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Changes in stand structure and environmental conditions of a mixed deciduous forest after logging and shifting cultivation in Lao PDR

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In this study, stand structure, species and family composition and diversity and microclimate were determined to compare the natural regeneration patterns of primary and secondary forests (logged-over and fallow) of mixed deciduous forests after logging and shifting cultivation. All woody species with stem diameter of ≥ 5 cm were identified and counted. Diameter at breast height (DBH) of 1.3 m was measured in all plots and the distance time to recovery was compared among the sites. The fallow stand density was higher 1,153 trees ha^{-1} in 10-year, 980 tree ha^{-1} in 15-year, 813 tree ha^{-1} in 5-year and lower 12 trees ha^{-1} in 1-year old fallow, respectively. The number of family and species composition increased to 25 species and 15 families, 31 species and 21 families, 44 species and 24 families and 45 species and 25 families after slash and burn for the secondary forest with 1-, 5-, 10- and 15-year old fallow periods, respectively. Species composition increase to 77 species and 30 families in the logged-over secondary forest while 82 species and 35 families in the primary forest. Three pioneer species had higher importance value such as *Schima wallichii* in the primary forest (17.22%), *Cratoxylum cochinchinensis* in the secondary forest with different

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fallow periods (9.67 - 17.31%) and logged-over forest (16.20%) and *Aporosa microcalyx* in the secondary forest with 1-year fallow period (22.47%). Meanwhile, there were three dominant families namely Leguminoseae with 34 species followed by Euphorbiaceae with 14 species and Dipterocarpaceae with nine species. Soil chemical properties were not significantly different among six forest types compared to previous study. This study also showed that secondary fallow and logged-over forests have higher mean air temperature but lower relative humidity compared to primary forest. The data obtained in this study will be very useful in managing secondary forests and promote natural regeneration in the future.

Key words: mixed deciduous forest, fallow period, natural regeneration, primary forest, secondary forest, species diversity, stand structure, environmental conditions, logging, shifting cultivation, Lao PDR

INTRODUCTION

The tropics and sub-tropics constituted about 56% of the total world's forests having higher level of deforestation rate 16 million ha per year recorded (FAO 2001). In these regions, shifting cultivation, logging and fuel-wood and wood charcoal consumption are very common problems (FAO 2006, Mertz *et al*. 2009, Lawrence *et al*. 2010). Shifting cultivation and over-logging are serious problems in tropical countries particularly in Lao PDR, which contribute to the largely to the increase of deforestation in country and also among the region. The main drivers of deforestation and forest degradation in Lao PDR were shifting cultivation followed by logging, infrastructure development, and land conversion to agriculture and industrial activities (MAF 2005b, GoL 2006, Phongoudome & Sirivong 2007). In Lao PDR, it was estimated that more than 6.5 million ha of forests (28.2% of the total land area) were affected by shifting cultivation involving about 17% of the total population (Messerli *et al*. 2009, Sovu *et al*. 2009, Schmidt-Vogt *et al*. 2009). Rehabilitation and restoration of forests in Lao PDR are mainly based on natural regeneration. The government aims to increase the national forest cover up to 70% by the year 2020 through establishment of 6.5 million ha by natural regeneration and 0.5 million ha by plantations especially in degraded forests including fallow forests and logged-over forests as stipulated in the Forestry Strategy 2020 (MAF 2005b). Tropical mixed deciduous forests are the most extensive and important tropical vegetation in Lao PDR, which were about 8.7 million ha in 1982 and 6.3 million ha or 65% of total current forest in 2002 (MAF 2005a).

Ecological restoration by natural regeneration or man-made approaches using native species is becoming common in forest ecosystem management and may contribute to the improvement of forest environmental conditions (Jordan *et al*. 1987, Brown & Lugo 1990, Urbanska *et al.* 1997, Sayer *et al.* 2004). Currently, tropical forests and trees are becoming subjects of concern because of its species diversity (Condit *et al*. 1996, de Jong & Chokkalingam 2001). Basic information on species composition can be useful in evaluating the impact of previous forest activity. It can also indicate the capability of forest recovering from past disturbances and can thus, be used for planning and better management of forests on a sustainable forest management basis. If forest is to be regarded as a renewable resource, good forestry practices must be designed to prevent wastage and damage to the standing stock and environmental protection must be carried out during harvesting (Faridah *et al*.1999). Tree species diversity contributes to the forest ecosystem stability and sustainable developments (Rennolls & Laumonier 2000). Floristic inventory is necessary for fundamental research in tropical community ecology, such as modelling patterns of species diversity or understanding species distribution. This is because forest communities are dynamic and individual and species composition levels are changing continuously (Felfili 1995, Phillips *et al*. 2003). Therefore, species composition and structure as well as their natural regeneration or assisted natural regeneration in tropical rainforest or tropical deciduous forest (Jordan *et al*. 1987, Kennard *et al*. 2002, Hardwick *et al.* 2004) must be fully understood in conducting research. However, only few in-depth studies have characterized tree species composition and stand structure of forests in Lao PDR compared to other tropical countries. The objective of our study aimed to identify recovery/potential changes in stand structure and environmental conditions, natural regeneration pattern in the primary mixed deciduous forest with secondary forest after logging and shifting cultivation in Lao PDR.

MATERIALS AND METHODS

Study site. The study was conducted in Bolikhan District, Bolikhamxay Province, in the central part of Laos. It is about 185 km from Vientiane Capital City to the south and situated between the 18° 30' to 18° 40' N latitude and 103° 36' to 103° 42' E longitude. The elevation ranges from 165 to 175 m above sea level (asl), with a slope of 2 to 5°. The mean temperature for a decade (2000 to 2010) ranged from 21.4 to 31.2 °C and the mean annual rainfall ranged from 2,000 to 2,700 mm.

The tropical mixed deciduous forests managed by the Bolikhan District Forest Office and local communities in the study site, total area was 12,951 ha which covered a primary forest (719 ha), a secondary logged-over forest (5,323 ha), secondary fallow forest (6,496 ha) and a non-forested area (414 ha) (Figure 1). According to a nationwide reconnaissance survey in 1982, the original forest type was a mixed deciduous forest (MDF), with the tree heights of 26 to 28 m and the canopy cover was 55 to 60%. The dominant commercial species were *Pterocarpus macrocarpus, Afzelia xylocarpa, Dipterocarpus alatus, D. terbicunatus, Anisoptera costata, Vatica cinerea, Hopea odorata, Dalbergia cochinchinensis, D. cultrata, Sindora cochinchinensis, Lagerstroemia paniculata, Schima wallichii,* among others.

The soil property of the study was characterized by Alizol Ferric (ALF) and was sandy loam. The soil texture was sandy loam-clay loam at depth 120 cm consisting of 46 to 56 % sand, 25 to 27 % silt and 18 to 28% clay. For the chemical properties, it had 1.09 % Carbon, 1.87 % OM, 2.70 ppm P, 5.60 ppm K, 4.5 of pH of H_2O, 0.28-0.43 mg Ca/100g, 0.22-0.36 mg Mg/100g, 0.09-0.12 ppm K-av and 0.05 - 0.07 mg Na/100g (Soil Research Centre 1993).

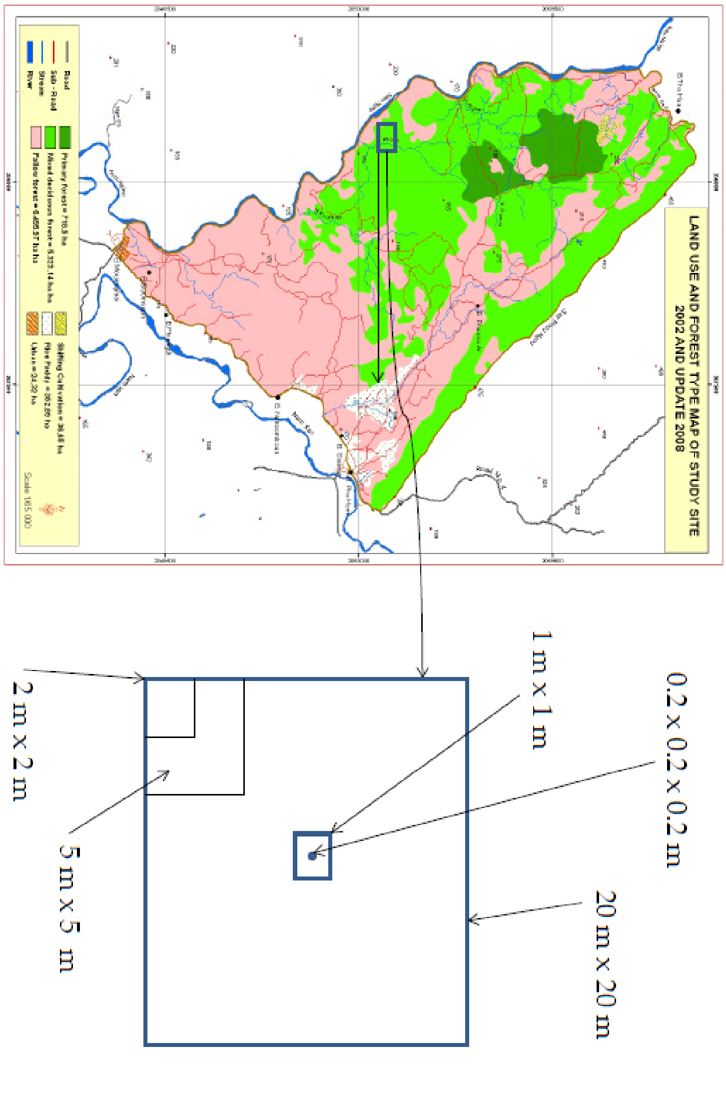


Figure 1. Location of the study site in Bolikhan District, Bolikhamxai Province, Lao PDR.

Deciduous forest structure after logging-shifting cultivation

The first selective cutting method was carried out in the natural forest from 1984 to 1985 and subsequently from 1994 to 1995 by the State Forest Enterprise Company. Timber harvesting seriously affected the forests in this area and was followed by human anthropogenic activities such as shifting cultivation, clearing land for agriculture, fuel-wood collection and charcoal making after 1993.

Data collection.

Species composition and diversity. We layout the line and plot inventories system throughout forest types, the number and size of sample plots established in each forest type were different due to the coverage area of the study site. A total of inventories was 180 plot were layout in six different forest types such as primary forest, secondary logged-over forest, secondary fallow forests of 1-, 5-, 10- and 15-year fallow period (30 plots for each forest type) with 20 x 20 m size were systematically established in the study area (72,000 m^2). Tree taxon was identified (species and family), diameter at breast height (DBH $\geq$ 5 cm) and height of each tree were measured in each plot. For measuring the saplings height (>1.3 m) and DBH (<5 cm), sub-plots of 5 x 5 m were established. Sub-plots of 2 x 2 m, were established for measuring of seedlings (<1.3 m).

Soil sample and analysis. At the center of each plot, soil samples were collected at 20 cm depth to compare with previous study by Soil Research Centre (SRC) in 1993 (Figure 1). The samples obtained were brought to the Soil Research Centre, National Agriculture and Forestry Research Institute (NAFRI), Lao PDR for analysis of soil chemical properties, namely: pH (H_2O), pH (KCl), total nitrogen (N%), phosphorus (P), potassium (K), soil organic matter (SOM), soil organic carbon (SOC), and cation exchange capacity Ca^{2+}, Mg^{2+}, Na^{2+} and K^+.

Microclimate data collection. To compared temperature and relative humidity changes we setup three portable HOBO data loggers were launched in each stand at an above ground height of 3 m to measure air temperature and relative humidity in between 1- and 5-year old fallows, in boundary between 10- and 15-year old fallows, and logged-over and primary forests during the research period. All data were automatically saved with one-hour interval (BoxCar Pro 4.0 Onset Computer Corporation, USA).

Data analysis. Equations used for species composition and diversity indices are shown in Table 1. The mean values and standard errors of vegetation parameters and soil chemical properties were analyzed using MS Excel 2010 and SAS 9.3 for Windows 7 (SAS Institute Inc., USA). Duncan's Multiple Range Test (DMRT) was used to examine the difference soil chemical properties in the forests. The significance for all analyses was determined at $p<0.05$.

RESULTS AND DISCUSSION

Vegetation characteristics of primary, secondary logged-over and secondary fallow forest in Lao PDR. Based on data of six forest types from this study, a total of 124 tree species and 41 families were identified (DBH $\geq$5 cm). The number of species

Table 1. Equations used for stand structure and species composition analysis.

Series no.	Equations	Remarks
1	IV (%)=(RA+RF+RD)/3	Where *RA* is the relative abundance, *RF* is the relative frequency, *RD* is the relative dominance (Curtis and McIntosh, 1950)
2	$H' = -\sum_{i=1}^{s} pi \ln pi$	Where Shannon diversity index (*H'*), p_i is the proportion of the individuals in the i^{th} species, the values of *H'* were compared through *t*-test according to Magurran (1987). (Pielou, 1975; Shannon and Weaver, 1949; Magurran, 1987; Zar, 1984)
3	$Hj = \frac{j}{r}$	Jaccard' similarity index was calculated as follow, Where *j* is number of the same species found in both communities and *r* total species found in both communities.
4	$D = \sum_{i=1}^{s} \left[\frac{n_i (n_i - 1)}{N (N - 1)}\right]$	Where Simpson's diversity index where, *D* is the Simpson's index of diversity, n_i is the number of individuals of species "*i*" in the sample, *s* is the number of species in the sample, and *N* is the total number of individuals in the sample
5	$E (\%) = 100\left(\frac{H'}{\ln H_{max}}\right)$	Shannon evenness index, Evenness index, a structural composition index, which reflects the dominance of species, where, *E* is the Shannon's evenness (evenness measure, range 0-1), *H'* is the Shannon diversity index, H_{max} is the *ln* (*S*), and *S* is the number of total species found in the sample plot.

and families increased with increasing fallow age. For instance, when comparing between 1and 15-year fallow periods, the number of species increased from 25 to 45 while the number of families increased from 15 to 25 (Table 2). This is similar with the studies of Vieira *et al*. (2006), Faria *et al*. (2009) and Mostacedo *et al*. (2009) in 1 to 10 years after shifting cultivation where trees naturally regenerated from soil seed bank, root suckers and root sprout or stump sprout. Species composition was also found to increase with increasing fallow periods (Fukushima *et al*. 2007, Fukushima *et al*. 2008, Sovu *et al*. 2009, Tran *et al.* 2010). There were 82 species and 35 families in the primary forest, while in the logged-over secondary forest 77 species and 30 families (Table 2). This study found that loss of commercial species lost and decrease in number of species after logging was attributed to canopy opening. However, selective logging has both positive and negative effects on tree species diversity (Brown 1998, Van-Gemenden *et al*. 2003). Positive implications include efficient removal of one or two trees leaving the rest intact and canopy stratification. On the other hand, negative implications include disturbance of undergrowth, decline in animal population and decrease in site productivity among others.

Stock density reflects the spatial distribution of trees within the forest and the distribution of different species in relation to one another (Krebs 1999). Diameter size distribution is often used in management to manipulate forest stocking (Hitimana *et al*. 2004). The stock or stem density was highest (1,153 ha^{-1}) in 10-year-old fallow forest and lowest (12 ha^{-1}) in 1-year-old fallow forest (F=2.37, p=0.0013). Species competition from year one was low as the starting point of recovery starts in 10 year-old fallow period. Species diversity can be maximized from soil seed bank, root and stump sprout and dispersal of seeds from remaining forests. Most of the DBH classes ranged from 5 to 10 cm and 11 to 15 cm, while height classes ranged from 1 to 5 m and 6 to 10 m. The highest density of saplings and seedlings in 15-year-old fallow was 10,563 ha^{-1} and 8,393 ha^{-1}, respectively. These values of stem density was higher than other tropical countries such as 739 ha^{-1} in Mulu, Sarawak (Anonymous 2007), 625 ha^{-1} in Uppangala, India (Davis & Johnson 1987), 429 ha^{-1} in East Kalimantan, Indonesia (Gross *et al*. 2000) and 535 ha^{-1} in Letpanpin Community Forest, Myanmar (Oo *et al*. 2008). In tropical forest, some species are producing seeds at 15years old. At the same time, seedlings from soil seed bank as well as, root and stump sprout continue to grow into saplings. The growth patterns for height and DBH exhibits inverse J-shaped or L-shaped as shown in Figure 2. It indicates that the number of trees decreased with increasing DBH and height in all study sites which is similar to other related studies (Tran *et al*. 2005, Oo *et al*. 2007, Oo & Lee 2008, Tran *et al*. 2010).

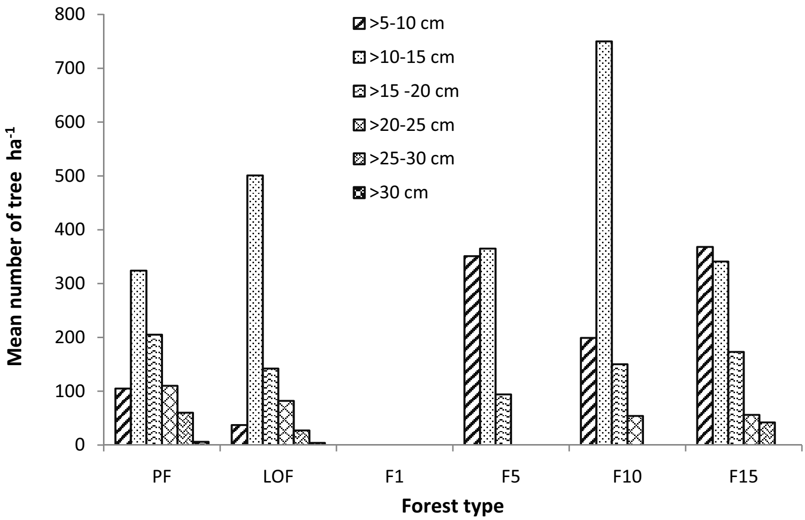
Species diversity is one of the basic concepts of ecology used to characterize communities and ecosystem. Environment heterogeneity has strong effects on species diversity (Whitmore 1998). This study found that species composition and diversity index were affected by logging and shifting cultivation. The vegetation characteristics in the primary and secondary forests (logged-over and fallow) are shown in Table 2. The Shannon diversity index increased from 2.13 in 1 year-old to 2.91 in 15 year-old fallow period compared to primary forest with 3.40 and logged-over forest with 3.09. The results of this study will serve as basic information for conservation and

Table 2. Vegetation characteristics of primary and secondary forests (logged-over and fallow).

				1		
Vegetation characteristics	Primary forest	Logged-over forest	15-year-old fallow	0-year-old fallow	5-year-old fallow	1-year-old fallow
Stem density (n ha^{-1})	810 (61)	793 (74)	980 (92)	1,153 (69)	813 (73)	12 (3)
Sapling density (n ha^{-1})	2,476 (1,240)	6,386 (1,627)	10,536 (3,652)	5,993 (1,132)	6,250 (1,002)	1,000 (408)
Seedling density (n ha^{-1})	4,050 (1,389)	1,932 (422)	8,393 (3,135)	2,500 (1,051)	1,964 (1,002)	408 (250)
Species number	82 (0.62)	77 (0.49)	45 (0.86)	44 (0.80)	31 (0.40)	25 (0.89)
Family number	35 (0.46)	30 (0.39)	25 (0.69)	24 (0.56)	21 (0.30)	15 (0.66)
Basal area (m^2 ha^{-1})	50.30 (4.13)	38.92 (6.94)	30.51 (2.93)	24.43 (0.08)	11.42 (0.03)	1.05 (0.09)
Volume density (m^3 ha^{-1})	316.87 (40.85)	275.73 (67.54)	150.95 (19.72)	120.24 (0.45)	47.75 (0.20)	1.34 (0.17)
Canopy cover (m^2/ha^{-1})	4,773 (596)	3,027 (208)	4,489 (320)	2,130 (173)	3,087 (780)	43.3 (5)
Litter layer and litter-fall (t ha^{-1})	4.8 (0.44)	7.1 (0.45)	4.1 (0.44)	5.3 (0.53)	3.7 (0.33)	3.4 (0.59)
DBH (cm)	15.69 (0.6)	12.58 (1.01)	12.19 (0.63)	10.93 (0.45)	7.49 (0.30)	2.27 (0.11)
Height (m)	12.97 (0.45)	11.09 (0.53)	11.52 (0.65)	9.61 (0.32)	8.02 (0.44)	2.64 (0.16)
Shannon's (*H'*)	3.40^{a}	3.09^{b}	2.91^{b}	2.72^{c}	2.71^{c}	2.13^{d}
Simpson's (*D*)	0.98^{a}	0.91^{ab}	0.78^{bc}	0.62^{c}	0.86^{b}	0.78^{bc}
Species evenness (*J'*)	0.66^{a}	0.62^{ab}	0.36^{b}	0.35^{b}	0.25^{c}	0.20^{cd}
Family evenness (*J'*)	0.85^{a}	0.73^{ab}	0.61^{b}	0.59^{bc}	0.51^{c}	0.37^{d}

Values in parenthesis indicates standard error and different letters indicate significant differences using DMRT ($p<0.05$).

A



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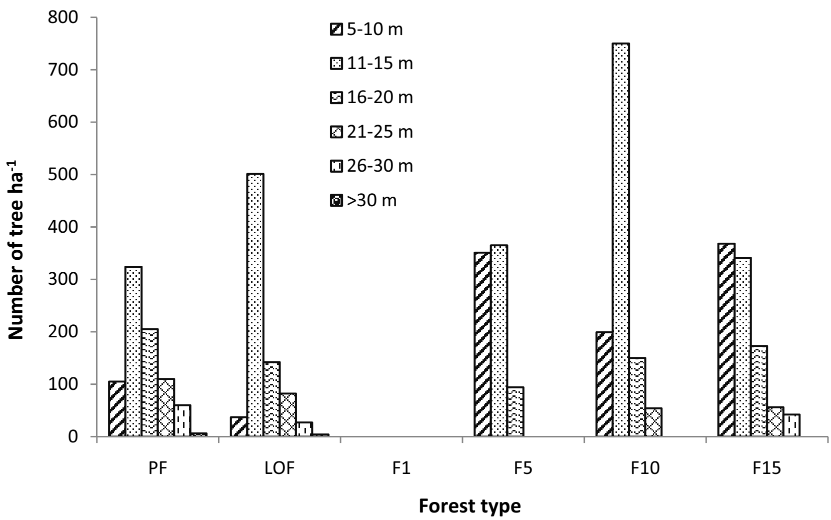

Figure 2. Distribution patterns of DBH (A) and height (B) of trees in the study area in Bolikhan District, Bolikhamxay Province, in the central part of Laos.

Legend: PF= primary forest; LOF = logged-over forest; F1 = fallow one-year-old; F5 = fallow 5-year-old; F10 = fallow 10-year-old; F15 = fallow 15-year-old.

restoration which is needed in forest management for example in selective logging by strip clear-cut method (Hartshorn 1989, Fredericksen & Mostacedo 2000, Vieira & Scariot 2006, Villela *et al*. 2006). Disturbance regimes are some of the most important factors in species composition and diversity (Mani & Parthasarathy 2006). In this study, shifting cultivation and logging were the determining factors in the forests.

The changes in importance value (IV) of different tree species in the primary and secondary forests are shown in Table 3. *Schima wallichii* had higher IV (17.22%) in the primary forest, while *Cratoxylum cochinchinensis* had higher IV in the fallow 10-year-old fallow (17.31%), secondary logged-over forest (16.2%), 15-year-old (15.99%), 5-year-old (9.67%), and 1-year-old fallow (8.05%). In 1-year-old fallow forest, it was found that *Aporosa microcalyx* had the highest IV (22.47%). The species with the highest IV are dominant or common in the site indicating the measure of their influence on the forest community (Karkee 2004). Pioneer tree species play an important role in natural regeneration of tropical forests as they are mostly distributed in the second and third storey during forest succession (Lamb *et al*. 2005, Kariuki *et al*. 2006, Sovue *et al*. 2009, Tran *et al*. 2010).

The success of natural regeneration depends on seed bank in soil, seed rain, seedling banks and seed dispersal or predation, stump sprouts, root sprouts, layering and remaining native tree species. Other factors are the level of disturbances, management system and environmental condition (Kennard *et al*. 2002, Parrotta *et al*. 2002, Okuda *et al.* 2003, Lamb *et al*. 2005).

In the Southeast Asia and other tropical developing countries, most of the natural regeneration after logging and shifting cultivation focuses on economic consideration for the next felling rotation or estimated times of recovery, such as 30 to 120 years of stabilization period (Kariuki *et al*. 2006, Read & Lawrence 2003, Fukushima *et al*. 2007) and 150 to 500 years (Riswa *et al*. 1985, Kartawinata 1994) for returning to original condition rather than the important role of environment and diversity. However, silvicultural techniques by assisted natural regeneration such as enrichment planting, direct seeding and mixed plantation of native or exotic tree species can also increase biodiversity in the future (Chazdon 2003, van Gemerden *et al*. 2003, Tran *et al*. 2005, Bischoff *et al*. 2005).

Changes in soil chemical properties after logging and shifting cultivation. This study found that not all soil chemical properties were changed after different types of disturbances and recovery time of forests (Table 4). In comparison with the results from the national forest inventory and soil survey and land classification conducted in 1993 in this area (Soil Research Centre 1993), most of the soil chemical properties did not significantly change except K ($F = 5.34$, $p = 0.0001$) compared to 15 years before shifting cultivation and logging activities. Both logging and shifting cultivation can affect local and regional global balance of carbon and nutrient cycles, litter decomposition, recovery of forest biomass, soil fertility, land use cover change, flora and fauna and increase deforestation rate in tropical counties (Lawrence & Forster 2002, Eaton & Lawrence 2009). Some studies showed that aboveground biomass and carbon are usually affected by disturbances compared to soil chemical properties and forests have also been lost through other activities such as mining and

Table 3. Changes in the importance value (%) of different tree species in the primary and secondary (logged-over and fallow) forests.

No.	Species	Primary forest	Logged-over forest	15-year-old fallow	10-year-old fallow	5-year-old fallow	1-year-old fallow
1	*Schima wallichii*	17.22	6.40	2.34	5.14	6.67	3.42
2	*Castanopsis sp*	8.06	2.91	4.67	-	-	-
3	*Anisoptera costata*	6.62	2.28	1.65	0.47	-	-
4	*Measua ferrea*	5.48	2.32	1.79	1.85	-	-
5	*Cratoxylum formosum*	3.40	-	-	-	-	-
6	*Eugenia ssp*	3.36	2.16	3.88	2.73	2.28	1.88
7	*Arytera litoralis*	3.05	1.62	2.06	2.12	1.57	-
8	*Glochidion fagifolium*	2.99	2.19	4.43	7.37	6.93	1.42
9	*Dipterocarpus alatus*	2.67	-	-	-	-	-
10	*Sandoricum indicum*	2.63	0.34	1.44	0.54	-	-
11	*Aporosa microcalyx*	2.23	9.93	15.58	17.10	8.76	22.47
12	*Irvingia malayana*	1.89	1.07	4.20	3.93	2.46	1.29
13	*Ziziphus cambodiana*	1.49	2.10	3.38	4.54	-	2.00
14	*Ormosia cambodiana*	1.41	0.39	4.79	1.10	1.29	-
15	*Croton joufra*	1.18	0.63	-	1.70	6.43	5.20
16	*Dillenia indica*	0.70	1.48	3.11	2.72	4.13	-
17	*Croton crassifolius*	0.66	-	-	-	-	3.35

18	*Sp 4 (Xou khi khouay)*	0.60	0.75	-	0.98	4.15	-
19	*Gmerina arborea*	0.53	0.29	-	1.85	1.90	2.59
20	*Vitex pubescens*	0.40	1.07	1.13	0.78	3.07	-
21	*Croton argyratus*	0.28	5.02	0.94	1.20	1.09	-
22	*Macaranga denticulata*	-	0.32	-	-	5.48	19.47
23	*Machilus cochinchinensis*	-	0.62	3.34	1.56	3.07	-
24	*Diospyros malabarica*	-	2.39	0.42	0.42	0.99	-
25	*Macaranga triloba*	-	2.44	-	-	0.15	1.42
26	*Lagerstroemia balansae*	-	2.73	-	-	-	-
27	*Peltophorum dasyrachis*	-	8.75	2.46	4.81	1.09	4.72
28	*Cratoxylum cochinchinensis*	-	16.20	15.99	17.31	9.67	8.50
29-123	Other species	33.15	23.6	22.4	19.78	28.82	22.27
	Sum	100.0	100.0	100.0	100.0	100.0	100.0

Blank (-) indicated no species exits and under lined value (_) indicate top ten dominant species in each forest types

Table 4. Changes in soil chemical properties after logging and shifting cultivation at (0-20cm)

Forest types	pH H_2O	pH Kcl	Total N %	Organic Carbon %	C/N ratio	OM %	P-av ppm	K-av ppm	Ca^{++} mg/100g	Mg^{++} mg/100g	Na^{++} mg/100g	K^{++} mg/100g
Primary	3.93 (0.03)	3.71 (0.03)	0.13 (0.01)	1.49 (0.09)	11.71 (0.13)	2.56 (0.15)	2.75 (0.23)	32.94 (3.05)	0.22 (0.03)	0.46 (0.02)	0.04 (0.00)	0.08 (0.01)
Logged-over	4.29 (0.06)	3.89 (0.04)	0.13 (0.01)	1.44 (0.15)	10.66 (0.32)	2.48 (0.26)	1.46 (0.12)	106.32 (19.41)	0.32 (0.08)	0.52 (0.05)	0.18 (0.02)	0.25 (0.15)
Fallow (15 yrs)	4.24 (0.02)	3.92 (0.04)	0.11 (0.01)	1.12 (0.19)	10.04 (0.79)	1.92 (0.33)	1.38 (0.37)	56.97 (9.46)	0.28 (0.04)	0.56 (0.05)	0.24 (0.01)	0.21 (0.15)
Fallow (10 yrs)	3.93 (0.05)	3.75 (0.05)	0.17 (0.01)	1.74 (0.12)	10.52 (0.38)	3.00 (0.21)	2.25 (0.29)	61.87 (5.35)	0.29 (0.03)	0.44 (0.03)	0.09 (0.02)	0.17 (0.04)
Fallow (5 yrs)	4.05 (0.05)	3.83 (0.05)	0.16 (0.01)	1.66 (0.11)	10.39 (0.32)	2.87 (0.18)	2.24 0.14)	90.16 (7.77)	0.29 (0.02)	0.45 (0.01)	0.09 (0.03)	0.20 (0.03)
Fallow (1 yr)	4.10 (0.05)	3.87 (0.04)	0.15 (0.01)	1.58 (0.12)	10.67 (0.39)	2.66 (0.20)	2.59 (0.24)	81.27 (5.29)	0.28 (0.03)	0.45 (0.02)	0.10 (0.02)	0.15 (0.02)
Soil Research Centre, 1993	4.5 (0.00)	4.0 (0.00)	0.12 (0.00)	1.09 (0.00)	9.08 (0.00)	2.87 (0.00)	2.70 (0.00)	5.60 (0.00)	0.43 (0.03)	0.46 (0.03)	0.06 (0.00)	0.11 (0.01)

Values in parenthesis indicated standard errors infrastructure development (Kariuki *et al*. 2006, Yemefack *et al*. 2006, Neergaard 2008). Prasit (2002) studied the change in 5-year old fallow compared to secondary forest in northern Thailand. He found that SOM, total N and tree biomass increased, while pH, P, K^+, Ca^{2+} and Mg^{2+} decreased. In tropical forest of East Kalimantan of Indonesia, aboveground biomass increased by secondary fallow forest age after shifting cultivation from 8-10 t ha^{-1} in 1-year old and 45 to 56 t ha^{-1} in 10- to 12-year old (Hashimotio *et al*. 2000).

Changes in microclimate condition of primary and secondary forests (logged-over and fallow). Microclimate is a factor that determines the environmental conditions for forage productivity (Feldhake 2001). The results also showed that 5-year old secondary fallow forest had higher air temperature (AT) ranging from 21.3 to 27.7 ^{o}C between February and April and relative humidity (RH) ranging from 66.7 to 99.8% between March and August (Figure 3). The maximum average AT was higher in fallow forests (27.5^{o}C) compared to logged-over and primary forests (27.3 ^{o}C). However, the maximum average of RH was higher in logged-over (105%) and primary forest (103%) compared to fallow forests (98%) (Figure 3). Therefore, anthropogenic disturbances such as logging and shifting cultivation which led to canopy opening subsequently caused higher AT but lower RH in young age fallows compared to primary forest as shown by results. Vegetation plays a critical role in shaping the microclimate through the change of energy and water balance across the landscape (Xu *et al*. 2002). Trees leaves protect against fluctuation of temperature through evaporation cooling or shading (Kimmins 1997). Air temperature affects growth and development of woody plants directly by including injury and directly by influencing physiological processes and yield and quality of fruit and seeds (Kozlowski & Pallardy 1997).

The changing environmental conditions allow for the simultaneous occurrence of species characteristic of both early and late succession stages (Mani & Parthasarathy 2006). Microclimate is a host of climatic variables unique to a specific location at a specific time and forest types (Meyer *et al*. 2001). Microclimate, especially the thermal regime of the microenvironment, is very important in forest management (Kimmins 1997, Weng *et al*. 2007, Zhu *et al*. 2007, Stoffel *et al*. 2010). In humid tropical forest, RH is higher in forested than cleared area during rainy months, but RH in affected areas are less pronounced during dry months. According to Ghuman and Lal (1986), AT during rainy season is lower by 1 to 5^{o}C under forested than cleared land area. In leaves of an oak-hornbeam forest, approximately 50% of incident photosynthetically active radiation was absorbed by the upper 4 m layer of leaves and only less than 5% penetrated to the forest floor. Meanwhile, vertical gradients of AT and RH were generally differences in diurnal ranges of AT and RH were observed between vertical levels of tree leaves in an oak-hornbeams forest trees (Elias *et al*. 1989). In clear-cut beech forest, there was a strong correlation between microclimatic parameters and distance from the forest edge (Godefroid *et al*. 2006).

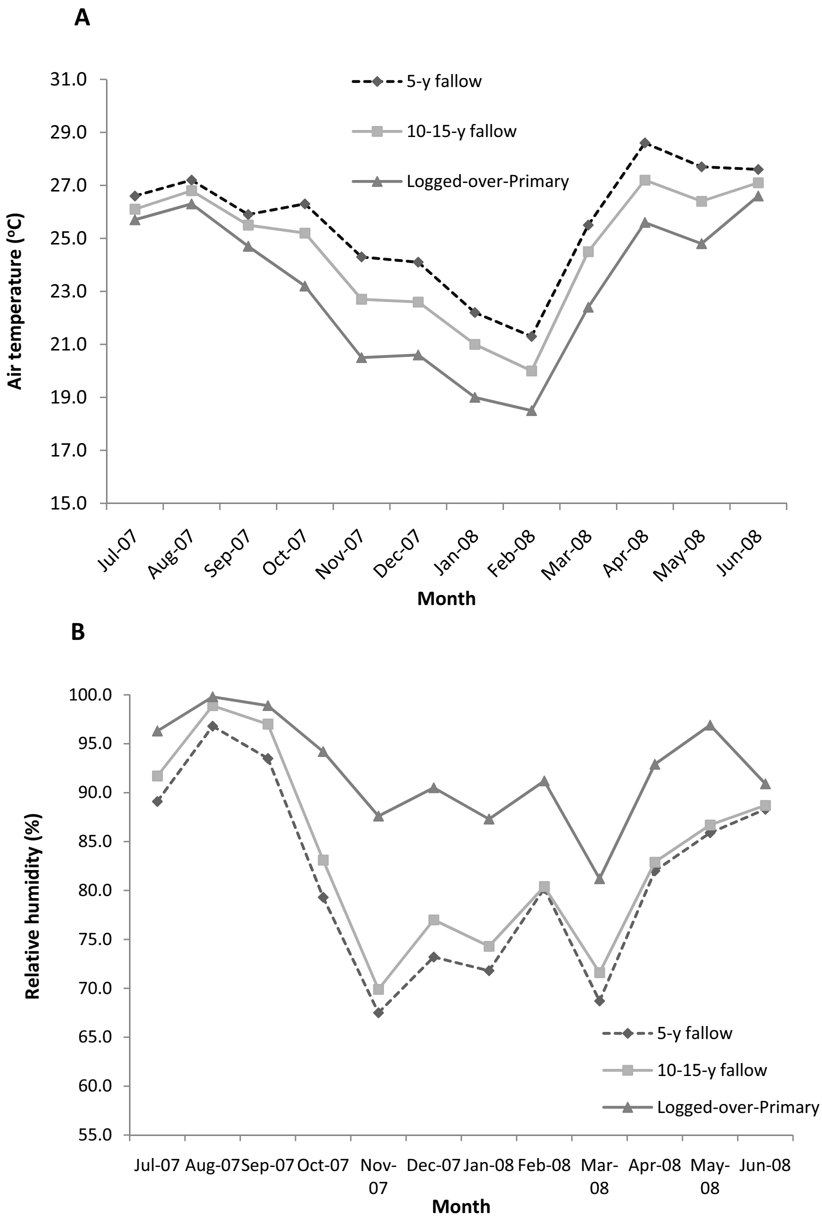

Figure 3. Changes of means air temperature (AT) and relative humidity (RH) in the study site in Bolikhan District, Bolikhamxay Province, in the central part of Laos.

CONCLUSION

Our results show that different environment factors play important roles in stand structure in forest recovery. The number of species, family, was increased from logged-over and fallows period. The number of pioneer species stand was increased in 10-year and decreased in 15-year old fallow. The maximum sapling and seedling was found in Natural regeneration of secondary forest after logging, shifting cultivation and other disturbances is becoming an important method for restoring degraded forest ecosystem in tropical countries. Therefore, human assistance is needed to restore the forest structure, species composition and species interaction on secondary forests which is important in tropical secondary for biodiversity conservation. However, in restoring degraded forestlands, economically viable and suitable approaches should be considered for rehabilitating degraded forest, mixed plantation and agro forestry area.

Therefore, data from this study could be applied for management implications such as time to forest recovery after shifting cultivation and logging in mixed deciduous forest (stand structure and species diversity). The forest management model should be integrates ecological, economic and social principles into a production system designed for sustainable development of tropical forest resources. The potential to apply these methods should be explored when formulating plans to restore forests on degraded and denuded land. Monitoring of microclimate condition in different types of vegetation during recovery process would be helpful for forest and climate change in large scale.

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