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Forest recovery assessment in degraded dry evergreen forestlands in Vientiane Province, Lao People's Democratic Republic

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Abstract. *Alias MAB, Rahmani W, Azizi F, Ninchaleune B, Abdu A. 2024. Forest recovery assessment in degraded dry evergreen forestlands in Vientiane Province, Lao People's Democratic Republic. Asian J For 8: 31-40.* Shifting cultivation and logging are the significant causes of deforestation and forest degradation in tropical region. Lao PDR has vast shifting cultivation areas, and regrowth forests have spontaneously been established on fallow fields. This study aims to assess the forest recovery through vegetative succession after fallow cultivation and logging in degraded dry evergreen forestlands in Vientiane Province, Lao PDR. Braun-Blanquet method was applied to assess vegetation composition in primary forest, logged-over forest and fallow lands with age of 1-, 5- and 15-year-old. Data obtained from the vegetation study has enabled the community plant identification and forest recovery calculation by various analytical methods using statistical software. Based on the phytosociological analysis, logged-over forests had the highest vegetation composition similarity to primary forests with a similarity of 42.29%, followed by the 15, 5, and 1-year-old fallows with similarity value of 39.90%, 34.80%, and 26.10%, respectively. The three fallows with 1-, 5- and 15-year-old age and two forest types were compared for their canopy structure recovery with each other. The logged-over forest, harvested by wood logging companies and local villagers in the past two decades, recorded the lowest recovery in the canopy structure. The sites of 1-, 5- and 15-year-old fallows have not fully recovered their top layers (ST and T1). Only the T2 layer of the 15-year-old fallow recovered. This indicated that the three fallow types heavily degraded and required a longer time to recover naturally. In conclusion, local authorities should avoid over-using the natural forest in the future and should control timber and non-timber forest products. Alternative land use with integrated land management should be established. Long-term tree planting programs will enable the people to use and own their land.

Keywords: Forest fallows, primary forest, recovery assessment, shifting cultivation

INTRODUCTION

Lao People's Democratic Republic (Lao PDR) is a Southeast Asian country covering an area of 23.68 million hectares (JICA 2001) that presented the highest forest cover (70% of land area) in the 1940s (Chien 2019). Nonetheless, forest cover in Lao PDR has declined significantly in recent decades. Compared to that in 1940s, forest cover had declined to 47% (11.1 million hectares) by 1992, and decreasing further to 41.5% (9.7 million hectares) by 2002. By 2010, forest cover was estimated at 40.34% (9.5 million hectares) of total land area of the country (Phimmavong et al. 2009; Thomas 2015).

Changes in land use are the primary causes of deforestation in Lao PDR including forest conversion into commercial agriculture, hydropower, logging, and plantations (Thomas 2015). Legal and illegal logging, especially salvage logging and pioneering shifting agriculture, are the major drivers of degradation (Liebsch et al. 2008). The lack of consistent rules, compliance procedures, and land use planning and management processes, including sustainable forest management and planning, led to forest depletion (Phongoudome and Sirivong 2007). That includes significant deforestation at a rate of 1.25% each year, equating to a reduction of 140,000 ha of forest annually (FAO 2015). Agriculture land expanded significantly, almost doubling from 708,700 ha in 1982 to 1,200,000 ha in 2002. This was followed by a reduction in the area of other forested land from 1.5 million ha to 287,000 ha (Phongoudome and Sirivong 2007).

Shifting cultivation and inappropriate logging are the practices that depleted the forest cover and caused serious environmental degradation, e.g., drought, flooding, and plant diseases in many parts of Lao PDR. Shifting cultivation, also known as swidden or slash-and-burn, is a traditional land use in the tropical forest-agriculture frontier that has shaped the foundation of land uses, livelihoods, and traditions in upland areas for centuries (Metzger 2003; Mertz et al. 2009; van Vliet et al. 2012; Dressler et al. 2015). Shifting cultivation is one of the major causes of habitat destruction as well as forest and land degradation in Lao PDR (Phompila et al. 2017). Shifting cultivation, practiced by most of the rural population, which accounts for about 70% of the total population, is also a significant cause of deforestation and forest destruction (Koch 2017). Despite ongoing efforts to eliminate the age-old farming tradition of slash and burn, this continues to be practiced across large areas of the region. One important prevalence of slash-and-burn farming activity in rural Lao PDR is the lack of alternative livelihood sources (Heinimann et al. 2017).

In Lao PDR, regrowth forests provide valuable local livelihoods and ecological services (Heinimann et al. 2017; Phompila et al. 2017). In regrowth forests, many early successional and shade-tolerant plants initially colonize such abandoned areas, primarily determined by recruitment, competition, mortality, and species regeneration (van Breugel 2007). Following the elimination of invasive species, some pioneer and later-stage species would gradually dominate fallow areas, each giving way to a successor until the appearance of a climax community, according to the classical relay floristics concept. Therefore, barring human interference, the initial floristic composition is largely determined by species dispersal through natural predators, resprouting from stumps and root suckers, and regeneration from soil seed banks (Egler 1954; Kammesheidt 1999; Norman et al. 2006; Vieira and Proctor 2007). With the latest global pattern of abandonment of swidden agriculture for other means of subsistence, such regrowth forests offer an excellent opportunity to be studied regarding the long-term successional changes in vegetation (Teegalapalli and Datta 2016).

Over the last two decades, there have been rising research activities in Southeast Asia to investigate species diversity and biomass regeneration trends in regrowth forests on former swidden land (Widiyatno et al. 2017). This understanding of the natural ecosystem serves as the basis for both passive and active restoration methods in the now-burgeoning research and practice of ecological restoration (SER 2004; Walker and Del Moral 2008; Jacobs et al. 2015). The wider ecological and environmental literature development has begun attracting more due to the potential of regrowth forests in promoting landscape regeneration (Chazdon et al. 2009; Chazdon 2014). However, the rate and trajectory of vegetation transition on former fallow lands are still poorly understood due to the different biotic and abiotic factors, and their dynamic interactions that influence forest succession (Maza-Villalobos et al. 2011; Mwampamba and Schwartz 2011).

In Lao PDR, the encroachment of natural forests by the three main ethnic groups (i.e., Lao Loum, Lao Theung, and Lao Soung), mainly for agricultural production and livestock raising, has exacerbated the country's deforestation rate. Other issues that disturb forest in this country include inappropriate logging, diminishing national timber and important habitats, and shifting cultivation in areas with short fallows and steep terrain. Allowing the disturbed forests to regrow naturally might be a realistic policy and management option in Lao PDR considering the socio-economic and political conditions. However, the trajectory of such regrowing forests remains unclear. Therefore, this study aims to assess the forest recovery through vegetative succession after fallow cultivation and logging in degraded dry evergreen forestlands in Vientiane Province, Lao People's Democratic Republic. In doing so, we compared vegetation composition in primary forest with that in fallow lands with age of 1, 5 and 15-year-old, and logged-over forest.

MATERIALS AND METHODS

Study site

The study site is situated in the nine villages in Feuang District, Vientiane Province, Lao PDR, which lie between the latitude of 18°10'10" N and 18°64'45" N and the longitude of 102°06'25" E and 102°88'30" E in the North-western Vientiane City. Lao PDR has a traditional monsoon climate with two distinct seasons: wet seasons from May to October and dry seasons from November to April. The southwest monsoon prevails from mid-May to early October, while the northeast monsoon prevails from early November to mid-March. The estimated annual rainfall varies between 1,400 mm and 2,500 mm, with the central and southwest regions receiving more than 3,500 mm. Temperatures remain high throughout the year, except in the northern parts of the region, with an average maximum temperature of 35-38^{o}C and a minimum temperature of 16-18°C (Soares and Himmelfarb 2018).

According to the FAO (2015), the natural forests in the study area are dry evergreen forest located at an altitude above 200 masl and classified as upper evergreen forests found in mountain areas. These forests consist of more than 80% of evergreen species; usually, the height of the trees of the upper storey is more than 30 m. Another typical characteristic of this forest type is climbers and lichens on tree stems; bamboo is usually not found except when the canopy is open. The study area geologically belongs to the Lower Indochina and Mountain chain (Sayphoupha) formations. These formations particularly consist of reddish and greyish sandstone of the Precambrian (JICA 2001).

Phytosociological studies

The study was carried out in several vegetation types to assess the status of natural vegetation succession after the agricultural practices and forest utilization of the three main ethnic groups (i.e. Lao Loum, Lao Theung, and Lao Soung). The condition of the study area is dependent on the explanation of the main vegetation and plant communities, species composition of the degraded land area of secondary, and primary forests, composition of vegetation succession in degraded forest areas. forty-four various vegetation samples (relatives) which were established in several vegetation types such as 1-, 5- and 15-year-old fallows, logged-over forest, and primary forest in nine villages, Feuang District, Vientiane Province, Lao PDR, could be characterized as selection of homogenous sites without a gap, creation of survey boundary areas with homogenous species composition, identification and record of all species found in each layer such as emergent or super tree (ST), dominant (T1), co-dominant and suppressed (T2), shrub (S), herb (H), and moss layer (M), estimation of canopy coverage, sociability, and identification of communities. Based on Dümmler et al. (1973) and Fujiwara and Ariki (1978), the sample size of five various vegetation types were 40x60 m for primary forest and logged-over forest, 20x30 m for 15-year-old fallow, 20x20 m for 5-year-old fallow, and 10x20 m for 1 year-old fallow. The assessment was mainly based on the rate of natural recovery of 3 fallow types and logged-over forests after slashing and burning and harvesting towards achieving their natural status prior to disturbance. The assessment was carried out in three steps, namely forest layer coverage, species composition, and dominance and height recovery, and Braun-Blanquet (van der Maarel 1979) method was applied to assess vegetation composition in primary forest, logged-over forest and fallow lands with age of 1-, 5- and 15-year-old.

Data analysis

The assessment mainly focused on the natural recovery rate in logged-over forest and fallow land after shifting cultivation towards achieving their natural status before disturbance. Analysis of the Variance (ANOVA) followed by Duncan Multiple's Range Test (DMRT) and the Principal Component Analysis (PCA) were applied to assess the canopy structure recovery. Additionally, the cluster analysis was used to calculate the Jaccard's Coefficient for assessment of species dominance recovery. The further calculation used the Euclidean Distance Coefficient to assess the species composition's recovery. The Statistical Application System (SAS) and Multivariate Statistical Package (MVSP) were used to analyze the collected data.

RESULTS AND DISCUSSION

The assessment of forest recovery carried out in this study is primarily based on the results of the phytosociological study. Primary forest was used as a standard for each vegetation type-site to assess the recovery of natural succession. To assess the forest recovery trajectory, we made the comparisons on canopy structure and coverage, and species composition and dominance among primary forest, logged-over forest and fallow lands with age of 1-, 5- and 15-year-old.

The three fallows with 1-, 5- and 15-year-old age and two forest types were compared for their canopy structure recovery with each other. The logged-over forest, harvested by wood logging companies and local villagers in the past two decades, recorded the lowest recovery in the canopy structure. The sites of 1-, 5- and 15-year-old fallows have not fully recovered their top layers (ST and T1). Only the T2 layer of the 15-year-old fallow recovered. All the 1- and 5-year-old fallows only recovered their S and H layers with coverage of 26.43% to 68.44% and 70.56% to 78.89%, respectively (Table 1).

Table 1 shows that the sites harvested in 1978/79 attained moderate canopy structure recovery of 9.44%, 27.22%, 31.67%, 59.44%, 72.77%, and 3.33% for ST, T1, T2, S, H, and M layers, respectively. The ST-layer coverage of 9.44% was lower than the primary forest; however, *Lagerstroemia* was mainly followed by *Ficus* in these forest stands. Valuable commercial tree species like *Dalbergia cultrata, Pterocarpus pedatus,* and *Afzelia xylocarpa* were totally extracted by logging companies in the past two decades. Some herbs were found on the logging road and timber landing sites, such as *Eupatorium odoratum* and *Lycopodium* sp.

ANOVA was used to determine the difference in-group means of different layers to assess the canopy structure recovery of various vegetation types. The result of the analysis is shown in Table 2.

The ANOVA result showed significant differences in ST, T1, T2, S, H and M layers. Therefore, to determine which groups were significantly different, the results of the Duncan Multiple's Range Test (DMRT) was presented in Table 3.

From the above summary Table 3, the following pairs of groups were found to be significantly different at a 5% confidence level (P <0.05) of significance. For emergent or supertree layer (ST), the average height cover of ST in primary forest is higher than that of 15-, 5- and 1-year-old fallows. The mean height cover of ST in logged-over forests is higher than the average height cover of 15-, 5-, and 1-year-old fallows. The differences amongst all other height cover values of ST are not significant.

For dominant (T1) layer, the average height cover of T1 in primary forest is higher than that of 1-year-old fallow and 5-year-old fallow. The mean height cover of T1 in logged-over forest is higher than the average cover of 5- and 1-year-old fallows. The average height cover of T1 in 5-year-old fallow is higher than 1-year-old fallow. The mean height covers of T1 are not significantly different from all others.

Table 1. Average canopy coverage at different vegetation types and forest layers

Forest layer	Vegetation types				
	1-year-old fallow (%)	5-year-old fallow (%)	15-year-old fallow (%)	Logged-over forest (%)	Primary forest (%)
ST	0	0	0	9.44	11.67
T1	0	0	5.00	27.22	31.11
T2	0	33.33	35.00	31.67	25.56
S	26.43	68.44	66.78	59.44	66.11
H	78.89	70.56	71.67	72.77	65.56
M	0	0	0	3.33	3.33
Recovery rate	Almost grasses and herbs	Very low	Low-medium	Medium	Good

Table 2. Result of ANOVA on canopy structure recovery

Vegetation layer	CV%	Sum of square	Mean square	F value
ST	4.44	0.54	0.14	42.90 S2*
T1	7.88	2.07	0.52	45.32 S2*
T2	11.12	1.50	0.37	13.15 S2*
S	6.88	1.09	0.27	17.44 S2*
H	5.14	0.03	0.01	0.56 S2*
M	1.51	0.08	0.02	60.04 S2*

Note: *S2- Significant difference at 0.05 level (p<0.05), ns – not significantly different

Table 3. Result of Duncan's Multiple Range Test (DMRT)

Duncan grouping		Mean difference
Primary forest layer (I)	**Vegetation type (J)**	**(I-J)**
ST	Primary forest	1.42 a*
	Logged-over forest	1.38 a
	15-year-old fallow	1.18 b
	5-year-old fallow	1.18 b
	1-year-old fallow	1.18 b
T1	Primary forest	1.59 ab*
	Logged-over forest	1.67 a
	15-year-old fallow	1.67 a
	5-year-old fallow	1.49 b
	1-year-old fallow	1.18 c
T2	Primary forest	1.64 a*
	Logged-over forest	1. 60 a
	15-year-old fallow	1.19 b
	5-year-old fallow	1.18 b
	1-year-old fallow	1.18 b
S	Primary forest	1.90 a*
	Logged-over forest	1.86 a
	15-year-old fallow	1.91 a
	5-year-old fallow	1.90 a
	1-year-old fallow	1.51 b
H	Primary forest	1.88 a
	Logged-over forest	1.94 a
	15-year-old fallow	1.93 a
	5-year-old fallow	1.93 a
	1-year-old fallow	1.96 a
M	Primary forest	1.26 a*
	Logged-over forest	1.26 a
	15-year-old fallow	1.18 b
	5-year-old fallow	1.18 b
	1-year-old fallow	1.17 b

Note: *range of height cover means with the same alphabet are not significant differences at a 5% confidence level (P<0.05), according to DMRT

For suppressed (T2) layer, the mean height cover of T2 in primary forest is higher than 15-, 5- and 1-year-old fallows. The average height cover of T2 in logged-over forest is higher than 15-, 5- and 1-year-old fallows. Differences amongst all other average T2 height cover values are not significant.

For shrub (S) layer, the mean height cover of S in the primary forest is higher than that in the 1-year-old fallow. The average height cover of S in logged-over forest is higher than 1-year-old fallow. The average height cover of S in 15-year-old fallow is higher than that in the 1-year-old. The average height cover of S in 5-year-old fallow is higher than that in the 1-year-old. Differences among all other average covers of S are not significant.

For herb (H) layer, differences amongst all average height H covers in different forests are insignificant. On the other hand, for moss layer (M), the mean height cover of M in primary forest was higher than 15-, 5- and 1-year-old fallows. The average height cover of M in logged-over forest was higher than 15-, 5- and 1-year-old fallows. Differences amongst all other height cover values of M were not significant. ST, T2, and M layers share the same trend regarding the differences.

Species composition and dominance

The 1-year-old fallow sites was previously used for upland rice agriculture and had high level of land degradation. The recovery (succession) in term of species composition and dominance was very slow in this site. Only the early-succession species, such as herbs, grasses, shrubs, and climbers such as *Eupatorium, Imperata, Microstegium, Calycopteris, Lycopodium, Meyna, Erioglossum, Crassocephalum, Toxocarpus, Ardisia, Blumea, Echinochloa, Salacia, Diospyros, Trema, Barringtonia, Xerospermum* and *Peltophorum* were able to establish themselves on these sites. The dominant species in the recovery process were *E. odoratum, Microstegium ciliatum, Calycopteris floribunda,* and *Lycopodium cernuum* as herbs and grasses. In comparison, the tree species were mainly identified: *Trema angustifolium, Dyospyros embryopteris, Barringtonia longipes,* and *Salacia prinoides.*

Farmers used the 5-year-old fallows for upland rice cultivation and other food crops for 5 years. The succession species, including *Lycopodium, Erioglossum, Barringtonia, Eupatorium, Microstegium, Melanorrhoea, Dyospyros, Alpinia, Cinnamomum, Eurycoma, Schizostachyum, Bauhinia, Zizyphus, Combretum, Meyna, Croton, Flemingia, Acacia, Terminalia, Peltophorum, Oxytenanthera, Ardisia,* and *Phyllanthus*, recovered more than in 1-year-old fallow sites in terms of the number of species.

The 15-year-old fallow was abandoned after cultivating upland rice and other food crops. The succession species were dominated by perennial herbs, bamboo, climbers, shrubs, and tree species, e.g., *Lycopodium, Bauhinia, Erioglossum, Trema, Terminalia, Ardisia, Calamus, Combretum, Cinnamomum, Dyospyros, Ixora, Zizyphus, Barringtonia, Peltophorum, Lagerstroemia, Aporosa, Meyna, Arenga, Oxytenanthera, Alpinia, Toxocarpus, Microstegium, Melanorrhoea, Mucuna, Schizostachyum,* and *Amomum* found on these sites. Most 15-year-old fallows in Nontong and Nanhao's villages were dominated by bamboo species such as *Schizostachyum* and *Oxytenanthera* in the upper storey on the hill foot. At the same time, 15-year-old fallows recovered with tree species, for example, *Barringtonia, Peltophorum,* and *Lagerstroemia,* at the first and second layers in Phonexay's, Naphung and Phonthon's villages. In the ground layer, there were some non-timber forest products (NTFPs), such as *Alpinia* (wild ginger), *Amomum* (cardamom), *Cinnamomum,* and *Calamus* (rattan). These indicated that the soil condition and microclimate had improved in these forest stands.

The logged-over forests had low coverage of emergent species; only a few Lythraceae, Meliaceae and Moraceae, *Lagerstroemia balansae, Sandorium indicum,* and *Ficus gibbosa* were represented in these forest stands. *Lagerstroemia, Sandoricum,* and *Dyospyros* generally dominate this forest stand. The understorey of these forest stands had high coverage of bamboo species, herbs, shrubs, and climbers such as *Schizostachyum, Oxytenanthera, Lycopodium, Calamus, Rhaphiolepis, Alpinia, Acacia, Erioglossum, Paederia, Anaphora, Amomum, Cnestis,* and

Halopegia in the S and H layers. The valuable commercial tree species such as *Pterocarpus, Dalbergia, Sindora, Quercus, Vatica,* and *Fagraea* were also found in the forest stands, but in small quantities. Most of them were small trees or saplings in the understorey. These indicate that the logging company did not harvest them due to small-diameter trees. The saplings might disseminate from wind or wildlife. The species dominance recovery in these forest stands identified as bamboo (*Schizostachyum, Oxytenanthera), Calamus* (rattan), *Lycopodium* (fern), herb, shrub, and climber where canopy had been widely opened.

Species composition similarity

The classification analysis was used to identify similarity in species composition among the five vegetation types. The row matrix with five vegetation types and the column matrix with the number of tree species were prepared in the program Multivariate Statistical Packages (MVSP), version 3.1 for Windows. A similarity matrix of five vegetation types collected from forty-four vegetation recoveries was estimated using the centroid method using Jaccard's coefficient. The result shows the highest similarity to primary forests observed in logged-over forests with a value of 0.429, which means 42.90% of similarity in species composition. While the 15-, 5- and 1-year-old fallows resulted a value of 0.399 (39.90%), 0.348 (34.80%), and 0.261 (26.10%), respectively (Figure 1).

Dissimilarity distance (species abundance)

As shown in Table 4, the resulting dendrogram based on the dissimilarity coefficient represented the degree of dissimilarity distance among five various vegetation types as follows:

Group I had two sub-groups for comparison, 1 and 2, with a third sub-group of 1-year-old fallows. Compared to the sub-group of 1-year-old fallows, the subgroup of 1-year-old fallows also had an Euclidean distance value of 0.0. This indicates that there are no dissimilarity species among them. Further comparison included the sub-groups 4, 5, 6 and. The sub-groups 5-year-old fallows compared with those of 15-year-old fallows, which had an Euclidean Distance value of 0.0. This also indicates that there were no dissimilarity species in these sub-groups. The last sub-groups were sub-groups 8, which compared between the sub-groups of logged-over forest and those of primary forest. These sub-groups also had an Euclidean Distance value of 0.0 that meant nothing in terms of dissimilarity species. The above result shows no dissimilarity species among group I (Table 4).

In Group II, the first sub-groups in the second group were sub-groups 9 and 10, compared among 1-year-old fallows, including six sub-groups of 1-year-old fallows. These had an Euclidean Distance value of an average of 0.106 (10.60%), which indicates that 10% of dissimilarity species were found among them. The next comparison was between sub-groups 11, 12, 13, and 14, including sub-groups 5-year-old fallows, those of 15-year-old fallows, and sub-groups of logged-over forests and those of primary forest. These sub-groups had an Euclidean Distance value of 0.110 (11.10%), which indicates that dissimilarity species reached gradually. The last sub-groups in Group II were 15, 16, and 17 sub-groups, compared between sub-groups of 5-year-old fallows and those of 15-year-old fallows. The result shows a high Euclidean Distance value of 0.156 (16%), which indicates that among the sub-group of 5-year-old and 15-year-old fallows, many dissimilarity species were found among them. In Group III, there were two sub-groups. The first sub-groups were compared, including sub-groups:18, 19. These two sub-groups comprise 15-year-old fallow, and primary forest, which showed a dissimilarity coefficient of an average of 0.271. This indicates that two were about 27% dissimilarity species among them. A further comparison involved sub-groups of 20, 21, 22, 23, 24, 25, and 26, including logged-over forests, primary forests, 5-, 15- and 1-year-old fallows; the result shows a dissimilarity coefficient value of an average of 0.356 (36%). This indicates that there were dissimilarity species found in these sub-groups. In Group II, the highest dissimilarity species found were in sub-groups of primary forest and those of logged-over forest, with an Euclidean Distance value of 0.390 (39%).

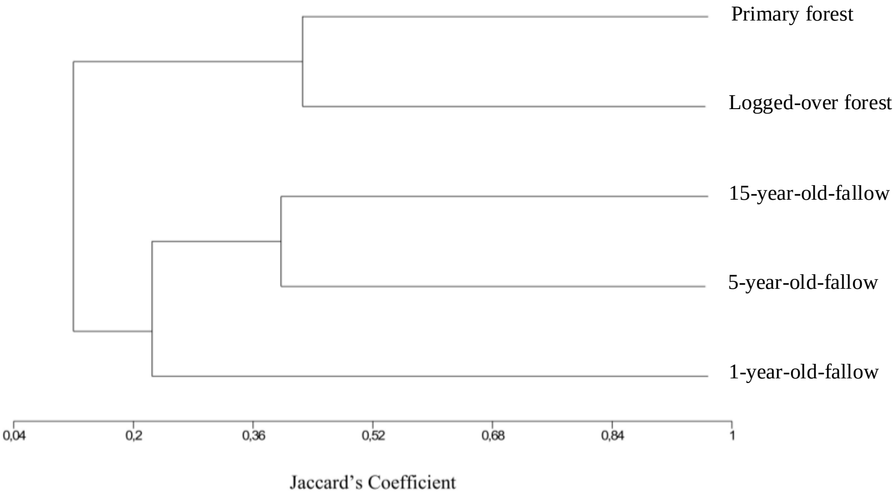

Figure 1. Dendrogram of similarity in species composition among the vegetation types calculated as Jaccard's coefficient

Table 4. Dissimilarity coefficient of the recovery vegetation types

Node/group	Sub-group	Sub-group	Dissimilarity coefficient	Object in group
Group I				
1	1-year-old fallow	1-year-old fallow	0.000	2
2	1-year-old fallow	1-year-old fallow	0.000	2
3	1-year-old fallow	1-year-old fallow	0.000	2
4	5-year-old fallow	15-year-old fallow	0.000	2
5	5-year-old fallow	15-year-old fallow	0.000	2
6	logged-over forest	15-year-old fallow	0.000	3
7	Primary forest	15-year-old fallow	0.000	4
8	Logged-over forest	Primary forest	0.000	2
Group II				
9	1-year-old fallows	1-year-old fallow with 1-year-old fallow	0.111	4
10	1-year-old fallow	1-year-old fallow	0.101	2
11	5-year-old fallows	15-year-old fallow	0.111	3
12	15-year-old fallows	15-year-old fallow	0.111	5
13	5-year-old fallow	5-year-old fallow	0.111	2
14	Logged-over forest	Primary forest	0.111	2
15	15-year-old fallow	5-year-old fallow	0.156	4
16	5-year-old fallow	15-year-old fallow	0.156	6
17	15-year-old fallow	5-year-old fallow	0.156	3
Group III				
18	1-year-old fallow	15-year-old fallow	0.271	7
19	5-year-old fallow	Primary forest	0.271	3
20	Logged-over forest	Logged-over forest	0.301	2
21	Primary forest	Primary forest	0.321	3
22	5-year-old fallow	15-year-old fallow	0.350	2
23	15-year-old fallow	1-year-old fallow	0.358	5
24	Logged-over forest	Primary forest	0.387	2
25	Logged-over forest	Primary forest	0.387	2
26	1-year-old fallow	Primary forest	0.390	4
Group IV				
27	1-year-old fallow	Primary forest	0.507	8
28	15-year-old fallow	Logged-over forest	0.549	3
29	Primary forest	1-year-old fallow	0.564	9
30	Logged-over forest	Primary forest	0.601	2
31	15-year-old fallow	Logged-over forest	0.607	7
32	Logged-over forest	15-year-old fallow	0.612	5
33	Primary forest	Logged-over forest	0.681	4
34	15-year-old fallow	Primary forest	0.681	10
35	Logged-over forest	5-year-old forest	0.743	9
36	Primary forest	Logged-over forest	0.882	11
37	15-year-old fallow	Primary forest	0.942	14
38	Logged-over forest	15-year-old fallow	0.945	14
Group V				
39	Primary forest	Logged-over forest	1.187	16
40	Logged-over forest	Primary forest	1.381	2
41	Primary forest	1-year-old forest	1.564	18
42	1-year-old forest	5-year-old forest	1.948	25
43	5-year-old forest	15-year-old forest	2.601	27
44	15-year-old forest	Logged-over forest	3.267	45

Note: Node: Joint or combined groups of five various vegetation types, which were divided into group I, group II, group III, group IV, and group V by the author, based on similar dissimilarity coefficients

In Group IV, the first sub-groups compared were sub-groups of 27, 28, and 29, including 1-year-old fallows, logged-over forests, primary forests, and 15-year-old fallows. The result shows a dissimilarity coefficient value of an average of 0.54. This meant that 54% of dissimilarity species were found among them. The next comparison included the sub-groups 30, 31, 32, 33, and 34, with an average dissimilarity coefficient value of 0.636. This indicates that 64% of dissimilarity species were in these sub-groups. Further comparison with sub-groups 35 and 36 had the Euclidean Distance values of an average of 0.812. This indicates that there were 81% dissimilarity species among these sub-groups. The last sub-groups of groups IV were sub-groups 37 and 38 and recorded with a dissimilarity coefficient value of an average of 0.94. This indicated that 94% of dissimilarity species were found among these sub-groups. The Euclidean Distance Values increased as the objects in groups increased.

Group V was the final group with the highest Euclidean Distance values compared to the previous groups. The first sub-groups were comprised of sub-groups: 39, 40, 41 and 42. This comparison included different sub-groups such as logged-over forest, primary forest, 1-, and 5-year-old fallows, which showed Euclidean Distance values of an average of 1.52. This indicates that 152% of dissimilarity species were highly recorded among these sub-groups. A further comparison involved sub-group 43, which comprised 1-, 5- and 15-year-old fallows with 27 objects in groups reaching a high dissimilarity coefficient value of 2.601. This indicates that 260% of dissimilarity species are found among these sub-groups. The last one was sub-group 44, which consisted of all vegetation types, such as 1-, 5-, 15-year-old fallows, logged-over forests, and primary forests, with 44 objects in groups. The result shows the highest dissimilarity coefficient value of 3.267; this indicates 327% dissimilarity species found by comparing all objects in groups. It could be concluded that the more disturbance to the primary forest, the more significant dissimilarity species found among various vegetation types.

Discussion

The study revealed that the more frequent the site for shifting cultivation, the longer the recovery process would become. Moreover, the rate of return to primary forest composition is contingent upon the proximity of seed sources. According to Yirdaw et al. (2019), regrowth forests in Napo and Dog Na Tard take even longer (more than 15 years) to achieve the structure of an old-growth forest. Finegan (1996) stated that for decades, the species diversity in secondary forests could be different or may never equate to that of a primary forest (Chazdon 2008). Furthermore, according to Liebsch et al. (2008), the Brazilian Atlantic Forest would take up to three centuries to approach the proportion of species present in mature forests and even longer (between one and four thousand years) to reach their original stages of endemism.

The sites of 1-, 5-, and 15-year-old fallows were heavily degraded by shortened-rotation of shifting cultivation by the three main ethnic groups and need a long time to recover their top layers fully. Previous analysis has also shown that regrowth forests require many decades to reach the structure of primary forests (Guariguata and Ostertag 2001; Chua et al. 2013; Mukul and Herbohn 2016). According to Liebsch et al. (2008), certain aspects of the Brazilian Atlantic Forest, could return quickly–within 65 years. However, the landscape to regain its native identity takes a lot longer–up to 4,000 years. Sobrinho et al. (2016) reported that Caatinga vegetation cannot recover completely in 15 years following land abandonment. This study, together with earlier studies, agrees that most woody plant assemblages take 20-70 years to recover after land abandonment in the absence of intense habitat degradation or disturbance (Kennard 2002; Chazdon 2003; Lebrija-Trejos et al. 2010; Maza-Villalobos et al. 2011). According to Hamzah (1999), the forest recovery rate in the logged-over forest after harvesting greatly depends on the extent of degradation during forest harvesting. Silvicultural treatment is necessary if these forest types have failed to recover valuable commercial tree species.

As shown in Table 1, the logged-over forests attained a moderate canopy structure, and the pre-harvesting survey was not carried out before logging. In this case, the logging company in the studied area harvested more logs as needed; the remaining were only non-commercial species. According to Hamzah (1999), concerning natural succession (recovery), it was suggested that a low-intensity logged-over area would recover in 40 to 50 years, while the patches within the forest area would take a maximum of 50 years.

The overall recovery (forest canopy structure and species) of heavily degraded and compacted sites, such as those formerly used as timber landings (decking sites) and logging roads during forest harvesting by the logging company in the study area, was shallow and slow. According to Baharuddin et al. (1995), land resource degradation is one of the most severe effects of deforestation and harvesting. He defines land degradation in general as the loss of the productive capacity of the land to sustain life, further defined as soil degradation and the loss or impoverishment of vegetation cover. Forestland degradation can be physical, chemical, or biological (Hamzah 1999). Physical degradation mainly involves soil compaction and erosion. Chemical degradation primarily reduces soil fertility, while biological degradation affects the loss of fauna and soil organisms. Natural forest regeneration does not proceed well in a natural way. According to Laycock (1991), forest succession alters species diversity as plants rise, die, and are replaced over time; more shade-tolerant climax species gradually replace it. Site factors such as soil type, topography, climate, environment, and local vegetation interact with disturbance type, diversity, and frequency to determine which plants invade a site after disturbance. In the case of three fallows, the three main ethnic groups' farmers could affect plant succession by slashing and burning, the severity and frequency of disturbance. The comparison among the five groups revealed that groups of 1-, 5- and 15-year-old fallows, along with the logged-over forest and primary forest groups, were far away from each other in terms of dissimilarity of species or species differences. The sites of 1-year-old fallows exhibited the lowest Jarcard's coefficient value (0.227). In addition, Dalmaso et al. (2020) found that the youngest site was more floristically distinct, showed fewer species, and had a less structured stand. Therefore, regarding structural composition and phylogeny, Hai et al. (2020) discovered a substantial difference between secondary forests (early and early mid-successions) and old-growth forests but no significant difference among early-successional forests. This indicates that complete disturbances in natural forests through slash-and-burn practices make forest regeneration by natural means difficult. Even if vegetation can recover on its own, it will take longer.

We found that logged-over forests recover naturally faster than shifting cultivation sites. This study shows the highest similarity to primary forests observed in logged-over forests with a coefficient of similarity of 0.429 (42.90%). While the 15-, 5- and 1-year-old fallows achieved a value of 0.399 (39.90%), 0.348 (34.80%), and 0.261 (26.10%), respectively. The average height cover of ST, T2 and M layer in primary forest is higher than that of 15-, 5- and 1-year-old fallows while the average height cover of T1 in primary forest is higher than that of 1-year-old fallow and 5-year-old fallow. The result of this study agrees with Ding et al. (2012) that recovery in logged-over forests is better than in shifting cultivation sites. When it comes to species diversity and composition, logging is less harmful than shifting cultivation, according to Ding et al. (2012). In Brazil, Piotto et al. (2009) reported that restoring an old-growth forest's structure after it has been used for shifting cultivation could take up to 40 years. Cameroon also discovered that forest structure recovers more steadily in fallow secondary forests after shifting cultivation than logged forests, taking 30 to 60 years versus 5 to 14 years, respectively (van Gemerden et al. 2003).

Regrowth forests can act as buffer areas across degraded old-growth forests, mitigating edge impacts, reducing anthropogenic disruptions, and enhancing landscape connectivity (Pardini et al. 2005; van Breugel et al. 2013). Buffer areas comprising regrowth trees provide extra shelter for the species living in the core habitat (Chazdon et al. 2009). Furthermore, by linking isolated remnant forest and agroforestry patches, regrowth forests can act as ecological corridors, improving flora and fauna dispersal and movement, as well as the viability of small populations in fragmented ecosystems (Chazdon et al. 2009; Morse et al. 2009; Schroeder et al. 2010).

Regrowth forests in the riparian area serve as stream bank stabilizers and natural corridors between upstream and downstream areas (Heartsill-Scalley and Aide 2003). In general, the location of regrowth forests in human-modified environments is critical for in-situ biodiversity restoration and degraded forestland regeneration. In Lao PDR, shifting cultivation employs over a quarter of the rural population, affecting about 34.6% of the country's forests a considerable amount of land (Sovu et al. 2009; Higashi 2015). Lao PDR can rehabilitate a significant portion of its degraded forests and raise the country's forest cover by protecting the vast area of regrowth forests that have sprung up on fallow lands due to changing agriculture. By 2020, Lao PDR expects to have 70% of its land covered in forest (Sovu et al. 2009). This mainly passive restoration is a low-cost and quick enough process. To summarize, regrowth forests occurring on fallow lands in Lao PDR are crucial in habitat protection and the regeneration of depleted forests and lands; as a result, regrowth forests should be the main consideration in Lao PDR' national forest conservation and restoration strategy.

In conclusion, according to the phytosociological study, it has proven to be very useful in elucidating the present status of the deforested area's natural recovery (succession). Data obtained from the vegetation study have enabled the calculation of forest recovery assessments using Jaccard's coefficient and the Euclidean Distance coefficient. Logged-over forests recover naturally faster than shifting cultivation sites. However, these forest stands require enrichment planting to ensure valuable commercial tree species, such as *A. xylocarpa*, *P. pedatus*, and other *Dipterocarpus* species. The natural recovery of species dominance and abundance, forest height, and canopy structure is still low. The required time is longer due to the extensive damage to the forest during harvesting. On the other hand, the three fallows need more time to regenerate in terms of soil condition and tree species naturally. The 5- and 15-year-old fallows must be protected from illegal slashing and burning by local farmers. The biggest forest recovery problem lies in the sites that were heavily degraded forestland areas through shifting cultivation, such as 1-, 5- and 15-year-old fallows. These regions have failed to recover the upper canopy layers (ST and T1 layers) and species composition. The study suggests that the harvested forests can naturally recover their forest height and canopy structure relatively quickly. However, valuable commercial tree species are still missing in these forest stands, necessitating enrichment planting. For 1-year-old fallow in steeper slopes, more than 12% should be applied to Slope Agriculture Land Technology (SALT). Simultaneously, 5- and 15-year-old fallows need rehabilitation with commercial tree and herb species for Timber Forest Products (TFPs) and Non-Timber Forest Products (NTFPs) in heavily degraded forest areas, using the different silvicultural treatments. The implications of this research can help conserve biodiversity and preserve degraded forestlands in various tropical areas.

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