove	-	-	-	-	-
Viburnum inopinatum	-	2	-	-	-
Vitex peduncularis	-	-	-	-	-
Vitex pinnata	3	1	-	-	-
Wendlandia tinctoria	-	12	-	-	-
Xylia xylocarpa var. kerrii	17	-	-	-	-
Zizyphus oenoplia	8	-	-	-	-
Zollingeria acuminata	2	-	-	-	-
Total tree death	106	132	63	50	154
Total species death	19	65	20	14	21

Fire and human are the next two principal factors controlling the group III (dry dipterocarp forest) and group II (Mixed deciduous forest) and are believed to be the most important factors for maintaining the forest structure and species composition. Sabhasri *et al*. (1968) recognized the dry dipterocarp forest as a pyric climax forest because, if it well protected from fire, tree species belonging to more mesic forest types will invade the dry dipterocarp forest. Although the Doi Inthanon National park has been well protected from fire for several years since the establishment, but the human settlement and unexpected ground fires sometimes occur during the dry season and may affect tree mortality, especially of small trees. The most tree component of this forest type are relatively tolerant of these factors. (Sahunalu and Dhanmanonda, 1995)

The principal component species of each group were observed, with unidentified species for every groups and *Aporosa villosa*, *Lithocarpus elegans* and *Castanopsis acuminatissima* were recruited species for group III (shown in Table 9). Group II found *Tectona grandis* and *Xylia xylocarpa var.kerii* were trees species recruited. The numbers of individuals of each species recruited varied between groups and it was found that groupIII had the highest recruitment and followed by group IV, VI, II and V respectively. In group II though, the recruitment of *Tectona grandis and Xylia xylocarpa var.kerii.* (highest IVI in the stand) seems to be superior to *Aporosa villosa*, the dominant species in group III, showed a relatively larger number of dead individuals.

The maintenance of species composition of the groups may be changed more or less than in 1999-2006. Two groups (group II and VI) did death more than recruited. Because group VI and II were usually destroyed by human and fire respectively, there fore wherever these causes occured, it is hard to find newly recruited trees in a sufficient number of individual and species in those stands.

Table 9 Number of trees recruited to DBH ≥ 4.5 cm (No/ha) during 1999-2006 in the five groups of Doi Inthanon National Park, Chiangmai, Thailand.

Species	Group				
	II	III	IV	V	VI
Acer laurinum	-	-	-	-	4
Actinodaphne henryi	-	-	-	-	2
Adinandra integerrima	-	-	2	-	-
Albizia chinensis	-	-	-	-	-
Albizia odoratissima	-	1	-	-	-
Anneslea fragrans	-	1	-	-	-
Aporusa villosa	-	26	-	-	2
Archidendron clypearia	-	-	-	-	-
Ardisia rubro-glandulosa	-	-	-	-	2
Brassiopsis speciosa	-	-	-	2	-
Buchanania lanzan	-	2	-	-	-
Canarium subulatum	-	1	-	-	-
Canthium parvifolium	3	-	-	-	-
Castanopsis acuminatissima	-	11	8	-	-
Castanopsis armata	-	-	-	-	-
Castanopsis cadatum	-	-	6	-	-
Castanopsis cerebrina	-	1	-	-	-
Castanopsis diversifolia	-	-	25	-	-
Castanopsis ferox	-	-	8	-	-
Castanopsis indica	-	-	-	-	-
Castanopsis tissima	-	1	-	-	-
Castanopsis tribuloides	-	6	8	-	-
Chionanthus ramiflorus	-	-	-	-	2
Cratoxylum cochinchinensis	-	1	-	-	-
Cratoxylum pruniflorum	-	2	-	-	-
Cryptocarya dencifolia	-	-	-	4	-
Cryptocarya sp.	-	-	-	2	-
Dalbergia assamica	-	2	-	-	-
Dalbergia cultrata	-	-	-	-	-
Dalbergia spp.	-	-	-	-	-
Dalbergia velutina	-	-	-	-	-
Dillenia obovata	-	-	-	-	-
Diospyros glandulosa	-	-	4	-	-
Dipterocarpus tuberculatus	-	1	-	-	-
Drypetes indica	-	-	-	4	-
Eurya acuminata	-	-	1-	-	-
Gardenia Sootepensis	-	-	-	-	-
Glochidion acuminatum	-	-	-	-	2
Gluta sp.	-	1	-	-	-
Gluta usitata	-	-	-	-	-

Table 9 (Continued)

Species	Group				
	II	III	IV	V	VI
Gomphandra quadrifolia	-	-	-	-	2
Grewia eriocarpa	-	-	-	-	-
Lagerstroemia sp.	2	-	-	-	-
Lithocarpus dealbatus	-	-	2	-	-
Lithocarpus elegans	-	13	6	-	-
Litsea beusekomii	-	-	-	2	-
Macaranga denticulata	-	-	-	-	-
Macaranga kurzii	-	-	-	-	-
Maesa sp.	-	-	-	-	-
Mangifera indica	-	2	-	-	-
Myrica esculenta	-	-	-	-	2
Myrsine semiserrata	-	-	-	-	2
Neolitsea pallens	-	-	-	-	6
Ostodes paniculata	-	-	-	4	-
Phoebe lanceolata	-	2	2	-	-
Phyllanthus emblica	-	1	-	-	-
Pinus kesiya	-	5	-	-	-
Pterocarpus macrocarpus	-	-	-	-	-
Quercus kerrii	-	2	-	-	-
Quercus ramsbottomii	-	1	-	-	-
Quercus sp.	-	1	-	-	-
Rapanea yunnanensis	-	-	-	-	13
Rhus chinensis	-	1	-	-	-
Rubiaceae	-	1	-	-	-
Schefflera hypoleucoides	-	-	-	-	2
Schima wallichii	-	3	4	-	-
Shorea obtusa	-	1	-	-	-
Sterculia sp.	-	-	-	-	-
Strychnos nux-vomica	2	-	-	-	-
Styrax benzoides	-	1	31	-	-
Symplocos hookerii	-	-	-	2	-
Symplocos longifolia	-	-	-	-	4
Syzygium albiforum	-	1	-	-	-
Syzygium cumini	-	1	-	-	-
Tectona grandis	38	-	-	-	-
Terminalia pierrei	16	-	-	-	-
Ternstroemia gymnanthera	-	-	-	-	-
Tristania rufescens	-	3	2	-	-
Unidentified	6	63	25	56	15
Vaccinium sprengelii	-	-	-	-	-
Viburnum inopinatum	-	6	-	-	-
Vitex peduncularis	-	-	-	-	-

Table 9 (Continued)

Species	Group				
	II	III	IV	V	VI
Vitex pinnata	2	-	-	-	-
Wendlandia tinctoria	-	5	-	-	-
Wrightia arborea	2	-	-	-	-
Xylia xylocarpa var. kerrii	22	-	-	-	-
Total tree recreited	91	175	146	77	60
Total species recruited	9	51	15	8	14

CONCLUSION AND RECOMMENDATION

Study on forest dynamics along an altitudinal gradient in Doi Inthanon National Park, northern Thailand can be concluded as follows:

1. The forest composition in 2006 composing of 5 types of forests, had totally found 289 species 150 genera and 69 families. The classification in both 1999 and 2006 could be classified into six forest groups (group I = DDF, group II = MDF, group III = DDF, PDF and POF, group IV, V and VI =HEF) and three forest zones (lowland, transition and montane forest zone) by Sorensen's distance and corelation's distance, respectively. The dominant species in 1999 and 2006 had almost the same tree species composed, Group I: *Shorea siamensis*, Group II: *Tectona grandis*, *Xylia xylocarpa var.kerrii*, *Millettia leucantha*, *Canarium subulatum,* Group III: *Pinus kesiya*, *Quercus rambottomii*, *Dipterocarpus tuberculatus*, *Shima wallishichii,* Group IV: *Schima wallichii*, *Syzygium angkae*, *Castanopsis tribuloides*, *C. ferox*, *Helicia nilagirica,* Group V: *Mastixia euonymoides Mangleitia garrettii*, *Drypetes indica*, *Ostodes paniculata*, *Castanopsis calathiformis* and Group VI: *Actinodaphne henryi*, *Castanopsis ferox*, *Neolitsea pallen.*

2. The absolute growth rate of trees were found to be different between groups and it was found that group II was lower than other groups and become negative. The relative grouth rate in group III was higher than other groups, however depending on successful establishment and survival of the component species of the stands in the groups.The mean DBH, density and basal area had showed the increasing trend along altitudinal gradient. Group V had the largest stand density than other groups and group II had the lowest. In spite of the large gain and loss of individuals, all stands gained in basal area coverage, about 0.34-7.81 m^2/ha and lost in the range of 0.34-5.60 m^2/ha of the initial basal area. The aboveground biomass was net chan gein the range of 13.40-54.95 ton/ha, group VI had the lowest values and loss more than gain while group III had the highest change being gain more than loss. Changes in tree populations during the seven-years period are found to be different in the six groups, resulting from tree death and replacement by new recruits. All group showed large variations in tree death and

recruitment. The most remarkable tree death were *Aporosa villosa* and *Wendlandia tinctoria* in group III, *Tectona grandis* and *Xylia xylocarpa var. kerii* in group II. *Lithocarpus elegan* and *Schima wallichii* in group IV. *Castanopsis calathiformis* and *Acer lauriumin* group V. *Litsea dubele* and *Myrsinese miserrata* in group IV, V and VI. Group III had recruitment involved *Aporosa villosa*, *Lithocarpus elegans* and *Castanopsis acuminatissima* as the abundant species. Group II found *Tectona grandis* and *Xylia xylocarpa var.kerii*, which are relatively common species in this group.

3. This studied forest dynamics along an altitudinal gradient in Doi Inthanon National Park, northern Thailand can be used for the ecological analysis on the community structure of forest, estimating the aboveground biomass and population dynamics in 1999-2006 for the forest management, including conservation of species diversity and rehabilitation of the disturbed forest further.

4. If the study on community dynamics could be carried out every year and a quite longer time period in this site, it will be helpful to know the population changes, DBH, H, species diversity, mortality rate, recruitment rate and biomass of all forest types in tis area for predicting the annual and future changes and providing management guideline of all forest community in this national park.

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APPENDIX

Appendix Table 1 Importance value index of tree species in deciduous dipterocarp forest stands in 2006.

Species	Family	A7	A8	A9	A10	A11	A12	A13	A14	A15	Average
Albizia odoratissima	Leguminosae	-	1.38	6.81	-	-	-	-	4.00	-	2.31
Anacardiaceae	Anacardiaceae	-	-	-	-	-	5.70	-	-	-	1.63
Anneslea fragrans	Theaceae	11.13	34.85	21.18	-	-	-	-	-	-	9.59
Antidesma ghaesembilla	Euphorbiaceae	-	1.23	-	-	-	-	-	-	-	0.18
Aporusa villosa	Euphorbiaceae	15.53	31.27	15.16	-	-	-	-	-	10.61	11.88
Bhesa robusta	Celastraceae	-	-	1.39	-	-	-	-	-	-	0.20
Bombax ancep	Bombaceae	-	-	-	9.33	-	-	-	-	-	2.66
Buchanania lanzan	Anacardiaceae	1.28	4.22	6.49	-	-	6.34	-	16.83	14.98	12.61
Canarium subulatum	Berseraceae	1.39	-	1.54	12.82	7.89	2.54	-	-	-	7.06
Canthium sp.	Rubiaceae	-	-	1.45	-	-	-	-	-	-	0.21
Castanopsis argyrophylla	Fagaceae	-	-	11.04	-	-	-	-	-	-	1.58
Castanopsis sp.1	Fagaceae	-	-	2.03	-	-	-	-	-	-	0.29
Chionanthus sp.	Fagaceae	-	-	1.74	-	-	-	-	-	-	0.25
Craibiodendron stellatum	Ericaceae	5.06	-	-	-	-	-	-	-	-	0.72
Cratoxylum formosum	Guttiferae	3.84	-	-	-	-	-	-	-	-	0.55
Dalbergia cultrata	Leguminosae	1.25	4.85	3.38	-	-	-	-	-	-	1.35
Dalbergia dongnaiensis	Leguminosae	-	-	-	3.11	14.83	-	-	-	-	5.12
Dalbergia rimosa	Leguminosae	-	-	6.96	-	-	-	-	-	-	0.99
Dillenia obovata	*Dilleniaceae*	-	-	-	-	-	13.64	15.02	23.68	-	14.95
Dillenia ovata	*Dilleniaceae*	-	-	-	-	-	-	-	8.95	-	2.56
Dipterocarpus tuberculatus	Dipterocarpaceae	52.18	68.75	55.08	-	-	64.58	112.80	61.85	80.84	116.60
Fernandoa adenophylla	Bignoniaceae	-	-	-	-	-	-	-	-	4.31	1.23
Gardenia obtusifolia	Rubiaceae	-	-	-	7.34	8.36	7.14	-	-	-	6.52
Gardenia sootepensis	Rubiaceae	3.09	-	4.12	6.34	-	4.80	-	-	-	4.21
Glochidion sphaerogynum	Euphorbiaceae	-	-	1.41	-	-	-	-	-	-	0.20
Gluta usitata	Anacardiaceae	15.49	12.43	2.46	-	-	-	-	-	-	4.34
Grewia eriocarpa	Tiliaceae	1.25	-	3.31	-	6.19	-	-	-	-	2.42
Lagerstroemia speciosa	Lythraceae	-	-	7.73	-	-	-	-	-	-	1.10
Lannea coromandelica	Anacardiaceae	-	-	-	12.43	4.77	-	-	-	-	4.91

Appendix Table 1 (Continued)

Species	Family	A7	A8	A9	A10	A11	A12	A13	A14	A15	Average
Lithocarpus polystachyus	Fagaceae	1.28	-	1.55	-	-	-	-	-	-	0.40
Lophopetalum wallichii	Celastraceae	6.04	-	-	-	-	-	-	-	-	0.86
Maesa sp.	Myrsinceae	-	-	2.28	-	-	-	-	-	-	0.33
Mangifera caloneura	Anacardiaceae	2.66	1.74	-	-	-	-	-	-	-	0.63
Mangifera indica	Anacardiaceae	-	-	-	-	-	5.76	4.60	-	-	2.96
Millettia xylocarpa	Leguminosae	-	-	-	7.43	-	-	-	-	-	2.12
Mitragyna brunonis	Bubiaceae	-	-	-	4.95	-	-	-	-	-	1.41
Morinda coreia	Bubiaceae	-	-	-	7.76	8.41	-	-	-	-	4.62
Morinda elliptica	Bubiaceae	-	-	-	-	2.67	-	-	-	-	0.76
Phyllanthus emblica	Euphorbiaceae	-	-	5.80	6.08	5.47	-	-	-	3.34	5.08
Pinus kesiya	Pinaceae	1.52	-	1.53	-	-	-	-	-	-	0.43
Pterocarpus macrocarpus	Leguminosae	-	-	1.39	3.30	18.47	4.53	-	-	-	7.71
Quercus kerrii	Fagaceae	12.36	1.26	28.35	-	-	2.37	8.03	3.40	24.92	17.06
Quercus kingiana	Fagaceae	-	3.31	7.32	-	-	-	-	-	-	1.52
Quercus ramsbottomii	Fagaceae	65.78	54.38	16.38	-	-	-	-	-	-	19.51
Quercus sp.	Fagaceae	-	-	1.39	-	-	-	-	-	-	0.20
Rubiaceae	Rubiaceae	-	-	-	-	-	5.81	-	-	-	1.66
Schima wallichii	Theaceae	-	1.81	-	-	-	-	-	-	-	0.26
Shorea obtusa	Dipterocarpaceae	30.42	-	10.27	4.10	9.52	92.15	86.81	111.86	87.89	117.91
Shorea siamensis	Dipterocarpaceae	6.37	-	-	142.58	123.41	29.62	3.60	-	-	86.40
Siphonodon celastrineus	Celastraceae	-	-	-	11.70	2.22	-	-	-	-	3.98
Sterculia sp.	Sterculiaceae	1.23	-	-	-	-	-	-	-	-	0.18
Stereospermum neuranthum	Bignoniaceae	-	-	6.47	-	-	-	-	-	-	0.92
Strychnos nux-vomica	Styracaceae	-	-	1.40	-	-	2.54	-	3.50	18.06	7.09
Symplocos racemosa	Symplocaceae	9.38	-	1.44	-	-	-	-	-	-	1.55
Symplocos sp.	Symplocaceae	-	2.73	19.13	-	-	2.71	-	-	13.61	7.79
Syzygium cumini	Myrtaceae	-	-	10.73	-	-	6.83	-	5.49	-	5.05
Syzygium siamense	Myrtaceae	1.33	3.88	-	-	-	-	-	-	-	0.74
Syzygium sp.	Myrtaceae	-	-	-	-	-	7.04	-	-	-	2.01

Appendix Table 1 (Continued)

Species	Family	A7	A8	A9	A10	A11	A12	A13	A14	A15	Average
Tarenna collinsae	Rubiaceae	-	-	1.42	-	-	-	-	-	-	0.20
Terminalia chebula	Combretaceae	-	-	1.48	-	-	-	-	-	-	0.21
Terminalia pierrei	Combretaceae	-	-	-	-	-	-	-	3.62	-	1.03
Terminalia sp.	Combretaceae	-	1.62	2.35	-	-	-	-	-	-	0.57
Tristania rufescens	Myrtaceae	8.38	29.82	1.46	-	-	-	-	-	-	5.67
Unidentified	Unidentified	2.04	-	3.41	54.38	56.99	35.90	69.14	56.83	41.44	90.68
Vaccinium sp.1	Ericaceae	3.19	-	1.51	-	-	-	-	-	-	0.67
Vaccinium sprengelii	Ericaceae	21.44	20.39	4.58	-	-	-	-	-	-	6.63
Vitex peduncularis	Labiatae	4.80	3.90	3.88	3.47	6.86	-	-	-	-	4.75
Vitex pinnata	Labiatae	-	-	-	2.89	-	-	-	-	-	0.83
Wendlandia tinctoria	Rubiaceae	10.29	16.18	11.20	-	-	-	-	-	-	5.38
Xylia xylocarpa var.kerrii	Leguminosae	-	-	-	-	23.94	-	-	-	-	6.84
Grand Total		30	300	300	300	300	300	300	300	300	300

Appendix Table 2 Importance value index of tree species in mixed deciduous forest stands in 2006

Species	Family	B1	B2	B3	B4	B10	B11	B12	Average
Albizia lebbeck	Leguminosae	-	-	6.88	-	-	-	-	0.98
Albizia odoratissima	Leguminosae	-	-	-	-	-	-	5.54	0.79
Anacardiaceae	Anarcadiaceae	-	-	-	-	-	4.06	-	0.58
Anogeisus acuminata	Combretaceae	-	4.14	-	-	-	-	-	0.59
Antidesma ghaesembilla	Euphobiaceae	-	3.60	-	-	-	5.48	-	1.30
Aporusa villosa	Euphobiaceae	-	-	-	-	-	6.06	5.70	1.68
Bombax ceiba	Bombaceae	-	-	-	14.42	-	-	22.33	1.09
Bauhinia sp.	Leguminosae	-	-	-	-	-	-	7.65	0.71
Bauhinia tenuiflora	Leguminosae	-	-	-	-	-	-	4.97	0.64
Bauhinia variegata	Leguminosae	-	-	-	4.46	-	-	-	5.25
Caeliaceae	Caeliaceae	-	-	-	-	9.33	-	-	1.33
Canarium subulatum	Burseraceae	-	3.65	-	40.34	3.64	3.99	-	7.37
Canthium parvifolium	Rubiaceae	-	-	3.95	-	2.47	-	-	0.92
Cassia fisstula	Leguminosae	-	-	-	-	9.68	2.00	-	1.67
Cratoxylum formosum	Guttiferae	-	-	-	7.07	-	-	-	1.01
Cratoxylum pruniflorum	Guttiferae	-	-	-	-	-	1.99	-	0.28
Cratoxylum sp.	Guttiferae	-	-	-	-	2.43	-	-	0.35
Dalbergia assamica	Leguminosae	-	-	-	-	2.48	-	-	0.35
Dalbergia dongnaiensis	Leguminosae	7.17	-	-	5.79	4.42	2.08	-	2.78
Dalbergia nigrescens	Leguminosae	-	-	-	8.70	-	-	8.34	2.43
Dalbergia oliveri	Leguminosae	17.08	-	-	-	-	-	5.08	3.17
Diospyros mollis	Ebenaceae	-	-	-	6.89	-	-	-	0.98
Diospyros spp.	Ebenaceae	-	-	-	-	2.46	-	-	0.35
Dipterocarpus tuberculatus	Dipterocarpaceae	-	-	-	-	16.70	18.93	-	5.09
Ehretia sp.	Boraginaceae	9.84	-	-	-	-	-	-	1.41
Engelhardtia spicata	Juglandaceae	-	3.49	-	-	-	-	-	0.50
Gardenia obtusifolia	Rubiaceae	-	-	-	-	-	3.99	-	0.57
Gardenia sootepensis	Rubiaceae	-	-	-	-	-	6.74	-	0.96
Grewia sp.	Tiliaceae	-	-	-	-	2.54	-	-	0.36

Appendix Table 2 (Continued)

Species	Family	B1	B2	B3	B4	B10	B11	B12	Average
Grewia eriocarpa	Tiliaceae	-	3.74	7.46	-	57.93	9.96	-	11.30
Haldina cordifolia	Rubiaceae	8.08	-	-	-	-	-	-	1.15
Hymenodictyon excelsum	Rubiaceae	-	-	-	20.50	-	-	-	2.93
Hymenodictyon orixense	Rubiaceae	-	-	-	-	-	-	4.98	0.71
Lagerstroemia calyculata	Lythraceae	11.70	-	-	16.47	-	-	-	4.02
Lagerstroemia floribunda	Lythraceae	-	-	-	-	5.20	-	74.02	11.32
Lagerstroemia sp.	Lythraceae	6.71	-	-	-	2.75	-	-	1.35
Lagerstroemia villosa	Lythraceae	14.10	-	-	-	-	-	-	2.01
Lannea coromandelica	Anacardiaceae	-	-	-	-	4.48	1.99	-	0.92
Lithocarpus sp.	Fagaceae	-	-	-	-	-	2.26	-	0.32
Lythraceae	Lythraceae	-	-	-	-	5.61	-	-	0.80
Mangifera indica	Anacardiaceae	-	-	-	-	7.88	4.02	-	1.70
Millettia brandisiana	Leguminosae	-	-	-	10.53	-	-	-	1.50
Millettia leucantha	Leguminosae	59.26	-	12.55	36.99	-	-	-	15.54
Millettia xylocarpa	Leguminosae	-	-	-	-	-	-	33.49	4.78
Mitragyna brunonis	Rubiaceae	10.27	-	-	5.02	2.45	-	5.03	3.25
Morinda coreia	Rubiaceae	-	-	-	-	-	-	7.04	1.01
Pterocarpus macrocarpus	Leguminosae	-	3.94	-	-	5.82	-	5.09	2.12
Pterocymbium tinctorium	Sterculiaceae	-	-	-	-	7.50	-	-	1.07
Quercus kerrii	Fagaceae	-	-	-	-	-	12.53	-	1.79
Quercus sp.	Fagaceae	-	-	-	-	-	4.63	-	0.66
Sarcosperma arboreum	Sapotaceae	-	-	-	14.19	-	-	-	2.03
Schleichera oleosa	Sapindaceae	-	-	-	-	4.98	5.47	5.31	2.25
Shorea obtusa	Dipterocarpaceae	-	-	-	-	-	26.92	-	3.85
Shorea siamensis	Dipterocarpaceae	-	-	-	-	-	2.00	-	0.29
Spondias pinnata	Anacardiaceae	-	-	-	13.58	3.58	-	5.36	3.22
Sterculia pexa	Sterculiaceae	-	-	-	-	14.23	4.05	-	2.61
Sterculia sp.	Sterculiaceae	-	-	-	-	5.87	-	-	0.84
Stereospermum cylindricum	Bignoniaceae	-	-	-	4.27	-	-	-	0.61

Appendix Table 2 (Continued)

Species	Family	B1	B2	B3	B4	B10	B11	B12	Average
Strychnos nux-vomica	Styracaceae	-	14.63	28.33	-	-	-	-	6.14
Symplocos sp.	Symplocaceae	-	-	-	-	-	1.99	-	0.28
Tectona grandis	Labiatae	79.34	17-	140.73	6.26	-	-	-	56.62
Terminalia chebula	Combretaceae	-	3.60	5.14	-	-	-	-	1.25
Terminalia floribunda	Combretaceae	-	-	-	-	-	2.40	-	0.34
Terminalia mucronata	Combretaceae	-	-	-	-	9.85	-	-	1.41
Terminalia pierrei	Combretaceae	-	7.37	25.72	-	12.51	-	-	6.51
Terminalia triptera	Combretaceae	-	-	-	4.71	-	-	-	0.67
Unidentified	Unidentified	16.16	-	8.52	-	52.41	27.35	17.81	17.46
Vitex canescens	Labiatae	-	-	-	-	2.60	-	-	0.37
Vitex peduncularis	Labiatae	-	-	4.65	-	-	1.98	-	0.95
Vitex pinnata	Labiatae	-	-	4.41	31.14	-	-	56.88	13.20
Wrightia arborea	Apocynaceae	7.63	-	-	-	-	-	-	1.09
Xylia xylocarpa var.kerrii	Leguminosae	45.39	81.84	51.67	7.37	38.22	137.14	25.40	55.29
Zizyphus oenoplia	Rhamnaceae	-	-	-	32.57	-	-	-	4.65
Zollingeria acuminata	Sapindaceae	7.27	-	-	8.70	-	-	-	2.28
Grand Total		300	300	300	300	300	300	300	300

Appendix Table 3 Importance value index of tree species in pine-dipterocarp forest stands in 2006.

Species	Family	C1	C2	C4	C5	C6	Average
Adinandra sp.	Theaceae	-	-	-	-	1.44	0.29
Albizia chinensis	Leguminosae	-	-	-	-	1.53	0.31
Albizia lebbeck	Leguminosae	-	-	-	-	1.63	0.33
Albizia odoratissima	Leguminosae	5.68	9.15	2.10	-	1.39	3.66
Anneslea fragrans	Theaceae	2.07	4.93	11.93	2.94	5.70	5.51
Antidesma ghaesembilla	Euphorbiaceae	-	1.56	-	-	11.44	2.60
Aporusa villosa	Euphorbiaceae	7.46	28.67	29.20	37.19	47.13	29.93
Artocarpus sp.	Moraceae	-	-	-	2.34	-	0.47
Beilschmiedia gammieana	Lauraceae	2.19	-	-	-	-	0.44
Bhesa robusta	Celastraceae	-	-	1.05	6.90	-	1.59
Bridelia retusa	Euphorbiaceae	-	-	1.22	-	-	0.24
Buchanania lanzan	Anacardiaceae	-	3.90	-	-	-	0.78
Canarium subulatum	Burseraceae	1.67	-	1.86	-	3.52	1.41
Careya sphaerica	Lecythidaceae	-	-	-	2.69	-	0.54
Castanopsis argyrophylla	Fagaceae	11.28	7.00	-	-	4.15	4.49
Castanopsis armata	Fagaceae	1.63	1.68	-	-	-	0.66
Castanopsis sp.1	Fagaceae	-	1.62	-	-	-	0.32
Castanopsis sp.2	Fagaceae	2.13	-	-	-	-	0.43
Craibiodendron stellatum	Ericaceae	8.10	-	7.85	2.50	1.53	4.00
Cratoxylum cochinchinensis	Guttiferae	2.83	-	-	-	3.31	1.23
Cratoxylum formosum	Guttiferae	1.74	-	-	-	-	0.35
Cratoxylum pruniflorum	Guttiferae	5.94	-	-	-	-	1.19
Dalbergia assamica	Leguminosae	3.28	-	3.23	-	1.39	1.58
Dalbergia cultrata	Leguminosae	2.54	1.56	15.29	13.13	9.55	8.41
Dalbergia dongnaiensis	Leguminosae	2.33	13.37	-	-	-	3.14
Dalbergia nigrescens	Leguminosae	-	1.71	-	-	-	0.34
Dalbergia spp.	Leguminosae	-	-	-	-	1.37	0.27
Dillenia obovata	Dilleniaceae	1.64	1.60	-	-	-	0.65
Diospyros ehretioides	Ebenaceae	-	-	-	2.36	-	0.47

Appendix Table 3 (Continued)

Species	Family	C1	C2	C4	C5	C6	Average
Dipterocarpus tuberculatus	Dipterocarpaceae	32.53	11.81	24.51	68.62	31.30	33.75
Ellipanthus tomentosus	Connaraceae	-	-	-	-	1.43	0.29
Engelhardtia spicata	Juglandaceae	-	1.71	-	-	-	0.34
Gardenia sootepensis	Rubiaceae	-	-	3.36	-	4.88	1.65
Gluta sp.	Anacardiaceae	-	-	3.35	-	-	0.67
Gluta usitata	Anacardiaceae	16.85	13.78	6.97	18.04	6.29	12.38
Grewia eriocarpa	Tiliaceae	2.44	1.57	2.20	-	-	1.24
Helicia nilagirica	Proteaceae	2.76	9.61	-	-	-	2.48
Ilex umbellulata	Aquifoliaceae	-	-	-	-	1.57	0.31
Lithocarpus aggregatus	Fagaceae	-	9.01	-	-	-	1.80
Lithocarpus polystachyus	Fagaceae	18.62	9.27	-	-	1.47	5.87
Lithocarpus sp.	Fagaceae	-	1.57	-	-	-	0.31
Maesa sp.	Myrsinaceae	-	-	1.50	-	-	0.30
Mangifera caloneura	Anacardiaceae	4.03	-	1.12	-	3.00	1.63
Mangifera indica	Anacardiaceae	6.54	-	-	-	1.37	1.58
Maytenus curtisii	Calastraceae	-	1.59	-	-	-	0.32
Phyllanthus emblica	Euphorbiaceae	-	-	13.87	-	2.37	3.25
Pinus kesiya	Pinaceae	71.76	31.58	5.52	63.33	62.79	47.00
Pterocarpus macrocarpus	Leguminosae	1.96	-	-	2.40	-	0.87
Quercus kerrii	Fagaceae	10.97	2.21	18.24	-	15.73	9.43
Quercus kingiana	Fagaceae	-	-	-	-	2.38	0.48
Quercus ramsbottomii	Fagaceae	8.90	30.40	31.34	38.95	9.79	23.88
Quercus sp.	Fagaceae	-	-	-	-	3.17	0.63
Rubiaceae	Rubiaceae	-	-	1.86	-	-	0.37
Schima wallichii	Theaceae	-	18.26	-	2.37	-	4.13
Shorea obtusa	Dipterocarpaceae	1.86	-	5.40	2.92	3.38	2.71
Shorea siamensis	Dipterocarpaceae	-	30.43	2.36	-	3.30	7.22
Stereospermum neuranthum	Bignoniaceae	-	-	1.61	-	-	0.32
Symplocos sp.	Symplocaceae	-	-	-	-	1.43	0.29

Appendix Table 3 (Continued)

Species	Family	C1	C2	C4	C5	C6	Average
Syzygium cumini	Myrtaceae	-	-	-	-	5.43	1.09
Terminalia chebula	Combretaceae	-	-	3.66	-	1.40	1.01
Ternstroemia gymnanthera	Theaceae	-	1.60	-	-	-	0.32
Tristania rufescens	Myrtaceae	3.14	-	-	-	-	0.63
Tristaniopsis burmanica	Myrtaceae	-	-	4.96	5.04	22.17	6.43
Unidentified	Unidentified	18.49	14.42	23.46	-	6.14	12.50
Vaccinium sp.1	Ericaceae	-	-	-	-	1.55	0.31
Vaccinium sp.2	Ericaceae	-	-	-	-	1.51	0.30
Vaccinium sprengelii	Ericaceae	7.25	6.25	6.98	6.37	1.88	5.75
Vitex peduncularis	Labiatae	3.41	6.51	1.06	2.57	1.50	3.01
Vitex pinnata	Labiatae	-	-	1.81	-	-	0.36
Wendlandia tinctoria	Rubiaceae	25.93	21.66	61.09	19.34	7.68	27.14
Grand Total		300	300	300	300	300	300

Appendix Table 4 Importance value index of tree species in pine-oak forest stands in 2006.

Species	Family	D1	D2	D3	D4	D5	D6	D7	D8	D9	Average
Actinodaphne henryi	Lauraceae	1.77	-	-	-	-	-	-	-	-	0.20
Adenanthera pavonina	Leguminosae	-	-	-	1.67	9.75	-	-	-	-	1.27
Albizia chinensis	Leguminosae	-	3.57	-	-	-	4.27	-	-	-	0.87
Albizia cochinensis	Leguminosae	2.21	-	-	-	-	-	-	-	-	0.25
Albizia odoratissima	Leguminosae	-	-	-	-	-	-	1.05	-	-	0.12
Anneslea fragrans	Theaceae	-	3.26	-	8.32	1.36	-	4.45	1.86	11.36	3.40
Aporusa villosa	Euphorbiaceae	32.17	2.90	31.97	20.67	28.03	61.22	53.54	16.77	33.11	31.15
Archidendron clypearia	Leguminosae	-	2.97	-	2.66	3.79	-	2.18	2.69	1.33	1.73
Artocarpus chaplasha	Moraceae	-	-	-	1.29	1.51	-	-	-	-	0.31
Artocarpus lakoocha	Moraceae	-	-	-	-	-	1.97	-	-	-	0.22
Artocarpus lanceifolius	Moraceae	3.66	-	-	-	-	-	-	-	-	0.41
Beilschmiedia sp.	Lauraceae	1.62	-	-	-	-	-	2.95	1.30	-	0.65
Buchanania lanzan	Anacardiaceae	-	6.82	7.56	9.09	3.62	8.57	1.04	-	21.04	6.42
Callicarpa arborea	Verbenaceae	-	-	-	-	-	-	1.71	-	-	0.19
Canarium subulatum	Burseraceae	-	-	-	-	-	-	2.09	-	-	0.23
Castanopsis acuminatissima	Fagaceae	-	6.04	-	8.98	18.75	2.02	2.69	3.97	1.19	4.85
Castanopsis armata	Fagaceae	1.87	6.88	17.49	-	2.28	2.86	9.94	7.03	-	5.37
Castanopsis calathiformis	Fagaceae	4.49	-	-	-	-	-	2.36	1.32	-	0.91
Castanopsis cerebrina	Fagaceae	-	-	-	1.29	1.25	-	-	4.50	7.26	1.59
Castanopsis indica	Fagaceae	6.09	-	-	-	1.21	-	-	-	-	0.81
Castanopsis tissima	Fagaceae	-	-	-	-	2.43	-	-	-	-	0.27
Castanopsis tribuloides	Fagaceae	2.09	5.04	3.98	5.63	1.24	3.92	4.07	15.26	17.07	6.48
Chionanthus ramiflorus	Oleaceae	-	-	-	2.90	3.32	5.34	-	-	-	1.28
Cleidon javanicum	Euphorbiaceae	4.58	-	-	-	-	-	-	-	-	0.51
Colona floribunda	Tiliaceae	1.63	-	-	-	-	-	-	-	-	0.18
Craibiodendron stellatum	Ericaceae	-	-	-	-	9.14	-	-	-	-	1.02
Cratoxylum cochinchinensis	Guttiferae	-	-	-	-	10.46	-	9.03	1.29	-	2.31
Dalbergia cochinchinensis	Leguminosae	-	-	-	1.35	-	-	-	-	-	0.15
Dalbergia cultrata	Leguminosae	-	-	3.84	11.26	6.07	8.58	12.30	24.22	6.22	8.05

Appendix Table 4 (Continued)

Species	Family	D1	D2	D3	D4	D5	D6	D7	D8	D9	Average
Dalbergia dongnaiensis	Leguminosae	-	-	-	-	-	-	1.14	-	-	0.13
Dalbergia floribunda	Leguminosae	6.49	-	-	-	1.20	-	-	-	-	0.85
Dalbergia velutina	Leguminosae	1.65	-	-	-	-	-	14.35	-	-	1.78
Dillenia parviflora	Dilleniaceae	5.35	-	1.90	-	-	2.86	1.31	3.08	-	1.61
Elacocarpus sp.1	Elacocarpaceae	1.83	-	-	-	-	-	-	-	-	0.20
Elaeocarpus sp.1	Elacocarpaceae	-	2.10	-	-	-	-	-	-	-	0.23
Elaeocarpus sp.2	Elacocarpaceae	-	-	2.14	-	-	-	-	-	-	0.24
Engelhardtia serrata	Juglandaceae	-	-	-	2.77	-	1.95	2.76	1.34	-	0.98
Engelhardtia sp.	Juglandaceae	-	1.80	-	-	-	-	-	-	-	0.20
Eriobotrya bengalensis	Rosaceae	1.71	-	-	-	-	-	-	-	-	0.19
Euonymus cochinchinensis	Celastraceae	2.52	-	-	5.72	-	5.03	-	-	-	1.47
Euonymus similis	Celastraceae	1.62	-	-	-	-	-	-	-	-	0.18
Eurya acuminata	Theaceae	12.18	1.45	-	1.30	1.27	-	2.10	-	1.23	2.17
Flacourtia jangomas	Flacourtiaceae	3.36	-	-	-	-	-	-	-	-	0.37
Glochidion rubrum	Euphorbiaceae	6.67	-	-	-	-	-	-	-	-	0.74
Glochidion sp.	Euphorbiaceae	-	-	-	-	-	-	-	1.30	-	0.14
Glochidion sphaerogynum	Euphorbiaceae	1.62	1.63	-	1.34	1.21	2.28	9.79	1.32	-	2.13
Gluta usitata	Anacardiaceae	-	1.57	-	-	-	-	1.06	-	1.56	0.47
Gordonia dalglieshiana	Theaceae	2.65	-	-	-	-	-	-	-	-	0.29
Helicia nilagirica	Proteaceae	-	32.10	8.41	5.03	4.29	-	-	1.30	-	5.68
Helicia sp.	Proteaceae	1.97	-	-	-	-	-	-	-	-	0.22
Ilex umbellulata	Aquifoliaceae	1.74	-	-	-	-	1.99	-	2.25	1.68	0.85
Lannea coromandelica	Anacardiaceae	-	-	-	1.40	-	-	1.09	3.13	-	0.62
Lindera sp.	Lauraceae	-	-	-	-	-	-	1.44	-	-	0.16
Lithocarpus aggregatus	Fagaceae	-	-	-	-	-	-	1.28	-	-	0.14
Lithocarpus annamensis	Fagaceae	7.56	-	2.23	-	-	-	-	-	-	1.09
Lithocarpus elegans	Fagaceae	8.12	37.54	16.37	11.46	23.75	18.04	7.66	32.03	19.06	19.34
Lithocarpus nestratus	Fagaceae	-	-	-	-	-	1.97	-	-	-	0.22
Lithocarpus polystachyus	Fagaceae	-	-	-	-	-	2.71	3.93	1.31	1.28	1.03

Appendix Table 4 (Continued)

Species	Family	D1	D2	D3	D4	D5	D6	D7	D8	D9	Average
Litsea glutinosa	Lauraceae	3.58	-	-	-	-	-	-	-	-	0.40
Macaranga denticulata	Euphorbiaceae	-	-	-	1.28	-	-	-	-	-	0.14
Macaranga kurzii	Euphorbiaceae	-	-	-	-	-	1.95	-	-	-	0.22
Maesa ramentacea	Myrsinaceae	-	-	-	-	-	-	-	-	1.60	0.18
Meliosma simplicifolia	Mriosmaceae	1.61	-	-	-	-	-	-	-	-	0.18
Paramichelia bailonii	Magnoliaceae	-	-	-	1.34	-	2.02	-	-	-	0.37
Pavetta tomentosa	Rubiaceae	-	-	3.67	-	-	-	-	-	-	0.41
Payena paralleloneura	Sapotaceae	-	-	-	-	-	2.51	-	-	-	0.28
Phoebe lanceolata	Lauraceae	1.64	1.54	7.13	1.38	-	2.70	6.29	1.67	-	2.48
Phyllanthus emblica	Euphorbiaceae	-	-	-	1.44	-	2.24	-	-	-	0.41
Pinus kesiya	Pinaceae	81.23	65.20	113.45	88.90	50.19	94.40	71.55	69.22	79.19	79.26
Quercus kerrii	Fagaceae	-	-	-	1.57	1.18	-	-	5.40	9.49	1.96
Rhus chinensis	Anacardiaceae	-	-	-	-	11.51	8.84	-	-	-	2.26
Rhynchotechum obovatum	Gesneriaceae	3.00	-	-	-	-	-	-	-	-	0.33
Sarcosperma arboreum	Sarcospermataceae	3.48	-	-	-	-	-	-	-	-	0.39
Saurauia napaulensis	Actinidiaceae	-	-	-	-	-	-	-	2.58	-	0.29
Schima wallichii	Theaceae	36.72	18.50	18.00	4.38	20.06	10.59	27.65	31.80	-	18.63
Sterculia rubiginosa	Sterculiaceae	-	-	-	-	-	2.70	-	-	-	0.30
Stereospermum cylindricum	Bignoniaceae	1.81	-	-	-	-	-	-	-	-	0.20
Stereospermum neuranthum	Bignoniaceae	-	-	-	-	-	-	-	1.44	-	0.16
Styrax benzoides	Stryraceae	3.67	17.58	2.34	5.61	1.21	2.13	9.46	9.95	5.05	6.33
Symplocos cochinchinensis	Symploceae	-	-	-	-	-	-	-	-	1.24	0.14
Syzygium albiforum	Myrtaceae	1.68	5.96	13.84	2.56	1.65	-	-	-	-	2.85
Syzygium angkae	Myrtaceae	1.64	-	-	-	-	-	-	-	-	0.18
Ternstroemia gymnanthera	Theaceae	3.97	23.72	6.67	-	-	-	-	8.12	4.95	5.27
Tristania rufescens	Myrtaceae	-	3.21	-	6.02	-	-	1.06	4.91	32.55	5.31
Tristaniopsis burmanica	Myrtaceae	1.65	-	-	3.01	23.57	4.79	-	-	-	3.67
Unidentified	Unidentified	13.22	13.97	22.11	22.75	11.88	6.59	5.21	8.05	6.66	12.27
Unidentified 17	Unidentified	-	-	-	-	-	-	2.48	-	-	0.28

Appendix Table 4 (Continued)

Species	Family	D1	D2	D3	D4	D5	D6	D7	D8	D9	Average
Unidentified 37	Unidentified	-	-	-	-	-	-	1.51	-	-	0.17
Unidentified 18	Unidentified	-	-	-	-	-	-	-	4.36	-	0.48
Unidentified 27	Unidentified	-	-	-	-	-	-	1.42	-	-	0.16
Vaccinium sprengelii	Ericaceae	-	1.47	-	17.19	6.29	-	1.03	1.43	-	3.05
Viburnum inopinatum	Caprifoliaceae	5.09	3.66	-	10.86	8.95	3.92	3.71	8.31	8.43	5.88
Vitex peduncularis	Labiatae	1.65	1.47	-	1.68	-	-	-	-	-	0.53
Wendlandia tinctoria	Rubiaceae	5.14	28.04	15.06	25.90	27.57	19.01	11.35	15.49	27.46	19.45
Wrightia arborea	Apocynaceae	-	-	1.84	-	-	-	-	-	-	0.20
Grand Total		300	300	300	300	300	300	300	300	300	300

Appendix Table 5 Importance value index of tree species in hill evergreen forest stands in 2006.

Species	Family	E1	E2	E3	E4	E5	E6	E7	E8	E9	Average
Acer laurinum	Aceraceae	-	-	-	20.47	3.27	2.03	-	8.68	3.72	4.24
Actinodaphne henryi	Lauraceae	-	-	-	-	-	2.24	72.59	-	-	8.31
Adenandra integerrima	Leguminosae	-	1.19	2.56	-	-	-	-	-	-	0.42
Adinandra sp.	Theaceae	-	-	-	-	1.39	-	-	-	-	0.15
Aidia yunnanensis	Rubiaceae	1.66	1.86	-	6.66	17.98	12.77	-	-	-	4.55
Anneslea fragrans	Theaceae	-	-	3.21	-	-	-	-	-	-	0.36
Aporusa nervosa	Euphorbiaceae	-	1.19	-	-	-	-	-	-	-	0.13
Aporusa octandra	Euphorbiaceae	3.09	-	3.81	-	-	-	-	-	-	0.77
Aporusa villosa	Euphorbiaceae	-	-	-	-	-	-	-	1.46	-	0.16
Archidendron clypearia	Leguminosae	-	5.53	-	-	-	-	-	-	-	0.61
Ardisia rubro-glandulosa	Myrsinaceae	-	-	-	-	-	-	22.70	1.46	-	2.68
Ardisia sp.	Myrsinaceae	-	-	-	-	-	3.31	-	-	-	0.37
Artocarpus chaplasha	Moraceae	-	2.48	-	-	-	-	-	-	-	0.28
Atalantia monophylla	Rutaceae	-	-	-	-	-	1.12	-	-	-	0.12
Beilschmiedia assamica	Lauraceae	-	2.59	-	-	-	-	-	-	-	0.29
Beilschmiedia gammieana	Lauraceae	2.19	-	-	-	1.31	-	-	-	-	0.39
Beilschmiedia globularia	Lauraceae	-	-	-	-	-	-	-	6.05	1.43	0.83
Beilschmiedia roxberghiana	Lauraceae	-	-	-	-	-	-	33.24	-	-	3.69
Betula alnoides	Betulaceae	-	3.91	-	-	-	-	-	-	-	0.43
Bombax ancep	Bombaceae	2.19	-	-	-	-	-	-	-	-	0.24
Brassiopsis speciosa	Araliaceae	-	-	-	-	1.88	-	-	-	-	0.21
Calophyllum polyanthum	Guttiferae	-	-	-	6.45	21.23	5.05	-	-	-	3.64
Camellia oleifera	Theaceae	-	-	-	1.32	1.93	5.59	-	-	-	0.98
Camellia siamensis	Theaceae	-	-	-	-	-	-	1.89	7.68	2.81	1.38
Canarium denticulatum	Burseraceae	-	1.18	-	-	-	-	-	-	-	0.13
Canarium strictum	Burseraceae	-	1.19	-	-	-	-	-	-	-	0.13
Canthium coffeoides	Rubiaceae	1.57	-	-	-	-	-	-	-	-	0.17
Carellia braciata	Rhizophoraceae	-	-	-	-	-	2.79	-	-	-	0.31
Castanopsis acuminatissima	Fagaceae	-	-	6.87	-	-	2.92	-	-	1.48	1.25

Appendix Table 5 (Continued)

Species	Family	E1	E2	E3	E4	E5	E6	E7	E8	E9	Average
Castanopsis cadatum	Fagaceae	-	-	3.38	-	-	-	-	-	-	0.38
Castanopsis calathiformis	Fagaceae	10.87	6.07	10.63	-	-	55.35	-	-	-	9.21
Castanopsis diversifolia	Fagaceae	-	-	17.00	-	-	-	-	-	-	1.89
Castanopsis ferox	Fagaceae	1.51	55.88	-	-	-	-	-	50.99	52.73	17.90
Castanopsis purpurea	Fagaceae	-	-	-	2.41	-	-	-	-	-	0.27
Castanopsis tribuloides	Fagaceae	27.12	-	25.49	-	-	-	-	-	-	5.85
Chionanthus ramiflorus	Oleaceae	-	-	-	4.01	-	-	-	13.35	9.98	3.04
Cinnamomum bejolghota	Lauraceae	-	-	-	2.51	2.81	-	-	-	-	0.59
Cinnamomum caudatum	Lauraceae	-	-	3.83	-	-	-	-	-	-	0.43
Cinnamomum glaucescens	Lauraceae	-	4.85	-	-	-	-	-	-	-	0.54
Cinnamomum javanicum	Lauraceae	-	-	-	6.22	-	-	-	-	-	0.69
Claoxylou longifolia	Euphorbiaceae	3.83	-	-	-	-	-	-	-	-	0.43
Cryptocarya dencifolia	Lauraceae	-	-	-	4.27	19.11	6.96	-	-	-	3.37
Cryptocarya sp.	Lauraceae	-	-	-	8.18	8.12	-	-	-	-	1.81
Dalbergia velutina	Leguminosae	15.39	1.30	2.05	-	-	-	-	-	-	2.08
Daphniphyllum sp.	Daphniphyllaceae	-	-	-	-	-	2.33	-	-	-	0.26
Dillenia parviflora	Dilleniaceae	4.19	1.69	-	-	-	-	-	-	-	0.65
Diospyros glandulosa	Ebenaceae	10.89	2.56	10.63	-	-	-	-	-	-	2.68
Drypetes hoaensis	Euphorbiaceae	-	1.22	-	-	-	-	-	-	-	0.14
Drypetes indica	Euphorbiaceae	-	-	-	25.26	23.52	-	-	-	-	5.42
Elaeocarpus floribundus	Elaeocarpaceae	-	-	7.74	-	-	-	-	-	-	0.86
Elaeocarpus lanceaefolius	Elaeocarpaceae	-	-	-	9.27	-	2.08	-	-	-	1.26
Elaeocarpus sp.1	Elaeocarpaceae	1.52	-	-	-	-	-	-	-	-	0.17
Eleaocarpus branciana	Elaeocarpaceae	-	-	-	-	-	1.28	-	-	-	0.14
Engelhardtia sp.	Juglandaceae	-	-	-	1.19	-	1.74	-	-	-	0.33
Engelhardtia spicata	Juglandaceae	3.21	1.39	1.86	-	-	-	-	-	-	0.72
Eriobotrya bengalensis	Rosaceae	-	1.66	-	-	-	-	-	-	-	0.18
Eriolaena candollei	Rosaceae	1.74	-	-	-	-	-	-	-	-	0.19
Erythrina subumbrans	Leguminosae	-	5.58	1.93	-	-	-	-	-	-	0.83

Appendix Table 5 (Continued)

Species	Family	E1	E2	E3	E4	E5	E6	E7	E8	E9	Average
Eurya acuminata	Theaceae	17.20	3.11	17.30	-	-	-	-	-	-	4.18
Eurya nitida	Theaceae	-	1.35	-	-	-	4.57	-	2.24	-	0.91
Garcinia sp.	Guttiferae	-	-	-	-	-	1.45	-	-	2.16	0.40
Glochidion acuminatum	Euphorbiaceae	-	-	-	-	-	-	28.85	4.01	-	3.65
Glochidion sp.	Euphorbiaceae	3.93	-	-	-	-	-	-	-	-	0.44
Glochidion sphaerogynum	Euphorbiaceae	-	2.43	3.25	-	-	-	-	-	-	0.63
Glyptopetalum sp.	Calastraceae	-	-	-	1.47	-	-	-	-	-	0.16
Gomphandra quadrifolia	Icacinaceae	-	-	-	-	-	-	-	5.68	4.89	1.17
Helicia attenuata	Proteaceae	-	9.60	-	-	-	-	-	-	-	1.07
Helicia formosana var.oblane	Proteaceae	-	-	-	-	-	-	24.06	10.21	4.26	4.28
Helicia nilagirica	Proteaceae	10.47	43.70	-	-	-	-	-	-	-	6.02
Helicia sp.	Proteaceae	-	-	6.79	-	-	-	-	-	-	0.75
Homalium ceylanicum	Flacourtiaceae	-	-	3.48	-	-	-	-	-	-	0.39
Ilex sp.	Aquifoliaceae	-	-	-	-	2.74	-	-	-	-	0.30
Ilex triflora	Aquifoliaceae	-	-	-	-	-	14.05	4.08	-	7.56	2.85
Ilex umbellulata	Aquifoliaceae	-	-	-	-	-	-	-	-	4.00	0.44
Lasianthus kurzii	Rubiaceae	-	-	-	1.16	-	-	-	-	-	0.13
Lindera metacafaena	Lauraceae	-	-	-	-	-	13.22	-	-	-	1.47
Lindera missneri	Lauraceae	5.85	1.23	6.64	-	-	-	-	-	-	1.53
Lindera sp.	Lauraceae	1.54	-	-	-	-	12.41	-	-	1.32	1.70
Lithocarpus aggregatus	Fagaceae	-	-	-	9.08	14.84	7.33	4.11	24.18	7.04	7.40
Lithocarpus ceriferus	Fagaceae	3.81	-	8.07	-	-	-	-	-	-	1.32
Lithocarpus dealbatus	Fagaceae	3.02	-	13.99	-	-	-	-	-	-	1.89
Lithocarpus elegans	Fagaceae	9.47	15.35	10.72	-	-	-	-	-	-	3.95
Lithocarpus triboides	Fagaceae	-	-	18.41	-	-	-	-	-	-	2.05
Lithocarpus truncatus	Fagaceae	1.52	-	-	-	-	-	-	-	-	0.17
Litsea beusekomii	Lauraceae	-	-	-	7.70	5.07	-	-	-	-	1.42
Litsea chatacea	Lauraceae	-	-	-	2.56	7.72	-	-	-	-	1.14
Litsea dubele	Lauraceae	-	-	-	6.63	1.43	-	39.06	38.89	5.89	10.21

Appendix Table 5 (Continued)

Species	Family	E1	E2	E3	E4	E5	E6	E7	E8	E9	Average
Litsea firma	Lauraceae	-	-	-	1.21	-	-	-	-	-	0.13
Litsea glutinosa	Lauraceae	-	-	-	-	-	-	-	1.58	-	0.18
Litsea lancifolia	Lauraceae	-	-	-	12.12	5.50	-	-	-	-	1.96
Litsea sp.1	Lauraceae	-	-	-	4.99	5.75	-	-	-	-	1.19
Litsea sp.2	Lauraceae	-	-	-	3.22	-	1.12	-	-	-	0.48
Litsea umbellata	Lauraceae	-	-	3.48	-	-	-	-	-	-	0.39
Litsia cubeba	Lauraceae	1.67	-	-	-	-	-	-	-	-	0.19
Mallotus khasianus	Euphorbiaceae	-	-	-	21.86	18.21	1.16	-	-	-	4.58
Mangleitia garrettii	Magnoliaceae	-	-	-	26.72	15.70	3.15	-	-	-	5.06
Mastixia euonymoides	Cornaceae	-	-	-	38.10	18.03	8.73	2.72	-	-	7.51
Myrica esculenta	Myricaceae	1.99	1.31	-	-	-	-	1.94	-	8.46	1.52
Myrsine semiserrata	Myrsinaceae	-	-	-	-	-	-	-	20.34	1.24	2.40
Neolitsea pallens	Lauraceae	-	-	-	-	-	-	10.79	28.42	70.22	12.16
Nyssa javanica	Nyssaceae	-	-	-	1.47	11.21	12.66	-	-	-	2.82
Ostodes paniculata	Euphorbiaceae	-	-	-	22.66	18.83	-	-	-	-	4.61
Parenaria camelliflora	Magnoliaceae	-	-	-	-	-	-	6.97	-	-	0.77
Pavetta aspera	Rubiaceae	-	-	-	-	-	-	-	5.35	3.54	0.99
Phoebe lanceolata	Lauraceae	1.64	3.71	-	-	-	9.12	4.71	-	-	2.13
Phyllanthus emblica	Euphorbiaceae	1.54	-	-	-	-	-	-	-	-	0.17
Podocarpus neriifolius	Podocarpaceae	-	-	-	-	-	2.21	-	-	-	0.25
Polyalthia sp.	Annonaceae	-	-	-	-	1.37	-	-	-	-	0.15
Polyosma integrifolia	Saxifragaceae	-	-	-	-	2.72	5.29	-	-	-	0.89
Premna villosa	Lbiatae	-	1.78	-	-	-	-	-	-	-	0.20
Protium serratum	Berseraceae	1.50	6.47	-	-	-	-	-	-	-	0.89
Prunas placostictus	Rosaceae	-	-	-	-	-	1.15	-	-	-	0.13
Pyrenaria camalliflora	Theaceae	-	-	-	-	1.60	-	-	-	-	0.18
Quercus glabricupula	Fagaceae	1.61	-	6.62	4.24	5.25	1.12	-	-	-	2.09
Quercus lenticellata	Fagaceae	-	-	-	-	2.29	26.88	1.91	31.31	16.21	8.73
Quercus purpurea	Fagaceae	-	-	-	-	1.36	-	-	-	-	0.15

Appendix Table 5 (Continued)

Species	Family	E1	E2	E3	E4	E5	E6	E7	E8	E9	Average
Rapanea yunnanensis	Myrsinaceae	-	-	-	-	-	14.68	-	19.28	49.58	9.28
Rhus chinensis	Anacardiaceae	-	-	-	2.54	1.28	-	-	-	-	0.42
Sarcosperma arboreum	Sacrospermataceae	-	-	-	8.38	-	-	-	-	-	0.93
Sauravia napaulensis	Actinidiaceae	1.50	12.24	-	-	-	-	-	-	-	1.53
Schefflera hypoleucoides	Araliaceae	-	-	-	-	-	-	-	1.45	15.04	1.83
Schima wallichii	Theaceae	53.73	36.15	32.31	-	-	-	-	-	1.27	13.72
Schoepfia fragrans	Oleaceae	-	-	-	-	-	1.11	-	-	-	0.12
Sterculia sp.	Sterculiaceae	-	-	-	3.26	1.35	-	-	-	-	0.51
Sterculia villosa	Sterculiaceae	-	1.32	-	-	-	-	-	-	-	0.15
Stereospermum neuranthum	Sterculiaceae	5.90	6.09	-	-	-	-	-	-	-	1.33
Styrax benzoides	Stryraceae	9.06	21.94	22.75	-	-	-	-	-	-	5.97
Symplocos cochinchinensis	Symplocaceae	1.55	1.45	8.51	-	1.28	1.11	-	-	-	1.54
Symplocos hookerii	Symplocaceae	-	-	-	4.54	8.32	1.11	-	-	-	1.55
Symplocos longifolia	Symplocaceae	-	-	-	-	-	-	8.69	14.47	15.19	4.26
Symplocos sp.	Symplocaceae	-	-	-	1.40	-	-	-	-	-	0.16
Syzygium angkae	Myrtaceae	27.94	8.63	10.21	2.53	9.48	5.60	25.66	-	-	10.01
Syzygium balsameum	Myrtaceae	-	1.36	-	4.23	10.34	14.84	-	-	-	3.42
Tarenna disperma	Rubiaceae	-	-	-	-	-	15.91	-	-	-	1.77
Tarennoidea wallichii	Rubiaceae	1.52	-	-	-	-	-	-	-	-	0.17
Ternstroemia gymnanthera	Theaceae	11.86	12.59	10.80	-	-	-	-	-	-	3.92
Tristania rufescens	Myrtaceae	-	-	3.68	-	-	-	-	-	-	0.41
Unidentified	Unidentified	1.50	1.19	12.00	7.66	17.63	9.00	6.03	2.92	2.40	6.70
Vaccinium sprengelii	Ericaceae	-	-	-	-	-	-	-	-	7.58	0.84
Walsura trijuga	Meliaceae	-	-	-	1.51	8.14	3.46	-	-	-	1.46
Wendlandia tinctoria	Rubiaceae	17.57	1.20	-	-	-	-	-	-	-	2.09
Xantolis burmanica	Sapotaceae	-	1.29	-	-	-	-	-	-	-	0.14
Xantolis sp.	Sapotaceae	10.14	-	-	-	-	-	-	-	-	1.13
Zizyphus incurva	Rhamnaceae	-	1.19	-	-	-	-	-	-	-	0.13
Grand Total		300	300	300	300	300	300	300	300	300	300