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Natural Regeneration and Tree Species Composition of Mixed Deciduous Forest after Logging and Shifting Cultivation in Lao PDR

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Abstract–Shifting cultivation and logging are serious problems in tropical countries like Laos which contribute to a large extent in the increase of deforestation. In this study, stand structure, species composition and diversity, soil chemical properties 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 in Laos. All woody species with stem diameter of ≥ 5 cm were identified and counted. Diameter at breast height (DBH) (1.3 m) was measured in all plots. The distance time to recovery was also compared among the sites. The family and species composition were increase from 25 species and 15 families, 31 species and 21 families, 44 species and 24 families, 45 species and 25 families after slash and burn for 1-year, 5- year, 10-year, 15-years fallow periods. While, species composition was increased 82 species and 30 families in logged-over secondary forest if compared to 77 species and 35 families found in primary forest. Three pioneer species were higher importance value such as *Schima wallichii* in primary forest, *Cratoxylum cochinchinensis* in 15, 10 and 5-year-old fallow and *Aporosa microcalyx* in 1-year-old fallow. The basics data obtained in this study will be very useful in managing secondary forests in the future.

Keywords: fallow, logged-over, microclimate, mixed deciduous forest, natural regeneration, recovery, shifting cultivation, soil chemical properties, species composition, stand structure

Introduction

The tropics and sub-tropics were about 56% of the total world's forests, which higher level rate of deforestation were recorded (FAO, 2001). In these areas, shifting cultivation, logging and fuel-wood and wood charcoal consumption are very common problems (FAO, 2006; Mertz *et al*., 2009; Lawrence *et al*., 2010). The main drivers of deforestation and forest degradation in Laos was mainly shifting cultivation, followed by logging, infrastructure development, land conversion to agriculture and industrial activities (MAF 2005b; GoL 2006; Phongoudome and Sirivong 2007). In Laos alone, it has been estimated that more than 6.5 million ha of forests (28.2% of the total land area) are affected by shifting cultivation involving about 17% of the human populations (Messerli *et al*., 2009; Sovu *et al*., 2009; Schmidt-Vogt *et al*., 2009). In Laos rehabilitation and restoration of forests in Laos are mainly based on natural regeneration and plantation. The government aims to increase the national forest cover of up to 70% by the year 2020 through establishment of more than 6 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, 2005a). Tropical mixed deciduous forests are the most extensive and important tropical vegetation in Laos, which was about 8.6 million ha in 1982 and 6.3 million ha (62% of total current forest) in 2002 (MAF, 2005b).

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 and 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 and Chokkalingam, 2001). Basic information on species composition would be useful in evaluating the impact of previous forest activity. It can also indicate the capability of forest recovering from past disturbances, so the information can 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 and Laumonier, 2000). Floristic inventory is necessary for much fundamental research in tropical community ecology, such as modelling patterns of species diversity or understanding species distribution. It is because forest communities are dynamic and individual and species composition levels are changing continuously (Felfili, 1995; Phillips *et al*., 2003). Only few in depth studies have characterized tree species composition and stand structure of forests in Laos. Thus, this study was conceptualizes with the main objective of comparing the natural regeneration patterns of logged-over and fallow forests of secondary mixed deciduous in Laos after logging and shifting cultivation using primary forest as a control.

Materials and Methods

Site description

The study was conducted in Bolikhan District, Bolikhamxay Province, in the central part of Laos. It is about 185 km from the 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 165-175 m above sea level (a.s.l.), with a slope of 2-5 degrees. The mean temperature for a decade (2000-2009) ranged from 21.4 C° to 31.2 C° and the mean annual rainfall ranged from 2,000-2,700 mm. The tropical mixed deciduous forests in the study site cover a primary forest with 719 ha,

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secondary logged-over forest with 5,323 ha, secondary fallow forest with 8,496 ha and non-forest with 414 ha (Figure 1). The first selective cutting method was carried out in the natural forest in 1983-84 and second in 1994-95 by the State Forest Enterprise Company. This practice followed by human activities such as several years of shifting cultivation, fuel-wood collection and charcoal making after timber harvesting seriously affected the forests in this area.

Stand measurement

The number and size of sample plots established in each forest type were different due to the area coverage of the coverage of the study area. A total of 180 plots (30 plots in 6 sites) with 20 m x 20 m size were systematically established in the study area (7.2 ha). Species, diameter at breast height of all trees (DBH ≥5 cm), height, and canopy cover of each tree were measured in each plot. Equations used for stand structure and species composition analysis are shown in Table 1. For measuring the saplings height (>1.3 m) and DBH (<5 cm) a sub-plot of 5 m x 5 m was established. While, for measuring seedlings' height (<1.3 m), a sub-plot of 2 m x 2 m, was established.

Litter layer

To determine the amount of litters in the litter layer, a sub-plot (1 m x 1 m) was established in each plot during inventory period. Litters were collected and weighed. Samples were than brought to the laboratory of Forest Research Centre (FRC) and were oven dried for 24 to 48 hours at 70°C until constant weight. The dried weight was recorded.

Soil analysis

At the center of each plot, soil sample was collected at 20 cm depth. The samples obtained were brought to the Soil Research Centre (SRC), National Agriculture and Forestry Research Institute (NAFRI), Laos for analyzing the soil chemical properties such as pH (H_2O), pH (Kcl), total N%, P available, K available, soil organic matter (SOM), soil organic carbon %, C and N ratio, cation exchange C^{++}, Mg^{++}, Na^{++}, and K^{++}.

Micro-climate data collection

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 during the research period. All data were automatically collected with one-hour interval (BoxCar Pro 4.0 Onset Computer Corporation, USA).

Data analysis

The mean value and standard errors of vegetation parameters and soil chemical properties were analyzed using MS Excel 2007 and SAS 9.1.3 for Windows 2007 (SAS Institute Inc., USA) Duncan's Multiple Range Test (DMRT) was used to examine the different soil chemical properties in the forests. The significance for all analyses was determined at α=0.05.

Results and Discussion

Vegetation characteristics of primary, secondary logged-over and secondary fallow forest in Laos

A total of 123 tree species and 40 families were found in the study site (DBH ≥5 cm). The number of species and families increased with increasing fallow age. For instance, 25 species and 15 families, 31 species and 21 families, 44 species and 24 families, 45 species and 25 families were recorded for after slash and burn activities in the area for 1-year, 5-years, 10-years and 15-years fallow period, respectively. This is similar with the studies of Vieira *et al*., (2006), Faria *et al*., (2009) and Mostacedo *et al*., (2009) where 1 to 10 years after slash and burn, most natural regeneration was based on soil seed bank, root suckers and root sprout or stump sprout and species composition increased 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 77 species and 30 families in the logged-over secondary forest (Table 2). This study found out that after logging canopy was became open and the number of species increased by 5 species. However, selective logging has also positive and negative effects on tree species diversity (Brown 1998; Van-Gemenden *et al*., 2003).

The stem density (DBH ≥5 cm) was highest (1,153/ha) in 10-year-old fallow forest and lowest (12/ha) in 1-year-old fallow forest. The competition among species from year one was not high as the starting point of recover is on 10-year-old fallow period. It is can maximize growth from (soil seed bank, root and stump sprout) and dispersal of seeds from remaining forests is possible. Most of the DBH classes ranged from 5-10 cm and 11-15 cm, while height classes ranged from 1-5 m and 6-10 m. The highest stem density in saplings and seedlings was 10,563/ha and 8,393/ha, respectively in 15-year-old fallow forest. In tropical forest some species are already producing seed during 15-year-old. At the same time, seedlings from soil seed bank as well as, root and stump sprout continue to growth into saplings. The growth patterns for height and DBH exhibits reverse J-shape or L-shape as shown in Figure 2.

Species composition diversity has been one of the basic concepts of ecology used to characterized communities and ecosystem, and environment heterogeneity has strong effects on species diversity (Whitmore, 1998). This study found out 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 to 2.91 in 1-year-old to 15-year-old fallow period or if compared to primary forest 3.40 and in logged-over forest 3.09. The results of this study will serve as a basic for conservation and restoration times frame which is needed in forest management, e.g. selective logging by strip clear-cuts methods (Hartshorn, 1989; Fredericksen and Mostacedo, 2000; Vieira and Scariot, 2006; Villela *et al*., 2006).

The changes in importance value (IV) of different tree species in the primary and secondary forests (logged-over and fallow) are indicated in Table 3. *Schima wallichii* had higher IV (17.22%) in the primary forest. While, *Cratoxylum cochinchinensis* had higher IV in the secondary logged-over forest, 15-year, 10-year, and 5-year-old secondary forests 16.20%, 15.99% and 16.20%, 15.99%, 17.31% and 9.67%, respectively). In 1-year-old secondary fallow forest, it was found out that *Aporosa microcalyx* had the highest IV 22.47%. The pioneer tree species were play important role for natural regeneration in tropical forest studies, when the forest succession most of them are distribution in second and third storey (Lamb et al., 2005; Kariuki et al., 2006; Sovue *et al*., 2009; Tran *et al*., 2010).

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

Most of natural regenerations in southeast Asia and other tropical developing countries after logging and shifting cultivation focuses on economic consideration for the next felling rotation or estimated times of recovery, such as 30-120 years of stabilization period (Kariuki *et al*., 2006; Read and Lawrence, 2003; Fukushima *et al*., 2007) and 150-500 years (Riswa *et al*., 1985; Katawinara, 1994) for returning to original condition, than the important role of environment and diversity. However, silvicultural techniques by assistant natural regeneration such as enrichment planting, direct seeding and mixed plantation of native or exotic tree species can also increased biodiversity in the future (Chazdon, 2003; van Gemerden *et al*., 2003; Tran *et al*., 2005; Bischoff *et al*., 2005). Therefore, species composition and structure and their natural regeneration or assistant natural regeneration in tropical rain-forest or tropical deciduous forest (Jordan *et al*., 1987; Kennard *et al*., 2002; Hardwick *et al.*, 2004) must be fully understood in conducting research.

Changes in soil chemical properties after logging and shifting cultivation

This study shows that 5-year-old secondary fallow forest had higher air temperature (AT) ranging from 8 to 48°C in dry season (November 2007 to July 2008) and relative humidity (RH) ranging from 35 to 84% in October 2007. The AT and RH slightly decline from May 2007 to July 2008 (8 to 38°C and 35 to 95%, respectively) in between 10 and 15-year-old fallows, but RH of logged-over secondary forest and primary forest became (8 to 35 °C and 25 to 85%).Microclimate is a host of climatic variables unique to a specific location at a specific time and forest types (Meyer *et al*., 2001). In humid tropical forest, (RH) is higher in forested than cleared area during rainy months, but affected areas are less pronounced during dry months. According to Ghuman and Lal (1986), (AT) during rainy season is lower by 1-5°C under forested than cleared land area. In leaves of an oak-hornbeam forest, approximately 50% of incident photo-synthetically active radiation (PAR) was absorbed by the upper 4 m layer of leaves and only less than 5% penetrated to the forest floor. While, vertical gradients of AT and RH were generally low, but large differences in diurnal ranges of AT and RH were observed between vertical levels (Elias *et al*., 1989). In clear-cut beech forest there was strong correlation between microclimatic parameters and distance from the forest edge (Godefroid *et al*., 2006). 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).

Conclusions

Natural regeneration of secondary forest after logging, shifting cultivation or other disturbances is becoming an important method for restoring degraded forest ecosystem in tropical countries. Therefore, human's assistance is needed to recover forest structure, species composition, and species interaction on secondary forests. This is important in tropical secondary forest and in conserving biodiversity. However, in restoring degraded forestlands, cheapest and easy approach for rehabilitating degraded forest, mixed plantation and agro forestry areas should be considered.

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Figure 1. The location of the study site in Bolikhan District, Bolikhamxay Province, Laos

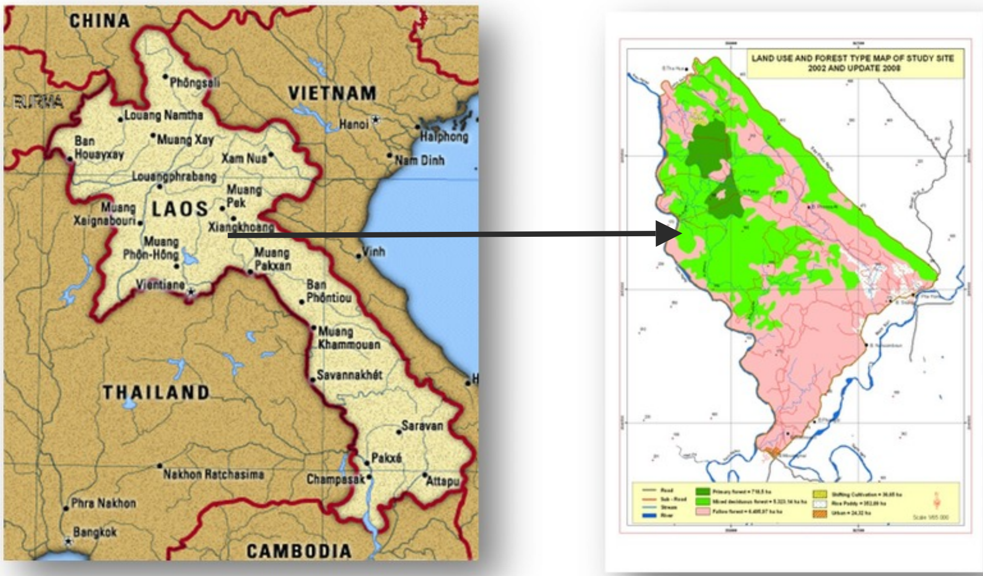
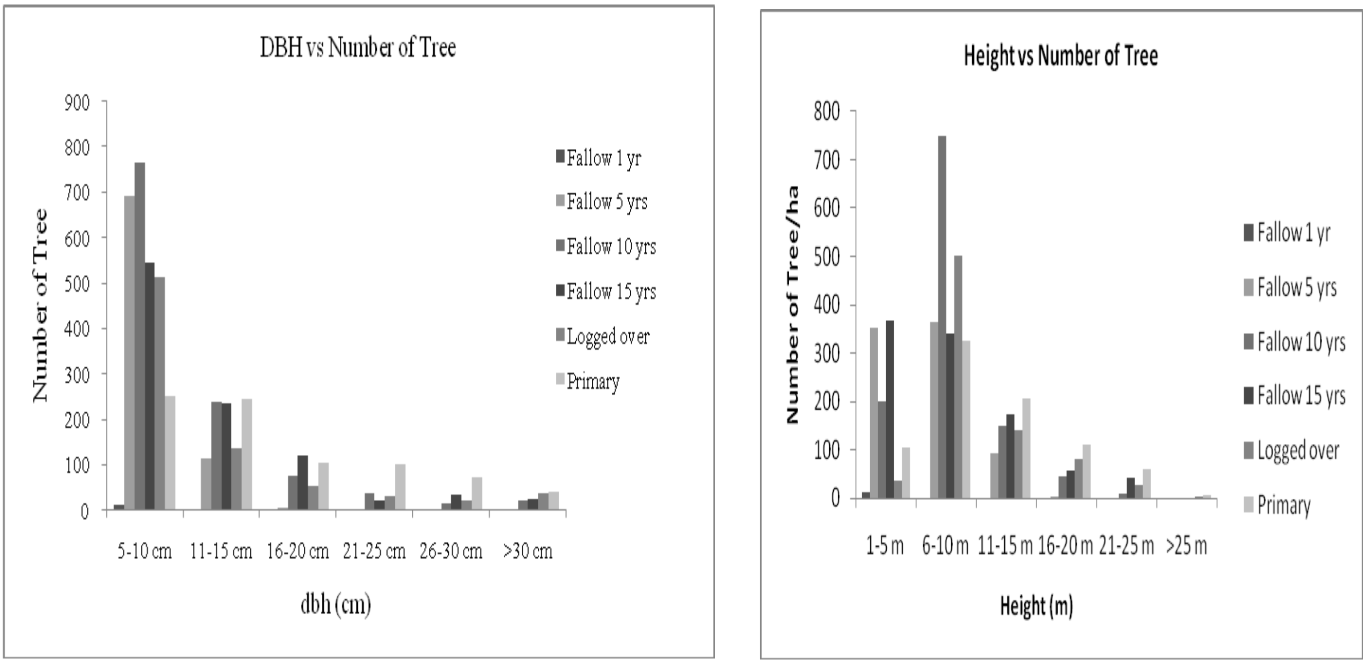


Figure 2. Distribution patterns of DBH and height in study area (A-B)



(A) (B)

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

Series no.	Equations	Remarks
1	**IVI (%)=(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	$H' = -\sum_{i=1}^{s} pi\, 1n\, pi$	Where Shannon diversity index (H'), pi is the proportion of the individuals in the ith 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, ni 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	$E(\%) = 100 \left(\frac{H'}{InH_{\max}} \right)$	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, Hmax is the ln (S), and S is the number of total species found in the sample plot.

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

Vegetation characteristics	Primary forest	Logged-over forest	15-year-old fallow	10-year-old fallow	5-year-old fallow	1-year-old fallow
Stem density (n/ha)	810 (61)	793 (74)	980 (92)	1,153 (69)	813 (73)	12 (3)
Sampling density (n/ha)	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)	4,050 (1,389)	1,932 (422)	8,393 (3,135)	2,500 (1,051)	1,964 (1,002)	408 (250)
Species number	77 (0.62)	82 (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 (m2/ha)	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 (m3/ha)	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 (m2/ha)	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)	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')	0.62^{ab}	0.66^{a}	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}

Value in parenthesis indicates standard error and different letters indicate significant differences using DMRT

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

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	6.4	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	3.4	–	–	–	–	–
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	Dipterocar pus alatus	2.67	–	–	–	–	–
10	Sandoricum indicum	2.63	0.34	1.44	0.54	–	–
11	Aporosa microcalyx	2.23	9.93	15.58	17.1	8.76	22.47
12	Irvingia malayana	1.89	1.07	4.2	3.93	2.46	1.29
13	Ziziphus cambodiana	1.49	2.1	3.38	4.54	–	2·00
14	Ormosia cambodiana	1.41	0.39	4.79	1.1	1.29	–
15	Croton joufra	1.18	0.63	–	1.7	6.43	5·20
16	Dillenia indica	0.7	1.48	3.11	2.72	4.13	–
17	Croton crassifolius	0.66	–	–	–	–	3.35
18	Sp 4 (Xou khi khouay)	0.6	0.75	–	0.98	4.15	–
19	Gmerina arborea	0.53	0.29	–	1.85	1·90	2.59
20	Vitex pubescens	0.4	1.07	1.13	0.78	3.07	–
21	Croton argyratus	0.28	5.02	0.94	1.2	1·90	–
22	Macaranga denticulata	–	0.32	–	–	5.48	19.47
23	Machilus cochinchinen sis	–	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	8.5
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

(-) The blank indicated no species exits and under line are indicate top ten dominant species of each forest types

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

Forest types	**pH**	**pH**	**Total**	**Organic**	**C/N**	**OM**	**P-av**	**K-av**	**Ca++**	**Mg++**	**Na++**	**K++**
	H2O	Kcl	N %	Carbon %	ratio	%	ppm	ppm	mg/100 g	mg/100 g	mg/100 g	mg/100 g
Primary	3.93	3.71	0.13	1.49 (0.09)	11.71	2.56 (0.15)	2.75	32.94	0.22 (0.03)	0.46 (0.02)	0.04 (0.00)	0.08 (0.01)
	(0.03)	(0.03)	(0.01)		(0.13)		(0.23)	(3.05)				
Logged-over	4.29	3.89	0.13	1.44 (0.15)	10.66	2.48 (0.26)	1.46	106.32	0.32 (0.08)	0.52 (0.05)	0.18 (0.02)	0.25 (0.15)
	(0.06)	(0.04)	(0.01)		(0.32)		(0.12)	(19.41)				
Fallow (15yrs)	4.24	3.92	0.11	1.12 (0.19)	10.04	1.92 (0.33)	1.38	56.97	0.28 (0.04)	0.56 (0.05)	0.24 (0.01)	0.21 (0.15)
	(0.02)	(0.04)	(0.01)		(0.79)		(0.37)	(9.46)				
Fallow (10yrs)	3.93	3.75	0.17	1.74 (0.12)	10.52	3.00 (0.21)	2.25	61.87	0.29 (0.03)	0.44 (0.03)	0.09 (0.02)	0.17 (0.04)
	(0.05)	(0.05)	(0.01)		(0.38)		(0.29)	(5.35)				
Fallow (5yrs)	4.05	3.83	0.16	1.66 (0.11)	10.39	2.87 (0.18)	2.24	90.16	0.29 (0.02)	0.45 (0.01)	0.09 (0.03)	0.20 (0.03)
	(0.05)	(0.05)	(0.01)		(0.32)		(0.14)	(7.77)				
Fallow (1 yr)	4.1	3.87	0.15	1.58 (0.12)	10.67	2.66 (0.20)	2.59	81.27	0.28 (0.03)	0.45 (0.02)	0.10 (0.02)	0.15 (0.02)
	(0.05)	(0.04)	(0.01)		(0.39)		(0.24)	(5.29)				

Value in parenthesis indicated standard error