STRUCTURAL CHARACTERISTICS OF NATURAL EVERGREEN FORESTS IN EASTERN REGION OF THAILAND

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ABSTRACT

The structural characteristics of natural evergreen forests in eastern region of Thailand was studied in moist evergreen forest (MEF), hill evergreen forest (HEF) at Khao Khitchakut National Park, and in dry evergreen forest (DEF) at Khao Soi Dao Wildlife Sanctuary, Chanthaburi province during November 1999 to December 2000. The results revealed that the species numbers of trees with DBH larger than 4.5 cm. of MEF, DEF, and HEF are 135, 138, and 129 species.ha^{-1} DEF is found to have maximum species diversity while the minimum is recorded for HEF. Stand densities of MEF, DEF, and HEF are 1,510, 1,355 and 2,513 trees.ha^{-1}, respectively with the basal areas of 0.4799, 0.3995 and 0.3161%, respectively. *Scaphium macropodum* Beaumee is found to have the highest importance value index in MEF, while *Diospyros dictyoneura* Hiern in DEF and *Castanopsis acuminatissima* Rehd in HEF. The vertical arrangements in MEF and DEF are divided into 4 layers while HEF has only 3 layers. The crown covers of MEF, DEF, and HEF are 83.05, 89.05 and 81.52%, respectively.

INTRODUCTION

It is accepted that the tropical forest ecosystem has a very high biodiversity. This ecosystem also has high gross production and rapid decomposition rate of organic matter. However, the tropical forest ecosystem can be sub-divided into many forest types which have different characteristics. The tropical forest ecosystem in Thailand, especially the evergreen forest ecosystem is sub-divided into many subtypes based

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on their structure and species composition. The interesting sub-types are moist evergreen forest (MEF), dry evergreen forest (DEF) and hill evergreen forest (HEF). The distribution ranges of these three forest types depend on average annual precipitation, soil characteristics and elevations. The MEF covers on the lowland areas of the southern and eastern regions of the country while the DEF occurs on high plains of every regions and the HEF is found only on high mountains especially at the elevations over 1,000 meters above mean sea level. The three forest types play an important role for many kinds of benefit of the country such as wood production, watershed conservation, soil erosion protection and wildlife conservation. Therefore, the sustainable use concept should be applied to these forest types for the benefits of the country.

In order to apply the forest sustainable management concept for a sustainable use of the forest resources, it needs many background knowledge, especially, the structure of the forests. Therefore, this research was aimed at providing the structural characteristics of the three forest types for the forest management planning. For the time and budget limitation the data were collected only from the three forest types of the eastern region. The special objective was to compare structural characteristics of the three evergreen forest types in eastern region of Thailand. The main concerns were quantitative ecological analysis of stand structure, species composition and species diversity. The three basic ecological characteristics of the forest types should provide valuable information for sustainable forest management planning in this region of the country.

MATERIAL AND METHODS

Study Site and Sample Plots

Khao Khitchakut National Park and Khao Soi Dao Wildlife Sanctuary were selected as study sites. Both sites are in Chanthaburi Province (Figure 1).

A square permanent sample plot of 100 x 100 m^2 (1 hectare) in size was set in each forest type; MEF, DEF and HEF. The descriptions of each plot are as follows:

Data Collection

Each sample plot was further divided into 100 sub-plots of 10x10 m^2. In each (10x10 m^2) sub plot, all trees with DBH equal to and larger than 4.5 cm. were mapped, species recorded, the label number tacked at the DBH level and botanical names identified. Stem position and crown area projection were mapped, together with species composition checked. Total height (H) and first living branch height (H_B) were also measured at the beginning of the study. Profile diagram was drawn using a strip of 10x100 m^2 belt in each forest type.

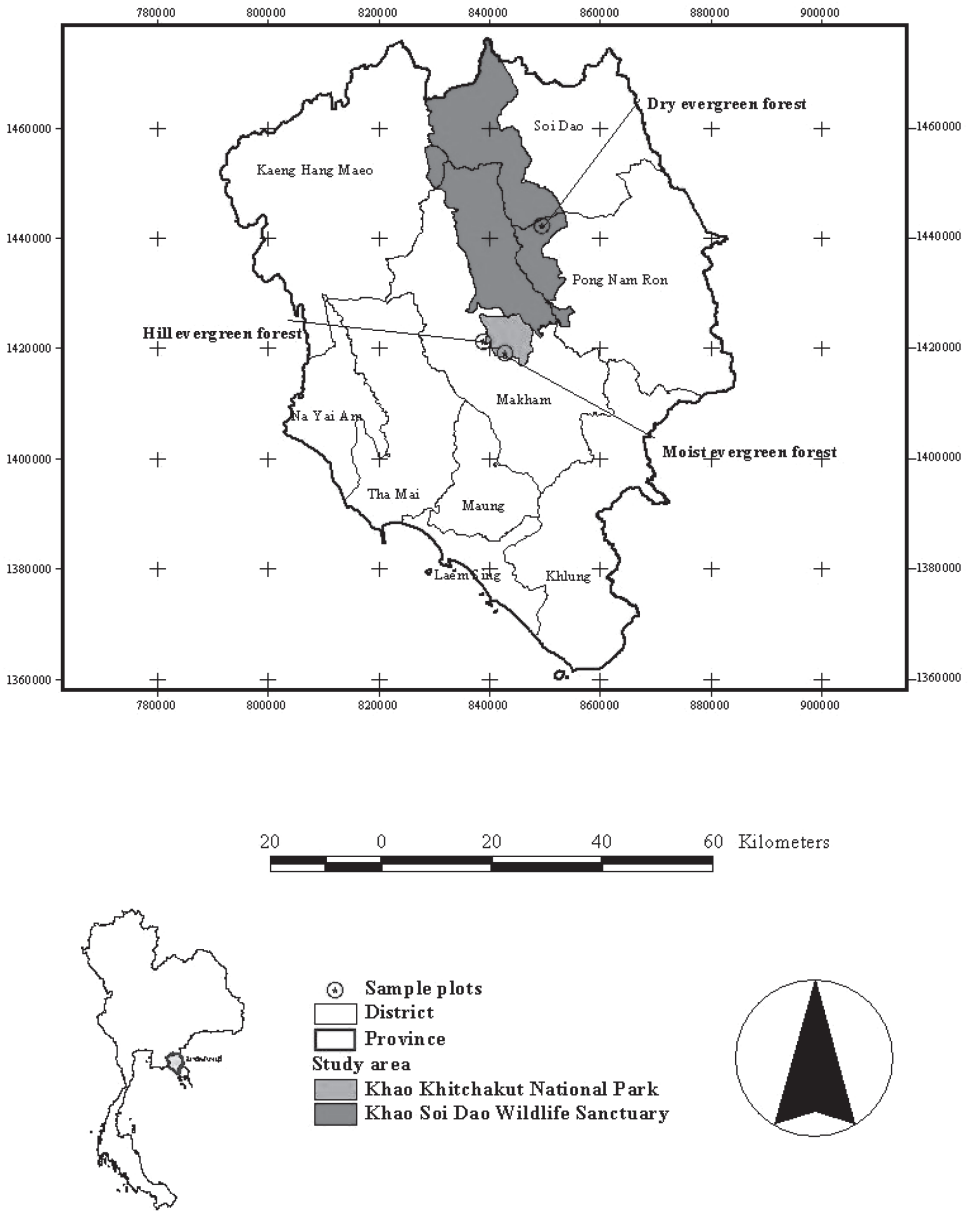

Figure 1. Map showing the location of research sites in Khao Khitchakut National Park and Khao Soi Dao Wildlife Sanctuary, Chanthaburi Province

1st plot: Khao Khitchakut National Park
Forest type: Moist evergreen forest (MEF)
Position: 12° 49′ 16″ N latitude and 102° 09′ 21″ E longitude
Elevation: 315 m. above mean sea level
2nd plot: Khao Khitchakut National Park
Forest type: Hill evergreen forest (HEF)
Position: 12° 56′ 28″ N latitude and 102° 09′ 23″ E longitude
Elevation: 925 m. above mean sea level
3rd plot: Khao Soi Dao Wildlife Sanctuary
Forest type: Dry evergreen forest (DEF)
Position: 13° 05′ 28″ N latitude and 102° 03′ 11″ E longitude
Elevation: 360 m. above mean sea level

Data Analysis

Structural characteristics

The study on forest structure and floristic composition were carried out by adopting the quantitative ecological methods as follows:

1. Stratification

Vertical structure showing vertical stratification of each forest stand was examined by using crown depth diagram basing on measurements of tree height (H) and first living branch height (H_B). The relationships between H and H_B was also used for supplementary analysis. The stratum separation was judged from three principle criteria: the minimum point of vertical crown curve together with the abrupt downward change in height curve and the step-like distribution of tree grouping on the H-H_B diagram (Ogawa *et al.,* 1965).

2. The importance value index (IVI).

The importance value index (IVI) of each sample plot was determined as follows:

IVI = Relative density (%) + Relative frequency (%) + Relative dominance (%)

where

Relative density (%)

$$= \frac{\text{Density of species i}}{\text{Total tree density}} \times 100$$

Relative frequency (%)

$$= \frac{\text{Frequency of species i}}{\text{Total basal area of all species}} \times 100$$

Relative dominance (%)

$$= \frac{\text{Total basal area of species i}}{\text{Total basal area of all species}} \times 100$$

where

i = species number ranging from 1,2,3,4,.....,N,

N = total number of species,

Basal area = $\pi D^2/4$,

D = diameter at breast height (DBH) (cm).

The relative density was determined from all standing trees of DBH exceeded 4.5 cm in the sample plot of 100x100 m^2 in size. The relative frequency was determined for one hundred sub-plots (10x10 m^2 in size), which set by regular subdividing in the plot of 100x100 m^2 in size. The relative dominance was obtained from the basal area at breast height, which was calculated as $\pi D^2/4$ of each tree in the sample plot.

3. Species diversity.

Species diversity of all standing tree of DBH $\geq$ 4.5 cm. in each sample plot was determined by using diversity indices as follows:

a. The Shannon-Wiener index of species diversity ($H_{(S)}$) (Shannon and Weaver, 1949) is estimated by :

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

where

pi = proportion of the number of individuals of species i to the total number of individuals of all species (i=1,2,.,S),

S = total number of species in the sample area, $\log_2$ = logarithm to the base 2.

b. The Fisher's index of species diversity (α) (Fisher *et al.,* 1943) is estimated by:

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

or

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

$$S = -\alpha \ln (1 - X) \quad \text{.....(2)}$$

where

N = number of individuals in the sample area,

α = the Fisher's index of diversity,

S = number of species,

X = constant value (calculated from trial and error method), from (2)/(1) or $\frac{S}{N} = [\frac{(1-X)}{X}] [-\ln(1-X)]$

ln = natural logarithm.

c. The Simpson's index of species diversity (D) (Simpson, 1949; Pielou 1969; Gini, 1972) is estimated by:

$$D = 1 - \sum_{i=1}^{N} \frac{N_i (N_i - 1)}{N(N - 1)}$$

where

N_i = total number of individuals of species i,

N = total number of individuals of all species,

D = Simpson's index of species diver sity.

d. The richness indices (R_1 and R_2). The richness indices were calculated in the forms of richness index 1 (R_1) (Margalef, 1958) and richness index 2 (R_2) or Menhinick's index (Menhinick, 1964) as follows:

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

$$R_2 = \frac{S}{\sqrt{N}}$$

where

S = total number of species,

N = total number of individuals of all species,

ln = natural logarithm.

e. The evenness index (E) (Pielou, 1969) is used:

$$E = \frac{H}{H_{max}} = \frac{H}{\log_2 S}$$

where

E = species evenness,

H = Shannon-Wiener index of species diversity,

H_{max} = maximum of Shannon - Wiener index of species diversity,

S = total number of species,

$\log_2$ = logarithm to the base 2.

The results of the study on quantitative ecological parameters were compared among these three evergreen forests and similarly and/or difference to other forest types was further discussed.

RESULTS AND DISCUSSION

Stand Composition

Species composition.

Number of tree species (DBH ≥ 4.5 cm.) in each plot is shown in Table 1. The moist evergreen forest (MEF) and dry evergreen forest (DEF) showed slightly higher number of trees species than Hill evergreen forest (HEF). These results indicated that the number of species on lower elevation was higher than that on higher elevation. However, it is not clear that species composition of HEF is mixed with MEF tree species or not. Therefore, HEF in this area seems to be the transitional zone between MEF and HEF which is found to be high in number of species. Generally, the number of species in HEF is approximately less than 100 species.

Compared to other forests in Thailand for examples: moist evergreen forest at Khao Chong, Trang and Khao Pra Taew, Phuket (Kiratiprayoon, 1986), dry evergreen forest at Sakaerat, Nakhon Ratchasima (Visaratana, 1983) and dry evergreen forest at Khun Korn Waterfall Forest Park, Chiang Mai (Nukool, 2002), hill evergreen forest at Huay Nam Dang, Chiang Mai (Suksomut, 1987), hill evergreen forest at Khun Korn Waterfall Forest Park, Chiang Rai (Nukool, 2002), Yang stand at Pa Klang Ao, Prachuap Khiri Khan (Wachrinrat *et al.,* 1999), mixed deciduous forest at Mae Moh, Lampang (Ratcharoen, 1996), mixed deciduous forest at Khun Korn Waterfall Forest Park, Chiang Rai (Nukool, 2002), dry dipterocarp forest at Ping Kong, Chiang Mai (Ogawa *et al.,* 1961), Toh Daeng peat forest, Narathiwat (Sirirattanakorn, 1994), the results showed that number of species of all plots in present study were higher than other forests (Table 1). It is probable that moisture content of soils in MEF and DEF in this area are higher than other forests in other sites. It is recognized that moisture is one of the important factors that control species composition of each forest, this results is also supported by Pongumpai (1976). Number of species depends on soil moisture in the forest and it will increase as soil moisture content gradient increases from dry dipterocarp forest to mixed deciduous forest, dry evergreen forest, hill evergreen forest toward the moist evergreen forest respectively (Ogawa *et al.,* 1965).

Tree density.

The density of trees with DBH ≥ 4.5

Table 1. Number of species, tree density and basal area of some forest types in Thailand, only trees with DBH ≥ 4.5 cm. were included

Forest/Locality	No. of species ($sp.ha^{-1}$)	Tree density ($tree.ha^{-1}$)	Basal area (%)	Source
MEF, Khao Khitchakut National Park, Chanthaburi	135	1,510	0.480	Present study
DEF, Khao Soi Dao Wildlife Sanctuary, Chanthaburi	138	1,355	0.399	Present study
HEF, Khao Khitchakut National Park, Chanthaburi	129	2,513	0.316	Present study
MEF, Khao Chong, Trang	150* ± 22	1,018 ± 174	0.386 ± 0.40	Kiratiprayoon (1986)
MEF, Khao Pra Taew, Phuket.	112* ± 19	1,114 ± 360	0.341 ± 0.05	Kiratiprayoon (1986)
DEF, Sakaerat, Nakhon Ratchasima	57	1,488	0.309	Visaratana (1983)
DEF, Khun Korn Waterfall Forest Park, Chaing Rai	73	365	0.111	Nukool (2002)
HEF, Khun Korn Waterfall Forest Park, Chiang Rai	40	213	0.156	Nukool (2002)
HEF, Huay Nam Dang, Chiang Mai	56	521	0.365	Suksomut (1987)
MDF, Khun Korn Waterfall Forest Park, Chiang Rai	62	358	0.358	Nukool (2002)
MDF, Mae Moh, Lampang	40* ± 14	765 ± 353	0.078 ± 0.026	Ratcharoen (1996)
DDF, Ping Kong, Chiang Mai	33	1,488	0.147	Ogawa *et al.* (1961)
Secondary DDF, Kalasin	22*	1,444	0.069	Kanzaki *et al.* (1991)
Toh Daeng peat forest, Narathiwat	46	1,381	0.333	Sirirattanakorn (1994)
Yang stand, Pa Klang Ao, Prachuap Khiri Khan	53	980	0.303	Wachrinrat *et al.* (1999)

Remark : * number of tree species calculated from Fisher's index.
MDF is mixed deciduous forest; MEF is moist evergreen forest
DEF is dry evergreen forest; HEF is hill evergreen forest
DDF is dry dipterocarp forest

cm. is shown in Table 1. The HEF showed higher tree density than MEF and DEF, because it is abundant with small trees. Table 1 also shows the comparison of tree density in present study plots with other forest types in various locations in Thailand. It is clearly indicated that tree density in all plots in present study are relatively dense, especially HEF shows the greatest difference from other forests.

Basal area.

The percentages of basal area are also different among lowland forests (MEF and DEF) and HEF. Compared to other forest types in various sites (Table 1), it is clearly indicated that percentage of basal area of all present studied plots are higher than all those forests. Actually, evergreen forest is generally known as a very productive forest. In addition, compared to the evergreen for ests in other sites in Thailand (Table 1), the results shows that percentage of basal area of MEF and DEF in present study are higher than those forests while HEF is lower due to the abundance small trees of this forest.

Importance Value Index (IVI).

The relative density, relative frequency, relative dominance and importance value index in each plot are shown in Table 2. Importance value index (IVI) is used to determine dominant trees in each plot. The result showed that dominant trees of MEF are *Scaphium macropodum* Beaumee, *Archidendron guocense* (Pierre) Nielsen, *Syzygium lineatum* (DC.) Merr.& L.M. Perry, *Gonocaryum lobbianum* Kurz, *Strombosia javanica* Bl. While the dominant trees of DEF plot are *Diospyros dictyoneura* Hiern, *Xerospermum laevigatum* Radlk. ssp. *Laeviga, Strombosia javanica* Bl., *Crytocarya scortechnii*, and *Cyathocalyx martabanicus* Hook.f. & th., and the dominant trees of HEF were *Castanopsis acuminatissima* Rehd., *Diospyros* sp., *Syzygium* sp., *Callophyllum saigonense* Pierre, and *Diospyros pendula* Hasselt ex Hassk., respectively.

The IVI has been used for determining dominant species and its association in various forest communities by many ecologists such as Sahunalu and Dhanmanonda (1995), Bunyavejchewin (1983) etc.

Species Diversity

Species diversity determined by Fisher's index (α), Shannon's index (H) and Simpson's index (D) in MEF, HEF and DEF are shown in Table 3. For most indices, there are differences between MEF and HEF. This result indicated that forest in lower elevation had more diversity than forest in higher elevation. MEF and DEF had slightly difference in species diversity although DEF occurs in less rainfall area but DEF plot in present study was set in deeper soil site and less steep slope where it is likely to be suitable for many tree species than those in MEF plot.

Table 2. Relative density, relative frequency, relative dominance and important valueindex of trees (DBH ≥ 4.5 cm) in MEF, DEF, and HEF plot

Plot	No.	Scientific name	% Relative density	% Relative frequency	% Relative dominance	IVI (%)
MEF	1	*Scaphium macropodum* Beaumee	12.7815	6.8493	8.1056	27.7364
	2	*Archidendron guocense* (Pierre)Nielsen	9.7351	5.5708	2.0984	17.4043
	3	*Syzygium lineatum* (DC.) Merr.& L.M.Perry	0.9272	1.1872	12.7491	14.8635
	4	*Gonocaryum lobbianum* Kurz	4.5695	3.3790	2.0950	10.0435
	5	*Strombosia javanica* Bl.	3.7748	3.6530	2.2227	9.6505
		Other species	68.2119	79.3607	72.7292	220.3018
		Total	**100**	**100**	**100**	**300**
DEF	1	*Diospyros dictyoneura* Hiern	5.9041	5.0598	5.8068	16.7707
	2	*Xerospermum laevigatum* Radlk. ssp. *Laeviga*	7.7491	5.4278	3.4584	16.6353
	3	*Strombosia javanica* Bl.	4.6494	4.0478	3.3426	12.0399
	4	*Crytocarya scortechnii*	4.0590	3.5879	1.3795	9.0264
	5	*Cyathocalyx martabanicus* Hook.f. & th.	1.6974	1.7479	5.4169	8.8623
		Other species	75.9410	80.1288	80.5931	236.6654
		Total	**100**	**100**	**100**	**300**
HEF	1	*Castanopsis acuminatissima* Rehd.	25.428	40.252	7.983	73.663
	2	*Diospyros* sp.	10.466	8.354	6.807	25.626
	3	*Syzygium* sp.(1)	11.381	7.271	6.807	25.459
	4	*Callophyllum saigonense* Pierre	5.292	5.553	5.630	16.475
	5	*Diospyros pendula Hasselt* ex Hassk.	5.850	3.936	4.118	13.903
		Other species	41.583	34.634	68.655	144.874
		Total	**100**	**100**	**100**	**300**

Compared to other forests, The fisher's index of the three forests in these studies are found to be higher than other forests e.g. mixed deciduous forest at Lampang (Ratchareon, 1996), Nam Prom Dam, Chaiyaphum (Handechanon, 1990), hill evergreen forest at Huay Nam Dang, Chiang Mai (Suksomut, 1987) and Toh Daeng peat forest, Narathiwat (Siriratanakorn, 1994). In addition, they are also higher than the moist and dry evergreen forest e.g. the Sakaerat dry evergreen forest (Visaratana, 1983), Yang stand, Prachuap Khiri Khan (Wachrinrat *et al.,* 1999), dry evergreen forest at Nam Prom Dam, Chaiyaphum (Handechanon, 1990), and moist evergreen forest at Khao Chong natural and wildlife study center, Trang (Kiratiprayoon, 1986).

Richness indices are also shown in Table 3. MEF and DEF show higher richness index in terms of R_1 and R_2 than HEF. These indices show proportion between number of species and tree density in each forest type. From the results, forests on lower sites had the tendency of higher richness index than on higher site. However, richness index in terms of R_2 is an index that is likely to be sensitive to change in correspond to the change of number of individuals or sample plot size.

From Table 3, all the indices of the three forest types are very high due to their high number of species composition.

Distribution of individuals among species is called species evenness. Evenness is maximum when all species have the same number of individuals and decrease toward to zero as the relative abundance of the species diverge away from evenness. The E index is one of evenness index. There are not much different among the three forest types investigated from these three plots. Their evenness indices are moderately high.

Actually, the Shannon-Wiener's index and Simpson's index are a product of richness and evenness. Species richness is weighted by species evenness, and formulae are available, which permit the diversity to be estimated (Barbour *et al,* 1980). Shannon-Wiener's index and Simpson's index of species diversity are composed of two components. The first is the number of species in the community, which is called species richness. The second component is species evenness or equitability. Evenness refers to how the species abundance are distributed among the species (Ludwig and Reynolds, 1988). If the relative abundance was assumed to be linearly related to the significance for the system (Pielou, 1969; 1975; Gini, 1972; Jacobsen, 1983), for this case, Simpson (1949) proposed a useful method for diversity measurement. The Simpson's index of diversity gives very little weight to rare species and is the most sensitive to abundant species, while Shannon-Wiener's index is most sensitive to rare species. (Barbour *et al.,* 1980)

Table 3. Species diversity indices in the various forest types of Thailand

Forest/Locality	Diversity index			Richness index		Evenness	Source
	Fisher (α)	Shanon (H)	Simpson (D)	R_1	R_2	(E)	
MEF, Khao Khitchakut National Park, Chanthaburi	35.864	3.978	0.961	18.306	3.474	0.811	Present study
DEF, Khao Soi Dao Wildlife Sanctuary, Chanthaburi	38.460	4.093	0.974	18.997	3.749	0.831	Present study
HEF, Khao Khitchakut National Park, Chanthaburi	28.791	3.167	0.900	16.349	2.573	0.783	Present study
MEF, Khao Chong, Trang	nd	6.027 ± 0.197	nd	21.514	4.701	0.834	Kiratiprayoon (1986)
MEF, Khao Pra Taew,Phuket	nd	5.430 ±0.441	nd	15.822	3.356	0.798	Kiratiprayoon (1986)
DEF, Sakaerat, Nakhon Ratchasima	19.680	4.833	0.961	8.529	3.411	0.890	Visaratana (1987)
DEF, Khun Korn Waterfall Forest Park, Chiang Rai	27.430	5.500	0.973	12.204	3.821	0.892	Nukool (2002)
HEF, Huay Nam Dang, Chiang Mai	9.573	4.280	0.959	5.940	1.688	0.815	Suksomut (1987)
HEF, Khun Korn Waterfall Forest Park, Chiang Rai	14.540	3.573	0.817	7.274	2.741	0.671	Nukool (2002)
MDF, Namprom Dam, Chaiyaphum	8.007	3.466	0.916	3.574	2.271	0.912	Handechanon (1990)
MDF, Khun Korn Waterfall Forest Park, Chiang Rai	21.670	4.958	0.953	10.373	3.277	0.833	Nukool (2002)
Toh Daeng peat forest, Narathiwat	8.437	3.822	0.859	6.224	1.238	0.692	Sirirattanakorn (1994)
Yang stand, Pa Klang Ao, Prachuap Khiri Khan	12.606	3.770	0.869	7.695	1.725	0.658	Wachrinrat *et al.*,(1999)

Remark : MEF is moist evergreen forest; DEF is dry evergreen forest
HEF is hill evergreen forest; MDF is mixed deciduous forest

DBH Class Distribution

Size class distributions of trees with DBH larger than 4.5 cm are typical of natural regeneration, with high stem counts in the smaller size classes. Actually, the reverse J-shape or L shape is shown as balance maintenance. This trend was usually shown in various primary forests in Thailand (Ogawa, 1961, 1965; Sahunalu *et al.,* 1979; Visaratana, 1983; Suksomut, 1985; Nilroung, 1986; Kiratiprayoon, 1986; Bannasopit, 1989; Sahunalu and Dhanmanonda, 1995; Bunyavejchewin, 1999 and Watchrinrat *et al.,* 1999). However, some forest types did not show the L-shape such as MDF in Nam Prom dam, Chaiyaphum that its trend showed very few numbers of small size classes due to poor natural regeneration and survival rate. In addition, there was dense bamboo on the ground floor, which affected to the germination and regeneration of trees (Sahunalu *et al.,* 1979).

In present study, diameter distribution of trees with DBH larger than 4.5 cm in each plot are shown in Figure 2. Their trends are in reverse J-shape or L shape. In MEF and DEF, frequency of trees in each DBH size classes are large, from 4.5-9.5 cm and gradually decreases relatively to DBH class increasing. However, there are rather high density in small size class, and have very few number of large trees in HEF, and their trends also show reverse J-shape or L shape but the biggest tree is less than 60 cm in DBH. This outcome indicated that some limiting factors such as soil, topography play an important role on the tree growth.

Horizontal and Vertical Arrangement

Evergreen forest is characterized by the sparsely distributed trees and continuous crown cover, thus creating numerous canopy closure. The results of this study reflect the same trend as studies in the evergreen forest performed by Wachrinrat *et al.,* (1999); Dhanmanonda (1988) and Sahunalu *et al.* (1979). This is shown by a horizontal projection of all tree crowns above 4.5 cm in DBH (Figure 3) where the crown of trees in the moist and hill evergreen forests are continuous. The total coverage by crown of trees larger than 4.5 cm in DBH are about 83.05, 89.05 and 81.52% in MEF, DEF and HEF, respectively, which were slightly different among each evergreen forest in present study (Figure 3).

Vertical arrangement or stratification is analyzed by using standard profile diagram adopted from Richards (1952), the result comes up with an insufficient reflection to describe the more quantitative aspects of stratification, particularly in a narrow strip of the forest (i.e. the present 10x100 m^2 transect). Based on Ogawa's method of crown depth diagram analysis (Ogawa *et al.,* 1965) applied to the whole plot (100x100 m^2), the relationships between total tree height (H) and first living branch height (H_B) were

Table 4. The vertical arrangement of natural evergreen forests, Chanthaburi Province (only trees with DBH (4.5 cm were included) and some forest types in Thailand

Forest/Locality	No. of layer	Height class (m)				Source
		1st layer	2nd layer	3rd layer	4th layer	
MEF, Khao Khitchakut National Park, Chanthaburi	4	30 -40	25 - 30	11 - 25	<11	Present study
DEF, Khao Soi Dao Wildlife Sanctuary, Chanthaburi	4	25.5-40	17.5-25.5	9.5-17.5	<9	Present study
HEF, Khao Khitchakut National Park, Chanthaburi	3	17.5-27	9-17.5	<9	-	Present study
HEF, Khun Korn Waterfall Forest Park, Chiang Rai	3	>20	10-20	<10	-	Nukool (2002)
DEF, Khun Korn Waterfall Forest Park, Chiang Rai	3	>13	9 - 13	<9	-	Nukool (2002)
MDF, Mae Moh, Lampang	2	> 5->10	<5-<10	-	-	Ratcharoen (1996)
MDF, Mae Moh, Lampang	3	>15->20	10-20	<5-<10	-	Ratcharoen (1996)
DDF, Sakaerat, Nakhon Ratchasima *S. obtusa-S. siamensis* type	2	>13->18	<13-<18	-	-	Chaimongkol (1989)
S. obtusa-S. siamensis type	3	>18->22	15-22	<15-<17	-	Chaimongkol (1989)
Toh Daeng peat forest, Narathiwat	3	>20	10-20	< 10	-	Sirirattanakorn (1994)

Remark : MEF is moist evergreen forest; DEF is dry evergreen forest
HEF is hill evergreen forest; MDF is mixed deciduous forest
DDF is dry dipterocarp forest

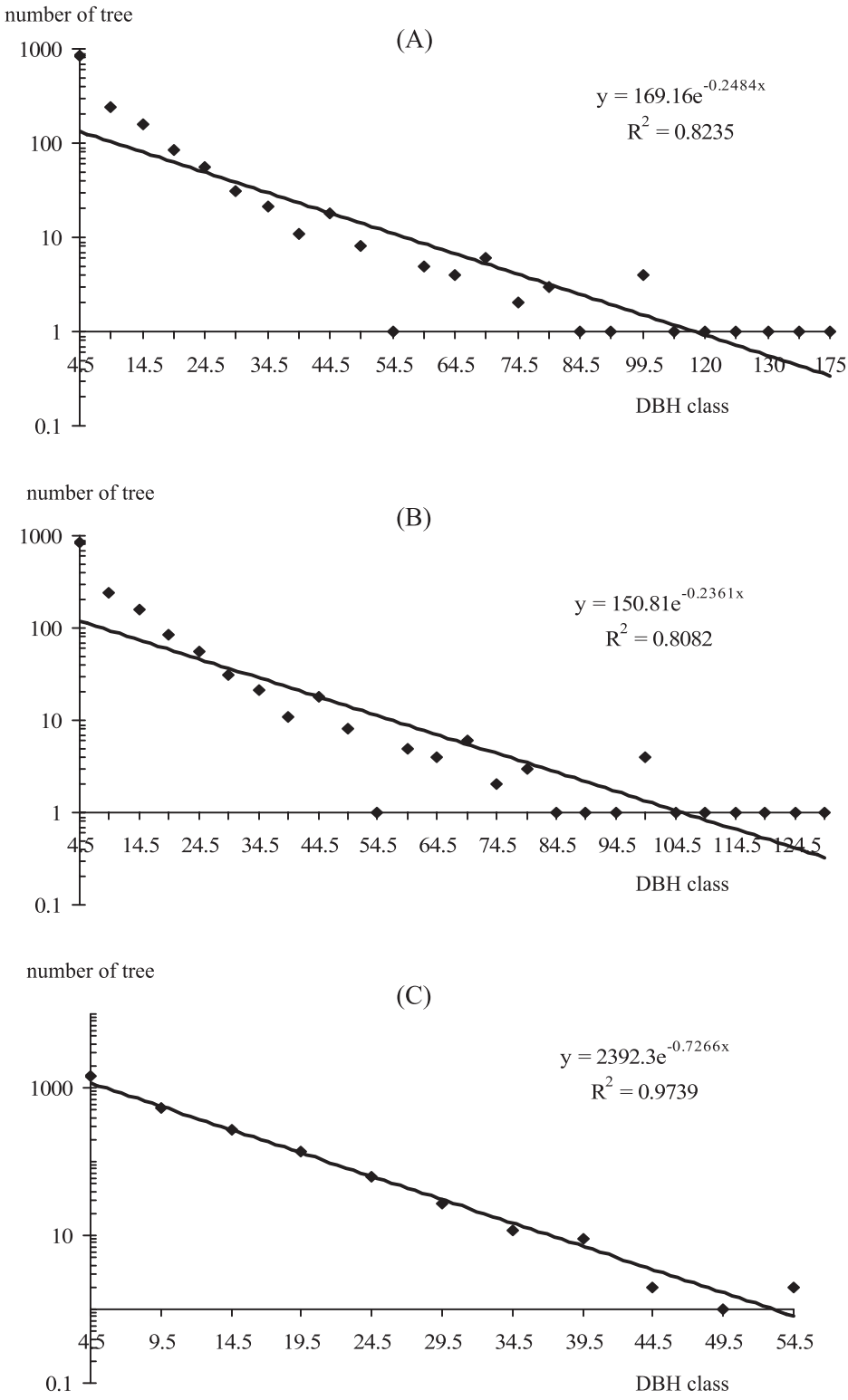

Figure 2. DBH distribution of evergreen forests, (A) moist evergreen forest, (B) dry evergreen forest and (C) hill evergreen forest, Chanthaburi Province. Equations represent the thick lines for each relationship of number of tree and DBH class

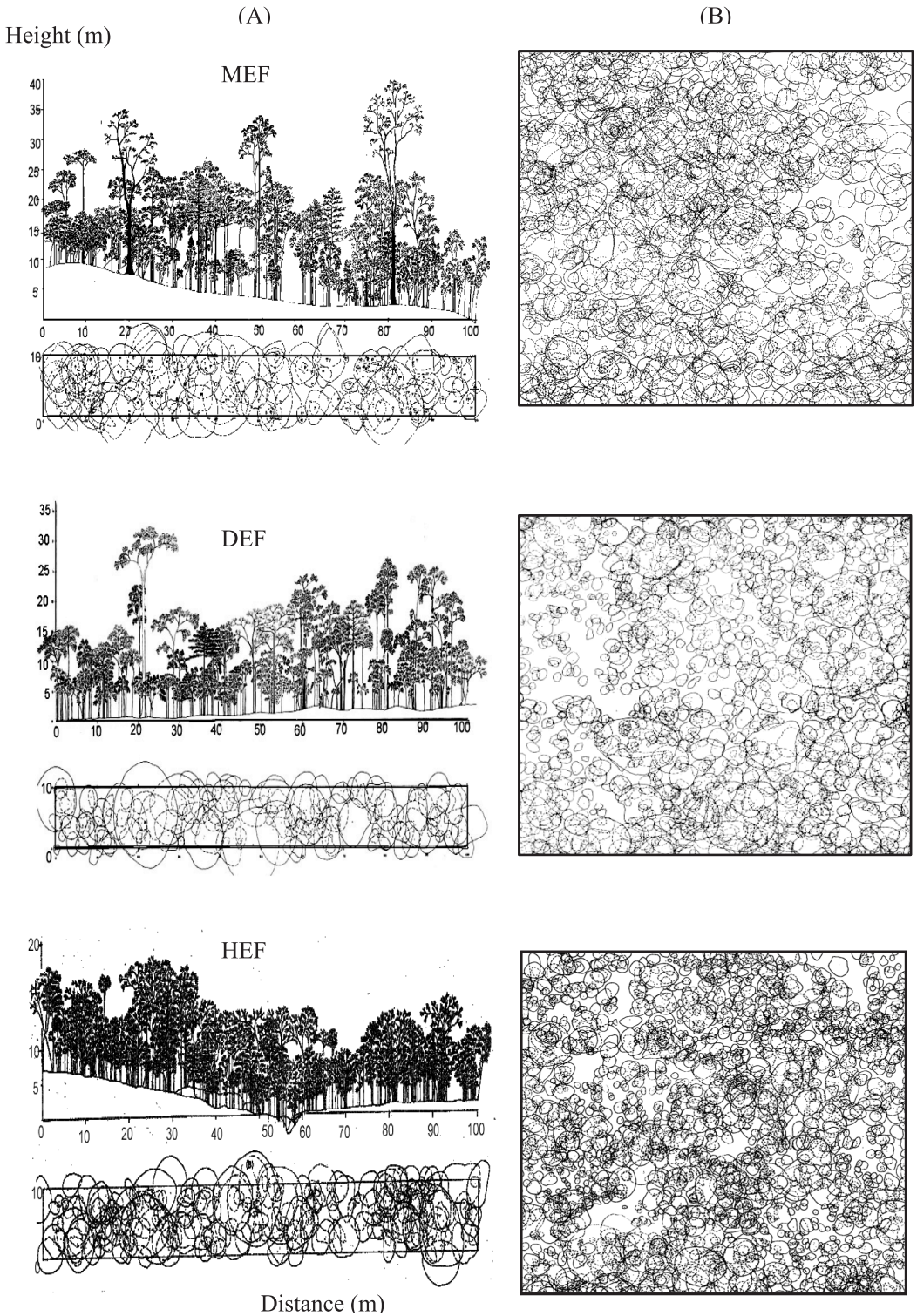

Figure 3. Profile diagram along randomly selected belt transect of 10 x 10 m² (A) and crown projection diagram (B) of trees with DBH larger than 4.5 cm. of moist evergreen forest (MEF), dry evergreen forest (DEF) and hill evergreen forest (HEF), Chanthaburi Province

studied. According to the current studies, the arrangement of tree layers (DBH) larger than 4.5 cm tended to have 3 - 4 layers. The vertical stratification using crown depth diagram is shown in Table 4. The first layer of MEF is judged above 36 m, the second layer is 25 - 30 m and the third layer is 11 - 25 m. The suppress layer is less than 11 m DEF plot is divided into 4 layers. The top layer is 25.5 - 40 m, the second layer is 17.5 - 27 m, the third layer is 9 - 17.5 m and the suppress layer is less than 9 m. In case of HEF, it is divided into three layers. The top layer is 17.5 - 27 m, the second layer is 9 - 17.5 m and the third layer is less than 9 m. A comparison using profile diagram and crown depth diagram analysis found that stratification of the three forest types corresponded the similar result (Figure 4). Actually, the most important feature, which had been taken into consideration is a degree of crown overlapping. MEF and DEF have very large crown cover and percentage of overlapping. Many small trees are found under the crown of big trees. Therefore, small trees underneath the canopy of large trees have low growth rate because it is likely to get insufficient light.

CONCLUSION

The structure of natural evergreen forests in eastern region of Thailand, moist evergreen forest (MEF), dry evergreen forest (DEF) and hill evergreen forest (HEF) are found to be relatively complex. The species composition of the three forest types are also very rich and high diversity. The MEF and DEF, locating on lower elevation exhibit higher number of species and species diversity than HEF. The size class distribution of trees in each evergreen forest is shown to be typical of a good natural regeneration showing on L-shape curve by the high abundance of small trees and gradual decline of the medium size and few or rare on the large emergent canopy trees. The vertical arrangement in MEF and DEF are found to be 4 layers while only 3 layers are found out in HEF. The crown covers are estimated at 83.05, 89.05 and 81.52 % for MEF, DEF, and HEF, respectively.

ACKNOWLEDGEMENT

We would like to give thanks to Mr. Surachai Pransilpa, chief of Khao Khitchakut National Park, Chanthaburi and his staffs; especially Mr. Kittisak Rattanadadas and Mr. Mothien, chief of Khao Soi Dao Wildlife Sanctuary, Chanthaburi for helping to facilitate this research. Special thanks also to Dr. Wichan Eidthong, Mr. Sarawuth Sungkaew, Mr. Panumas Chansuwan, Mr. Sermpong Nualngam, Mr. Pornthep Muanpong, Mr. Suwit Poomprasertchoke, Miss Rabieb Srigongparn who helped with field work. This work was supported by the TRF/BIOTEC Special

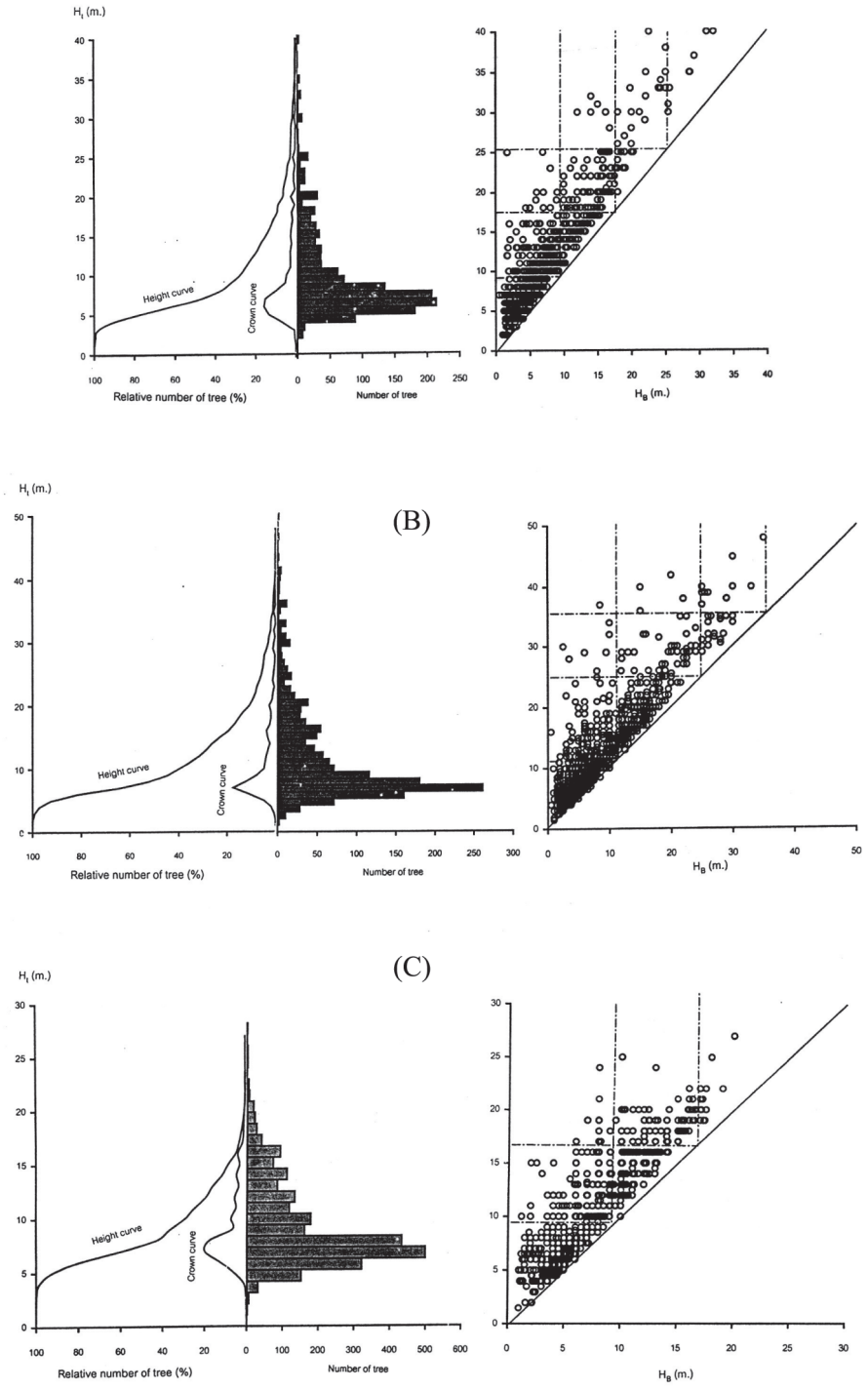

Figure 4. Crown depth diagram and H-H_B relation of trees with DBH larger than 4.5 cm. in each plot; (A) dry evergreen forest (DEF), (B) moist evergreen forest (MEF) and (C) hill evergreen forest (HEF), Chanthaburi Province

Program for Biodiversity Research and Training grant T-344009. We would also like to give special thanks to them.

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