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Original article

Influences of Environmental Factors on Tree Distribution of Lower Montane Evergreen Forest at Doi Sutep-Pui National Park, Chiang Mai Province

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ABSTRACT

The influences of environmental factors on tree distribution of lower montane evergreen forest were studied at Doi Sutep-Pui National Park, Chiang Mai province during October 2012. The objective aimed to clarify the principal environmental factors affecting tree distribution. Temporary plots, 20 × 50 m, were established based on altitudinal gradient from 900 to 1,600 m above mean sea level, total 63 plots. All trees with diameter at breast height over than 4.5 cm were measured and identified, and in addition, soil samples were collected in every plot.

The results showed that there were 299 tree species in 181 genera and 87 families. Tree density was 102.82 trees/ 0.1 ha and basal area was 174.11 m^2/0.1 ha. The dominant trees based on importance value index, IVI, were *Castanopsis acuminatissima*, *Schima wallichii*, *Castanopsis armata*, *Pinus kesiya*, *Helicia nilagirica* and *Styrax benzoides* with IVI of 30.28, 16.07, 13.02, 11.06, 7.41 and 7.07 %, respectively.

The ordination analysis showed that the environmental factor that determined the distribution of Oaks with Pine stand was high altitude. Soil properties, especially percentage of clay, determined tree distribution of montane evergreen forest; the most species were *Castanopsis acuminatissima*, *Castanopsis tribuloides*, *Styrax benzoides*, *Eurya acuminata* var. *acuminata, Magnolia baillonii* and *Schima wallichii*. Thus, for reforestation of degraded montane evergreen forest, these species should be considered in order to reduce the succesional time to the climax stage.

Keywords: Ecological niche, Montane evergreen forest, Doi Sutep-Pui, Tree distribution, Reforestation

INTRODUCTION

Nowadays, much importance is given to preserving various ecosystems globally, in hope of their continuing existence. The loss of natural resources, the deterioration of ecosystems (both structure and functionality), and the loss of biodiversity have occurred consecutively for a long period of time, especially global warming that influences the rise of temperature around the world (Office of Natural Resources and Environmental Policy and Planning, 2010).

Mountain ecosystems cover about 27% of the earth (Office of Natural Resources and Environmental Policy and Planning, 2009), and is a system of relationships among living and non-living components in mountains where both flora and fauna are complex, and vary according to height, rock, soil, climate and anthropogenic activities. In Thailand, mountain ecosystems are found scattered at elevations 1,000 meters above sea level (m asl.) and higher (Santisuk, 2003). The ecosystems are considered to be fragile and under threatened. Many mountainous areas are of high biological diversity, but some of them were classified as biodiversity hotspot areas due to severe threat (Uttanavanit, 2011). Disturbances lead to high risk of local extinction and they are hard to restore. Therefore, conservation should be promoted to prevent loss of ecological balance and eventual extinction of endemic and endangered species. Moreover, in mountain ecosystems, there are relationships between higher elevation areas and lower plains in water resources and soil aspects. Thus, locals, especially, have to adapt their lifestyles to conserve and harness on ecosystems for maintaining the biological resources and future food security.

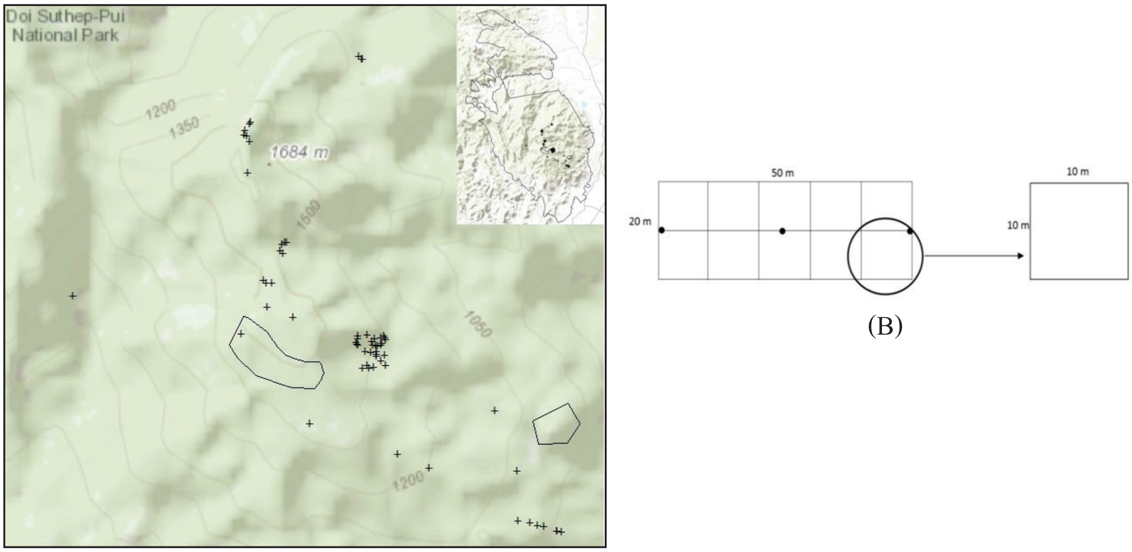
Montane evergreen forest (MEF) can only been found in mountain ecosystems. It occupies area at elevation 1,000 m asl. or higher. Many are found in the northern part of Thailand (Ruangpanit, 1991) where the climate is colder or lower temperature persists longer than at lower plains. Such conditions are suitable for various kinds of trees of temperate climate to grow. Almost year-round high humidity results in fertile soil with high permeability, deep and able to absorb much water. This results in great plant diversity in both species and genetics. Many flora and fauna are specific to MEF. Tree distributions in the MEF not only depend on elevation, other environmental factors, especially soil properties, are also crucial. However, not many studies have been done on the relationships between tree distributions and soil properties in Thailand.

Most plant communities in the Doi Sutep-Pui mountain ecosystem are covered with lower MEF, both undisturbed and degraded forest, ranged from 1,000-1,650 m asl. (Sutthipibul, 2010). Therefore, before restoring degraded MEF, it is essential to study the ecological niche of trees in nature where the tree distributions are different due to anthropogenic activities. This study aimed to clarify the environmental factors that affect tree distribution in lower MEF. Results from this study will be applied to select suitable tree species for highland forest restoration.

MATERIALS AND METHODS

Data Collection

Temporary plots, 20 × 50 m, were established based on altitudinal gradient from 900 to 1,600 m asl. Plots were spread throughout both undisturbed and degraded forests, total 63 plots (FIGURE 1). Each plot was divided into 10 × 10 m subplots and all



(A)

Figure 1 Distribution of sample plots (+) at Doi Sutep-Pui National Park, Chiang Mai province (A). Sample plot, 20 × 50 m, was divided into subplots of 10×10 m (B) and black dots (●) were the soil sample positions.

trees with diameter at breast height (DBH) at least 4.5 cm were measured and identified. The elevation was recorded and soil samples (0-15 cm deep) were collected (at least 500 g) in every plot. Soil properties, including soil pH, soil texture (percentage of sand, silt and clay, respectively), amount of organic matter, available phosphorus, exchangeable potassium, exchangeable calcium and exchangeable magnesium, were analyzed. Tests were done in the soils laboratory of the Department of Soil Science, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand.

Data Analysis

1. Ordination analysis was done using the Canonical Correspondence Analysis (CCA) method and a prefabricated program PC-ORD version 6.08 (McCune and Mefford, 2011). The analysis examined the relationships between environmental factors, elevation and soil properties, and tree distributions in lower MEF.

2. Soil properties were evaluated in the laboratory. For pH analysis, the ratio of soil: water used is 1:1 and measured with a pH meter. Soil texture was analyzed using a hydrometer (modified). The amount of organic matter in the soil was determined using Walkley and Black's Rapid Titration, a wet oxidation method. Available phosphorus was determined using Bray's II (modified) method. Exchangeable K, exchangeable Ca and exchangeable Mg were measured using NNH_4OAc atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

The results showed that 299 species in 181 genera and 87 families of trees were found in the study area. The tree density was 102.82 trees/0.1 ha and basal area was

174.11 m^2/0.1 ha. The top ten dominant tree species based on importance value index (IVI) were *Castanopsis acuminatissima*, *Schima wallichii*, *Castanopsis armata*, *Pinus kesiya*, *Helicia nilagirica*, *Styrax benzoides*, *Wendlandia tinctoria*, *Vernonia volkameriiolia*, *Castanopsis tribuloides* and *Litsea martabanica* with IVI of 30.28, 16.07, 13.02, 11.06, 7.41, 7.07, 6.89, 6.17, 5.34 and 5.20 %, respectively (APPENDIX 1).

The ordination analysis using the CCA method based on 63 plots and several environmental factors, including pH, percentage of sand, percentage of silt, percentage of clay, amount of organic matter, available phosphorus, exchangeable potassium, exchangeable calcium and exchangeable magnesium, resulted in the separation of the tree distribution into 4 groups (Pearson correlation, Species-Environment, r = 0.937) (FIGURE 2). The information of each group was as follows:

Group 1: The main factors determining this group, which included 6 plots, were high elevation (elev) above 1,500 m asl., and organic matter (organ) in the soil. Dominant trees were *Pinus kesiya* (PINUSKES), *Vaccinium sprengelii* (VACCISPR), *Castanopsis diversifolia* (CASTADIV), *Engelhardtia spicata* (ENGELSPI), *Alseodaphne birmanica* (ALSEOBIR) and *Turpinia pomifera* (TURPIPOM).

Group 2: The main factors determining this group, which included 12 plots, were acidity and alkalinity (pH) of the soil, exchangeable Ca (Ca), available P (P), percentage of sand (% sand) and percentage of silt (% silt). Soil pH ranged from 5.3-5.8, while exchangeable Ca and available P were classified into low-medium level (240 - 2,228 mg/kg). Soil texture was sandy loam with percentage of sand and silt of 53-67 % and 18-32 %, respectively. Dominant trees were *Litchi chinensis* (LITCHCHI), *Betula alnoides* (BETULALN), *Prunus cerasoides* (PRUNUCER), *Alangium* sp. (ALANGSP), *Vernonia volkameriiolia* (VERNOVOL), *Saurauia roxburghii* (SAURAROX), *Diospyros glandulosa* (DIOSPGLA), *Erythrina subumbrans* (ERYTHSUB), *Saurauia nepaulensis* (SAURANEP), *Cinnamomum porrectum* (CINNAPOR) and *Dimocarpuslongan* subsp. *longan* var. *longan* (DIMOCLON).

Group 3: Tree distribution of this group, which included 37 plots, was determined by the percentage of clay (% clay). Dominant tree species were *Castanopsis acuminatissima* (CASTAACU), *Castanopsis armata* (CASTAARM), *Castanopsis tribuloides* (CASTATRI), *Schima wallichii* (SCHIMWAL), *Eurya acuminata* (EURYAACU), *Magnolia baillonii* (MAGNOBAI), HELICNIL (*Helicia nilagirica*), *Wendlandia tinctoria* (WENDLTIN), *Styrax benzoides* (STYRABEN), *Litsea martabanica* (LITSEMAR), *Lithocarpus truncata* (LITHOTRU), *Persea gamblei* (PERSEGAM), *Aporosa octandra* (APOROOCT), *Choerospondias axillaris* (CHOERAXI), *Symplocos macrophylla* (SYMPLMAC), *Bridelia glauca* (BRIDEGLA) and *Cinnamomum iners* (CINNAINE).

Group 4: The distribution of trees in this group were determined by low elevation from sea level and organic matter in soil, and included eight plots. Dominant trees were *Quercus kerrii* (QUERCKER), *Dipterocarpus tuberculatus* (DIPTETUB), *Wendlandia paniculata* (WENDLPAN), *Dipterocarpus obtusifolius* (DIPTEOBT), *Quercus brandisiana* (QUERCBRA), *Lithocarpus polystachyus* (LITHOPOL), *Gardenia sootepensis* (GARDESOO), *Tristaniopsis burmanica* (TRISTBUR) and *Aporosa villosa* (APOROVIL).

Appendix 1 Species list of trees at Doi Sutep-Pui, Chiang Mai province

Species	Botanical Name	Family	Abbreviation	Basal areas (m^2)	Density (tree/0.1ha)	RDo (%)	RD (%)	RF (%)	IVI (%)
ก่อเดือย	*Castanopsis acuminatissima* (Blume) A.DC.	FAGACEAE	CASTAACU	25.322	0.014	14.544	13.166	2.574	30.284
ทะโล้	*Schima wallichii* (DC.) Korth.	THEACEAE	SCHIMWAL	16.621	0.004	9.547	3.462	3.064	16.072
ก่อหรั่ง	*Castanopsis armata* Spach	FAGACEAE	CASTAARM	11.353	0.004	6.521	3.925	2.574	13.019
สนสามใบ	*Pinus kesiya* Royle ex Gordon	PINACEAE	PINUSKES	14.308	0.002	8.218	2.163	0.674	11.055
เหมือดคนตัวผู้	*Helicia nilagirica* Bedd.	PROTEACEAE	HELICNIL	3.064	0.003	1.760	3.384	2.267	7.411
กำยาน	*Styrax benzoides* Craib	STYRACACEAE	STYRABEN	2.197	0.004	1.262	3.724	2.083	7.070
แข้งกวาง	*Wendlandia tinctoria* (Roxb.) DC.	RUBIACEAE	WENDLTIN	2.230	0.004	1.281	3.771	1.838	6.889
ยาแก้	*Vernonia volkameriiolia* Wall. ex DC.	ASTERACEAE	VERNOVOL	1.429	0.004	0.821	4.002	1.348	6.171
ก่อใบเลื่อม	*Castanopsis tribuloides* (Sm.) A.DC.	FAGACEAE	CASTATRI	4.951	0.001	2.844	1.267	1.225	5.336
เมียดต้น	*Litsea martabanica* (Kurz) Hook.f.	ASTERACEAE	LITSEMAR	1.815	0.002	1.042	2.380	1.777	5.199
ก่อดำ	*Lithocarpus truncatus* (King) Rehder & Wilson	FAGACEAE	LITHOTRU	4.535	0.001	2.605	1.267	1.164	5.036
อินทวา	*Persea gamblei* (Hook.f.) Kosterm.	LAURACEAE	PERSEGAM	2.022	0.002	1.161	1.854	1.900	4.915
ก่อแป้น	*Castanopsis diversifolia* (Kurz) King et Hook.f.	FAGACEAE	CASTADIV	3.044	0.002	1.749	2.364	0.551	4.664
จำปีป่า	*Magnolia baillonii* (Pierre) Finet & Gagnep.	MAGNOLIACEAE	MAGNOBAI	2.727	0.001	1.566	0.819	2.083	4.469
ปลายสาน	*Eurya acuminata DC.* var. *acuminata*	THEACEAE	EURYAACU	0.792	0.002	0.455	1.994	1.777	4.225
มะกอกพราน	*Turpinia pomifera* (Roxb.) DC.	STAPHYLEACEAE	TURPIPOM	1.314	0.002	0.755	1.824	1.348	3.926
ส้านเห็บ	*Saurauia roxburghii* Wall.	ACTINIDIACEAE	SAURAROX	0.614	0.002	0.353	1.978	1.164	3.495
ก่อตาควาย	*Quercus brandisiana* Kurz	FAGACEAE	QUERCBRA	2.389	0.002	1.372	1.468	0.306	3.147
หว้าเขา	*Cleistocalyx operculatus* (Roxb.) Merr. & L.M.Perry var. *operculatus*	MYRTACEAE	CLEISOPE	2.513	0.001	1.443	0.572	0.797	2.811

Appendix 1 (continued)

Species	Botanical Name	Family	Abbreviation	Basal areas (m^2)	Density (tree/0.1ha)	RDo (%)	RD (%)	RF (%)	IVI (%)
ส้มปี้	*Vaccinium sprengelii* (G.Don) Sleumer	ERICACEAE	VACCISPR	1.061	0.001	0.610	1.236	0.919	2.765
เชียด	*Cinnamomum iners* Reinw. ex Blume	LAURACEAE	CINNAINE	1.380	0.001	0.792	0.896	1.042	2.730
กล้วยฤาษี	*Diospyros glandulosa* Lace	EBENACEAE	DIOSPGLA	0.613	0.001	0.352	0.757	1.593	2.702
ทองหลางป่า	*Erythrina subumbrans* (Hassk.) Merr.	FABACEAE	ERYTHSUB	1.833	0.001	1.053	0.665	0.980	2.698
หว้าหิน	*Syzygium claviflorum* (Roxb.) a.M.Cowan & Cowan	MYRTACEAE	SYZYGCLA	1.373	0.001	0.788	0.587	1.103	2.479
นวลเสี้ยน	*Aporosa octandra* (Buch.-Ham ex D.Don) Vickery	PHYLLANTHACEAE	APOROOCT	0.671	0.001	0.386	1.051	1.042	2.478
สารภีดอย	*Anneslea fragrans* Wall.	THEACEAE	ANNESFRA	1.348	0.001	0.774	0.943	0.674	2.391
มุ่นดง	*Elaeocarpus sphaericus* (Gaertn.) K.Schum.	ELAEOCARPACEAE	ELAEOSPH	1.548	0.001	0.889	0.556	0.919	2.364
มะมือ	*Choerospondias axillaris* (Roxb.) B.L.Burtt & Hill	ANACARDIACEAE	CHOERAXI	1.905	0.000	1.094	0.340	0.919	2.353
กะทังใบใหญ่	*Litsea grandis* (Wall. ex Nees) Hook.f.	LAURACEAE	LITSEGRA	1.935	0.000	1.111	0.371	0.797	2.279
นางพญาเสือโคร่ง	*Prunus cerasoides* D.Don	ROSACEAE	PRUNUCER	1.223	0.001	0.703	0.927	0.551	2.181
มะขามแป	*Archidendron clypearia* (Jack) I.C. Nielsen	FABACEAE	ARCHICLY	0.399	0.001	0.229	0.618	1.287	2.134
ค่าหด	*Engelhardtia spicata* Blume	JUGLANGDACEAE	ENGELSPI	1.106	0.001	0.635	0.541	0.919	2.095
เหมือดดอย	*Symplocos macrophylla* Wall. ex DC.	SYMPLOCACEAE	SYMPLMAC	0.332	0.001	0.191	0.742	1.103	2.036
แข้งกวางดง	*Wendlandia paniculata* (Roxb.) DC.	RUBIACEAE	WENDLPAN	0.454	0.001	0.261	1.375	0.306	1.943
กะอวม	*Acronychia pedunculata* (L.) Miq.	RUTACEAE	ACRONPED	1.160	0.001	0.666	0.587	0.674	1.928

Appendix 1 (continued)

Species	Botanical Name	Family	Abbreviation	Basal areas (m^2)	Density (tree/0.1ha)	RDo (%)	RD (%)	RF (%)	IVI (%)
ลิ้นจี่	*Litchi chinensis* Sonn.	SAPINDACEAE	LITCHCHI	1.268	0.001	0.729	0.850	0.245	1.824
ยางเหียง	*Dipterocarpus obtusifolius* Teijsm. ex Miq.	DIPTEROCARPACEAE	DIPTEOBT	2.067	0.000	1.187	0.340	0.245	1.772
สิวาละที	*Bridelia glauca* Blume	PHYLLANTHACEAE	BRIDEGLA	0.269	0.001	0.155	0.525	1.042	1.722
กำลังเสือโคร่ง	*Betula alnoides* Buch.-Ham. ex G.Don	BETULACEAE	BETULALN	1.388	0.001	0.797	0.525	0.306	1.629
ยางพลวง	*Dipterocarpus tuberculatus* Roxb.	DIPTEROCARPACEAE	DIPTETUB	1.554	0.000	0.892	0.433	0.184	1.509
ขมิ้นต้น	*Alseodaphne birmanica* Kostern	LAURACEAE	ALSEOBIR	0.390	0.001	0.224	0.711	0.429	1.364
หม่อนหิน	*Alangium* sp.	ALANGIACEAE	ALANGSP	0.622	0.000	0.357	0.247	0.551	1.156
ก่อแพะ	*Quercus kerrii* Craib	FAGACEAE	QUERCKER	0.067	0.000	0.038	0.108	0.061	0.208
ช้าส้าน	*Saurauia nepaulensis* DC.	ACTINIDIACEAE	SAURANEP	0.194	0.000	0.111	0.448	0.245	0.805
เทพทาโร	*Cinnamomum porrectum* (Roxb.) Kosterm.	LAURACEAE	CINNAPOR	0.009	0.000	0.005	0.015	0.061	0.082
ลำไย	*Dimocarpus longan* Lour. subsp. *longan* var. *longan*	SAPINDACEAE	DIMOCLON	0.100	0.000	0.057	0.077	0.123	0.257
ก่อนก	*Lithocarpus polystachyus* (A.DC.) Rehder	FAGACEAE	LITHOPOL	0.002	0.000	0.001	0.015	0.061	0.078
คำมอกหลวง	*Gardenia sootepensis* Hutch.	RUBIACEAE	GARDESOO	0.005	0.000	0.003	0.015	0.061	0.080
เหมือดโลด	*Aporosa villosa* (Wall. ex Lindl.) Baill.	PHYLLANTHACEAE	APOROVIL	0.201	0.000	0.116	0.371	0.245	0.732
ก้าว	*Tristaniopsis burmanica* (Griff.) Peter G.Wilson & J.T.Waterh. var. *rufescens* (Hance) J.Parn. & Nic Lughadha	MYRTACEAE	TRISTBUR	0.235	0.000	0.135	0.294	0.245	0.674
Others (249 species)				44.155	0.028	25.361	27.446	50.551	103.358
	Total			174.107	0.103	100.000	100.000	100.000	300.000

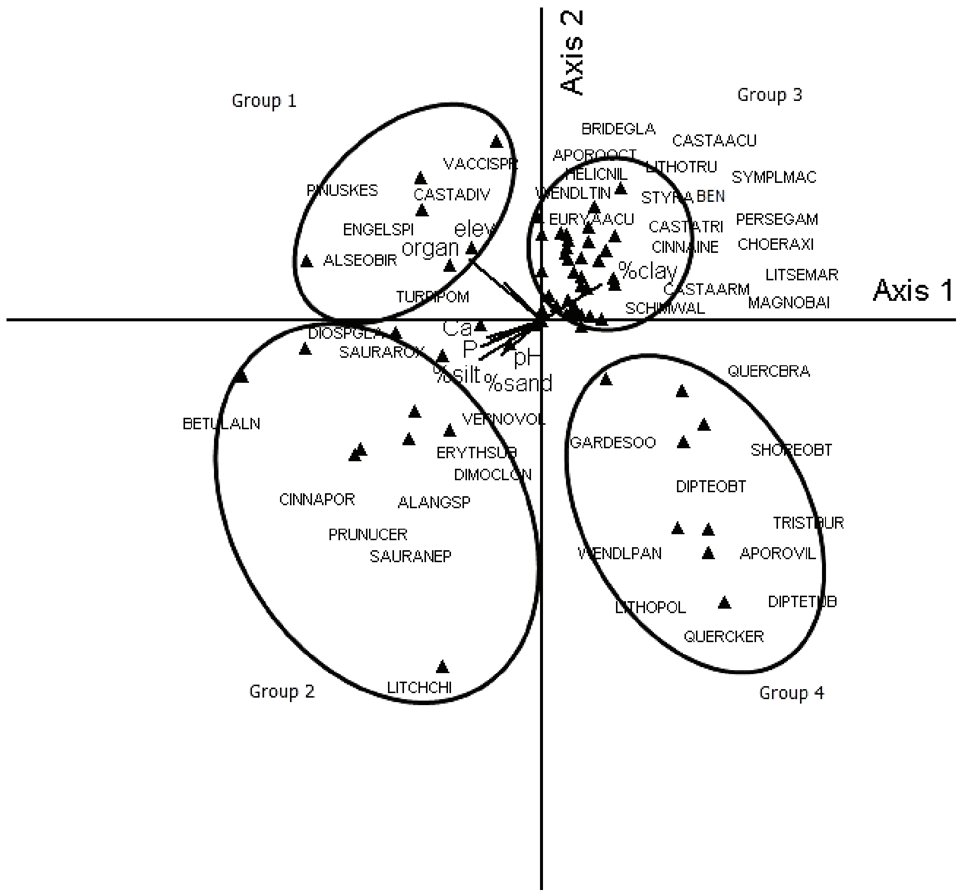


Figure 2 Results of ordination analysis, CCA, which showed the important environmental factors that determined species distribution. Abbreviations represent the tree species that were found (see APPENDIX 1), and elev represented the elevation, organ represented the organic matter, pH represented the acidity and alkalinity, % sand represented the percentage of sand, % silt represented the percentage of silt, % clay represented the percentage of clay, P represented the available P, Ca represented the exchangeable Ca, and black triangles (▲) were the temporary plots..

Results indicated that tree stands in Group 1 was classified as oaks with pine subtype, and are found at high elevation and organic matter in the Doi Suthep-Pui. The dominant family found is FAGACEAE intermixed with pine trees (*Pinus merkusii* and *Pinus kesiya*), as was also reported by. A possible reason for this distribution is the frequent disturbance of evergreen forests as well as occasional wildfires and multi-year periods of cool-wet dry seasons that activate the regeneration of pines (Koskela *et al*., 1995; Zimmer and Baker, 2009). *Pinus kesiya* was found growing densely, especially in mountain ridges and steep slopes where high soil erosion occurs. Therefore, the number of pine trees in oak forests is depended on the rate of soil disturbance and erosion in mountain ridges (Santisuk, 2012). However, high amounts of organic matter were found on the forest floor due to low decomposition rate. Low temperature is an important factor that reduces the decomposition rate in high elevation and results in high organic matter accumulation (*Leeteeraprasert*, 1967). Thus, organic matter increases as elevation increases (Rueangruea, 2009).

Tree stand in Group 2 was classified as secondary MEF that were previously destroyed and abandoned to recover naturally. Dominant trees were pioneer species, such as, *Vernonia volkameriiolia*, *Saurauia roxburghii* and *Erythrina subumbrans*. Land use changes, especially deforestation, affected soil pH and resulted in an increase of calcium and phorphorus (*Leeteeraprasert*, 1967; Santudkarn, 1973; Mason, 1976; Viranant, 1982; Rueangruea, 2009). Plenty of available phosphorus was found on the soil surface (Smeck and Runge, 1971) and this resulted in increased soil pH (Cole and Johnson, 1978). High percentages of sand and silt in this area were the result of high erosion due to rainfall after deforestation (Nobert and Packer, 1972).

Tree stand in Group 3 consisted mostly of species of low MEF in Doi Suthep-Pui. These trees were generally distributed throughout, but were dense in areas where the clay percentage was high. They grow well in high elevation and soil moisture content areas. Apart from being able to hold moisture well, clay particles are also able to absorb high nutrient and are an important source for plant growth and species composition (Lecturers of Department of Silviculture, 2007). Considering the ecological niche of trees in this group, they have wide amplitude of tolerance, and are suitable for restoring degraded MEF. The appropriate species for MEF restoration program were the same as previously reported, and included *Castanopsis tribuloides*, *Castanopsis acuminatissima*, *Styrax benzoides*, *Eurya acuminata* and *Schima wallichii* (Marod *et al*., 2012; Asanok *et al*., 2012, 2013).

Tree stand in Group 4 was classified as deciduous dipterocarp forest (DDF) with oaks subtype and distributed in the ecotone areas between DDF and MEF (Hermhuk*et. al*, 2013). The trees were found at elevation lower than 900 m asl. where organic matter is low (Kiratiprayoon, 2002). Most plants shed their leaves during the dry season resulting in frequent wildfires. Because of this, soils in this area have low organic matter and the dominant tree species in DDF grow better than the MEF tree species.

CONCLUSION

Environmental factors (elevation and soil properties) are the main factors that determined tree distribution in low MEF at Doi Suthep-Pui (Pearson correlation, Species-Environment, r = 0.937), and tree stands can be categorized into four groups based on their relationship with environmental factors as follows:

1) Oaks with pine subtype stand. *Pinus kesiya* is the dominant tree species. High elevation and amount of soil organic matter are the main factors affecting tree distribution in this group.

2) Secondary MEF stand. Most abundant trees were the pioneer species in MEF, such as, *Vernonia volkameriiolia*, *Saurauia roxburghii* and *Erythrina subumbrans*. Environment factors determining this tree distribution were soil pH, exchangeable calcium, available phosphorus, and percentage of sand and silt.

3) MEF stand. The MEF is distributed in more areas than other stand types, and grows well in areas with a high percentage of clay.

The dominant species were in the family of FAGACEAE, LAURACEAE and THEACEAE.

4) DDF with oaks subtype stand. Low organic matter and elevation (about 900 m asl.) were the factors that determined this tree distribution. Coexisting species of DDF and MEF can be found in this stand.

Results from this study indicate that trees with wide amplitude of tolerance, and are suitable to be used for restoring degraded MEF, are *Castanopsis tribuloides*, *Castanopsis acuminatissima, Styrax benzoides*, *Eurya acuminata* and *Schima wallichii.* However, wildfire prevention should be done during the first 4 - 5 years of restoration to allow stand establishment. Then, they can be regenerated and fulfill the success story of forest recovery.

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