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Tree Distribution across the Forest Ecotone of Lower Montane Forest at Doi Suthep-Pui National Park, Chiang Mai Province

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ABSTRACT

A study of the tree distribution across the forest ecotone of lower montane forest (LMF) was carried out at Doi Suthep-Pui National Park, Chiang Mai province during 2014. The objectives aimed to clarify the species composition and determine environmental factors for coexisting tree species. A permanent transect plot, 30×600 m, was established from 900 to 1,100 m above mean sea level, and divided into 180 subplots (10 m x 10 m). All trees with diameter at breast height, DBH, ≥ 4.5 cm were tagged, measured and identified. The soil moisture content and elevation were recorded in every subplot.

The results showed high tree species numbers for 192 tree species in 126 genera and 56 families, while the density and basal area of trees with DBH ≥ 4.5 cm were 1,220 individual. ha^{-1} and 28.60 $m^2.ha^{-1}$, respectively. The dominant tree species based on the importance value index (IVI) were *Quercus brandisiana, Dipterocarpus obtusifoliu, Schima wallichii, Wendlandia paniculata* and *Litsea martabanica* with IVI values of 31.52, 18.40, 15.34, 15.31 and 13.32 %, respectively. The ordination analysis showed that the elevation and soil moisture content were the important factors for determining tree distribution across the forest ecotone. High elevation is dominated by the species of lower montane forest (LMF); in contrast, low elevation and low soil moisture content sites are occupied by the deciduous dipterocarp forest (DDF). In addition, high moisture content was found along the forest ecotone which facilitated the coexistence of species from both LMF and DDF such as *Dipterocarpus obtusifolius, Wendlandia paniculata, Castanopsis tribuloides* and *Litsea martabanica* etc. They can be used as indicator species of environmental change, especially for drought conditions. The drought ecosystem may be shifted to high elevation as these areas are faced with global climate warming.

Keywords: Tree distribution, Forest ecotone, Deciduous dipterocarp forest, Montane forest, Doi Suthep-Pui

INTRODUCTION

The mountain ecosystem is the most fragile due to steep slopes, climatic conditions and sensitivity to human disturbances (Office of Natural Resources and Environmental Policy and Planning, 2009; Marod *et al*., 2012). There is a strong relationship between highland and lowland areas in terms of water resources and soil properties (Santisuk, 2003). In addition, a mountain ecosystem has unique environmental factors supporting high numbers of endemic flora and fauna species, especially climatic factors. Thus, it very difficult to restore when it becomes degraded, especially where there is high susceptibility to environmental changes. The impact of global warming may easily be the greatest change affecting the biological diversity of this ecosystem.

Moderated natural change may occur in mountain ecosystems, for instance, a gap created by a tree falling down (Odum, 1913; Turner, 2004), and micro-climatic changes along the forest edge or ecotone (Kremsater and Bunnell, 1999; Asanok *et al*., 2012). The forest edge or ecotone between the forest and surrounding open area can be considered as a buffer zone for important forests, (Kapos, 1989; Laurance *et al*., 1998). Microclimatic variables (light intensity and duration, relative humidity and air temperature) and soil factors (pH, organic carbon, total nitrogen, available phosphorus, soil moisture and temperature) vary along the ecotone (Williams-Linera *et al*., 1998), influencing the vegetation structure and species composition (Benitez-Malvido and Martinez-Ramos, 2003; Cagnolo *et al*.,

2006; Zhang and Zhang, 2011). In general, light requirement is the major trait in the tropics that has been used to classify forest tree species into two ecological groups: light demanding (or pioneer) species and shade-tolerant (or late-succession) species (Swaine and Whitmore, 1988). Usually, pioneer species are more abundant along the forest edges than shade-tolerant species (Marod *et al*., 2004), due to germination stimulated by light exposure (Aide and Cavelier, 1994). Identifying common life-history traits that affect the sensitivity of species to environmental change is very important for developing conservation programs. Thus, this study aimed to clarify the tree species composition and to determine environmental factors influencing the tree distribution along the forest ecotone between deciduous dipterocarp forest and lower montane forest in Doi Suthep-Pui National park, Chiang Mai province.

MATERIALS AND METHODS

Data Collection

The study was conducted along a forest ecotone between the deciduous dipterocarp forest (DDF) and lower montane forest (LMF) at Doi Suthep-Pui National Park, Chiang Mai province during 2014. A permanent transect plot, 30 m × 600 m, was established ranging from 900 to 1,100 m above mean sea level (asl) and covered both DDF and LMF. The transect plot was divided into 180 subplots of 10x10 size. All tree species with diameter at breast height

(DBH) larger than 1 cm were tagged; DBH was measured, and identified. In addition, the elevation (ELV) and soil moisture content (SMC) factors were recorded in every subplot using an altimeter and soil moisture sensors (User's Manual version 10; Decagon Devices), respectively.

Data Analysis

The importance value index (IVI) was used to evaluate the dominant species in the area. It was calculated as the sum of the relative density, relative dominance in basal area and relative frequency (Whittaker, 1975). A species with a higher IVI value indicates greater dominance of the site (Parrotta *et al.*, 1997).

A vegetation data matrix of the "trees" category (presence/absence using the IVI of each species), comprising 60 stands (one row equal 3 subplots which were combined into a stand) was constructed (Kent and Coker, 1992; Jongman *et al.*, 1995) to evaluate the species distribution in the multidimensional space represented by the various environmental parameters (ELV and SMC). Ordination analysis based on canonical correspondence analysis (CCA) was conducted, using the program PC-ORD, version 6.08 (McCune and Mefford, 2011) to determine the importance of the environmental factors.

RESULTS AND DISCUSSION

Vegetation structure and species composition

There were 3,846.32 tagged trees (DBH $\geq$ 1 cm) across the forest ecotone of DDF and LMF in 192 species, 126 genera and 56 families. The tree density and basal area with DBH $\geq$ 4.5 cm were 1,220 individual.ha^{-1} and 28.60 m².ha^{-1}, respectively. *Dipterocarpus obtusifolius* had the highest basal area cover (5.45 m².ha^{-1}) followed by *Quercus brandisiana* (4.44 m².ha^{-1}), *Castanopsis tribuloides* (3.71 m².ha^{-1}), *Shorea obtusa* (2.64 m².ha^{-1}) and *Schima wallichii* (1.99 m².ha^{-1}), respectively, indicating these species were the large-sized trees and had high potential to be parent trees. The dominant families based on species number in the Fagaceae, Phyllanthaceae, Fabaceae, Rubiaceae and Lauraceae with species numbers of 15, 12, 10, 8 and 7, respectively (Figure 1). The dominant tree species based on IVI were *Quercus brandisiana*, *Dipterocarpus obtusifolius, Schima wallichii*, *Wendlandia paniculata*, *Litsea martabanica*, *Castanopsis tribuloides, Lithocarpus garrettianus*, *Dipterocarpus tuberculatus* and *Castanopsis armata* with IVI values of 31.52, 18.40, 15.34, 15.31, 13.32, 12.88, 10.45, 9.30, 8.87 and 8.33%, respectively (Appendix 1). The dominant families across the forest ecotone, especially in LMF were similar to those reported by Jingjai (2014) who studied undisturbed LMF, indicating that that area had had little anthropogenic disturbance even though it was close to a settlement.
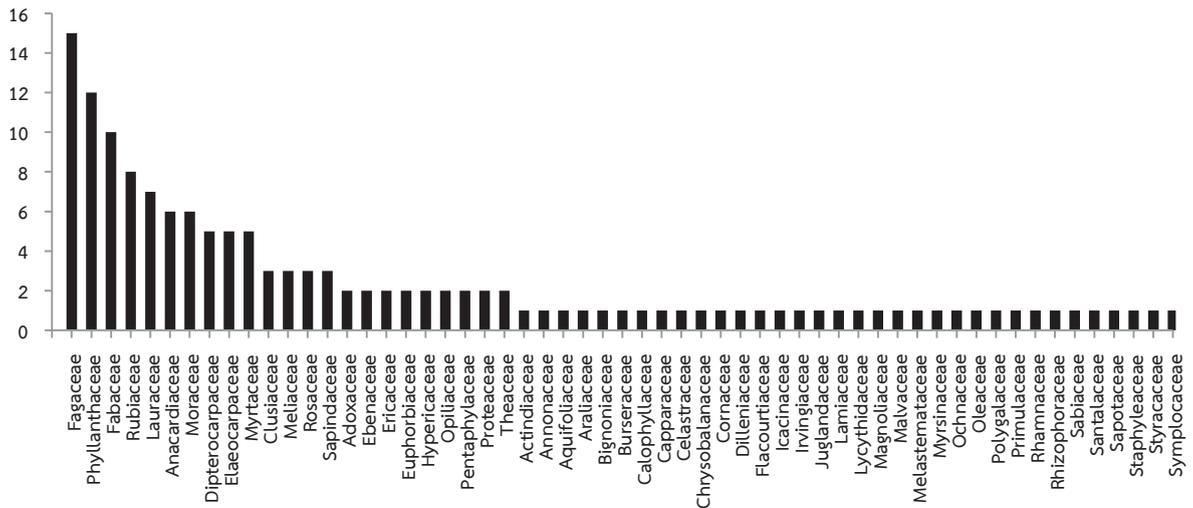
Figure 1 Species number in each family across the forest ecotones of DDF and LMF.

Factors determining tree distribution across forest ecotone

The CCA ordination analysis of the "trees" category found a high species-environment correlation using the Pearson correlation statistic (r=0.96). The environmental factors, ELV (r=0.98) and SMC (r=0.86), had negative correlations. According to Axis1, the the tree distribution can be divided into three groups (Figure 2).

Group 1 was composed of 18 Stands (ST42-60) and the main determining factor was ELV above 985 m asl. Dominant trees were mainly from LMF and included *Apodytes dimidiata* (Apodydim), *Aporosa octandra* (Aporooct), *Castanopsis acuminatissima* (Castaacu), *Cinnamomum iners* (Cinnaine), *Choerospondias axillaris* (Choeraxi), *Chukrasia tabularis* (Chukrtab), *Diospyros vera* (Diospver), *Elaeocarpus floribundus* (Elaeoflo), *Eriobotrya bengalensis* (Eriobben), *Gluta glabra* (Glutagla), *Heliciopsis terminalis* (Helicte), *Castanopsis diversifolia* (Castadiv)

and *Lithocarpus mekongensis* (Lithomek)

Group 2 was composed of 17 Stands (ST24-41) and the main determining factor was high SMC, approximately above 22%. Coexisting species from DDF and LMF were found in this area such as from DDF—*Canarium subulatum* (Canarsub), *Dipterocarpus obtusifolius* (Dipteobt), *Shorea roxburghii* (Shorearox), *Spondias pinnata* (Spondpin), *Symplocos racemosa* (Symplrac) and *Wendlandia paniculata* (Wenlpan)—and from LMF—*Antidesma sootepense* (Antidsoo), *Castanopsis tribuloides* (Castatri) *Helicia nilagirica* (Helicnil), *Lithocarpus garrettianus* (Lithogar), *Litsea martabarnica* (Litsemar), *Magnolia baillonii* (Magnobal), *Phoebe lanceolata* (Phoeblan), *Rothmannia sootepensis* (Rothmsoo), *Semecarpus cochinchinensis* (Semecalb), *Tarennoidea wallichii* (Tarenwal) and *Turpinia pomifera* (Turpiporn).

Group 3 was composed of 23 Stands (ST 1-23) and the main determining factor was low ELV (lower than 917 m asl), and SMC (less

than 4.5%). Dominant trees were mainly from the DDF including *Aporosa villosa* (Aporovil), *Anneslea fragrans* (Annestra), *Archidendron clypearia* (Archicly), *Dalbergia cultrata* (Dalbecul), *Dalbergia dongnaiensis* (Dalbedon), *Dipterocarpus tuberculatus* (Diptetub), *Dillenia* *obovata* (Dilleobo), *Elaeocarpus serratus* (Elaeose), *Gardenia sootepensis* (Gardesoo), *Gluta laccifera* (Glutalac), *Quercus kerrii* (Quercker), *Lithocarpus polystachyus* (Lithopol), *Shorea obtusa* (Shoreaob), *Syzygium claviflorum* (Syzygcla), and *Vitex peduncularis* (Vitexped).
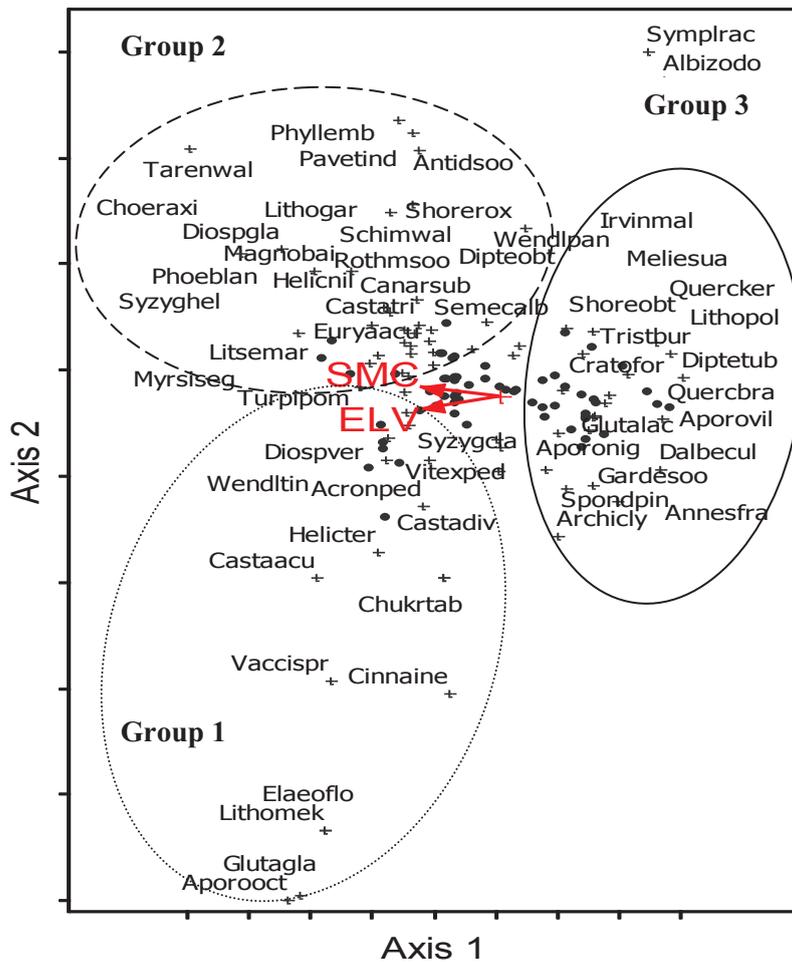

Figure 2 Two-dimensional simplified CCA ordination of tree species (capital abbreviations, see Appendix 1) assemblages on environmental gradients (ELV and SMC) across forest ecotone. Closed dots and (+) symbols indicated the stands and existing species coordination, respectively.

This study found that high elevation or altitude influenced the tree distribution across the forest ecotone between DDF and LMF. Many researchers have reported that LMF was distributed at elevations above 1,000 m asl. (Aksornkaoe and Bonyawat, 1977; Leowanawat, 1982; Marod *et al*., 2014 and Nakornsri, 1985). However, the vegetation cover varied due to the

altitudinal gradient. In addition, the gradient of SMC was also important for tree distribution. The soil properties and organic matter on the forest floor were important factors supporting high SMC, especially in LMF where a higher SMC was found than in DDF (Asanok *et al.*, 2012; Marod *et al.*, 2014). These environmental factors facilitated the tree distribution of LMF, especially for species in the families Fagaceae, Lauraceae and Theaceae (Kanzaki *et al.* 2004; Santisuk, 2012). Coexisting species of LMF and DDF was found in the Group 2 and can be classified as a forest ecotone. This area facilitated a suitable environment-soil moisture content, temperature and light intensity, etc-for supporting tree establishment. Thus, high plant diversity was mainly found along the forest ecotone (Hermhuk *et al.*, 2013; Teejuntuk *et al.*, 2002). In addition, Group 3 can be classified as DDF where a low EVL and SMC were found. Here, more deciduous species had established in the area than evergreen species because the former can adapt well to drought conditions (Marod *et al.*, 2014).

Recently, climate change has become a hot issue globally and may influence species diversity, especially in mountain ecosystems. Meteorological Department of Thailand, (2010) analyzed the climatic data of Doi Suthep-Pui, Chiang Mai province from 1975 to 2009 based on the Providing Regional Climate for Impact Studies (PRECIS) model and indicated that the area was in crisis due to climate change with a shortage of rainfall and expanded drought areas. The changes may cause biodiversity loss (Bakkenes *et al.*, 2002), especially, with species that prefer high moisture

conditions as in forest ecotone area Group 2. As a result, evergreen species from LMF such as *Castanopsis tribuloides*, *Lithocarpus garrettianus*, *Anneslea fragrans*, and *Shima wallichii* may be replaced by deciduous species from DDF such as *Dipterocarpus obtusifolius*, *Wendlandia paniculata*, *Shorea roxburghii*, *Tristaniopsis burmanica*, and *Craibiodendron stellatum*. Therefore, the moist ecosystem may shift to a drought ecosystem where deciduous species can become established at upper altitudes (Amedie, 2013). Thus, these species can be classified as indicator species to detect climate change, in particular at the seedling stage during which individuals are high susceptible to environmental changes (Hermhuk *et al*, 2014).

CONCLUSION

The vegetation structure and species composition along the forest ecotone of DDF and LMF at Doi Suthep-Pui National Park were strongly determined by elevation and soil moisture content factors (Pearson correlation, Species-Environment, $r = 0.96$). Three groups based on their relationships were found: 1) LMF was determined by high ELV which mainly comprised evergreen species from the families Fagaceae and Lauraceae, 2) forest ecotone stand was determined by high SMC with medium ELV and coexisting species of *Dipterocarpus obtusifolius*, *Wendlandia paniculata*, *Shorea roxburghii*, *Castanopsis tribuloides*, *Lithocarpus garrettianus*, *Schima wallichii,* and *Eurya acuminata* etc., and 3) DDF was determined by low ELV and SMC

with mainly deciduous species from the families Dipterocarpaceae, Fagaceae, Rubiaceae and Fabaceae; such as *Dipterocarpus tuberculatus*, *Quercus kerrii*, *Lithocarpus polystachyus* and *Dalbergia cultrate.*

The species which had high potential to indicate climate change were *Dipterocarpus obtusifolius*, *Wendlandia paniculata* and *Shorea roxburghii* based on their high adaptation to drought. The species *Castanopsis tribuloides*, *Lithocarpus garrettianus*, *Michelia floribunda, Schima wallichii, Litsea martabarnica* and *Eurya acuminata* were susceptible to climate change.

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Appendix 1 Species list based on IVI of tree along Forest ecotone between DDF and LMF at Doi Suthep-Pui, Chiang Mai Province.

Botanical name	Family	Abbreviation	Basal areas (m²)	Density (tree/1Ha)	RD (%)	Rdo (%)	RF (%)	IVI (%)
Quercus brandisiana Kurz	FAGACEAE	Quercbra	4.18	137.37	11.26	14.62	5.64	31.52
Dipterocarpus obtusifolius Teijsm. ex Miq.	DIPTEROCARPACEAE	Dipterobt	3.11	47.37	3.88	10.88	3.64	18.40
Schima wallichii (DC.) Korth.	THEACEAE	Schimwal	2.73	30.00	2.46	9.54	3.34	15.34
Wendlandia paniculata (Roxb.) DC.	RUBIACEAE	Wendlpan	0.59	95.26	7.81	2.08	5.42	15.31
Litsea martabarnica (Kurz) Hook. f.	LAURACEAE	Litsemar	0.48	82.11	6.73	1.69	4.90	13.32
Castanopsis tribuloides (Sm.) A. DC.	FAGACEAE	Castatri	2.11	40.00	3.28	7.38	2.23	12.88
Lithocarpus garrettianus (Craib) A. Camus	FAGACEAE	Lithogar	0.68	64.21	5.26	2.36	2.82	10.45
Shorea obtusa Wall. ex Blume	DIPTEROCARPACEAE	Shoreobt	1.44	24.21	1.98	5.03	2.38	9.39
Dipterocarpus tuberculatus Roxb.	DIPTEROCARPACEAE	Diptetub	1.16	30.00	2.46	4.04	2.38	8.87
Castanopsis armata (Roxb.) Spach	FAGACEAE	Castanarm	0.91	31.05	2.55	3.19	2.60	8.33
Castanopsis acuminatissima (Blume) A. DC.	FAGACEAE	Castaacu	0.90	38.95	3.19	3.16	1.78	8.13
Syzygium claviflorum (Roxb.) Wall	MYRTACEAE	Syzygcla	1.00	24.74	2.03	3.48	2.52	8.03
Aporosa nigricans Hook. f.	PHYLLANTHACEAE	Aporonig	0.21	36.32	2.98	0.72	3.19	6.89
Myrsine seguinii H. Lév.	PRIMULACEAE	Myrsiseg	0.45	23.16	1.90	1.57	2.52	5.99
Anneslea fragrans Wall.	PENTAPHYLACACEAE	Annesfra	0.63	18.95	1.55	2.19	1.71	5.45
Rothmannia sootepensis (Craib) Bremek.	RUBIACEAE	Rothmsoo	0.21	24.74	2.03	0.75	2.60	5.38
Tarennoidea wallichii (Hook. f.) Tirveng. & Sastre.	RUBIACEAE	Tarenwal	0.38	21.58	1.77	1.34	2.15	5.26
Lithocarpus dealbatus Rehder	FAGACEAE	Lithodea	0.42	20.53	1.68	1.47	1.78	4.94
Aporosa villosa (Wall. ex Lindl.) Baill.	PHYLLANTHACEAE	Aporovil	0.15	24.21	1.98	0.51	1.78	4.27
Vitex peduncularis Wall. ex Schauer	LAMIACEAE	Vitexped	0.35	14.74	1.21	1.21	1.86	4.27
Tristaniopsis burmanica var. *rufescens* (Hance)	MYRTACEAE	Tristbur	0.32	19.47	1.60	1.11	1.56	4.26
Scleropyrum pentandrum (Dennst.) Mabb.	SANTALACEAE	Sclerpen	0.21	17.89	1.47	0.73	1.78	3.98
Gluta laccifera (Pierre) Ding Hou	ANACARDIACEAE	Glutalac	0.28	13.68	1.12	0.99	1.41	3.52
Magnolia baillonii Pierre	MAGNOLIACEAE	Magnobai	0.20	13.16	1.08	0.71	1.63	3.42
Persea gamblei (Hook. f.) Kosterm.	LAURACEAE	Persegam	0.13	15.26	1.25	0.46	1.63	3.35
Quercus oidocarpa Korth.	FAGACEAE	Quercoid	0.25	13.68	1.12	0.89	1.04	3.05
Semecarpus cochinchinensis Engl.	ANACARDIACEAE	Semecalb	0.20	12.11	0.99	0.71	1.26	2.97
Canarium subulatum Guillaumin	BURSERACEAE	Canarsub	0.38	8.95	0.73	1.31	0.89	2.94
Phoebe lanceolata (Nees) Nees	LAURACEAE	Phoeblan	0.10	13.16	1.08	0.34	1.26	2.68
Others (112 species)			4.45	263.16	21.57	15.54	30.29	67.40
			28.60	1220	100	100	100	300

Remarks: RD = Relative Density; RDo = Relative Dominance; RF = Relative Frequency; IVI = Importance Value Index