*Article*

# Forest structure and species diversity of secondary forest after cultivation in relation to various sources at lower northern Thailand

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**Abstract**
The purpose of this study was to explore the characteristic of structure, species composition and species diversity in secondary mixed deciduous forest at Thung Salaeng Luang National Park, Lower North of Thailand. This vertical stratification of the tree canopy can affect the growth of young trees on the ground surface, especially that of saplings and seedlings. Ground species can establish themselves very quickly when the light intensity is high enough and especially when the light can penetrate directly to the ground during gap formation. The data of tree individuals have served to give insight into the stand density, basal area, and frequency number of DBH class ranges. There were a large number of DBH class ranges but there were low DBH values. The species composition of secondary mixed deciduous forest is low rich and diversity but that is high density. The comparison between secondary mixed deciduous forest at Thung Salaeng Luang National Park and other forest is tree density higher than other forest but number of species is similarity or lower. The dominant species of trees were *Haldina cordifolia, Albizia odoratissima* and *Lagerstroemia duperreana*. The IVI values of trees were 132.91, 17.78 and 14.22, respectively. Species diversity compared to other forests, The Fisher's, Shannon-Wiener's index and Simpson's index in these studies are found to be lower than other forests. The size class distribution of trees in secondary mixed deciduous forest is shown to be on L-shape curve, which is high abundance of small trees.

**Keywords** forest structure; species diversity; secondary forest; cultivation land; northern Thailand.

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## 1 Introduction

Cultivation has been practiced all over the world and two-thirds of the world's secondary forest area in 1980 was shifting cultivation fallow (Lanly, 1982). The currently degraded forest in upland northern Thailand is largely the result of shifting cultivation and it was logged forest converted to agricultural land by shifting cultivators. In general, the main shifting cultivation in mountainous area northern Thailand is upland rice, which is cultivated together with numerous other crops, such as cotton, sorghum, pepper, squash, yam, cucumber, millet, sesame, red pepper, and various herbs and spices (Fugushima et al., 2008). The shifting cultivation in lower northern Thailand is upland area so; the main shifting cultivation is economic cultivation such as maize, cassava, cotton, chili and fruit.

Tropical forest ecosystem has a very high biodiversity that is accepted in the generalness. This ecosystem also has high gross production and rapid decomposition rate of organic matter. The forest in Thailand is decreasing area at crisis point that has only 26.6% of all area. More than 70% of the forest area in Thailand is not protected and much of the non-protected areas have less biodiversity than protected areas due to human disturbance, but they are very important to people in the rural areas. In Thailand, the Royal Forestry Department reported that 0.46 million hectares of the forest land had been destroyed annually during the past three decades. The situation of forest degradation has continuously increased even in the protected areas and species diversity of Thailand biodiversity in danger. Studies of secondary forest regeneration in South-east Asia have been made in Peninsular Malaysia (Symington, 1933; Wyatt-Smith, 1955; Kochummen, 1966; Kochummen and Ng, 1977), Thailand (Kunstadter et al., 1978), the Philippines (Kellman, 1969) and East Kalimantan (Kartawinata et al., 1980). Some of these studies dealt with secondary succession after agricultural land use while others used experimental manipulation to compare secondary forest recovery under a range of conditions.

In Thailand, previous studies have recognized that differences in shifting farming practices of various ethnic groups have resulted in differences in the secondary forest (Fugushima et al., 2008) in mountainous area northern Thailand. The previous reporting studied secondary forest in fallow fields after shifting cultivation by the Karen, Hmong, and Lisu groups and reported relatively rapid forest recovery after shifting cultivation by the Karen compared to the other groups (Kanjunt and Oberhauser, 1994) and an experimental shifting cultivation in which primary forest was burned for upland farming in northeastern Thailand (Kyuma and Pairintra, 1983; Boonyanuphap, 2007). Thung Salaeng Luang National Park is exceptionally interesting to research because of that diversified biota and head water area of Nan River that is the longest river in Thailand. The Secondary mixed deciduous forest (SMDF) plays an important role for many kinds of benefit of the Wang-Thong watershed conservation, soil erosion protection and water regulator. Therefore, the suitable use concept should be applied to this SMDF for the benefits of the watershed. This study investigated the structure, composition and species diversity by exploring at SMDF. The research focused on the three following questions such as: 1) what are the ecosystem structure of the SMDF? 2) What are the dominant species of the tree, sapling and seedling groups in SMDF? 3) What are the ecosystem species compositions of the SMDF? The special objective was to compare structural characteristics of other forest in Thailand. The three basic ecological characteristics of SMDF should provide valuable information for sustainable forest management planning in this region of the country.

## 2 Methods and Materials

### 2.1 Study site

The study was conducted in Thung Salaeng Luang National Park, which lies in the Lower North of Thailand, located between 16°25′ - 16°57′ N and 100°37′ - 101°00′ E (Fig. 1).

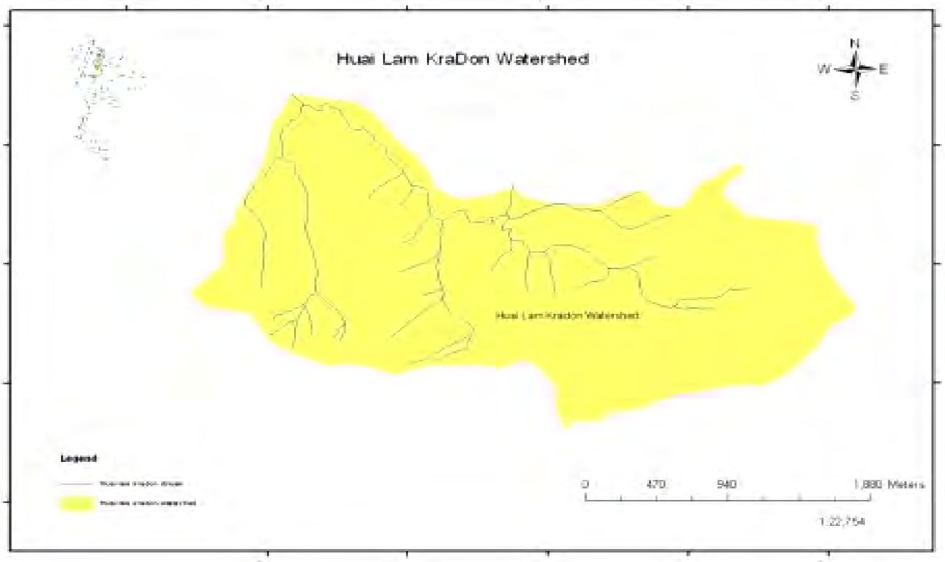


**Fig. 1** Study area at Thung Salang Luang National Park, Phitsanulok province, Thailand.

The site is mountainous and ranges in elevation between 400-1,003 m above sea level, surrounded by the five main watersheds such as: Huai Klag Yai, Huai Klag Noi, Lam Nam Tum, Klong Chum Poo and Klong Wang Thong, there are importance on producing water of Nan watershed. The geological formation of the study area is composed of sedimentary rock and metamorphic rock (Royal Forestry Department, 1990). The climate is tropical and sub-tropical with three distinct seasons such as: cold, hot and rainy. March to June are the hottest month with highest mean maximum temperature (29 °C), and November to February are the coldest months with highest mean minimum temperature (17 °C), and the mean temperature is 22 °C. The maximum rainfall occurs during the monsoon season May to October with mean rainfall 1,300-1,700 mm. The study area covers forest in the Thung Salang Luang National Park. The geographical characteristics of the sampling sites were recorded in (Table 1).

**2.2 Sample plots**

Forest community data was collected from permanent plots in 50 × 50 m quadrate that divided into 25 sub plots of 10 × 10 m. A vegetation census was used to collect data on forest structure and species composition.

**2.3 Data collection**

All trees in these plots were recorded all trees DBH > 4.5 cm in each plot of 10 × 10 m, with five random subplots of 4 × 4 m within this plot selected for the recording of all tree DBH ≤ 4.5 cm (sapling). Finally, all tree heights ≥ 1.30 m was measured in five randomly located plots of 1 × 1 m, while all trees in five plots of 4 × 4 m was recorded for trees DBH ≤ 4.5 cm and height < 1.30 m (seedling). Analysis gives precise measures of the floristic composition, species density, basal area and ecological characteristics.

**2.4 Data analysis**

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

(1) Stratification: vertical structure showing vertical stratification of each plot 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 $H_B$ were also used for supplementary analysis

(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 (%). The relative density was determined from all standing trees of DBH exceeded 4.5 cm in the sample of 50 x 50 $m^2$ 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 50 x 50 $m^2$ 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≥4.5 cm. in each sample plot was determined by using diversity indices as follows:

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

$$H = -\sum_{i=1}^{s} p_i \log_2 p_i$$

where Pi = proportion of the number of individuals of species i to the total v 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.

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

$$\alpha = N(1-x)/x$$

where N = number of individuals in the sample area, α = the Fisher's index of diversity, S = number of species, x = constant value ((4) / (3)), ln = natural logarithm.

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

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

where D = Simpson's index, N = total number of individuals of species.

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:

$$R_1 = S-1/In(N)$$
$$R_2 = S/\sqrt{N}$$

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

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

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

where E = species evenness, H= Shannon-Wiener index of species diversity, $H_{max}$= maximum of Shannon - Wiener max 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 this forest and similarly and difference to other forest types was further discussed.

**Table 1** Geographical coordination of the study area at Wang-Thong head water.

| Name | Location (UTM) | Land use types | Sampling plot size |
|---|---|---|---|
| MDF1 | 1852004<br>47Q0679176 | Mixed deciduous forest | 50 x 50 m |
| MDF2 | 1852077<br>47Q0679108 | Mixed deciduous forest | 50 x 50 m |
| MDF3 | 1851955<br>47Q 0679133 | Mixed deciduous forest | 50 x 50 m |
| MDF4 | 1851688<br>47Q0679217 | Mixed deciduous forest | 50 x 50 m |

## 3 Results and Discussion

### 3.1 Stand composition

3.1.1 Vertical structure

In the SMDF ecosystem, crown cover was continuous. Canopy openings were rarely found so that available light could not reach the ground surface easily. In the SMDF sapling and seedling were densely established within the gap area. The tree canopy was also divided into 3 vertical stratifications (Fig. 2). The top stratum was higher than 15 m and dominated by *Tetrameles nudiflora* and *Parkia sumatrana*. The second stratum was between 10-15 m high the dominated tree in this stratum was *Butea* monosperma. The third stratum was lower than 10 m and dominated by *Haldina cordifolia, Albizia odoratissima and Lagerstroemia duperreana*.

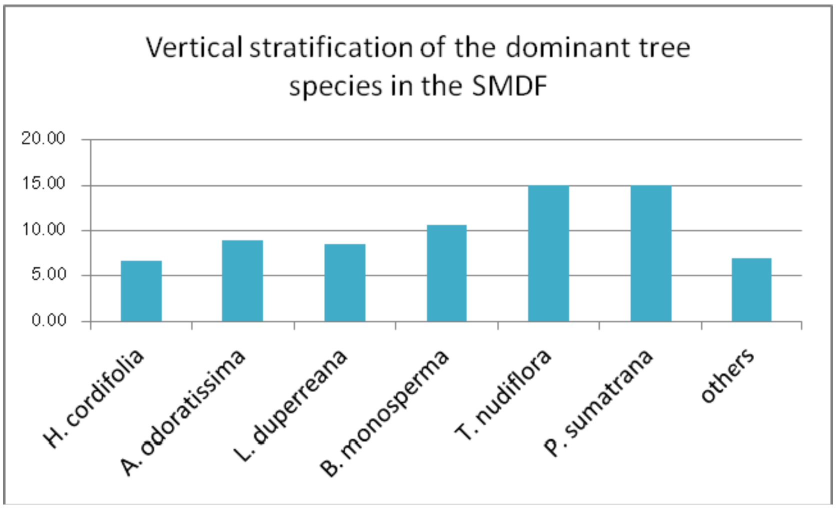


**Fig. 2** Vertical stratifications of the dominant tree species in the SMDF.

**Table 2** Number of species, tree density and basal area of some forest types in Thailand, only trees with DBH ≥ 4.5 cm. were included.

| **Forest** | **Area** | **No. of species** ($sp.ha^{-1}$) | **Tree density** ($tree.ha^{-1}$) | **Source** |
|---|---|---|---|---|
| SMDF | Thung Salaeng Luang National Park | 35 | 2,025 | Present study |
| MDF | Huai Kha Khaeng Wildlife Sactuary | 21 | 780 | Srikansa and Gajaseni, 2000 |
| MDF | Khao Kaset Forest area | 33 | 959 | Khophai, 2006 |
| MDF | Khun Korn Waterfall Forest park | 62 | 358 | Nukool,2002 |
| DDF | Huai Kha Khaeng Wildlife Sactuary | 14 | 720 | Srikansa and Gajaseni, 2000 |
| SDDF | Kalasin Forest area | 22 | 1,444 | Kanzaki, 1991 |
| MEF | Khao Khitchakut National Park | 135 | 1,510 | Glumphabutr et al., 2006 |
| DEF | Khao Soi Dao Wildlife Sanctury | 138 | 1,355 | Glumphabutr et al., 2006 |

3.1.2 Species composition

Number of tree species (DBH ≥ 4.5 cm) in each plot is shown in Table 1. The SMDF showed low number of trees species. Compared to other forests in Thailand for examples: Moist evergreen forest at Khao Khitchakut National Park, Thailand (Glumphabutr et al., 2006), Dry evergreen forest at Khao Soi Dao Wildlife Sanctuary, Thailand (Glumphabutr et al., 2006), Dry Dipterocarp forest at Huai Kha Khaeng Wildlife Sactuary, Thailand (Srikansa and Gajaseni, 1999), Secondary Dry Dipterocarp forest at Kalasin Forest area, Thailand (Kanzaki, 1991), Mixed deciduous forest at Huai Kha Khaeng Wildlife Sactuary, Thailand (Srikansa and Gajaseni, 1999), Khao Kaset Forest area, Thailand (Khopai, 2006), Khun Korn Waterfall Forest park, Thailand (Nukool, 2002). The results showed that number of species of all plots in present study was nearly other forest (Table 2). It is probable that moisture content of soils in MEF and DEF in this comparison is higher than other forests in other site. It is recognized that moisture in one of the important factors that control species composition of each forest, this results is also supported by Pongumpai (1976), Glumphabutr et al. (2006). Number of species depends on soil moisture in the forest and it will increase as soil moisture content gradient increase from dry dipterocarp forest to mixed deciduous forest, dry evergreen forest, hill evergreen forest toward the moist evergreen forest respectively (Ogawa et al., 1965).

### 3.2 Tree density

The density of trees with DBH ≥ 4.5 cm. is shown in Table 2. The SMDF showed higher tree density than other forest, because it is abundant small trees. Table 2 shows the comparison of tree density in present study plots with other forest types in various locations in Thailand.

### 3.3 Importance Value Index (IVI)

In the SMDF ecosystem, the dominant species of the trees were the same species, *Haldina cordifolia*, *Albizia odoratissima* and *Lagerstroemia duperreana*. The IVI values of trees were 132.91, 17.78 and 14.22, respectively. The dominant species of the saplings were the same species, *Haldina cordifolia*, *Fermandoa adenophylla* and *Harrisonia perforata*. The IVI values of saplings were 102.31, 47.10 and 34.29, respectively. The dominant species of the seedling were the same species, *Haldina cordifolia*, *Fermandoa adenophylla* and *Harrisonia perforata*. The IVI values of saplings were 113.74, 37.49 and 28.51, respectively (Table 3).

**Table 3** Relative density, relative frequency, relative dominance and important value index of trees (DBH ≥ 4.5) in SMDF plot.

| | **Tree group Scientific name** | **Relative Density %** | **Relative Frequency %** | **Relative Dominance %** | **IVI %** |
|---|---|---|---|---|---|
| 1 | *Haldina cordifolia* | 49.34 | 78.62 | 4.94 | 132.91 |
| 2 | *Albizia odoratissima* | 5.58 | 7.27 | 4.94 | 17.78 |
| 3 | *Lagerstroemia duperreana* | 6.89 | 2.39 | 4.94 | 14.22 |
| 4 | *Fermandoa adenophylla* | 6.60 | 2.35 | 4.94 | 13.89 |
| 5 | *Croton roxburghii* | 5.00 | 1.15 | 4.94 | 11.08 |
| 6 | *Harrisonia perforata* | 3.35 | 2.62 | 4.94 | 10.91 |
| 7 | *Cratoxylum formosum* | 3.44 | 1.39 | 4.94 | 9.77 |
| 8 | *Dalbergia foliacea* | 3.49 | 1.13 | 4.94 | 9.57 |
| 9 | *Xylia xylocarpa* | 2.52 | 1.06 | 4.94 | 8.52 |
| 10 | *Antidesma sootepense* | 3.15 | 0.40 | 4.94 | 8.50 |

**Table 4** Species diversity index, Richness index, Evenness of trees (DBH ≥ 4.5) in SMDF plot compare with various source.

| **Forest/Area** | **Diversity index** | | | **Richness index** | | **Evenness** | **Source** |
|---|---|---|---|---|---|---|---|
| | **Fisher (α)** | **Shanon (H)** | **Simpson (D)** | **$R_1$** | **$R_2$** | | |
| SMDF/ Thung Salaeng Luang National Park | 8.051 | 2.078 | 0.726 | 4.466 | 0.778 | 0.627 | Present |
| HEF/Huay Nam Dang National Park | 9.573 | 4.280 | 0.959 | 5.940 | 1.688 | 0.815 | Suksomut,1978 |
| MDF/ Khun Korn Waterfall Forest park | 14.540 | 3.578 | 0.817 | 7.274 | 2.741 | 0.671 | Nukool,2002 |
| MDF/ Namprom Dam | 8.007 | 3.466 | 0.916 | 3.574 | 2.271 | 0.912 | Handechnon,1990 |
| MEF/ Khao Khitchakut National Park | 35.864 | 3.978 | 0.961 | 18.306 | 3.474 | 0.811 | Glumphabutr et al., 2006 |
| DEF/ Khao Soi Dao Wildlife Sanctury | 38.460 | 4.093 | 0.974 | 18.997 | 3.749 | 0.831 | Glumphabutr et al., 2006 |

**3.4 Species diversity**

Species diversity determined by Fisher's index (α), Shannon's index (H) and Simpson's index (D) in SMDF are shown in Table 4. Compared to other forests, the fisher's in these studies are found to be lower than other forests e.g. hill evergreen forest at Huay Nam Dang, Chiang Mai (Suksomut, 1987), Mixed deciduous forest at Khun Korn Waterfall, Chiang Rai (Nukool, 2002) except Mixed deciduous forest at Namprom Dam, Chai Yaphum (Handechnon, 1990), Moist evergreen forest at Khao Khitchakut, Chantaburi (Glumphabutr et al., 2006) and Dry evergreen forest at Khao Soi Dao, Chantaburi (Glumphabutr et al., 2006).

Richness indices are also shown in Table 4. These indices show proportion between number of species and tree density in each forest type. From the results, the richness indices in these studies are found to be lower than other forests except mixed deciduous forest at Namprom Dam, Chai Yaphum (Handechnon, 1990). Distribution of individuals among species is called species evenness, Evenness is maximum when all species have the same number of individuals and decrease of the species diverges away from evenness. The E index is one of evenness index. There are not much different among other forest. 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 formulate are available, which permit the diversity to be estimated (Barbour et al., 1980). Shannon-Weiner'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), for this study, Simpson (1949) proposed a useful method for diversity measurement. The Simpson's index of diversity gives very little weight to rare species, while Shannon-Wiener's index is most sensitive to rare species (Barbour et al., 1980).

**3.5 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 (Glumphabutr et al., 2006). However, some forest type did not shown L-shape 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 generation of trees (Sahunalu et al., 1979).

In present study, diameter distribution of trees with DBH larger than 4.5 cm this plot are shown in Fig. 3. This trend is in L-shape. In SMDF frequency of trees in this DBH size class is large, from 6 cm and gradually decreases relatively to DBH class increasing. However, this is rather high density in small size class, and has very little number of large trees in SMDF and this trend also shown reverse J-shape or L-shape but the biggest tree is less than 90 cm in DBH. This outcome indicated that some limiting factors such as soil, topography play an important role on the tree growth.

**3.6 Number of tree**

However, this is rather high density in small size class, and has very little number of large trees in SMDF and this trend also shown reverse J-shape or L-shape but the biggest tree is less than 90 cm in DBH. This outcome indicated that some limiting factors such as soil, topography play an important role on the tree growth.

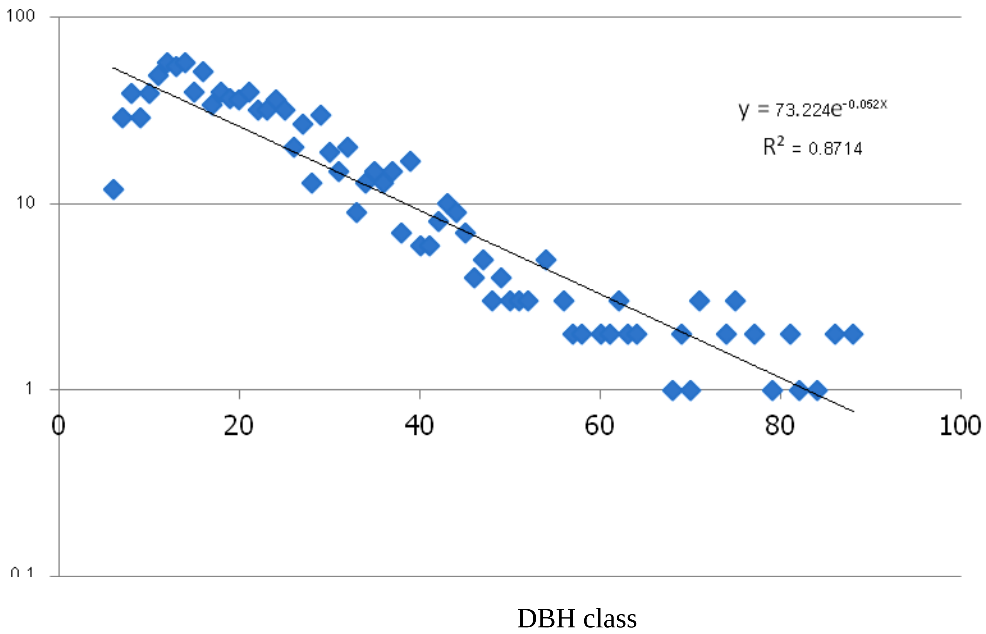


**Fig. 3** DBH distribution of secondary mixed deciduous forest, Thung Salaeng Luang National Park, Equations represent the thick lines for each relationship of number of tree and DBH class.

## 4 Conclusion

The purpose of this study was to explore the characteristic of structure, species composition and species diversity in secondary mixed deciduous forest at Thung Salaeng Luang National Park, Lower North of Thailand. This vertical stratification of the tree canopy can affect the growth of young trees on the ground surface, especially that of saplings and seedlings. Ground species can establish themselves very quickly when the light intensity is high enough and especially when the light can penetrate directly to the ground during gap formation. The data of tree individuals have served to give insight into the stand density, basal area, and frequency number of DBH class ranges. There were a large number of DBH class ranges but there were low DBH values. The species composition of secondary mixed deciduous forest is low rich and diversity but that is high density. The comparison between secondary mixed deciduous forest at Thung Salaeng Luang National Park and other forest is tree density higher than other forest but number of species is similarity or lower. The dominant species of trees were *Haldina cordifolia*, *Albizia odoratissima* and *Lagerstroemia duperreana*. The IVI values of trees were 132.91, 17.78 and 14.22, respectively. Species diversity compared to other forests, The Fisher's, Shannon-Wiener's index and Simpson's index in these studies are found to be lower than other forests. The size class distribution of trees in secondary mixed deciduous forest is shown to be on L-shape curve, which is high abundance of small trees.

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**References**

Boonyanuphap J, Sakurai K, Tanaka S. 2007. Soil nutrient status under upland farming practice in the Lower Northern Thailand. Tropics, 16 (3): 215-231

Barbour MG, Burk JH, Pitts WD. 1980. Terrestrial Plant Ecology. Benjamin/Cummings Publishing Company, Menlo Park, CA, USA

Fugushima M, Kanzaki M, Hara M, et al. 2008. Secondary forest succession after the cessation of swidden cultivation in the montane forest area in Northern Thailand. Forest Ecology and Management, 255: 1994-2006

Fisher RA, Corbet AS, Williams CB. 1943. The relationship between the number of species and the number of individuals in a random sample of an animal population. Journal of Animal Ecology, 12: 42-58

Glumphabutr P, Kaitpraneet S, Wachrinrat J. 2006. Structural characteristic of natural evergreen forests in eastern region of Thailand. Thai Journal of Forestry, 25: 92-111

Handechanon N. 1990. Comparative ecologicalstudy on three forest types at Namprom Basin, Changwat Chaiyaphum. MSc Thesis. KasetsartUniversity, Thailand

Kanjunt C, Oberhauser U. 1994. Successional forest development in abandoned swidden plots of Hmong, Karen, and Lisu ethnic groups. NAMSA Research Paper. Sam Muen-Highland Development Project, Thailand

Kanzaki M, Kawaguchi H, Sahunalu P, et al. 1991. Climate, topography, and initial vegetation of experiment sites with reference to the dynamics of natural forest. In: Improvement of Biological Productivity of Tropical Wastelands in Thailand (Yoda K, Sahunalu P, eds). 23-47, Department of Biology Osaka City University, Osaka, Japan

Kartawinata K, Riswan S, Soedjito H. 1980. The Floristic change after disturbances in lowland dipterocarp forest in East Kalimantan, Indonesia. Tropical Ecology and Development. Proceedings of the 5$^{th}$ International Symposium of Tropical Ecology, 47-54

Kellman MC. 1969. Some environmental components of shifting cultivation in upland Mindanao. Journal of Tropical Geography, 28 40-56

Khopai A. 2006. The study of plant community in Khao Kaset forest area and tree species diversity in Kasetsart Si Racha Campus. Thai Journal of Forestry, 25: 1-18

Kochummen KM. 1966. Natural plant succession after farming in Sg. Kroh. Malayan Forester, 29: 170-181

Kochummen KM, Ng FSP. 1977. Natural plant succession after farming in Kepong. Malayan Forester, 40: 61-78

Kunstadter P, Sabhasri S, T. Simitinand. 1978. Flora of a forest fallow farming environment in northwestern Thailand. Journal of the National Research Council, 10(1): 1-45

Kyuma K, Pairintra C. 1983. Shifting cultivation: An Experiment at Nam Phrom, Northeast Thailand, and Its Implications for Upland Farming in the Monsoon Tropics. Faculty of Agriculture, Kyoto University, Japan

Lanly JP. 1982 Tropical Forest Resources. FAO Forestry Paper 30. FAO, Rome, Italy

Ludwig JA, Reynold JF. 1988. Statistical Ecology. John Wiley, New York, USA

Margalef R. 1958. Information theory in ecology. General Systems, 3: 36-71

Menhinick EF. 1964. Acomparison of some species diversity indices applied to samples of field insects. Ecology, 45: 859-861

Nagy L, Proctor J. 1997. Early secondary forest growth after shifting cultivation in management of secondary and logged-over forest in Indonesia. Proceeding of an International Workshop.

Nukool T. 2002. Structural characteristics of three forest types at Khun Korn Waterfall Forest Park, Changwat Chiang Rai. MSc Thesis. Kasetsart University, Thailand

Ogawa H, Yoda K, Ogino K, et al. 1965. Comparative ecological studies on three main types of forest vegetation in Thailand II Plant biomass. Net Life Southeast Asia, 4: 49-80

Pielou EC. 1969. An Introduction to Mathematical Ecology. John Wiley, New York, USA

Pongumpai S. 1976. Dendrology. Forest Biology Department, Faculty of Forestry, Kasetsart University, Thailand

Riswan S, Abdulhadi R. 1992 Succession after disturbance of lowland mixed dipterocarp forest by shifting agriculture in East Kalimantan, Indonesia. In: Tropical Forests in Transition (Goldammer JG, ed). 77-84, Birkhaeuser Verlag, Basel, Switzerland

Sahunalu P, Dhanmanonda P. 1995. Structure and dynamic of dry dipterocarpforest, Sakaerat, northeast Thailand. In: Vegetation Science in Forestry (Box EO et al., eds). 165-194, Kluwer Academic Publisher, Netherland

Shannon CE, Weaver W. 1949. The Mathematical Theory of Communication. University of Illinois Press, Urbana, USA

Simpson EH. 1949. Measurement of diversity. Nature, 163-688

Srikansa P, Gajaseni J. 2000. Journal of Scientific Research, 25(1): 51-62

Sukardjo J. 1990. Secondary forest of Tanah Grogot, East Kalimantan. 213-224, Proceedings of the Plant Diversity of Malaysia Symposium, Leiden, Netherlands

Suksomut P. 1987. Community dynamics of hill evergreen forest at Huay NamDang Watershed Station, Chiang Mai Province. MSc Thesis. Kasetsart University, Thailand

Symington CF. 1993. The Study of Secondary growth on rain forest sites in Malaya. Malayan Forester, 2: 107-117

Werner S. 1997. The Impact of Management Practices on Species Richness within Productive Rubber Agroforests of Indonesia in Management of Secondary and Logged-Over Forest in Indonesia. Proceeding of an International Workshop

Wyatt-Smith J. 1955. Changes in composition in early natural plant succession. Malayan Forester, 18: 44-49