CECZH UNIVERSITY OF LIFE SCIENCIES PRAGUE

Faculty of Forestry and Wood Sciences

Forestry, Water and Landscape Mangement

Diploma Thesis

Forest structure characteristics at Hoa Binh Hydropower reservoir areas, Vietnam

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

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DIPLOMA THESIS ASSIGNMENT

Pham Thi Quynh

Thesis title

Forest structure characteristics at the Hoa Binh Hydropower reservoir area, Vietnam

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Objectives of thesis

the main goal is proposing the regulation of forest structure to enhance water resources protection

Methodology

- collection data and relevant information on the specified area
-s pecies composition of the forests and its diversity index evaluation
- spatial structures of forest
- quantity and quality data on the forest
- proposal species composition of forests
- regulation of forest structure to enhancing water resources protection

Schedule for processing

- collection data and relevant information on the specified area - spring 2013
- species composition of the forests and its diversity index evaluation -summer 2013
- spatial structures of forest -summer 2013
- quantity and quality data on the forest -autumn 2013
- proposal species composition of forests -winter 2013/14
- regulation of forest structure to enhancing water resources protection - winter 2013/14

The proposed extent of the thesis
by the need to fulfill the tasks

Keywords
species composition, diversity index, spatial structures of forest, environmental services

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Recommended information sources

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Declaration

I hereby declare that I have written diploma thesis "Forest structure characteristics at Hoa Binh Hydropower reservoir areas, Vietnam" by myself. It is my own work and all the sources I cited in it are listed in references.

In Prague, April 19th 2014. Signature

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Quynh Pham Thi

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Abstract

Purpose of the thesis is to analyse forest structure to in Hoa Binh hydropower reservoir area of Vietnam in order to enhance by silvicultural management water resources protection. The content of this thesis is based on structure of upper tree layer and tree regeneration to propose suitable species composition, improving cover canopy and tree species diversity. The analysis focuses on different type of forest, their structure characteristic and spatial structure. Thus, the forest management depends on type of forest to properly adjust structure. This study is focusing on two types of forest: poor type forest and medium one. The results suggest species composition to improve forest growing stock and still ensuring protection capacity of forest.

Key words: species composition, diversity index, spatial structures of forest, water protection forest.

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1. Introduction

Forests play an important role for human society in many fields such as economic, culture, environment…but, especially in maintaining and regulating water resources.

In Vietnam, the protection forest is essential for regulating water in the watershed. The protection forests have also ensured for stability, sustainability of living environment and lasting hydropower. However, the basic study in forests structure is still lacked, so the impactof silvicultural measures are difficult to apply or the effect of measures is not known. The research has just study natural forest recovery. It is necessary to have general method based on science and practice.

From the point of view, the forest structure features are described as relationship between the components of the forest ecosystem and environment. The study of forest structure is going to maintain stability ecosystem with the balance of structure factors, maximum the potential of all site conditions and promote sustainability functions in socio-economic and environment of forest. The practice has proved that the management solution and forest development can be resolved when there is deeply understanding of the forest ecosystem. Therefore, the identification of silvicultural measures which improve the rational use of forest resources is a very important and urgent task.

The protection forest at Hoa Binh hydropower reservoir is one of three important protection zones in Northwestern. The Hoa Binh province plays an extremely important role. This is one of four provinces in Northern, which has large proportion of watershed protection forest area with 212,930.5 hectares. The protection forest land area is 137,920.6 ha of forest. In recent years, the forest resources are currently at risk of serious deterioration in both quantity and quality.

That was the initial idea to start the work on - the thesis "Forest structure characteristics at Hoa Binh Hydropower reservoir areas, Vietnam".

2. Objective

The aim of this thesis is to analyse forest structure in Hoa Binh hydropower reservoir area of Vietnam in order to enhance by silvicultural management water resources protection.

Therefore the main tasks are:

+ Evaluation of actual forest structure, species composition

+ Description of forest structure in relevant form (diversity index evaluation etc.)

+ Proposal for forest structure and species composition which enhance water resource protection

+ Proposal for regulation of forest structure in the future to maintain water resources

3. Literature review

3.1. Forest structure definitions

Forest structure usually refers to attributes of tree, which are distributed within a forest ecosystem. Forest structure mentions distribution of vegetation (woody and herb) and arrangement of various physical and biological components of an ecological system (Franklin et al.2002, Noss 1990, Franklin 1988). Forest structure influences the forest functions and environmental services it can provide. Structure and diversity are important characteristic because they contribute to the functions of a forest ecosystem (Harmon et al.1986; Ruggiero et al.1991; Spies 1997).

3.2. Species composition of the forests and species diversity

According to Sandalow (2000), forests cover 40 percent of the earth's land surface and home to more than 70 percent of land living plants, animals and provide a wide range of ecological, social and economical benefits, tropical forests in particular have high productive and protective natural value, an estimate of 10-30 million species is found in tropical forest alone and having complex ecological communities of different species that have unique ecological importance. More than 2.5 million people live in areas adjacent to tropical forests, they rely on the forest for their water, fuel wood and other resources.

Composition means variety of species, communities and ecosystems. Forest composition means plants species found in a stand including tree, shrubs, herbs and grasses. It also means forest communities whose canopies could be dominated by a single tree species or by a mixture of species. A different composition structure will lead to corresponding differences in other forest structural features (Noss 1999). Thus, composition structure of humid tropical forests is the first most important indicator in the study of forest structure. The species composition is unique for forest, with some forests consisting of many hundreds of species of trees while others consist of just a handful of species (Magurran 1988).

Richards.P.W (1952) has studied tropical rainforest morphology. According to the author, the most important feature of tropical rainforest is woody plants. Richards also distinguished two categories of plant composition in rainforest, which are mixed rainforest with complex species and single rainforest with simple species. Rainforests have often many layers.

Baur G.N (1976) has been studied rainforest nearly Belem on the Amazon River. The sample plot has approximately 2 hectares and he has found 36 flora families. The other sample plot (≥ 4 ha) in northern New South Wales has also as much as 31 families.

Catinot.R (1974) have found hundreds plant species in the humid tropical forest of Africa and plant composition in Southeast Asia often have a group of dominant species – *Dipterocarpaceae*group, accounting for 50% population.

Kanel K.R. and Shrestha K (2001) have reported about biological diversity in the secondary forest at Nepal with more than 6500 flowering plants species and 4064 non-flowering plants species including over 1500 fungi species and over 350 lichen species.

The composition structure has also been mentioned by scientists in Vietnam. Bao Huy (1993) and Dao Cong Khanh (1996) who determined composition rate of species purpose tree and non-specific purposes in Dac Lak and Ha Tinh provinces, which adjust composition by increasing purpose tree species and reducing non-purpose species to suit with economic or protection purpose. He proposed appropriate exploitation measures for resonable objecties based on this structure studies.

Le Sau (1996) has been studied the structure of natural forests in Gia Lai provinces. He determined the list of specific species followed by composition level.Ngo Minh Man (2005) investigated forest structure in Cat Tien National Park. He has proposed the distribution of the number of tree species composition according to distance distribution.

Natural forest structure in Vietnam is based on ecosystem idea. Thai Van Trung (1970, 1978) has studied an amount and biomass of dominant species in humid tropical forest and he proposed determine species group composition.

In mixed species natural forest in Vietnam, Nguyen Van Truong (1983) has shown that having about 30 – 40 species over one hectare in typical for maturity state of forest.

There have been many Vietnamese authors who have studied biodiversity, particularly in diverse flora. Thai Van Trung (1999)studied "Vietnam forest vegetation" and he has been also summarized his studies with 7004 higher plants. He stressed the advantages of angiosperm in Vietnam flora with 6336 species occuping 90.9%; 1227 genus accounted for 93.5% and 239 family make up 82.7% of total taxon each level. The next study is "Preliminary studies on Northern Forest" by Tran Ngu Phuong (1970). He proposed forest classification in the north of Vietnam following soil, climate, elevation and typical factors of forest to classify forests in the north into 3 forest belts. Each forest belt comprises one or some fundamental forest types:

A. Seasonal rainy tropical forest belt:

- Mangrove evergreen broad leaved tropical forest
- Evergreen broad leaved seasonal rainy tropical forest
- Evergreen broad leaved tropical rain forest
- Vally broard leaved tropical forest
- Limestone evergreen broad leaved tropical forest

B. Seasonal rainy sub-tropical forest belt:

- Evergreen broad leaved sub-tropical forest
- Limestone needle leaved sub-tropical forest
- Earth mountain needle leaved sub-tropical forest

C. Highland seasonal rainy sub-tropical forest belt:

- This belt comprises 3 types that are Fokienia hodginsii, Cunninghamia lanceolata and Rhododendron simsii.

This ecosystem classification is seen as initial results of study on forest silviculture in northern part of Vietnam, which was reported at the Forestry Conference held in Bac Kinh in 1967, published in 1970.

According to Phung Ngoc Lan (2006), the biodiversity of the forests in Vietnam were ranked very high, not only in the region but worldwide. In terms of flora, apart from indigenous and endemic characteristics, Vietnam is the convergence of three plant migration streams from China, India - Himalaya, Malaysia - Indonesia and other regions, including temperate ones. The diversity of plant and animal species is a determining factor in the diversity of natural forest ecosystems of Vietnam. On the flora, Vietnam is also the convergence of three streams of plant 11 migration from China, India - Himalaya, Malaysia - Indonesia and other regions, including temperate besides indigenous and endemic species. According to Nguyen Nghia Thin (2008), Vietnam has around 19,357 plant species with 2524 genus and 378 families, 1600 fungus and other species.

Botanists predict the number of plants in Vietnam can be up to 25,000 species. Le Tran Chan (1997) has found out that in the above-mentioned species, around 15,000 species of vascular plants, some endemic species of Vietnam account for about 30% of plants in the north and about 25% of the total number of plants across the country, atleast 1,000 trees reach large size, 354 species of trees can be used for commercial timber production. The bamboo species in Vietnam is very abundant, about 40 species have commercial value. The abundance of species has given Vietnam's forests are of tremendous value in economics and science. According to the statics of the Institute of Pharmaceuticals (2003), 3,850 plants has now been discovered and used as herbal treatment. In addition, 76 species of myrrh trees, 600 species of trees for tanning, 500 species of trees and 260 species of plant oils to oil have been discovered.

3.3. Spatial structures of forest

3.3.1. Canopy cover

Burgman and Lindenmayer (1998) have found out that canopy cover is one of the most important features of forest structure. It also can be used to describe distribution and abundance of biomass.

Walker and Hopkins (1990) defined canopy cover asthe percentage of total area of a sample site covered by a vertical projection of the crown. A method for reporting cover of plants over 1.5-2m high estimated or measured. Crowns are treated as opaque. Generally used for the upper stratum.

There are distinct changes in canopy cover during stand development. For example, Franklin (2002) found out that canopy cover will increase from a low level at stand initiation, reaching a maximum at the stem exclusion period, then reducing as overstorey elements disintegrate and canopy gaps form during the old-growth stage.

Quantifying canopy cover is as a component of an index of forest structure for closed forests in Belgium with maximum score in their index for stands with 1/3 to 2/3 canopy cover (Van Den Meersschaut and Vandekerkhove 1998).

In North America, the average size of gaps and the distribution of gaps amongst size classes were all important attributes for distinguishing old-growth hemlock (*Tsuga Canadensis* (L.) Carr.) hardwood forests from earlier successional stages (Ziegler, 2000 and Tyrrell and Crow, 1994). Similarly, the number of trees with dead tops or broken crowns was a key attribute that distinguished between old-growth, mature and young stands in Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco) forests (Spies and Franklin 1991).

3.3.2. Density structure

To determine optimal density structure of the forest, Nguyen Ngoc Lung (1987) used three empirical equations. He represents nutrition space for *Pinus Kesiya* which was studied at Tay Nguyen province of Vietnam. This equation has form:

$$Gt = a + p.A \qquad (1)$$

Where:

Gt is the vertical projection of foliage;

A is the age of stand;

a, p are parameters

This equation is chosen to design reasonable forest density. This method is only suitable for pure (monoculture) forest. It is difficult to apply for uneven-aged mixed species forest.

Tran Van Con (1991) proposed application of mathematics simulation in investigation of dynamic nature forest, which is based on the correlation between total trees number and basal area of dry dipterocarp forests. The appropriate calculation of parameters for each type of forest structure is needed to determine the optimal density of the forest. The results of this investigation proved that Tay Nguyen dry dipterocarp forest is very thin and stand density is not high.

3.3.3. Stratification of forest structure

The forest structure influences the growth potential and future economic value of a forest (Knoebel and Burkhart 1991). Forest structure includes vertical and horizontal features (Maltamo, 2005). Vertical forest structure hasdifferent layers, which are described from the top to the bottom of forest stand (Bourgeron, 1983). The vegetation layers are stratified at different heights and diverse species in varied canopies (Whittaker, 1975). Therefore, vertical structure describes different tree species groups from tall to smaller trees such as dominant, upper canopy (codominant), lower canopy and understorey tree species as well as shrub and grasses layers (Richards, 1981; Njunge, 1996).

According to Kraft (1884) has distinguished for evergreen rain forest 5 storey:

A1 – Dominant

A2 – Co-dominant

A3 – Partly co-dominant

A4 – Intermediate

A5 – Suppressed

According to the report of Research Center on Forest ecology and Environment of Vietnam (2011), forest structure is divided with 5 storeys:

+ Upper storey (A1): Tree height of over 40 m belonging different families as Combretaceae, Dipterocarpaceae in addition to some common species as: *Dracontomelum duperreanum, Tetrameles nudiflora, Pometia pinnata, Anogeissus acuminata.*

+ Ecological dominant storey (A2): including trees with from 20 - 30m height and belonging to different families as: Fagaceae, Lauraceae, Caesalpiniaceae, Mimosaceae, Fabaceae, Sapindaceae, Magnoliaceae, Meliaceae and various *Hopea siamensis, Knema sp and Hopea sp*.

+ Lower storey (A3): including trees below 15m height and growth scateredly and belong 18 to various families as Clusiaceae, Ulmaceae, Annonaceae with many genus: *Pterospermum* sp, *Baccaurea ramiflora* and typical species as *Streblus ilicifolius*.

+ Bushes storey (B): including bushes, small trees below 8m height belonging to various families as Apocynaceae, Rubiaceae, Melastomataceae, Araliaceae, Euphorbiaceae and Acanthaceae, etc.

+ Fresh vegetation storey (C): including low plant below 2 m and belonging various families as Urticaceae, Zingiberaceae, Begoniaceae, Araceae, Acanthaceae. Other plants include liana of different families Vitaceae, Fabaceae, Connaraceae in addition to medlar-trees and parasitic plants of different families as Araceae, Loranthaceae.

3.4. The quantity of forest growth

3.4.1. Tree diameter

Tree diameter is the most important dimension of standing trees. Diameter at breast height is one of the most common measurements. There are three attributes as amongst the most important for characterizing wildlife habitat, ecosystem function and successional development in Douglas-fir forests (Spies and Franklin 1991).

Spies and Franklin (1991) has realized that diameter at breast height (DBH) usually increases with tree age and has been used to distinction between successional stages in Douglas-fir forests. Notwithstanding, although the old-growth stand had nearly twice the coefficient of variation in dbh compared to the young stand, old-growth and young stand of Douglas-fir had a similar mean dbh (Franklin et al; 1981).

Diameter at height breast is related to stand basal area. According to Kappelle et al (1996), stand basal area has been used to discriminate between primary and secondary Quercusforest in Costa Rica. Based on dbh, Berger and Peutmann (2000) have proved that stand basal area was important in explaining differences in herbaceous plant diversity which occurred between three types of aspen-conifer forest.

Acker et al, Van Den Meerschautt and Vandekerkhove (1998) found that the standard deviation of tree dbh is a measure of the variability in tree size, and it is considered indicative of the diversity of micro-habitats within a stand. For instance, the standard deviation of dbh was more useful than a measure of height diversity in discriminating between successional stages of Douglas-fir forests (Spies and Franklin 1991). Similarly, a Structural Complexity Index based on a three dimensional model of forest structure was significantly correlated with the standard deviation of dbh (Zenner 2000).

3.4.2. Tree height

According to Martin and Flewelling (1998) there are quantitative relationships between tree height and diameter. For example, Buongiorno et al (1994) has realized that some extent structural attributes associated with diameter may also serve as proxies for attributes associated with tree height. However, because the relationship between height and diameter is non-linear it is often more meaningful to use attributes directly associated with height when characterizing vertical elements of structure. For instance, Zenner (2000) found that the standard deviation of tree height will be more indicative of the vertical layering of foliage than the standard deviation of dbh.

Bebi et al (2001) and Means et al (1999) found that the simplest attribute associated with height is the height of the overstorey, which is readily derived from remotely sensed data, and according to Kappelle et al (1996), it is considered indicative of successional stage.

Zenner (2000) has realized that variation in tree height is considered as an important attribute of structure because stands containing a variety of tree heights are also likely to contain a variety of tree ages and species thereby providing a diversity of micro-habitats for wildlife. To quantify this type of variation in terms of a simple measure called structural richness, which was based on the number of height classes occupied by the trees in the stand (Sullivan et al; 2001).

The variation in tree height is more complex than structural richness, because it depends on the horizontal arrangement of the trees as well as the height of the trees (Svensson and Jeglum 2001). Thus,it should be used a three dimensional model of the position of trees to describe variation in tree height in terms of a structural complexity index (Zenner 2000).

3.5. Tree regeneration

Regeneration is the process by which trees and forests survive over time. Ayyappan and Parthasarathy (1999) have found out that the future composition of forests depends on the potential regenerative status of tree species within a forest stand in space and time. According to Dias (2004) has realized that unlike homogeneous plantations, management of natural forests relies largely on natural regeneration, where successful management therefore depends on good natural regeneration of valuable species. The regeneration potential of a species in a community can be from the population dynamics of seedlings and saplings in a community (Ashton and Hall, 1992; Uma Shankar, 2001). Saxena et al (1984) found that the regeneration status of trees can also be predicted by the age structure of their population.Streng et al (1989) and Schupp (1990) have found out that change in seedling composition in a stand is a result of changes among species through regeneration processes, such as seed production, dispersal and seedling emergence, survival and growth. Eilu and Obua (2005) found that successful management and conservation of natural forests require reliable data on regeneration trends.

- Natural regeneration

According to Bazzaz (1991), regeneration may be promoted by certain types of forest manipulation that can lead intentionally to new and more productive stages of forest growth. Ackzel (1994) has found that the natural regeneration of forest ecosystem is fundamental for evolution. Denslow (1987) found that the rate of establishment of diversity, distribution and composition of the regeneration depend on many factors. The light environment is one of the factors, which affects natural regeneration. The immediate effect of canopy opening is an increase in duration and intensity of direct sunlight to lower strata of the forest. The amount of sun radiation received by the gap depends on gap size, shape and orientation, local topography and the height of the surrounding forest. Lawton (1990) has realized that natural disturbance to forest canopies create broad varieties of opportunities for the growth of nearly by plants and establishment of new ones, largely by increasing the amount of light penetrating in to the forest interior. Different species are successful in growing up in gaps of different size; therefore, the size of gap has an important influence on species composition and their spatial arrangement in the forest. Gap size ranges from the tiniest gaps formed by natural death of trees in a natural forest to formation of large gaps created through intensive tree felling.

Different species respond differently to different intensity of canopy opening. Depending on the requirement of the species, some tree species which are light demanding can grow better on open area while others require shade for growing. Based on their characteristics tropical trees are divided crudely in to two: those which regenerate in the shade of the high forest and those which regenerate in gaps, known as respectively shade demanding, and light demanding in their early life.

According to Mengesha (1996), the retention of enough seed trees of good phenotype, well distributed through the stand is important for future sustainable productivity and for genetic resource conservation, where there are imbalances and inadequate levels of established seedlings and advance growth of desirable species and where there is an inadequate soil seed bank.

The number of germinating seeds depends on seed availability, seed quality and germination conditions. The forest environment and the dynamic nature of forest canopies provide many different regeneration niches to which different species have become specialized. Forest regeneration begins with the dispersal of seeds to sites suitable for germination. The dispersed seeds must be viable, encounter the light, moisture and temperature required for germination. The characteristics of the seed, together with nutrient relations and herbivore control, growth and reproduction affect the process of germination (Clack, 1986). Under natural forest environmental conditions different groups of species with different characteristics and growth requirements, collectively with form a forest environment that favors regeneration of different sets of species dominating in different stage of succession, interact and compete for the available resources. According to West (1981), the seed pool in the soil will generate mixtures of species with different floristic compositions, depending on the treatment received by the soil.

The life span of the seed also plays a significant role in the process of regeneration. Seed longevity is low in tropical trees, however, pioneer species have better longevity, as a result the forest seed bank is the major source of regeneration for the pioneer’s, than for late succession species. Whitmore and Burnham (1984) have realized that in contrast to pioneers, seeds of most primary species have short life span; therefore, germination of many pioneer and secondary species are trigger more by forest disturbance.

Some species are triggered by light intensity while others do better under shade. The inherited characteristics of seed physiology and morphology for example frequency and time of seed production, its nature of dispersal and the seed type/group (Orthodox and Recalcitrant seeds) influence germination. Some seeds may remain for a century in the soil seed bank until favorable environmental conditions for germination are met others deteriorates easily within few weeks or months. Generally the combination of all this factors results in success and failure of regeneration of different tree species. Regenerations of different species in the natural forest react differently under different environment.

3.6. The relationship between forest structure and hydraulic function

Forests play an important role in the protection of the world's water resource. Forests improve groundwater regeneration by slowing water absorption and release under vegetation cover. Soil erosion is also reduced by as much as 80-90% in closed forests. This regeneration ensures regular flow of water into streams and rivers, supplying water for hydropower plants, agricultural production and human life in the dry season.Forests are very important in reducing surface water flow and increasing infiltration. Watershed forests, especially natural forests with a multilayered canopy are very important in maintaining water flow rates during rainy seasons and in supplying water during dry seasons for local use, hydro-power generation and irrigation.Forests and forest plant roots also play role in reducing erosion and hence reduce the impairment of water quality due to sedimentation. Without forests, there would be increased run-off of rain water and with it topsoil erosion. For example, Krecmer (1982) found out that the total forest area in Czech Republic have 17% in protection zones for drinking water, about 27% is in mountain forests of headwater regions protecting foothills against floods and erosion.

Perina (1980) and Perina & Krecmer (1981) have divided forest types according to functional groups from the water conservation standpoint. Afterward, silvicultural measures specifically supporting and adapting wood production producers to water conserving activities are derived for each of these groups, which are the regulation of tree species composition, stand density, rotation length, methods of forest tending, methods of logging and haulage, density and quality of the forest road network (including logging roads), and forest amelioration (drainage, torrent control).

Reforestation also has effects on hydrology and erosion, for example eastern Raukumara Range, New Zealand. Reforestation appears to have reduced runoff by 30% (170 mm year-1) at c 200 m elevation (1350 mm year-1 rainfall) and by about 25% (400mm year-1) at 800 m elevation (c 2500 mm year-1 rainfall). For most of the year the soil profile under forest stands is substantially drier than it would have been under pasture. Under mature forest stands the annual period of high soil water content is about 3-4 months in winter, compared with 6-8 months under pasture cover (Swason, Bernier & Woodard, 1987).

The relationship between forest and waters is complex. Foster and Chilton (1993) found that forest cover influences groundwater levels, wells and springs, as well as safeguarding water quality. This statement is true for more than the humid tropics. The safest protection for groundwater is forest cover on its sources (Working Group on the Influence of Man on the Hydrologic Cycle; 1972).

4. Study area and Methods

4.1. Description of Study Sites

The study area is located in Hoa Binh province, northwestern Vietnam. The climate is tropical monsoon with an average annual temperature from 22.5 to 23.2^{o}C. The average annual precipitation is from 1300 to 2200 mm, with almost 85% of total annual rainfall falling between May to September. The average annual humidity is ranging 80–85%. The topography is complex with elevations from 300 to more than 2000 m above sea level. Only 19% of the land area have the elevations below 500 m; and 34% of the land area have the elevations higher than 1000 m. The complex topography is also illustrated with the various levels of land slopes. Only 3% of the land area have the slopes less than10^{o}; 54% of the land area have the slopes between 20 and 30^{o}; and 12% of the land area have the slopes of more than 30%.

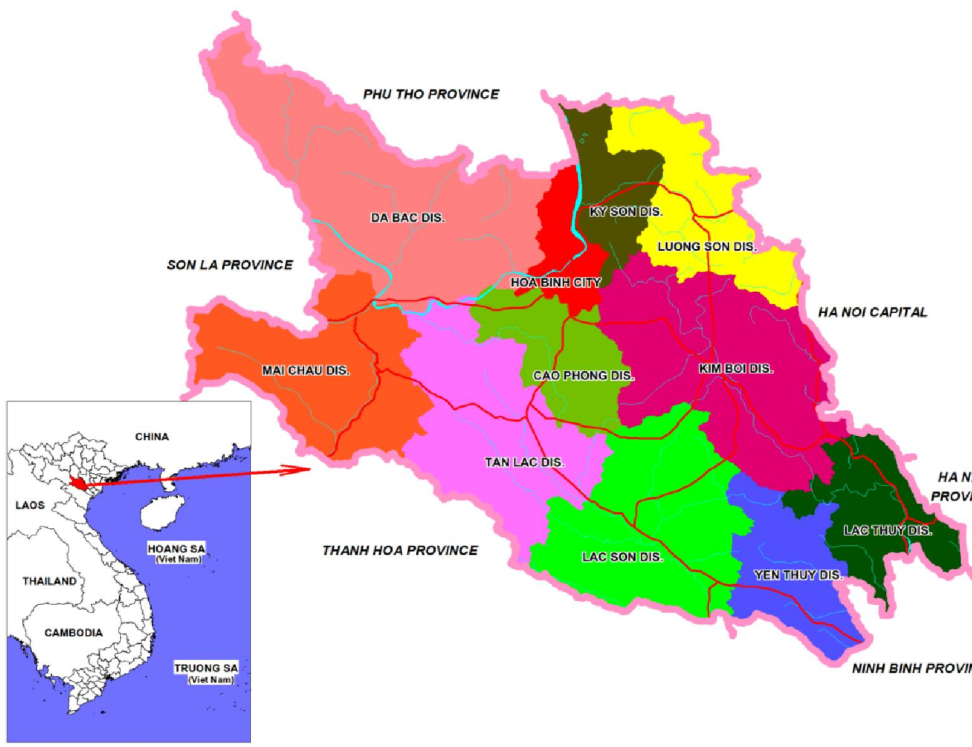


Figure 1: Study area

4.2. Method data collection

- Using sample plots:

The sample plots are distributed according to ecological conditions, vegetation and standing volume differences. Specific; sample plots are divided into two types of forest according to differences in forest standing volume and species diversity.

- Poor forest: 6 plots, each of 1000m^2 area.

- Medium Forest: 6 plots, each of 1000m^2 area.

Study on structural characteristics of upper tree layer of watershed forest

- Investigated upper tree layer:

+ Determining the tree species name.

+ DBH (diameter at breast height) of those with ($D_{1.3}$) ≥ 6cm: Diameter at breast height ($D_{1.3}$): Using diameter caliper to measure the diameter at breast height diameter with two direction West – East and North – South, then calculating the average values (accuracy level of caliper to 0.1 cm);

+ Tree height: Using Blumeleiss hypsometer (accuracy 0.1 m),

+ Measuring crown diameter (Dc): By measuring indirectly through its projection, using tape-line with accuracy 0.1 m in both directions West - East and North - South of all the trees in sample plots, then taking average value.

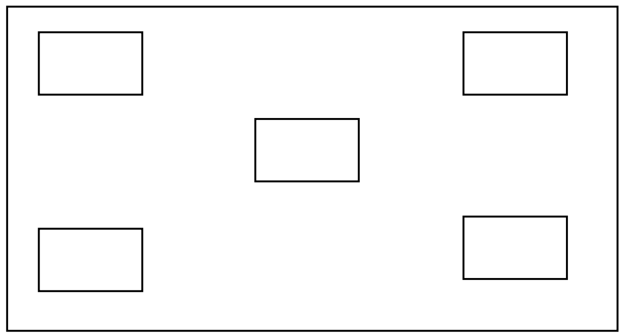
- Canopy of higher trees layer is determined by the method of point nets system:

+ Identify 100 points (positions) distributed evenly on sample plots

+ At each point, using a straight hollow cylinder with the length 0.8 - 1m, seeing up the vertical. If seeing the foliage, recording number 1. If not recording 0, the case of two intermediate above cases recording 0.5.

Study on regeneration

* Establish five small square plots inside each sample plots to investigating regeneration trees with area 25m^2 (5mx5m) . Each cell is arranged in the following diagram:



- Investigate indicator and recording the regenerated tree form.

- Name of regenerated tree species.

- Original of the regeneration (sprout, seeds).

- The height of regenerated trees.

- The growth of regenerated trees according to 3 levels: good (A), median (B), bad (C).

+ A good tree: The tree has a straight stem, symmetrical large crown, no pests, good growth.

+ A bad tree: the tree is diseased and it has bad growth.

+ Median tree is remaining trees.

4.3. Data analysis method

From the data obtained on the sample plots would to calculate based on Applied Informatics in the Forest (Ngo Kim Khoi, Nguyen Hai Tuat and Nguyen Van Tuan; 2001) and using excel software.

4.3.1. Upper tree layer structure

a, Determining species composition of upper tree layer

To determine species composition, the used method according to Daniel Marmillod (Dao Cong Khanh, 1996) is:

$$IV_i\% = \frac{\text{Ni\%+Gi\%}}{2} \qquad (2)$$

IV_i % is an important values indicator

Ni% is percent of the tree number of species i in the forest plant community

Gi% is percent according to sum of basal area of species i in the forest plant community

According to Daniel Marmillod, the tree species have IV_i %> 5%, is important in terms of ecology and presented in composition formula. On the other hand, according to Thai Van Trung (1970), in a forest stand, the tree species group occupy 50% of individuals total of upper tree layer that is considered dominant species groups, the species group have IV_i % > 50% is considered the dominant species group.

b, Diversity index evaluation:

Determining species diversity by using Shannon-Weiner diversity index:

$$H' = -\sum_{i=1}^{s} p_i * \ln p_i \qquad (3)$$

Where:

H' is the Shannon-Weiner index. The communitywhich has a higher index value is the more diverse

s is the number of species

pi is proportion abundance contributed by the i^{th} species to the total species

c, Density, higher tree layer canopy

- Density formula:

$$\text{N/ha} = \frac{n}{S} \text{ x } 10.000 \qquad (4)$$

Where:

n is total number of individuals in sample plot.

S is sample plot area.

- Canopy cover:

$$C = \frac{n_1}{n} \quad (5)$$

With C is canopy cover

n_1 is the number of points having foliage

n is total point investigation

d, The quanlity and quality data of forest growth

The quantity: $D_{1.3}$, H, S_D (Sandard deviation), S_D%, G, M are analysed by Excel software 2007.

4.3.2. The regeneration structure

- The regeneration structure

+ The regenerated tree composition

+ Identify the number of individuals of species i (ni)

+ Identify the total number of individual of all species (N)

+ Determine the rate of composition trees according to species, based on formula:

$$N_i = \frac{n_i}{N} x\ 100 \quad (6)$$

If $N_i \geq 5\%$, this tree species are present in the composition formula

If $N_i < 5\%$, this tree species are not present in the composition formula

+ The composition coefficient is calculated by formula:

$$Ki = \frac{ni}{N} x10 \quad (7)$$

Where: Ki is the composition coefficient of i^{th} species

ni is the number of individuals of species i

N is the total number of individuals of all species

- The density of tree regeneration

Regeneration density is determined by the formula:

$$N = \frac{10000}{\sum S_{sp}} x \sum n_{sp} \qquad (8)$$

Where: N is the density of tree regeneration

$\sum n_{sp}$ is total tree regeneration in the small square plots

$\sum S_{sp}$ is small square plots area

- The quality of regenerated tree

Research regeneration according to qualities: good trees, bad trees, average trees and determining potential regeneration trees.

To calculating regenerated trees proportion based on formula:

$$N\% = \frac{n}{N} X 100 \qquad (9)$$

Where: N%: The corresponding percentage of good trees, bad trees and median trees (%).

n: Number of tree good trees, bad trees and median trees, respectively.

N: The total number of trees.

- The potential regeneration trees belong to priority species groups with height > 1m, medium-quality or higher, seeds regeneration.

- The distribution regenerated trees according to height:

Statistics the number of tree regeneration according to five height levels: <0.5m; 0.5 - 1m; 1 – 1.5m; 1.5 – 2m; > 2m.

- The horizontal distribution of tree regeneration:

Estimating regeneration distribution of the species in plots is used Poisson standard:

$$\omega = \frac{S^2}{\bar{X}} \qquad (10)$$

Where:

$\bar{X}$ is the number of average tree regeneration on small square plots

$$\overline{X} = \frac{N}{n} \qquad (11)$$

Where:

N is the total number of trees in small square plots

n is the number of small square plots in a sample plot

S^2 is the variance, which is calculated according to number of trees

$$S^2 = \frac{\sum (Xi - \overline{X})^2}{n-1} \qquad (12)$$

Where:

Xi is the total number of trees in the small square plots i

+ ω> 1: aggregate distribution

+ ω< 1: regular distribution

+ ω = 1: Poisson distribution (random distribution)

5. Results and Discussion

5.1. Structure characteristics of upper tree layer

5.1.1. Species composition of the forests

There are many ways to calculate, simulate vegetation composition as composition formula according to the number of trees, basal area and yield. However, each method has advantages and disadvantages. Index IV% (Important Value) is used in the thesis to denote the composition formula for state forests in the study area. The result of species composition data is analyzed and summarized in the following Table 1:

Table 1: The species composition of upper tree layer

Forest Status	Sample plot	Composition formulas
Poor forest	1	2.124CI + 1.370LB + 0.955SH + 0.954CT + 0.595UK1 + 0.594LF + 3.408 other species (Σ 23 species in sample plot)
	2	0.997CB + 0.963SS + 0.759ER + 0.739LB + 0.734CP + 0.691MC + 0.595EP + 0.514ST + 4.010 other species (Σ 27 species)
	3	1.187ER + 0.989LB + 0.905MP + 0.698CI + 0.610ML + 0.600OB + 0.518FI + 4.493 other species (Σ 25 species)
	4	1.928ER + 1.292CP + 0.898SW + 0.725LP + 0.667CC + 0.555CI + 3.084 other species (Σ 20 species)
	5	2.163LB + 1.774MC + 1.006ER + 0.730MH + 0.724PP + 3.603 other species (Σ 19 species)
	6	2.075ER + 1.415CI + 1.262LB + 0.809AC + 0.594OB + 0.508MD + 3.336 other species (Σ 20 species)
Medium forest	7	0.998MH + 0.846DD + 0.782MD + 0.678MC + 0.671DS + 0.624PP + 0.517AT + 4.884 other species (Σ 31 species)
	8	0.752LF + 0.749LP + 0.738LB + 0.588EF + 0.568PP + 0.524LD + 6.080 other species (Σ 31 species)
	9	1.028PP + 0.922CL + 0.707PA + 0.619CT + 0.510OB + 6.213 other species (Σ 34 species)
	10	1.139LP + 1.054ER + 0.977LB + 0.638CC + 0.628PP + 4.793 other species (Σ 26 species)
	11	2.140ER + 1.488LB + 1.262AT + 0.818MC + 0.534PA + 0.517CA + 3.241 other species (Σ 20 species)
	12	1.058ER + 0.758LB + 0.639VM + 0.638SP4 + 0.581GC + 6.326 other species (Σ 30 species)

The name of tree species is presented on index

The results in Table 1 show that:

- In poor forest: The number of species in the sample plot is ranging from 20 – 27 species, in the composition formula have from 5 – 8 main species. The most important species in all six plots are *Engelhartia roxburghiana (ER), Castanopsis indica (CI), Lithocarpus bonnetii (LB)* which mainly contribute to the composition. In addition, there are some timber tree species with high value proportion such as *Madhuca pasquieri (MP), Cinamomum balansae (CB), Michelia hypolampra (MH)*…The species composition on sample plots are quite complex, appearing the light demanding species as *Liquidambar formosana (LF)* and shade tolerant tree species in the first stage such as *Diospyros sylvatica (DS), Syzygium wightianum (SW)*...That shows one part of poor forest status is going move to stable status. Furthermore, the survey also shows a lot of trees are flowering period as *Sterculia alata (SA), Liquidambar formosana (LF)* and some species is belonged family *Cinamomum*, *Apocynaceae*, *Caesalpinioideae*... This result is demonstrated high germination ability of upper tree layer.

- In medium forest: The most dominant species in all six plots are similar with poor forest status such as *Engelhartia roxburghiana (ER), Castanopsis indica (CI), Lithocarpus bonnetii (LB)*. However, the most imported phenomenone is the number of species in this plots which are much higher than in poor forest status, having from 20 - 34 species, specific in plots: 7, 8, 9 and 12 having more than 30 species. The main species is involved in composition formula ranged from 5 - 7 species. There is less one species than in poor forest. Due to this forest status it has been exploited several times but now thanks to the protection measures, forest are being restored with a lot of species having economic and protection value such as *Liquidambar formosana (LF), Peltophorum pterocarpum (PP), Manglietia conifera (MC)*...Most of this tree are large timber trees and can grow up to occupy main forest canopy, capable of developing into population which plays an important role into establishment of microclimate of forest if this species would be under suitable siviculture measures. In addition, these trees are of large diameter, dense canopy, strong root development, which reduce the possibility of erosion and having role in watershed protection in the study area.

Besides the main timber trees, the supporting trees is one of the important component involved in the forest canopy. These trees haven't large economic value but it has an important role in protection, supporting the main species and regeneration trees during growth and developing such as *Cratoxy maingayi (CM), Cryptocarya lenticellata (CL), Knema pierrei (KP), Wrightia tomentosa (WT)...*

However, in both these forest status mostly trees composition have low economic value, not enough for economic and protection goal. Therefore, to maintaining stable forest structure and promoting protection capacity, it is necessary to establish specific impact measures. This is an important goal that we need to make to enhancing water protection capacity of forest.

5.1.2. Species diversity index

From the collected data, using species diversity index of Shannon-Weiner to calculate, the results are summarized in the following Table 2:

Table 2: Shannon-Weiner diversity index of upper tree layer

Forest Status	Sample Plot	H'
Poor forest	1	2.785
	2	3.064
	3	3.026
	4	2.636
	5	2.576
	6	2.682
Medium forest	7	3.281
	8	3.276
	9	3.339
	10	2.967
	11	2.711
	12	3.295

The result in Table 2 is shown that the species diversity index in medium forest is higher than poor forest.The Shannon-Weiner diversity index is dependent on sample size and species dominant level. In medium forest, the number of species and dominant species are higher than in poor forest. This is the reason why their diversity index is higher. Thus, in poor forestit needs to adjust composition structure to increase abundance species.

5.1.3. The density and cover canopy of both types of forest

The research results of density and canopy cover are summarized in the following Table 3:

Table 3: Density and cover canopy of upper tree layer

Forest status	Sample plots	Density (N) (tree/ha)	Cover Canopy (C)
Poor forest	1	520	0.56
	2	530	0.63
	3	510	0.58
	4	580	0.60
	5	580	0.67
	6	530	0.64
	Average	542	0.61
Medium forest	7	560	0.58
	8	590	0.61
	9	570	0.65
	10	550	0.71
	11	600	0.62
	12	560	0.63
	Average	572	0.63

The result in Table 3 is shown that:

Density: The density of both study forest statusis not varying too much, from 510 - 600 trees/ha. The highest density has the sample plots 11 of medium forest status with 600 trees/ha and the lowest density has the sample plots 3 of poor forest with 510 trees/ha. The average density of poor forest are 542 trees/ha. The average density of medium forest statusis 572 trees/ha, it is higher than the poor forest by 30 trees. This density has shown that both the forest status have rather low density, therefore; we need to increase the forest density for ensuring watershed protection forest.

Cover canopy: Using point nets system, it is obtained the results: in all 12 sample plots of two forest status, there are9 plots with cover canopy more than 0.6. This cover canopy isgood enough for watershed protection forest. There are only 3 sample plots (1; 3 and 7) which have cover canopy lower than 0.6. We need to increase cover canopy on these three plots to ensure water source protection capacity of forest.

5.1.4. The quantity of the forest growth

The results of some quantity indicators such as average diameter, average height, total basal area, volume, growth forest are presented in the following Figures 2; 3; 4 and Table 4:

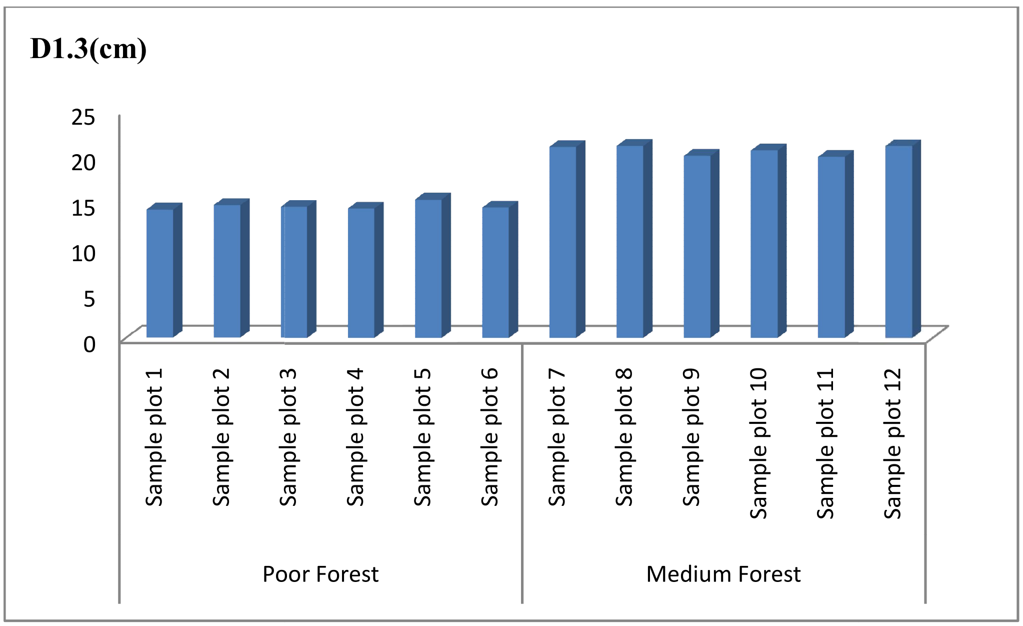


Figure 2: The average diameter on investigated plots belonging to two types of forest

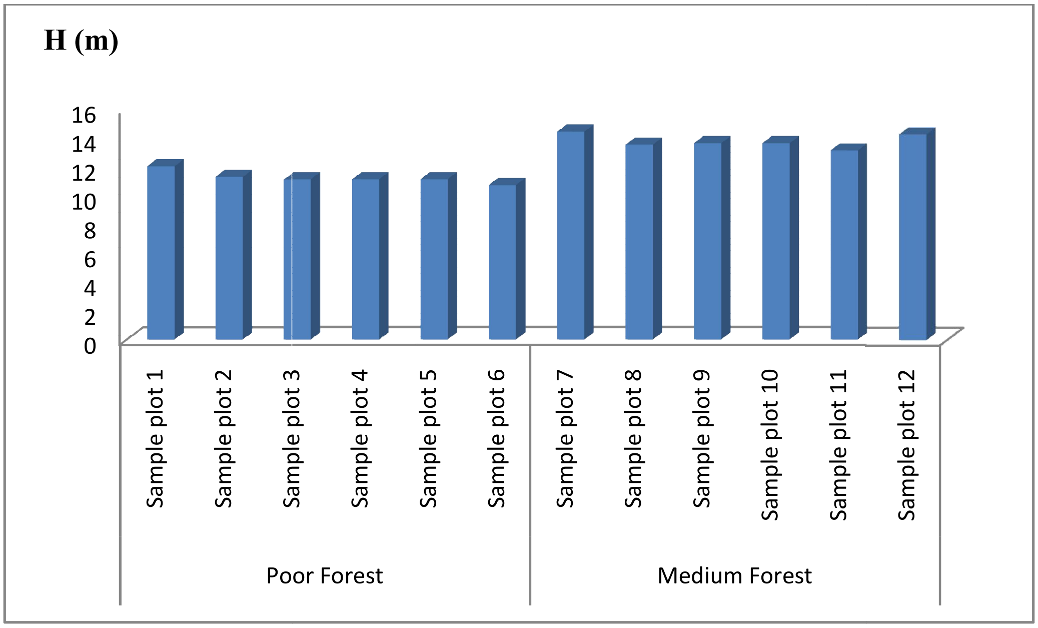


Figure 3: The average height on investigated plots belonging to both types of forest

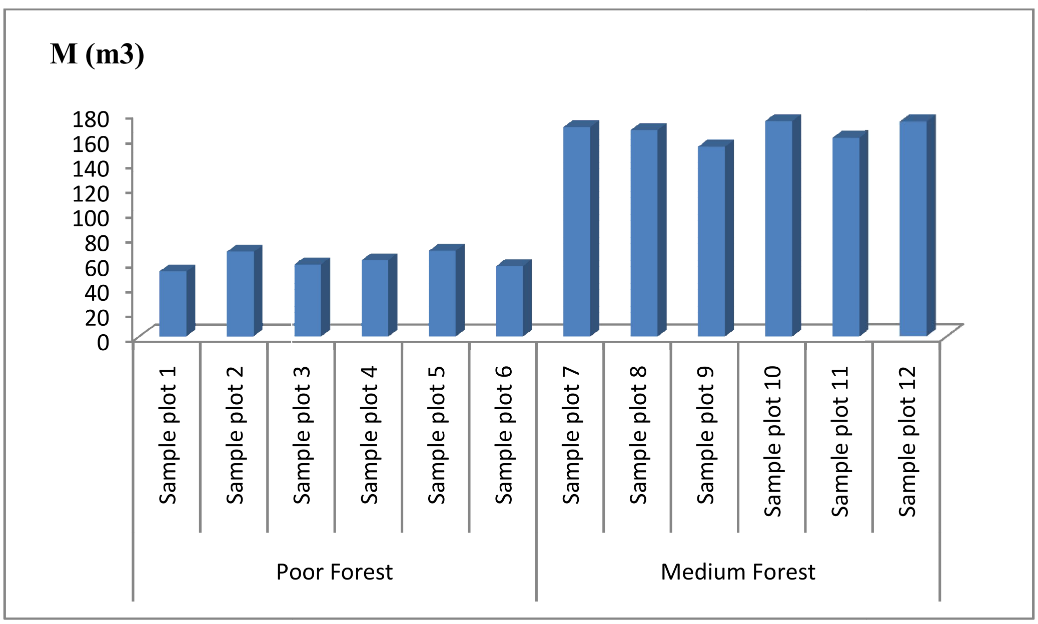


Figure 4: The volume on investigated plots belonging to both types of forest

Table 4: The growth data for sample plots belonging to both types of forest

Indicator	**Type of Forest**													
	Poor Forest							**Medium Forest**						
	Sample plot 1	*Sample plot 2*	*Sample plot 3*	*Sample plot 4*	*Sample plot 5*	*Sample plot 6*	***Average***	*Sample plot 7*	*Sample plot 8*	*Sample plot 9*	*Sample plot 10*	*Sample plot 11*	*Sample plot 12*	***Average***
$\overline{D_{1,3}}$ *(cm)*	14.10	14.60	14.40	14.20	15.20	14.30	**14.47**	21.00	21.10	20.00	20.60	19.90	21.00	**20.60**
S_D	4.60	8.14	6.43	5.99	7.70	6.08	**6.49**	9.09	9.04	9.80	10.95	9.87	10.04	**9.80**
$S_D\%$	32.62	55.75	44.65	42.18	50.66	42.52	**44.73**	43.29	42.84	49.00	53.16	49.60	47.81	**47.62**
$\overline{H}$ *(m)*	12.0	11.30	11.10	11.10	11.10	10.70	**11.22**	14.40	13.50	13.60	13.60	13.10	14.20	**13.73**
S_H	2.04	2.12	2.58	2.33	2.29	2.47	**2.30**	4.01	2.81	2.72	3.50	3.21	3.33	**3.26**
$S_H\%$	17.00	18.76	23.24	20.99	20.63	23.08	**20.62**	27.85	20.81	20.00	25.74	24.50	23.45	**23.73**
G (m^2/ha)	8.93	11.47	9.88	10.76	13.18	9.97	**10.70**	22.92	24.57	22.07	26.63	23.09	23.71	**23.83**
M (m^3/ha)	52.28	68.56	58.07	61.58	69.01	56.80	**61.05**	168.88	166.42	152.94	173.70	160.23	172.64	**165.80**

The results in the Table 4 and from Figures 2; 3; 4 have shown that the growth in both forest status is clearly different.

In poor forest: $\overline{D_{1.3}}$is ranging from 14.10 to 15.20 cm. The average is 14.47 cm. The diameter variation coefficient is ranging from 32.62 to 55.75%, it means large diameter variation between trees in the sample plot. $\overline{H}$ is from 10.70 – 12.00m. The average is 11.22m. The height variation coefficient is from 17.00 to 23.24%, it means the trees height in sample plot are small variance. The total basal area is from 8.93 – 13.18 m^2/ha. The average is 10.70 m^2/ha. The average volume is 61.05 m^3/ha.

The medium forest: $\overline{D_{1.3}}$ and $\overline{H}$ are higher than poor forest status.The average diameter is 20.62cm. It is higher than diameter of the poor forest status by 6.15cm. The average is 13.73m. The diameter and height variation coefficient are larger than poor forest status. The total basal area is ranging from 22.07 – 26.63m^2/ha. The average is 23.83m^2/ha. The average volume is 165.80 m^3/ha.

The diameter and volume in both types of forest are quite low compared to European forest. These are mixed secondary forest impacted by human inappropriate activities. Now the forest is recovering. The poverty people who live nearly forest, earning money by illegal logging. The trees in forest are mostly small trees, the big trees are harvested.

5.2. Regeneration characteristics of watershed protection forest

Study on regeneration characteristics shows the actual forest development, as well as the potential development in the future. The forest regeneration characteristics effects also the appropriate silviculture technique, which develops sustainability both economic, environment and biodiversity.

5.2.1. The composition of tree regeneration

The composition of tree regenerationcreates the composition of the future forest if the ecological condition is favorable for the growth of given tree species. It is an indicator reflecting the appropriate level forforest management purpose. On the other hand, the regeneration research is supporting sustainable management and appropriate use of forest resource.

The collected data on 60 small sample plots of two forest status are summarized in following Table 5:

Table 5: The tree regeneration composition on sample plotsin both types of forest

Forest status	Sample Plot	Composition Formula
Poor Forest	1	1.536LB + 1.250CL + 0.938KP + 0.938UK5 + 0.625EP + 0.625SA + 2.813 other species (Σ 16 species)
	2	1.429GO + 1.429CP + 1.143AC + 0.857LB + 0.857VM + 0.571CL + 0.571SW + 3.143 other species (Σ 18 species)
	3	1.515ER + 1.515LB + 1.212CP + 0.909MP + 0.909LY+0.909CM + 0.909CI + 2.121 other species (Σ 14 species)
	4	1.250CC + 0.938MP + 0.938LB + 0.625CI + 0.625ST + 0.625CL + 5.00 other species (Σ 22 species)
	5	1.316MC + 1.053ER + 0.789MH + 0.789EP + 0.789LB + 0.789SA + 0.526SM + 0.526SS + 0.526PA + 2.895 other species (Σ 19 species)
	6	1.538GS+1.538CI+1.282CT+1.282CP+1.282LD+1.026IC+0.769LB+0.513 OB+0.513FR+0.256 other species(Σ 10 species)
Medium Forest	7	1.538CI + 1.026MC + 0.769LB + 0.769AC + 0.769SW + 0.513TO + 0.513DS + 3.077 other species (Σ 20 species)
	8	1.750CT + 1.250SA + 1.000CP + 0.750CT + 0.500PP + 4.750 other species (Σ 24 species)
	9	1.628LB + 1.163OB + 1.163ER + 0.930CI + 0.698CC + 0.698AC + 0.698ML + 4.186 other species (Σ 20 species)
	10	1.389LB + 1.111VM + 0.833 MC + 0.833EP + 0.556GS + 4.167 other species (Σ 21 species)
	11	1.351AT + 1.081PP + 1.081BJ + 0.811SA + 0.541ML + 0.541CI + 0.541DD + 4.054 other species (Σ 22 species)
	12	1.707SW + 0.976MA + 0.976LB + 0.732MP + 0.732PP + 0.732GC + 4.146 other species (Σ 21 species)

The name of tree species is presented on index

The result in Table 5 has shown that:

- In poor forest: The number of regeneration tree species is ranging from 10 to 22 species. There is from 6 to 9 species which involved in composition formula. The number of regeneration tree is less than the number species of upper tree layer. However, almost regeneration trees species is presented in the upper trees layer in the future. Althought some species in small sample plot haven't presented in upper trees layer composition, this species have present in regeneration tree composition formula such as: *Litsea yunnanensis (LY), Sterculia tonkinensis (ST), Gironniera subaequalis (GS)...* The composition of tree regeneration is complex. There are several dominant species in almost plots as *Lithocarpus bonnetii (LB), Engelhartia roxburghiana (ER), Castanopsis indica (CI)*, but the species's coefficient is different each other.

- In medium forest: The number of regeneration tree species is ranging from 20 to 24 species. There is from 5 to 8 species, which involved in composition formula. There are different in composition formula of both forest states. In the medium forest state, there are some dominant species as *Syzygium wightianum (SW), Vernicia motana (VM), Prunus arborea (PA)...*

In summary, the species composition of timber trees species and regeneration trees are similar each other. Therefore, we can apply regeneration measure to restore original forest. The number of tree species is abundant in composition formula. This is proved that mother tree have germination capacity for next generation.

5.2.2. Species diversity index of tree regeneration

From the collected data, using species diversity index of Shannon-Weiner to calculate, the results are summarized in following Table 6:

Table 6: Shannon-Weiner diversity index of tree regeneration on investigated sample plots

Forest Status	Sample Plot	H'
Poor Forest	1	2.575
	2	2.670
	3	2.441
	4	2.956
	5	2.787
	6	2.195
Medium Forest	7	2.779
	8	2.891
	9	2.711
	10	2.830
	11	2.892
	12	2.802

The result in Table 6 has shown that the species diversity index in medium forest is higher than in poor forest but is the differences are not big. The Shannon-Weiner diversity index is dependening on sample size and species dominant level. In medium forest, the number of species and dominant species are higher than poor forest. This is the reason their diversity index is higher. Thus, in poor forest it is needed to adjust composition structure by increasing abundance species.

5.2.3. The quality and original regeneration

The tree quality regeneration are aggregated results of interaction of trees between each other of forest trees with site conditions. The regeneration capacity are evaluated according to criteria in density, quality, regeneration original and prospects of regenerated trees. The survey result is summarized in the following Table 7:

Table 7: The quality and regeneration origin on sample plots in two types of forest

Forest Status	Sample Plot	N/ha (tree/ha)	Quality Proportion (%)			Origin			
			Good	Median	Bad	Seed	%	Sprout	%
Poor forest	1	2560	31,25	62.50	6.25	1840	71.88	720	28.12
	2	2800	25.71	65.71	8.57	2000	71.43	800	28.57
	3	2640	33.33	57.58	9.09	2080	78.79	560	21.21
	4	2560	33.33	60.00	6.67	1840	71.88	720	28.12
	5	3280	31.58	55.26	13.16	2240	73.68	800	26.32
	6	3120	20.51	66.67	12.82	2320	74.36	800	25.64
	Average	2827	29.29	61.29	9.43	2053	73.67	733	26.33
Medium forest	7	3120	33.33	53.85	12.82	2240	71.79	880	28.21
	8	3200	38.24	73.53	5.88	2720	85.00	480	15.00
	9	3440	41.18	76.47	8.82	2960	86.05	480	13.95
	10	2880	33.33	63.89	2.78	2240	77.78	640	22.22
	11	2960	37.84	56.76	2.40	2560	86.49	400	13.51
	12	3280	34.15	56.10	9.75	2720	82.93	560	17.07
	Average	3147	36.67	64.05	7.61	2573	81.67	573	18.33

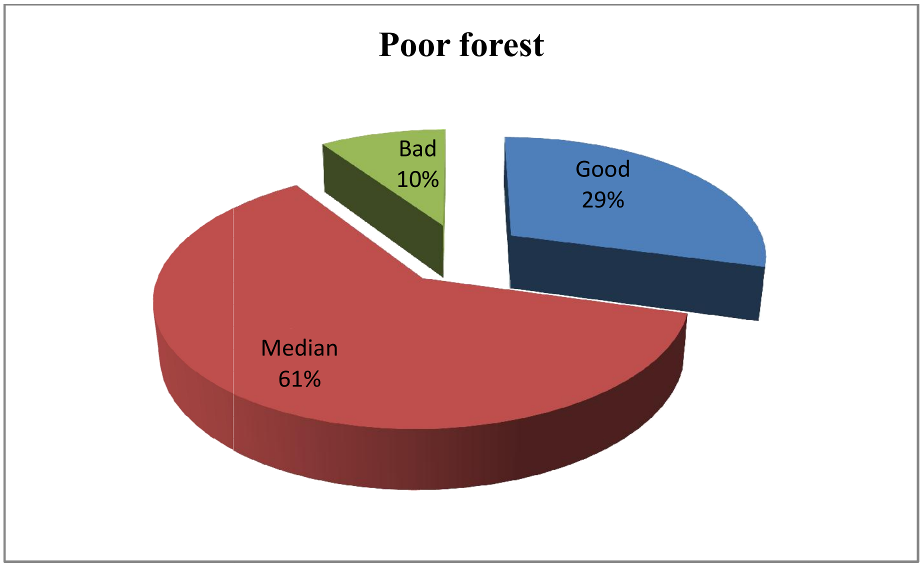


Figure 5: The rate of quality in poor forest

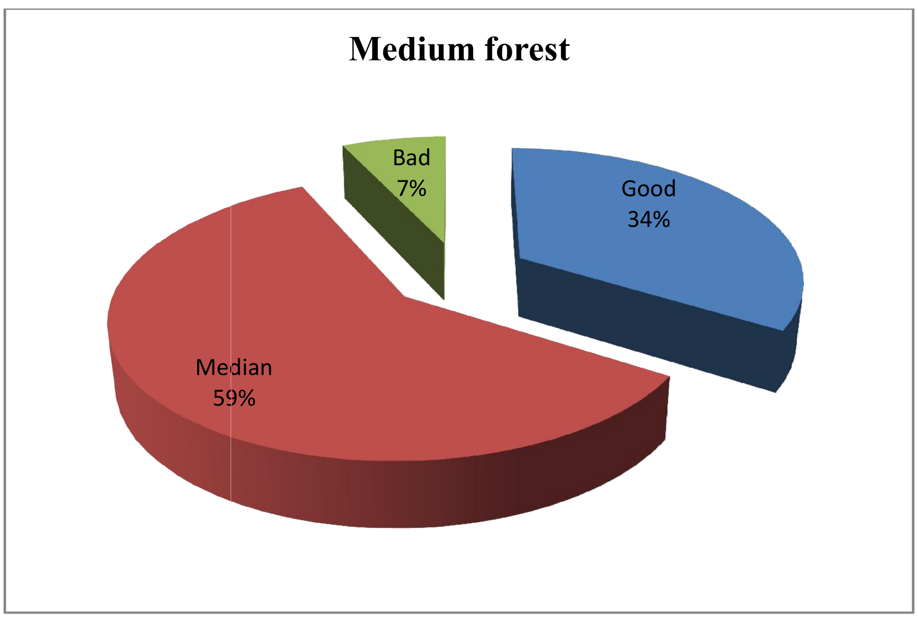


Figure 6: The rate of quality in medium forest

The result in Table 7 has shown that the regeneration capacity of study area is quite lengthy. The regeneration density in both typesof forest are low. The average tree density of poor forest is 2827 tree/ha and in medium forest is 3147 tree/ha.

The quality of regeneration:

- In poor forest: The good quality regenerated tree is ranging from 20.55% to 33.33%, medium quality from 55.26% to 66.67%, bad quality from 6.25% to 13.16%. Thus, the majority of tree regeneration are good and medium quality, which is favorable for regeneration process and restoration forest.

- In medium forest: The percentage of tree regeneration of good and medium quality are raising. The proportion of bad quality of tree regeneration is reduced. It shows that tree regeneration of medium forest is more favorable than poor forest status.

- Original of tree regeneration:

Both of forest status are originally from seed. In the poor forest status with 73.67% is original from seed and 26.33% from sprout. In the medium forest status with 81.67% is original from seed. This characteristic is very favorable for restoration forest in the future. The trees which are from seed will be more resistant to the disadvantage conditions of external environment much better than those regeneratedby sprout.

In summary, the rate of regeneration of two forest status is quite good quality. Most of the tree regeneration are originally from seeds. This is a favorable condition for forest succession in the future because the seeds regeneration are adapted better than sprout regeneration.

5.2.4. Tree regeneration distribution according to height

The data from small sample plots are analyzed and the result are given in the following Table 8:

Table 8: The regeneration density according to tree height level in both forest status

Forest Status	Sample Plot	N/ha (tree/ha)	The number of tree regeneration				
			< 0.5m	0.5 – 1m	1 – 1.5m	1.5 – 2m	>2m
Poor Forest	01	2560	0	400	880	560	720
	02	2800	0	240	880	1200	480
	03	2640	160	480	480	800	720
	04	2560	80	160	960	800	560
	05	3280	160	400	640	1120	720
	06	3120	80	400	1040	640	960
	Average	**2827**	**80**	**347**	**813**	**853**	**693**
	Rate (%)		**2.83**	**12.26**	**28.77**	**30.19**	**24.53**
Medium Forest	07	3120	160	400	720	960	880
	08	3200	80	720	960	800	640
	09	3440	240	560	800	1120	720
	10	2880	0	240	880	1280	480
	11	2960	80	480	720	1120	560
	12	3280	160	560	960	960	640
	Average	**3147**	**120**	**493**	**840**	**1040**	**653**
	Rate (%)		**3.81**	**15.68**	**26.69**	**33.05**	**20.76**

The result in Table 8has shown that: Both of two forest status, the number of tree regeneration is mainly accuring into two height levels 1 – 1.5 m and 1.5 - 2 m. In this height level, tree regeneration has been able to compete with other species for growth and development.

- In poor forest: At the height from 1 – 1.5 m, the tree regeneration density is ranging from 480 to 1040 trees/ha, an average 813 trees/ha (accounting for 28.77% of the total number of seedlings). At the height from 1.5 - 2 m, the tree regeneration density is ranging from 560 - 1200 trees/ha, an average 853 trees/ha (accounting for 30.19% of the total number of seedlings). It is shown that in two height level the number of tree regeneration had the high percentage up to 58.96%.

- In medium forest: At the two height levels 1 – 1.5 m and 1.5 - 2 m, the number of tree regeneration had also high percentage up to 59.74%. This is the main tree layer, which involved into forest composition in the future. It is noted that this object will impact to forest regeneration structure.

5.2.5. The regeneration density and rate of potential regeneration

The density is one of the most important characteristic of the population. It is one of the important indicator to evaluate the prospects of forest and choice the measure to ensure the rapid forest restoration. The potential tree regeneration is belong to priority species groups with height > 1m, medium-quality or good quality and from seed. The survey results are summarized in the following Table 9:

Table 9: The regeneration density and rate of potential regeneration in both types of forest

Forest Status	Sample Plot	N/ha (tree/ha)	The potential regeneration	
			N/ha (tree/ha)	Rate (%)
Poor Forest	**01**	2560	2160	84.38
	02	2800	2560	91.43
	03	2640	2000	75.76
	04	2560	2320	90.63
	05	3280	2480	75.61
	06	3120	2640	84.62
	Average	**2827**	**2360**	**83.74**
Medium Forest	07	3120	2560	82.05
	08	3200	2400	75.00
	09	3440	2640	76.74
	10	2880	2640	91.67
	11	2960	2400	81.08
	12	3280	2560	78.05
	Average	**3147**	**2533**	**80.77**

The results in Table 9 has shown:

- In poor forest: The tree regeneration density is ranging from 2560 - 3280 trees/ha. The highest density is in sample plot 5 with 3280 trees/ha and the lowest density is in sample plots 1 and 4 with 2560 trees/ha. The rate of potential regeneration tree is high from 75.61 to 91.43%.

- In medium forest: The tree regeneration density is ranging from 2880 - 3440 trees/ha. The highest density is in sample plot 9 with 3440 trees/ha and the lowest density is in sample plot 11 with 2880 trees/ha. The rate of potential regeneration tree is also high from 75.00 to 91.67%.

Overall, the results of the regeneration density study and regeneration rate in both of two status had high density. However, the rate of potential regeneration in the medium forest is lower than the poor forest. The reason is the coverage of vegetation in medium forest is higher than poor forest. The survey results of regeneration is shown that almost tree regeneration is light demanding species and some shade tolerant species in the early stages. The light is a main factor that affect to regeneration processing. When the cover of vegetation is high, the light competition of tree regeneration is also rapid increasing specially with light demanding species.

5.2.6. The horizontal distribution of tree regeneration

A typical characteristic of tree regeneration is not regular distribution on the ground. It creates gaps lack of tree regeneration and showing by the results of distribution regeneration trees on the horizontal plane. The study on tree regeneration distribution is very important to using suitable measures according to development goals. The tree distribution on the ground is depend on silvicultural characteristics of species, nutrition space and natural seedling resources. Therefore, the research of tree regeneration distribution is the basis to propose suitable silviculture method to promote regeneration better. The results of test tree regeneration distribution are summarized in following Table 10.

Table 10: The horizontal distribution of tree regeneration

Forest Status	Sample Plot	N/ha (tree/ha)	$\overline{X}$	S^2	ω	Type of distribution
Poor Forest	01	2560	6.4	13.	0.203	Regular
	02	2800	7.0	8.8	1.250	Aggregate
	03	2640	6.6	1.3	0.197	Regular
	04	2560	6.4	9.3	1.297	Aggregate
	05	3280	7.6	5.3	0.697	Regular
	06	3120	7.8	7.2	0.923	Regular
Medium Forest	07	3120	7.8	14.7	1.885	Aggregate
	08	3200	8.0	9.0	1.125	Aggregate
	09	3440	8.6	11.3	1.314	Aggregate
	10	2880	7.2	4.7	0.653	Regular
	11	2960	7.4	8.4	1.128	Aggregate
	12	3280	8.2	10.2	1.244	Aggregate

The results in the Table 10 has shown that:

- In poor forest: 2/3 sample plots having regular distribution, only 2 sample plots(plot 2 and 4) is aggregated tree distribution.

- In medium forest: 5/6 sample plots having cluster distribution, only sample plots 10 is regular distribution.

Therefore, the silvicultural measures need to regulate regeneration distribution by creating regular distribution. The method can be used as thinning in areas having high density or growing tree in areas having low density to adjust regeneration distribution more regular.

5.3. Proposal species composition of forest and impacted solution

The identification of purpose tree species is based on two forest status (poor forest and medium forest) of protective forest system at Hoa Binh province. The main purpose in species selection is how to select the highest protection capacity to ensure requirements of watershed protection forest. However, we also have to focus on the economic value. It is an important contribution of forest tree that ensuring for living of people who live nearly forest because they will affect to the survival of the forest.

To reach the goal, the species is chosen have to ensuring some criteria:

+ Suitable with the ecological condition of the watershed and can be contribution to create the watershed protection forest.

+ Perennial tree with deep root, thick foliage and evergreen.

+ The tree can be tolerant drought condition, living on steep hillslope, complex terrain and poor nutrient soil.

+ Multi-effects, capable of providing products to increasing income but do not affect the protective capacity.

Based on this standard and combination with available species data of two forest states and based on local conditions (rainfall, climate, land...). The species is chosen divided into two main group:

Group1: The tree species is selected, which is dominant species, having economic value and involved in composition formula in both types of forest. Tree species are adapted to the condition of the study area and they comply enough to the watershed protection forest standards.

Group2: tree species are adapted to the condition of the study area but they have just some standard of the watershed protection forest. For example, tree species is not having high economic value but having an important role in protection and support for dominant species can be accepted.

- To suitable with currently local condition, the thesis has suggested some solution:

+ Prohibit all activities destroy forest: people illegal logging, illegal land and conversion...

+ Felling bad tree and keeping good tree and dominant tree

+ Combine tree restocking in where is low density and tending tree

+ Protect seedings, purpose tree regeneration and maintaining native species

+ Watershed protection forests should be established with multiple layers and to contribute to biodiversity conservation. Protection forest is mainly to be based on natural regeneration

+ Forest protection and conservation must be based on the development principle, which creates conditions for forest owners and local people to engage in forest protection and development activities in order to make legitimate income on forestry activities.

5.4. Discussions

The most significant contribution of forest to the hydrological balance of watershed ecosystems is in maintaining high-quality water. Forests protect water by reducing surface erosion and sedimentation, enhancing precipitation. According to Swason (1987), forest canopy will intercepts rainfall, its fall slowing to the ground and the forest floor, which acts like an enormous sponge, typically absorbing up to 18 inches of precipitation (depending on soil composition) before gradually releasing it to natural channels and recharging ground water. For example,in Vietnam where meticulous studies have been carried out on rates of erosion at the local level, forest trees can reduce rates of erosion to around ten times less than on bare land (Do Dinh Sam, 2002). In this thesis, the average canopy cover in both types of forest is more than 0.6. This canopy value is suitable for forest watershed requirement.

Besides canopy cover, other structure factors are also effect to water quality such as density, growing stock, natural regeneration. The results of this thesis show that in upper tree layer, the stand density is ranging from 510 - 600 trees/ha. The average diameter is ranging from 14.1 cm to 21.1 cm. The height is ranging from 10.7m to 14.6m. The total basal area is from 8.93m^2/ha to 26.63m^2/ha. The growing stock is ranging from 52.28 m^3/ha to 173.70 m^3/ha. The growing stockis quite low compared to European forest. These reasons are mixed secondary forest, impacted by human. Now the forest is recovering. The tree in forest are mostly small trees, the big trees are harvested. These are major problem of study area in recovering forest structure to ensuring watershed protection capacity. According to two types of species selection criteria, the forest can be created from tree species having high economic value and still ensuring watershed protection capacity, combine with restocking in where is low density and tending tree.

In this study, tree regeneration composition is inherited from high tree layer. The number of regeneration species in medium forest is higher than in poor forest. Thus, the restoration capacity of medium forest can be better. The regeneration density in both of forest status is medium, ranging from 2560 – 3440 trees/ha. The rate of potential regeneration is quite high more than 2000 trees/ha. The quality of tree regeneration is high. Regeneration is mostly natural, from seed ranging from 71.43% to 86.49%. The tree regeneration is mainly composed of two layers in 1 – 1.5 m and 1.5 - 2 m. Tree regeneration is able to survive under these conditions where they have to compete with mature trees for nutrients and light. The horizontal distribution of seedlings is mostly aggregated trees distribution. Tree regeneration characteristics have shown the forest development currently, as well as the potential development in the future. Hence, protection and tending trees for seedlings should be focused because these trees are future generation to recovering forest better.

6. Conclusions

This study shows that both of forest types have abundant species. The composition of upper tree layer as well as the tree regeneration are mostly formed by light demanding species. According to the structure characteristics it can be made the species selection which ensure watershed protection and at the same time improving production of forest.

To reach the goal, the species are chosen to ensuring some criteria.The tree species which are selected, are dominant species and they are involved in composition formula in both types of forest . The tree species are adapted tothe ecological condition of the watershed areas and therefore they can contribute to the watershed protection forest. The species are perennial tree with deep root, thick foliage and they are evergreen. The tree can be tolerant to the local conditions, living on steep hillslope, complex terrain and poor nutrient soil. They have multi-effects, as they are capable of providing products to increasing income but do not decrease the protective capacity. Based on this standard and combination with available species data of two forest status and based on local conditions (rainfall, climate, land...) the selection of the best tree species is proposed.Thus, understanding species characteristics will help to improve forest cover for keeping water, control erosion and sedimentation in watershed areas in Hoa Binh.

However, due to limited time, this study were focused on two type of forest with large areas. In the future, we need to make research on other type of forest and combining it with study on the influence of terrain, soil and micro-habitat of tree regeneration to evaluate appropriate species within the local conditions.

7. References

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8. Appendix

Appendix 1: The tree species at Hoa Binh hydropower reservoir area in Vietnam

Tree Species	Species Symbol
Aglaia argentea	AA
Archidendron clypearia	AC
Artocarpus tonkinensis	AT
Bischofia javanica	BJ
Canarium album	CA
Cinamomum balansae	CB
Cullen corylifolium	CC
Castanopsis indica	CI
Cryptocarya lenticellata	CL
Cratoxy Maingayi	CM
Cinnadenia paniculata	CP
Canarium tramdeum	CT
Dracontomelon duperreanum	DD
Diospyros sylvatica	DS
Erythrophleum fordii	EF
Elaeocarpus petiolatus	EP
Engelhartia roxburghiana	ER
Ficus Sp	FI
Ficus racemosa	FR
Garcinia cowa	GC
Garcinia oblongifolia	GO
Gironniera subaequalis	GS
Ixonanthes chinensis	IC
Knema pierrei	KP
Lithocarpus bonnetii	LB
Lansium domesticum	LD
Liquidambar formosana	LF
Lithocarpus proboscideus	LP
Litsea yunnanensis	LY
Melia azedarach	MA
Manglietia conifera	MC
Manglietia dandyi	MD
Michelia hypolampra	MH
Melanorrhoea laccifera	ML
Madhuca pasquieri	MP
Ormosia balansae	OB
Prunus arborea	PA
Pterospermum pierrei	PP
Sterculia alata	SA
Schefflera heptaphilla	SH
Swietenia macrophylla	SM
Sapindus saponaria	SS
Sterculia tonkinensis	ST
Syzygium wightianum	SW
Trema orientalis	TO
Unkown1	UK1
Unkown5	UK5
Vernicia motana	VM
Wrightia tomentosa	WT

Appendix 2: The composition coefficient and diversity index of upper tree layer at sample plot 1

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Mallotus philippensis	1	0.0192	-0.0760	1.923	10	0.011	1.266	1.595	0.159
Garcinia oblongifolia	1	0.0192	-0.0760	1.923	10	0.005	0.563	1.243	0.124
Schefflera heptaphilla	5	0.0962	-0.2252	9.615	50	0.085	9.481	9.548	0.955
Engelhartia roxburghiana	1	0.0192	-0.0760	1.923	10	0.040	4.452	3.187	0.319
Castanopsis indica	10	0.1923	-0.3170	19.231	100	0.208	23.254	21.242	2.124
Neolamarckia cadamba	1	0.0192	-0.0760	1.923	10	0.053	5.944	3.934	0.393
Archidendron clypearia	1	0.0192	-0.0760	1.923	10	0.013	1.486	1.705	0.170
Phyllanthus fasciculatus	1	0.0192	-0.0760	1.923	10	0.006	0.712	1.318	0.132
Phyllanthus fasciculatus	1	0.0192	-0.0760	1.923	10	0.011	1.266	1.595	0.159
Cryptocarya chingii	1	0.0192	-0.0760	1.923	10	0.005	0.563	1.243	0.124
Cryptocarya lenticellata	1	0.0192	-0.0760	1.923	10	0.014	1.603	1.763	0.176
Polyathia juncuda	2	0.0385	-0.1253	3.846	20	0.032	3.581	3.714	0.371
Cullen corylifolium	1	0.0192	-0.0760	1.923	10	0.005	0.563	1.243	0.124
Cinamomum tonkinensis	5	0.0962	-0.2252	9.615	50	0.085	9.466	9.541	0.954
Syzygium samarangense	1	0.0192	-0.0760	1.923	10	0.006	0.712	1.318	0.132
Sterculia lanceolata	2	0.0385	-0.1253	3.846	20	0.017	1.875	2.861	0.286
Liquidambar formosana	3	0.0577	-0.1646	5.769	30	0.055	6.114	5.941	0.594
Lithocarpus bonnetii	6	0.1154	-0.2492	11.538	60	0.142	15.868	13.703	1.370
Unknown1	3	0.0577	-0.1646	5.769	30	0.055	6.122	5.946	0.595
Unknown2	1	0.0192	-0.0760	1.923	10	0.020	2.251	2.087	0.209
Cratoxy Maingayi	1	0.0192	-0.0760	1.923	10	0.003	0.317	1.120	0.112
Wrightia tomentosa	2	0.0385	-0.1253	3.846	20	0.018	1.979	2.912	0.291
Syzygium wightianum	1	0.0192	-0.0760	1.923	10	0.005	0.563	1.243	0.124
Σ 23 species	52		2.785	100.000	520	0.893	100.000	100.000	10.000

Appendix 3: The composition coefficient and diversity index of upper tree layer at sample plot 2

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Sapindus saponaria	3	0.0566	-0.1625	5.660	30	0.156	13.597	9.628	0.963
Garcinia oblongifolia	3	0.0566	-0.1625	5.660	30	0.027	2.370	4.015	0.402
Microdesmis caseariaefolia	5	0.0943	-0.2227	9.434	50	0.050	4.380	6.907	0.691
Engelhartia roxburghiana	3	0.0566	-0.1625	5.660	30	0.109	9.512	7.586	0.759
Elaeocarpus petiolatus	3	0.0566	-0.1625	5.660	30	0.072	6.235	5.948	0.595
Lithocarpus fissus	1	0.0189	-0.0749	1.887	10	0.009	0.754	1.321	0.132
Castanopsis indica	1	0.0189	-0.0749	1.887	10	0.006	0.554	1.220	0.122
Symplocos laurina var.acuminata	1	0.0189	-0.0749	1.887	10	0.008	0.684	1.285	0.129
Cinnadenia paniculata	5	0.0943	-0.2227	9.434	50	0.060	5.246	7.340	0.734
Archidendron clypearia	1	0.0189	-0.0749	1.887	10	0.064	5.557	3.722	0.372
Knema pierrei	1	0.0189	-0.0749	1.887	10	0.052	4.558	3.223	0.322
Senna siamea	1	0.0189	-0.0749	1.887	10	0.009	0.828	1.357	0.136
Polyathia cerasooides	1	0.0189	-0.0749	1.887	10	0.011	0.985	1.436	0.144
Unknown3	1	0.0189	-0.0749	1.887	10	0.062	5.364	3.625	0.363
Ormosia balansae	1	0.0189	-0.0749	1.887	10	0.020	1.752	1.819	0.182
Cinamomum tonkinensis	1	0.0189	-0.0749	1.887	10	0.006	0.494	1.191	0.119
Syzygium samarangense	1	0.0189	-0.0749	1.887	10	0.014	1.247	1.567	0.157
Sterculia alata	1	0.0189	-0.0749	1.887	10	0.033	2.875	2.381	0.238
Lithocarpus bonnetii	6	0.1132	-0.2466	11.321	60	0.040	3.453	7.387	0.739
Melanorrhoea laccifera	1	0.0189	-0.0749	1.887	10	0.007	0.617	1.252	0.125
Wrightia tomentosa	1	0.0189	-0.0749	1.887	10	0.008	0.684	1.285	0.129
Canarium tramdenum	2	0.0377	-0.1237	3.774	20	0.007	0.631	2.203	0.220
Syzygium wightianum	3	0.0566	-0.1625	5.660	30	0.018	1.603	3.632	0.363
Vernicia motana	1	0.0189	-0.0749	1.887	10	0.029	2.528	2.207	0.221
Sterculia tonkinensis	1	0.0189	-0.0749	1.887	10	0.096	8.389	5.138	0.514
Nephelium cuspidatum	1	0.0189	-0.0749	1.887	10	0.009	0.828	1.357	0.136
Cinamomum balansae	3	0.0566	-0.1625	5.660	30	0.164	14.274	9.967	0.997
Σ 27 species	53		3.064	100.000	530	1.147	100.000	100.000	10.000

Appendix 4: The composition coefficient and diversity index of upper tree layer at sample plot 3

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Litsea glutinosa	1	0.020	-0.077	1.961	10	0.006	0.643	1.302	0.130
Litsea yunnanensis	1	0.020	-0.077	1.961	10	0.013	1.342	1.651	0.165
Mallotus philippensis	1	0.020	-0.077	1.961	10	0.006	0.643	1.302	0.130
Engelhartia roxburghiana	5	0.098	-0.228	9.804	50	0.138	13.929	11.867	1.187
Elaeocarpus petiolatus	2	0.039	-0.127	3.922	20	0.016	1.652	2.787	0.279
Castanopsis indica	3	0.059	-0.167	5.882	30	0.080	8.086	6.984	0.698
Lithocarpus proboscideus	2	0.039	-0.127	3.922	20	0.056	5.632	4.777	0.478
Michelia hypolampra	1	0.020	-0.077	1.961	10	0.028	2.867	2.414	0.241
Ficus Sp	2	0.039	-0.127	3.922	20	0.064	6.436	5.179	0.518
Lauraceae Sp	2	0.039	-0.127	3.922	20	0.049	4.987	4.454	0.445
Euphorbiaceae Sp	1	0.020	-0.077	1.961	10	0.013	1.342	1.651	0.165
Cinnadenia paniculata	2	0.039	-0.127	3.922	20	0.013	1.360	2.641	0.264
Chukrasia tabularis	2	0.039	-0.127	3.922	20	0.019	1.946	2.934	0.293
Choerospondias axillaris	1	0.020	-0.077	1.961	10	0.011	1.144	1.552	0.155
Knema pierrei	1	0.020	-0.077	1.961	10	0.053	5.368	3.665	0.366
Bischofia javanica	1	0.020	-0.077	1.961	10	0.004	0.447	1.204	0.120
ormosia balansae	4	0.078	-0.200	7.843	40	0.041	4.163	6.003	0.600
Cinamomum tonkinensis	1	0.020	-0.077	1.961	10	0.004	0.389	1.175	0.117
Dracontomelon duperreanum	1	0.020	-0.077	1.961	10	0.020	2.033	1.997	0.200
Madhuca pasquieri	6	0.118	-0.252	11.765	60	0.063	6.343	9.054	0.905
Lithocarpus bonnetii	4	0.078	-0.200	7.843	40	0.118	11.930	9.887	0.989
Melanorrhoea laccifera	2	0.039	-0.127	3.922	20	0.082	8.275	6.098	0.610
Cratoxy Maingayi	3	0.059	-0.167	5.882	30	0.040	4.082	4.982	0.498
Diospyros sylvatica	1	0.020	-0.077	1.961	10	0.043	4.386	3.173	0.317
Syzygium wightianum	1	0.020	-0.077	1.961	10	0.006	0.574	1.267	0.127
Σ 25 species	51		3.026	100.000	510	0.988	100.000	100.000	10.000

Appendix 5: The composition coefficient and diversity index of upper tree layer at sample plot 4

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Rauvolfia vietnamensis	1	0.017	-0.070	1.724	10	0.006	0.527	1.126	0.113
Garcinia oblongifolia	2	0.034	-0.116	3.448	20	0.048	4.414	3.931	0.393
Schefflera heptaphilla	2	0.034	-0.116	3.448	20	0.033	3.021	3.235	0.323
Engelhartia roxburghiana	11	0.190	-0.315	18.966	110	0.211	19.600	19.283	1.928
Elaeocarpus petiolatus	2	0.034	-0.116	3.448	20	0.012	1.087	2.267	0.227
Castanopsis indica	3	0.052	-0.153	5.172	30	0.064	5.932	5.552	0.555
Lithocarpus proboscideus	5	0.086	-0.211	8.621	50	0.063	5.874	7.247	0.725
Neolamarckia cadamba	1	0.017	-0.070	1.724	10	0.006	0.591	1.157	0.116
Sindora tonkinensis	1	0.017	-0.070	1.724	10	0.045	4.200	2.962	0.296
Cinnadenia paniculata	9	0.155	-0.289	15.517	90	0.111	10.317	12.917	1.292
Steblus macrophyllus	1	0.017	-0.070	1.724	10	0.038	3.530	2.627	0.263
Tamarindus indica	1	0.017	-0.070	1.724	10	0.045	4.200	2.962	0.296
Cryptocarya lenticellata	3	0.052	-0.153	5.172	30	0.022	2.078	3.625	0.363
Cullen corylifolium	2	0.034	-0.116	3.448	20	0.109	10.100	6.774	0.677
Syzygium samarangense	1	0.017	-0.070	1.724	10	0.051	4.742	3.233	0.323
Lithocarpus bonnetii	6	0.103	-0.235	10.345	60	0.082	7.622	8.984	0.898
Melanorrhoea laccifera	1	0.017	-0.070	1.724	10	0.012	1.139	1.432	0.143
Cratoxy Maingayi	1	0.017	-0.070	1.724	10	0.006	0.527	1.126	0.113
Syzygium wightianum	4	0.069	-0.184	6.897	40	0.107	9.907	8.402	0.840
Sterculia tonkinensis	1	0.017	-0.070	1.724	10	0.006	0.591	1.157	0.116
Σ 20 species	58		2.636	100.000	580	1.076	100.000	100.000	10.000

Appendix 6: The composition coefficient and diversity index of upper tree layer at sample plot 5

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Litsea glutinosa	2	0.034	-0.116	3.448	20	0.013	0.965	2.207	0.221
Microdesmis caseariaefolia	7	0.121	-0.255	12.069	70	0.309	23.417	17.743	1.774
Engelhartia roxburghiana	5	0.086	-0.211	8.621	50	0.152	11.498	10.059	1.006
Elaeocarpus petiolatus	2	0.034	-0.116	3.448	20	0.039	2.973	3.211	0.321
Lithocarpus proboscideus	2	0.034	-0.116	3.448	20	0.077	5.875	4.662	0.466
Symplocos laurina var.acuminata	1	0.017	-0.070	1.724	10	0.033	2.503	2.114	0.211
Michelia hypolampra	4	0.069	-0.184	6.897	40	0.102	7.704	7.300	0.730
Cinnadenia paniculata	2	0.034	-0.116	3.448	20	0.064	4.827	4.138	0.414
Archidendron clypearia	1	0.017	-0.070	1.724	10	0.006	0.482	1.103	0.110
Manglietia conifera	2	0.034	-0.116	3.448	20	0.014	1.056	2.252	0.225
Pometia pinnata	5	0.086	-0.211	8.621	50	0.077	5.862	7.241	0.724
Sterculia alata	1	0.017	-0.070	1.724	10	0.027	2.038	1.881	0.188
Dracontomelon duperreanum	1	0.017	-0.070	1.724	10	0.062	4.669	3.197	0.320
Lithocarpus bonnetii	14	0.241	-0.343	24.138	140	0.252	19.122	21.630	2.163
Wrightia tomentosa	1	0.017	-0.070	1.724	10	0.009	0.721	1.222	0.122
Syzygium cumini	1	0.017	-0.070	1.724	10	0.009	0.721	1.222	0.122
Canarium Album	2	0.034	-0.116	3.448	20	0.023	1.718	2.583	0.258
Sterculia tonkinensis	4	0.069	-0.184	6.897	40	0.033	2.509	4.703	0.470
Ficus benjamina	1	0.017	-0.070	1.724	10	0.018	1.340	1.532	0.153
Σ 19 species	58		2.576	100.000	580	1.318	100.000	100.000	10.000

Appendix 7: The composition coefficient and diversity index of upper tree layer at sample plot 6

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Litsea glutinosa	1	0.019	-0.075	1.887	10	0.006	0.638	1.262	0.126
Artocarpus tonkinensis	1	0.019	-0.075	1.887	10	0.013	1.330	1.609	0.161
Engelhartia roxburghiana	9	0.170	-0.301	16.981	90	0.244	24.517	20.749	2.075
Castanopsis indica	8	0.151	-0.285	15.094	80	0.132	13.205	14.150	1.415
Michelia hypolampra	1	0.019	-0.075	1.887	10	0.009	0.868	1.377	0.138
Trema orientalis	2	0.038	-0.124	3.774	20	0.052	5.215	4.494	0.449
Chukrasia tabularis	1	0.019	-0.075	1.887	10	0.009	0.952	1.420	0.142
Pterospermum pierrei	2	0.038	-0.124	3.774	20	0.027	2.676	3.225	0.323
Archidendron clypearia	5	0.094	-0.223	9.434	50	0.067	6.748	8.091	0.809
Phyllanthus fasciculatus	1	0.019	-0.075	1.887	10	0.008	0.787	1.337	0.134
Cryptocarya lenticellata	2	0.038	-0.124	3.774	20	0.022	2.198	2.986	0.299
Diospyros apiculata	1	0.019	-0.075	1.887	10	0.009	0.952	1.420	0.142
Polyathia cerasooides	1	0.019	-0.075	1.887	10	0.028	2.842	2.364	0.236
Ormosia balansae	4	0.075	-0.195	7.547	40	0.043	4.324	5.935	0.594
Syzygium samarangense	1	0.019	-0.075	1.887	10	0.008	0.787	1.337	0.134
Liquidambar formosana	1	0.019	-0.075	1.887	10	0.080	8.061	4.974	0.497
Lithocarpus bonnetii	5	0.094	-0.223	9.434	50	0.158	15.811	12.622	1.262
Vatica odorata ssp.brevipetiolata	2	0.038	-0.124	3.774	20	0.017	1.663	2.718	0.272
Manglietia dandyi	3	0.057	-0.163	5.660	30	0.045	4.520	5.090	0.509
Cinamomum balansae	2	0.038	-0.124	3.774	20	0.019	1.905	2.839	0.284
Σ 20 species	53		2.682	100.000	530	0.997	100.000	100.000	10.000

Appendix 8: The composition coefficient and diversity index of upper tree layer at sample plot 7

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Styrax tonkinensis	1	0.018	-0.072	1.786	10	0.027	1.172	1.479	0.148
Schefflera heptaphilla	1	0.018	-0.072	1.786	10	0.020	0.877	1.331	0.133
Engelhartia roxburghiana	1	0.018	-0.072	1.786	10	0.023	0.990	1.388	0.139
Elaeocarpus tonkinensis	2	0.036	-0.119	3.571	20	0.071	3.083	3.327	0.333
Castanopsis indica	1	0.018	-0.072	1.786	10	0.047	2.056	1.921	0.192
Symplocos laurina var.acuminata	3	0.054	-0.157	5.357	30	0.097	4.235	4.796	0.480
Broussonettia papyrifera	1	0.018	-0.072	1.786	10	0.007	0.309	1.047	0.105
Michelia hypolampra	5	0.089	-0.216	8.929	50	0.253	11.036	9.982	0.998
Aglaia spectabilis	1	0.018	-0.072	1.786	10	0.010	0.453	1.119	0.112
Trema orientalis	2	0.036	-0.119	3.571	20	0.048	2.076	2.824	0.282
Pterospermum pierrei	2	0.036	-0.119	3.571	20	0.073	3.192	3.382	0.338
Knema pierrei	1	0.018	-0.072	1.786	10	0.071	3.083	2.434	0.243
Manglietia conifera	3	0.054	-0.157	5.357	30	0.188	8.205	6.781	0.678
Unknown4	1	0.018	-0.072	1.786	10	0.030	1.302	1.544	0.154
Cinamomum cassia	1	0.018	-0.072	1.786	10	0.053	2.315	2.051	0.205
Cinamomum tonkinensis	1	0.018	-0.072	1.786	10	0.024	1.049	1.417	0.142
Pometia pinnata	4	0.071	-0.189	7.143	40	0.123	5.347	6.245	0.624
Dracontomelon duperreanum	3	0.054	-0.157	5.357	30	0.265	11.564	8.461	0.846
Madhuca pasquieri	1	0.018	-0.072	1.786	10	0.043	1.891	1.839	0.184
Dillenia scabrella	1	0.018	-0.072	1.786	10	0.018	0.771	1.278	0.128
Lithocarpus bonnetii	1	0.018	-0.072	1.786	10	0.042	1.812	1.799	0.180
Antiaris toxicaria	2	0.036	-0.119	3.571	20	0.155	6.762	5.167	0.517
Vatica odorata ssp.brevipetiolata	1	0.018	-0.072	1.786	10	0.019	0.821	1.303	0.130
Diospyros sylvatica	3	0.054	-0.157	5.357	30	0.185	8.061	6.709	0.671
Alangium chinense	3	0.054	-0.157	5.357	30	0.017	0.724	3.041	0.304
Wrightia tomentosa	1	0.018	-0.072	1.786	10	0.011	0.493	1.139	0.114
Canarium tramdenum	1	0.018	-0.072	1.786	10	0.004	0.168	0.977	0.098
Saraca dives	2	0.036	-0.119	3.571	20	0.083	3.639	3.605	0.361
Manglietia dandyi	3	0.054	-0.157	5.357	30	0.236	10.279	7.818	0.782
Ficus trivia	1	0.018	-0.072	1.786	10	0.009	0.414	1.100	0.110
Melia azedarach	2	0.036	-0.119	3.571	20	0.042	1.820	2.695	0.270
Σ 31 species	56		3.281	100.000	560	2.292	100.000	100.000	10.000

Appendix 9: The composition coefficient and diversity index of upper tree layer at sample plot 8

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Caryodaphnopsis tonkinensis	1	0.017	-0.069	1.695	10	0.122	4.986	3.340	0.334
Lansium domesticum	2	0.034	-0.115	3.390	20	0.174	7.085	5.238	0.524
Castanopsis indica	1	0.017	-0.069	1.695	10	0.075	3.071	2.383	0.238
Castanopsis indica	1	0.017	-0.069	1.695	10	0.045	1.841	1.768	0.177
Castanopsis indica	1	0.017	-0.069	1.695	10	0.020	0.818	1.256	0.126
Lithocarpus proboscideus	5	0.085	-0.209	8.475	50	0.160	6.513	7.494	0.749
Markhmia stipulata	1	0.017	-0.069	1.695	10	0.110	4.494	3.094	0.309
Bombax malabarica	1	0.017	-0.069	1.695	10	0.142	5.772	3.733	0.373
Aglaia argentea	1	0.017	-0.069	1.695	10	0.008	0.320	1.007	0.101
Arecaceae Sp	2	0.034	-0.115	3.390	20	0.105	4.285	3.838	0.384
Cinnadenia paniculata	2	0.034	-0.115	3.390	20	0.023	0.931	2.160	0.216
Erythrophleum fordii	3	0.051	-0.151	5.085	30	0.164	6.676	5.880	0.588
Peltophorum pterocarpum	1	0.017	-0.069	1.695	10	0.038	1.547	1.621	0.162
Pterospermum pierrei	3	0.051	-0.151	5.085	30	0.154	6.281	5.683	0.568
Archidendron clypearia	2	0.034	-0.115	3.390	20	0.075	3.049	3.219	0.322
Knema pierrei	3	0.051	-0.151	5.085	30	0.048	1.970	3.527	0.353
Deutzianthus tonkinensis	1	0.017	-0.069	1.695	10	0.019	0.768	1.231	0.123
Acer erythranthum Gagnep	2	0.034	-0.115	3.390	20	0.053	2.177	2.783	0.278
Bischofia javanica	2	0.034	-0.115	3.390	20	0.160	6.513	4.952	0.495
Unknown4	2	0.034	-0.115	3.390	20	0.021	0.847	2.118	0.212
ormosia balansae	1	0.017	-0.069	1.695	10	0.009	0.352	1.024	0.102
Syzygium samarangense	1	0.017	-0.069	1.695	10	0.008	0.320	1.007	0.101
Liquidambar formosana	4	0.068	-0.182	6.780	40	0.203	8.268	7.524	0.752
Dillenia scabrella	1	0.017	-0.069	1.695	10	0.093	3.804	2.749	0.275
Lithocarpus bonnetii	5	0.085	-0.209	8.475	50	0.155	6.292	7.383	0.738
Cratoxy Maingayi	2	0.034	-0.115	3.390	20	0.045	1.813	2.601	0.260
Syzygium wightianum	3	0.051	-0.151	5.085	30	0.036	1.481	3.283	0.328
Canarium tramdenum	1	0.017	-0.069	1.695	10	0.031	1.278	1.487	0.149
Sterculia tonkinensis	2	0.034	-0.115	3.390	20	0.059	2.384	2.887	0.289
Homalocladium platycladum	1	0.017	-0.069	1.695	10	0.027	1.094	1.394	0.139
Prunus arborea	1	0.017	-0.069	1.695	10	0.073	2.973	2.334	0.233
Σ 31 species	59		3.276	100.000	590	2.457	100.000	100.000	10.000

Appendix 10: The composition coefficient and diversity index of upper tree layer at sample plot 9

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Sapindus saponaria	1	0.018	-0.071	1.754	10	0.038	1.721	1.738	0.174
Gleditsia triacanthos	1	0.018	-0.071	1.754	10	0.057	2.592	2.173	0.217
Litsea yunnanensis	1	0.018	-0.071	1.754	10	0.045	2.048	1.901	0.190
Schefflera heptaphilla	1	0.018	-0.071	1.754	10	0.023	1.028	1.391	0.139
Camellia sinensis	1	0.018	-0.071	1.754	10	0.009	0.430	1.092	0.109
Engelhartia roxburghiana	1	0.018	-0.071	1.754	10	0.031	1.422	1.588	0.159
Elaeocarpus tonkinensis	1	0.018	-0.071	1.754	10	0.011	0.512	1.133	0.113
Castanopsis indica	3	0.053	-0.155	5.263	30	0.029	1.303	3.283	0.328
Lithocarpus proboscideus	2	0.035	-0.118	3.509	20	0.038	1.729	2.619	0.262
Markhmia stipulata	1	0.018	-0.071	1.754	10	0.038	1.721	1.738	0.174
Neolamarckia cadamba	2	0.035	-0.118	3.509	20	0.044	1.999	2.754	0.275
Aglaia argentea	1	0.018	-0.071	1.754	10	0.049	2.223	1.988	0.199
Chukrasia tabularis	2	0.035	-0.118	3.509	20	0.196	8.865	6.187	0.619
Choerospondias axillaris	1	0.018	-0.071	1.754	10	0.075	3.417	2.586	0.259
Archidendron clypearia	1	0.018	-0.071	1.754	10	0.007	0.321	1.038	0.104
Knema pierrei	2	0.035	-0.118	3.509	20	0.038	1.711	2.610	0.261
Cryptocarya lenticellata	7	0.123	-0.258	12.281	70	0.136	6.165	9.223	0.922
Gironniera subaequalis	1	0.018	-0.071	1.754	10	0.011	0.512	1.133	0.113
Diospyros apiculata	1	0.018	-0.071	1.754	10	0.020	0.910	1.332	0.133
Bischofia javanica	2	0.035	-0.118	3.509	20	0.066	2.991	3.250	0.325
Cullen corylifolium	2	0.035	-0.118	3.509	20	0.038	1.711	2.610	0.261
Ormosia balansae	4	0.070	-0.186	7.018	40	0.070	3.191	5.104	0.510
Cinnamomum tonkinensis	1	0.018	-0.071	1.754	10	0.043	1.964	1.859	0.186
Pometia pinnata	3	0.053	-0.155	5.263	30	0.338	15.307	10.285	1.028
Lithocarpus bonnetii	2	0.035	-0.118	3.509	20	0.041	1.837	2.673	0.267
Melanorrhoea laccifera	3	0.053	-0.155	5.263	30	0.097	4.413	4.838	0.484
Alangium chinense	1	0.018	-0.071	1.754	10	0.028	1.284	1.519	0.152
Euodia bodinieri	1	0.018	-0.071	1.754	10	0.059	2.689	2.222	0.222
Syzygium wightianum	2	0.035	-0.118	3.509	20	0.050	2.245	2.877	0.288
Canarium Album	1	0.018	-0.071	1.754	10	0.014	0.648	1.201	0.120
Saraca dives	1	0.018	-0.071	1.754	10	0.047	2.135	1.944	0.194
Zanthoxylum acanthopodiun	1	0.018	-0.071	1.754	10	0.023	1.028	1.391	0.139
Prunus arborea	1	0.018	-0.071	1.754	10	0.273	12.379	7.067	0.707
Melia azedarach	1	0.018	-0.071	1.754	10	0.122	5.548	3.651	0.365
Σ 34 species	57		3.339	100.000	570	2.207	100.000	100.000	10.000

Appendix 11: The composition coefficient and diversity index of upper tree layer at sample plot 10

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Garcinia oblongifolia	1	0.018	-0.073	1.82	10	0.038	1.427	1.623	0.162
Caryodaphnopsis tonkinensis	1	0.018	-0.073	1.82	10	0.008	0.295	1.056	0.106
Microdesmis caseariaefolia	1	0.018	-0.073	1.82	10	0.085	3.210	2.514	0.251
Engelhartia roxburghiana	8	0.145	-0.280	14.55	80	0.174	6.535	10.540	1.054
Elaeocarpus petiolatus	1	0.018	-0.073	1.82	10	0.038	1.427	1.623	0.162
Castanopsis indica	3	0.055	-0.159	5.45	30	0.265	9.965	7.710	0.771
Lithocarpus proboscideus	6	0.109	-0.242	10.91	60	0.316	11.867	11.388	1.139
Symplocos laurina var.acuminata	1	0.018	-0.073	1.82	10	0.152	5.707	3.763	0.376
Ailanthus triphysa	1	0.018	-0.073	1.82	10	0.008	0.295	1.056	0.106
Euphorbiaceae Sp	2	0.036	-0.121	3.64	20	0.078	2.926	3.281	0.328
Trema orientalis	1	0.018	-0.073	1.82	10	0.059	2.229	2.024	0.202
Cinnadenia paniculata	1	0.018	-0.073	1.82	10	0.020	0.755	1.286	0.129
Peltophorum pterocarpum	4	0.073	-0.191	7.27	40	0.141	5.295	6.284	0.628
Archidendron clypearia	1	0.018	-0.073	1.82	10	0.009	0.325	1.072	0.107
Knema pierrei	2	0.036	-0.121	3.64	20	0.077	2.891	3.263	0.326
Manglietia conifera	2	0.036	-0.121	3.64	20	0.080	2.999	3.318	0.332
Unknown5	2	0.036	-0.121	3.64	20	0.147	5.514	4.575	0.457
Cullen corylifolium	2	0.036	-0.121	3.64	20	0.243	9.122	6.379	0.638
Sterculia alata	1	0.018	-0.073	1.82	10	0.152	5.707	3.763	0.376
Lithocarpus bonnetii	6	0.109	-0.242	10.91	60	0.230	8.638	9.773	0.977
Vatica chevalieri	1	0.018	-0.073	1.82	10	0.083	3.114	2.466	0.247
Wrightia tomentosa	1	0.018	-0.073	1.82	10	0.017	0.620	1.219	0.122
Wrightia tomentosa	1	0.018	-0.073	1.82	10	0.009	0.357	1.087	0.109
Syzygium wightianum	3	0.055	-0.159	5.45	30	0.060	2.241	3.848	0.385
Canarium Album	1	0.018	-0.073	1.82	10	0.117	4.390	3.104	0.310
Vernicia motana	1	0.018	-0.073	1.82	10	0.057	2.149	1.984	0.198
Σ 26 species	55		2.967	100	550	2.663	100	100	10.000

Appendix 12: The composition coefficient and diversity index of upper tree layer at sample plot 11

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Mallotus philippensis	1	0.017	-0.068	1.667	10	0.017	0.715	1.191	0.119
Microdesmis caseariaefolia	5	0.083	-0.207	8.333	50	0.185	8.029	8.181	0.818
Artocarpus tonkinensis	7	0.117	-0.251	11.667	70	0.313	13.574	12.621	1.262
Engelhartia roxburghiana	11	0.183	-0.311	18.333	110	0.565	24.469	21.401	2.140
Elaeocarpus petiolatus	2	0.033	-0.113	3.333	20	0.031	1.333	2.333	0.233
Castanopsis indica	2	0.033	-0.113	3.333	20	0.015	0.650	1.992	0.199
Michelia hypolampra	2	0.033	-0.113	3.333	20	0.104	4.505	3.919	0.392
Cinnadenia paniculata	2	0.033	-0.113	3.333	20	0.029	1.268	2.301	0.230
Archidendron clypearia	2	0.033	-0.113	3.333	20	0.130	5.631	4.482	0.448
Swietenia macrophylla	1	0.017	-0.068	1.667	10	0.010	0.450	1.058	0.106
Syzygium samarangense	2	0.033	-0.113	3.333	20	0.020	0.850	2.092	0.209
Lithocarpus bonnetii	7	0.117	-0.251	11.667	70	0.418	18.087	14.877	1.488
Ficus racemosa	1	0.017	-0.068	1.667	10	0.031	1.360	1.513	0.151
Garcinia cowa	1	0.017	-0.068	1.667	10	0.009	0.411	1.039	0.104
Wrightia tomentosa	2	0.033	-0.113	3.333	20	0.028	1.192	2.263	0.226
Wrightia tomentosa	2	0.033	-0.113	3.333	20	0.053	2.298	2.816	0.282
Canarium Album	4	0.067	-0.181	6.667	40	0.085	3.673	5.170	0.517
Vernicia motana	2	0.033	-0.113	3.333	20	0.106	4.604	3.969	0.397
Sterculia tonkinensis	1	0.017	-0.068	1.667	10	0.028	1.227	1.447	0.145
Prunus arborea	3	0.050	-0.150	5.000	30	0.131	5.673	5.336	0.534
Σ 20 species	60		2.711	100	600	2.309	100.000	100.000	10.000

Appendix 13: The composition coefficient and diversity index of upper tree layer at sample plot 12

Species	N	Pi	Pi*(LN(Pi))	%N	N/ha	G	%G	IV%	K
Mallotus macrostachyus	1	0.018	-0.072	1.786	10.000	0.020	0.848	1.317	0.132
Mallotus philippensis	2	0.036	-0.119	3.571	20.000	0.017	0.722	2.147	0.215
Artocarpus tonkinensis	2	0.036	-0.119	3.571	20.000	0.148	6.248	4.910	0.491
Engelhartia roxburghiana	4	0.071	-0.189	7.143	40.000	0.332	14.018	10.580	1.058
Elaeocarpus petiolatus	1	0.018	-0.072	1.786	10.000	0.015	0.649	1.217	0.122
Lansium domesticum	1	0.018	-0.072	1.786	10.000	0.057	2.414	2.100	0.210
Castanopsis indica	2	0.036	-0.119	3.571	20.000	0.103	4.324	3.948	0.395
Symplocos laurina var.acuminata	1	0.018	-0.072	1.786	10.000	0.003	0.119	0.952	0.095
Michelia hypolampra	1	0.018	-0.072	1.786	10.000	0.053	2.238	2.012	0.201
Euforbiaceae Sp	1	0.018	-0.072	1.786	10.000	0.075	3.182	2.484	0.248
Myrtaceae Sp	1	0.018	-0.072	1.786	10.000	0.009	0.365	1.075	0.108
Cinnadenia paniculata	2	0.036	-0.119	3.571	20.000	0.045	1.878	2.725	0.272
Peltophorum pterocarpum	2	0.036	-0.119	3.571	20.000	0.042	1.782	2.677	0.268
Archidendron clypearia	2	0.036	-0.119	3.571	20.000	0.035	1.473	2.522	0.252
Bischofia javanica	2	0.036	-0.119	3.571	20.000	0.073	3.076	3.324	0.332
Unknown4	3	0.054	-0.157	5.357	30.000	0.175	7.394	6.375	0.638
Ormosia balansae	3	0.054	-0.157	5.357	30.000	0.101	4.258	4.807	0.481
Cinamomum tonkinensis	3	0.054	-0.157	5.357	30.000	0.073	3.077	4.217	0.422
Madhuca pasquieri	1	0.018	-0.072	1.786	10.000	0.078	3.285	2.535	0.254
Dillenia scabrella	1	0.018	-0.072	1.786	10.000	0.020	0.848	1.317	0.132
Lithocarpus bonnetii	4	0.071	-0.189	7.143	40.000	0.190	8.007	7.575	0.758
Melanorrhoea laccifera	2	0.036	-0.119	3.571	20.000	0.066	2.789	3.180	0.318
Garcinia cowa	3	0.054	-0.157	5.357	30.000	0.149	6.265	5.811	0.581
Canarium tramdenum	2	0.036	-0.119	3.571	20.000	0.060	2.520	3.045	0.305
Syzygium zeylanicum	1	0.018	-0.072	1.786	10.000	0.028	1.195	1.490	0.149
Canarium Album	1	0.018	-0.072	1.786	10.000	0.007	0.299	1.042	0.104
Vernicia motana	2	0.036	-0.119	3.571	20.000	0.218	9.208	6.390	0.639
Amesiodeuchon chinense	2	0.036	-0.119	3.571	20.000	0.023	0.964	2.268	0.227
Prunus arborea	2	0.036	-0.119	3.571	20.000	0.139	5.861	4.716	0.472
Melia azedarach	1	0.018	-0.072	1.786	10.000	0.017	0.696	1.241	0.124
Σ 30 species	56		3.295	100	560.000	2.37103	100	100	10

Appendix 14: The composition coefficient and diversity index of tree regeneration at sample plot 1

Species	N	Pi	Pi*(LN(Pi))	%N	K	N/ha
Microdesmis caseariaefolia	1	0.031	-0.108	3.13	0.313	80
Schefflera heptaphilla	1	0.031	-0.108	3.13	0.313	80
Elaeocarpus petiolatus	2	0.063	-0.173	6.25	0.625	160
Castanopsis indica	4	0.125	-0.260	12.50	1.250	320
Michelia mediocris	1	0.031	-0.108	3.13	0.313	80
Unknown5	3	0.094	-0.222	9.38	0.938	240
Archidendron clypearia	1	0.031	-0.108	3.13	0.313	80
Knema pierrei	3	0.094	-0.222	9.38	0.938	240
Cryptocarya lenticellata	4	0.125	-0.260	12.50	1.250	320
Cullen corylifolium	1	0.031	-0.108	3.13	0.313	80
Cinamomum tonkinensis	1	0.031	-0.108	3.13	0.313	80
Sterculia alata	2	0.063	-0.173	6.25	0.625	160
Lithocarpus bonnetii	5	0.156	-0.290	15.63	1.563	400
Unknown1	1	0.031	-0.108	3.13	0.313	80
Wrightia tomentosa	1	0.031	-0.108	3.13	0.313	80
Syzygium wightianum	1	0.031	-0.108	3.13	0.313	80
Σ 16 species	32	2.575		100.00	10.000	2560

Appendix 15: The composition coefficient and diversity index of tree regeneration at sample plot 2

Species	N	Pi	Pi*(LN(Pi))	%N	K	N/ha
Garcinia oblongifolia	5	0.143	-0.278	14.29	1.429	400
Microdesmis caseariaefolia	1	0.029	-0.102	2.86	0.286	80
Elaeocarpus petiolatus	1	0.029	-0.102	2.86	0.286	80
Lithocarpus fissus	1	0.029	-0.102	2.86	0.286	80
Castanopsis indica	1	0.029	-0.102	2.86	0.286	80
Cinnadenia paniculata	5	0.143	-0.278	14.29	1.429	400
Sterculia foetida	1	0.029	-0.102	2.86	0.286	80
Unknown5	1	0.029	-0.102	2.86	0.286	80
Archidendron clypearia	4	0.114	-0.248	11.43	1.143	320
Knema pierrei	1	0.029	-0.102	2.86	0.286	80
Phyllanthus fasciculatus	1	0.029	-0.102	2.86	0.286	80
Cryptocarya lenticellata	2	0.057	-0.164	5.71	0.571	160
Sterculia alata	1	0.029	-0.102	2.86	0.286	80
Lithocarpus bonnetii	3	0.086	-0.211	8.57	0.857	240
Alangium chinense	1	0.029	-0.102	2.86	0.286	80
Wrightia tomentosa	1	0.029	-0.102	2.86	0.286	80
Syzygium wightianum	2	0.057	-0.164	5.71	0.571	160
Vernicia motana	3	0.086	-0.211	8.57	0.857	240
Σ 18 species	35		2.67	100.00	10.000	2800

Appendix 16: The composition coefficient and diversity index of tree regeneration at sample plot 3

Species	N	Pi	Pi*(LN(Pi))	%N	K	N/ha
Litsea glutinosa	1	0.030	-0.106	3.03	0.303	80
Litsea yunnanensis	3	0.091	-0.218	9.09	0.909	240
Mallotus philippensis	1	0.030	-0.106	3.03	0.303	80
Engelhartia roxburghiana	5	0.152	-0.286	15.15	1.515	400
Castanopsis indica	3	0.091	-0.218	9.09	0.909	240
Castanopsis indica	1	0.030	-0.106	3.03	0.303	80
Ficus Sp	1	0.030	-0.106	3.03	0.303	80
Cinnadenia paniculata	4	0.121	-0.256	12.12	1.212	320
ormosia balansae	1	0.030	-0.106	3.03	0.303	80
Madhuca pasquieri	3	0.091	-0.218	9.09	0.909	240
Lithocarpus bonnetii	5	0.152	-0.286	15.15	1.515	400
Melanorrhoea laccifera	1	0.030	-0.106	3.03	0.303	80
Cratoxy Maingayi	3	0.091	-0.218	9.09	0.909	240
Melia azedarach	1	0.030	-0.106	3.03	0.303	80
Σ 14 species	33		2.441	100.00	10.000	2640

Appendix 17: The composition coefficient and diversity index of tree regeneration at sample plot 4

Species	N	Pi	Pi*(LN(Pi))	%N	K	N/ha
Rauvolfia vietnamensis	1	0.031	-0.108	3.13	0.313	80
Schefflera heptaphilla	1	0.031	-0.108	3.13	0.313	80
Engelhartia roxburghiana	1	0.031	-0.108	3.13	0.313	80
Castanopsis indica	2	0.063	-0.173	6.25	0.625	160
Symplocos laurina var.acuminata	1	0.031	-0.108	3.13	0.313	80
Sindora tonkinensis	1	0.031	-0.108	3.13	0.313	80
Cinnadenia paniculata	1	0.031	-0.108	3.13	0.313	80
Dillenia turbiana	1	0.031	-0.108	3.13	0.313	80
Archidendron clypearia	1	0.031	-0.108	3.13	0.313	80
Steblus macrophyllus	1	0.031	-0.108	3.13	0.313	80
Cryptocarya lenticellata	2	0.063	-0.173	6.25	0.625	160
Polyathia cerasooides	1	0.031	-0.108	3.13	0.313	80
Cullen corylifolium	4	0.125	-0.260	12.50	1.250	320
Homalocladium platycladum	1	0.031	-0.108	3.13	0.313	80
Madhuca pasquieri	3	0.094	-0.222	9.38	0.938	240
Dillenia scabrella	1	0.031	-0.108	3.13	0.313	80
Lithocarpus bonnetii	3	0.094	-0.222	9.38	0.938	240
Garcinia cowa	1	0.031	-0.108	3.13	0.313	80
Syzygium wightianum	1	0.031	-0.108	3.13	0.313	80
Sterculia tonkinensis	2	0.063	-0.173	6.25	0.625	160
Homalocladium platycladum	1	0.031	-0.108	3.13	0.313	80
Manglietia dandyi	1	0.031	-0.108	3.13	0.313	80
Σ 22 species	32		2.956	100.00	10.000	2560

Appendix 18: The composition coefficient and diversity index of tree regeneration at sample plot 5

Species	N	Pi	Pi*(LN(Pi))	%N	K	N/ha
Microdesmis caseariaefolia	5	0.132	-0.267	13.16	1.316	400
Artocarpus tonkinensis	2	0.053	-0.155	5.26	0.526	160
Engelhartia roxburghiana	4	0.105	-0.237	10.53	1.053	320
Elaeocarpus petiolatus	3	0.079	-0.200	7.89	0.789	240
Castanopsis indica	1	0.026	-0.096	2.63	0.263	80
Michelia hypolampra	3	0.079	-0.200	7.89	0.789	240
Cinnadenia paniculata	1	0.026	-0.096	2.63	0.263	80
Archidendron clypearia	1	0.026	-0.096	2.63	0.263	80
Swietenia macrophylla	2	0.053	-0.155	5.26	0.526	160
Syzygium samarangense	2	0.053	-0.155	5.26	0.526	160
Pometia pinnata	1	0.026	-0.096	2.63	0.263	80
Sterculia alata	3	0.079	-0.200	7.89	0.789	240
Lithocarpus bonnetii	3	0.079	-0.200	7.89	0.789	240
Ficus racemosa	1	0.026	-0.096	2.63	0.263	80
Wrightia tomentosa	1	0.026	-0.096	2.63	0.263	80
Vernicia motana	1	0.026	-0.096	2.63	0.263	80
Sterculia tonkinensis	1	0.026	-0.096	2.63	0.263	80
Prunus arborea	2	0.053	-0.155	5.26	0.526	160
Melia azedarach	1	0.026	-0.096	2.63	0.263	80
Σ 19 species	38		2.787	100.00	10.000	3040

Appendix 19: The composition coefficient and diversity index of tree regeneration at sample plot 6

Species	N	Pi	Pi*(LN(Pi))	%N	K	N/ha
Lansium domesticum	5	0.128	-0.263	12.82	1.282	400
Castanopsis indica	6	0.154	-0.288	15.38	1.538	480
Ixonanthes chinensis	4	0.103	-0.234	10.26	1.026	320
Cinnadenia paniculata	5	0.128	-0.263	12.82	1.282	400
Phyllanthus fasciculatus	1	0.026	-0.094	2.56	0.256	80
Gironniera subaequalis	6	0.154	-0.288	15.38	1.538	480
ormosia balansae	2	0.051	-0.152	5.13	0.513	160
Lithocarpus bonnetii	3	0.077	-0.197	7.69	0.769	240
Ficus racemosa	2	0.051	-0.152	5.13	0.513	160
Canarium tramdeum	5	0.128	-0.263	12.82	1.282	400
Σ 10 species	39		2.195	100.00	10.000	3120

Appendix 20: The composition coefficient and diversity index of tree regeneration at sample plot 7

Species	N	Pi	Pi*(ln(Pi))	%N	K	N/ha
Rauvolfia vietnamensis	1	0.026	-0.094	2.56	0.256	80
Adinandra integerrima	1	0.026	-0.094	2.56	0.256	80
Engelhartia roxburghiana	1	0.026	-0.094	2.56	0.256	80
Elaeocarpus petiolatus	4	0.103	-0.234	10.26	1.026	320
Castanopsis indica	6	0.154	-0.288	15.38	1.538	480
Trema orientalis	2	0.051	-0.152	5.13	0.513	160
Cinnadenia paniculata	1	0.026	-0.094	2.56	0.256	80
Archidendron clypearia	1	0.026	-0.094	2.56	0.256	80
Knema pierrei	1	0.026	-0.094	2.56	0.256	80
Manglietia conifera	4	0.103	-0.234	10.26	1.026	320
Cryptocarya lenticellata	1	0.026	-0.094	2.56	0.256	80
ormosia balansae	1	0.026	-0.094	2.56	0.256	80
Dillenia scabrella	2	0.051	-0.152	5.13	0.513	160
Lithocarpus bonnetii	3	0.077	-0.197	7.69	0.769	240
Diospyros sylvatica	1	0.026	-0.094	2.56	0.256	80
Alangium chinense	3	0.077	-0.197	7.69	0.769	240
Euodia bodinieri	1	0.026	-0.094	2.56	0.256	80
Wrightia tomentosa	1	0.026	-0.094	2.56	0.256	80
Syzygium wightianum	3	0.077	-0.197	7.69	0.769	240
Canarium tramdeum	1	0.026	-0.094	2.56	0.256	80
Σ 20 species	39		2.779	100.00	10.000	3120

Appendix 21: The composition coefficient and diversity index of tree regeneration at sample plot 8

Species	N	Pi	Pi*(LN(Pi))	%N	K	N/ha
Garcinia oblongifolia	1	0.025	-0.092	2.50	0.250	80
Caryodaphnopsis tonkinensis	1	0.025	-0.092	2.50	0.250	80
Engelhartia roxburghiana	1	0.025	-0.092	2.50	0.250	80
Lansium domesticum	1	0.025	-0.092	2.50	0.250	80
Castanopsis indica	1	0.025	-0.092	2.50	0.250	80
Markhmia stipulata	1	0.025	-0.092	2.50	0.250	80
Cinnadenia paniculata	4	0.100	-0.230	10.00	1.000	320
Erythrophleum fordii	1	0.025	-0.092	2.50	0.250	80
Peltophorum pterocarpum	2	0.050	-0.150	5.00	0.500	160
Archidendron clypearia	1	0.025	-0.092	2.50	0.250	80
Cryptocarya lenticellata	1	0.025	-0.092	2.50	0.250	80
Carallia dipplopetala	1	0.025	-0.092	2.50	0.250	80
Cinamomum tonkinensis	7	0.175	-0.305	17.50	1.750	560
Pometia pinnata	1	0.025	-0.092	2.50	0.250	80
Sterculia alata	5	0.125	-0.260	12.50	1.250	400
Liquidambar formosana	1	0.025	-0.092	2.50	0.250	80
Dracontomelon duperreanum	1	0.025	-0.092	2.50	0.250	80
Dillenia scabrella	1	0.025	-0.092	2.50	0.250	80
Lithocarpus bonnetii	1	0.025	-0.092	2.50	0.250	80
Unknown1	1	0.025	-0.092	2.50	0.250	80
Wrightia tomentosa	1	0.025	-0.092	2.50	0.250	80
Canarium tramdeum	3	0.075	-0.194	7.50	0.750	240
Syzygium wightianum	1	0.025	-0.092	2.50	0.250	80
Sterculia tonkinensis	1	0.025	-0.092	2.50	0.250	80
Σ 24 species	40		2.891	100.00	10.000	3200

Appendix 22: The composition coefficient and diversity index of tree regeneration at sample plot 9

Species	N	Pi	Pi*(LN(Pi))	%N	K	N/ha
Garcinia oblongifolia	1	0.023	-0.087	2.33	0.233	80
Engelhartia roxburghiana	5	0.116	-0.250	11.63	1.163	400
Castanopsis indica	4	0.093	-0.221	9.30	0.930	320
Michelia mediocris	1	0.023	-0.087	2.33	0.233	80
Sindora tonkinensis	1	0.023	-0.087	2.33	0.233	80
Ficus Sp	1	0.023	-0.087	2.33	0.233	80
Myrtaceae Sp	1	0.023	-0.087	2.33	0.233	80
Cinnadenia paniculata	1	0.023	-0.087	2.33	0.233	80
Chukrasia tabularis	1	0.023	-0.087	2.33	0.233	80
Archidendron clypearia	3	0.070	-0.186	6.98	0.698	240
Cryptocarya lenticellata	1	0.023	-0.087	2.33	0.233	80
Gironniera subaequalis	1	0.023	-0.087	2.33	0.233	80
Cullen corylifolium	3	0.070	-0.186	6.98	0.698	240
Ormosia balansae	5	0.116	-0.250	11.63	1.163	400
Pometia pinnata	1	0.023	-0.087	2.33	0.233	80
Liquidambar formosana	1	0.023	-0.087	2.33	0.233	80
Lithocarpus bonnetii	7	0.163	-0.296	16.28	1.628	560
Melanorrhoea laccifera	3	0.070	-0.186	6.98	0.698	240
Syzygium wightianum	1	0.023	-0.087	2.33	0.233	80
Zanthoxylum acanthopodiun	1	0.023	-0.087	2.33	0.233	80
Σ 20 species	43		2.711	100.00	10.000	3440

Appendix 23: The composition coefficient and diversity index of tree regeneration at sample plot 10

Species	N	Pi	Pi*(LN(Pi))	%N	K	N/ha
Garcinia oblongifolia	1	0.028	-0.100	2.78	0.278	80
Caryodaphnopsis tonkinensis	1	0.028	-0.100	2.78	0.278	80
Microdesmis caseariaefolia	3	0.083	-0.207	8.33	0.833	240
Elaeocarpus petiolatus	3	0.083	-0.207	8.33	0.833	240
Castanopsis indica	1	0.028	-0.100	2.78	0.278	80
Symplocos laurina var.acuminata	1	0.028	-0.100	2.78	0.278	80
Euphorbiaceae Sp	1	0.028	-0.100	2.78	0.278	80
Knema pierrei	4	0.111	-0.244	11.11	1.111	320
Phyllanthus fasciculatus	1	0.028	-0.100	2.78	0.278	80
Manglietia conifera	1	0.028	-0.100	2.78	0.278	80
Unknown5	1	0.028	-0.100	2.78	0.278	80
Cryptocarya lenticellata	1	0.028	-0.100	2.78	0.278	80
Gironniera subaequalis	2	0.056	-0.161	5.56	0.556	160
Cullen corylifolium	1	0.028	-0.100	2.78	0.278	80
Cinamomum tonkinensis	1	0.028	-0.100	2.78	0.278	80
Sterculia alata	1	0.028	-0.100	2.78	0.278	80
Lithocarpus bonnetii	5	0.139	-0.274	13.89	1.389	400
Alangium chinense	1	0.028	-0.100	2.78	0.278	80
Wrightia tomentosa	1	0.028	-0.100	2.78	0.278	80
Syzygium wightianum	1	0.028	-0.100	2.78	0.278	80
Vernicia motana	4	0.111	-0.244	11.11	1.111	320
Σ 21 species	36		2.83	100.00	10.000	2880

Appendix 24: The composition coefficient and diversity index of tree regeneration at sample plot 11

Species	N	Pi	Pi*(LN(Pi))	%N	K	N/ha
Microdesmis caseariaefolia	1	0.027	-0.098	2.70	0.270	80
Artocarpus tonkinensis	5	0.135	-0.270	13.51	1.351	400
Engelhartia roxburghiana	1	0.027	-0.098	2.70	0.270	80
Elaeocarpus petiolatus	1	0.027	-0.098	2.70	0.270	80
Castanopsis indica	2	0.054	-0.158	5.41	0.541	160
Markhmia stipulata	1	0.027	-0.098	2.70	0.270	80
Aglaia spectabilis	1	0.027	-0.098	2.70	0.270	80
Euphorbiaceae Sp	1	0.027	-0.098	2.70	0.270	80
Cinnadenia paniculata	1	0.027	-0.098	2.70	0.270	80
Peltophorum pterocarpum	4	0.108	-0.240	10.81	1.081	320
Dillenia turbiana	1	0.027	-0.098	2.70	0.270	80
Knema pierrei	1	0.027	-0.098	2.70	0.270	80
Gironniera subaequalis	1	0.027	-0.098	2.70	0.270	80
Polyathia cerasooides	1	0.027	-0.098	2.70	0.270	80
Bischofia javanica	4	0.108	-0.240	10.81	1.081	320
Cullen corylifolium	1	0.027	-0.098	2.70	0.270	80
Cinamomum tonkinensis	1	0.027	-0.098	2.70	0.270	80
Sterculia alata	3	0.081	-0.204	8.11	0.811	240
Dracontomelon duperreanum	2	0.054	-0.158	5.41	0.541	160
Lithocarpus bonnetii	1	0.027	-0.098	2.70	0.270	80
Melanorrhoea laccifera	2	0.054	-0.158	5.41	0.541	160
Melia azedarach	1	0.027	-0.098	2.70	0.270	80
Σ 22 species	37		2.892	100.00	10.000	2960

Appendix 25: The composition coefficient and diversity index of tree regeneration at sample plot 12

Species	N	Pi	Pi*(LN(Pi))	%N	K	N/ha
Mallotus philippensis	3	0.073	-0.191	7.32	0.732	240
Engelhartia roxburghiana	1	0.024	-0.091	2.44	0.244	80
Lansium domesticum	1	0.024	-0.091	2.44	0.244	80
Castanopsis indica	2	0.049	-0.147	4.88	0.488	160
Symplocos laurina var.acuminata	2	0.049	-0.147	4.88	0.488	160
Lagerstroemia calyculata	1	0.024	-0.091	2.44	0.244	80
Peltophorum pterocarpum	1	0.024	-0.091	2.44	0.244	80
Unknown5	1	0.024	-0.091	2.44	0.244	80
Archidendron clypearia	1	0.024	-0.091	2.44	0.244	80
Bischofia javanica	1	0.024	-0.091	2.44	0.244	80
ormosia balansae	1	0.024	-0.091	2.44	0.244	80
Cinamomum tonkinensis	1	0.024	-0.091	2.44	0.244	80
Pometia pinnata	3	0.073	-0.191	7.32	0.732	240
Sterculia alata	1	0.024	-0.091	2.44	0.244	80
Liquidambar formosana	1	0.024	-0.091	2.44	0.244	80
Lithocarpus bonnetii	4	0.098	-0.227	9.76	0.976	320
Garcinia cowa	3	0.073	-0.191	7.32	0.732	240
Unknown4	1	0.024	-0.091	2.44	0.244	80
Canarium tramdeum	1	0.024	-0.091	2.44	0.244	80
Syzygium wightianum	7	0.171	-0.302	17.07	1.707	560
Melia azedarach	4	0.098	-0.227	9.76	0.976	320
Σ 21 species	41		2.802	100.00	10.000	3280

Appendix 26: The medium forest status

Appendix 27: The poor forest status