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论文题目/Title：**Stand growth and species diversity of indigenous plantation in Namxuang Forestry Research Center, Naxaythong district Vientaine capital, Lao PDR**

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老挝 Namxuang 林业研究中心 5 种人工林的生长及林分结构研究

摘要

在老挝首都万象市捞赛通区的 Namxuang 林业研究中心，选择了刀状黑黄檀（*Dalbergia cultrata*）、香坡垒（*Hopea odorata Roxb*）、倒吊笔（*Wrightia pubescens*）、粗轴双翼苏木（*Peltophorum dasyrachi*)）和铁刀木（*Cassia siamea Lam*）5 种重要树种人工林林分，对目的树种的生长、林下树种及草本植物的生长和数量进行了较为系统的研究。每种人工林随机选择 100m^2 样地（10m×10m），调查目标树种的生长，同时在样地中随机选择 4m^2（2m×2m）的小样地，调查自然生长木本树种的种类、数量和生长。另外在小样地中随机选取 1m^2 的样方，调查样方内草本植物的种类和数量，每个样地均 3 次重复。研究结果表明：

1、粗轴双翼苏木材积最大为 0.0115±0.0018m^3・hm^{-2}，其次为铁刀木材积为 0.007±0.0018 m^3・hm^{-2}、香坡垒材积为 0.003±0.0007 m^3・hm^{-2}、刀状黑黄檀材积为 0.00030± 0.0001 m^3・hm^{-2} 和毛倒吊笔材积为 0.00088±0.0001 m^3・hm^{-2}。

2、样地上总共 35 个科，53 个种，11,302 株(297 株存活造林树种，379 株自然更新树种，126 株幼苗和 10,500 株杂草）。灌木树种十蕊风车子(*Combretum roxburghii Spreng*)在铁刀木样地有最高的比例，高达 17.85%，倒吊笔在倒吊笔样地的比例为 10%，粗轴双翼苏木和破布叶(*Microcos paniculata Linn)*在每块样地都占优势。倒吊笔样地每公顷的科丰富度高（18 科），铁刀木低（8 科）。香坡垒样地每公顷的物种丰富度高（45 种），铁刀木低(12 种)。此外，香坡垒样地的辛普森指数和香农指数相当高，高达(0.96 和 0.06)，刀状黑黄檀也高达(0.94 和 3.06)，明显高于其他样地。

3、刀状黑黄檀样地，幼苗和杂草密度较大，为 2,200 株・ hm^{-2}，而在粗轴双翼苏木样地上，幼苗和杂草密度最小，为 900 株・ hm^{-2}。铁刀木样地幼苗和杂草密度为 3000 株・ hm^{-2}，胸径在 3-6cm 之间，高度大于 1.2m。只有双翼苏木样地缺乏秧苗和杂草长度等或大于 0.9m。

Stand growth and species diversity of indigenous plantation in Namxuang Forestry Research Center. Naxaythong district Vientiane capital, Lao PDR

Abstract

This study was in the different plantation at Namxuang (Forest Research Center) in Vientiane capital, Lao PDR. The aim of the study was to evaluate the growth performance and density of different plantations whereas affected to the understory plant diversity between the indigenous tree and natural tree growth on plantation together by investigation from 15 plots (1500m^2) with 10x10m plot and 2mx2m planting space. For the indigenous tree; 1893 tree ha^{-1} which were analyzed for growth performance. Natural tree; the average estimation of all plots were 672 tree ha^{-1}(stem density), 1066 ha^{-1}(saplings) and 2231 ha^{-1}(seedlings); 376 individuals were analyzed for growth performance. The result indicated that: *Dalbergia cultrata* , *Hopea odorata and Wrightia arborea* were smaller than natural tree but *Peltopholum dasyrachis and Cassia Siamea* were bigger than natural tree. So the volume of *P dasyrachis* (0.0115±0.0018 m^3 ha^{-1}) and *C siamea* (0.007±0.0018m^3 ha^{-1}), *H odorata* (0.003±0.0007m^3 ha^{-1}),*D cultrata* and *W arborea* with 0.00030± 0.0001 and 0.00088±0.0001 m^3 ha^{-1}; because *P dasyrachis* and *C siamea* were fast growing tree species well known as fuel wood. On the other hand, natural tree growth well on the *D cultrata* and *W arborea* plot but they couldn't grow well on *P dasyrachis* and *C siamea* plot. A total of 35 families, 53 species, 11302 individuals (297 of living plantation trees, 379 of natural trees, 126 of seedlings and 10500 of grasses). The changes in importance value (IV) was *Combretum decandrum* highest (17.85%) in *C siamea* plots. *Combretum decandrum* was the highest of important value (17.85%), *W arborea* (10%) in plots of *W arborea* Denn(natural and plantation trees combination). *P dasyrachis* and *Microcos paniculata* L were the dominant in all plots. Family richness ha^{-1} was high in *W arborea* plot (18 families) but the low in *C siamea* plots(8 families). Species richness ha^{-1} was high in *H odorata* plot (45 species) and low in *C siamea* plots (12 species). The Simpson's and Shannon's index were similar high in *H odorata* Roxb plots (0.96&0.06) and *W arborea* plots (0.94&3.06). Seedlings and grasses were the most density in *D cultrata* plot (2200 ha^{-1}) which mean 3.16 cm DBH and 4.14 height but the least in *P dasyrachis* plot (900 ha^{-1}) with low height (0.90m) and DBH (1.74 cm); high density during 30 – 60 cm height (3000 ha^{-1}), their height over 1.2m in *C siamea* plot. Plantation trees were smaller than natural tree because almost all of natural trees were pioneer species which integrated at plantation. Only *P dasyrachis* plot lacked of seedling and grass ≥ 0.90 m height.

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Acronyms

B	-	Basal Area
d	-	Diameter
H	-	Total height
F	-	Formfactor
DoF	-	Department of Forestry
FRA	-	Forest Resources Assessment
FFLA	-	Forest and Forest Land Allocation Programs
NBCAs	-	National Biodiversity and Conservation Areas
FORMACOP	-	Forest Management and Conservation Project
FPRCAP	-	Forest Rehabilitation and Afforestation Project
APFReN	-	Asia-Pacific Forest Rehabilitation Network
NAWACOP	-	Nam Ngum Watershed Conservation Project
AKECOP	-	Asian- Korean Environment Cooperation Project
SUFORD	-	Sustainable Forest and Rural Development
FRC	-	Forest Research Center
5MHRP	-	Five Million Hectares Rehabilitation Program
ASEAN	-	Association of Southeast Asia Nation
FAO	-	Food and Agriculture Organization
MAF	-	Ministry of Agriculture and Forestry
Yr^{-1}	-	Per year
ha	-	Hectares

a.sl	-	Above Sea Level
℃	-	Degree Celsius
°	-	Degree
%	-	Percentage
m^2	-	Square meter
m^3	-	Cubic meter
mm	-	Millimeter
cm	-	Centimeter
Pich	-	Evaporation in millimeter
Rep	-	Replicate
Poly	-	Polynomial
R^2	-	Square root
H'	-	Shannon diversity index
J'	-	Jaccard' similarity index
D	-	Simpson's index
ln	-	Natural logarithms
SS	-	Sum of Square
T	-	Species
NS	-	North- South
EW	-	East- West
CRD	-	Complete Randomize Design
sp	-	Unknown species
UNEP	-	United Nations Forum on Forests

TRMF	-	Tropical Mountain Rain Forest
DBH	-	Diameter at Breath Height
PAFO	-	Provincial Agriculture and Forestry Office
DAFO	-	District Agriculture and Forestry Office
V	-	Volume
IV	-	Important Value
RD	-	Relative Density
RA	-	Relative Abundance
RF	-	Relative frequency
7.7E-08	-	7.7x10^-8… which is of course 0.000000077

1 Introduction

1.1Background

Forests play important roles in our lives and in conservation of the environment. Yet in spite of their significance, forests around the world are disappearing and are being degraded at an alarming rate. In 2005 the world's forest covered about 4 billion ha, or about 30% of the world's total land area (FAO, 2005). Between 1990 and 2000 there was a net loss of forest area of about 9.4 million ha yr^{-1} (FAO, 2001). Also, from 2000 to 2005 especially in Asia, forest cover has been reduces by about 3.4 million ha every year in recent year. In 2010, forest area of South Asia and South East Asia about 294.373 million ha. However, in South East Asia from 2000 to 2005 forest cover has been reduced about 3 % and continued to reduced 3.81 % from 2005 to 2010 (FAO, 2010).

Laos has a rich forest resource compared to other ASEAN member countries. Forest cover in Laos has been decreasing originally from 70% of total land area in 1940 to only 41.5% in 2002, therefore, Lao government established a sustainable forest management system with three forest categories which are conservation forest covering 4.827.000 ha (56.45%), protection forest covering 517.000 ha (6.04%) and production forest (natural forest, natural regeneration and plantation forests) covering 3.207.000 ha (37.50%) (MAF, 2005).Forest lost during 62 years as 28.5% with an average 0.4% per annum, degraded forest as more than 6.3 million ha consider as secondary forest. Laos is a tropical country with extremely rich biological diversity, and it is also a country that experienced serious forest cover change during the second half of the 20th century. According from survey in 2002 and satellite image analysis from 1999-2000; Land use has been changing very rapidly since 2003-2004 mainly due to influx of investment in commercial crops and in many cases conversion of rich forest precedes plantation establishment. The Laos People's Democratic Republic (hereafter Laos) is a developing country where the call for both natural and plantation wood is great (Department of Forest, 2007). Large areas are also transformed for hydroelectric power/dams and mining. In addition, forest degradation due to shifting cultivation, logging and others carry on (Phongoudom, 2009). The shifting cultivation in the upland of Laos PDR was a well-adapted and sustainable farming system for centuries but has lately became a foremost problem, cause by overuse of forest land due to an increase of the population. The fallow period has been shortened, leading to a rise in weed profusion, soil poverty, and minor crop harvests (see e.g. McAllister, et al, 2000).

In Laos, forestry sectors concentrated on forest rehabilitation strategy, and forest policy has undergone several significant changes over the last decades in an attempt to overcome these losses. During 2001-2010, many projects had been implemented for increasing forest cover, economic and ecological benefits. Depending on these projects, many plantations had been established the *Pterocarpus macrocarpus*, *Dipterocarpus Alatus*, *Dalbergia chochinchinensis*, *Xylia xylocarpa*, *Afzelai xylocarpa*, and *Casia saemia*. All projects had been conducted on degradation forest, uncultivated forest, watershed preservation, etc. (Rattanasavanh et al, 1994; Mounda, 1995; Chanthalangsy, 2002; Oji paper co. Ltd, 2005; Phongoudom et al, 2007). Previous rehabilitation projects conducted on protection forest, production forest and genetic forest in Laos; during 1932-2006 Department of Forest (DoF)launched the project on 186000 ha and also 220000 ha by Forest Resource Assessment (DoF, 2005), in 1986-2007 implemented on logged over area with 181920 ha by DoF, in 1989-2006 implemented on 4827000 ha by Forest and Forest Land Allocation Programs (FFLAP) and National Biodiversity and Conservation Areas (NBCAs) , in 1995-2000 implemented by Forest Management and Conservation Project (FORMACOP), during 1989-2006 implemented by Forest Rehabilitation and Afforestation Project (FORCAP), in 1998-2001 Asia-Pacific Forest Rehabilitation Network (APFReN) was implemented on lowland mixed deciduous forest with enrichment planting, Nam Ngum Watershed Conservation Project (NAVACOP) piloted direct seedling project with local involvement, Asian-Korean Environment Cooperation Project (AKECOP) researched on restoration among three forest situation (logged over, fallow forest and degrades forest) by enrichment planting and agro-forestry in 2001-2005 and also Sustainable Forest and Rural Development (SUFORD) conducted on enrichment planting in degrade forest during 2004-2008. Similarly in region, there were a pilot project in Vietnam implemented through the National Forestry Action Plan developed in the early 1990s (Nguyen and Gilmour, 2000; Morris et al, 2004; Ohlsson et al, 2005). A recent development has been the introduction of the ‘‘Five Million Hectares Rehabilitation Program (5MHRP)’’, the target of which is to increase forest cover to 43% (MARD, 2001; Phan, 2004; Morris et al, 2004; Ohlsson et al, 2005). If successful this will return forest cover in Vietnam to the levels presented in the 1940s. Therefore, according form previous projects there are many projects have been done by Forestry Research Center (FRC)/National Agriculture and Forestry (NAFRI) such as the enrichment planting at FRC’s plantation.

1.2Justification:

There were many studies on restoration of degraded forests by either plantation or natural forest, but reforestation in degraded areas is difficult. Not only is it difficult to establish trees in fire-prone grasslands (e.g. Turvey, 1994) but many of the soils are also very infertile and very few native species are able to tolerate such sites. The seedlings of some tropical tree species also appear to require initial shading (Aide et al, 1995; Parrotta et al, 1997). Early plantations developed in Vietnam had focused on monocultures of fast-growing exotic species of Eucalyptus, Acacia and Pinus (Nghia and Kha, 1998; Turnbull et al, 1998; Kha et al, 2003). However, many indigenous species have failed when their pure plantations were established the *Erythphoelum fordii*, *Chukrasia tabularis*, *Canarium albume*tc. When these tree species replanted in pure plantations, they do not perform well usually. There are also some other cases, such as *Manglietia glauca* planted in north, *Pahudia chochinchinensis*, *Michelia spp*., *Pterocarpus spp* and *Toona spp* established in central highland, *Hopea odorata* and *Dipterocarpus spp*planted in southern Vietnam (Nguyen Ngoc Lung, 1995).

It is important to understand the forest structure in order to propose the appropriate forest management measures. In addition, it is also important for selection of tree species and sustainable forest management.

1.3 Objective

Our research objectives are as following:

1) To assess the structure of commercial tree plantation and to compare changes in regeneration dynamics among five tree species plantation;

2) To evaluate plant diversity (tree and grass species) among different tree species plantation.

Research Questions include:

How distribution tree were planted by people?

How many other tree species can grow in five tree species plantation?

How many grass species can grow in five tree species plantation?

2 Literature review

2.1 Restoration of degraded ecosystem

The degradation of forest ecosystems may be attributed to various natural and anthropogenic factors, such as climatic stress, biotic impacts, and selection of tree species for planting, harvesting regimes, litter ranking, amelioration practices, atmospheric pollution and soil acidification caused by internal and external processes （Hüttl, 1991). Other definitions denoted that restoration ecology was the science of ecological restoration, and recently redefined as “the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed” (SER, 2002). Smith (2001) point that the goal of restoration ecology is to return a particular habitat or ecosystem to conditions as similar as possible to the predegraded state. In Vietnam, Will de Jong et al (2006) defined forest rehabilitation as all deliberate activities that have as an outcome the reversal of forest degradation. Natural regeneration is one of the best options for rehabilitating degraded hill slopes, especially in areas where favorable environmental conditions such as those of temperature and rainfall prevail. Many researchers have pointed out that the exclusion of people and animals contributes to the initial establishment of plant cover and a possible succession of herbs and grasses to shrubs and small trees. Smart et al (1985), for example, showed that between 1967 and 1981 protection from grazing in Murchison Falls National Park (Uganda) resulted in a decrease in the diversity of grassland species and an increase of woody species in all stages.

2.2 Role of mixed species plantations for restoration

Tree plantations can be effective tools for restoration or rehabilitation of degraded forest (Fang and Peng, 1997; Haggar *et al*, 1997; Loumeto and Huttel, 1997; Obehouser, 1997; Zhuang, 1997). Plantations can support biodiversity conversation (Hartley, 2002), arrest site degradation (Lugi, 1997) and facilitate forest succession through modification of both physical and biological conditions (Parrota et al., 1997). Plantations promote understorey regeneration by shading out grasses and other light-demanding species, changing understorey microclimate, improving soil properties and increasing vegetation structural complexity. These changes lead to increased seed inputs by attracting seed dispersing wildlife (Parrotta et al, 1997). In addition, forest plantations reduce soil erosion and fire hazards (Cusack and Montagnini, 2004). For native species, mixed plantation systems seem to be the most appropriate for providing a broader range of options, such as production, protection, biodiversity conservation, and restoration of degraded areas (Montagnini *et al*, 1995; Keenan *et al*, 1995; Guariguata *et al*, 1995; Parrotta and Knoweles, 1999). Mixed plantation can produce more biomass per unit area because competition among individuals is reduced and the site is used integrally (Montagnini *et al*., 1995). However, the success of the establishment of mixed forest plantations depends on plantation design and an appropriate definition of the species to be used, taking into consideration ecological and silvicultural aspects (Wormald, 1992). There exits very litter information on the growth of tree species native to the dry tropics and information on experiences comparing pure and mixed plantations is limited. Projects conducted on this species for reforestation, natural germination, active restoration on enrichment planting, e.g. after planting 7 years diameter and height growth was favored more in gaps than in planting lines (Sovu et al, 2012). However, higher species diversity in B. alnoides plantations than native forests indicates that B. alnoides plantations can facilitate the development of plant species und er their canopy in terms of species composition, diversity, and restoring native species diversity. The species could thus be an effective tree species for restoring tree diversity in tropical southwestern China (Zhang et al, 2012)

2.3 Five indigenous species plantation

Indigenous tree species are expected to provide high value timber and contributed to the conservation of biodiversity as well as local culture against the background of decrease and degradation of forest resource around the world (FAO, 2010). But, silvicultural techniques for indigenous tree species have not been improved compared with those of exotic fast-growing tree owing to limited experience and a lack of information about site suitability and growth performance in a given environmental (Montagini and Jordan, 2005). Also, other researchers are interesting to study about high value timber products such as hardwoods species in Southeast Asia because it is the home of many rare tropical trees that are in great demand for exotic hardwoods, religious objects and as medicinal oils. Further concept denoted that : “hardwood species became endangered in Laos because of a combination of demand and unsustainable harvesting to meet that demand, also in Cambodia had planted enrichment and gab planting with 5 species (*Hopea odorata*, *Dipterocarpus alatus*, *Pterocarpus macrocarpus*, *Afzelia xylocarpa* and *Tectona grandis*)” (Ty Sukhom, 2007). However, the afforestation was began in Indonesia since the end of 17th century with planted 7 species (*Acacia mangium*, Dipterocarpus species, *Pinus merkusii*, *Paraserianthes falcataria*,*Gmerina arborea*, *Tectona grandis* and Mangrove species)(Suhardi Eny Faridahjo NH 2007). The following century, there had been many projects implemented on plantation in Lao PDR since 1932 (Phongoudome and Khamfeua Sirivong, 2007). Also, it spread to other countries by the same idea of indigenous tree planation such as: “in Malaysia had done as similar technique but it was difference only indigenous species” (Daniel B.Krishnapilay, et al, 2007), In Mynmar had done since 1987 (Thuang Neigh, 1997), in Thailand had done since 1906 (Monton Jamroenprucksa, 2007)”. More than that, in Vietnam had established the indigenous tree plantation since 1920 with the most species preferred such as *Dipterocarpus alatus*, *Hopea odorata*, *Cassia siamea*, *Senna siamensis*, *Manglietia conifera*, *Styrax tonkinensis*, *Cinnamomum cassia* and *Tectona grandis* (Nguyen Hoang Nghia, 2007). Many projects focused on plantations for production of timber using various indigenous and exotic tree species. For instance, Brunei was the first country had launched the deforestation in ASEAN since 1985 which conducted on two main projects such as watershed protection and old timber harvest area by planting native species (*Acacia mangium*, *Pinus caribea*, *Aracauria pines*, Fruitree, Dryobalanops and *Shorea ssp*) in 500 ha

(Hahmud Yussof, 2007). Traditionally, foresters tend to consider tree plantations as a renewable resource for producing timber and cellulose. Using a plantation to accelerate the natural regeneration of tree species is a very different concept from the traditional approach. Various understorey tree species arising in stands with single tree species could be used to achieve high biological diversity at the landscape level by creating various types of forests, such as human-induced natural forest, mixed indigenous stands and mixed exotic and indigenous stands through various silvicultural treatments, while stands with single tree species could be managed for traditional timber and cellulose production at the same time (KAKO K, et al, 2002). Furthermore, Chinese researchers studied about provenance tests of *Pterocarpus macrocarpus* at seedling stage in Xishuangbanna of Yunnan Province, China (ZHUet al, 2007). Also, there was other plantations mixed with *Xylia xylocarpa*, *Shorea obtusa, Pentacme siamensis, Mitragyne sp*, etc (Cao Thi Ly, 2009). Tefera et al (2014) measured plant frequencies, density, and diversity by compared with 55 woody plants for considering preventing disturbance between indigenous woody plant and monoculture of non-native species.

2.4 Growth performance of 5 indigenous species in plantation

In general, 5 indigenous tree species are usually distributed at elevation below 1000m. It usually grows along river banks, streams or near the water sources in mixed, semi-deciduous forest or in thin Dipterocarp forest. It usually grows mixed with broad-leaved species such as *Afzelia xylocarpa, Cassia siemea, Lagerstroemia* sp., *Vitex* sp., *Dipterocarpusintricatus, Terminalis* sp., *Shorea roxburghii.* It rarely grows into dominant population (Vu Dung, Ng Dung, 1998). In 1947, French foresters planted *P. macrocarpus* as a trial planting in an area of 0.5ha in the experimental area at Eakmat-Daklak in Vietnam. At present this trial planting has grown into a population of good growth. At this experimental area in 1999 *P. macrocarpus* attained average height and diameter of 16.03 m and 28.49 cm respectively. Mean annual increment: D1.3> 0.55 cm, H > 0.3 m (Ha Thi Mung, 2001). Phongoudom (2010) denoted that : the growth of *Xylia xylocarpa* in plantation was 13.9-15.9 cm DBH and 14 – 16.3 m height when 20 years old, the growth of *Dalbergia chochinchinensis* in plantation was 18.5 cm DBH a nd 19 m height when 20 years old, the growth of *Pterocarpus macrocarpus*on planation in Vietn am was 34.25 cm DBH and 22 m height when 35 years old, also the growth of *Pterocarpus m acrocarpus* at 9 years old plantation in Lao at FRC's area was 8.6 cm DBH and 13.5 m height, for the growth of *Dalbergia chochinchinensis*in plantation was 11.5 cm DBH and 14.1 m heigh t when 9 years old , in plantation of *Xylia xylocarpa was* 4.8 cm DBH and 8.7 m height when 8 years old. There was more data for indigenous tree growth in planation such as: *Pterocarpus* *macrocarpus was* 7.69 cm DBH and 6.39 m height when 13 years old had done by faculty of forestry/national university of Laos. Also, in Vietnam showed that the growth of *Hopea odorata* in planation was 24.17 cm DBH and 11.34 m height when 13 years old, the growth of *Peltophorum dasyhachic* in plantation was 5.31 cm DBH and 6.59 m height when 5 years old, the growth of *Casia siamea* was 7.29 cm DBH and 6.47 m height when 6 years old (F. Coles and J.B. Boyle, 1999).

2.5 Plant biodiversity in forest plantation

Sustainable forestry management, including improving biodiversity in plantation systems, is encouraged by the international certification process and promoted through the United Nations Forum on Forests (UNEP, 2002). Plant diversity mentions to the variety of plants that be existent in the world. Plants contest with other plants and organism to stay alive in ecosystem. The adaptation of plant species to fresh environments and habitations to rise genetic and species diversity. Plant diversity is very essential because the existing of various species might depend on each other's, so elimination of one species may perhaps affect the living of several other species. The idea of biodiversity is well characterized in linguistics, social and physical sciences (Patil and Tailie, 1982). Also, complexity of a community's plant species structure does not reflect the diversity of other sort levels. Applying the theories of species variety to the diversity of growth forms arising in a community has been advised as an alternative (Maugurran, 1988). Only limited and rudimentary research has been carried out on the biodiversity dynamics of its plantation underneath the context of conservation of species diversity in plantation, which is an imperative objective for sustainable forest management (Burton et al, 1992). Sample plot is the percentage of a sample area from which data are collected (Avery and Burkhart, 1983). Tropical mountain rain forest (TMRF) is a local climax community of forest succession, some studies have been done by them. In their trial, three basic tree sample plots (20×20m) were established in each community. Within each plot, five 5×5m shrub layer plots and five 2×2m herbaceous layer plots were established (Chen et al, 1999). The species, number, height, and coverage of all the plants within the plots were noted. Species density is a quantity of statistical properties which define the relationship between species richness and evenness within a sample plot or a larger unit of study (Gove et al, 1996). Replication of sample areas is distinct from replication of plots within a sample area; the latter, which has been regarded as 'pseudo-replication' by Hurlbert (1984), might not be used as a substitute for the former. They mention a minimum of 3 replicate sample areas for field types within yearly cropping, agroforestry, fallow and tree-crop stand land-use stages (Zarin, 1995).

The notion of species diversity encompasses two concepts: species number and species evenness are relative profusion. Plant species number was major presented (Fisher et al, 1943). Also is a simple number of species originated in a given community. In order to the inference that the exact number of species could be determined for boundless community, the concept was later mentioned to as species richness (Whitaker, 1965). Species evenness, on the other views, denotes to the degree to which governance is dispersed among the species in a community. Evenness is maximum if all species in the community are similarly represented. Evenness is frequently characterized by species relative profusion (Patil and Tailie, 1982). Pielou (1975) have given comprehensive treatment to the derivation of the many indices and the concerns associated with their application. The concepts of diversity and greatest of the proble ms associated with its measurement can be seen in the most recognized indices. Species richnes s, Simpson's index (1949), and Shannon's (1963) index are the most remarkable of a wide array of indices which aim to narrow the broad idea of species diversity a single number. As previousl y mentioned, species richness is a count. Ideally, a richness value would represent the number o f species in a given community. However, most ecologist distinguishes that a community has no definitive bounds and therefore cannot contain a fixed number of species (Peet, 1974). Therefore, species richness must be estimated through sampling and the number of species expressed on an area basis. The obvious problem encountered when comparing richness values from various communities is the total area sample must be equivalent. Many botanical studies express species richness as the number of species per square meter (Maugurran, 1988). However, the equality of plot size does not eliminate the possible inequality of sample size, nor does it ensure equality in the number of individuals sampled. A number of method have been proposed for transforming species richness to value independent of sample size (Menhinick,1964; Odom et al, 1960), but seldom are the condition needed to these transformation found (Peet,1974). Simpson's index and Shamnon's index belong to a family of index known as heterogeneity index, which incorporate both richness and evenness (Peet, 1974). These indexes stem from information theory, and specific a diversity value based on the sum of each species contribution to general of abundance. Measure of abundance most commonly used includes number of individual per species, percent cover, and biomass. The selection of which measure to apply is entire subject and can promote bias in the index value (Peet, 1974). Give that species vary greatly in size, the number individual is an inappropriate representation of dominance. Whitteker (1965) recommended that species was direct result of resource partitioning, and hence represented a species true dominance in a community. Since determining the biomass of all the species in a community can be time consuming and costly, dominance can also be represented by the crown cover of each species (Whittaker, 1965). Despite the bias associated with the variable used to characterize abundance, two indices utilizing the same measure might nevertheless fail to agree on the rank of several communities (Hurbert 1971; Peet 1974; Patil &Taillie 1982). The inability of the indices to concur results from uneven weighting of the individual in the community by the index formulation itself, mathematical theory show that some index are more affected by changes in relative abundance of dominant species while others are more sensitive to changes among scarce species. More complicated issue point that, ecologists fail to approve on indices those are the most sensitive of species. For example, Peet (1974) illustrated that Shannon's index is best sensitive to rare species, but others understood it to be most sensitive to dominant species (Monk, 1974; Sager and Hasler, 1969), and some considered Shannon's to respond utmost to changes in species of middle abundance (Fager, 1972; Poole, 1974; Whittaker, 1965). In many parts of the world, plantations make up a considerable percentage of the total forest area. While the percentage of the forest area composed of plantations (usually managed forest, established artificially by planting or seedling) is on average 4% for Europe, in some countries they make up a considerably larger percentage, for example, constituting 89%in the Republic of Ireland,78%in Denmark and 77% in Britain (Forest Europe et al, Coot et al,2011). Plantation forest has been increasingly used for a wide range of wood transformation processes because timber sources from natural forest are declining (White et al, 1987). The association of forests planted with single tree species with a high species in the ecosystems might enable to complete a high biological diversity at the landscape level, which could bring various benefits to the forest of Sakaerat (KAKO et al, 2002). One of the major factors that affect the abundant colonization of tree species in a planted forest is the proximity to a natural forest, i.e. seed source which relies on selecting fast-growing tree species with dense crowns that can rapidly shade out competing weeds and attract seed-dispersing wildlife, particularly birds and bats(Lambet al, Parrota, 1997). There are four characteristic phases after disturbance in a plant community, including regenerative phase, building phase, mature phase and degenerative phase (Watt, 1947). In the building phase or the stem exclusion stage in Oliver and Larson's stand development model (Oliver, Larson, 1990). Leaving stand untended after establishment may facilitate the establishment of indigenous tree species within plantation forest (Parrotta et al, 1997).

2.6 Species diversity in natural forest

In Amazon forest there are more than 280 tree species with DBH ≥10cm per hectare

(Valencia et al, 1994; Oliveira and Mori, 1999). Many studies have concentrated on species diversity in natural forest. For instance; a project in Lao to study about changes in stand structure and environmental condition of a mix deciduous forest after logging (Phongoudome et al., 2013). Structure diversity is an important property of forest stands (Powelson and Martin, 2001). Both natural forest and forest plantation are studied on forest discipline which the stand structure talk about the within-stand spreading of trees and other plants characteristics such as size, age, vertical and horizontal arrangement, or species composition. And also that a more composite forest structure is linked to a great diversity of plant and animal species (Pretzch 1997; Shimatani 2001). Its statistical view on a number of methods have been used for assessing forest structure (Neumann and Starlinger 2001; Staudhammer and LeMay 2001; Kin et al. 2004). Moreover, it is common opinion in forest ecology that dissimilar management practices are main determinant of forest diversity (e.g., Boncima 2000). The communal way to evaluate forest structure contains of using simple attributions, such as the DBH of alive and tree species, the volume of alive trees, or the number of sapling of the governing tree species (Motta et al, 1999). Tropical forests and trees currently are becoming themes of concern because of its species diversity (Condit et al, 1996; de Jong and Chokkalingam, 2001). Rudimentary information on species composition can be useful in estimating the impact of trailer forest activities. It can also specify the capability of forest recuperating from past disturbances and can thus, be used planning and better management of forest on a sustainable forest management basis. Tree species diversity contributes to the forest ecosystem stability and sustainable developments (Rennolls and Laumonier, 2000). Same as the similar impression on species composition and structure are equally their natural regeneration in tropical rainforest or tropical deciduous forest (Jordan et al, 1987; Kennard et al, 2002; Hardwick et al, 2004)

3 Materials and methods

3.1 General information of study site

3.1.1 Study site history

The study site was established at plantation of Forestry Research Center (FRC) which located in Phonethone village (NamSuang), Naxaythong district, Vientiane capital, Lao PDR. FRC shares border with three villages, Phosi village to the North, Phonethong village to the South, border with Sivilay to the East and Namxuang reservoir to the West. FRC's area belong to plain, and its total area is 400 ha (Figure 1).

Forty-four kilometer to North from Vientiane capital, where indigenous tree species plantation is located. Latitude is 18º16'41.3"N, and longitude is 102º6'41.9"E, and average altitude is 205m. The site was selected because the plantations at this site were relatively well-documented and preventive areas for rehabilitation in the center part of Laos since 1970. Plantation in the research area has a potential of natural species regeneration. This research area was planted in 2009 by ASEAN-Korea Environment Cooperation Project (AKECU). However, there is a lack of regenerated seedlings in some places due to the lack of mother trees for seed supply or unsuitable conditions for natural germination.

In generally, the characteristics of research sites belong to poor forest basing according from natural forest classification of Laos. Growths of plantations showed slow growth rate than the same species which were planted in fertile soils. The original vegetation in this area is characterized as Tropical Rain Forest. The area was subjected to over-harvesting, illegal cutting, shifting cultivation and grazing and the top soil layer was removed. Now in the unplanted area, vegetative cover is mainly of some annual grass species mixed with some pioneer forest tree species such as Schima wallichii, Litsea cubeba, Ficus fulva and Macaranga denticulata.

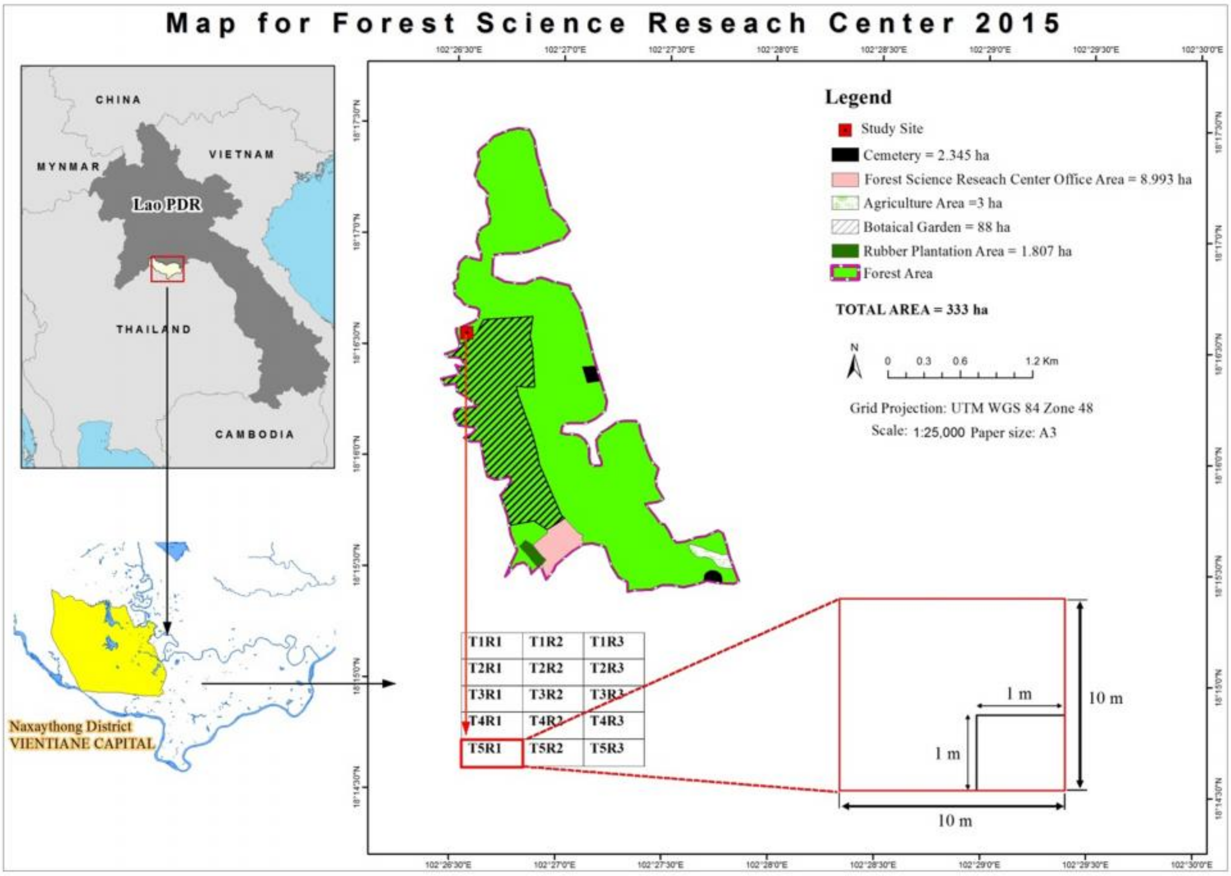


Figure 1 Forestry Research Center location (*FRC, 2014)*

3.1.2 Climate of study site

The research site has a monsoonal climate. The raining period ensues from May to October, and the dehydrated period is from November to April. The mean temperature in Vientiane is 25.9℃. Mean monthly temperatures have a variation of 6.8 °C which is a very low range. The variation of daily average temperature is 4.5 °C. April is the warmest month (very hot) having a mean temperature of 28.5°C. January is the coldest month (really warm) with a mean temperature of 21.7°C.

The average rainfall is 1648.7 mm in Vientiane per year. On average, there are 111 days per year with more than 0.1 mm of rainfall or 9.3 days with an amount of sleet and snow per year. The driest weather is in December with an average of 2.8 mm of precipitation. The wettest weather is in August with an average of 322.5 mm of rainfall. The average hours of sunshine per day rang from 4:00 to 8:12 during June to December. The longest day and shortest day of the year is 13:04 and 10:55 separately. There is an average of 2420 hours of sunlight per year with an average of 6:37 of sunlight per day. It is sunny 55.2% of daylight hours. The remaining 44.8% of daylight hours are likely cloudy or with shade, haze or low sun intensity. At midday the sun is on average 70.7° above the horizon at Vientiane. The average annual relative humidity is 75.2% and average monthly relative humidity ranges from 66% in March to 84% in August.

3.1.3 Average precipitation and temperature in Vientiane

It is important to evaluate how climate has varied and changed in the past. The monthly mean rainfall, temperature, humidity, evaporation and sunshine data can be showed the baseline climate and seasonality for specific years (Table 1). Also, the figure 2 shows mean monthly temperature and rainfall o f Lao during 1998-2014. The dataset was record at Vientiane's station by Department of Meteology and Hydrology, Water Resources and Environment administration.

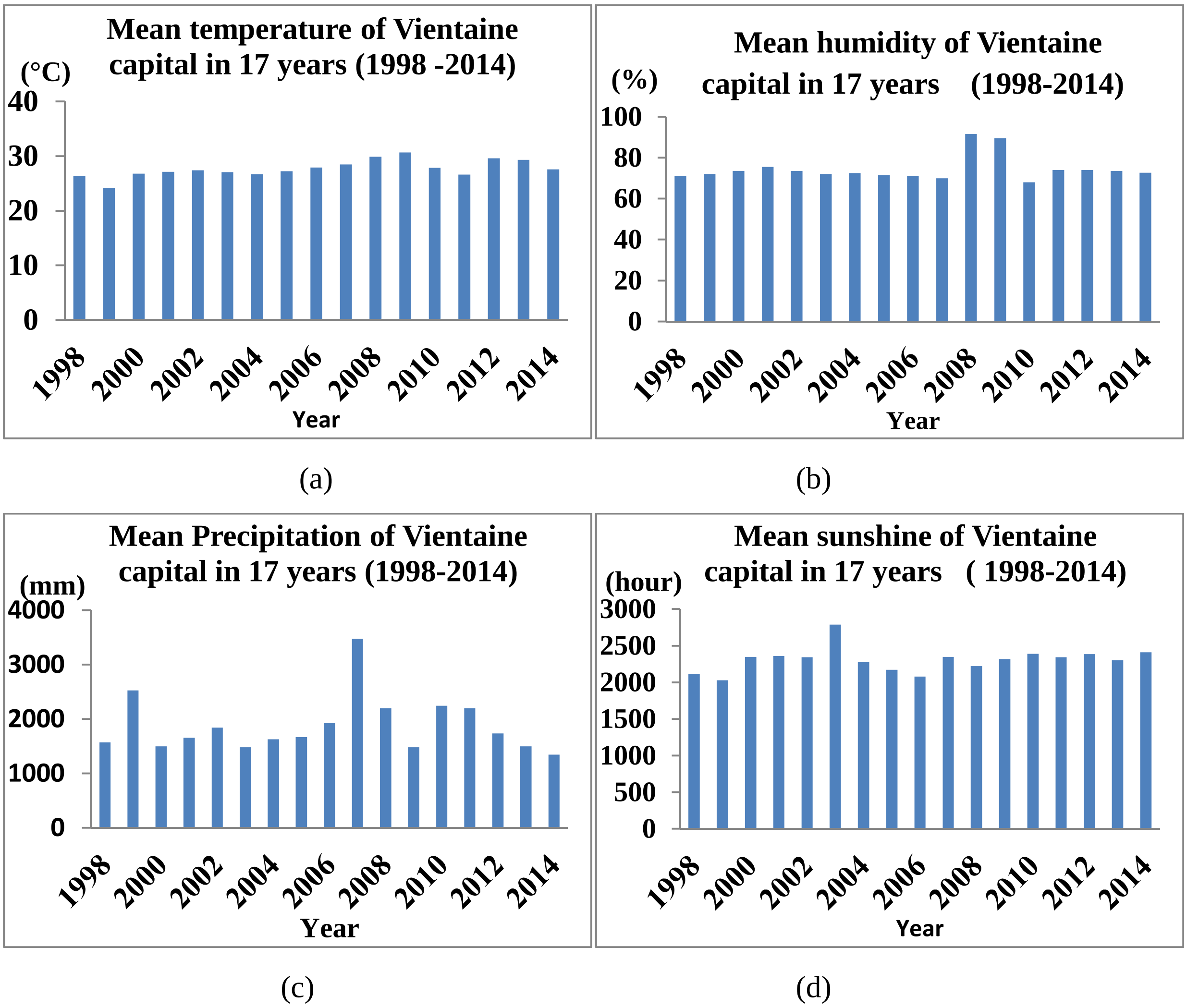


Figure 2 Climate of Vientiane from 1998 to 2014. a, Temperature; b, Humidity; c, Precipitation; d, Sunshine (***Sources :****Department of Meteology and Hydrology, Water Resources and Environment Admisnistration)*

Table 1 Climate data of Vientiane in 2014

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
T_x	27.5	31.5	34.7	34.7	34.9	32.9	31.8	31.8	32.2	32.7	31.8	28.8	32.1
T_n	15.4	20.1	23.6	25.3	25.9	25.9	25.5	25.1	25.2	24.2	22.7	18.7	23.1
T_{xn}	21.5	25.8	29.1	30	30.4	29.4	28.6	28.5	28.7	28.4	27.2	23.8	27.6
U_x	90	83	84	86	89	93	94	95	94	88	90	86	89.3
U_n	46	46	46	52	55	64	67	68	65	54	55	48	55.5

U_{xn}	68	65	65	69	72	79	81	82	80	71	73	67	72.7
R	0.0	0.0	5.5	51	88	255	363	321	140	42.4	79.9	0.0	1349
E	99.	105	135	114	102	67.5	58.2	55.7	62.7	101	88.6	97.8	1088
W	2.65	2.61	2.68	4.1	4.24	3.17	3.2	3.44	2.82	3.34	2.75	2.89	3.2
Sun	272	217	212	183	235	146	100	140	174	243	258	228	2408

Remark: T_{xn} $(T_x+ T_n)/2$ = Mean temperature(°C); T_x = Mean max temperature; T_n = Mean minimum temperature(°C); U_{xn} $(U_x+ U_n)/2$ = Mean humidity of air(%); U_x = Mean maximum humidity of air (%); U_n = Mean minimum humidity of air (%); R = Total rainfall(mm); E = Evaporation in mm (Piche); W = Mean of Wind Velocity in meter per second (m/s); S = Total sunshine duration in hour(h)(Source: Department of Meteology and Hydrology, Water Resources and Environment Administration, 2014).

3.1.4 Soil property data

3.1.4.1 Soil sampling and analysis

Soil samples were collected at 0-20 cm in depth at mixed plantation and secondary forest of two study sites. The fresh weight of the soil was obtained and all the soil media were air-dried for 2 weeks, pulverized and sieved in 2mm mesh wire. The soil samples in five sites were analyzed in the Soil laboratory, Agriculture Land research Center, National Agriculture and Forestry Research Institute. Soil properties such as pH, N, OM (organic matter), cation exchange capacity (CEC) were analyzed at five sites.

The whole area of FRC’s plantation used to be the sifting cultivation or degradation forest. According to soil property analysis, FRC’s plantation is loamy sand consist of 88.46% sand, 4.82% silt and 6.72% clay particle. The average pH (H_2O) for all plots was 5.38 and average pH (KCL) was 4.65. The soil contained 2.23%, Carbon (C) , 3.85% organic matter (OM), 1.60% Phosphorus (P_2O_5), 2.79% Calcium (Ca), 0.177% Potassium (K_2O), 0.08% Sodium (Na), 0.156 me^{-100g} of Magnesium (Mg) and 5.49 me^{-100g} of Cation Exchange Capacity (C.E.C).

3.1.4 Vegetation type

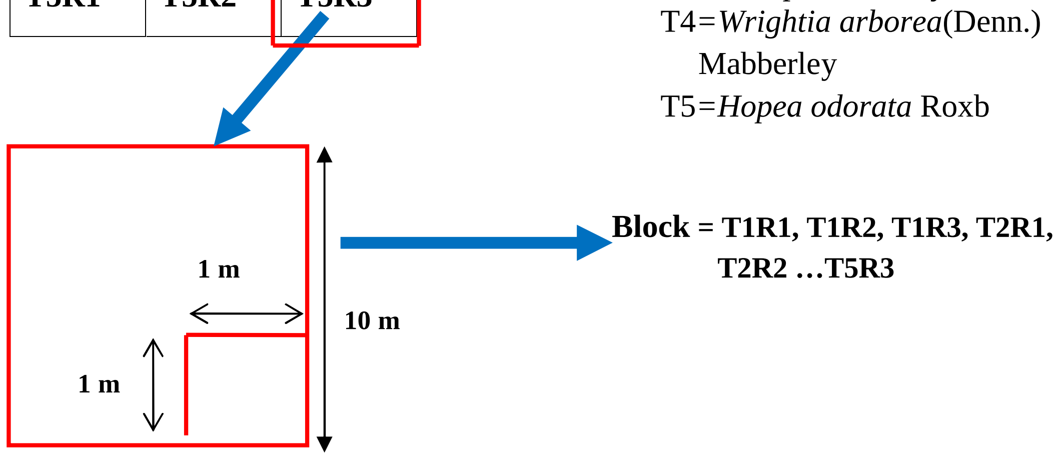
FRC’s plantation is quite similar to natural forest consist of difference plant species as the community forest in ecosystem. We can find five crown layers in plantations generally. First layer is big trees (*Pterocarpus macrocarpus*, *Acacia mangium*, *Acacia auriculiformis*, *Pleltophorum dasyrachis* Kurz,), second layer is medium trees (*Wrightia arborea*, *Casia siamea*, *Anstonia scholaris* and bamboos(*Oxytenanthera parviflora*)), third layer is the shrub (*Cratox-*

ylum Cratoxylum cochinchinense, *Barringtonia annamica Gagnepain*, *Celtis cinnamomea* LINDL, *Daemonorops jenkinsiana*,*Streblus taxoides*), fourth layer is sapling and vine (*Calycopteris floribunda*, *Tinospora crispa*, *Combretum decandrum*, *Mucuna pruriens*), and fifth layer is grass and small seedling (moss, *Imperata cylindrical*, *Blumea riparia*) (Savath, 2011). The inventory of FRC at the *Pterocarpus macrocarpus* plantation during 1983-1987 found that there were 99 tree species including mature tree, medium tree, shrub, sapling, and seedling and grass species.

3.2 Experiment design

Complete Randomize Design (CRD) was used in this experiment. We chose five tree species plantations (T1, *Dalbergia cultrate* Grah.ex Pierre; T2, *Cassia Siamea* Lam; T3, *Peltopholum dasyrachis* Kurz; T4, *Wrightia arborea*(Denn.) Mabberley; T5, *Hopea odorata* Roxb), and a 10m×10m sample plot was established for every plantation with three replication randomly (Figure 3). The tree species and number, DBH, height and crown width were measured in sample plot. A another sample plot of 1m×1m was set up from every 10m×10m sample plot to assess the understory floral composition. All tree species (trees, shrubs and saplings and seedlings) were surveyed in 100m^2 rectangle plot. But grass species were investigated in 1m^2 rectangle plot. Tree and grass species are directly identify in the field or taken to laboratory to identify.

Species	**Rep 1**	**Rep 2**	**Rep 3**
T1	**T1R1**	**T1R2**	**T1R3**
T2	**T2R1**	**T2R2**	**T2R3**
T3	**T3R1**	**T3R2**	**T3R3**
T4	**T4R1**	**T4R2**	**T4R3**
T5	**T5R1**	**T5R2**	**T5R3**



Detail:

Replication

Rep1 = Replication 1
Rep2 = Replication 2
Rep3 = Replication 3

Species

T1 = *Dalbergia cultrate* Grah.ex Pierre
T2=*Cassia Siamea* Lam,
T3=*Peltopholum dasyrachis* Kurz
T4=*Wrightia arborea*(Denn.) Mabberley
T5=*Hopea odorata* Roxb

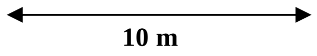


Figure 3 Experiment designs of 5 species trees plantation and sampling layout in study sites

3.3 Data collection

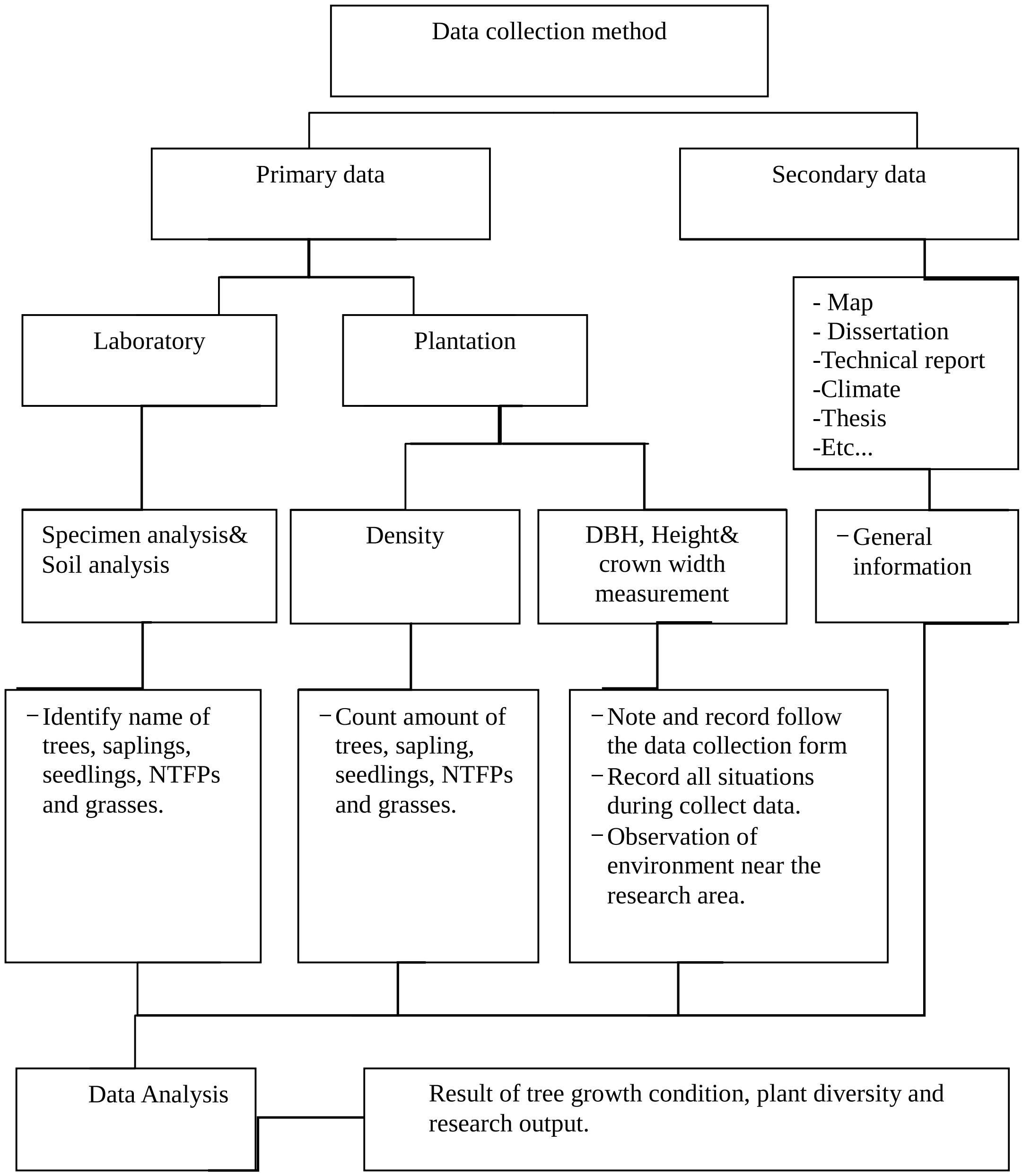


Figure 4 Data collection method

3.3.1. Secondary Data

The secondary data came from Forestry Research Center, ASEAN-Korea Environment Cooperation Project (AKECU), District Agriculture and Forest Office (DAFO), Department of Forest (DOF), Department of Meteology and Hydrolog Resource and Environment Administration. These offices supported the practical plan, project document, reports, official document, maps, statistics and climate data. For example, DOF support information about forest plantation, forest product policy and general socio-economics. Other sources came from internet such as journal, dissertation and research papers.

3.3.2 Primary Data.

3.3.2.1 Tree growth

Survival rate was assessed through the number of trees that still live and the record number of planting. Height was measured by clinometer with 0.1 m accuracy. Diameter at breath height (DBH) of all tree species was measured by caliper and diameter tape, and the smaller tree which less than 1.3 m height was not measured DBH. Crown width was measured from two directions, one was North to South, and another was East to West. The mean value of two directions was calculated to representative crown diameter.

Understory trees (other tree species) that grew naturally in 10m×10m sample plot were measure d and recorded on DBH, height and crown width. Also, sapling and seedling were measured on height. In 1m×1m sample plot, grass species, amount and height were measured.

3.4 Data analysis

3.4.1 Stand growth

The mean values of DBH, height, and crown width were calculated, and the mean values were used to calculate the basal area (B) and volume (V).

$$\mathbf{B = d^2/4x¶/10000 \quad V = d^2 \times \frac{\pi}{4} \times H \times F}$$

B = Basal Area (m^2ha^{-1})

¶ =3.14159

V = Mean total stand volume (m^3).

d = Diametter at BreathHeigh1.30 m (cm).

H = Total height (m).

F = Formfactor (0.45), $\frac{\pi}{4}$= 0.7854

3.4.2 Species composition and diversity

Importance Value (IV) for all vegetation intended with three components as follows (Curtis and McIntosh, 1951) to identify indicator species.

$$\text{Relative density (\%)} = \frac{\text{Number of individuals of species}}{\text{Total number of individuals}} \times 100$$

$$\text{Relative Abundance (\%)} = \frac{\text{Number individuals of species}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Relative frequency (\%)} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100$$

$$\text{Importance Value (\%)} = (RD + RA + RF) / 3$$

For the measurement of changes in species diversity after different restoration techniques, three different measures of diversity calculated.

Shannon diversity index (H') was used to features the structural composition of the communities (Pielou, 1975; Shannon and Weaver, 1949; Magurran, 1987; Zar, 1984). It was calculated from the formula:

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

Where pi is the percentage of the individuals in the ith species, the values of H' were compared through t-test according to Magurran (1987).

Simpson's index (D) is the probability that two randomly chosen individuals will be of different species, and it was calculated from the formula:

$$D = 1 - \sum_{i=1}^{s} pi^2$$

Evenness was calculated as follow (Brower and Zar, 1977):

$$J' = \frac{H'}{H \max}$$

Where H' is Shannon index and $H_{max} = \ln S$ (S, number of species) Jaccard' similarity index was calculated as follow:

$$Hj = \frac{j}{r}$$

Where j is number of the same species found in both communities and r total species found in both communities. Species richness is number of species found in the research site and abundance is total number of individuals.

The SAS (2002) software package was used for all statistical analysis. The differences in species richness and diversity among the study plots determined by analysis variance (ANOVA). The significance for analyses was determined at $p<0.05$.

4 Results

4.1 Trees growth

4.1.1 Survival rate

The survival rate of T1 was 84%, T2 was 68%, T3 was 69.33%, T4 was 66.67% and T5 was 68%. T1 had the highest survival rate because it is the shade tolerance tree species. On the other hand, T4 had the lowest rate because it is bothered by weeds, vines and grass.

4.1.2 Density

The high density of T1 was 420 tree ha^{-1}, T2 was 340 tree ha^{-1}, T3 was347 tree ha^{-1}, T4 wa s 333 tree ha^{-1} and T5 was 420. T1 and T5 had the highest density because they were the high s urvival.

4.1.3 DBH

The DBH of T1 was smallest among five tree species. The DBH of T4 and T5 were medium. T2 and T3 had highest DBH. The means of 5 species are the significant difference individual (Table 2).

Table 2 The DBH of five tree species

Tree species	DBH (cm)		
	Max	Min	Average
T1	4.00	0.50	1.93 ± 0.12^{e}
T2	5.00	1.20	5.24 ± 0.30^{b}
T3	13.5	3.5	5.25 ± 0.37^{a}

T4	5.7	1.00	3.13 ±0.16^{d}
T5	7.5	0.70	3.48 ±0.28^{c}

Note: Value in difference letters indicate significant differences using DMRT (p<0.05).

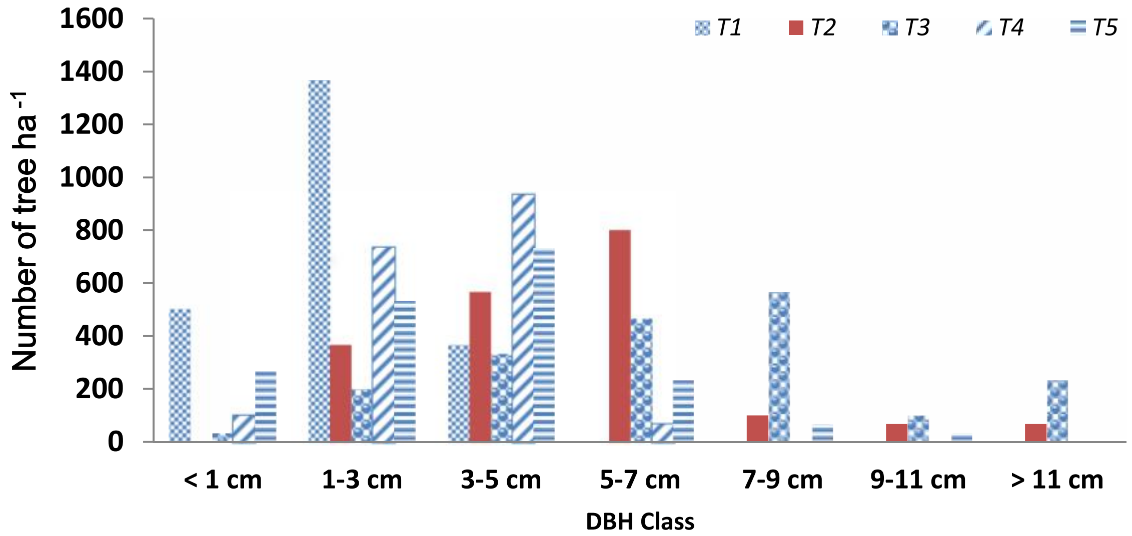


Figure 5 The DBH distributions of five tree species per hectare.

Figure 5 represented 7 DBH classes , class 1-3 cm was the highest, for example T1 in DBH class 1-3cm recorded the highest (1367 ha^{-1}) and T2 recorded the lowest (200 ha^{-1}). In T4 couldn't find the DBH bigger than 7 cm, also there wasn't tree DBH more than 5 cm in T1. DBH of T2 and T3 were over than 7 cm. Table 3 were showed a significant difference in the DBH among 5 species were observed (p<0.001), F was higher variance because among their group were many differences DBH between fast growing tree species (T3, T2 and T4)and slow growing tree species (T1, T5) (table 2).

Table 3 Analysis of variance (ANOVA) for DBH of indigenous tree plantations

Source	DF	Anova SS	F Value	Pr > F
Species	4	370.05263158	99999.99	0.0001
REP	2	0.00000000		
Block	73	170.54542484	99999.99	0.0001

4.1.4 Tree Height

4.1.4.1 Bole height

Bole height of T1 and T4 had the highest. The medium height was T3 and T4. T2 was the highest of bole height, because there were many branches and they had not pruned by natural but other species had pruned (table 4).

Table 4 The bole height of five tree species

Tree species	Bole height (m)		
	Max	Min	Average
T1	2.50	0.80	3.07 ±0.10 [c d]
T2	2.50	1.20	3.78±0.26 [a]
T3	7.00	1.50	3.07 ±0.37 [b]
T4	2.10	0.50	1.02±0.09 [d]
T5	4.50	1.20	1.82 ±0.16 [c]

Note: Value in difference letters indicate significant differences using DMRT (p<0.05).

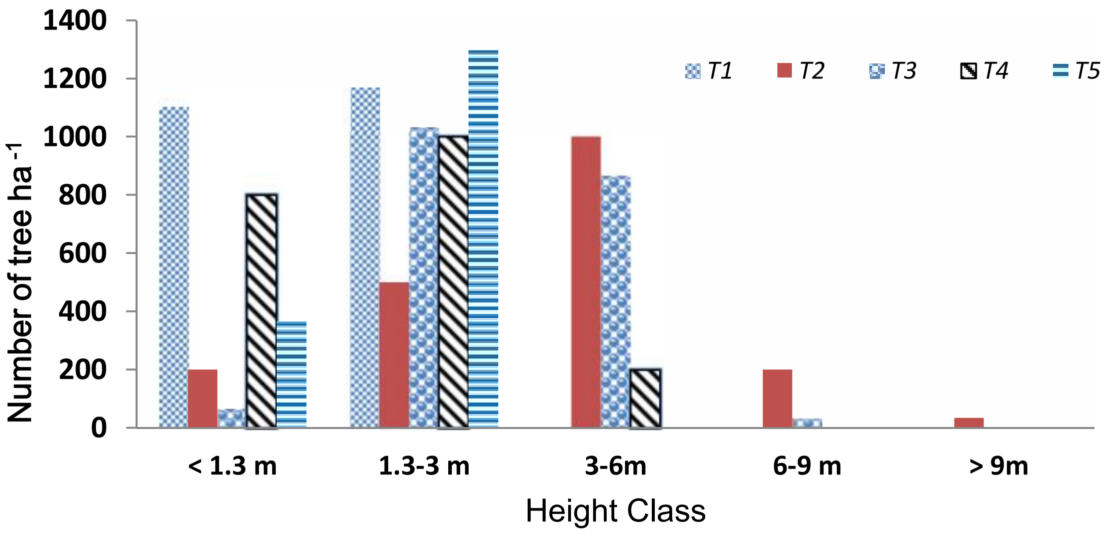


Figure 6 The bole height distribution of five tree species per hectare

Figure 6 represented 5 height classes , class 1.3-3 m was the highest, for example T5 in height class 1-3cm recorded the highest (1300 ha^{-1}) and T2 recorded the lowest (500 ha^{-1}). T2 were found all of classes and only this species was over than 9m. All species found in class <1.3 m. Both, T1 and T5 were found only 2 classes (<1.3 m and 1.3-3 m).

Table 5 Analysis of variance (ANOVA) for bole height of indigenous tree plantations

Source	DF	Anova SS	F Value	Pr > F
Species	4	286.44135573	30.15	0.0001

REP	2	0.81193653	0.17	0.8429

A significant difference in the bole height of 5 species (F=30.15, p=0.0001) and replications (F=0.17, p=0.8429) were observed (Table 5), the means of T2 was higher than all species, only T1 was not significantly different, because bole height of T1 was the smallest (table 4).

4.1.4.2 Tree height

Tree height of T1 and T4 were the lowest. Tree height of T5 was the medium. Tree height of T2 and T3 were the highest (table 6). In fact, fuel wood is fast growing tree species. It is easy to visible tree height layer by observation in the plantation.

Table 6 The tree height of five tree species

Tree species	Tree height (m)		
	Max	Min	Average
T1	4.50	0.15	2.25 ± 0.16^{c}
T2	4.50	0.40	7.99 ± 0.37^{a}
T3	12.00	1.40	7.68 ± 0.25^{a}
T4	4.50	0.50	2.55 ± 0.15^{c}
T5	8.58	0.50	4.47 ± 0.29^{b}

Note: Value in difference letters indicate significant differences using DMRT (p<0.05).

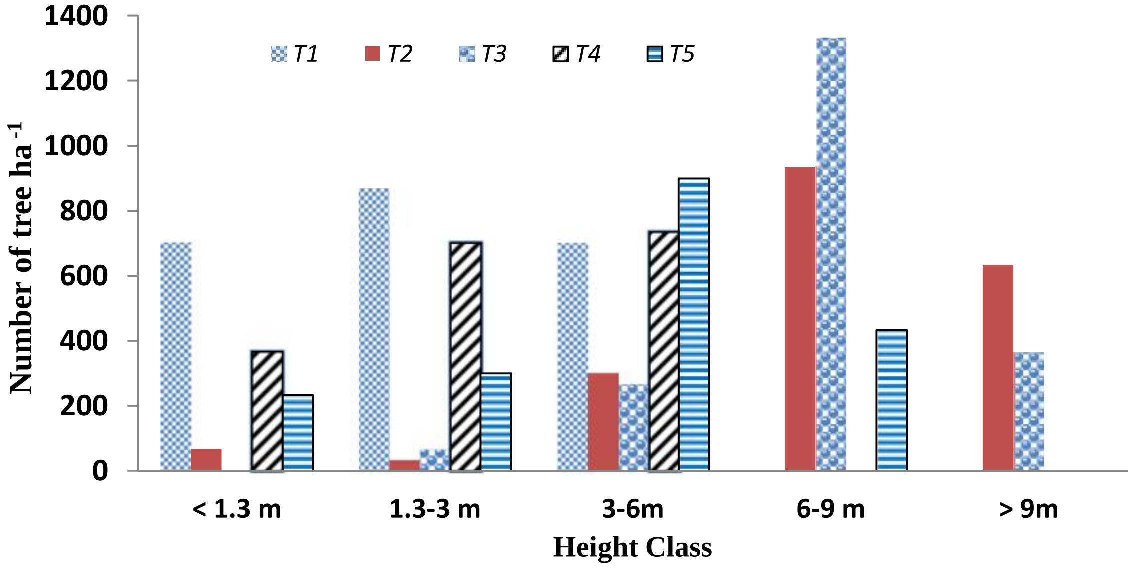


Figure 7 The tree height distribution of five tree species per hectare

Figure 7 represented 5 height classes , class 6-9 m was the highest, for example T3 in height class 6-9 m recorded the highest (1333 ha^{-1}) and T5 recorded the lowest (500 ha^{-1}). T4, T5 and T1 had all classes. Both, T1 and T3 had only 3 classes. T2 had all classes. Only T2 and T3 were higher over 7 m. T3 did not nave class < 1.30 m.

Table 7 Analysis of variance (ANOVA) for tree height of indigenous tree plantations

Sources	DF	Anova SS	F Value	Pr> F
Species	4	1405.39080640	42.21	0.0001
REP	2	25.35639520	1.52	0.2194

A significant difference in the tree height of 5 species (F=42.21, p=0.0001) and replications (F=1.52, p=0.2194) were observed (table 7), and the means of T2 and T3 were higher than all other species, two of them were not significant different. T1 and T5 were not significantly different by similar means of tree height, both of them were the smaller height (table 6).

4.1.4.3 Crown width

T1 was the narrowest. T4 and T5 were the medium sized. T2 and T3 were the larger sized and the canopy is much closed. Naturally, the canopy of fuel wood or fast growing tree is increased the size in short time (e.g. 3 years, 5years, etc.).

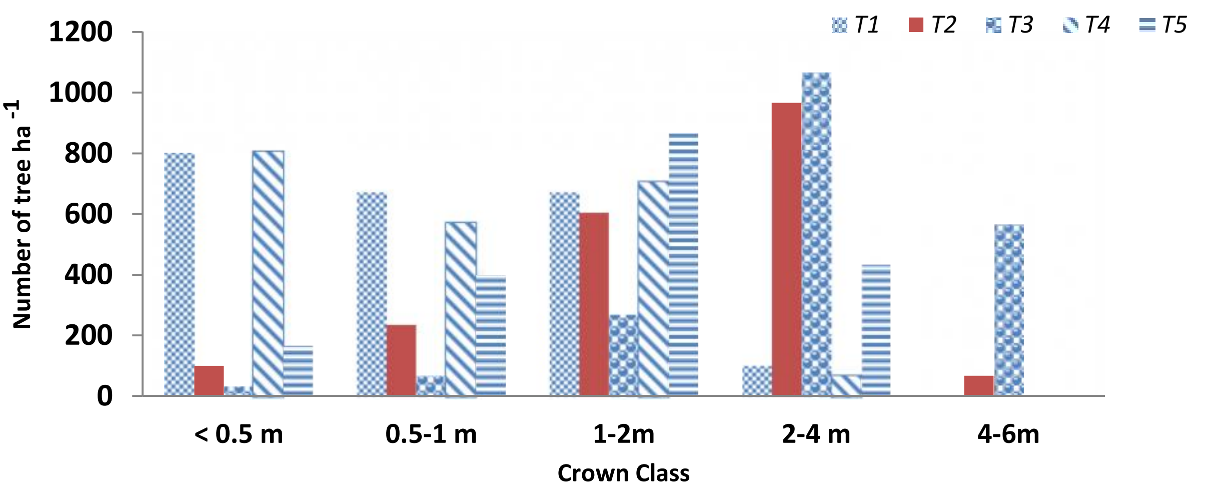


Figure 8 The tree crown width distribution of five tree species per hectare

Figure 8 represented 5 crown classes , class 2-4 m was the largest, for example T3 in height class 2-4 m recorded the highest (1067 ha^{-1}) and T4 recorded the lowest (67ha^{-1}). T2 and T3 had all of classes and also were in class 4-6 m.

Table 8 The crown width (NS) of five tree species

Tree species	Crown width (NS) (m)		
	Max	Min	Average
T1	2.20	0.40	0.89±0.07 [c]
T2	2.20	0.30	2.23±0.16[b]
T3	6.00	0.40	3.29±0.16 [a]
T4	3.00	0.20	1.14±0.09 [c]
T5	2.80	0.30	1.58±0.10 [c]

Note: Value in difference letters indicate significant differences using DMRT ($p<0.05$).

Table 9 Analysis of variance (ANOVA) for crown width (NS) of indigenous tree plantations

Source	DF	Anova SS	F Value	Pr > F
Species	4	177.44754400	31.99	0.0001
REP	2	13.60244053	4.90	0.0079

A significant difference in the crown width (NS) of 5 species (F=32.99, p=0.0001) and replications (F=4.9, p=0.0079) were observed (table 9), the means of 3 species (T1, T2 and T3) were not significantly different; all of them were the narrower crown. T3 was the largest and significantly different. T2 was larger than 3 species (T1, T4 and T5), it was significant different (table 8).

T1 and T4 were the narrower crown. T2 and T5 were the medium crown. T3 was the largest (table 10).

Table 10 The crown width (EW) of five tree species

Tree species	Crown width (EW) (m)		
	Max	Min	Average
T1	2.20	0.30	0.84±0.07[cd]
T2	2.20	0.20	2.06±0.14[b]
T3	5.60	1.50	3.08±0.16 [a]
T4	3.00	0.20	0.92±0.08[d]
T5	3.20	0.30	1.48±0.09[c]

Note: Value in difference letters indicate significant differences using DMRT ($p<0.05$).

Table 11 Analysis of variance (ANOVA) for crown width (NS) of indigenous tree plantations

Source	DF	Anova SS	F Value	Pr > F
Species	4	161.15077067	32.16	0.0001
REP	2	2.64148000	1.05	0.3495

A significant difference in the crown width (EW) of 5 species (F=32.16, p=0.0001) and replications (F=4.9, p=0.3495) were observed (table 11), and the means of 2 species (T2 and T4) were not significantly different and were narrow. T3 was the largest and significantly different from other tree species. T2 was larger than 3 species and it was significant different (table 10).

4.1.5. Basal area

In table 12 showed about the basal area of 5 indigenous tree species plantation. It showed the highest basal area of indigenous tree was in T3, T3 was quite high, T5 was the medium, T4 was quite low and T1 was the lowest.

Table 12 The Basal area of 5 indigenous tree species plantation

Species	**Basal Area(m^2 ha^{-1})**
Dalbergia cultrata Grah(T1)	2.93E-08 (±1.24E-10)
Cassia Siamea Lam(T2)	2.16E-07 (±7.34E-10)
Peltopholum dasyrachis(T3)	4.55E-07 (±2.69E-07)
Wrightia arborea (Denn) (T4)	7.69E-08(±5.41E-08)
Hopea odorata Roxb(T5)	1.30E-07(±6.37E-07)

Value in parenthesis indicates standard error

4.1.6 Volume

The volume of indigenous tree in T3 (0.0115±0.0018 m^3 ha^{-1}) was the highest, T2 was next higher, then T5 was the medium. On the other hand, T1 and T4 was the lowest (table 13).

Table 13 The volume of 5 indigenous tree species plantation

Species	**Volume (m^3)**

Dalbergia cultrata Grah(T1)	0.00030±0.0001
Cassia Siamea Lam(T2)	0.00779±0.0018
Peltopholum dasyrachis(T3)	0.011574±0.0018
Wrightia arborea (Denn) (T4)	0.00088±0.0001
Hopea odorata Roxb(T5)	0.00364±0.0007

Table 13 showed the volume of 5 indigenous tree species plantation which compared among tree species. T3 was the highest, T2 was quite high, T5 was the medium, T4 was the low, and T1 was the lowest.

4.2 Growth and diversity of Understory Tree species

4.2.1 Understory tree species

Combretum decandrum had higher importance value (IV) in T2, T1 and T3, and the IV reached 17.85%, 10.77% and 11.60% respectively (table 14). *Wrightia arborea* (Denn.) Mabberley had higher IV (10%) in T5. The species with the highest IV are dominant or common in the site indicating the measurement of their influence on the forest community (Karkee, 2004). There were only two species (*Peltophorum dasyrachis* Kurz and *Microcos paniculata* L) found on all species plantation (table 14), because these two species were the pioneer tree species.

Table 14 Changes in the important value (%) of difference tree species in the five indigenous tree plantations

No.	Species	*Dalbergia cultrate*	*Cassia Siamea*	*Peltopholum dasyrachis*	*Wrightia arborea*	*Hopea odorata*
1	*Acacia auriuliformis* A. Cunningham ex.Benth	8.58		3.92	2.33	1.48
2	*Acacia mangium* Will	1.50		1.33	3.87	
3	*Adenanthera parvifolia*	1.50				
4	Ailanthus triphysa (Dennst.) Alston			1.33		
5	Ancistrocladus extensus VAHLL, Me'				2.86	4.45
6	Aporosa villosa (Lindl.)			1.33		1.11

	Baill.					
7	Ardisia graciliflora Pit.			3.98	0.78	1.11
8	*Artocarpus sp.*		2.98			
9	*Arytera littoralis BL*					1.11
10	*Barringtonia annamica Gagnepain*				1.04	2.59
11	*Calamus tenuis*		5.65			
12	*Celtis cinnamomea* LINDL	1.50				
13	*Colubrina longipes* Back.				0.78	1.48
14	*Combretum decandrum* Roxb.			11.60	6.92	1.11
15	*Combretum decandrum*	10.77	17.85			
16	*Coscinium fenestratum* (Gaertner) Colebr.(LPN)			1.33	1.04	
17	*Cratoxylum formosum* (Jack) Dyer	3.00		3.61		
18	*Dalbergia dyeriana* Pierre			2.60	1.29	
19	*Dalbergia sp*	3.59				
20	*Didymosperma caudatum (Loureiro) H. Wendl. & Drude (LPN)*					1.11
21	*Ficus callosa* Willd.				0.78	
22	*Ficus hirta* Vahl				1.82	
23	*Garcinia cowa* Roxb.					1.48
24	Gonocaryum lobbianum (Mier) Kurz				0.78	1.85
25	*Hydrocharis sp.*	1.85				

26	*Lannea coromandelica* (Houtt.) Merr.				1.29	
27	*Largerstroemia sp.*		2.98			
28	*Lepisanthes rubiginosa (Roxb.) Leenh.*	1.50			1.82	
29	*Limacia triandra*	1.50				
30	*Markhamia stipulata (Wallich) Seem. ex. K.*		5.95		3.34	4.82
31	*Markhamia stipulata* var. kerrii Sprague				1.29	1.11
32	*Microcos paniculata* L.	5.54	5.95	4.24	4.13	2.22
33	*Ormosia semicastrata* Hance					3.70
34	*Oxytenanthera parviflora* Brandis	1.50				1.85
35	*Peltophorum dasyrachis* Kurz.	1.50	2.98	2.65	1.82	2.59
36	*Phyllanthus emblica* L.				0.78	
37	*Platanus kerrii* Gagnep.				0.78	
38	*Pterocarpus macrocarpus* Kurz.	6.49		11.28	2.33	4.45
39	*Streblus taxoides* (Roth) Kurz			1.33	2.31	3.70
40	*Syzygium cumini (L.)* Skeels				0.78	
41	*Trema orientalis* (L.) Blume.				0.78	1.11
42	*Wrightia arborea* (Denn.) Mabberley	3.35	2.98	4.93		10.00
43	*Xerospermum cochinchinensis* Pier			3.23	4.36	
44	*Ziziphus oenoplia* (L.)				0.78	1.48

	Mill.					
45-72	Other species	46.55	52.69	41.31	49.11	44.06
	Sum	**100**	**100**	**100**	**100**	**100**

There were 53 species of important understory tree species, and they belong to 35 families (table 14). Only 10 families were high frequency during investigation, and they were Fabaceae (7 species), Rhamnaceae (3 species), Euphorbiaceae (3 species), Moraceae (3species), Guttiferae (2 species), Sapindaceae (3 species), Poaceae (2 species), Bignoniaceae (2 species) and Arecaceae (2 species). Fabaceae was the most frequent observation. However, other families were only a species to representation, such as Combretaceae, Dipeterocarpaceae, Cardiopteridaceae, Ancistrocladaceae, Menispermaceae, Lauraceae, Ulmaceae. All of them were integrated on community of forest as plantation which consisted of trees, shrubs, saplings, vines and grasses (table 16, 19, 20, 21 and 22, figure 21). Soukhavong M et al (2013) found 4 mains families (Achariaceae, Myrtaceae, Lauraceae and Rubiaceae) and 3 species (Rubiaceae, Myrtaceae, and Lauraceae) at the natural national park in Laos. Also researchers found the most abundant family was Dipterocarpceae in tropical rainforest (Protor et al, 1983; Hanman et al, 1999; Small et al, 2004; Kesslerts et al. 2005; Lu et al. 2010; Blane et al. 2000).

Table 15 Important understory tree species in the five indigenous tree plantations

No	Tree Species (Lao Name)	Scientific Name	Family Name	Tree Species (Chinese Name)
1	ກະຖິນນະລົງ	*Acacia auriuliformis* A. Cunningham ex.Benth	Fabaceae	大叶相思
2	ກະຖິນເທພາ	*Acacia mangium* Will	Fabaceae	马占相思
3	ຍົມຜາ	*Ailanthus triphysa* (Dennst.) Alston	Simaroubaceae	岭南臭椿
4	ຫາງກວາງ	*Ancistrocladus extensus* VAHL L, Me'	Ancistrocladaceae	钩枝藤
5	ເມືອດ	*Aporosa villosa* (Lindl.) Baill.	Euphorbiaceae	毛银柴
6	ຕີນຈຳ	*Ardisia graciliflora* Pit.	Myrsinaceae	小花紫金牛
7	ກະດຸກ	*Arytera littoralis* BL	Sapindaceae	滨木患

8	ນິມຍານ	*Barringtonia annamica* Gagnepain	Barringtoniaceae	云南玉蕊
9	ຫວາຍແຫຍ້	*Calamus tenuis* Roxb.	Arecaceae	细叶省藤
10	ໝາກຢາງຂາວ	*Calophyllum sp*	Calophyllaceae	胡桐 (红厚壳)
11	ອ້ອມຕໍ	*Casearia flexuosa* Craib	Flacourtiaceae	曲枝脚骨脆
12	ຊ່າຈວງ	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & C.H.Eberm.	Lauraceae	柴桂
13	ຜັກກ້ານຕິງ	*Colubrina longipes* Back.	Rhamnaceae	蛇藤
14	ເຄືອຫວາຍດິນ	*Combretum decandrum* Roxb.	Combretaceae	风车子
15	ແຫມຄວາຍ	*Coscinium fenestratum* (Gaertner) Colebr.(LPN)	Menispermaceae	防己
16	ຕົ້ວສົ້ມ	*Cratoxylum formosum* (Jack) Dyer	Guttiferae	越南黄牛木
17	ດອກຮ່ານ	*Cryptophragmium signatum*	Acanthaceae	裸柱花
18	ຄຳພິເຂົາຄວາຍ	*Dalbergia cultrata* Grah.ex Pierre	Fabaceae	黑黄檀
19	ຄຳພິເຄືອ	*Dalbergia dyeriana* Pierre	Fabaceae	大金刚藤
20	ຕາວແດງ	*Didymosperma caudatum* (Loureiro) H. Wendl. &.Drude(LPN)	Arecaceae	双子棕
21	ມີປ່າ	*Ficus callosa* Willd.	Moraceae	硬皮榕
22	ເດືອປ່ອງ	*Ficus hirta* VAHL	Moraceae	粗叶榕
23	ຂີ້ໝອນ	*Garcinia cowa* Roxb.	Guttiferae	云树
24	ຂະນ່ອງໄກ່	*Glochidion sphaerogynum* (Müll.Arg.) Kurz	Euphorbiaceae	圆果算盘子
25	ສົ້ມຊື່ນ	*Glycosmis parviflora* (Sims) Little	Rutaceae	小花山小橘
26	ກ້ານເຫຼືອງ	*Gonocaryum lobbianum* (Mier) Kurz	Cardiopteridaceae	琼榄
27	ແຄນເຮືອ	*Hopea odorata* Roxb.	Dipeterocarpaceae	香坡垒

28	ດອກເຂັມປ່າ	*Ixora chinensis* Lam.	Rubiaceae	龙船花
29	ກອກກັນ	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	厚皮树
30	ໝາກຫອດ	*Lepisanthes rubiginosa* (Roxb.) Leenh.	Sapindaceae	赤才
31	ຕອງເຫົ້າ	*Mallotus barbatus* Müll.Arg.	Euphorbiaceae	毛桐
32	ແຄລ້າວ	*Markhamia stipulata* (Wallich) Seem. ex. K.	Bignoniaceae	猫尾木
33	ແຄປ່າ	*Markhamia stipulata* var. *kerrii* Sprague	Bignoniaceae	毛叶猫尾木
34	ເຂົ້າສານ	*Memecylon harmandii* Guill (LPN)	Melastomaceae	哈曼谷木
35	ຄອມ	*Microcos paniculata* L.	Tiliaceae	破布叶
36	ໝາກລຳ	*Ormosia semicastrata* Hance	Fabaceae	软荚红豆
37	ຊອດ	*Oxytenanthera parviflora* Brandis	Poaceae	南峤滇竹
38	ສະຝາງ	*Peltophorum dasyrachis* Kurz.	Leguminosae	粗轴双翼豆
39	ໝາກຂາມປ້ອມ	*Phyllanthus emblica* L.	Phyllanthaceae	余甘子
40	ເປືອຍນຳ	*Platanus kerrii* Gagnep.	Platanaceae	老越悬铃木
41	ດູ່ເລືອດ	*Pterocarpus macrocarpus* Kurz.	Fabaceae	大果紫檀
42	ກໍເລົາ	*Saccharum arundinaceum* Retz	Poaceae	斑茅
43	ຂີເຫຼັກບ້ານ	*Senna siamea* (Lam.) Irwin & Barneby	Fabaceae	铁刀木
44	ໝາມຂີ້ແຮດ	*Streblus taxoides* (Roth) Kurz	Moraceae	叶被木
45	ຂີ້ກາ	*Strychnos nux-vomica* L.	Loganiaceae	马钱子
46	ໝາກຫວ້າ	*Syzygiumcumini* (L.) Skeels	Myrtaceae	乌墨
47	ເຄືອຢານາງ	*Tiliacora triandra* (Colebr.) Diels	Menispermaceae	竹草
48	ປໍຣິນ	*Trema orientalis* (L.) Blume.	Ulmaceae	山黄麻

49	ຂີເຫງັນ	*Vitex altissima* L.f.	Lamiaceae	牡荆
50	ມູກ	*Wrightia arborea* (Denn.) Mabberley	Apocynaceae	倒吊笔
51	ໝາກແງວ	*Xerospermum cochinchinensis* Pier	Sapindaceae	干果木
52	ກຳລັງເສືອໂຄ່ງ	*Ziziphus attopensis* Pierre	Rhamnaceae	毛果枣
53	ໝາມເລັບແມວ	*Ziziphus oenoplia* (L.) Mill.	Rhamnaceae	小果枣

4.2.2 Number of understory tree species

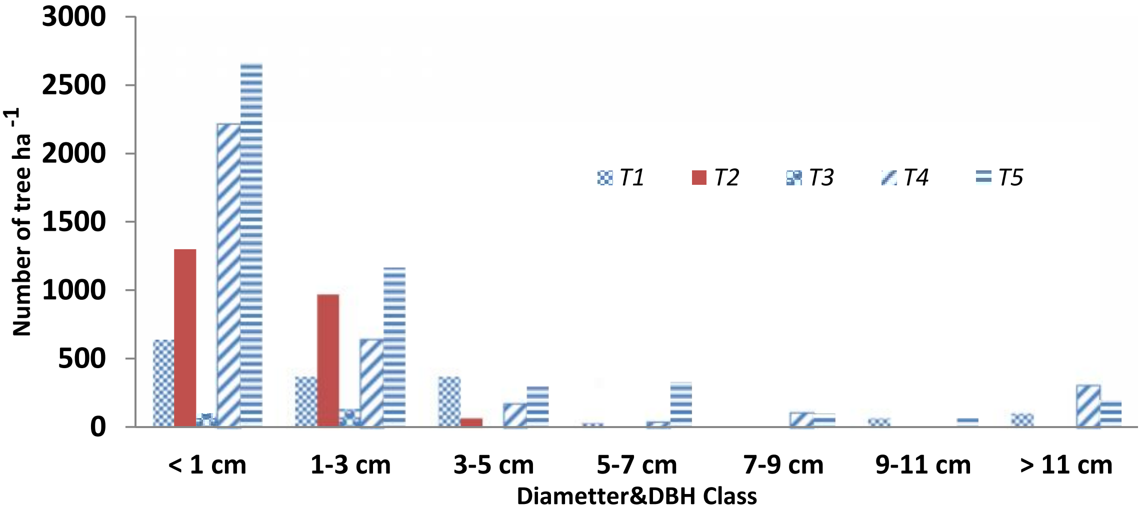


Figure 9 Other species number in different DBH class at 5 species (T1, T2, T3, T4, and T5).

Figure 9 represented 7 DBH classes of the understory trees, class <1m was the highest, for example in T5 in DBH class <1m recorded the highest (2667 ha^{-1}) and in T3 recorded the lowest (100 ha^{-1}) (Figure 9). T4, T5 and T1 had all classes. Both, T1 and T3 had only 3 classes. T2 had all classes. Only T2 and T3 were higher over 7 m. T3 did not nave class < 1.30 m. We could find all of diameter and DBH classes in T5, T1 and T4 had six classes. In T2 had no DBH class>5 cm. In T4 and T5 had more big trees with DBH over than 7 cm.

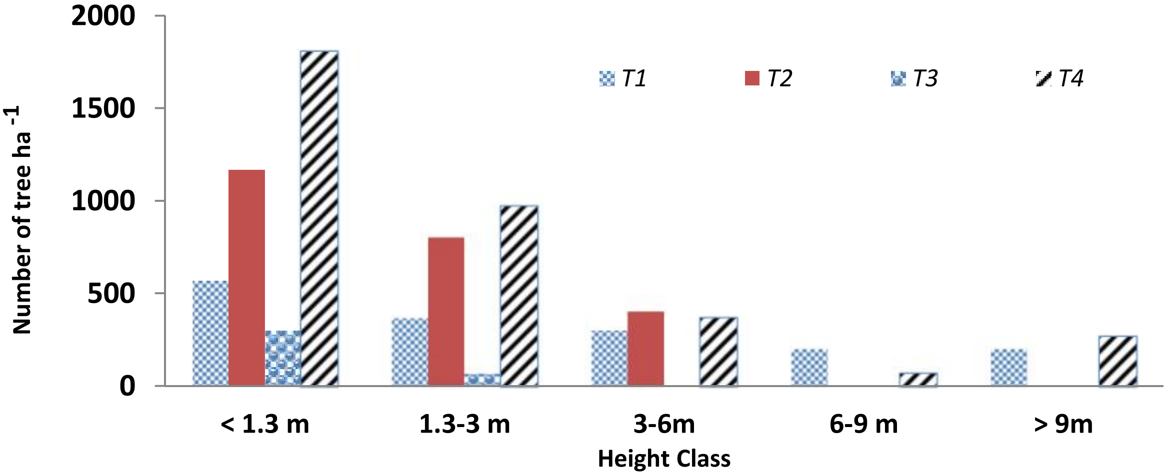


Figure 10 Other tree species number in different height class at 5 species (T1, T2, T3, T4 and T5).

Figure 10 represented 5 height classes of the understory trees, class <1.30m was the highest, for example in T4 was height class <1.30m recorded the highest (1800 ha^{-1}) and in T3 recorded the lowest (300 ha^{-1}). T4 and T5 found all of classes of height. There wasn't tree higher than 3m in T3. In T2 didn't have trees higher than 6 m.

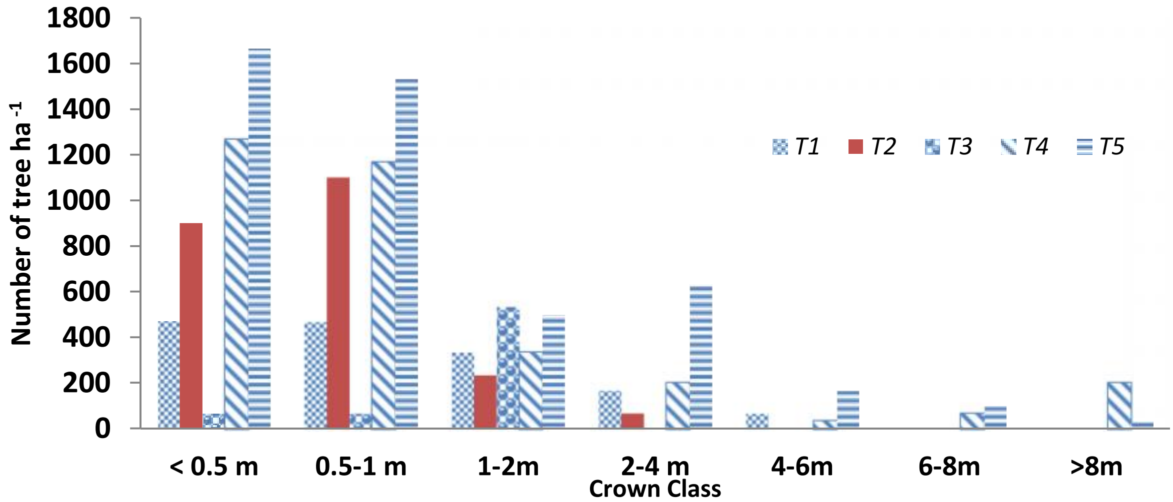


Figure 11 Other tree species number in different crown width class at 5 species (T1, T2, T3, T4 and T5)

Figure 11 represented 5 crown classes of the understory trees, class <0.5 m was the highest, for example in T5 was height class <1.30m recorded the highest (1667 ha^{-1}) and in T3 recorded the lowest (67 ha^{-1}). T5 and T4 found all of classes. There weren't tree crown width than 4m in

T2 and T3.

4.2.3 Vegetation characteristics of five indigenous tree plantations

The most amount of species was found in T4 (45±0.15), and the smallest amount of species was in T2 (12±0.55) (table 16). The species evenness (*J'*) was the highest in T5 and lowest in T2. Other results from inventory in mixed deciduous forest and dry evergreen Diptercarp forest in center part of Laos found 24 families and 33 species of saplings together with 88 families and 153 species of seedlings (Soukhavong, 2013). The most families was found in T5, and the smallest families was found in T2. The family evenness was highest in T5, and lowest in T2. This study found that species composition and diversity index of different indigenous plantation had the Simpson's index (*D*) more than 0.90 in T1, T4 and T5, and for T2 and T3 it was only 0.82 and 0.88 (table 16).T4 and T5 had higher Shannon index (*H*'), but T2 was very low.

The stem density was high in T5, also in T1 and T4, but we couldn't find any stem of natural tree which DBH reached in T2 and T3. Other results from inventory in mixed deciduous forest and dry evergreen Diptercarp forest in center part of Laos found 24 families and 33 species of saplings together with 88 families and 153 species of seedlings (Soukhavong, 2013). Sapling had higher density in T5, T2 and T4. T1 had highest seedling number. The seedling number in T3 was lowest. DBH of understory trees in T1 and T4 were higher, and in T3 it was lower. The height of understory tree in T1 was higher, and it was very low in T3.

Table 16 Understory tree characteristics of five indigenous tree plantations

Vegetation characteristics	T1	T2	T3	T4	T5
Species number	20(0.42)	12(0.55)	19(0.42)	45(0.15)	33(0.29)
Family number	12(0.47)	8(0.63)	12(0.35)	17(0.20)	18(0.21)
Stem number (n ha^{-1})	266(30)	-	-	700(109)	1050(55)
Saplings number DBH>1cm(n ha^{-1})	800(73)	1233(113)	133(15)	1233(83)	1933(200)
Seedlings number <1.3m height (n ha^{-1})	2766(930)	2600(537)	1166(344)	1925(380)	2700(466)
DBH (cm)	3.16(0.57)	1.12 (0.09)	1.74 (1.27)	3.03 (0.66)	2.51 (0.14)
Height (m)	4.14(0.58)	1.65 (0.14)	0.90 (0.60)	2.73 (0.36)	2.86 (0.33)

Basal Area (m^2ha^{-1})	7.87E-08 (7.29E-08)	9.86E-09 (2.39E-09)	2.39E-08 (1.43E-09)	7.22E-08 (1.39E-07)	4.97E-08 (6.71E-08)
Volume (m^3ha^{-1})	0.00212 (0.007)	0.00010 (0.0001)	0.00014 (0.0001)	0.0012 (0.0134)	0.00092 (0.0057)
Family Evenness (*J'*)	0.44	0.30	0.44	0.63	0.67
Simpson's index(*D*)	0.90	0.82	0.88	0.96	0.94
Shannon Index(*H'*)	2.50	1.99	2.42	3.06	3.06
Species Evenness(*J'*)	0.28	0.17	0.26	0.63	0.46

Value in parenthesis indicates standard error. T1, *Dalbergia cultrate* Grah, T2, *Cassia Siamea* Lam; T3, *Peltopholum dasyrachis* Kurz; T4, *Wrightia arborea* (Denn), T5 *Hopea odorata* Roxb

4.2.4 Growth of understory tree species

4.2.4.1 DBH and diameter

The diameter and DBH of natural trees in T2 and T3 were the smallest in this plantation. The medium DBH was at T5. The biggest diameter and DBH was at T1 (table 17).

Table 17 The DBH of natural tree from investigation plot with number of tree have been remained on indigenous plantation.

Indigenous plantation	Number of sample tree	DBH (cm)		
		Max	Min	Average
T1	43	18	0.5	3.16±0.57
T2	58	18	0.3	1.12 ±0.09
T3	11	3	0.1	1.74 ±1.27
T4	76	31.5	0.4	3.03 ±0.66
T5	131	24.5	0.2	2.51 ±0.14
Total	319			

4.2.4.2 Height

The total height of natural trees in T2 and T3 were the smallest in this plantation. The medium height was at T4 and T5. The highest was at T1 which natural tree were fast growing tree species well known as fuel wood (table 18).

Table 18 The tree height of natural tree from investigation plot with number of tree have been remained on indigenous plantations

Indigenous plantation	Number of sample tree	Tree height(m)		
		Max	Min	Average
T1	51	16.80	2.4	4.14±0.58
T2	70	5.35	0.18	1.65 ±0.14
T3	11	1.7	0.5	0.90 ±0.60
T4	100	15.5	0.35	2.73 ±0.36
T5	146	20.5	0.30	2.86 ±0.33
Total	376			

4.2.4.3 Crown width

The mean crown width of natural trees in T2 and T3 were the narrowest in this plantation. The medium was at T1. The largest was at T4 and T5 (table 19).

Table 19 The crown width (NS&EW) of natural tree from investigation plot with number of tree have been remained on indigenous plantations

Indigenous plantation	Number of sample tree	Crown width (m)		
		Max	Min	Average
T1	34	4.25	0.5	1.07±0.13
T2	52	2.05	0.35	0.67±0.05
T3	11	0.85	0.6	0.20±0.43
T4	66	10.5	0.25	1.47 ±0.27
T5	127	9	0.2	1.30 ±0.15
Total	290			

4.2.4.4 Basal area

The full detail was in table 20. It summarized basal area of natural trees at indigenous tree plantation by visible view or chart (detail in figure 22). It showed the highest basal area of natural tree was in T1, quite high was T4, medium was in T5, quite low in T3, and the lowest was in T2

4.2.4.5 Volume

Natural tree growth also studied either indigenous tree as showed in table 20. The volume of natural tree in T4 was the highest (table 20). For example, the lowest were in T2 and T3. The medium volume was in T5. Table 20 summarized volumes of natural trees at indigenous tree plantation by visible view or chart (detail in figure 16). The highest volume of natural tree was in T1 and quite high was T4, the medium was in T5, the lowest was in T3 and T2.

Table 2**0** Summarized trees growth condition of natural trees at indigenous tree plantation

	DBH (cm)	Height (m)	Crown width (m)	Basal Area ($m^2 ha^{-1}$)	Volume ($m^3 ha^{-1}$)
T1	3.16±0.57	4.14±0.58	1.07±0.13	7.87E-08 (±7.29E-08)	0.00212±0.0070
T2	1.12 ±0.09	1.65 ±0.14	0.67±0.05	9.86E-09 (±2.39E-09)	0.00010±0.0001
T3	1.74 ±1.27	0.90 ±0.60	0.20±0.43	2.39E-08(±1.43E-09)	0.00014±0.0001
T4	3.03 ±0.66	2.73 ±0.36	1.47 ±0.27	7.22E-08(±1.39E-07)	0.00128±0.0134
T5	2.51 ±0.14	2.86 ±0.33	1.30 ±0.15	4.97E-08 (±6.71E-08)	0.00092 ±0.0057

Value in parenthesis indicates standard error

4.3 Growth of seedling and grass species

4.3.1 Height

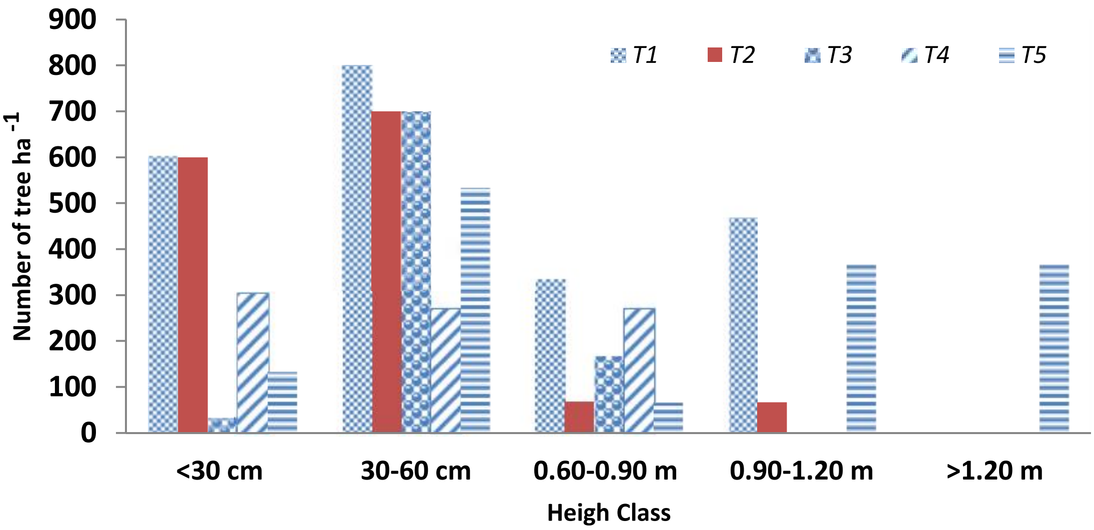


Figure 12 Other seedling species diversity in different height class at 5 species (T1, T2, T3, T4

and T5)

Figure 12 represented 5 height classes of the seedling, class 30-60cm was the highest, for example in T1 was height class 30-60cm recorded the highest (800 ha^{-1}) and in T3 recorded the lowest (267 ha^{-1}). In T5 could find all classes from smaller to taller seedling. T1 and T2 could find 4 classes. Natural tree seedling and grass couldn't disturb on T2 and T3 because they had tolerated and growth faster than natural tree, grasses and vines which couldn't disturb as well on nutrient competition for growth. Also T3 couldn't find any grass and seedling bigger than 0.9 m height; because T3's canopy was covered by and under shade of indigenous tree around those plots.

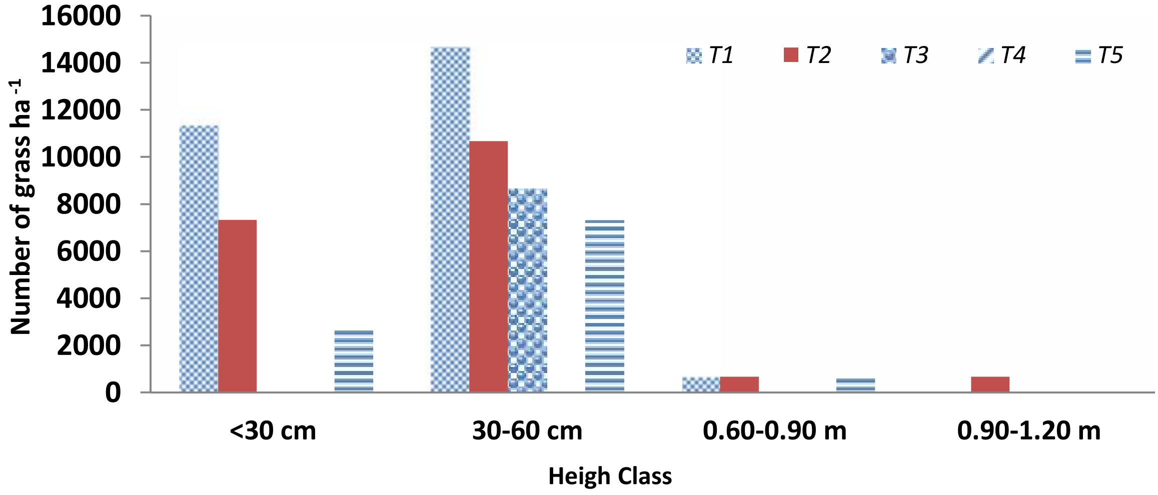


Figure 13 Grass species number in different height class at 5 species (T1, T2, T3, T4 and T5)

According from survey and grass estimate density was the highest in T1. Grasses could cover of all plots as understory of indigenous and natural tree species (Fig 13), but they covered in different height class, some species were the vine which combined with seedlings. In T2 and T3 had only a few grass species distributed around the plot. According from interview of forest staff who responded to maintain on this plantation. For instance; at first grass was very height and growth very fast in the indigenous tree plantation due to have the weeding activity for 2 times a year during first 3 years.

4.3.2 Grass and seedling species density

When seedling and grass species were assessed for species diversity of plant communities in individual indigenous plantation had maximum family richness per hectare in T5 but minimum in T2 together with family evenness highest in T5 and lowest was T2 (table 21). For the species richness ha^{-1} was highest in T4 and lowest in T2. The Simpson's index was high in T4 and T5, also Shannon's index was high in T4 and T5. Among species richness, family richness, Simpson's index and Shannon's index they were different individual themself. For instance; Simpson's index was high in T4 (0.96) but other researcher found relatively low indices of species diversity (*H'*=0.58) and evenness (J' = 0.21) in an Afromontane agriculture landscape (Tefera B et al,2014) , Shannon's index was high on both T4 and T5 as similar estimation. Thus, that result linked to natural tree some growing well than plantation tree (Fig 14 and 15). The number of family and species composite of fallow forest denote that ; 25 species and 15 families (15-year-old fallow), 31 species and 21 families (5-year-old fallow), 44 species and 24 families (10-year-old fallow) and 25 species and 15 families (1-year-old fallow) (Phongoudome, 2013). Phongoudome's research results were lower than in this indigenous plantation.

Table 21 Summarized species diversity of seedling and grass by plant communities (1)

Site	Species/ha Richness	Family/ha Richness	Family Evenness (*J*)	Simpson's index (D)	Shannon Index (H')	Species Evenness (*J'*)
T1	20	12	0.44	0.90	2.50	0.28
T2	12	8	0.30	0.82	1.99	0.17
T3	19	12	0.44	0.88	2.42	0.26
T4	45	17	0.63	0.96	3.06	0.63
T5	33	18	0.67	0.94	3.06	0.46
Total	129	67	0.41	0.75	2.17	0.30

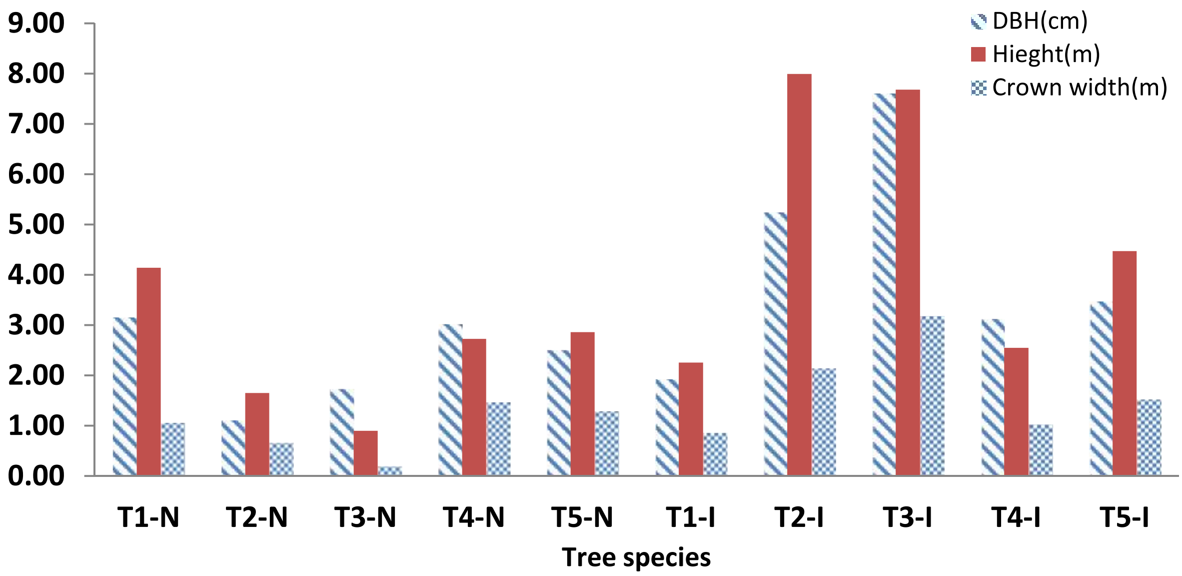
Table 22 Summarized species density of seedling and grass by plant communities (2)

Indigenous plantation	Species	Family	Seedlings &Grasses ha^{-1}	Height (m)
T1	20	12	2200	4.14
T2	12	8	1433	1.65
T3	19	12	900	0.9

T4	45	17	833	2.73
T5	33	18	1467	2.86

From table 21 it could explain deeper detail in table 22 which species density of seedlings and grasses such as they were the most density in T1 (table 21). And also, the least in T3, these seedlings or grasses some liked as between sapling and seedling why DBH reached and bigger than 1 cm thus they combined each other's to be seedling stage. Because this study need to assessed on volume and basal area of all trees in plot which DBH bigger than 1 cm. On the other method, for further estimation of the seedling growth in next research future such as the biomass and carbon stock estimation. The stand density of this study was higher than density of 5 years and 10 years fallow forest as the research from Phongoudome's research result.

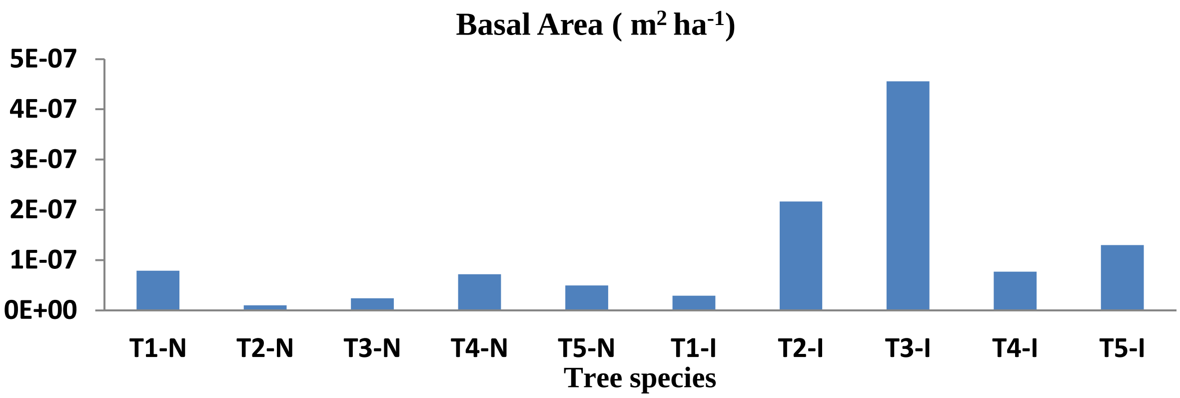
4.4 Relationship between growth condition of indigenous plantation and natural tree.



Remark: Natural tree species	*Indigenous tree species*
T1-N = Natural tree species in T1	T1-I = Indigenous species plantation (T1)
T2-N= Natural tree species in T2	T2-I = Indigenous species plantation (T2)
T3-N = Natural tree species in T3	T3-I = Indigenous species plantation (T3)
T4-N = Natural tree species in T4	T4-I = Indigenous species plantation (T4)
T5-N= Natural tree species in T5	T5-I = Indigenous species plantation (T5)

Figure 14 Chart of summarized on tree growth distribution between natural trees and indigenous plantation by range of DBH, Height and crown width.

In figure 14 to compared all trees growth condition between natural tree and indigenous plantation according from observation data which analyzed in brief for visionary understanding. Normally in young stage, plantation tree was grown faster than natural tree because natural tree were dropped during land preparation period or some small trees were cleared cut, but in this research site those commercial tree (important species) or natural tree were remained nearby such as parent tree, also every species were planted by row and line suitability. Chart was viewed of the trees in plot on horizontal which imagined stand by plantation and natural, on vertical that imagined the growth condition such as DBH, height and crown width.



Remark: *Natural tree species* *Indigenous tree species*

T1-N = Natural tree species in T1	T1-I = Indigenous species plantation (T1)
T2-N= Natural tree species in T2	T2-I = Indigenous species plantation (T2)
T3-N = Natural tree species in T3	T3-I = Indigenous species plantation (T3)
T4-N = Natural tree species in T4	T4-I = Indigenous species plantation (T4)
T5-N= Natural tree species in T5	T5-I = Indigenous species plantation (T5)

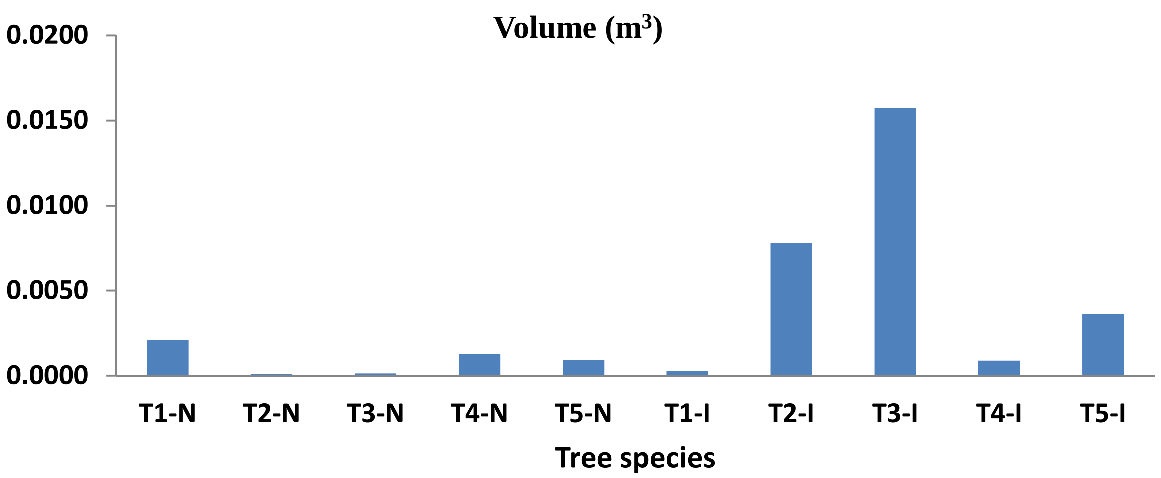
Figure 15 Summarized on tree growth distribution between natural trees and indigenous plantation by range of basal area.

In figure 14 to compared all trees growth condition between natural tree and indigenous plantation according from observation data which analyzed in brief for visionary understanding of basal area. They were arranged in 5 classes from high to low basal area value both indigenous trees and natural trees. For indigenous tree species, the first was T3 and the fifth was T1. On the other side, for natural trees the first was T1 and the fifth was T1 (Fig 15), it could write with following below symbols:

①T1-N ② T4-N ③ T5-N ④ T3-N ⑤ T2-N (natural trees)

① T1-I ② T4-I ③ T5-I ④ T2-I ⑤T3-I (Indigenous tree species)

Normally in young stage, basal area of tree plantation were higher than natural tree because natural tree were dropped during land preparation period or some small trees were cleared cut, but in this research site those commercial tree or natural tree were remained nearby such as parent tree, As in Figure 15 almost all of them were basal areal much more than natural trees, however only T1 and T4 were rather similar level of basal area. Also, T4 was a few difference from basal area of natural trees.



Remark: *Natural tree species* *Indigenous tree species*

T1-N = Natural tree species in T1	T1-I = Indigenous species plantation (T1)
T2-N= Natural tree species in T2	T2-I = Indigenous species plantation (T2)
T3-N = Natural tree species in T3	T3-I = Indigenous species plantation (T3)
T4-N = Natural tree species in T4	T4-I = Indigenous species plantation (T4)
T5-N= Natural tree species in T5	T5-I = Indigenous species plantation (T5)

Figure 16 Summarized on tree growth distribution between natural trees and indigenous plantation by range of volume

In figure 16 to compared all trees growth condition between natural tree and indigenous plantation according from observation data which analyzed in brief for visionary understanding of volume. They were arranged in 5 classes from high to low volume of yield for both indigenous tree plantation and natural trees. They were arranged same as basal area style into top five such as below symbols (Fig16)

①T1-N ② T4-N ③ T5-N ④ T3-N ⑤ T2-N (natural trees)

① T1-I ② T4-I ③ T5-I ④ T2-I ⑤T3-I (Indigenous tree plantation)

Normally in young stage, volumes of tree plantation were higher than natural tree. Also every species were planted by row and line suitability or depended on real area. As in Figure 16 almost all of them gained volume much more than natural trees, On T4 was rather nearly volume between natural (0.0012 $m^{-3}ha^{-1}$) and indigenous plantation tree (0.0013 $m^{-3}ha^{-1}$). Especially T1; natural tree (0.0021 $m^{-3}ha^{-1}$) was higher volume than plantation tree (0.00029 $m^{-3}ha^{-1}$) and T1 of natural tree was higher than T4 of plantation tree. This chart was viewed of the trees in plot on horizontal which imagined stand by plantation and natural, on vertical that imagined the yield or volume distribution individual species.

5 Discussion and conclusion

5.1 Discussion

Actually, natural and plantation tree were the competition each other of growth performance which depended on plantation maintenance during young stage whereupon it related to this study for further research. For instance; *D cutrata*, *H odorata* and *W arborea* were quite smaller than natural tree opposite in *P dasyrachis* and *C siamea* were quite bigger than natural tree. Plantation trees was smaller than natural tree because almost of natural trees were pioneer species which integrated at plantation and their canopy were increased very fast such as *P dasyrachis* and *C Siamea*. Pioneer tree species play a key role in natural renewal of tropical forests as they are mostly distributed in the second and third story during forest progression (Lamb *et al.* 2005, Kariuki *et al.* 2006, Sovou *et al.*2009, Tran *et al.*2005). *W arborea* and *H odorata* was medium and the smallest was *D cutrata*. Unexpectedly, *D cutrata* was the smallest which nearby sapling stage. As we can see percentage of indigenous tree plantation was the maximum (85.67%) and the minimum (50.67%) the amount of indigenous tree plantation. Thus the volume of *P dasyrachis* was the highest and *C siamea* was following higher, then *H odorata* was the medium, the lowest were *D cutrata* and *W arborea*. Beacuse *P dasyrachis* and *C siamea* are fast growing tree species well known as fuel wood (fire wood).

Natural tree was bigger in plantation of commercial tree species (*Dalbergia cutrata* and *Wrightia arborea*), because they affected to each other on nutrient competition. Due to plantation tree was slowly growth. However, the plantation tree also reflected to natural tree growth such as in fire wood plots due to they won on this completion, because natural tree couldn't disturb as well. According from observing, they are many parent trees surrounding pla ntation. More than that, this area used to be the deforestation since many years and the commer cial tree remainder when the land was cleared for planting. On the other hand, the volume of natural tree in commercial tree plot was the highest because of the affection from parent trees surrounding planation. But opposite, the lowest were in fire wood plots.

In naturally, grass and seedling grow fast on the fallow stage (< 5 years), so it is likely happening on this research site. Therefore, the changes in importance value (IV) of *Combretum decandrum* was the highest in *C siamea*, *D cultrata* and *P dasyrachis* plot. In plot of *W arborea* had high IV in plots with *W arborea* (natural and plantation trees combination), so there are similar species between natural and planation tree which integrated by nature at *W arborea* plots. *P dasyrachis* and *Microcos paniculata* L were the dominant with the highest IV that found all plots, because they are the pioneer tree species and that is essential in natural renewal of tropical forest as the relate research similar with the idea of other authors as following; Lamb *et al.* 2005, Kariuki *et al.* 2006, Sovou *et al.*2009, Tran *et al.*2005.

Grasses and seedlings had the most density in all plots with 30 – 60 cm height, Also there was not seedling smaller than 30 cm and taller than1.2 m in *W arborea* plots, like this because those plots were the commercial tree species (slow growing), thus natural tree, grass and vine species disturbed while commercial tree were in young around 1-2years old. However, only *C siamea* plots were found seedlings and grasses which were more than 1.2 m height, fire wood (*Cassia siamea* Lamk and *Peltophorum dasyrachis* Kurz) plots were found seedling height from 0.3-1.20 m, the natural tree seedling and grass couldn't disturb on fire wood plot because they had tolerated and grew faster than natural tree, grasses and vines. Natural tree, grass and seedling couldn't disturb as well on nutrient competition for growth. So, we can see the result in *Peltophorum dasyrachis* plots. For example, that plot could not find any grass and seedling bigger than 0.9 m height because of their canopy could not get enough sufficient light intensity from the sun cause of under shade of fire wood species.

The successful natural regeneration depends in seed bank in soil, seed rain, seedling bank and seed dispersal or predation, stump sprouts, root sprouts, layering and remaining native tree species. Other factors are the level of conflicts, management system and environmental (Kennard *et al.* 2002, Parrotta *et al.*2002, Okuda *et al.* 2003, Lamb *et al.*2005). Preview study from Phongoudome (2013) of changes in important value (IV) in Laos; found the highest in primary forest and secondary forest , fallow 10-year-old, secondary logged-over forest , 15-year-old , 5-year-old , and 1-year-old fallow. Also, next research from Soukhavong M (2013) found the Important Value Index (IVI) of natural forest with highest and lowest in mountain area. The most abundant species diversity of plant communities in individual indigenous plantation had maximum family richness per ha in *W arborea* plots but minimum in *C siamea* plots. For the species richness per ha was the highest in *H odorata* plots and the lowest in

Cassia siamea Lamk plots (12 species, 0.61 of rich evenness). The Simpson's and Shannon's index were similar high in *H odorata*and *W arborea* plots. About the seedling and grass species density were the most in *Dalbergia cutrata* Grah plots but the least in *Peltophorum dasyrachis* Kurz.

Among species richness, family richness, Simpson's index and Shannon's index they were different individual themselves. But other researchers found relatively low indices of species diversity (*H'*=0.58) and evenness (J' = 0.21) in an Afromontane agriculture landscape (Tefera B et al,2014) , Shannon's index was high on both *H odorata* and *W arborea* as similar estimation(3.06). Thus, that result linked to natural tree some growing well than plantation tree, the number of family and species composite of researcher result from Phongoudome (2013) on fallow forest were lower than this indigenous plantation. Finally, there are rarely research on diversity on planation both indigenous tree plantation and commercial tree plantation. The previous research focused on fallow forest as in northern part of Laos.

5.2 Conclusion

Recently, it is quite lack of published papers which research on the indigenous plantation growth performances. Therefore, this study tries to find the answer with a few published papers.

The growth condition of natural tree and indigenous tree plantation was the opposite on DBH, height, crown width, basal area and volume in commercial tree plantation plots (*Wrightia arborea* Denn, *Dalbergia cutrata* Grah and *Hopea odorata* Roxb). On the other site, two plots (*Cassia siamea* Lamk and *Peltophorum dasyrachis* Kurz) were not disturbed by natural tree as well, thus they grew very fast. Consequently, *Dalbergia cultrata*, *Hopea odorata and Wrightia arborea* were smaller than natural tree. Nevertheless *Peltopholum dasyrachis and Cassia Siamea* were bigger than natural tree. So the volume of *P dasyrachis* (0.0115±0.0018 m^3ha^{-1}) and *C siamea* (0.007±0.0018m^3 ha^{-1}), *H odorata* (0.003±0.0007m^3 ha^{-1}), *D cultrata* (0.00030± 0.0001m^3 ha^{-1}), and *W arborea* (0.00088±0.0001m^3ha^{-1}).

Obviously, six years old of indigenous plantation had maximum survival (86.67%) and minimum (50.67%). Natural tree density recorded the average stem density were 672 tree ha^{-1}, 1066 ha^{-1} of saplings and 2231 $ha^{-1}$of seedlings.

From the result, on this plantation and surround had 35 families, 53 species, and 11302 individuals (297 of living planted trees, 379 of natural trees, 126 of seedlings and 10500 of grasses).

The highest of importance value (IV) was *Combretum decandrum* (17.85%) in *C siamea* plots. *W arborea* (natural) had 10% of IV in plots of *W arborea* (plantation). *P dasyrachis* and

Microcos paniculata L were the dominant in all plots. Family richness per ha was high in *W arborea* plot (18 families) but the low in *C siamea* plots (8 families). Species richness per ha was high in *H odorata* plot (45 species) and low in *C siamea* plots (12 species). The Simpson's index (0.96) and Shannon's index (3.06) were similar high in *H odorata* Roxb and *W arborea* plots.

Seedlings and grasses were the most density in *D cultrata* plot (2200 ha^{-1}) which mean 3.16 cm DBH and 4.14 height but the least in *P dasyrachis* plot (900 ha^{-1}) with low height (0.90m) and DBH (1.74 cm); high density during 30 – 60 cm height (3000 ha^{-1}), their height over 1.2m in *C siamea* plot. Only *P dasyrachis* plot lacked of seedling and grass ≥ 0.90 m height.

5.3 Recommendation

Some species of trees and grass couldn't clearly identify the scientific name and its characteristic as well, it will be better if deeply identified. However, further study or research should find out and combine with the light intensity between difference species and plots on both natural and indigenous planation which affected for understory plant (e.g. sapling, seedling and grass grown concern to shade tolerance) together with plantation forest structure drawing according from their characteristic as forest community.

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