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Contributed Paper

Woody Plant Diversity in Sacred Forests and Fallows in Chiang Mai, Thailand

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ABSTRACT

All woody plant and seedling diversity was compared in a Karen and a Lawa hill-tribe village in northern Thailand in four different habitats: sacred forests and fallow fields of three ages derived from rotational shifting cultivation (young fallows, 1–2 years old; medium-age fallow, 3-4 years old; old fallow, 5-6 years old). All woody plant species were identified and counted in three transects (20 x 40 m). Seedlings were inventoried in 12 circular (5 m diam.) plots. The highest species richness of all woody species and seedlings were found in the sacred forests in both villages. The highest values of the Shannon-Wiener index for both trees and seedlings were in the sacred forest of the Karen village. There were significant differences in species richness between the four studied habitats surrounding both villages ($p<0.05$). All woody plant and seedlings species compositions in the sacred forests of both villages were distinct from all the fallow plots as revealed by cluster analysis. Pearson's correlation test showed that only the Simpson diversity index was significantly and positively related to distances from the fallows to the sacred forest. The percentages of plants originating from sprouts were highest in the young fallow and decreased when the fallows aged in both villages, and vice versa for plants originated from seedlings. Furthermore, the sacred forest of both villages harbored endemic and threatened species in Thailand.

Keywords: fallow, Karen, Lawa, seedlings, sprouts, succession

1. INTRODUCTION

Since ancient times forests have been the fundament for people's existence, not only supporting their livelihoods, but also contributing to the maintenance of their culture. Forest resources are declining due to increasing human populations, rapid industrial growth, and increasingly intensive land use. Many regions of the world have been vigilant to preserve the natural resources. One of the ways of conserving forests is to maintain them as sacred forests [1]. Sacred forests are often part of the cultures of indigenous people living in remote areas. Villagers respect the sacred forests with their traditional beliefs that include nature worshiping in ceremonies inherited from their ancestors [2]. These sacred forests have been preserved as a part of the natural environment for many reasons and they are usually informally managed by local cultural traditions without intervention from the government [3]. Many studies show that sacred forests have become well-preserved areas with higher biological diversity than degraded surrounding environments. This is true in many parts of the world such as Africa [4], China [5], India [6], Indonesia [7], Israel [8], and Vietnam [9]. Recently, sacred forests were listed as one of the six protected categories recognized by the International Union for Conservation of Nature [10].

Sacred forests are found throughout Thailand and they differ in types and sizes, ranging from a single tree to forests covering entire mountains [11]. Sacred forests are more common in the northern regions than in the rest of Thailand [12]. These forests are often found around hill-tribe communities such as those of the Karen, the Hmong, the Lisu, the Lawa and the Tai lue [13]. Local norms, laws and customs usually limit human activity in these forests. Hunting, grazing and logging may be prohibited or restricted and villagers take care not to damage them.

In northern Thailand, shifting cultivation is still performed, particularly in the upland areas and it is considered to be a major driver of deforestation in those regions [14]. This land use is also wide-spread in other parts of Southeast Asia [15]. Fallow forests, generated by shifting cultivation, therefore cover over 5% of the highlands of northern Thailand [16]. After cultivation the land is abandoned and left to recover without any further use for 5–15 years, after which the farmers return to cultivate the land again. The recruitment of pioneer species and the ecological succession on abandoned lands after shifting cultivation is affected by several factors including the seed bank, seed rain [17], survival and growth of seedlings [18], light conditions [19], and various forms of soil disturbance [20]. Seeds and sprouts are the two main sources of regeneration depending on type of disturbance and age of fallow [21]. Sprouts are important in sites that were manually cleared under shifting cultivation [22]. If the roots and stumps are not destroyed by intensive site preparation or burning, then pioneers and vegetative sprouts are quick to colonize and occupy the land after abandonment [23]. Several studies found the number of sprouts and stems that produce sprouts is reduced with advancement of succession [24–25]. Simultaneously, the the number of plants that grow from seeds increase with fallow age [26]. Furthermore, seed dispersal accelerates with forest recovery [27]. In general, succession of the pioneer vegetation that follows the abandonment of cultivation is rapid in the early stages of regeneration, followed by delayed recovery of woody biomass [28]. There have been many studies of the recovery process and fallow vegetation on rotational shifting cultivation fields in Southeast Asia including studies in Thailand [14, 16, 29], Myanmar [23], Laos [30], and Vietnam [31]. From these studies we know, that even if the first stage of the ecological succession can be successful in terms of seedlings achieving high survival rate and fast growth, the success of the later stages depends to a large extent on seedling recruitment by various means. Furthermore, the distance to intact primary forest affects the seed availability to abandoned tropical forest plots after farming [26]. There have been only a few studies of the floristic diversity of sacred forests in Thailand and little is known about how sacred forests function in these fragmented landscapes. Sponsel et al.

[1, 11] studied social and management aspects and they pointed to the need of biodiversity studies of plants from these forests. The only known study of vegetation diversity is from a Hmong sacred forest in Chiang Mai [32]. Which showed that the ground flora and tree diversity in natural (sacred) forest were higher than in restoration areas. In this study tree species in natural forest (sacred forest) and seedlings in planting plots were compared, and we demonstrate that most seedling in sacred forest and planting plots were the same species.

Empirical evidence of the ecological benefits of sacred forest is very scarce. Here, we examined the impact that sacred forest has on the ecological succession of woody plant species and seedling during the fallow period of rotational shifting cultivation. Our specific objectives were: 1) To assess plant diversity, species composition and similarities between sacred forests and fallow fields in various stages of secondary succession. 2) To assess the role that sacred forests play as sources of seeds for the regeneration of fallow fields near them. 3) To determine the relation between diversity indices of the fallow fields in different ages and distance to sacred forest.

2. Materials and Methods

2.1 Study Sites

The study was done in two villages in the Mae Cheam watershed in Chiang Mai province in northern Thailand where the landscape is a mosaic of sacred forest, fields that are cultivated for short periods, and fallows that may be up to six years old. The Mae Cheam watershed covers about 4000 km^2 [59] and Mae Cheam river is a tributary of the Ping river which is one of the four main rivers in northern Thailand (Figure 1). The highlands of northern Thailand are composed of landscape complexes featuring steep mountains with slopes >35% interspersed with small narrow valleys. The soils on the upper, middle, and

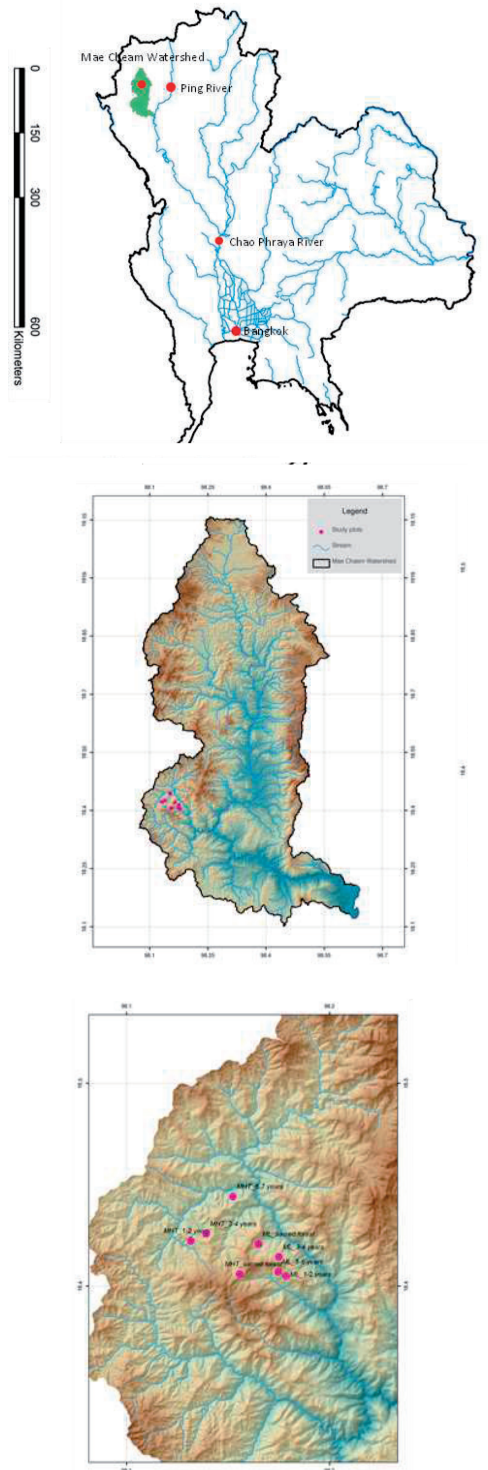


Figure 1. Map of Thailand excluding southern Thailand, showing the location of Mae Cheam watershed and the study sites; MHT= Mae Hae Tai, ML= Mude Lhong [52].

lower slopes have different moisture regimes which is reflected in different plant communities. Politically the watershed covers most of Mae Cheam district in Chiang Mai province. It is known for its forest biodiversity including a variety of vegetation types and plant species. Many different land use systems have been practiced in this watershed including human communities, paddy fields in the valleys, permanent agriculture on slopping areas, shifting cultivation, different stages of forest succession, forest plantation and primary forest or protected forest.

Two villages were selected for this study, the Christian Karen village, Mae Hae Tai and the Animist-Buddhist Lawa village, Mude Lhong (Table 1, Figure 2). In the sacred forests of both communities, the villagers are only allowed to extract minor forest products in quantities agreeable to the village committees. For the Karen in Mae Hae Tai village, one of many natural worshiping done by the villagers involves forest or tree ordination ceremonies every two or three years in the sacred forest. The villagers cover the trees with fabric of different colors. That means that regulations limit their use of the forest, forbidding cutting of trees or killing of any wildlife within it. The Lawa in Mude Lhong village are now Animist-Buddhists. Generally, animists believe that every living things on earth, both animals and plants, possess a soul. The Lawa are usually seen as more deeply involved with spirits than other ethnic group in the northern Thailand highlands. Every year, in the beginning of each season the Lawa have payment ceremony to the spirits for their good health and good products. They believe in spirits, such as ancestral spirits, house spirits, field spirits, and spirit of various localities, especially forest spirit, which demand worshiping. Further details about the study site and conditions can be found in [29].

Table 1. Base line information and study plots location in the two villages.

	Mae Hae Tai - Karen village (Sampling plots)				**Total areas of swidden fallow fields (ha)/ Percentage of total areas of fallow fields of total areas of the village (%)**	**Total areas of sacred forest (ha)/ Percentage of total areas of sacred forest of total areas of the village (%)**
	1-2 years fallow	3-4 years fallow	6-7 years fallow	Sacred forest		
Aspect	Southeast	East	South	North	540/63	325/34
Elevation (m)	1,066	1,112	1,104	1,342		
Location co-ordinates	N 18^{o} 25' 20.22" E 98^{o} 7' 53.91"	N 18^{o} 25' 32.77" E 98^{o} 8' 21.20"	N 18^{o} 26' 38.83" E 98^{o} 9' 8.65"	N 18^{o} 24' 21.4" E 98^{o} 9' 20.5"		
Distance from the sacred forest (km)	1.95	2.12	4.36	-		
	Mude Lhong- Lawa village (Sampling plots)				**Total areas of swidden fallow fields (ha)/ Percentage of total areas of fallow fields of total areas of the village (%)**	**Total areas of sacred forest (ha)/ Percentage of total areas of sacred forest of total areas of the village (%)**
	1-2 years fallow	3-4 years fallow	6-7 years fallow	Sacred forest		
Aspect	South	East	South	Northeast	590/63	330/43
Elevation (m)	1,040	1,063	1,093	950		
Location co-ordinates	N 18'24'17.6" E 98'10'43.2"	N 18'24'51.9" E 98'10'30.3"	N 18'24'25.6" E 98'10'29.0"	N 18'25'14.6" E 98'09'54.1"		
Distance from the sacred forest (km)	2.26	1.27	1.82	-		

Figure 2. Landscape of the stydy sites; A= Mae Hae Tai, the Karen village; B= Mude Lhong, the Lawa village.

2.2 Sampling of Field Data

Field sampling was done in the two villages between October, 2009, and December, 2010. The area belonging to each village was divided into fallow I (1–2 years), fallow II (3–4 years), fallow III (5–6 year), and sacred forest. Around each village, and in each habitat type (Fallow I, II, III and sacred forest) we placed one 20x40 m (=800m^2) plot parallel to the contour lines in each of three slope positions (lower, middle, upper slope) giving a total of 24 plots that together covered 1.92 hectares. The geographic locations of the plots were determined with a GPS in order to calculate distances between plots. To facilitate data-recording in the field, each 20x40m plot was subdivided into 8 subplots of 10x10m. The definitions of the vegetation types in this study are given in Table 2. Trees were measured in order to calculate total basal area, which was used to calculate the importance value index (IVI), along with density and frequency. For seedlings, 12 circular plots 5 m in diameter were placed at the corner of each subplot. Species richness and plant numbers were recorded for the seedlings. For each seedling we excavated the soil around its base to 10 cm depth to determine whether it was an independent genet derived from a seed or if it was had sprouted from another individual (Figure 3).

Table 2. Definition of plants in this study.

Categories (References)	Definitions		Note
	DBH	Tall	
Tree species [24]	>10 cm	> 1.3 m	-
Saplings [53]	< 5 cm	> 1-1.3 m	-
Seedlings [25, 27]	< 2 cm	< 1m	Growing from seeds
Sprouts [25, 27]	< 2 cm	< 1m	Regenerated from coppicing, stem or root
All woody plants species [53]	-	-	Tree + Sapling + Seedling
Mature/ mother woody species [53]	-	-	Woody species that there have own fruits or flowers

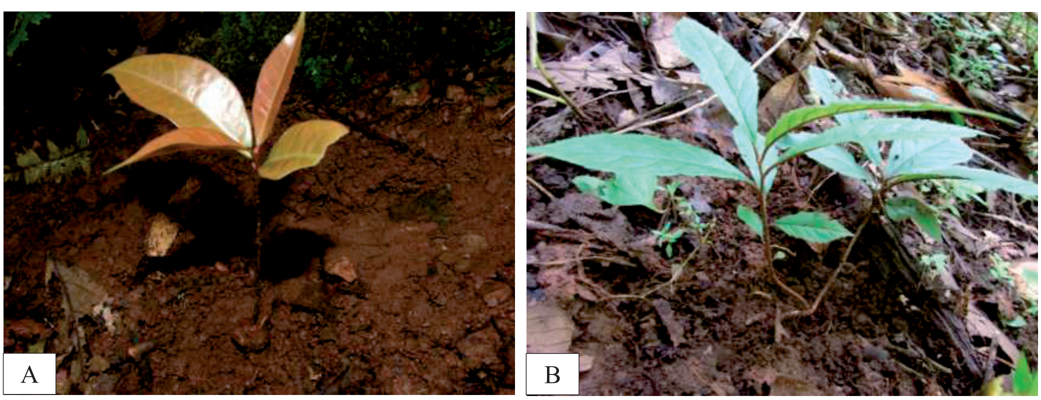


Figure 3. Example of seedling and sprout in study sites; A= Seedling of Apodytes dimidiate., B= Sprouts of Antidesma sootepensis.

2.3 Dispersal Mode

Dispersal mode of each species was assessed by questioning the villagers, visually examining the diaspores, and reviewing existing literature.

2.4 Plant Identification

Specimens of all species were taxonomically identified using taxonomic literature [33] and cross checking with specimens in the Queen Sirikit Botanic Garden Herbarium (QSBG), Chiang Mai, Thailand.

2.5 Data Analyses

Species diversity of all woody plants and seedlings was calculated using the Shannon-Wiener index of diversity, Shannon's evenness index and Simpson's index of diversity . Shannon-Wiener index is an information statistic index [34], it was calculated in order to know the species diversity in different habitat based on the abundance of the species, which means it assumes all species are represented in a sample and that they are randomly sampled by the following formula:

$$H' = -\sum_{i-1}^{S} p_i \ (ln\, pi)$$

Simpson's Index (D) is a dominance index giving more weight to common or dominant species. This index calculates the probability that two organisms sampled from a community will belong to different species (the more even the abundance of individuals across species, the higher the probability that the two individuals sampled will belong to different species). Simpson's Index values range from 0 to 1, with 1 representing perfect evenness (all species present in equal numbers) [35]. It has been measured by the given formula:

$$D= 1\text{-}\{\sum n_i(n_i - 1)\,|N(N-1)\}$$

Where as; H' = Shannon-Wiener Diversity Index , D= Simpson's Index, p_i = relative abundance of species " i " ($p_i = \frac{n_i}{N}$), n_i = number of individuals of species " i ", N = total number of individuals of all species, S = total number of species

Shannon's evenness index [34] is a measure of the relative abundance of different species making up the richness of an area. This evenness is an important component of diversity indices and expresses evenly distribution of the individuals among different species. It has been measured by the given formula:

$$E_H = H/H_{max}; = H/ln\, S$$

Where as; E_H = Shannon's evenness index, H= Shannon-Wiener Diversity Index

The relative ecological importance of each tree species was expressed using the Importance Value Index (IVI) [36].

IVI of a species is defined as the sum of its relative dominance, its relative density and its relative frequency, and was calculated as follows:

IVI= RDo +RD+RF

Where as; RDo= Relative dominance, RD= Relative density, RF= Relative frequency.

Rdo = (total basal area of a species/total basal area of all species) x 100

RD = (number of individuals of a species /total number of individuals) x 100

RF = (frequency of a species/sum frequency of all species) x 100

For seedlings we used the Species Importance Value (SIV) [37] to identify the most important seedling species. SIV of a species is defined as the sum of its relative density and its relative frequency:

SIV= RD+RF

One-way ANOVA (multiple comparisons) was used to examine differences in species richness of all woody plants and seedlings at each village and site using SPSS software (version 17). Pearson's correlation test was used to examine relationships between ecological parameters and distances from the sacred forests to fallows of different ages. PC-ORD (version 5) program [38] was used to determine similarities and species groupings at all the sites. Each species in each plots in the two villages was grouped according to the similarity of presence/absence data by cluster analysis.

3. RESULTS

3.1 Species Richness and Diversity

For all woody plant as well as for seedlings separately, species richness in both villages increased with the age of the fallow plots and were highest in the sacred forests; all woody plant together were represented by more species than the seedlings alone in all plot (Table 3). Basal area of trees also increased with fallow age and topped in the sacred forests. Densities of all woody plant, seedlings (mean±S.D.) and of tree (stem/ha) varied less consistently but tended to fall with fallow age in both villages but with the sacred forests showing opposite patterns in this respects (Table 3). In general both the Shannon-Wiener and the Simpson's diversity indices increased with increasing age of the fallows and culminated in the sacred forests with values of 3.9 and 3.2 for the all woody plants and 3.6 and 3.0 for the seedlings. The 3–4 years old fallow around the Lawa village did not fit the pattern having higher values than the other Lawa habitats. The Shannon evenness index varied less dramatically but tended to increase with age of the habitat around the Karen village and reamain more constant with age of habitat around the Lawa village (Table 3). The one-way ANOVA test of species richness of both all woody plant species and seedlings separately were significantly different among the sampling sites in both villages (Table 4). Different tree

Table 3. Species diversity and evenness of woody plant and seedling (number in parentheses) species in fallow fields of different age and sacred forest around two villages in the Mae Cheam watershed.

	Karen village (Mae Hae Tai)				Lawa village (Mude Lhong)			
	1–2 years	3-4 years	5-6 years	Sacred forest	1-2 years	3-4 years	5-6 years	Sacred forest
All woody plants								
Number of plots	3	3	3	3	3	3	3	3
Areas (m2)	2400	2400	2400	2400	2400	2400	2400	2400
Number of species	60	72	89	136	62	100	103	141
Density (m-2) (mean ± S.D.)	0.74±1.57	0.39±0.91	0.18±0.31	0.14±0.28	0.46±1.89	0.26±0.48	0.26±0.77	0.43±1.38
Density of trees (stems/ha)	25	379	1200	1258	25	629	1854	766
Total basal area of trees (m2/ha)	0.79	0.95	12.04	21.58	1.12	1.54	15.12	28.20
Shannon-Wiener diversity	2.74	2.95	3.63	3.94	2.17	3.65	3.29	3.32
Simpson diversity	0.90	0.91	0.95	0.96	0.71	0.95	0.90	0.92
Shannon Evenness	0.32	0.37	0.80	0.80	0.52	0.79	0.70	0.67
Seedlings								
Number of plots	12	12	12	12	12	12	12	12
Areas (m2)	943	943	943	943	943	943	943	943
Number of species	49	57	64	66	35	48	37	62
Density (m-2) (mean ± S.D.)	0.92±1.88	0.98±1.88	0.54±0.83	0.24±0.32	0.28±0.05	0.30±0.44	0.33±0.51	0.58±1.35
Density of seedlings (stems/ha)	9480	11664	7242	3329	2311	3075	2545	7507
Shannon-Wiener diversity	2.76	3.07	3.41	3.57	2.48	3.21	2.90	3.00
Simpson diversity	0.89	0.91	0.94	0.96	0.88	0.93	0.90	0.90
Shannon Evenness	0.71	0.75	0.81	0.85	0.69	0.82	0.80	0.70

Table 4. One-way ANOVA test of species richness for all woody plant and seedlings separately in the two villages.

Sources	DF	Sum of Squares	Mean Squares	F- ratio	F- probability
Karen village					
All woody plants					
Between group	3	2060.865	686.955	27.607	0.000*
Within group	92	2289.296	24.884		
Total	95	4350.156			
Seedlings					
Between group	3	468.167	156.056	3.413	0.025*
Within group	44	2011.833	45.723		
Total	47	2480.000			
Lawa village					
All woody plants -					
Between group	3	4104.375	1368.125	45.272	0.000*
Within group	92	2780.250	30.220		
Total	95	6884.625			
Seedlings					
Between group	3	948.083	316.028	38.715	0.000*
Within group	44	359.167	8.163		
Total	47	1307.250			

Table 5. Relative Importance Value Indices (IVI, %) and dispersal mode (in parentheses) of the dominant tree species in the sacred forests and the fallows of the Karen and the Lawa villages. For each species is dispersal agent is indicated (An=Ant, Bd=Barking deer, Bi= Bird, Co=Cow, Fl=Flying lemur, Hu=Human, Ra=Rat, Ru=Ruminant, Wi=Wind, Wp=Wild pig, Sq= Squirrel, (-) =No data).

Trees dbh > 10 cm								
	1–2-years fallow	**IVI**	**3–4-years fallow**	**IVI**	**5–6-years fallow**	**IVI**	**Sacred forest**	**IVI**
The Karen village	*Flueggea virosa* (-)	18.1	*Lithocarpus polystachyus* (Bi,Wp,Hu,Ra)	21.4	*Lithocarpus polystachyus* (Bi,Wp,Hu,Ra)	18.0	*Lithocarpus mekongensis* (Wp)	13.5
	Eugenia cumini var. *cumini* (Hu,Bi,Ra,Sq)	15.2	*Aporosa villosa* (Hu)	20.9	*Gluta usitata* (-)	6.1	*Castanopsis diversifolia* (Hu,Sq)	10.4
	Albizia odoratissima (Wi)	7.8	*Schima wallichii* (Bi,Wi,Fl)	20.5	*Tristaniopsis burmanica var. rufescens* (Wi)	6.0	*Calophyllum polyanthum* (-)	10.2
	-	-	*Lithocarpus elegans* (Sq,Hu,Wp)	12.4	*Shorea roxburghii* (Wi)	5.9	*Mitrephora vandaeflora* (-)	4.2
	-	-	*Callicarpa arborea* (Bi)	6.8	*Aporosa villosa* (H)	5.7	*Lithocarpus polystachyus* (Bi,Wp,Hu,Ra)	3.6
	1–2-years fallow	**IVI**	**3–4-years fallow**	**IVI**	**5–6-years fallow**	**IVI**	**Sacred forest**	**IVI**
The Lawa village	*Gmelina arborea* (Bi,Bd,Hu,Co)	27.8	*Diospyros glandulosa* (Ru)	29.6	*Quercus kerrii* (Hu, Sq)	11.3	*Schima wallichii* (Bi,Wi,Fl)	6.9
	Dalbergia cultrata (Wi)	25.3	*Castanopsis calathiformis*	9.5	*Dalbergia rimosa* (Wi,Sq)	9.0	*Aphananthe aspera* (An)	5.8
	Lagerstroemia undulata var. subangulata (Wi)	24.0	*Quercus kerrii* (Hu,Sq)	9.3	*Kydia calycina* (Wi)	7.9	*Alangium kurzii* (Hu, Bi)	5.4
	Phyllanthus emblica (Hu,Bd)	11.4	*Glochidion sphaerogynum* (Wp,Hu)	7.4	*Phyllanthus emblica* (Hu,Bd)	6.3	*Engelhardia spicata* (Wi)	4.7
	Diospyros coaetanea (Co,Hu)	11.2	*Schima wallichii* (Wi)	7.1	*Dalbergia cultrata* (Wi)	5.1	*Protium serratum* (Hu,Sq,Wp,Bi)	4.4

species were dominant at the different sites (Tables 5). *Flueggea virosa* had the highest IVI in the Karen 1–2 years fallow, while in the Lawa village, *Gmelina arborea* had the highest ranking. In the other Karen sampling sites, members of Fagaceae had the highest IVI values, for example, *Lithocarpus mekongensis* in the sacred forest, and *L. polystachyus* in the 3-4 years and the 5-6 years fallows. In contrast, in the Lawa village, there were different dominant tree species in the different aged fallows and forest, for example *Schima wallichii* in the sacred forest, *Quercus kerrii* in the 5–6-years fallow and *Diospyros glandulosa* in the 3-years fallow. Furthermore, some species that are endemic and threatened in Thailand were found in both sacred forests *Antidesma bunius* var. *bunius, Archidendron clypearia, Kopsia arborea, Ilex umbellulata,* and *Ostodes paniculata*.

3.2 Species Composition of Seedlings

The species compositions of seedlings were different in each of the plots. The SIV (%) ranking of the species in the sacred forest of the Karen village was topped by *Kopsia arborea*, while in the Lawa village *Combretum latifolium had the highest score*. In the fallows of different ages, different species had the highest SIV (%). For example, in the Karen village, it was *Kydia calycina* in the 5–6 years fallow, *Aporosa villosa* in the 3–4 years fallow and *Helicteres isora* in the 1-2 years fallow. In the Lawa village, it was *A. villosa* in the 5–6 years fallow, *A. octandra* var. *octandra* in the 3–4 years fallow and *Diospyros coaetanea* in the 1–2 years fallow (Table 6).

Table 6. Relative seedling importance value indices (SIV, %) and dispersal mode (in parentheses) of the dominant seedlings in the sacred forests and the fallows of the Karen and the Lawa villages (An=Ant, Bd=Barking deer, Bi= Bird, Co=Cow, Fl=Flying lemur, Hu=Human, Ra=Rat, Ru=Ruminant, Wi=Wind, Wp=Wild pig, Sq= Squirrel, (-) =No data).

	1-2 years fallow	SIV	3-4 years fallow	SIV	5-6 years fallow	SIV	Sacred forest	SIV
The Karen village	*Helicteres isora* (-)	26.9	*Aporosa villosa* (Hu,Bi)	24.6	*Kydia calycina* (-)	16.9	*Kopsia arborea* (Hu,Wi)	18.1
	Cratoxylum formosum ssp. *pruniflorum* (Hu,An)	21.6	*Clausena lenis* (-)	20.2	*Olea salicifolia* (-)	14.5	*Lithocarpus mekongensis* (Wp)	13.1
	Ficus semicordata (Bi,Hu,Sq,Wp,Bd,R)	14.7	*Fluggea virosa* (-)	12.2	*Lithocarpus polystachyus* (Bi,Wp,Hu,Ra)	10.2	*Cinnamomum iners* (Hu)	12.2
	Aporosa villosa (Hu,Bi)	14.5	*Aporosa octandra var. octandra*	12.1	*Styrax benzoides* (Bi,Sq)	9.9	*Quercus kingianus* (Wp)	11.8
	Solanum torvum (Hu)	12.8	*Helicteres elongata* (Hu,Wp)	11.1	*Dalbergia cultrata* (Wi)	9.6	*Wendlandia tinctoria* (Bi,Wi)	10.7

	1-2 years fallow	SIV	3-4 years fallow	SIV	5-6 years fallow	SIV	Sacred forest	SIV
The Lawa village	*Diospyros coaetanea* (Co,Hu)	45.0	*Aporosa octandra var. octandra* (-)	23.6	*Aporosa villosa* (Hu,Bi)	33.9	*Combretum latifolium* (Wi)	34.3
	Helicteres elongata (Hu,Wp)	16.0	*Aporosa villosa* (Hu,Bi)	18.7	*Antidesma sootepense* (Hu,Bi,Rab,)	20.5	*Siphonodon celastrineus* (-)	22.1
	Antidesma sootepense (Hu,Bi,Rab,)	12.9	*Helicteres elongata* (Hu)	16.1	*Kydia calycina* (-)	12.7	*Cinnamomum iners* (Hu)	12.6
	Cratoxylum formosum ssp. *pruniflorum* (Hu,An)	11.5	*Macaranga denticulata* (Bi,Ra,Hu)	9.8	*Theapesia lampas var. lampas* (-)	11.8	*Clerodendrum disparifolium* (-)	8.7
	Lagerstroemia undulata var. subangulata (Wi)	10.0	*Dalbergia cultrata* (Wi)	9.7	*Helicteres elongata* (Hu,Wi,Wp)	10.3	*Engelhardia spicata var. spicata* (Wi)	6.3

3.4 Plant Regeneration in Fallows

The relative proportion of seedling species gradually increased with the age of the fallow in both villages. Concomitantly, the relative proportion of the sprouts decreased with increasing age of the fallows (Figure 4). Furthermore, we also compared similarity of seedling and mature woody species among the fallow plots and the sacred forests. The highest proportion of seedlings species as well as mature tree species from the sacred forest was found in the older fallows (5–6 years and 3–4 years) of the Karen village. Meanwhile, the highest percentage of total number of seedlings species as well as mature tree species within fallow plots was found in the same age class but different village (Figure 5). The lowest proportion of seedlings species as well as mature tree species in sacred forest was found in 3-4 years fallow followed by 5-6 years fallow in the Lawa village.

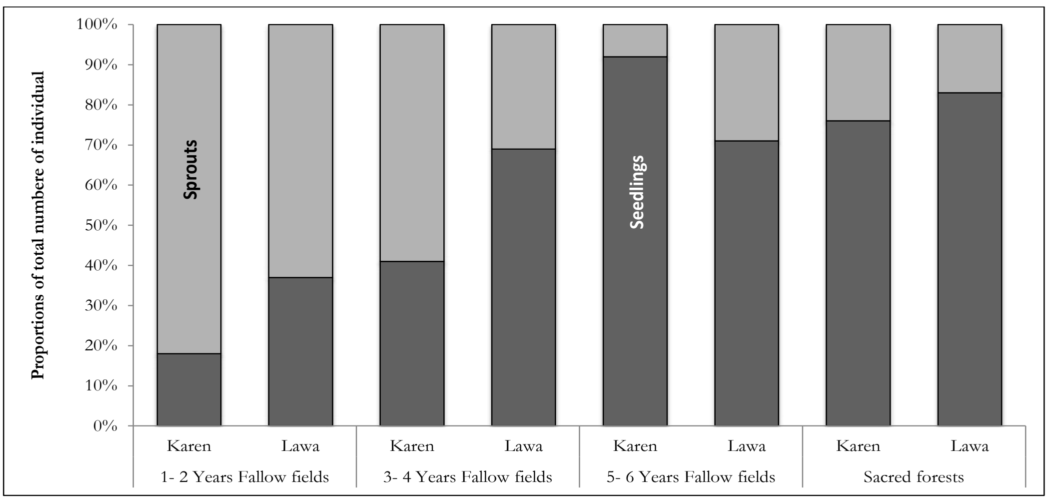


Figure 4. Proportions of total number of individuals of seedlings and sprouts in the Karen and Lawa villages.

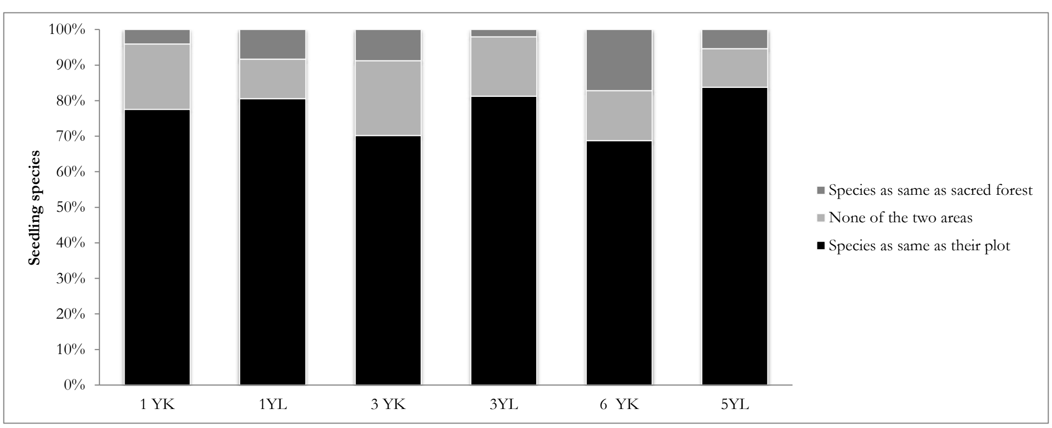


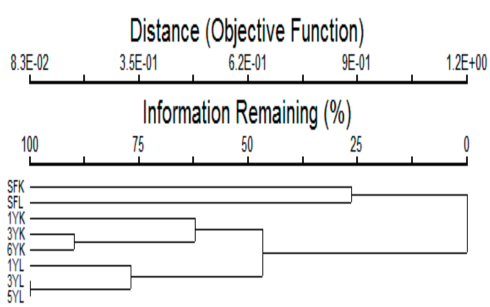
Figure 5. Percentages of seedlings species and mother tree species within their plot and in the sacred forest in two villages (1-2YK=1-2 years fallow plot of Karen, 1-2 YL=1-years fallow plot of Lawa, 3-4YK=3-4 years fallow plot of Karen, 3-4YL=3-4 years fallow plot of Lawa , 5-6YK=5-6 years fallow plot of Karen, 5-6YL=5-6 years fallow plot of Lawa).

3.5 Diversity and Distance from the Sacred Forest

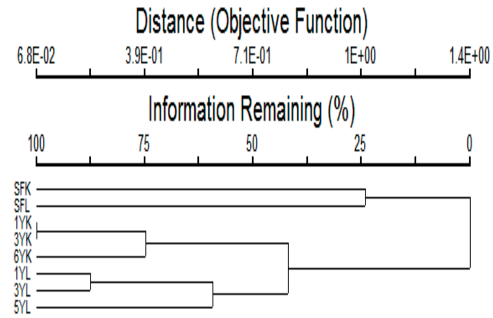
Pearson's correlation test was used to examine the relationship between ecological parameters such as species richness, Shannon-Wiener diversity index, Simpson's diversity index and Evenness index and distances between the sacred forest and the fallow plots. For all woody plants, there was only a significant positive linear relationship between distances and Simpson's diversity index at 99% ($P<0.05$) in the Karen village while, in the Lawa village, there were no relationship with all the parameters. For seedlings, there was no statistically significant relationship between distances from sacred forests and fallow plots in all sampling sites in the two villages ($P>0.05$).

3.6 Cluster Analysis

All woody plants and seedlings species in all the sampling sites in both villages were separated into two groups corresponding to sacred forest and fallow fields according to the presence-absence data for each species (Figure 6). Within the fallow fields, the groupings were also separated into two groups reflecting the differences of species in each village (Figure 6).



A



B

Figure 6. Cluster analysis of; all woody plants species (A) and of only seedlings (B) in all sampling sites of the Karen and the Lawa villages (1YK=1-2 years fallow of Karen, 1YL=1-2 years fallow of Lawa, 3YK=3-4 years fallow of Karen, 3YL=3-4 years fallow of Lawa , 6YK=5-6 years fallow of Karen, 5YL=5-6 years fallow of Lawa, SFK= Sacred forest of Karen, SFL= Sacred forest of Lawa).

4. Discussion

4.1 Species Richness of all Woody Plant Species and Seedlings in Sacred Forests and Fallow Fields

The highest species richness and the highest measures of the ecological diversity indices of all woody plants and seedlings were found in the sacred forest in both villages. The density of all woody plants and seedling species of Karen village were highest in the young fallow plots. These results agree with the many studies of sacred forests in India that sacred forests had higher plant diversity than surrounding areas [39-40]. The higher species richness and diversity in the Karen sacred forests might be explained by the fact that these forests have been protected more strongly by villagers compared to the Lawa village. The villagers are not allowed to disturb by logging but they can extract minor forest products from the sacred forests. The species compositions of the sacred forests in two villages were different from the fallows surrounding them. These results were confirmed by cluster analysis and statistical tests. The species compositions in the fallow plots in the two villages were different among sampling sites. We can see these results expressed as IVI and SIV rankings in each plot. The differences in vegetation in the same year or same fallow periods in early successional stages were caused by variations in environmental factors such as site condition, seed dispersal, germination and predation [41]. Furthermore, human over-exploitation based on ethnobotanical knowledge for food, medicine, fuel, and construction material also affected the variation of vegetation. Additionally, the forest that grows back from the original vegetation was in many sites qualitatively and quantitatively different after major disturbance [42] and in some cases the species composition of secondary forests may not develop towards that of the primary forests [40]. One important reason for the differences of woody plant species and seedling species composition in our study may be the fact that the majority of species in fallow plots are pioneer species of early successional stages, including species as Aporosa villosa, Clausena lenis, Diospyros coaetanea, Wendlandia tinctoria, and Schima wallichii, that are all species that can only germinate under full sunlight [43]. The species in both sacred forests in our study are evergreen forest species such as Kopsia arborea, Cinnamomum iners, Lithocarpus mekongensis [33]. These results are similar to the situation in the sacred groves of Jaintia Hills in northeast India which have a large number of evergreen species [39]. Our results also agree with the situation in uncultivated forest stands, where Castanopsis acuminatissima and other Fagaceae were the dominant while Schima wallichii was the most dominant species in succession of secondary forest. Many species were absent in fallow plots but present in sacred forests. This may be the result of history and human use such as food resources, structure plants and also medicinal purpose were affected on species richness and plant diversity in the sacred forests and the fallows fields. The villagers usually cut and burn vegetation in fallow fields before growing rice and sometime they have left some trees in their field especially in 1 year fallow fields because some trees were either too thick or their wood is too big for cutting. The presence or absence patterns suggest that some species can cope with the environment such as fire or shade tolerance species. However, the adaptation of plant species in the areas was considered in this case. This phenomenon can explain that, when seedlings are established during the fallow periods, the ecosystem conditions at that time will determine seedlings survival. Furthermore, we also found higher species richness and values of diversity indices than what was found in a previous study at the same site [29] in a study of regeneration of secondary forest through several successional stages but with younger ages of the fallow fields. These results are similar to what was found in the swidden farming and fallow vegetation in northern Thailand where vegetation change induced by shifting cultivation is a highly diversified process [14]. The different shifting cultivation techniques and the variation in length of cultivation- and fallow periods, cause a strongly differentiating influence on the process of secondary succession and the composition and structure of secondary vegetation on fallow swidden. The ages of old fields significantly affect trees species richness and composition along a chronosequence [44]. The longer a pasture had been abandoned the greater similarity of its vegetation structure and community composition to the mature forest. The dominant tree species and seedlings, when measured as IVI and SIV rankings, were mostly animal dispersed. However, we found some species in the young fallow that were dispersed by wind such as Albizia odoratissima, Dalbergia cultrata and Schima wallichii. The seed rain of animal dispersed species decreased dramatically in the pasture >5m from the forest/ pasture edge and woody plant species in the pasture were mostly dispersed by wind so they always regenerate in the pasture rather than in the forest. However, the difference was much less than for animal dispersed seeds [45]. Limited dispersal of seeds and seedlings is known to influence spatial distribution of pioneer trees [46]. Several studies revealed that the tropical tree species vary in their ability to disperse seeds and is determined by their dispersal mode. Limited seed dispersal often results in aggregated patterns of recruitment for seeds and seedlings [47]. Tree species with limited seed dispersal would be expected to have more aggregated spatial patterns than those that have mechanisms for long-distance seed dispersal. The two most important barriers to the restoration of tropical montane forest on abandoned pasture are the lack of dispersal of forest seeds and seedling competition with pasture grasses [48].

4.2 The Relationship Among Ecological Parameters and Distance from the Fallow Plots to the Sacred Forest

There was no a significant relationship between ecological indices and distance from the fallow plots to the sacred forests in seedlings and all woody plants species. This agrees with other studies that found no relationship between the distances to the primary forest on trees, seedling, sapling richness, abundance, or species composition [26]. In these studies it was suggested that it might be that colonizing species were specialists to disturbed habitats rather than primary forest [30]. Some studies shown that the distances from sacred forests to the forest reserves had a weak influence on trees diversity and had little influence on their similarity with forest reserve sites [49]. However, one study [48] reported that seeds input to the successional areas declined with distance from seed source habitat. Another study [26] also confirmed that the abundance and diversity of seeds dispersed from tropical forests into open old fields is inversely related to the distance. Dispersal is much reduced at distances greater than 5–10 m from forest edges, but in some cases, small seeds of wind and animal dispersed species can travel greater distance [50-51].

4.3 Plant Regeneration Characteristic in Fallow Plots

In early stages of succession of rotational shifting cultivation or fallow fields, the important factors for maintenance of plant diversity and species richness are sprouts or coppicing [23]. Total number of sprouts decreased with advancement of successional stage. Our results agree with the study of Nzunda [24]. Plants originated from seeds may come from the soil seed bank or from surrounding forests that have mature trees that can produce seeds. Our results show that the most abundant trees species in 1–3 years old fallow plots originated from sprouts rather than seeds, but those in older fallow more than 5-years old, the proportion of plants originated from seeds more often than from sprouts. These results agree with the study of Vieira and Proctor [27]. In tropical forests one ecological advantage of sprouting over establishment from seeds is rapid regrowth and a greater capacity for exploitation of limited resources [24]. Most of the plants in young fallow plots were coppices. The remainder came from mature trees that the villagers left in the plot, or from adjacent vegetation in secondary forest surrounding them. When we compared similarity of seedling species and all woody plant species within their fallow plot and sacred forest, we found that seedling species were the same as all mature woody plant species within their plot and , some of them were the same as the mature tree species in the sacred forest, and some species came neither from sacred forests nor the fallows. This result may explain that species richness of young fallow plots is limited by the potential species capable to producing seeds in the surrounding areas. In our study starting with the 3-4 years plots there are many species that can grow to mature trees and act as seed donors for their plot such as Aporosa villosa, Diospyros glandulosa, Lithocarpus. elegans, L. polystachyus, Quercus kerrii, Tristaniopsis burmanica var. rufescens, etc. The total number of mother trees that can act as seed donors were high when the age of fallow plots increased. The presence of mother trees within fallow sites and in surrounding primary forest patches greatly enhance the regeneration process [42], being sources of seedlings that promote colonization during succession stage. However, the one potential limitation for the establishment of seedlings is the extensive invasion of shrubs into fallow site. Shrub encroachment is always found in the early successional stage at our study sites in the 1–2 years fallows as well as in the 3–4 years fallows in both villages.

5. Conclusions

The sacred forest are of value for a variety of reasons, such as ecological function as a reservoir of biodiversity for preserving plant species in this region. We observed the highest of species richness and calculated the highest values for the diversity indices in both sacred forests. We conclude that the two sacred forests of the Karen and the Lawa do not act as sources of seedling for pioneer species for the early succession stage. Because the species in the sacred forest are evergreen forest species or climax species while, species composition in the fallow plots of this study almost are pioneer species. Natural succession of rotational shifting cultivation fields to secondary forest is a process by which plant species grow in habitats due to environmental factors and time. The succession takes a long time to recover a vegetation structure that is the same as the primary forests. However, the forest management of indigenous people in remote areas is an important key to successful local biodiversity conservation and highly effective forest management. Some sacred forests in Thailand have recently been developed into community forest networks which are currently being implemented by the local communities [14]. Thus, the Thai government should pay attention and give priority to these networks in their policy formulation for the purpose of conserving and increasing forest areas of the country.

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