CHAPTER 2

Plant Species Diversity in Pine Forest

Abstract

Three subtypes of pine-dry dipterocarp forest (P-DDF) and one subtype of pine-lower montane forest (P-LMF) at Kunlaya Ni Wattana district, Chiang Mai province were studied for plant species diversity, forest conditions and productions. The P-DDF included pine-*Dipterocarpus obtusifolius* (P-DDF1), pine-*D. tuberculatus* (P-DDF2) and pine-*Shorea obtusa* (P-DDF3). Seventy plots, 40 x 40 m in size, were used for vegetation sampling over the forest by a stratified random method covering areas at altitude between 900-1,200 m. Stem girth at 1.3 m above ground, height and crown width of all trees with ≥1.5 m height were measured. Species richness in all subtypes of the pine forest was 64 species (in 43 genera and 26 families). They included 47 tree species, 14 small trees, 5 shrubs and 2 climbers. Species richness in P-DDF1, P-DDF-2, P-DDF-3 and P-LMF were 37, 46, 56 and 24 species, respectively. Dominant trees which had the highest frequency (100%) were different among subtypes: P-DDF1; *P. merkusii*, *D. obtusifolius* and *Gluta usitata*, P-DDF2; *P. merkusii*, *D. tuberculatus* and *G. usitata*, P-DDF3; *S. obtusa* and *G. usitata* and P-LMF; *P. kesiya*, *Castanopsis accuminatissima*, *Quercus kingiana* and *Q. brandisiana*. Species diversity indexes by Shannon-Wiener function were calculated to 2.55, 3.66, 3.88 and 3.61, respectively, whereas the average forest condition indexes (FCI) were in the order of 25.06, 20.33, 18.74 and 19.02. These implied to the lower species diversity and the better forest condition of P-DDF1. Over timber harvesting in the P-DDF3 resulted in the forest degrade. Plant community in P-DDF1 had the higher similarity with P-DDF2, but lower with P-DDF3.

2.1 Introduction

The forest in northern Thailand has been typically classified into five types according to dominant tree species and species composition; two deciduous and three evergreen forests. The deciduous forests are dry dipterocarp (DDF) and mixed deciduous (MDF) forests. The evergreen forests are dry evergreen (DEF), pine (PF) and montane (MF) forests. These forests distribute in areas with different altitude in the watershed. The DDF occupies on dry to extremely dry habitat particularly upper slope and along the ridges with altitude range, 150-1,200 m m.s.l. The MDF usually covers in the valley and stream banks, below 800 m. The DEF is found in a limited area in the north, and normally distribute in the narrow areas along perennial stream, below 1,000 m. The pine forest is subdivided into the pine-dry dipterocarp (pine-DDF) and pine-lower montane (oak) (pine-LMF) forests. The pine-DDF is usually observed in the dry site, 500-1200 m (Santisuk, 1988), whereas The pine-LMF covers the moderately moist and cool area, 1,000-1,900m altitude. The MF is the climax ecosystem on the high mountains above 1,000 m, divided into lower (LMF) and upper

montane (UMF) forests. The latter covers the summit of Doi Inthanon, the highest mountain in Thailand (Khamyong *et al*., 2004).

The pine-DDF is distributed on the drier area as compared to the pine-LMF, and dominated by many xeric tree species including *Pinus merkushi*, *P. kesiya*, *Shorea obtusa*, *S. siamensis*, *Dipterocarpus obtusifolius* and *D. tuberculatus*. The dominant trees in the pine-LMF usually consist of three needle pine, *P. kesiya* and many oak species. The pine is the uppermost tree canopy and oak species are the lower canopy. The pine-DDF can be divided into different subtype communities according to existence of different dipterocarp tree species including *D. tuberculatus*, *D. obtusifolius*, *S. obtusa* and *S. siamensis*. Their species composition, richness and diversity may be different among subtypes. The variations of physical environments such as soil nature, nutrient status, site temperature, moisture, etc. may be occurred as well as nutrient cycles particularly carbon.

Objectives of this research were to investigate plant species diversity, forest conditions and productions in four subtypes of the natural pine forest including three subtypes of pine-dry dipterocarp forest (P-DDF) and one subtype of pine-lower montane forest (P-LMF) at Kunlaya Ni Wattana district, Chiang Mai province.

2.2 Materials and Methods

2.2.1 Research Location

The research had been carried out in Banchun sub-district, Kunlaya Ni Wattana district, Chiang Mai province, about 140 km northwest of Chiang Mai city. The forest is mainly the natural pine forest. It is the head watershed of Mae Cham river which is a tributary of the Mae Ping river.

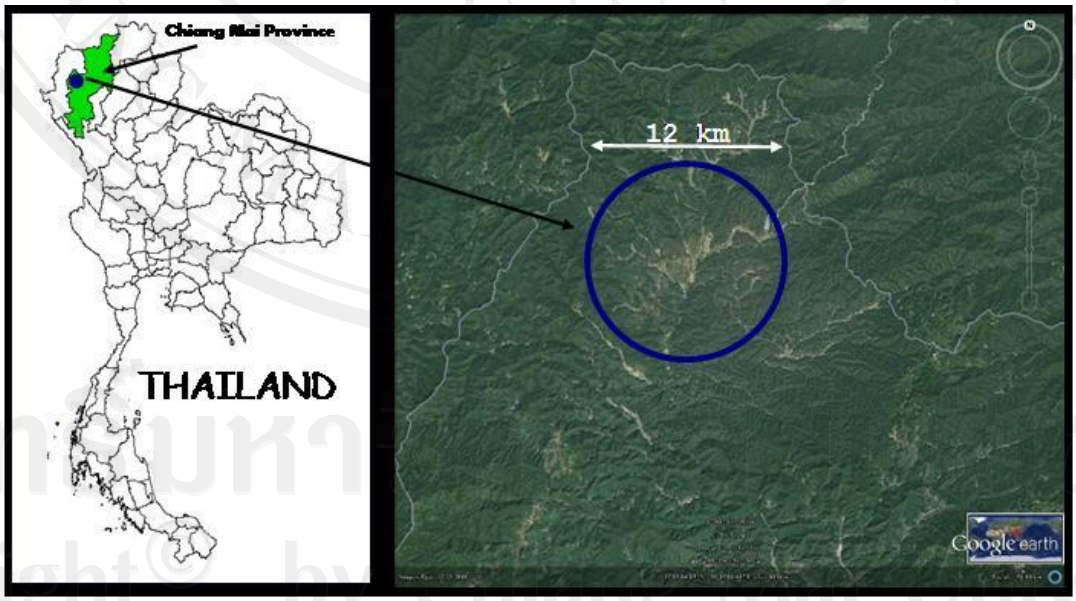


Figure 2-1 Research area at Ban Chun sub-district, Kunlaya Ni Wattana district, Chiang Mai province, northern Thailand

2.2.2 Sampling of forest vegetation

Preliminary survey of the natural pine forest was taken in Kunlaya Ni Wattana district, Chiang Mai province. Subtype communities and their spatial distribution were determined using a topographic map and GPS. Sampling of forest vegetation based on a method of plant community analysis (Greig-Smith, 1983; Kershaw & Looney, 1985; Krebs, 1985; Kimmins, 1987), using a quadrat method/sampling plot with 40 x 40 m in size and a stratified random sampling technique. The number of sampling plots per each subtype community was depended upon the area. In each plot, stem girth at 1.3 m above ground and height of all trees with $\geq$ 1.5 m height were measured.

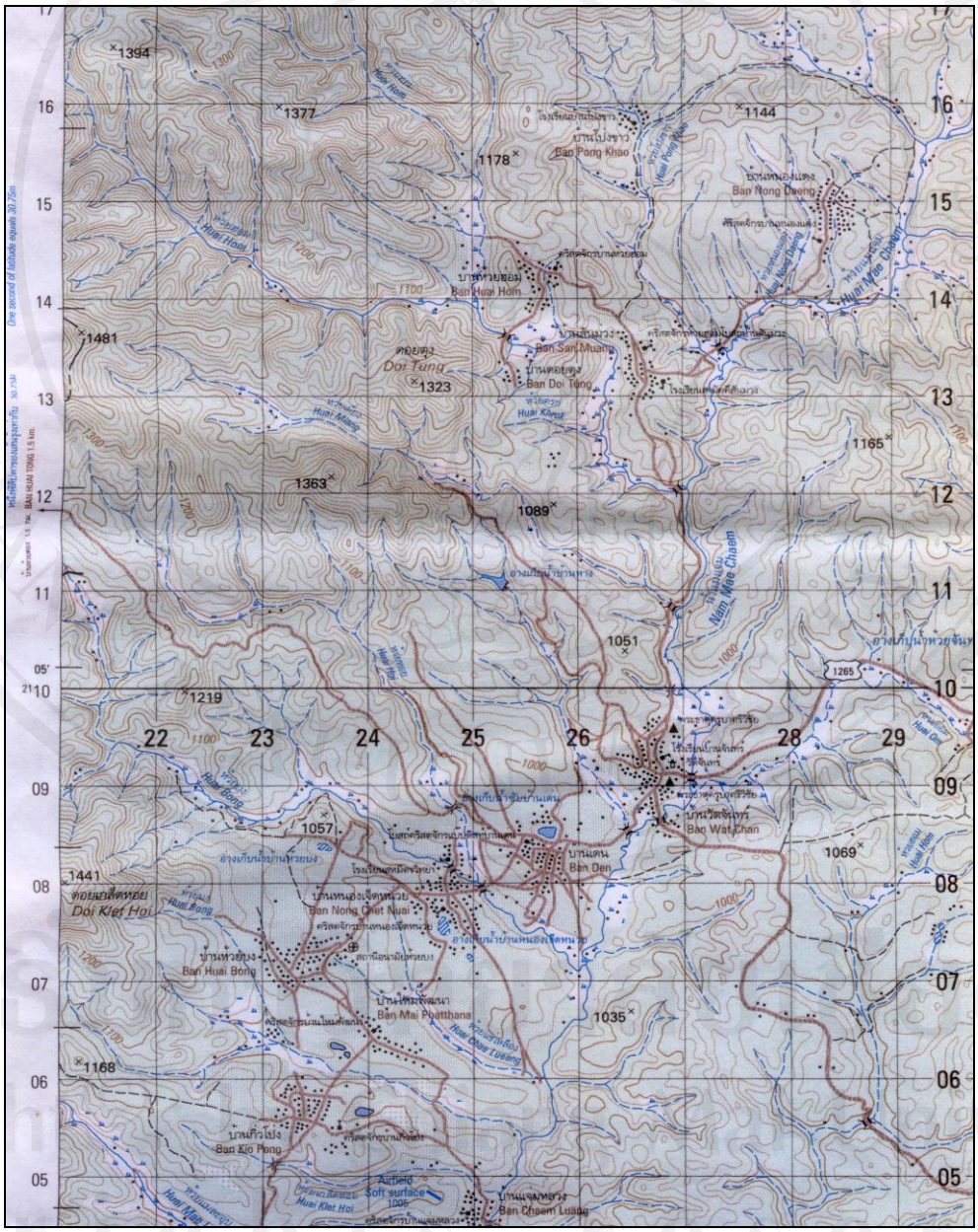


Figure 2-2 Location of Ban Chun sub-district, Kunlaya Ni Wattana district, Chiang Mai province, northern Thailand

2.2.3 Quantitative characteristics

The collected data were calculated for the following ecological parameters.

(1) Plant Frequency

$$\text{Plant Frequency} = \frac{\text{Number of plots of existed species i.}}{\text{Total number of plots}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Frequency of species i.}}{\text{Sum of frequencies of all species}} \times 100$$

(2) Plant Density

$$\text{Plant Density} = \frac{\text{Number of individuals of species i.}}{\text{Total number of plots}} \text{ (individuals/plot)}$$

$$\text{Relative Density} = \frac{\text{Number of individuals of species i.}}{\text{Total number of individuals of all species}} \times 100$$

(3) Plant Dominance

The relative dominance of tree species is calculated from stem basal area.

$$\text{Plant dominance} = \frac{\text{Sum of stem basal area of species i.}}{\text{Sum of stem basal area of all species}} \times 100$$

(4) Important Value Index (IVI)

The ecological importance value index (IVI) is the sum of relative frequency, relative density and relative dominance. It is an integrated influence of a tree species in the forest. The value varies between 0 and 300. It can be expressed in term of relative IVI.

$$\text{IVI (300)} = \text{Relative frequency + Relative density + Relative dominance}$$

$$\text{Relative IVI (100)} = \frac{\text{IVI of species i.}}{\text{Sum of IVI of all species}} \text{ X } 100$$

(5) Species Diversity Index

Many indexes have been used for describing the plant species diversity. In this study, the Shannon-Wiener Index (SWI) was used (Krebs, 1985).

$$H = -\sum_{i=1}^{S} (p_i)(\log_2 p_i)$$

where H = index of species diversity
S = number of species
p_i = proportion of total individuals belonging to the it species

(6) Forest Conditions Index (FCI)

The index of species diversity does not imply to the forest condition. Different types of primary forests usually have different species diversity. Some forest types may be classified as the species-poor ecosystems whereas the others are the species-rich ecosystems. Within the same forest type, the species diversity is changed with different stages of plant succession. The forests at the early and middle stages may also have the higher diversity than that in the climax stage. The forest conditions as good, intermediate or poor are considered from the number of big trees. On the other hand, the poor forests compose of mainly small trees.

Assessment of forest communities as the good, intermediate or poor conditions was carried out using the number of individual trees with different stem-girth classes. The big trees were significant more than smaller trees. The plenty of individuals in the small size classes was indicated to the good regeneration. The stem-girth classes were divided into 0-25, 25-50, 50-75, 75-100, ……, respectively and the FCI was calculated for each class. The index of forest condition was the sum value of the number of individual trees for all classes. The index based on the use of 40 x 40 m sampling plot.

$$FCI = \Sigma\, n_1.10^{-2} + n_2.10^{-1} + (n_3 + n_4 + n_{5\,+\ldots} + n_n).1$$

Where
- FCI = index of forest conditions
- n_1 = number of individual trees with gbh < 25 cm
- n_2 = number of individual trees with gbh 25-50 cm
- n_3 = number of individual trees with gbh 50-75 cm
- n_4 = number of individual trees with gbh 75-100 cm
- n_5 = number of individual trees with gbh 100-125 cm
- n_n = number of individual trees with gbh n cm

2.2.4 Qualitative characteristics

Species list was made as the qualitative data. All plant species in the sampling plots were listed for their local names, scientific names, families and life forms. The trees were identified as common, intermediate and rare species according to their ecological parameters. The density and frequency values of these trees were also used for this identification.

2.3 Results

2.3.1 Plant Species Richness and Composition

Table 2-1 to **2-4** show the quantitative data of tree species in four subtypes of the pine forest. Species list, species diversity index (SWI) and forest condition index (FCI) were given in **Table 2-5**, **2-6** and **2-7**, respectively. Using 70 sampling plots, the species richness in the pine forest at Ban Wat Chan area was found as 64 species (in 43 genera and 26 family). They included 47 tree species, 14 small trees, 5 shrubs and 2 climbers.

The number of tree species in the forest subtypes as species richness in P-DDF1, P-DDF2, P-DDF3 and P-LMF were 37, 46, 56 and 24 species, respectively.

(1) P-DDF1 (Pine-*D. obtusifolius*)

This subtype consisted of 37 tree species, and had mainly two dominant trees; a two- needle pine (*P. merkusii*) and a xeric dipterocarp tree, *D. obtusifolius*.

a. Tree frequencies:

Three tree species had the highest frequency (100%) in the forest including *P. merkusii*, *D. obtusifolius* and *Gluta usitata*. This implied that these trees were distributed over the forest. The trees having the lower frequencies were *P. kesiya* (57.14%), *Phyllanthus emblica* (28.57%), *Semecarpus anacardium* and *Anneslea fragrans* (25.71%), *Wendlandia tinctoria* (22.86%), *Zizyphus oenoplia* and *Craibiodendron stellatum* (20%), etc. The remained species had the frequencies between 2.86-20.00%.

b. Tree densities:

Average tree density in the forest was 349.29 trees ha^{-1}. *D. obtusifolius* had the highest density, 140.7 trees ha^{-1}. The trees which had the lower densities were *P merkusii* (102.3), *G. usitata* (40.4), *P. kesiya* (23.9), *Castanopsis tribuloides* (8.4), etc. Other tree species had densities less than 8.0 trees.ha^{-1}.

c. Tree dominance:

Total stem basal area in this subtype was 21.36 m^2 ha^{-1}. *P merkusii* had the highest contribution to the stem basal area, 12.93 m^2 ha^{-1}, and *D. obtusifolius* was the second order, 5.67 m^2 ha^{-1}. The relative dominance of *P. merkusii* was the highest as 60.53% of all species. The tree species which had the lower dominances were *D. obtusifolius* (26.55), *P. kesiya* (7.01), *G. usitata* (4.50), etc. The remained species had the values less than 1.0%.

d. Importance Value Index (IVI):

P. merkusii had the highest IVI in the forest, 34.77% of all species. This implied to the highest ecological influence of this tree species in this subtype forest community. The tree species which had the lower IVI were *D. obtusifolius* (27.11), *G. usitata* (10.17), *P. kesiya* (7.38), *P. emblica* (1.76), *C. tribuloides* (1.56), *S. anacardium* (1.50), etc.

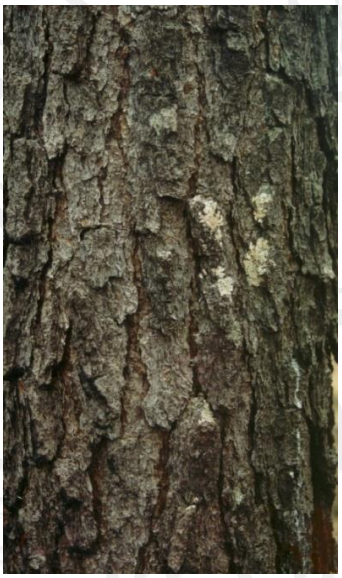
เต็ง (*Shorea obtusa*)

รัง (*Shorea siamensis*)

เหียง (*Dipterocarpus obtusifolius*)

พลวง (*Dipterocarpus tuberculatus*)

Figure 2-3 Four xeric dipterocarp tree species as the indicators of DDF



A B

Figure 2-4 Outer barks of *P. merkusii* (A) and *P. kesiya* (B)

(2) P-DDF2 (Pine-*D. tuberculatus*)

Totally 46 tree species were existed in this subtype community. The forest was dominated mainly by *P. merkusii* and *D. tuberculatus*.

a. Tree frequencies:

Three tree species had the highest frequency (100%) in the subtype including *P. merkusii*, *D. tuberculatus* and *Gluta usitata*. These trees were therefore distributed over the forest. The trees which had the lower frequencies included *P. kesiya*, *Vaccinium sprengelii* and *Aporosa villosa* (76.19%), *Wendlandia tinctoria* and *Quercus brandisiana* (66.67%), *Tristaniopsis burmanica* (61.90%), *Shorea obtusa* and *Q. kerrii* (52.38%), etc. The remained tree species had the frequencies between 4.76-47.62%.

b. Tree densities:

The average tree density in the forest was 769.35 trees ha^{-1} that higher than P-DDF1. A shrubby tree, *T. burmanica* had the highest density, 136.6 trees ha^{-1}. The trees which had the lower densities were *D. tuberculatus* (116.1), *P merkusii* (94.3), *V. sprengelii* (84.8), *P. kesiya* (83.0), *W. tinctoria* (62.5), *Q. brandisiana* (51.8), *G. usitata* (34.8), *Aporosa villosa* (15.8), etc. The other species had the densities less than 10.0 trees ha^{-1}.

c. Tree dominance:

The total stem basal area in this subtype community was 17.45 m^2 ha^{-1}. *P merkusii* had the highest contribution to the stem basal area (7.51 m^2 ha^{-1}), and *D. tuberculatus* was the second order, 4.98 m^2 ha^{-1}. The relative dominance of *P. merkusii* was the highest, 43.02% of all species. The species which had the lower dominances included *D. obtusifolius* (28.54), *P. kesiya* (10.96), *G. usitata* (7.08), etc. The remained species had the values less than 2.0%.

d. Importance Value Index (IVI):

P. merkusii had the highest IVI in this subtype forest, 20.84% of all species. It had the highest ecological influence among 46 tree species in this subtype community. The tree species which had the lower dominances were *D. obtusifolius* (16.96), *P. kesiya* (9.09), *T. burmanica* (7.86), *G. usitata* (6.28), *V. sprengelii* (5.89), *W. tinctoria* (4.55), *Q. brandiaiana* (4.47), *A. villosa* (2.60), etc. The other species had values less than 2.0%.

(3) P-DDF3 (Pine-*S. obtusa*):

This subtype of the pine forest composed of 56 tree species dominated mainly by *P. kesiya* and *S. obtusa*. *P. kesiya* was the dominant tree whereas *S. obtusa* was the co-dominant tree.

a. Tree frequencies:

Two tree species had the highest frequency (100%) in the forest including *S. obtusa* and *G. usitata*. This indicated that these trees were distributed over the forest. Those trees which had the low frequencies included *T. burmanica* and *Q. brandiaiana* (91.67), *P. kesiya* (83.33%), *W. tinctoria, V. sprengellii, Q. kerrii* and *Craibiodendron stellatum* (66.67%), *P. emblica* (58.33), *P. merkuii, Q. kingiana, A. villosa, Glochidion spahaerogynum* and *Symplocos recemosa* (50.0%), etc. The remained tree species had the frequencies between 8.33-41.67%.

b. Tree densities:

The average tree density in this subtype forest was the highest among four subtypes, 1,115.63 trees ha^{-1}. *S. obtusa* had the highest density, 174.5 trees ha^{-1}. The trees which had the lower densities included *W. tinctoria* (164.6), *T. burmanica* (155.7), *P kesiya* (125.0), *V. sprengelii* (114.1), *Q. brandisiana* (64.1), *Q. kerrii* (57.8), *G. usitata* (47.4), *P. emblica* (27.1), *P. merkusii* (25.00), *A. villosa* (21.9), etc. Other species had the densities below 20.0 trees.ha^{-1}.

c. Tree dominance:

The total stem basal area in this subtype was 18.49 m^2 ha^{-1}. *P kesiya* had the highest contribution to the stem basal area 5.43 m^2 ha^{-1}, and followed by *P. merkusii* (3.26), *S. obtusa* (5.67), *T. burmanica* (1.65) and *Q. brandisiana* (1.26). The relative dominance of *P. kesiya* was the highest as 29.35% of all species. Those tree species having the lower dominances were *P. merkusii* (17.65), *S. obtusa* (14.74), *T. burmanica* (8.91), *Q. brandisiana* (6.83), etc. The remained species had values less than 5.0%.

d. Importance Value Index (IVI):

P. kesiya had the highest IVI in this subtype forest, 15.14% of all species. This tree species had the highest ecological influence in the forest community. The tree species which had the lower IVI included *S. obtusa* (12.07), *T. burmanica* (9.40), *P. merkusii* (7.60), *W. tinctoria* (6.98), *Q. brandisiana* (5.97), *V. sprengelii* (5.56), etc. The other tree species had the values less than 5.0%.

(4) P-LMF (Pine-oaks):

Most areas of this subtype were a secondary forest developed after shifting cultivation. The area of pine-oak forest was limited in Ban Wat Chan sub-district, and thus only two sampling plots were used. *P. merkusii* was not existed in this subtype. The forest was dominated mainly by *P. kesiya,* and three oak species, *Castanopsis acuminatissima, Quercus kingiana* and *Q. brandisiana*

a. Tree frequencies:

Ten tree species had the highest frequency (100%) in the forest including *P. kesiya, C. acuminatissima, Q. kingiana, T. burmanica, Q. brandisiana, V. sprengelii, G. usitata, P. emblica, Q. kerrii* and *Gardenia coronaria*. The remained tree species had frequencies of 50%.

b. Tree densities:

The average tree density in the forest was 825.0 trees ha^{-1}. *P. kesiya* had the highest density, 193.80 trees ha^{-1}, and followed by *T. burmanica* (109.4). The tree species which had the lower densities included *W. tinctoria* (87.5), *Q. brandisiana* (75.0), *C. acuminatissima* (68.8), *V. sprengelii* (59.4), *Q. kingiana* (46.9), *A. villosa* (43.8), *G. usitata* (31.1), *P. emblica* (21.9), etc. The other tree species had the densities below 20.0 trees ha^{-1}.

c. Tree dominance:

The total stem basal area in this subtype was 17.13 m^2 ha^{-1}. *P kesiya* had the highest contribution to the stem basal area 10.06 m^2 ha^{-1}, and followed by *C. accuminatissima* (2.87), *Q. kingiana* (2.14). The relative dominance of *P. kesiya* was the highest as 58.71% of all species. Those tree species having the lower dominances were *C. acuminatissima* (16.74), *Q. kingiana* (12.50), *Q. brandisiana* (3.08), *T. burmanica* (2.29), *V. sprengelii* (2.04), *G. usitata* (1.67), etc. The other species had the values less than 1.0%.

d. Importance Value Index (IVI):

P. kesiya had the highest IVI in this subtype forest, 29.36% of all species. This pine had the highest ecological influence in the forest. The tree species which had the lower IVI were *C. accuminatissima* (10.32), *Q. kingiana* (8.02), *T. burmanica* (7.14), *Q. brandisiana* (6.02), *V. sprengelii* (6.98), *W. tinctoria* (4.76), *G. usitata* (3.78), etc. The remained species had the values less than 3.0%.

Figure 2.5 Overall view of DDF with dominant *D. obtusifolius* (P-DDF1)

Figure 2.6 Overall view of DDF with dominant *D. tuberculatus* (P-DDF2)

Figure 2.7 Overall view of DDF with dominant *S. obtusa* (P-DDF3)

Figure 2.8 Overall view of pine-lower montane forest (P-LMF)

2.3.2 Plant Species Diversity

As already mentioned, the species richness in P-DDF1, P-DDF2, P-DDF3 and P-LMF were found as 37, 46, 56 and 24 species, respectively. It was the highest for the P-DDF3 and the lowest for P-LMF.

However, species diversity index according to Shannon-Wiener Index (SWI) in P-DDF1, P-DDF2, P-DDF3 and P-LMF were calculated to 2.56, 3.66, 3.88 and 3.61. The species diversity was therefore the highest for P-DDF3 and the lowest for P-DDF1. The concept of species diversity combines species richness and heterogeneity of their population abundance.

2.3.3 Forest Condition Index (FCI)

The species diversity index did not imply to the forest condition as good, intermediate or poor since tree size was not considered. The Shannon-Wiener Index (SWI) of species diversity was the highest for P-DDF3 and the lowest for P-DDP1.

The forest condition is considered from the number of big trees. The number of tree individuals with different stem-girth classes was used for calculation. The big trees were more significant than the smaller trees. The plenty of individuals in the small size classes is indicated to the good regeneration.

The forest condition indexes (FCI) of P-DDF1, P-DDF2, P-DDF3 and P-LMF were calculated to 25.06 $\pm$ 6.90, 20.33 $\pm$ 6.40, 18.74 $\pm$ 6.40 and 19.02 $\pm$ 0.88. Thus, the FCI was the highest for P-DDF1, and the lowest for P-DDF3. Illegal cutting of trees in the forests resulted in the degrading forest conditions.

Table 2-1 Quantitative characteristics of various tree species in Pine - *Dipterocarpus obtusifolius* forest subtype (P-DDF1)

No	Species	Frequency (%)	Density (trees/ha)	Basal area (m^2/ha)	Relative (%)			IVI (%)	
					Frequency	Density	Dominance	(300)	(100)
1	*Pinus merkusii*	100.00	102.3	12.93	14.46	29.31	60.53	104.30	34.77
2	*Dipterocarpus obtusifolius*	100.00	140.7	5.67	14.46	40.31	26.55	81.32	27.11
3	*Gluta usitata*	100.00	40.4	0.96	14.46	11.56	4.50	30.52	10.17
4	*Pinus kesiya*	57.14	23.9	1.50	8.26	6.85	7.01	22.13	7.38
5	*Phyllanthus emblica*	28.57	3.9	0.01	4.13	1.13	0.03	5.29	1.76
6	*Castanopsis tribuloides*	14.29	8.4	0.04	2.07	2.40	0.21	4.68	1.56
7	*Semecarpus anacardium*	25.71	2.1	0.03	3.72	0.61	0.16	4.49	1.50
8	*Anneslea fragrans*	25.71	1.8	0.02	3.72	0.51	0.08	4.31	1.44
9	*Wendlandia tinctoria*	22.86	3.2	0.02	3.31	0.92	0.08	4.31	1.44
10	*Ziziphus oenoplia*	20.00	2.0	0.01	2.89	0.56	0.05	3.50	1.17
11	*Craibiodendron stellatum*	20.00	2.0	0.01	2.89	0.56	0.04	3.49	1.16
12	*Lithocarpus glandifolius*	17.14	2.3	0.04	2.48	0.66	0.17	3.32	1.11
13	*Glochidion sphaerogynum*	17.14	2.0	0.00	2.48	0.56	0.01	3.05	1.02
14	*Lithocarpus sootepensis*	14.29	1.3	0.01	2.07	0.36	0.06	2.48	0.83
15	*Shorea obtusa*	11.43	1.6	0.00	1.65	0.46	0.01	2.13	0.71
16	*Dipterocarpus tuberculatus*	8.57	1.6	0.07	1.24	0.46	0.31	2.01	0.67
17	*Terminalia chebula*	11.43	1.1	0.00	1.65	0.31	0.01	1.97	0.66
18	*Quercus kingiana*	11.43	0.9	0.01	1.65	0.26	0.02	1.93	0.64
19	*Vaccinium sprengelii*	8.57	1.3	0.00	1.24	0.36	0.02	1.62	0.54
20	*Tristaniopsis burmanica*	8.57	1.1	0.01	1.24	0.31	0.04	1.59	0.53
21	*Symplocos recemosa*	8.57	0.9	0.00	1.24	0.26	0.01	1.50	0.50
22	*Aporosa villosa*	5.71	0.9	0.00	0.83	0.26	0.01	1.09	0.36
23	*Castanopsis acuminatissima*	5.71	0.36	0.01	0.83	0.10	0.03	0.96	0.32
24	*Vangueria pubescens*	5.71	0.4	0.01	0.83	0.10	0.03	0.96	0.32
25	*Quercus kerrii*	5.71	0.4	0.00	0.83	0.10	0.00	0.93	0.31
26	*Dalbergia cultrata*	5.71	0.4	0.00	0.83	0.10	0.00	0.93	0.31
27	*Engelhardtia spicata*	2.86	0.4	0.00	0.41	0.10	0.00	0.52	0.17
28	*Quercus brandisiana*	2.86	0.2	0.00	0.41	0.05	0.01	0.47	0.16
29	*Buchanania lanzan*	2.86	0.2	0.00	0.41	0.05	0.01	0.47	0.16
30	*Catunaregam tomentosa*	2.86	0.2	0.00	0.41	0.05	0.00	0.47	0.16
31	*Glochidion hirsutum Voigt*	2.86	0.2	0.00	0.41	0.05	0.00	0.47	0.16
32	*Antidesma acidum*	2.86	0.2	0.00	0.41	0.05	0.00	0.47	0.16
33	*Colona flagrocarpa*	2.86	0.2	0.00	0.41	0.05	0.00	0.47	0.16
34	*Lithocarpus truncatus*	2.86	0.2	0.00	0.41	0.05	0.00	0.47	0.16
35	*Flacourtia indica*	2.86	0.2	0.00	0.41	0.05	0.00	0.46	0.15
36	*Lithocarpus lindleyanus*	2.86	0.2	0.00	0.41	0.05	0.00	0.46	0.15
37	*Dillenia obovata*	2.86	0.2	0.00	0.41	0.05	0.00	0.46	0.15
	total	**694.29**	**349.29**	**21.37**	**100.00**	**100.00**	**100.00**	**300.00**	**100.00**

Table 2-2 Quantitative characteristics of various tree species in Pine-*Dipterocarpus tuberculatus* forest subtype (P-DDF2)

No	Species	Frequency (%)	Density (trees/ha)	Basal area (m^2/ha)	Relative (%)			IVI (%)	
					Frequency	Density	Dominance	(300)	(100)
1	*Pinus merkusii*	100.00	94.3	7.51	7.24	12.26	43.02	62.52	20.84
2	*Dipterocarpus tuberculatus*	100.00	116.1	4.98	7.24	15.09	28.54	50.87	16.96
3	*Pinus kesiya*	76.19	83.0	1.91	5.52	10.79	10.96	27.27	9.09
4	*Tristaniopsis burmanica*	61.90	136.6	0.24	4.48	17.76	1.35	23.59	7.86
5	*Gluta usitata*	100.00	34.8	1.24	7.24	4.53	7.08	18.85	6.28
6	*Vaccinium sprengelii*	76.19	84.8	0.20	5.52	11.03	1.14	17.68	5.89
7	*Wendlandia tinctoria*	66.67	62.5	0.12	4.83	8.12	0.71	13.66	4.55
8	*Quercus brandisiana*	66.67	51.8	0.32	4.83	6.73	1.86	13.42	4.47
9	*Aporosa villosa*	76.19	15.8	0.04	5.52	2.05	0.22	7.79	2.60
10	*Shorea obtusa*	52.38	7.1	0.09	3.79	0.93	0.52	5.24	1.75
11	*Quercus kerrii*	52.38	7.7	0.06	3.79	1.01	0.36	5.16	1.72
12	*Castanopsis tribuloides*	47.62	8.9	0.09	3.45	1.16	0.54	5.15	1.72
13	*Phyllanthus emblica*	47.62	8.0	0.01	3.45	1.04	0.06	4.56	1.52
14	*Craibiodendron stellatum*	42.86	8.6	0.03	3.10	1.12	0.20	4.42	1.47
15	*Dipterocarpus obtusifolius*	19.05	7.4	0.31	1.38	0.97	1.78	4.13	1.38
16	*Anneslea fragrans*	38.10	9.2	0.02	2.76	1.20	0.12	4.08	1.36
17	*Ziziphus oenoplia*	33.33	6.0	0.03	2.41	0.77	0.17	3.35	1.12
18	*Glochidion sphaerogynum*	28.57	2.1	0.00	2.07	0.27	0.01	2.35	0.78
19	*Symplocos recemosa*	28.57	1.8	0.00	2.07	0.23	0.01	2.31	0.77
20	*Vangueria pubescens*	23.81	1.8	0.00	1.72	0.23	0.01	1.97	0.66
21	*Quercus kingiana*	19.05	1.2	0.06	1.38	0.15	0.36	1.89	0.63
22	*Semecarpus anacardium*	19.05	1.2	0.05	1.38	0.15	0.27	1.80	0.60
23	*Schima wallichii*	19.05	1.8	0.01	1.38	0.23	0.04	1.65	0.55
24	*Albizia odoratissima*	14.29	2.4	0.01	1.03	0.31	0.06	1.40	0.47
25	*Syzygium albiflorum*	14.29	0.9	0.03	1.03	0.12	0.16	1.31	0.44
26	*Syzygium cumini*	14.29	1.2	0.01	1.03	0.15	0.07	1.26	0.42
27	*Cratoxylum formosum*	14.29	1.2	0.00	1.03	0.15	0.01	1.19	0.40
28	*Gardenia coronaria*	9.52	1.2	0.00	0.69	0.15	0.00	0.85	0.28
29	*Dalbergia cultrata*	9.52	0.6	0.01	0.69	0.08	0.07	0.83	0.28
30	*Lithocarpus lindleyanus*	9.52	0.9	0.00	0.69	0.12	0.02	0.82	0.27
31	*Antidesma acidum*	9.52	0.6	0.00	0.69	0.08	0.01	0.77	0.26
32	*Terminalia chebula*	9.52	0.6	0.00	0.69	0.08	0.00	0.77	0.26
33	*Castanopsis purpurea*	9.52	0.6	0.00	0.69	0.08	0.00	0.77	0.26
34	*Catunaregam tomentosa*	9.52	0.6	0.00	0.69	0.08	0.00	0.77	0.26
35	*Dillenia obovata*	9.52	0.6	0.00	0.69	0.08	0.00	0.77	0.26
36	*Quercus helferiana*	4.76	1.2	0.02	0.34	0.15	0.11	0.61	0.20
37	*Glochidion hirsutum Voigt*	4.76	0.9	0.01	0.34	0.12	0.08	0.54	0.18
38	*Semecarpus albescens*	4.76	0.6	0.01	0.34	0.08	0.06	0.48	0.16
39	*Lithocarpus truncatus*	4.76	0.6	0.00	0.34	0.08	0.00	0.42	0.14
40	*Buchanania lanzan*	4.76	0.3	0.00	0.34	0.04	0.02	0.41	0.14
41	*Colona flagrocarpa*	4.76	0.3	0.00	0.34	0.04	0.00	0.39	0.13

Table 2-2 (continued)

No	Species	Frequency (%)	Density (trees/ha)	Basal area (m^2/ha)	Relative (%)			IVI (%)	
					Frequency	Density	Dominance	(300)	(100)
42	*Castanopsis acuminatissima*	4.76	0.3	0.00	0.34	0.04	0.00	0.39	0.13
43	*Castanopsis diversifolia*	4.76	0.3	0.00	0.34	0.04	0.00	0.39	0.13
44	*Lithocarpus glandifolius*	4.76	0.3	0.00	0.34	0.04	0.00	0.39	0.13
45	*Engelhardtia spicata*	4.76	0.3	0.00	0.34	0.04	0.00	0.38	0.13
46	*Pavetta tomentosa*	4.76	0.3	0.00	0.34	0.04	0.00	0.38	0.13
	total	**1,380.95**	**769.35**	**17.45**	**100.00**	**100.00**	**100.00**	**300.00**	**100.00**

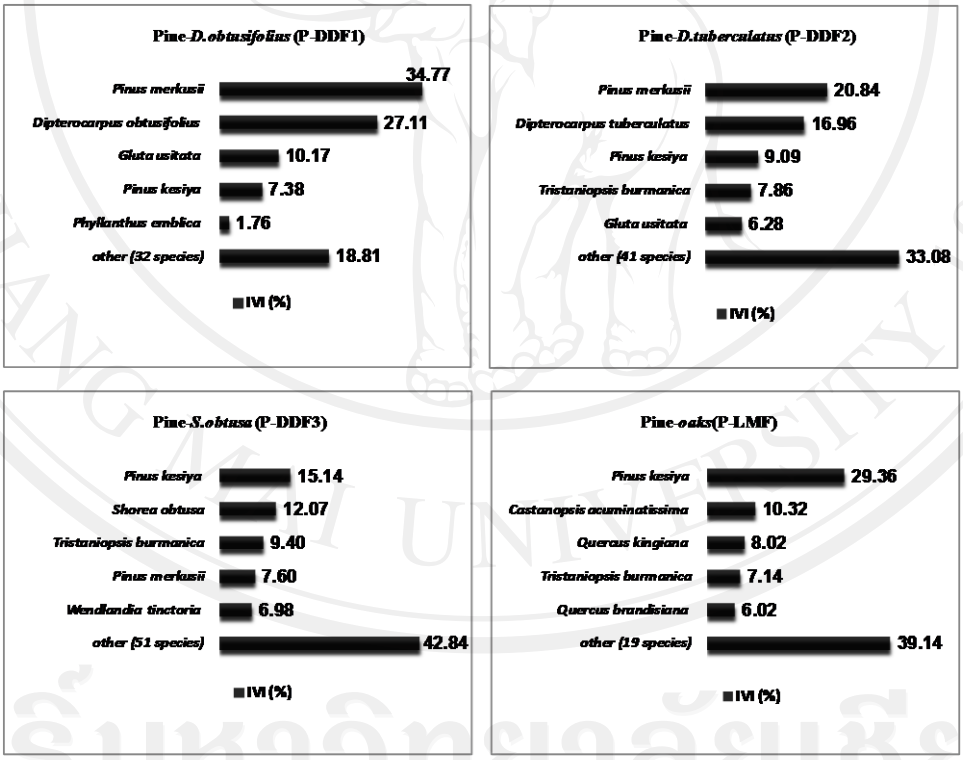


Figure 2.9 IVI values of tree species in four subtypes of pine forest

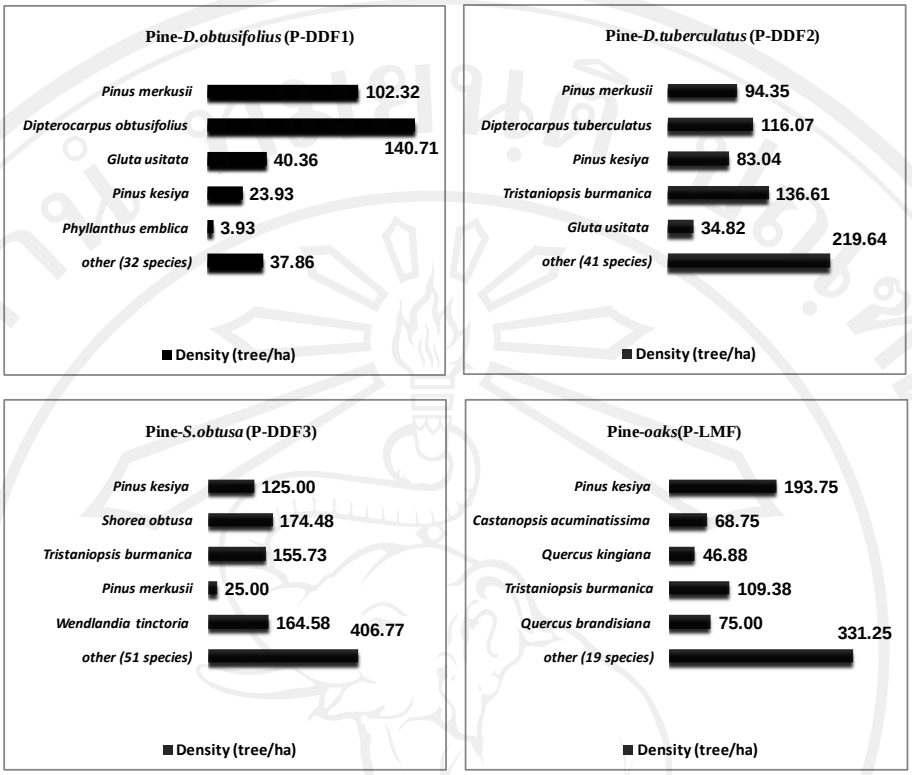


Figure 2.10 Densities of tree species in four subtypes of pine forest

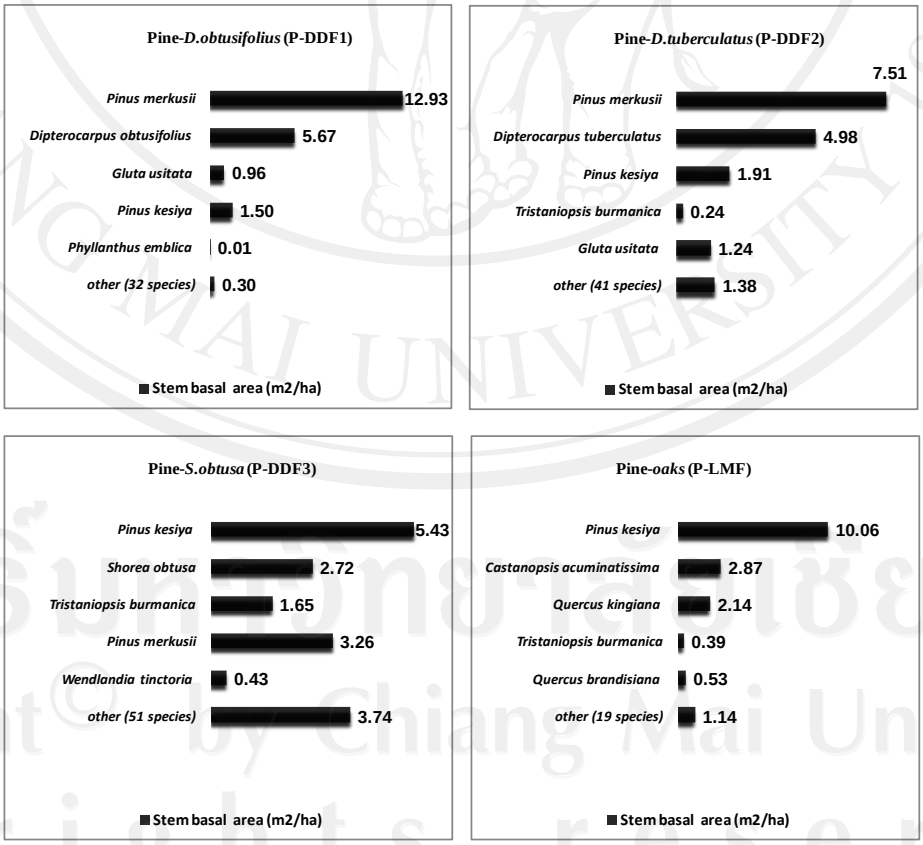


Figure 2.11 Stem basal area of tree species in four subtypes of pine forest

Table 2-3 Quantitative characteristics of various tree species in pine-*Sorea obtuse* forest subtype (P-DDF3)

No	Species	Frequency (%)	Density (trees/ha)	Basal area (m^2/ha)	Relative (%)			IVI (%)	
					Frequency	Density	Dominance	(300)	(100)
1	*Pinus kesiya*	83.33	125.0	5.43	4.85	11.20	29.35	45.41	15.14
2	*Shorea obtusa*	100.00	174.5	2.72	5.83	15.64	14.74	36.20	12.07
3	*Tristaniopsis burmanica*	91.67	155.7	1.65	5.34	13.96	8.91	28.21	9.40
4	*Pinus merkusii*	50.00	25.0	3.26	2.91	2.24	17.65	22.80	7.60
5	*Wendlandia tinctoria*	66.67	164.6	0.43	3.88	14.75	2.31	20.95	6.98
6	*Quercus brandisiana*	91.67	64.1	1.26	5.34	5.74	6.83	17.91	5.97
7	*Vaccinium sprengelii*	66.67	114.1	0.48	3.88	10.22	2.57	16.68	5.56
8	*Gluta usitata*	100.00	47.4	0.79	5.83	4.25	4.25	14.32	4.77
9	*Quercus kerrii*	66.67	57.8	0.85	3.88	5.18	4.60	13.67	4.56
10	*Quercus kingiana*	50.00	17.2	0.53	2.91	1.54	2.88	7.34	2.45
11	*Phyllanthus emblica*	58.33	27.1	0.04	3.40	2.43	0.23	6.05	2.02
12	*Craibiodendron stellatum*	66.67	17.7	0.07	3.88	1.59	0.37	5.84	1.95
13	*Aporosa villosa*	50.00	21.9	0.06	2.91	1.96	0.31	5.18	1.73
14	*Semecarpus anacardium*	41.67	4.2	0.14	2.43	0.37	0.77	3.57	1.19
15	*Glochidion sphaerogynum*	50.00	5.7	0.01	2.91	0.51	0.04	3.47	1.16
16	*Symplocos recemosa*	50.00	5.2	0.01	2.91	0.47	0.05	3.43	1.14
17	*Shorea siamensis*	25.00	8.9	0.15	1.46	0.79	0.83	3.08	1.03
18	*Castanopsis acuminatissima*	33.33	5.7	0.11	1.94	0.51	0.61	3.06	1.02
19	*Gardenia coronaria*	33.33	5.2	0.03	1.94	0.47	0.14	2.55	0.85
20	*Ziziphus oenoplia*	33.33	5.7	0.02	1.94	0.51	0.09	2.55	0.85
21	*Glochidion hirsutum Voigt*	25.00	9.9	0.03	1.46	0.89	0.14	2.48	0.83
22	*Semecarpus albescens*	25.00	4.7	0.11	1.46	0.42	0.58	2.45	0.82
23	*Anneslea fragrans*	33.33	3.6	0.01	1.94	0.33	0.04	2.31	0.77
24	*Catunaregam tomentosa*	33.33	3.6	0.01	1.94	0.33	0.03	2.30	0.77
25	*Lithocarpus garrettianus*	25.00	6.3	0.04	1.46	0.56	0.24	2.26	0.75
26	*Dalbergia cultrata*	25.00	5.2	0.05	1.46	0.47	0.25	2.17	0.72
27	*Castanopsis tribuloides*	25.00	3.6	0.03	1.46	0.33	0.14	1.92	0.64
28	*Schima wallichii*	25.00	2.1	0.02	1.46	0.19	0.12	1.76	0.59
29	*Antidesma ghaesembilla*	25.00	2.1	0.00	1.46	0.19	0.02	1.66	0.55
30	*Terminalia chebula*	16.67	1.6	0.04	0.97	0.14	0.23	1.34	0.45
31	*Lithocarpus sootepensis*	16.67	1.6	0.03	0.97	0.14	0.14	1.25	0.42
32	*Dillenia indica*	16.67	2.1	0.00	0.97	0.19	0.01	1.16	0.39
33	*Syzygium albiflorum*	16.67	1.0	0.00	0.97	0.09	0.02	1.08	0.36
34	*Cratoxylum formosum*	16.67	1.0	0.00	0.97	0.09	0.00	1.07	0.36
35	*Stereospermum neuranthum*	8.33	1.6	0.02	0.49	0.14	0.11	0.73	0.24
36	*Xantoris burmanica*	8.33	0.5	0.03	0.49	0.05	0.18	0.71	0.24
37	*Dillenia obovata*	8.33	1.6	0.00	0.49	0.14	0.00	0.63	0.21
38	*Castanopsis calathiformis*	8.33	1.0	0.01	0.49	0.09	0.05	0.63	0.21
39	*Colona flagrocarpa*	8.33	1.0	0.00	0.49	0.09	0.01	0.58	0.19
40	*Shorea roxburghii*	8.33	0.5	0.01	0.49	0.05	0.05	0.58	0.19
41	*Stereospermum colais*	8.33	0.5	0.01	0.49	0.05	0.03	0.56	0.19

Table 2-3 (continued)

No	Species	Frequency (%)	Density (trees/ha)	Basal area (m^2/ha)	Relative (%)			IVI (%)	
					Frequency	Density	Dominance	(300)	(100)
42	*Castanopsis purpurea*	8.33	0.5	0.00	0.49	0.05	0.02	0.55	0.18
43	*Dipterocarpus tuberculatus*	8.33	0.5	0.00	0.49	0.05	0.02	0.55	0.18
44	*Lithocarpus sootepensis*	8.33	0.5	0.00	0.49	0.05	0.01	0.54	0.18
45	*Markhamia stipulata*	8.33	0.5	0.00	0.49	0.05	0.01	0.54	0.18
46	*Lithocarpus truncatus*	8.33	0.5	0.00	0.49	0.05	0.00	0.54	0.18
47	*Engelhardtia spicata*	8.33	0.5	0.00	0.49	0.05	0.00	0.54	0.18
48	*Quercus semiserrata*	8.33	0.5	0.00	0.49	0.05	0.00	0.54	0.18
49	*Strychnos nux-vomica*	8.33	0.5	0.00	0.49	0.05	0.00	0.54	0.18
50	*Schoepfia fragrans*	8.33	0.5	0.00	0.49	0.05	0.00	0.54	0.18
51	*Holarrhena pubescens*	8.33	0.5	0.00	0.49	0.05	0.00	0.54	0.18
52	*Protium serratum*	8.33	0.5	0.00	0.49	0.05	0.00	0.53	0.18
53	*Quercus helferiana*	8.33	0.5	0.00	0.49	0.05	0.00	0.53	0.18
54	*Pavetta tomentosa*	8.33	0.5	0.00	0.49	0.05	0.00	0.53	0.18
55	*Celastrus paniculata*	8.33	0.5	0.00	0.49	0.05	0.00	0.53	0.18
56	*Syzygium cumini*	8.33	0.5	0.00	0.49	0.05	0.00	0.53	0.18
	total	1,716.67	1,115.63	18.49	100.00	100.00	100.00	300.00	100.00

Table 2-4 Quantitative characteristics of various tree species in pine-oak forest subtype (P-LMF)

No	Species	Frequency (%)	Density (trees/ha)	Basal area (m^2/ha)	Relative (%)			IVI (%)	
					Frequency	Density	Dominance	(300)	(100)
1	*Pinus kesiya*	100.00	193.8	10.06	5.88	23.48	58.71	88.08	29.36
2	*Castanopsis acuminatissima*	100.00	68.8	2.87	5.88	8.33	16.74	30.96	10.32
3	*Quercus kingiana*	100.00	46.9	2.14	5.88	5.68	12.50	24.06	8.02
4	*Tristaniopsis burmanica*	100.00	109.4	0.39	5.88	13.26	2.29	21.43	7.14
5	*Quercus brandisiana*	100.00	75.0	0.53	5.88	9.09	3.08	18.06	6.02
6	*Vaccinium sprengelii*	100.00	59.4	0.35	5.88	7.20	2.04	15.12	5.04
7	*Wendlandia tinctoria*	50.00	87.5	0.13	2.94	10.61	0.74	14.29	4.76
8	*Gluta usitata*	100.00	31.3	0.29	5.88	3.79	1.67	11.34	3.78
9	*Phyllanthus emblica*	100.00	21.9	0.04	5.88	2.65	0.23	8.76	2.92
10	*Aporosa villosa*	50.00	43.8	0.05	2.94	5.30	0.29	8.53	2.84
11	*Quercus kerrii*	100.00	6.3	0.01	5.88	0.76	0.08	6.72	2.24
12	*Gardenia coronaria*	100.00	6.3	0.01	5.88	0.76	0.05	6.69	2.23
13	*Dalbergia cultrata*	50.00	15.6	0.01	2.94	1.89	0.07	4.91	1.64
14	*Terminalia chebula*	50.00	9.4	0.08	2.94	1.14	0.47	4.55	1.52
15	*Anneslea fragrans*	50.00	9.4	0.03	2.94	1.14	0.17	4.24	1.41
16	*Craibiodendron stellatum*	50.00	6.3	0.03	2.94	0.76	0.15	3.85	1.28
17	*Lithocarpus garrettianus*	50.00	6.3	0.02	2.94	0.76	0.12	3.82	1.27
18	*Quercus helferiana*	50.00	6.3	0.01	2.94	0.76	0.06	3.76	1.25
19	*Lithocarpus glandifolius*	50.00	3.1	0.07	2.94	0.38	0.42	3.74	1.25
20	*Antidesma ghaesembilla*	50.00	6.3	0.00	2.94	0.76	0.01	3.71	1.24
21	*Glochidion hirsutum Voigt*	50.00	3.1	0.01	2.94	0.38	0.04	3.36	1.12
22	*Colona flagrocarpa*	50.00	3.1	0.01	2.94	0.38	0.04	3.36	1.12
23	*Ziziphus oenoplia*	50.00	3.1	0.00	2.94	0.38	0.01	3.33	1.11
24	*Dillenia indica*	50.00	3.1	0.00	2.94	0.38	0.01	3.33	1.11
	total	1,700.00	825.00	17.13	100.00	100.00	100.00	300.00	100.00

Table 2-5 The species list and growth forms of tree species in natural pine forest

Family	Thai name	Scientific name	Habit	P-DDF1	P-DDF2	P-DDF3	P-LMF
1. ANACARDIACEAE	มะม่วงหัวแมง	*Buchanania lanzan* Spreng.	T	X	X		
	รักใหญ่	*Gluta usitata* (Wall.) Ding Hou	T	X	X	X	X
	รักขน	*Semecarpus anacardium* Linn.f.	T	X	X	X	
	รักขี้หมู	*Semecarpus albescens* Kurz	T		X	X	
2. APOCYNACEAE	โมกหลวง	*Holarrhena pubescens* Wall. ex G.Don	T			X	
3. BIGNONIACEAE	แคทราย	*Stereospermum colias* (Buch.-Ham. ex Dillwyn) Mabb.	T			X	
	แคฝอย	*Stereospermum neuranthum* Kurz	T			X	
4. BURSERACEAE	มะแฟน	*Protium serratum* Engl.	T			X	
5. CELASTRACEAE	กระทงลาย	*Celastrus paniculata* Willd.	C			X	
6. COMBRETACEAE	สมอไทย	*Terminalia chebula* Retz. var. chebula	T	X	X	X	X
7. DILLENIACEAE	มะตาด	*Dillenia indica* L.	T			X	X
	ส้าน	*Dillenia obovata* (Blume) Hoogland	T	X	X	X	
8. DIPTEROCARPACEAE	พลวง	*Dipterocarpus tuberculatus* Roxb.	T	X	X	X	
	เหียง	*Dipterocarpus obtusifolius* Teijsm. ex Miq.	T	X	X		
	เต็ง	*Shorea obtusa* Wall. ex Blume	T	X	X	X	
	พะยอม	*Shorea roxburghii* G.Don.	T			X	
	รัง	*Shorea siamensis* Miq.	T			X	
9. ERICACEAE	ดาวราย	*Craibiodendron stellatum* (Pierre) W.W.Sm	ST	X	X	X	X
	ส้มปี้	*Vaccinium sprengelii* (G.Don) Sleumer	S	X	X	X	X
10. EUPHORBIACEAE	มะเม่า	*Antidesma ghaesembilla* Gaertn.	S			X	X
	มะเม่าสร้อย	*Antidesma acidum* Retz.	S	X	X		
	เหมือดหลวง	*Aporosa villosa* (Wall. ex Lindl.) Baill.	ST	X	X	X	X
	มันปลา	*Glochidion sphaerogynum* (Mull.Arg) Kurz	T	X	X	X	
	ขี้มด	*Glochidion hirsutum* Voigt	S	X	X	X	X
	มะขามป้อม	*Phyllanthus emblica* L.	ST	X	X	X	X
11. FAGACEAE	ก่อเดือย	*Castanopsis acuminatissima* (Blume) A.DC.	X	X	X	X	X
	ก่อตี	*Castanopsis purpurea* Barnett	T		X	X	
	ก่อน้ำ	*Castanopsis calathiformis* (Skan) Rehder & Wilson	T			X	
	ก่อใบเหลื่อม	*Castanopsis tribuloides* (Sm.) A.DC.	T	X	X	X	
	ก่อแป้น	*Castanopsis diversifolia* (Kurz) King	T		X		
	ก่อหัวหมู	*Lithocarpus sootepensis* A. Camus	T			X	
	ก่อก้างด้าง	*Lithocarpus garrettianus* (Craib) A.Camus	T			X	X
	ก่อด่าง	*Lithocarpus lindleyanus* (Wall.) A. Camus	T	X	X		
	ก่อระฒัง	*Lithocarpus truncatus* (King) Rehder & Wilson	T	X	X	X	
	ก่อหม่น	*Lithocarpus glandifolius* (D.Don) Bigwood	T	X	X		X
	ก่อเหลื่อมเงิน	*Lithocarpus sootepensis* (Craib) A.Camus	T	X		X	
	ก่อกระดุม	*Quercus semiserrata* Roxb.	T			X	
	ก่อแดง	*Quercus kingiana* Craib	T	X	X	X	X
	ก่อแพะ	*Quercus kerrii* Craib	T	X	X	X	X

Table 2-5 (continued)

Family	Thai name	Scientific name	Habit	P-DDF1	P-DDF2	P-DDF3	P-LMF
	ก่อหมาก	*Quercus brandisiana Kurz*	T	X	X	X	X
	ก่อแอบ	*Quercus helferiana* A.DC.	T		X	X	X
12. FLACOURTIACEAE	ตะขบป่า	*Flacourtia indica* (Burm.f.) Merr.	S	X			
13. GUTTIFERAE	ติ้ว	*Cratoxylum formosum* (Jack) Dyer subsp. pruniflorum (Kurz) Gogel.	T		X	X	
14. JUGLANDACEAE	ค่าหด	*Engelhardtia spicata* Blume var. colebrookeana (Lindl. ex. Wall.) Kuntze	T	X	X	X	
15. LEGUMINASAE-MIMOSOIDEAE	ก้างขี้มอด	*Albizia odoratissima* (L.f.) Benth.	T		X		
16 . LEGUMINASAE-PAPILIONOIDEAE	เก็ดดำ	*Dalbergia cultrata* Graham ex Benth.	T	X	X	X	X
17. MARKHAMIA	แคยอดดำ	*Markhamia stipulata* Seem. var. stipulata	T			X	
18. MYRTACEAE	มะห้า	*Syzygium albiflorum* (Duthie & Kurz) Bahadur & R.C. Guar	T		X	X	
	หว้า	Syzygium cumini (L.) Skeels	T		X	X	
	เคาะ	*Tristaniopsis burmanica* (Griff.) Peter G.Wilson & J.T. Waterh. var. rufescens (Hance) J.Parn. & Nic Lughadha	ST	X	X	X	X
19. OLACACEAE	ขี้หนอน	*Schoepfia fragrans* Wall.	C			X	
20. PINACEAE	สนสามใบ	*Pinus kesiya* Royle ex Gordon	T	X	X	X	X
	สนสองใบ	*Pinus merkusii* Jungh. & de Vrise	T	X	X	X	
21. RHAMNACEAE	มะขวัด	*Ziziphus oenoplia (L.) Mill. var. oenoplia*	S	X	X	X	X
22. RUBIACEAE	เก็ด	*Catunaregam tomentosa (Blume ex DC.) Tirveng.*	ST	X	X	X	
	คำมอกหลวง	*Gardenia coronaria Buch.-Ham.*	T		X	X	X
	ข้าวสารป่า	*Pavetta tomentosa Roxb. ex Smith*	S		X	X	
	หนามเนิ้ง	*Vangueria pubescens Kurz*	ST	X	X		
	แข้งกวาง	*Wendlandia tinctoria (Roxb.) DC.*	ST	X	X	X	X
23. SAPOTACEAE	ละมุดป่า	*Xantoris burmanica (Collett & Hemsl.) P. Royen*	T			X	
24. STRYCHNOS	แสลงใจ	*Strychnos nux-vomica L.*	ST			X	
25. SYMPLOCACEAE	เหมือดหอม	*Symplocos recemosa Roxb.*	ST	X	X	X	
26. THEACEAE	สารภีป่า	*Anneslea fragrans Wall.*	ST	X	X	X	X
	ทะโล้	*Schima wallichii (DC.) Korth.*	T		X	X	
27. TILIACEAE	ปอขาบ	*Colona flagrocarpa* Craib var. *siamica* Craib.	T	X	X	X	X

Note: T = Tree, S = Small tree, ST = Shrubby Tree, C = Climber

Table 2-6 Species diversity indexes (SWI) in four subtypes of pine forest

Forest subtype	No	Species	p_i	$\log_2 p_i$	$p_i \log_2 p_i$
P-DDF1	1	*Dipterocarpus obtusifolius*	0.40	-1.31	-0.53
	2	*Pinus merkusii*	0.29	-1.77	-0.52
	3	*Gluta usitata*	0.12	-3.11	-0.36
	4	*Pinus kesiya*	0.07	-3.87	-0.27
	5	*Castanopsis tribuloides*	0.02	-5.38	-0.13
	6	*Phyllanthus emblica*	0.01	-6.47	-0.07
	7	*Wendlandia tinctoria*	0.01	-6.76	-0.06
	8	*Lithocarpus glandifolius*	0.01	-7.23	-0.05
	9	*Semecarpus anacardium*	0.01	-7.35	-0.05
	10	*Ziziphus oenoplia*	0.01	-7.47	-0.04
	11	*Craibiodendron stellatum*	0.01	-7.47	-0.04
	12	*Glochidion sphaerogynum*	0.01	-7.47	-0.04
	13	*Anneslea fragrans*	0.01	-7.61	-0.04
	14	*Shorea obtusa*	0.00	-7.76	-0.04
	15	*Dipterocarpus tuberculatus*	0.00	-7.76	-0.04
	16	*Lithocarpus sootepensis*	0.00	-8.13	-0.03
	17	*Vaccinium sprengelii*	0.00	-8.13	-0.03
	18	*Terminalia chebula*	0.00	-8.35	-0.03
	19	*Tristaniopsis burmanica*	0.00	-8.35	-0.03
	20	*Quercus kingiana*	0.00	-8.61	-0.02
	21	*Symplocos recemosa*	0.00	-8.61	-0.02
	22	*Aporosa villosa*	0.00	-8.61	-0.02
	23	*Castanopsis acuminatissima*	0.00	-21.87	-0.01
	24	*Vangueria pubescens*	0.00	-9.93	-0.01
	25	*Quercus kerrii*	0.00	-9.93	-0.01
	26	*Dalbergia cultrata*	0.00	-9.93	-0.01
	27	*Engelhardtia spicata*	0.00	-9.93	-0.01
	28	*Quercus brandisiana*	0.00	-10.93	-0.01
	29	*Buchanania lanzan*	0.00	-10.93	-0.01
	30	*Catunaregam tomentosa*	0.00	-10.93	-0.01
	31	*Glochidion hirsutum Voigt*	0.00	-10.93	-0.01
	32	*Antidesma acidum*	0.00	-10.93	-0.01
	33	*Colona flagrocarpa*	0.00	-10.93	-0.01
	34	*Lithocarpus truncatus*	0.00	-10.93	-0.01
	35	*Flacourtia indica*	0.00	-10.93	-0.01
	36	*Lithocarpus lindleyanus*	0.00	-10.93	-0.01
	37	*Dillenia obovata*	0.00	-10.93	-0.01
		total	**1.00**	**-329.45**	**-2.56**
				SWI=	**2.56**
P-DDF2	1	*Pinus merkusii*	0.12	-3.03	-0.37
	2	*Dipterocarpus tuberculatus*	0.15	-2.73	-0.41
	3	*Pinus kesiya*	0.11	-3.21	-0.35
	4	*Tristaniopsis burmanica*	0.18	-2.49	-0.44
	5	*Gluta usitata*	0.05	-4.47	-0.20
	6	*Vaccinium sprengelii*	0.11	-3.18	-0.35
	7	*Wendlandia tinctoria*	0.08	-3.62	-0.29
	8	*Quercus brandisiana*	0.07	-3.89	-0.26
	9	*Aporosa villosa*	0.02	-5.61	-0.11
	10	*Shorea obtusa*	0.01	-6.75	-0.06
	11	*Quercus kerrii*	0.01	-6.64	-0.07
	12	*Castanopsis tribuloides*	0.01	-6.43	-0.07
	13	*Phyllanthus emblica*	0.01	-6.58	-0.07
	14	*Craibiodendron stellatum*	0.01	-6.48	-0.07
	15	*Dipterocarpus obtusifolius*	0.01	-6.69	-0.06

Table 2-6 (continued)

Forest subtype	No	Species	p_i	$\log_2 p_i$	$p_i \log_2 p_i$
	15	*Dipterocarpus obtusifolius*	0.01	-6.69	-0.06
	16	*Anneslea fragrans*	0.01	-6.38	-0.08
	17	*Ziziphus oenoplia*	0.01	-7.01	-0.05
	18	*Glochidion sphaerogynum*	0.00	-8.53	-0.02
	19	*Symplocos recemosa*	0.00	-8.75	-0.02
	20	*Vangueria pubescens*	0.00	-8.75	-0.02
	21	*Quercus kingiana*	0.00	-9.34	-0.01
	22	*Semecarpus anacardium*	0.00	-9.34	-0.01
	23	*Schima wallichii*	0.00	-8.75	-0.02
	24	*Albizia odoratissima*	0.00	-8.34	-0.03
	25	*Syzygium albiflorum*	0.00	-9.75	-0.01
	26	*Syzygium cumini*	0.00	-9.34	-0.01
	27	*Cratoxylum formosum*	0.00	-9.34	-0.01
	28	*Gardenia coronaria*	0.00	-9.34	-0.01
	29	*Dalbergia cultrata*	0.00	-10.34	-0.01
	30	*Lithocarpus lindleyanus*	0.00	-9.75	-0.01
	31	*Antidesma acidum*	0.00	-10.34	-0.01
	32	*Terminalia chebula*	0.00	-10.34	-0.01
	33	*Castanopsis purpurea*	0.00	-10.34	-0.01
	34	*Catunaregam tomentosa*	0.00	-10.34	-0.01
	35	*Dillenia obovata*	0.00	-10.34	-0.01
	36	*Quercus helferiana*	0.00	-9.34	-0.01
	37	*Glochidion hirsutum Voigt*	0.00	-9.75	-0.01
	38	*Semecarpus albescens*	0.00	-10.34	-0.01
	39	*Lithocarpus truncatus*	0.00	-10.34	-0.01
	40	*Buchanania lanzan*	0.00	-11.34	0.00
	41	*Colona flagrocarpa*	0.00	-11.34	0.00
	42	*Castanopsis acuminatissima*	0.00	-11.34	0.00
	43	*Castanopsis diversifolia*	0.00	-11.34	0.00
	44	*Lithocarpus glandifolius*	0.00	-11.34	0.00
	45	*Engelhardtia spicata*	0.00	-11.34	0.00
	46	*Pavetta tomentosa*	0.00	-11.34	0.00
		total	**1.00**	**-375.62**	**-3.66**
				SWI =	**3.66**
P-DDF3	1	*Pinus kesiya*	0.11	-3.16	-0.35
	2	*Shorea obtusa*	0.16	-2.68	-0.42
	3	*Tristaniopsis burmanica*	0.14	-2.84	-0.40
	4	*Pinus merkusii*	0.02	-5.48	-0.12
	5	*Wendlandia tinctoria*	0.15	-2.76	-0.41
	6	*Quercus brandisiana*	0.06	-4.12	-0.24
	7	*Vaccinium sprengelii*	0.10	-3.29	-0.34
	8	*Gluta usitata*	0.04	-4.56	-0.19
	9	*Quercus kerrii*	0.05	-4.27	-0.22
	11	*Phyllanthus emblica*	0.02	-5.36	-0.13
	12	*Craibiodendron stellatum*	0.02	-5.98	-0.09
	13	*Aporosa villosa*	0.02	-5.67	-0.11
	14	*Semecarpus anacardium*	0.00	-8.06	-0.03
	15	*Glochidion sphaerogynum*	0.01	-7.61	-0.04
	16	*Symplocos recemosa*	0.00	-7.74	-0.04
	17	*Shorea siamensis*	0.01	-6.98	-0.06
	18	*Castanopsis acuminatissima*	0.01	-7.61	-0.04
	19	*Gardenia coronaria*	0.00	-7.74	-0.04
	20	*Ziziphus oenoplia*	0.01	-7.61	-0.04

Table 2-6 (continued)

Forest subtype	No	Species	p_i	$\log_2 p_i$	$p_i \log_2$
	21	*Glochidion hirsutum Voigt*	0.01	-6.82	-0.06
	22	*Semecarpus albescens*	0.00	-7.89	-0.03
	23	*Anneslea fragrans*	0.00	-8.26	-0.03
	24	*Catunaregam tomentosa*	0.00	-8.26	-0.03
	25	*Lithocarpus garrettianus*	0.01	-7.48	-0.04
	26	*Dalbergia cultrata*	0.00	-7.74	-0.04
	27	*Castanopsis tribuloides*	0.00	-8.26	-0.03
	28	*Schima wallichii*	0.00	-9.06	-0.02
	29	*Antidesma ghaesembilla*	0.00	-9.06	-0.02
	30	*Terminalia chebula*	0.00	-9.48	-0.01
	31	*Lithocarpus sootepensis*	0.00	-9.48	-0.01
	32	*Dillenia indica*	0.00	-9.06	-0.02
	33	*Syzygium albiflorum*	0.00	-10.06	-0.01
	34	*Cratoxylum formosum*	0.00	-10.06	-0.01
	35	*Stereospermum neuranthum*	0.00	-9.48	-0.01
	36	*Xantoris bur*	0.00	-11.06	-0.01
	37	*Dillenia obovata*	0.00	-9.48	-0.01
	38	*Castanopsis calathiformis*	0.00	-10.06	-0.01
	39	*Colona flagrocarpa*	0.00	-10.06	-0.01
	40	*Shorea roxburghii*	0.00	-11.06	-0.01
	41	*Stereospermum colais*	0.00	-11.06	-0.01
	42	*Castanopsis purpurea*	0.00	-11.06	-0.01
	43	*Dipterocarpus tuberculatus*	0.00	-11.06	-0.01
	44	*Lithocarpus sootepensis*	0.00	-11.06	-0.01
	45	*Markhamia stipulata*	0.00	-11.06	-0.01
	46	*Lithocarpus truncatus*	0.00	-11.06	-0.01
	47	*Engelhardtia spicata*	0.00	-11.06	-0.01
	48	*Quercus semiserrata*	0.00	-11.06	-0.01
	49	*Strychnos nux-vomica*	0.00	-11.06	-0.01
	50	*Schoepfia fragrans*	0.00	-11.06	-0.01
	51	*Holarrhena pubescens*	0.00	-11.06	-0.01
	52	*Protium serratum*	0.00	-11.06	-0.01
	53	*Quercus helferiana*	0.00	-11.06	-0.01
	54	*Pavetta tomentosa*	0.00	-11.06	-0.01
	55	*Celastrus paniculata*	0.00	-11.06	-0.01
	56	*Syzygium cumini*	0.00	-11.06	-0.01
		total	**1.00**	**-468.78**	**-3.88**
				SWI =	**3.88**
P-LMF	1	*Pinus kesiya*	0.23	-2.09	-0.49
	2	*Castanopsis acuminatissima*	0.08	-3.58	-0.30
	3	*Quercus kingiana*	0.06	-4.14	-0.24
	4	*Tristaniopsis burmanica*	0.13	-2.92	-0.39
	5	*Quercus brandisiana*	0.09	-3.46	-0.31
	6	*Vaccinium sprengelii*	0.07	-3.80	-0.27
	7	*Wendlandia tinctoria*	0.11	-3.24	-0.34
	8	*Gluta usitata*	0.04	-4.72	-0.18
	9	*Phyllanthus emblica*	0.03	-5.24	-0.14
	10	*Aporosa villosa*	0.05	-4.24	-0.22
	11	*Quercus kerrii*	0.01	-7.04	-0.05
	12	*Gardenia coronaria*	0.01	-7.04	-0.05
	13	*Dalbergia cultrata*	0.02	-5.72	-0.11
	14	*Terminalia chebula*	0.01	-6.46	-0.07
	15	*Anneslea fragrans*	0.01	-6.46	-0.07
	16	*Craibiodendron stellatum*	0.01	-7.04	-0.05

Table 2-6 (continued)

Forest subtype	No	Species	p_i		$p_i \log_2$
	17	*Lithocarpus garrettianus*	0.01	-7.04	-0.05
	18	*Quercus helferiana*	0.01	-7.04	-0.05
	19	*Lithocarpus glandifolius*	0.00	-8.04	-0.03
	20	*Antidesma ghaesembilla*	0.01	-7.04	-0.05
	21	*Glochidion hirsutum Voigt*	0.00	-8.04	-0.03
	22	*Colona flagrocarpa*	0.00	-8.04	-0.03
	23	*Ziziphus oenoplia*	0.00	-8.04	-0.03
	24	*Dillenia indica*	0.00	-8.04	-0.03
		total	**1.00**	**-138.55**	**-3.61**
				SWI =	**3.61**

Table 2-7 Indexes of forest condition (FCI) in four subtypes of pine forest

Forest subtype	Plot No.	<25 cm	25-50 cm	50-75 cm	75-100 cm	100-125 cm	125-150 cm	150-175 cm	175-200 cm	200-225 cm	225-250 cm	250-275 cm	275-300 cm	FCI
P-DDF1	1	-	0.05	1.70	13.00	11.00	7.00	4.00	1.00	-	1.00	-	-	38.75
	2	-	0.13	1.20	12.00	1.00	2.00	-	2.00	-	1.00	-	-	19.33
	3	-	0.15	1.10	10.00	12.00	4.00	2.00	2.00	-	-	-	-	31.25
	4	-	0.06	1.10	4.00	3.00	3.00	4.00	2.00	1.00	-	-	-	18.16
	5	0.00	0.12	0.30	4.00	4.00	2.00	1.00	2.00	-	3.00	-	1.00	17.42
	6	0.00	0.05	0.90	11.00	2.00	7.00	3.00	-	1.00	-	-	-	24.95
	7	-	0.03	1.10	9.00	14.00	3.00	3.00	-	-	-	-	-	30.13
	8	0.00	0.02	0.50	15.00	7.00	3.00	2.00	1.00	-	-	-	-	28.52
	9	0.01	0.07	0.50	5.00	6.00	2.00	6.00	3.00	-	-	-	-	22.58
	10	0.01	0.06	1.30	14.00	7.00	4.00	-	2.00	1.00	-	-	-	29.37
	11	0.02	0.11	0.60	19.00	9.00	4.00	1.00	-	1.00	-	-	-	34.73
	12	-	0.09	1.30	8.00	6.00	3.00	-	-	1.00	-	-	-	19.39
	13	-	0.14	1.20	13.00	10.00	4.00	-	1.00	-	-	-	-	29.34
	14	0.00	0.16	1.30	13.00	7.00	-	-	2.00	-	-	-	-	23.46
	15	-	0.04	1.00	6.00	5.00	3.00	-	1.00	1.00	-	1.00	-	18.04
	16	-	0.19	0.20	1.00	4.00	1.00	1.00	2.00	-	2.00	-	-	11.39
	17	-	0.24	0.90	5.00	3.00	2.00	-	-	1.00	-	-	-	12.14
	18	0.00	0.08	0.20	8.00	8.00	3.00	5.00	-	1.00	-	-	-	25.28
	19	0.00	0.13	1.30	15.00	11.00	2.00	-	-	-	-	1.00	-	30.43
	20	0.00	0.06	0.70	13.00	10.00	2.00	1.00	1.00	-	-	-	-	27.76
	21	-	0.02	0.50	7.00	1.00	6.00	3.00	3.00	-	-	-	-	20.52
	22	0.00	0.11	1.50	5.00	9.00	6.00	5.00	2.00	-	-	-	-	28.61
	23	0.00	0.07	1.10	14.00	3.00	3.00	1.00	1.00	4.00	-	-	-	27.17
	24	-	0.25	0.30	12.00	9.00	6.00	-	1.00	-	-	-	-	28.55
	25	0.00	0.08	0.60	2.00	-	6.00	-	-	1.00	-	-	-	9.68
	26	-	0.05	0.90	7.00	4.00	3.00	2.00	2.00	-	1.00	-	-	19.95
	27	0.01	0.15	1.30	5.00	7.00	2.00	4.00	2.00	2.00	-	-	-	23.46
	28	0.01	0.03	1.00	11.00	7.00	7.00	4.00	4.00	-	-	-	-	34.04
	29	0.00	0.07	1.20	8.00	4.00	6.00	5.00	-	1.00	-	1.00	-	26.27
	30	0.00	0.04	0.80	8.00	12.00	13.00	3.00	1.00	-	-	-	-	37.84
	31	0.00	0.11	1.30	7.00	4.00	7.00	3.00	1.00	-	-	-	-	23.41
	32	0.00	0.18	1.70	8.00	4.00	2.00	2.00	1.00	3.00	-	-	-	21.88
	33	-	0.15	2.10	12.00	7.00	2.00	-	-	2.00	-	1.00	-	26.25
	34	-	0.10	0.90	11.00	7.00	4.00	2.00	4.00	1.00	-	-	-	30.00
	35	-	0.10	2.10	6.00	9.00	2.00	2.00	1.00	2.00	3.00	-	-	27.20
	Mean													25.06 ± 6.90

Table 2-7 (continued)

Forest subtype	Plot No.	<25 cm	25-50 cm	50-75 cm	75-100 cm	100-125 cm	125-150 cm	150-175 cm	175-200 cm	200-225 cm	225-250 cm	250-275 cm	275-300 cm	FCI
P-DDF2	1	-	0.17	1.20	13.00	3.00	4.00	1.00	-	1.00	-	-	-	23.37
	2	-	0.07	0.20	9.00	4.00	3.00	2.00	-	-	-	-	-	18.27
	3	-	0.05	0.60	12.00	7.00	-	-	1.00	1.00	-	-	-	21.65
	4	-	0.11	0.60	4.00	5.00	5.00	1.00	-	1.00	-	-	-	16.71
	5	-	0.15	1.50	12.00	2.00	5.00	2.00	-	-	-	1.00	-	23.65
	6	-	0.25	0.60	3.00	2.00	5.00	-	1.00	-	-	-	1.00	12.85
	7	-	0.35	0.80	3.00	4.00	2.00	2.00	2.00	-	-	-	-	14.15
	8	-	0.31	0.60	7.00	2.00	2.00	2.00	-	-	-	1.00	1.00	15.91
	9	-	0.09	0.50	5.00	8.00	6.00	-	3.00	-	-	-	-	22.59
	10	-	0.04	0.50	7.00	5.00	7.00	2.00	-	-	-	-	-	21.54
	11	-	0.17	0.60	10.00	10.00	1.00	-	-	-	-	-	-	21.77
	12	0.00	0.04	1.10	18.00	6.00	4.00	-	1.00	-	-	-	-	30.14
	13	0.00	0.12	0.90	8.00	3.00	3.00	1.00	-	1.00	-	-	-	17.02
	14	-	0.27	0.40	8.00	2.00	3.00	-	-	-	1.00	-	-	14.67
	15	0.00	0.26	1.00	4.00	4.00	1.00	-	1.00	1.00	-	-	-	12.26
	16	0.00	0.21	0.70	6.00	9.00	1.00	-	1.00	-	-	-	-	17.91
	17	0.00	0.28	0.90	4.00	7.00	1.00	1.00	-	-	-	-	-	14.18
	18	0.00	0.37	0.40	4.00	4.00	5.00	5.00	1.00	1.00	-	-	-	20.77
	19	0.00	0.39	0.90	9.00	2.00	3.00	2.00	2.00	-	-	-	-	19.29
	20	0.00	0.04	1.50	9.00	5.00	7.00	3.00	3.00	2.00	-	-	-	30.54
	21	0.00	0.07	1.70	16.00	7.00	5.00	4.00	3.00	1.00	-	-	-	37.77
	Mean													20.33 + 6.40
P-DDF3	1	0.01	0.31	0.50	7.00	5.00	1.00	2.00	-	-	-	-	-	15.82
	2	0.02	0.19	1.40	8.00	7.00	1.00	5.00	-	-	-	-	-	22.61
	3	0.00	0.76	3.50	13.00	2.00	-	-	-	-	-	-	-	19.26
	4	-	0.37	1.10	11.00	8.00	4.00	2.00	5.00	-	-	-	-	31.47
	5	-	0.07	0.90	1.00	-	1.00	1.00	2.00	1.00	1.00	-	-	7.97
	6	-	0.71	1.90	9.00	3.00	2.00	2.00	-	-	-	-	-	18.61
	7	-	0.78	2.60	6.00	3.00	-	-	-	-	-	-	-	12.38
	8	0.00	0.27	1.30	3.00	3.00	1.00	-	1.00	-	-	-	-	9.57
	9	0.00	0.35	2.20	13.00	6.00	3.00	-	1.00	-	-	-	-	25.55
	10	0.00	0.19	1.90	8.00	2.00	-	1.00	3.00	1.00	-	-	-	17.09
	11	-	0.25	2.30	10.00	10.00	5.00	-	1.00	1.00	-	-	-	29.55
	12	-	0.23	1.80	3.00	3.00	2.00	2.00	3.00	-	-	-	-	15.03
	Mean													18.74 + 7.42
P-LMF	1	0.03	0.16	0.20	4.00	8.00	4.00	2.00	-	-	-	-	-	18.39
	2	0.04	0.20	2.40	5.00	4.00	5.00	3.00	-	-	-	-	-	19.64
	Mean													19.02 + 0.88

2.4 Discussion

The natural pine forest in Thailand covers the highland area. It is divided into pine-dry dipterocarp (pine-DDF) and pine-lower montane (pine-LMF) forests. By field observation, the DDF in northern Thailand is distributed to the area of about 1,300 m m.s.l. However, it was reported that the pine-DDF covers the area at altitude between 800-1,200 m (Chayamarit and Ruff, 2007). *Pinus merkusii* can grow on dry site with poor soil and may exists in the DDF from about 500 m up to 1,100 m, whereas *P. kesiya* can be found in the area at altitude between 900 m to 1,900 m. Thus, *P. kesiya* may grow in the DDF mixed with *P. merkusii* at altitude between 900-1,300 m. In the area between 1,400-1,900 m, this pine exists in the LMF without *P. merkusii*. In the present study, *P. merkusii* had the highest importance value index in P-DDF1 and P-DDF2 whereas *P. kesiya* had the highest IVI in P-DDF3. The altitude of P-DDF3 was higher than the two subtypes, and considered as the transition zone. The pine-LMF usually has the higher soil fertility and moisture condition.

The pine-DDF can be divided into subtype communities as the present study. In Ban Chan area, there were three subtypes as already mentioned, pine-*Dipterocarpus obtusifolius* (P-DDF1), pine-*D. tuberculatus* (P-DDF2) and pine-*Shorea obtusa* (P-DDF3). Species richness in P-DDF1, P-DDF-2 and PDDF-3 were 37, 46 and 56 species, respectively. Species diversity indexes (SWI) were calculated as 2.55, 3.66 and 3.88, respectively. The species richness and diversity were the highest for P-DDF3. This subtype covered the higher altitude and close to LMF, therefore, some tree species from this evergreen forest were exited in the forest. In P-LMF, the species richness and SWI were 24 species and 3.61. They were lower than the pine-DDF since only two plots were used for this study. More sampling plots were required. Khamyong *et al.* (2001) reported that pine-DDF and pine-LMF forests in the Doi Inthanon national park consisted of 75 and 100 tree species, respectively. Seanchanthong (2005) found that these forests in Pang Ma Pha district, Mae Hong Son province composed of 63 and 85 species, respectively. The species richness was higher in the pine-LMF than the pine-DDF. However, forest condition indexes (FCI) of these three subtypes were in the order of 25.06, 20.33 and 18.74 that indicated to the better forest condition of P-DDF1 since the forest composed of more medium-sized and big trees. Over timber harvesting in P-DDF3 resulted in the forest degrade. Cutting of *D. tuberculatus* for making house and fuel wood was observed whereas *D. obtusifolius* might be cut for making house but it was not good for fuel wood. *Shorea obtusa* was cut by nearby villagers for mainly fuel wood. The plant community in P-DDF1 had the higher similarity to P-DDF2, but lower to P-DDF-3.