STRUCTURAL CHARACTERISTICS AND PLANT SPECIES DIVERSITY OF SOME NATURAL FOERST TYPES AT PHOU KHAO KHOUAY NATIONAL PARK, LAO PEOPLE'S DEMOCRATIC REPUBLIC

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SUMMARY

Phou Khao Khouay National Park (PKKNP) is one of the 24 National Parks and protected areas in Lao People's Democratic Republic (Lao PDR) that supports high biodiversity. The tree and seedling layers of natural forest in Thaphabat was represented 76 species belonging 42 families. The largest family was Dipterocarpaceae (9 species), followed by Fabaceae (5 species) and Rubiaceae (4 species). Species in terms of individual number were *Hydnocarpus ilicifolia, Hopea* spp. and the largest families in terms of species number were Rubiaceae and Dipterocarpaceae. Diversity was found very high in four forest types, the Menhinick's Richness ranged from 2.07 to 2.95. The Simpson index ranged from 1.43 to 1.62. The Shannon index ranged from 0.93 to 0.97. The largest tree height and maximum mean diameter ($D_{1.3}$) belong to the family of Dipterocarpaceae. Compared similarity index between seedling and tree species at four forest types were that, the average forest has the highest percentage of species common (76.58%). The lowest was in the extremely poor forest (47.66%).

Keywords: Composition, Phou Khao Khouay, species diversity, structural characteristics.

1. INTRODUCTION

The integrated knowledge of the structure, composition and plant diversity is the basis for sustainable management strategies in different forest ecosystems. These features play an important role in the global carbon budget as forest ecosystems sequester carbon dioxide from the atmosphere and act as huge carbon-pools (Odum, E.P. 1971). Forest stands, forest structure and plant diversity are also important for canopy community. However, the characteristics of forest structure and diversity of the world's national park and protected area remains many gaps, especially in Lao PDR.

Lao PDR is a country of plateaus, hills and mountainous terrain count for over 70% of its territory. Forest covers approximately 52% (Department of Forestry, Ministry of Agriculture and Forestry of Laos (MAF), 2018). It is essential to have a clear idea of the species and forest structure under different forest types in order to support forest management and conservation.

Phou Khao Khouay National Park (PKKNP) is a good example of the general situation in Laos, having previously undergone logging and degradation, and still experiencing disturbances. The intensive logging in the area until 1993 has been intensified by the recent construction of dams. This has not only increased accessibility to the remote forests by opening roads, but also resulted in further rigorous forest loggings during the creation of dams. Shifting cultivation and permanent extraction by local and non-local people continue to occur because the great biodiversity of the forest offers a wide range of food, medicinal and tradable products to them. The forests of Phou Khao Khouay have been unduly affected by human activities, resulting in the creation of patches of differing forest compositions and diversity which remain poorly documented. The research aims to answer the question of whether forest type affects composition, structure and diversity of tree species by (i) comparing composition and structure of stands in different forest types, and (ii) comparing diversity patterns of forest stands.

2. RESEARCH METHODOLOGY

2.1. Study area

The study area is located in the Phou Khao Khouay National Park, about 40 km from Vientiane Prefecture at the closest point in the Northeast. The Park is belonging to three provinces: Vientiane, Vientiane Prefecture and

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Bolikhamxay. Phou Khao Khouay National Park encompasses an area of about 2000km^2 (Figure 1). Most of the area covered by typical tropical red to brown soils (orthic acrisols and lithosols), which are sandy to sandy loam in texture and poor in organic matter (Kingston, 1987).

The monsoonal climate is similar to the rest of central Lao PDR, the rainy season is from May to October, and a distinct dry season from November to April. Average annual rainfall is 2,202.4 mm with 92% in rainy season. The temperatures are highest just before and during the early part of the rainy season, and the April is the hottest month with temperature average of 39°C. December is the coldest month with average 10°C at the low elevation.

Topography is generally steep sloping in the low elevation at the central portion of the area and on the PKK plateau. Elevation varies from less than 100 m to nearly 1,700 m above the sea level. Most of the area is over 500 m, and a large part is above 1,000 m.

The original vegetation cover of the area consisted primarily of lowland mixed deciduous forest and montance evergreen forest located centrally within the reserve. The forest types correspond spproximately to the mixed deciduous forest (mainly Fabaceae), dry evergreen Dipterocarpaceae forest and monospeific coniferuos forest (mainly Pinaceae).

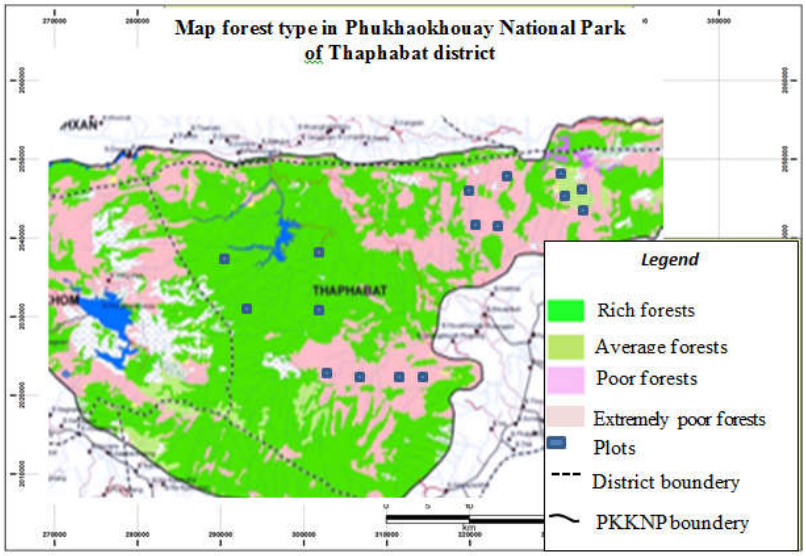

Figure 1. The map of forest types and the visited sites

2.2. Methods

2.2.1. Surveys and sampling plots

Preliminary data of PKKNP tree species and forest types were taken from the Department of Forestry (MAF, 2018). A classification of the forests with respect to the stock or volume of timbers was introduced by the Department of Forestry, so-called the RAPEN classification, which provides a general assessment of the forest structure and composition. *R: stands for the Rich forests with the standing stock of greater than 200 m^3/ha; A: Average forests with the standing stock of 100 to 200 m^3/ha; P: Poor forests with the standing stock of 50 to 100 m^3/ha; E: Extremely poor forests with the standing stock of 10 to 50 m^3/ha; N: Non-stock forests with the standing stock of less than 10 m^3/ha*.

Secondary data collection. The extensive field surveys were conducted with 16 typical standard forest plots of 40 m x 50 m, established in four different forest types of PKKNP during the period of 2019 - 2020 (see Figure 1). Each sampling plot comprised 5 subplots, one subplot of 5 × 5 m in the center, and four subplots in four corners of the sampling plot.

(i). In the sampling plot, the information about the trees, woody and herbaceous climbers were collected with tree name (Laos name,

scientific name); diameter at breast height ($D_{1.3}$ cm); maximum height (H_{vn} m), and canopy width (D_t m) for all trees of $D_{1.3} \geq 6$ cm.

(ii). In the subplot 5 x 5 m was used to collect the information on seedlings, shrubs, with species name (Laos name, scientific name) and maximum height for the seedlings of $D_{1.3} < 5$ (the maximum height not more than 5 m). If possible, specimens were colected to confirm identification at the herbarium of the Faculty of Forest- National University of Laos (Inthakoum and Delang, 2002; Min et al., 2006).

Data treatment:

The following equations were used:

(i).Similarity of species between studied plots using density was determined by Ward Linkage Method. These data was analyzed using R software.

(ii). The Important Value of every species (IV%)

$$IV_i\% = \frac{N_i\% + G_i\%}{2} \quad (1)$$

$$G_i = \frac{\pi}{4} D^2_{i\,(1.3)}\ (m^2)$$

(iii). Volume:

$$M = G.H.0.45\ (m^3/ha) \quad (2)$$

(iv). Menhinick Richness Index:

$$R = \frac{S}{\sqrt{N}} \quad (3)$$

(v). Shannon-Weiner Diversity Index (H'):

$$H = -\sum_{i=1}^{N}(N_i/N) log_2 (N_i/N) \quad (4)$$

(vi). Seedling:

$$Ki\% = \frac{N_i}{N}.10 \quad (5)$$

All where, S = ΣNo. of species

N = ΣNo. of trees

N_i = The number of individual in the species i

H = Average height of forest type

$D_{1.3}$ = Diameter at breast height

(vii). Sorensen's index:

$$SI = (2C/(A+B))*100 \quad (6)$$

Where, A: Total number of tree species;

B: Total number of seedling species;

C: Number of species (both trees and seedlings).

3. RESULTS AND DISCUSSION

3.1. Similarity of species between plots

To divide the species into homogeneous formation, all the sixteen plots were subjected to similarity analysis using clustered dendrogram. This analysis divided the species in to 4 cluster groups (CGS) at 50% similarity level (see Fig. 2).

Figure 2 showed that CG1 (Extremely poor forest: $10 < M \leq 50$ m^3ha^{-1}) comprised of OTC13, OTC15 and OTC14; CG2 (Poor forest: $50 < M \leq 100$ m^3ha^{-1}) comprised of OTC6, OTC7, OTC5 and OTC8; CG3 (Average forest: $100 < M \leq 200$ m^3ha^{-1}) comprised of OTC11, OTC12, OTC9 and OTC10; CG4 (Rich forest: ($M > 200$ m^3ha^{-1}) is represented by OTC2, OTC4, OTC1 and OTC3.

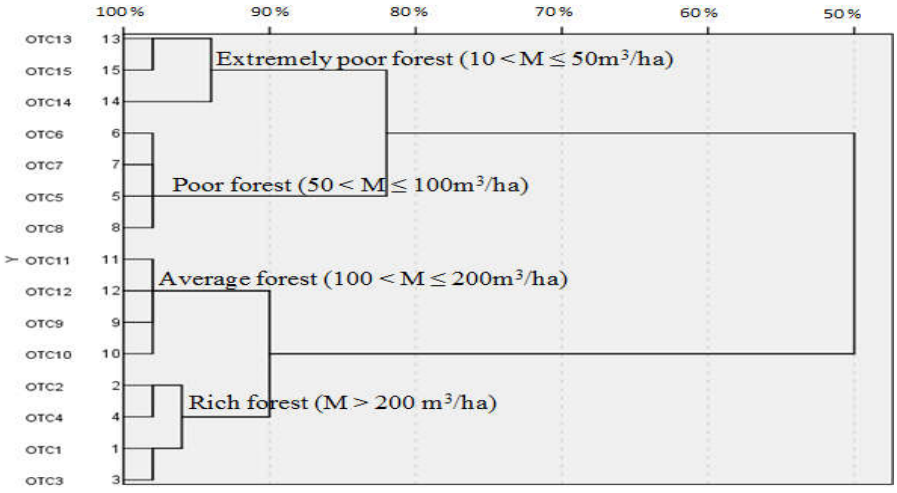

Figure 2. Dendrogram index of similarity between plots

(Abbreviation at the figure are: OTC1: Plot1; OTC2: Plot2...)

Similarity other studies, this criteria for classification of forest formation have been used by past researchers. The researchers divided the vegetation of their study area into the cluster groups at 50.00 similarity level (Adam and Enning, 1996; Adam, 2000; Mahmud et al., 1992; Jumaat H. Adam et al., 2007; Soepadmo, 1987). Other researchers found it very helpful to classify the heterogeneous forest formation of the tropical regions using cluster analysis using Ward Linkage Method at 49.66 similarity level (Adam, 1997; Adam and Enning, 1996; Mahmud et al., 1992; Ohsawa, 1984).

3.2. Tree layer

3.2.1. Structural parameters of each group (forest type)

Structural parameters of each forest type of the study site are showed in the Table 1, there was a significant difference among forest types.

Table 1. Structural parameters of each forest type

Cluster groups	Forest type	H_{vn} (m)	$D_{1.3}$ (cm)	M_{bq} (m^3/ha)	N/ha
CG4	Rich forest	13.38	22.14	224.82	774
CG3	Average forest	12.83	18.71	179.52	838
CG2	Poor forest	11.11	16.38	79.83	712
CG1	Extremely poor forest	10.59	12.59	30.99	654
	Average	**11.98**	**17.46**	**128.79**	**744**

The results revealed that, structural parameters of each group (forest type) increased from the extremely poor forest to the rich forest. The forest density (N/ha) was found to be maximum in the average forest type (838 trees ha^{-1}) and minimum in the extremely poor forest (654 trees ha^{-1}). The results derived from this study are compared and contrasted with the result found in similar found of natural forest in other Lao's national park or protected area. Tree density of this study is comparatively higher than the values in the Nampui National Park (683 trees ha^{-1}) (Bounphanh et al., 2019), Namngun Upstream Protected Area (612 trees ha^{-1}) (Tu and Latdavanh, 2019). The average height of tree species recorded was maximum in the rich forest and minimum in the extremely poor forest. In contrast to this, some of the highest of Laos National Parks were reported in the average forest type (Salter et al., 1990). Average tree dendity of four forest types values from 654 to 838 tree ha^{-1} which is consistent with the density values of 547 and 832 tree ha-1 for 2 forest types of Nanpui National Park of Laos reported by Buonphanh et al., (2019); Six forest types of the Eld's Deer in the Xonnabouly Sanctuary (Phiapalath. P et al., 2018). Tree density of our study is comparatively higher than the values in the Moist Temperate Conifers zone (90 ha^{-1}) and in the Central Himalaya Moist Temperate forest 9170 – 283 tree ha^{-1}) (Chaturvedi and Singh, 1982; Shaheen et al., 2012). The range of stem density values observed in other studies ranges 652 – 2321 tree ha-1 in the Eld's Deer in the Xonnabouly Sanctuary (Phiapalath. P et al., 2018). In this study, the average height of tree species recorded was maximum in the rich forest type which is consistent with the average height of tree species in the rich forest type in Nampui National Park (Bounphanh et al., 2019).

3.2.2. Forest Composition

The compositions were studied at 4 different forest types for tree layer. The details of each layers at different forests is shown in Table 2.

Table 2. Composition of tree layer at 4 forest types

Cluster group/No.	Name of the species		Ni (%)	Gi (%)	IV (%)
	Scientific name	Laos name			
CG4	**Rich forest (I + II) = 71 species**		**100**	**100**	**100**
I	***6 species***		***45.24***	***55.23***	***50.22***
1	*Shorea obtusa* Wall, ex Blume	Chik	16.29	17.51	16.90
2	*Dipterocarpus tuberculatus* Roxb	Koung	6.76	12.34	10.55
3	*Dipterocarpus obtusifolius* Teijsm. ex Miq.	Sad	6.24	9.97	9.11
4	*Xylia xylocarpa* (Roxb.) Taub.	Deng	7.80	6.97	8.39
5	*Shorea siamensis* Miq.	Hang	4.51	4.04	5.27
II	***65 other species***		***54.73***	***44.78***	***49.76***
CG3	**Average forest (I+II) = 52 species**		**100**	**100**	**100**
I	***5 species***		***45.87***	***56.29***	***49.85***
1	*Irvingia malayana* Oliv.	Ka bok	14.92	17.01	15.96
2	*Hopea odorata* Roxb.	Khen yong	7.57	13.37	10.47
3	*Dialium cochinchinensis* Pierre	Kheng	4.90	10.11	7.51
4	*Sindora siamensis* Teijsm.	Te hor	7.80	6.86	7.33
5	*Lagerstroemia calyculata* Kurz	Te hong	5.35	4.82	5.08
II	***47 other species***		***54.13***	***43.71***	***50.15***
CG2	**Poor forest (I +II) = 47 species**		**100**	**100**	**100**
I	***4 species***		31.54	32.18	32.21
1	*Anisoptera costata* Korth	Bark	10.93	10.74	10.84
2	*Peltophorum dasyrrhachis* (Miq.) Kurz	Arang	9.87	9.27	9.57
3	*Vatica odorata* (Griff.) Symington	Si	6.43	6.41	6.45
4	*Fagraea fragrans* Roxb.	Man pa	4.31	5.76	5.35
II	***39 species***		***68.07***	***67.53***	***67.79***
CG1	**Extremely poor forest (I + II) 14 species**		**100**	**100**	**100**
I	***9 species***		***70.83***	***78.46***	***76.82***
1	*Dipterocarpus tuberculatus* Roxb.	Kouang	12.50	10.39	11.45
2	*Shorea obtusa* Wall. ex Blume	Chik	12.50	10.00	11.25
3	*Syzygium cumini* (L.) Skeels	War kok	8.33	10.82	9.57
4	*Lagerstroemia floribunda* Jack	Te hor	8.33	10.82	9.57
5	*Terminalia alata* Roth	Som mor	4.17	11.84	8.76
6	*Careya sphearica* Roxb.	Ka don kok	8.33	5.79	7.29
7	*Diospyros ehretioides* Wall.	Heuan khouang	4.17	7.80	6.70
8	*Litsea glutinosa* (Lour.) C.Rob.	Mi	4.17	7.80	6.47
9	*Memecylon edule* Roxb.	Meuad	8.33	3.20	5.76
II	***5 other species***		***20.95***	***23.00***	***23.18***

In the rich forest, 71 species were recorded belonging to 32 families such as: Fabaceae, Dipterocarpaceae, Euphorbiaceae, Anacardiaceae, Podocarpaceae, and so on. Out of 71 tree species, only 5 species showed a significant preference to this forest type. The *Shorea obtusa* was the most ecologically important species with an IV% value of 16.9%. The second important tree species was *Dipterocarpus tuberculatus* with an IV% value of 9.55%. The third, the fourth and the fifth important tree species were *Dipterocarpus obtusifolius, Shorea siamensis, Lagerstroemia floribunda*, respectively. Among the other 65 associated tree species with an IV% value of 49.76%. In this information, the rich forest can be named by *Shorea obtusa, Dipterocarpus tuberculatus, Dipterocarpus obtusifolius.* Based on the IV% value of their species, the species composition equation for the rich forest is:

16.9 Shob + 10.55 Ditu + 9.12 Diob + 8.39 Xyxy + 5.27 Shsi + 49.76 others

Where: Shob: Shorea obtusa; Ditu: Dipterocarpus tuberculatus; Diob: Dipterocarpus obtusifolius; Xyxy: Xylia xylocarpa; Shsi: Shorea siamensis.

In the average forest: 52 species belonging 24 families were recorded (see table 2). Here, *Irvingia malayana* Oliv was the most ecologically important species with an IV% value of 15.96%. The second important tree species was *Hopea odorata* Roxb with an IV% value of 10.47%. Among the other 47 associated tree with an IV% value of 50.15%. An IV% the species composition equation for average forest is:

15.96 Irma + 10.47 Hood + 7.55 Dico + 7.33 Sisi + 5.08 Laca + 50.08 others

Where: Irma: Irvingia malayana Oliv; Hood: *Hopea odorata* Roxb; Dico: *Dialium cochinchinensis* Pierre; Sisi: *Sindora siamensis* Teijsm; Laca: *Lagerstroemia calyculata*.

In the poor forest, altogether 47 species belonging 19 families were recorded. Among them, *Anisoptera costata* was the most ecologically important species with an IV%value of 10.84%. *Peltophorum dasyrrhachis, Vatica odorata, Fagraea fragrans* were also found to be ecologically important species in this forest type. An IV% the species composition equation for poor forest is:

10.84 Anco + 9.57 Peda + 6.54 Vaod + 5.53 Fafr + 67.79 other

Where: Anco: Anisoptera costata; Peda: Peltophorum dasyrrhachis; Vaod: Vatica odorata; Fafr: Fagraea fragrans

In the extremely poor forest: altogether 14 species belonging 8 families were recorded. Among them, *Dipterocarpus tuberculatus* was the most ecologically important species with an IV% value of 11.45%. 8 species were also found to be ecologically important species in this forest type. An IV% the species composition equation for poor forest is:

11.45 Ditu + 11.25 Shob + 9.57 Sycu + 9.57 Lafl + 8.76 Teal + 7.29 Casp + 6.7 Dieh + 6.47 Ligl + 5.76 Meed + 23.18 other

Where: Ditu: Dipterocarpus tuberculatus; Shob: Shorea obtusa; Sycu: Syzygium cumini; Lafl: Lagerstroemia floribunda: Teal: Terminalia alata; Casp: Careya sphearica; Dieh: Diospyros ehretioides; Ligl: Litsea glutinosa; Meed: Memecylon edule

Two of the main attributes of the 4 forest types are the heterogeneity of their species composition and heterogeneous distribution of individuals among species (see table 2). These two characteristic features of the 4 forest types can be explained by the findings past researchers working on the floristic composition and forest structures (Adam and Zahiruddin, 2005; Adam, 1997, 2007; Adam and Norseha, 2000; Adam and Enning, 1996; Kochummen, 1982; Martin, 1977; Ohsawa et al., 1985; Soepadmo, 1987).

3.2.3. Species diversity

Tree species diversity was calculated for the 4 forest types separately and showed in figure 3.

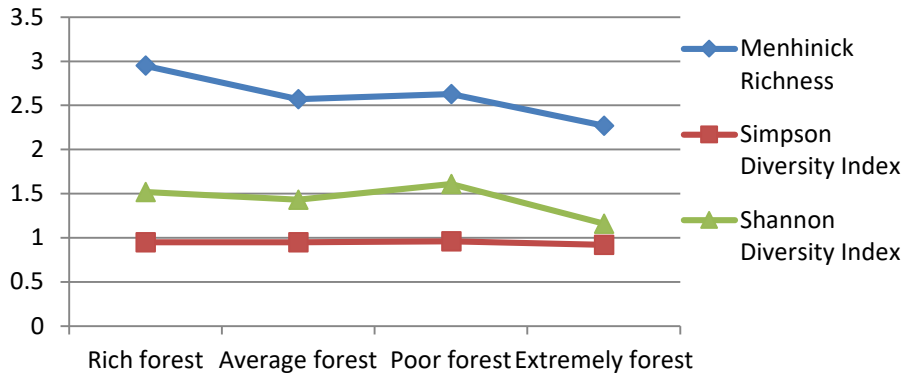

Figure 3. Tree diversity of the forest types

The Menhinick's Richness which measures diversity in four forest types ranged from 2.07 to 2.95. The values of this index were found to be gradually increasing with increasing the standing stock of tree. The maximum Shannon index at type of poor forest and minimum at type of extremely poor forest. The Simpson index ranged from 1.43 to 1.62. The Shannon index ranged from 0.93 to 0.97. There was no distinct trend for the latter 2 indices with increasing the standing stock of trees.

The species diversity indices in our study lies close to the reported for the PKKNP and other studies area (Lucas C. et al., 2013; Metmany Soukhavong et al., 2013; Adam, 2007).

3.3. Seedling layer

3.3.1. Seedling Composition

The details of seedling layers at different forest types shown in table 3.

Table 3. Composition of seedling layer at four forest types

Cluster group/No.	Species		Ni (No. per hectar)	Ki%
	Scientific name	Laos name		
CG4	**Rich forest (I + II) = 84 species**		**674**	**100**
I	***6 species***		***268***	***40.45***
1	*Peltophorum dasyrrhachis* (Miq.) Kurz	Arang	58	9.12
2	*Parashorea stellata* Kurz	Hao	46	7.34
3	*Syzygium cumini* (L.) Skeels	Wa khok	45	6.84
4	*Shorea obtusa* Wall. ex Blume	Chik	44	6.72
5	*Dipterocarpus tuberculatus* Roxb.	Koung	40	5.32
6	*Antidesma ghaesembilla* Gaertn.	Mao	35	5.11
II	***78 other species***		***406***	***59.55***
CG3	**Average forest (I+II) = 42 species**		**830**	**100**
I	***5 species***		***337***	***39.95***
1	*Canarium subulatum* Guillaumin	Kok Leuam	93	9.95
2	*Chaetocarpus castanocarpus* (Roxb.)	Bok khai	85	9.09
3	*Dialium cochinchinensis* Pierre	Kheng	61	6.52
4	*Sindora siamensis* Teijsm. & Miq.	Te hor	54	5.78
5	*Dillenia ovata* Wall. ex Hook.f. & Thomson	Sane	52	5.56
II	***35 other species***		***493***	***60.05***
CG2	**Poor forest (I +II) = 57 species**		**859**	**100**
I	***6 species***		***355***	***33.93***
1	*Dipterocarpus costatus* C.F.Gaertn.	Yang deng	95	9.08
2	*Litsea glutinosa* (Lour.) C.Rob.	Mi	87	8.32
3	*Fernandoa adenophylla* (Wall. ex G. Don)	Khe Lao	63	6.02
4	*Nephelium lappaceum* L.	Ngok dong	56	5.35
5	*Sindora siamensis* Teijsm. & Miq.	Te hor	54	5.16
II	***52 other species***		***504***	***66.07***
CG1	**Extremely Poor forest (I +II) = 26 species**		**612**	**100**
I	***6 other species***		268	40.13
1	*Canarium subulatum* Guillaumin	Kok Leuam	58	8.68
2	*Antidesma ghaesembilla* Gaertn.	Mao	46	6.89
3	*Microcos tomentosa* Sm.	Makkhom	45	6.74
4	*Syzygium cumini* (L.) Skeels	War kok	44	6.59
5	*Dipterocarpus obtusifolius* Teijsm	Sad	40	5.99
6	*Strychnos nux-blanda* A.W.Hill	Toum ka	35	5.24
II	***20 other species***		***344***	***59.87***

In the rich forest, 84 seedling species were recorded belonging to 32 families. Only 6 species showed a significant preference to this forest type. *Peltophorum dasyrrhachis* (Miq.) Kurz was the most ecologically important species with Ki value of 9.12%. Among the other 78 associated tree species with Ki value of 59.55%. Based on the Ki value of their species, the species composition for the seedlings of the rich forest is:

9.12 Peda + 7.34 Past + 6.84 Sycu + 6.72 Shob + 5.32 Ditu + 5.11 Angh + 59.55 other

Where: Peda: Peltophorum dasyrrhachis; Past: Parashorea stellata Kurz; Sycu: *Syzygium cumini* (L.) Skeels; Shob: *Shorea obtusa; Ditu: Dipterocarpus tuberculatus; Angh: Antidesma ghaesembilla.*

In the average forest. 59 species belonging 27 families were recorded. The *Canarium subulatum* Guillaumin was the most ecologically important species with Ki value of 9.95%. The second, third, fourth, fifth important tree species were *Chaetocarpus castanocarpus, Dialium cochinchinensis, Sindora siamensis, Dillenia ovata.* The other 54 associated seedlings with an Ki value of 60.05%. The species composition equation for average forest is:

9.95 Casu + 9.09 Chca + 6.52 Dico + 5.78 Sisi + 5.56 Diov + 60.05 other

Where: Casu: Canarium subulatum; Chca: Chaetocarpus castanocarpus; Dico: Dialium cochinchinensi; Sisi: Sindora siamensis; Diov: Dillenia ovata.

In the poor forest, altogether 57 seedling layer species belonging 29 families were recorded. Among them, *Dipterocarpus costatus* was the most ecologically important species with Ki value of 9.08%. The species composition equation for poor forest is:

9.08 Dico + 8.32 Ligl + 6.02 Fead + 5.35 Nela + 5.16 Sisi + 66.07 other

Where: Dico: Dipterocarpus costatus; Ligl: Litsea glutinosa; Fead: Fernandoa adenophylla; Nela: Nephelium lappaceum.

The extremely poor forest, altogether 26 species belonging 14 families were recorded. Among them, *Canarium subulatum* was the most ecologically important species with Ki value of 8.68%. 5 species also found to be ecologically important species in this forest type. Base with Ki value of their species, we established species composition equation for extremely poor forest is:

8.68 Casu + 6.89 Angh + 6.74 Mito + 6.59 Sycu + 5.99 Diob + 5.24 Stnu + 59.87 other

Where: Casu: Canarium subulatum: Angh: Antidesma ghaesembilla; Mito: Microcos tomentosa; Diob: Dipterocarpus obtusifolius; Stnu: Strychnos nux-blanda.

Similarity to the tree layer, the main attributes of seedling layer of the 4 forest types are the heterogeneity of their seedling species composition and heterogeneous distribution of individuals among seedling species (see table 3). These two characteristic features of the 4 forest types can be explained by the findings past researchers working on the floristic composition and forest structures (Adam and Zahiruddin, 2005; Adam, 1997, 2007; Adam and Norseha, 2000; Adam and Enning, 1996; Kochummen, 1982; Martin, 1977; Ohsawa *et al*., 1985; Soepadmo, 1987).

3.3.2. Seedling structural characteristics by the height

The total percent of seedlings per hectare by height classes of seedling layer is presented in figure 4.

The figure 4 shows the trend of seedling structure by their height along four forests. This analysis shows that, all forest types have the greatest percentages of seedling height in the 1 - 2 m range, they account for from 32% to 42%. The lowest percentages of seedling height in the ≥ 3 m range, only from 11 - 18%).

Seedling density was found to be maximum in the poor forest (962 seedlings ha^{-1}) and minimum in the rich forest (674 seedlings ha^{-1}).

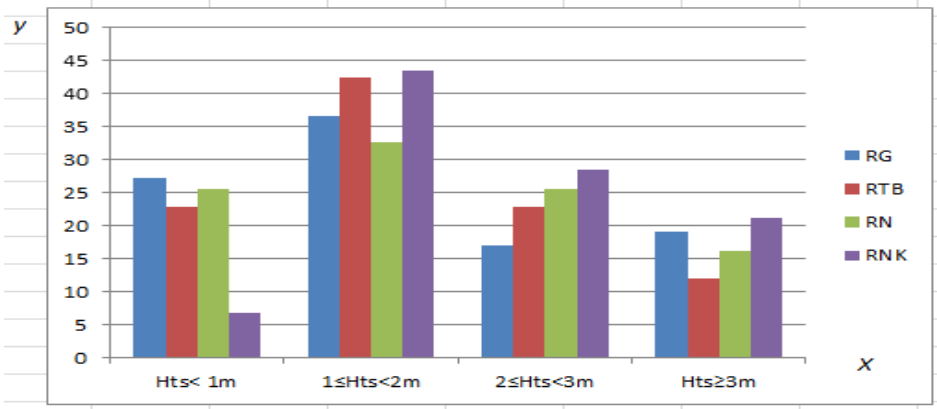

Figure 4. The tendency of No. of height seedling stems classes

(Abbreviation at the figure are: RG: rich forest; RTB: average forest; RN: poor forest; RNK: extremely poor forest)

3.4. Similarity index between seedling and tree layers

The Sorensen's index has been compared with field data. The result showed in table 4.

Table 4. Percent of similarity stem between seedling and tree layer at three forest types

Seedling layer	Forest types	Tree layer			
		Rich forest	Average forest	Poor forest	Extremely poor forest
	Rich forest	65.26			
	Average forest		76.58		
	Poor forest			57.83	
	Extremely poor forest				47.66

Comparing the similarity index between seedling species and tree species at four forest types showed that, the average forest has the highest percentage of species common (76.58%). The lowest percentages of species common was at the extremely poor forest (47.66%). The seedling species common is considered to the factor for the tree common in the future. It could be formed with the forest structure, diversity in the study area. The less similarity in the extremely poor forest might be explained by the reason that the dominant trees in this forest type has been drastically decreased.

Suggestion

In addition to the declining pristine forests, extremely poor forest and poor forests are of paramount importance in conservation and restoration of tropical biodiversity and they can also serve as a conduit for the restoration of forests in Laos. This study showed that poor and average forests can have a similar species richness as that of average foerst, rich forest and they have a potential to serve as biodiversity repositories. The species richness was similar to natural forest found in buffer zone of Nampui National Park (Bounphanh et al., 2019) or natural forest in Xieng Khoang province (Sovu Tigabu et al., 2009). One of the main factors afecting the recovery of extremely poor forests and poor forest is the proximity to average forest, rich forests and hence the protection of particularly extremely poor forests, which are close to rich forests should be given a priority (ICEM, 2003; The Department of Forestry of Laos, 2018). In general, as suggest, areas with an intermediate degree of disturbance such as extremely poor forests, should be considered a priority for landscape restoration activities as they have the

potential for larger gains associated to biodiversity and vegetation structure, thus increasing the conservation value of any given investment (Phiapalath. P et al., 2018). However, at present poor forests are underrated and the deforestation of poor forests is about three times higher than other forest categories in the lower Mekong Basin (Heinimann et al., 2017). Laos aims to increase its forest cover to 70% by 2020 (Sovu Tigabu et al., 2009). This type of mainly passive restoration is a cheap and acceptably quick method.

4. CONCLUSION

The understanding of forest structure, composition and plant diversity in natural forest of PKK National Park, Lao PDR is the basis for sustainable management. The knowledge derived from this study can be useful to identify features for management and conservation in such forests at the present and in the future as well. The information of the most ecologically important species in four forest types at the study area can be used to address the adaptability of species, it is necessary for forest management and conservation strategies.

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ĐA DẠNG THỰC VẬT VÀ ĐẶC TRƯNG CẤU TRÚC MỘT SỐ TRẠNG THÁI RỪNG TỰ NHIÊN VƯỜN QUỐC GIA PHOU KHAO KHOUAY, CỘNG HÒA DÂN CHỦ NHÂN DÂN LÀO

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TÓM TẮT

Vườn Quốc gia Phou Khao Khouay là một trong số 24 Vườn Quốc gia, khu bảo tồn có tính đa dạng sinh học cao của Cộng hòa Dân chủ Nhân dân Lào. Thành phần loài cây cao và lớp cây tái sinh tại khu rừng tự nhiện huyện Thaphabat gồm 76 loài thuộc 42 họ. Họ có số loài cao nhất là họ Dầu (Dipterocarpaceae), có 9 loài, họ Đậu (Fabaceae) có 5 loài và họ Cà phê (Rubiaceae) có 4 loài. Loài có số lượng cá thể cao nhất là loài *Hydnocarpus ilicifolia, Hopea* spp và họ có số lượng cá thể cao nhất là họ Cà phê (Rubiaceae) và họ Dầu (Dipterocarpaceae). Chỉ số đa dạng sinh học tương đối cao, mức độ phong phú loài từ 2,07 đến 2,95, chỉ số đa dạng loài từ 1,43 đến 1,62, mức độ chiếm ưu thế loài từ 0,93 đến 0,97. Loài cây có đường kính ($D_{1.3}$) và chiều cao vút ngọn cao nhất thuộc họ Dầu (Dipterocarpaceae). Hệ số tương đồng thành phần loài giữa tầng cây cao so với lớp cây tái sinh trên 4 trạng thái khá cao, trạng thái rừng trung bình đạt mức độ tương đồng cao nhất (76,58%), trạng thái rừng nghèo kiệt mức độ tương đồng thấp nhất (47,66%).

Từ khóa: Đa dạng loài, đặc trưng cấu trúc, Phou Khao Khouay, thành phần.

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