CHARACTERIZING *Dalbergia cochinchinensis* COMMUNITIES IN TAN PHU FOREST PROTECTION ZONE, DONG NAI

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SUMMARY
Dalbergia cochinchinensis Pierre is an endangered, precious, rare plant and also a priority native species to conserve in Vietnam. This paper shows the structural characteristics of *D. cochinchinensis* communities in natural forests in Tan Phu protection forest area, Dong Nai. 19 plots were set up on the poor forest, medium forest and rich forest types. The results showed that *D. cochinchinensis* distributed in poor forest, medium forest and rich forest types with density change by 74 trees/ha, 21 trees/ha, and 18 trees/ha, respectively. In overstory trees, there were 60 species in the medium forest which is higher 1.71 times and 1.25 times in comparison with the poor forest and rich forest. *D. cochinchinensis* only appeared in the species composition of the poor forest and the medium forest type with respective shares 9.1% and 5.0% of the important value index. All species richness, Shannon, Margalef, Fisher and Simpson indices of overstory trees were the lowest value in the poor forest type and the highest value in the medium and rich forest type. The distributions of the number of trees per DBH class of the three forest types were reverse J-shaped or decreased while the distributions of the number of trees per height class of all forest types were all left skewed and were well simulated by Weibull 2-parameter distribution functions. The medium forest has the highest number of regeneration species with 53 species, higher 1.20 times and 1.61 times compared with the poor forest (44 species) and the rich forest (33 species), respectively. The number of *D. cochinchinensis* seedlings regenerated in the poor forest was higher than that in the medium forest type with the composition species (N%) accounted for 10.6% (640 trees/ha) and 4.2% (440 trees/ha) of regeneration ratio, respectively; *D. cochinchinensis* has not recorded in the rich forest type.
Keywords: *Dalbergia cochinchinensis*, distribution, forest structure, regeneration, Tan Phu

1. INTRODUCTION

Dalbergia cochinchinensis is a native species of Thailand, Cambodia, Laos and Vietnam. It is a vulnerable plant in the IUCN Red List in 1998 (IUCN, 1998) as well as listed as an endangered species in Vietnam Red Data Book (VSAT, 2007). It was classified in IIA tree group of Management of Endangered, Precious and Rare Forest Plants and Animals by Vietnam Government (Government, 2019).

This species is a threatened species due to overexploitation for its valuable hardwood. It is a slow-growing, large and evergreen tree with a spherical well-branched canopy. It can reach up to 30 m height with trunk diameter up to 120 cm. Beside of resistance to insect attacks, its wood is famous by hardness, durability and beautiful timber grain known as "rosewood' (Moritsuka et al., 2017; PFAF, 2020; UTPD, 2020) leading to a high demand of its timber on the commercial market. Currently, *D. cochinchinensis* communities are fragmented into many subpopulations with a few individuals (Moritsuka et al., 2017).

In Vietnam, *D. cochinchinensis* populations were found in some provinces including Quang Nam, Kon Tum, Gia Lai, Dak Lak, Lam Dong, Đong Nai, Tay Ninh, Kien Giang (VSAT, 2007). In Dong Nai province, *D. cochinchinensis* mainly distributes in Tan Phu protective forest area (PFA) and Cat Tien National Park (CNP) (TPPFMB, 2017; VFA, 2010). There are many studies carried out about this species (Linh, My, Tho, & Hoang, 2018; Long, Thanh, Cuong, & Toan, 2017; Long, Tuyen, Toan, & Quy, 2018; Xuan, 2012), however the knowledge of the structural characteristics and regeneration of *D. cochinchinensis* community is still poor.

The objectives of this study aimed to study *D. cochinchinensis's* community structure from

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small to large trees. Species diversity, composition, tree sizes and their relationships were statistically analyzed in three different forest types related to different human impacts. We expected to provide detail information for *D. cochinchinensis's* protection, development and conservation in the study region.

2. RESEARCH METHODOLOGY

2.1. Study Site and Data Collection

Tan Phu PFA was established in 1978 according to Decision 4189/QD-UBND, 2016 Dong Nai province. This protected forest area is tropical moist evergreen forest belonging Dinh Quan district, Dong Nai province, geographic location from 11°2'32" to 11°10'00''N and from 107°20'00" to 107°27'30' E, with total area of 13,594 ha (Linh et al., 2018; Long et al., 2018).

Here, forest type was classified into three types following the Circular No. 33/2018/TT-BNNPTNT of The Ministry of Agriculture and Rural Development – Vietnam (MARD, 2018) based on total volume. Ranging from 200 – 300 m^3/ha of total volume is classified as the rich forest, from 100 – 200 m^3/ha as the medium forests and from 50 – 100 m^3/ha as the poor forest.

Our study focused on *D. cochinchinensis* communities in this natural forest region (Figure 1). Nineteen sample plots was randomly designed (each covering 1000 m^2 (25m x 40m)) on the *D. cochinchinensis* communities in Tan Phu protection forest, Dong Nai province. Due to the different area among forest types, the number plots among forest types are different and there were four plots, 10 plots and five plots were set up in the rich, medium and poor forest type, respectively. In each sample plot, 4 subplots, each covering 25 m^2 (5m x 5m) were set up at the four corners of the sample plots to investigate regeneration.

In each plot, all of the individual trees with diameter at breast height (DBH) greater than or equal to 6 cm were marked, identified local and scientific names, and measured their diameter at 1.3 m from the ground as well as total tree height. Seedling trees with DBH smaller than 6 cm in the subplots were identified by species, their height classes (< 0.5 m; 0.5 – 2.0 m; 2.0 – 3.0 m; > 3.0 m). Seedling quality was classified into 2 classes (good, bad), their origin also was determined (from sprout or seed). Besides, the canopy cover (cover) of each plot was estimated by Gap Light Analysis Mobile Application (GLAMA) (Tichý, 2015).

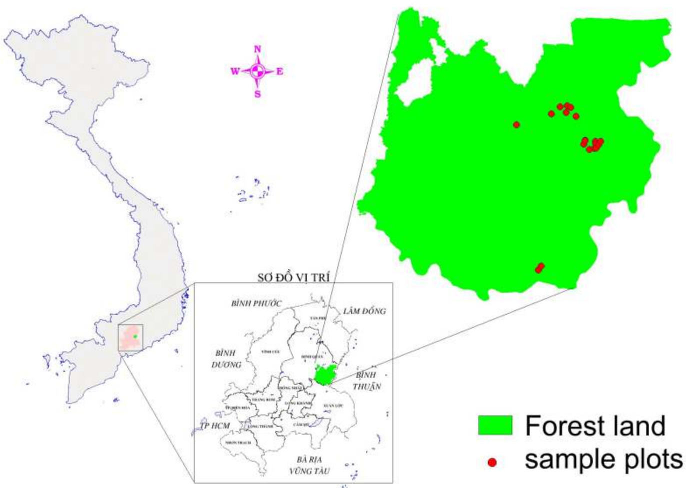

Figure 1. Maps of study region and plots

2.2. Data analysis

Species composition

Species composition was described by using IV- important value index as following (Trung, 1999): $IV_i\% = \frac{N_i\% + G_i\% + V_i\%}{3}$

Where: IV_i%: the composition ratio (important index), N_i%: relative abundance,

G_i%: relative basal area, V_i%: relative total volume of i^{th} species

Species diversity

Species diversity, which is sometimes called species heterogeneity, is an expression of community structure. Also, it is one of the basic concepts of ecology.

In this study, five commonly different species diversity indices (Table 1) were used for ecological interpretation to emphasize different aspects of species diversity. (Magurran, 1988), namely, species richness (SR), the Shannon's H and Simpson's D indices of entropy, Margalef's richness (Ma) and Fisher's alpha (Fa). Species richness is the number of species found in a plot. Simpson's dominance is weighted toward the abundance of a species combining species richness and evenness. The Shannon index (Shannon & Weaver, 1949) is more sensitive to rarer species, while the Simpson index (Simpson, 1949) responds more to abundant species, both representing two points in a spectrum of relative sensitivity to species number versus relative evenness (Heip, Herman, & Soetaert, 1998). Fisher's alpha index was calculated for all trees within each plot (Fisher, Corbet, & Williams, 1943), combining species richness and abundance in a single metric that is relatively independent of sample size and is commonly used in studies of tropical tree diversity (e.g.,(Condit et al., 1996)). Margalef's richness was calculated, including the number of species and the total amount of individuals in a sample (Roberts, 2000).

Species diversity indices were calculated separately for each plot in each forest type using the software PAST ver. 4.05 (PAleontological Statistics, https://www.nhm.uio.no/english/research/infrastructure/past/).

One-way analysis of variance at 5% significant level was used to test for significant difference among diversity index from all the forest types while Duncan Multiple Range Test (DMRT) was used to determine which diversity index of forest type are significantly different from which others.

Table 1. Five different species indices

Diversity index	Equation	Reference
Species richness	Total number of species	Magurran (1988)
Margalef	$D_\alpha = \frac{(S-1)}{\text{LnN}}$	Magurran (1988)
Shannon–Wiener	$H' = -\sum p_i Lnp_i \ \ but, p_i \frac{n_i}{\text{N}}$	Shannon & Weaver (1949)
Simpson	$D_s = 1 - \frac{n_i(n_i-1)}{\text{N(N -1)}}$	Simpson (1949)
Fisher	$S=a*\ln(1+n/a)$	Fisher et al. (1943)

Structural characteristics

Descriptive statistics on forest structure were calculated for each sample plot, namely stand density, mean diameter at breast height (DBH), mean height (H), basal area (G), and volume (V). Volume of each stem was estimated as equaling G*H*f, where G is stem basal area and f is form parameter, which is 0.45 for natural forest.

Aboveground biomass (AGB) of each measured individual stem was estimated using the following allometric equations (Bao, 2009)

$$AGB_f = 0.2626\, DBH^2$$

$$AGB = 0.454\, AGB_f^{1.032}$$

where AGB_f and AGB are individual stem fresh and dry biomasses in kg, respectively.

Then, AGB of a plot was calculated as the sum of the biomass of the individual trees in each plot.

Diameter and tree height distribution

Weibull 2-parameter function, Exponential and Log-normal distributions were used to model frequency distributions of the DBH and height. For goodness of fit, the Chi-square test was employed.

Regeneration of seedling

Regeneration of seedling plays an important role for forming canopy layers of forest in the future. To better understand the regeneration of seedling, some criteria are surveyed as follows.

- Number of regenerations per height class.

- Number of regenerations according to its quality.

+ Regeneration composition formula:

$$N_i\% = \frac{N_i}{N} \times 100$$

Where:

N: total number of regenerated investigated

Ni: total number of regenerated i^{th} species.

+ Density of regenerated trees:

$$N/ha = \frac{10.000 \times n}{S_{suplot}}$$

Where:

n: total number of regenerated investigated

S_{suplot}: total area of regenerated investigated.

- Besides, five different species diversity indices such as Species richness, Margalef, Shannon–Wiener, Simpson and Fisher index also were used for ecological interpretation to emphasize different aspects of species diversity of seedling.

Data analysis is applied by Excel 2010 and SigmaStat 3.2 software. Excel 2010 software is applied to model and test the diameter and tree height distribution. One-way ANOVA and the least significant difference (LSD) test were used to compare between means by SigmaStat 3.2 (SigmaStat version 3.2; Jandel Scientific, San Rafael, CA, U.S.A.)

3. RESULTS AND DISCUSSION

3.1. Species composition of forest types

The number of tree species and species compositions of the forest types were relatively diverse (Table 2). Species composition in medium forest includes 60 species. It was higher than poor and rich forest (35 species and 48 species, respectively). Meanwhile, the number of species in the medium forest was higher 1.71 times and 1.25 times in comparison with the poor forest and rich forest. In the medium forest, the species composition was composed from 7 dominant species including *P. ananmensis, S. roxburghii, I. malayana, D. cochinchinensis, S. siamensis, A. costata* and *S. zeylanicum*. In addition, the total IV of dominant species in this forest was 80.0%. It was much higher than poor and rich forest type (71.1% and 37.8%, respectively). *P. ananmensis* appeared in the species composition of all 3 forest types. This species is local and popular tree that adapts well with site condition at study area (Long et al., 2017; Long et al., 2018; Xuan, 2012). *S. roxburghii, I. malayana* and *D. cochinchinensis* involved in the species composition of 2 forest types. These species also are native and valued-economic trees therefore they had been strongly harvested in the past. Some species such as *C. ligustrinum; D. lancaefolia; S. siamensis; A. costata; S. zeylanicum* and *D. alatus* only dominated in one of the forest types.

D. cochinchinensis only appeared in the species composition of the poor and medium forests with 9.2% and 5.0% of the important value index (IV%); in the rich forest type, the IV% of *D. cochinchinensis* accounted for 4.3%. So, the IV% of *D. cochinchinensis* has a decreased trend from poor forest, medium forest to rich forest type. This can be explained that *D. cochinchinensis* is a precious wood tree and was overexploited in the part. *D. cochinchinensis* is left over mostly are small or restored trees. So, it mainly appears in the poor and medium forest type more than rich forest type.

Table 2. The species composition of the forest types (*Unit:* ha)

Forest types	Species	Density (N/ha)	G (m^2/ha)	V (m^3/ha)	IV (%)
Poor forest	*Cratoxylon ligustrinum*	320	2.84	16.74	26.7
	Parinari ananmensis	20	1.88	17.42	13.1
	Shorea roxburghii	78	1.31	9.00	10.2
	D. cochinchinensis	74	1.14	7.71	9.1
	Diospyros lancaefolia	78	0.62	3.48	6.0
	35 other species	326	3.90	23.43	28.9
	Total	**896**	**11.69**	**77.78**	**100**
Medium forest	*Parinari ananmensis*	33	3.01	29.75	26.7
	Shorea roxburghii	62	1.65	13.42	13.1
	Irvingia malayana	17	1.69	15.19	10.2
	D. cochinchinensis	21	1.33	13.02	9.1
	Sindora siamensis	29	1.25	10.68	6.0
	Anisoptera costata	23	1.24	10.66	7.0
	Syzygium zeylanicum	48	0.99	6.81	8.0
	53 other species	507	10.08	74.86	19.7
	Total	**740**	**21.23**	**174.39**	**100**
Rich forest	*Dipterocarpus alatus*	30	3.87	39.05	10.7
	Irvingia malayana	25	2.86	29.03	7.6
	Parinari ananmensis	15	2.93	29.12	7.3
	Desmos cochinchinensis	38	2.00	19.66	6.3
	Shorea guiso	28	2.11	19.01	6.0
	43 other species	520	17.54	149.10	62.2
	Total	**655**	**31.3**	**285.0**	**100**

3.2. Species diversity of forest types

Table 3 showed that the lowest species diversity was the poor forest and the highest species diversity was the medium and rich forest. The results of analysis of variance (Table 3) illustrated a significant difference ($p < 0.05$) among diversity indices from all the forest types. Species richness (number of species) per plot was significantly lower in poor forest (14.4 ± 5.55) than in medium forest (23.6 ± 3.37) and rich forest (23.5 ± 4.43) ($p < 0.05$, Duncan Multiple Range Test), but no significant differences were found between medium forest and rich forest ($p > 0.05$, Duncan Multiple Range Test, Table 3). The Shannon index, Margalef index, Fisher's alpha and Simpson index showed a similar tendency.

Table 3. Species diversity of the three forest types, (Mean ±SD)

Diversity indices	Poor forest	Medium forest	Rich forest
Species richness	$14.4^a \pm 5.55$	$23.6^b \pm 3.37$	$23.5^b \pm 4.43$
Shannon's index	$2.0^a \pm 0.58$	$2.9^b \pm 0.19$	$2.9^b \pm 0.34$
Margalef's index	$3.0^a \pm 1.35$	$5.3^b \pm 0.89$	$5.4^b \pm 1.03$
Fisher's alpha	$5.6^a \pm 3.93$	$13.3^b \pm 5.01$	$13.5^b \pm 4.38$
Simpson's index	$0.79^a \pm 0.11$	$0.93^b \pm 0.02$	$0.93^b \pm 0.04$

Values followed by the same letter are not significantly different based on LSD Test.

3.3. Diameter and tree height distribution

The distribution of the number of trees per DBH class

The density-diameter relations of trees in poor, medium and rich forest were shown in figure 2, respectively. Density-diameter distribution has often been used to represent the population structure of forest (Khan, Rai, & Tripathi, 1987; Manabe, Nishimura, Miura, & Yamamoto, 2000; Newton & Smith, 1988; Rao, Barik, Pandey, & Tripathi, 1990; Saxena & Singh, 1984). The frequency distributions of the DBH of the three forest types were reverse J-shaped or decreased distribution. These shaped distributions were common for mixed tropical forest and in line with authors' study (Hien, 1974; Lung, 1989; Newton & Smith, 1988; Rao et al., 1990; Truong, 1983). Among three forest types, the majority of stems were concentrated in the first two DBH classes. In poor forest, the tree diameter distribution was mainly in classes of 6.5 and 8.5 cm (DBH ≤ 9.5 cm) accounted for 448 trees/ha. While, DBH mainly distributed in greater classes of 8 and 12 cm (DBH ≤ 14 cm) accounted for 425 trees/ha and 297 trees/ha in the medium and rich forests, respectively.

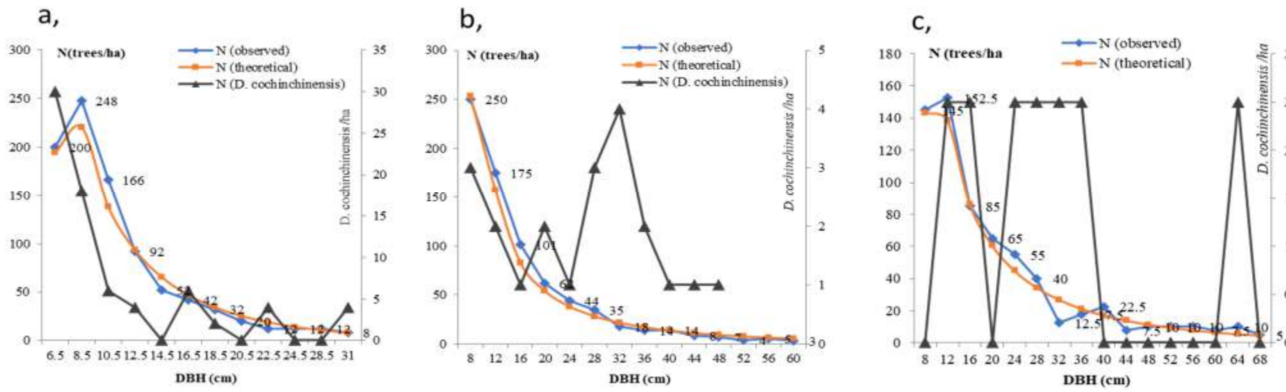

Figure 2. Frequency distributions of DBH for poor forest (a), medium forest (b) and rich forest (c)

In general, those distributions were all skewed to the left of the graph, with the total number of stems dramatically declining with the ascending DBH classes, suggesting that small-size trees dominate the forest stands (which in turn indicates good regeneration) (Truong, 1983).

Among Weibull 2-parameter, Exponential and Log-normal function, the Weibull 2-parameter function is the most appropriate one so it was used to fit distribution of diameter. The distributions were further tested with Chi-square test. The Chi-square test indicated that the Weibull distributions can provide a good fit for the diameter data, because its calculated Chi-square values were lower than critical Chi-square values, meaning the data followed the specified distribution. The parameters of Weibull distributions are $\alpha = 0.85$, $\lambda = 0.245$; $\alpha = 0.6$, $\lambda = 0.28$ and $\alpha = 0.75$. $\lambda = 0.147$ in the poor, medium and rich forest, respectively. These results are in line with the study of other authors (de Lima, Batista, & Prado, 2015; Loetsch, Zöhrer, & Haller, 1973) when modeling the frequency distributions of DBH for tropical forest.

About the frequency distributions of the DBH of the *D. cochinchinensis*, it has multi-peaks distributions in three forest types (Figure 2). However, those distributions were all skewed to the left of the graph in the poor forest type while those distributions were all skewed to the right of the graph in the medium and rich forest type. Meanwhile, in the poor forest, the diameter of the *D. cochinchinensis* was mostly equal to the average diameter of forest; while the diameter of the *D. cochinchinensis* was mostly greater to the average diameter of forest. According to the study at Di Linh district, Lam Dong province, the frequency distributions of the DBH of the *D. cochinchinensis* mainly concentrated in classes of 6.0 - 10.0 cm and there has not been recorded any *D. cochinchinensis* whose DBH is larger than 30.0 cm (Tien, Men, & Truong, 2018). This thing proves the high potential of *D. cochinchinensis* population's restore at Tan Phu PFA.

The distribution of the number of trees per height class

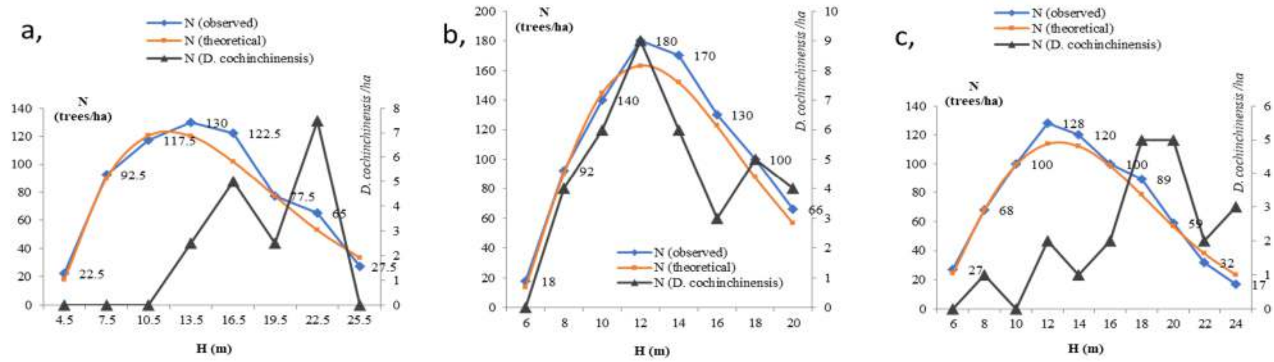

Figure 3. Frequency distributions of tree height for poor forest (a), medium forest (b) and rich forest (c)

The distributions of tree height frequency in poor, medium and rich forest were showed in figure 3a-c, respectively. In the poor and medium forest (figure 3a-b), the largest number of stems was found at a height of 12 m and 14 m which represented up to 350 and 248 stems per hectare, respectively. While in the rich forest, the largest number of stems was found at a height of 13.5 m and 16.5 m which represented up to 252 stems per hectare (figure 3c). In general, those distributions were all skewed to the left of the graph. Truong (1983) reported that in the standard forest model small-size trees dominate the stand (which in turn indicates good regeneration).

Similar to the distribution of the number of trees per DBH class, Weibull functions is the most appropriate one so it was used to fit distribution of height. The distributions were further tested with Chi-square test. The Chi-square test indicated that the Weibull distributions can provide a good fit for the height data, because its calculated Chi-square values was lower than critical Chi-square values, meaning the data followed the specified distribution. The parameters of Weibull distributions are $\alpha = 1.9$, $\lambda = 0.015$; $\alpha = 0.6$, $\lambda = 0.27$ and $\alpha = 1.7$, $\lambda = 0.014$ in the poor, medium and rich forest type, respectively.

About the frequency distributions of the tree height of *D. cochinchinensis*, it has multi-peaks distributions in three forest types (Figure 2). However, those distributions were all skewed to the left of the graph in the poor forest type while those distributions were all skewed to the right of the graph in the medium and rich forest type. Meanwhile, in the poor forest type, the height of the *D. cochinchinensis* is mostly equal to the average height of forest; while the height of the *D. cochinchinensis* is mostly greater to the average height of forest. This result proves the average height of *D. cochinchinensis* is higher in comparison with the study at Di Linh district, Lam Dong province, the frequency distributions of the H of the *D. cochinchinensis* mainly concentrated in classes of 4.0 - 8.0 m (Tien et al., 2018).

3.4. Similarity of forest types

The table 4 showed the density of *D. cochinchinensis* in all of three forest types were slightly different, it ranged from 30 – 180 trees/ha, an average of 74 trees/ha at the poor forest. This density was higher than medium and rich forest, with ranging from 10 – 40 trees/ha, an average of 21 trees/ha and ranging from 10 – 20 trees/ha, an average of 18 trees/ha, respectively. The density of *D. cochinchinensis* at the study area (among three forest types) was 34 trees/ha. This result is much higher in comparison with the density of *D. cochinchinensis* in Dong Nai, Kon Tum, Binh Phuoc and Dak Lak provinces. *D. cochinchinensis* has been recorded in the Yok Don National Park (Dak Lak province) and Dak Uy protected area (special use forest/SUF) of Kon Tum province with the trees' density is 0.7 tree/ha and 15.0 trees/ha, respectively (CCD, 2020a, 2020b, 2020c).

Table 4. Summary statistics of plots (Mean± SD)

Unit: plot (0.1ha)

Parameter	Poor forest			Medium forest			Rich forest		
	Min	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**Mean± SD**
Cover	0.3	0.6	$0.5^a \pm 0.13$	0.5	0.8	$0.6^b \pm 0.09$	0.6	0.9	$0.7^b \pm 0.13$
DBH (cm)	10.6	13.9	$11.4^a \pm 1.41$	11.4	19.7	$16.9^b \pm 2.41$	18	22.2	$20.3^c \pm 1.74$
H (m)	9.2	13.3	$11.9^a \pm 1.59$	12.2	16.8	$14.7^b \pm 1.7$	13.9	16	$15.1^b \pm 0.94$
N (tree/plot)	62	123	$89.6^a \pm 22.96$	55	121	$74^a \pm 23.51$	60	74	$65.5^a \pm 6.45$
N of Dc (tree/plot)	3	18	$7.4^a \pm 6.19$	1	4	$2.1^b \pm 0.99$	1	2	$1.8^b \pm 0.5$
BA (m^2/plot)	0.9	1.4	$1.2^a \pm 0.19$	1.8	2.7	$2.1^b \pm 0.24$	2.9	3.6	$3.2^b \pm 0.31$
V (m^3/plot)	6.09	9.22	$7.8^a \pm 1.27$	15.6	18.7	$17.4^b \pm 1.19$	26	30	$28.5^c \pm 1.74$
AGB_f (kg/plot)	3050	4590	$3908^a \pm 575$	6171	9057	$7100^b \pm 776$	9738	11956	$10470^b \pm 1016$
AGB (kg/plot)	1568	2375	$2049^a \pm 302$	3309	4853	$3812^b \pm 418$	5310	6533	$5729^b \pm 553$

Values followed by the same letter are not significantly different based on Duncan Multiple Range Test. Dc - D. cochinchinensis; SD- Standard deviation.

Besides, the density of the poor forest was from 620 trees/ha to 1230 trees/ha, while the density of the medium and rich forest ranged from 550 to 1210 trees/ha and 600 to 740 trees/ha, respectively. The mean diameter and height of the poor forest were 11.4 cm and 11.9 m, respectively, these values for the medium forest were 16.9 cm and 14.7 m, respectively, and these values for the rich forest were 20.3 cm and 15.1 m, respectively. The total basal area and volume of the poor forest were 12.0 m^2/ha and 70.0 m^3/ha; and of the medium forest were 21.0 m^2/ha and 174.0 m^3/ha whereas these numbers of the rich forest were 32.0 m^2/ha and 285 m^3/ha, respectively. Similarly, the total fresh and dry aboveground biomass aboveground biomass of the poor forest were 39,080 kg/ha and 20,490 kg/ha; and of the medium forest were 71,000 kg/ha and 38,120 kg/ha whereas these numbers of the rich forest were 104,700 kg/ha and 57,290 kg/ha.

The results of analysis of variance showed that tree density per plot did not differ significantly among the three forest types (Table 4). However, significant differences were found between the mean of canopy cover, DBH, H, numbers of *D. cochinchinensis*, BA, V, AGB_f and AGB among forest types. DBH showed the highest value in the rich forest type, medium value in the medium forest type and the lowest value in the poor forest type with significant differences between them. A similar tendency was detected also for other parameters such as V. In the poor forest type, cover, H, numbers of Dc per plot, BA, AGB_f and AGB were significantly lower than in the other two forest types (Table 4), but these parameters did not differ between medium and rich forest type.

3.5. Regeneration of seedling

3.5.1. Species composition of seedling

Composition of large trees and seedling were the assemblage of plant species that characterizes the vegetation (Isango, Varmola, Valkonen, & Tapaninen, 2007), therefore, determination of plant composition is necessary. Result of species composition for each forest type were showed in Table 5.

Similar to the species compositions of overstory trees, the number of seedling species in medium forest was highest (53 species). It was higher than poor and rich forests (44 species and 33 species, respectively). Meanwhile, the number of species in the medium forest was higher 1.20 times and 1.61 times in comparison with the poor forest and rich forest. The abundant species involved in the species regeneration composition of poor, medium and rich forest type were 4, 3 and 5 species, respectively. The total N% of species involving in the species composition in rich forest was 51.6%. It is much higher than poor and medium forest type (35.4% and 31.1%, respectively).

Table 5. Species composition of seedling

Forest type	No. species	Species composition
Poor forest	44	10.6 *D. cochinchinensis* + 10.3 *Barringtonia cochinchinensis* + 9.3 *Memecylon ligustrinum* + 5.3 *Diospyros lancaefolia* + 64.6 (40 other species)
Medium forest	53	13.3 *Vatica odorata* + 12.4 *Diospyros lancaefolia* + 5.4 *Barringtonia cochinchinensis* + 68.9 (50 other species)
Rich forest	33	14.8 *Diospyros lancaefolia* + 14.8 *Vatica odorata* + 11.7 *Barringtonia cochinchinensis* + 5.1 *Grewia paniculata* + 5.1 *Pterospermum grewiaefolium* + 48.4 (28 other species)

B. cochinchinensis and *D. lancaefolia* appear in the species composition of three forest types. *Vatica odorata* involved in the species composition of 2 forest types. *D. cochinchinensis* only appeared in the species composition of the poor forest with shares 10.6% (640 trees/ha) of regeneration ratio (N%); in the medium forest type, the N% of *D. cochinchinensis* accounts for 4.2% (440 trees/ha). *D. cochinchinensis* has not recorded in the rich forest. This result is much higher comparing with the report of CCD on natural regeneration of *D. cochinchinensis* in Dong Nai, Kon Tum, Binh Phuoc and Dak Lak provinces shown that the *D. cochinchinensis* has not appeared in the Southern of Cat Tien National Park (Dong Nai province) and Bu Gia Map national park of Binh Phuoc province; while *D. cochinchinensis* regeneration has been recorded in Yok Don National Park (Dak Lak province) and Dak Uy protected area (special use forest/SUF) of Kon Tum province with the trees' density is 4.3 tree/ha and 35.0 trees/ha, respectively (CCD, 2020a, 2020b, 2020c). This thing shows potential to restore and develop the *D. cochinchinensis* population in the Tan Phu PFA.

3.5.2. The quality and height classes of seedling

The regeneration layer is an important factor for species diversity of canopy layers in the future. Success or failure in forest regeneration depends on several constituents. The first indicator is the number and quality of seed sources dispersed from canopy layers. Secondly, environmental conditions are essential for regeneration germination, growth and development. The quality and tree height classes of seedling are showed in Figure 7.

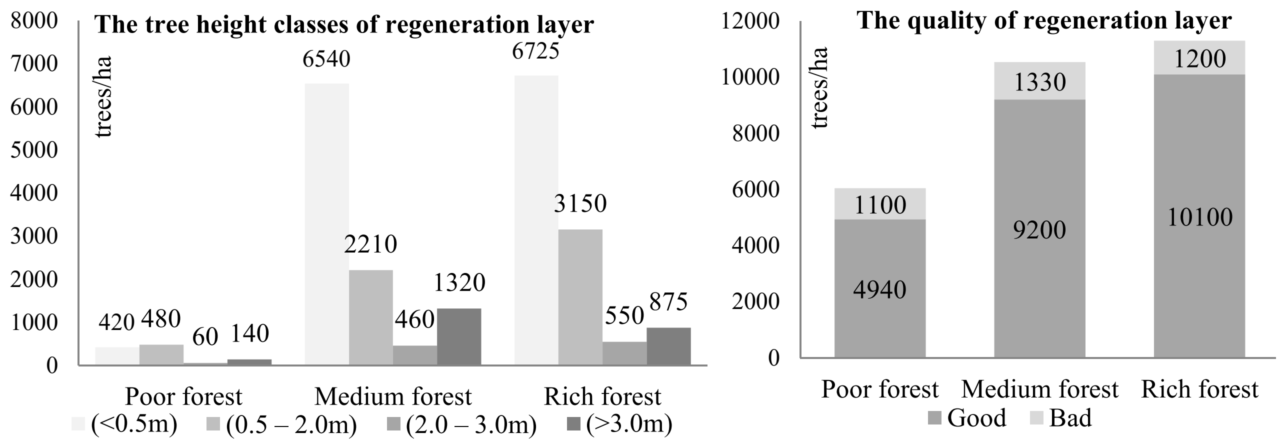

Figure 4. The quality and height classes of seedling

Figure 4 illustrates the generated inviduals appeared in all tree height classes of forest types. Generally, the number of generation trees decreased when the tree height classes increased. That means there are competition about light and spatial growth among generation trees, shurbs and vegetation, therefore, many generation trees were eliminated. Tree heigh is a parameter to assess the survival and development of generated trees (Them, 1992). The healthy of generated trees had heigh level > 100cm were considered as promosing in the reforestation because their heigh almost exceeds the heigh levels of shurbs in the forest (Long et al., 2018).

Besides, the density of generation trees in all forest types are very high, the quality of generation trees mostly are good (Figure 4). That means the potential of generation of forest at study are is good. Therefore, it is necessary to make favorable conditions to generation trees to increase and develop.

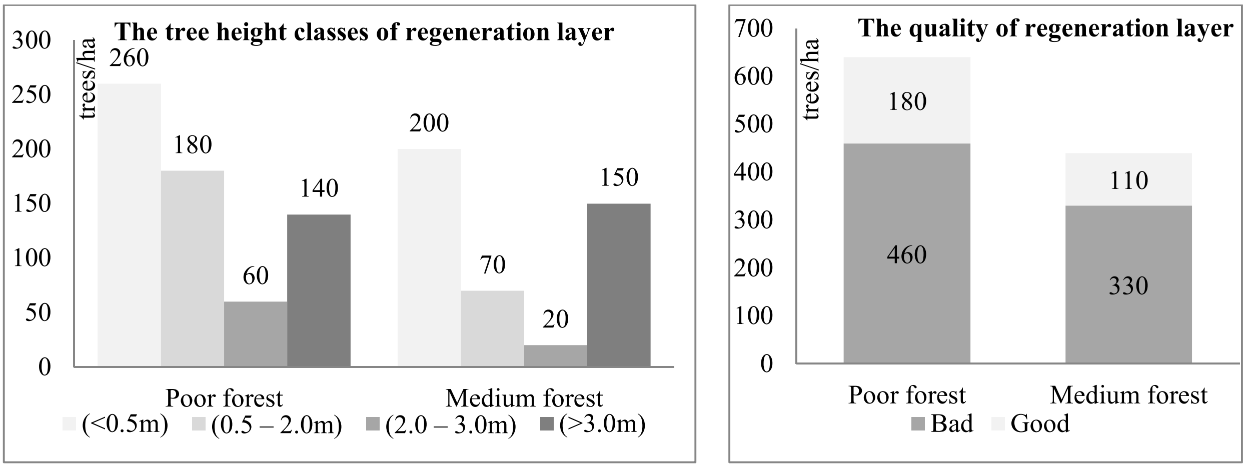

Figure 5. The quality and height classes of *D. cochinchinensis* seedling

Figure 5 shows that *D. cochinchinensis* seedling only appears in the poor and medium forest type with the trend of quality and height classes similar to the generation of seedling of all forest types. The density of *D. cochinchinensis* seedling very high and the quality of its mostly are good.

3.5.3. Species diversity of seedling

Plant diversity in tropical and temperate forests was maintained by seedlings (Dalling, Hubbell, & Silvera, 1998; Denslow, Newell, & Ellison, 1991; Harper, 1977). Table 6 illustrated Species richness and Shannon index in the poor forest were lower than in the rich forest and medium forest while Margalef and Fisher index have the opposite result. The results of analysis of variance showed no significant differences were found among diversity indices from all the forest types. However, Species richness per plot was significantly lower in poor forest (8.20 ± 2.50) than in medium forest (9.3 ± 1.77) and Fisher index was significantly higher in poor forest (10.1 ± 9.79) than in rich forest (5.4 ± 2.03) ($p < 0.05$, Duncan Multiple Range Test, Table 6).

Table 6. Species diversity of seedling, (Mean ±SD).

Diversity indices	Poor forest	Medium forest	Rich forest
Species richness	8.2^{a}±2.50	9.3^{b}±1.77	8.9^{ab}±1.15
Shannon's index	1.9^{a}±0.35	2.0^{a}±0.18	2.0^{a}±0.13
Margalef's index	2.8^{a}±0.97	2.7^{a}±0.4	2.4^{a}±0.28
Fisher's alpha	10.1^{a}±9.79	7.0^{ab}±6.59	5.4^{b}±2.03
Simpson's index	0.8^{a}±0.07	0.8^{a}±0.04	0.8^{a}±0.03

Values followed by the same letter are not significantly different based on LSD Test.

4. CONCLUSION

At study area, *D. cochinchinensis* distributed in poor forest, medium forest and rich forest type with density change by 74 trees/ha, 21 trees/ha, and 17 trees/ha, respectively.

The number of tree species of overstory tree are relatively diverse, there are 60 species in the medium forest which is higher 1.71 times and 1.25 times in comparison with the poor forest (35 species) and rich forest (48 species); *D.*

cochinchinensis only appears in the species composition of the poor forest and the medium forest type with respective shares 9.1% and 5.0% of the important value index (IV%).

All species richness, Shannon, Margalef, Fisher and Simpson indices of overstory trees have the lowest value in the poor forest type, and the highest value in the medium and rich forest type. However, diversity indices of seedlings showed that species richness and Shannon index in the poor forest were lower than in the rich forest and medium forest while Margalef and Fisher index have the opposite result.

The frequency distributions of the DBH of the three forest types are reverse J-shaped or decreased distribution. Among three forest types, the majority of stems were concentrated in the first two DBH classes. The Weibull function was the most appropriate function to fit distribution of DBH.

The distributions of height frequency (N/H) of all forest types were all skewed to the left of the graph. The Weibull function was used to fit distribution of height.

The medium forest type has the highest number of regeneration species with 53 species, higher 1.20 times and 1.61 times compared with the poor forest (44 species) and the rich forest (33 species), respectively. The number of *D. cochinchinensis* seedlings regenerated in the poor forest was higher than in the medium forest type with the composition species (N%) accounted for 10.6% (640 trees/ha) and 4.2% (440 trees/ha) of regeneration ratio, respectively. The *D. cochinchinensis* regeneration has not recorded in the rich forest type.

The density of generation trees in all forest types are very high, the number of generation trees decreased when the tree height classes increased the quality of it's mostly are good.

The study results indacated the distribution of *D. cochinchinensis* in Tan Phu PFA is relatively abundant. This thing shows the potential of restore of *D. cochinchinensis* population in Tan Phu PFA is relatively high. Therefore, some measures need to be done to protect and restore the forest especially *D. cochinchinensis* population such as preventing illegal logging, fire and encroaching on the forest by local people.

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ĐẶC ĐIỂM CẤU TRÚC QUẦN THỂ TRẮC (*Dalbergia cochinchinensis*) TẠI BAN QUẢN LÝ RỪNG PHÒNG HỘ TÂN PHÚ, TỈNH ĐỒNG NAI

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TÓM TẮT

Trắc (*Dalbergia cochinchinensis* Pierre.) là loài cây quý hiếm và được quan tâm bảo tồn. Bài báo này trình bày kết quả nghiên cứu một số đặc điểm cấu trúc rừng tự nhiên có phân bố loài Trắc tại Ban quản lý rừng phòng hộ Tân Phú, tỉnh Đồng Nai. Nghiên cứu áp dụng phương pháp lập 19 ô tiêu chuẩn (otc) ngẫu nhiên điểm hình trên đối tượng rừng tự nhiên có loài Trắc phân bố. Kết quả nghiên cứu cho thấy loài Trắc xuất hiện ở cả 3 trạng thái rừng với mật độ giảm từ trạng thái rừng nghèo (74 cây/ha), rừng trung bình (21 cây/ha) đến rừng giàu (17 cây/ha). Đối với tầng cây cao, số lượng loài ở trạng thái rừng trung bình (60 loài) cao hơn 1,71 lần so với trạng thái rừng nghèo và 1,25 lần so với trạng thái rừng giàu; Trắc chỉ xuất hiện trong công thức tổ thành của trạng thái rừng nghèo và trung bình chỉ số IV% lần lượt là 9,1% và 5,0%. Các chỉ số đa dạng loài, Shannon, Margalef, Fisher và Simpson của tầng cây cao ở trạng thái rừng nghèo có giá trị thấp hơn so với trạng thái rừng trung bình và giàu. Phân bố số cây theo cỡ đường kính là đường gấp khúc theo xu hướng số lượng cây giảm dần theo cỡ tăng lên của đường kính trong khi đó phân bố số cây theo chiều cao có dạng 1 hoặc 2 đỉnh lệch trái. Số loài cây tái sinh tập trung nhiều ở trạng thái rừng trung bình (53 loài), nhiều hơn 1,20 lần so với rừng nghèo và 1,61 lần so với rừng giàu. Loài Trắc tái sinh ở trạng thái rừng nghèo cao hơn rừng trung bình với hệ số tổ thành cây tái sinh (N%) lần lượt là 10,6% (640 cây/ha) và 4,2% (440 cây/ha), không ghi nhận loài Trắc tái sinh ở trạng thái rừng giàu.

Từ khóa: cấu trúc rừng, phân bố, tái sinh, Tân Phú, Trắc.

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