STRUCTURAL CHARACTERISTICS OF FOREST STATE IIIA$_3$ BETWEEN TWO ALTITUDE LEVELS IN CORE ZONE IN XUAN NHA NATURE RESERVE, VAN HO DISTRICT, SON LA PROVINCE

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SUMMARY
This study was conducted to understand altitudinal changes in stand structure and tree species diversity in evergreen broadleaf forest in core zone in Xuan Nha Nature Reserve. Six plots (20 m x 40 m), distributing between < 1,000 and > 1,000 m above sea level were used for stem census. All stems with diameter at breast height (DBH) ≥ 6 cm were identified to species and measured for DBH and height. Results indicated elevation zone of > 1,000 m above sea level had higher mean diameter, mean height, and basal area than those of < 1,000 m. The stem density and tree species diversity in > 1,000 m were slightly lower than that in < 1,000 m. There was virtually no difference in the frequency distributions of the DBH across the two altitudinal zones. Those distributions were all skewed to the left of the graph, with the total number of stems dramatically declining with the ascending DBH classes. In regard of relationship between tree height and diameter, the logarithmic function was chosen to describe this relationship. The highest number of regeneration trees focused on the first height class for both altitude above 1,000 m and below 1,000 m. Generally, most of regeneration trees in two altitude levels had good quality, and originated in seeds.

Keywords: Altitude levels, core zone, forest stucture characteristics, tree species diversity, Xuan Nha Nature Reserve.

1. INTRODUCTION

Tropical forests are among the most species-rich and structurally complex plant communities on earth. Species diversity and stand structure in tropical forests vary widely due to regional differences in climate, edaphic conditions, and topography (Con T.V., *et al*, 2013; Unger M. *et al*, 2012). The altitudinal changes in species diversity and vegetation structure vary greatly (Ohsawa M. *et al*, 1995; Bruijnzeel L.A., 2002).

Recently several detailed studies have focused on trends in the composition structure and diversity of tropical forests along various ecological gradients, including rainfall (Gentry 1982, 1986, 1988) edaphic conditions (Huston, 1980; Gartlan *et al*, 1986; Ashton, 1989; Clinebell *et al*, 1995; Dui venvoorden, 1996), successional time (Terborgh *et al*, 1996).

A number of studies have examined such community properties along substantial altitudinal gradients (Beals, 1969; Gentry, 1988; Beaman & Beaman, 1990; Kitayama, 1992; Nakashizuka *et al*, 1992; Kitayama & Mueller – Dombois, 1994; Lieberman D. *et al*, 1996) but few have sampled between two elevations from tropical rainforests.

Decrease of top canopy height toward higher elevation was found in Southeast Asian tropical forests (Kitayama K., Aiba S., 2002) and tropical forest of Costa Rica (Lieberman D. *et al*, 1996). While, stem density increases with increasing altitude (Takyu M. *et al*., 2003; Lieberman D. *et al*, 1996). Species richness decreasing with increasing altitude in tropical regions is also pronounced (Lieberman D. *et al*, 1996; Aiba S. and Kitayama K., 1999). While, the general trend in basal area shows an increase with increasing altitude in tropics (Luciana F.A. *et al*, 2010). However, basal area decreases with increasing altitude has also been found in tropical forests in Southeast Asian (Kitayama K. and Aiba S., 2002) and in tropical forests, south Ecuador (Moser R. *et al*, 2011). While Culmsee H. *et al*. (2010) found no clear change of basal area with altitude in tropical forests, Sulawesi Indonesia.

The study site, Xuan Nha Nature Reserve, has a high level of biodiversity and difference in terms of forest structure, species composition along altitude levels. The studies on forest compositon, structure, tree species diversity and regeneration of evergreen broadleaf forests geneally from different provinces have been studied but particulary in Xuan Nha Nature Reserve has so far not been analysed by any researcher between above 1,000 m and below 1,000 m altitudinal levels. The hypothesis of this study was that: (1) Does structure of forest stand change between two elevations and the regeneration of tree species change between two elevations. (2) Does tree species diversity change between two elevations? To test the hypothesis, the following objectives were selected: (1) To describe and analyze structure and regeneration of forest stand between two elevations. (2) To study tree species diversity between two elevations.

2. RESEARCH METHODOLOGY

2.1. Study area

Xuan Nha Nature Reserve is located in Van Ho District, Son La province, with geographical coordinates: $20^0$84'45''to $20^0$54'54'' North latitude; $104^0$28'38'' to $104^0$50'28'' East longitude. The nature reserve covers four mountainous communes, including Chieng Son, Chieng Xuan, Xuan Nha and Tan Xuan of Moc Chau district, Son La province.The special-use forest boundary is contiguous between Son La, Hoa Binh and Thanh Hoa provinces. The climate of the area consists of two distinct seasons: the hot and the cold seasons. The hot season from May to September has an average temperature of 20 - 25^0C. Heavy rain is concentrated in hot season, average humidity is 80 - 85%. Cold season from October to April of next year. In the cold season, the temperature is often lower than 20^0C. Sometimes, the temperature drops to below 13^0C and extremely down to 3 - 5^0C. Humidity is quite high in the cold season, around 70 - 80% and many days are foggy, wet. Annual rainfall is from 1,700 to 2,000 mm. The rainy season usually causes short-term local flooding in the valleys, slits or around the suction holes into underground rivers and streams.

2.2. Sampling

In this study, natural forest in the core zone were investigated. Two altitude levels were divided which is below 1000 m (ASL) and above 1000 m (ASL). Six sample plots (each covering 1000 m^2) were established in two different altitude levels, 3 sample plots in each. In each sample plot, 5 subplots (each covering 16 m^2 (4 m x 4 m)) were set up to investigate regeneration, where 4 subplots were at the four corners of the sample plots, and the 5^{th} subplot was in the center of the plot (Figure 1).

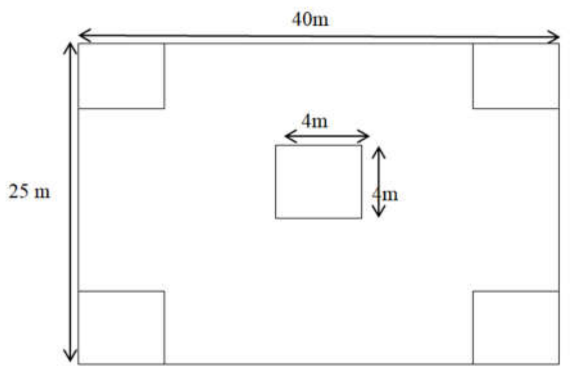


Figure 1. Plot and subplots scheme

- For trees in overstorey: In each plot, all of the individual trees found in diameter at breast height (DBH) greater than or equal to 6 cm was marked, local and scientific names identified, their diameter was measured at 1.3 m from the ground, and total tree height was also measured.

- For regeneration: Regeneration in this study is all trees with their diameter is smaller than 6 cm in the sample plot. In each subplot, regeneration was identified by species, their height was measured and classified into 3 classes (< 0,5 m; 0,5 – 1,0 m; > 1,0 m), their quality was classified into 3 classes (good, medium, bad), their origin also was determined (from sprout or seed).

2.3. Data analysis

2.3.1. Descriptive statistics

Descriptive statistics on forest structure were calculated for each sample plot, namely stand density, mean diameter (DBH), mean height (H), basal area (BA), and volume.

2.3.2. Frequency distribution

Weibull function (two parameters), Exponential and Log-normal distributions were used to model absolute frequency distributions of the DBH. For goodness of fit, the Chi-square test was employed

2.3.3. Relationship between height and diameter

In order to find the most appropriate equation for height-diameter relationships, three plots in each altitude were combined into one large plot. Based on several researches on the relationship between height and diameter (Huy D.V., 2017; Tuan V.H., 2017; Van P.Q. and Hien C.T.T., 2018), the five equations that were used to estimate the relationship between height and diameter are as follows: Linear, Logarithmic, Quadratic, Compound, and Power. The selection of the regression model is based on the model's coefficient of the determination (R^2).

2.3.4. Tree species diversity

Tree species diversity for two altitude levels was computed by using species count, Shannon-Wiener index, and Simpson index.

- Species count Δ_{SC}
- Shannon-Wiener Index

$$\Delta_{Sh} = -\sum_{i=1}^{s} p_i \, ln \, ln \, p_i \quad (1)$$

- Simpson Index

$$\Delta_{Si} = 1-\sum_{i=1}^{s} p_i^2 \quad (2)$$

Where: p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species.

2.3.5. Regeneration

- Number of regenerations per height class.
- Number of regenerations according to its quality.
- Number of regenerations according to its origin.

3. RESULTS AND DISCUSSION

3.1. Descriptive statistics

There was slightly difference in stand density, mean DBH, mean height, basal area, and volume between two altitude levels (Table 1).

Table 1. Descriptive statistics in six plots

Altitude	Plot	Density (trees/ha)	Mean DBH (cm)	Mean H (m)	BA (m^2/ha)	Volume (m^3/ha)	Forest state
> 1,000m	1	540	21.3	8.8	29.2	193.5	$IIIA_3$
	2	700	17.5	10.3	21.2	152.7	$IIIA_3$
	3	840	21.6	15.5	35.9	198.8	$IIIA_3$
< 1,000m	4	890	24.3	15.1	37.2	215.2	$IIIA_3$
	5	850	18.0	13.4	25.9	159.9	$IIIA_3$
	6	830	21.1	14.6	30.9	188.7	$IIIA_3$

The density in six plots ranged from 540 trees/ha to 890 trees/ha (Table 1). The average diameter lied from 17.5 cm to 24.3 cm, mean height varied from 8.8 m to 15.5 m, basal area ranged from 21.2 m^2/ha to 37.2 m^2/ha, and the volume varied from 152.7 m^3/ha to 215.2 m^3/ha. This result demonstrates that forest plots within the study area are well protected. Therefore, it is necessary to continue to strictly manage and protect the forest to grow well and restore forests completely following to natural laws.

As can be seen, the density of trees was slightly higher in < 1,000 m elevational zone than that in > 1,000 m elevational zone in Xuan Nha Nation Park, whereas mean diameter, mean height, and basal area increase with increasing altitude (Table 1). The patterns of increase of mean diameter, mean height, and basal area with increasing altitude were reported in tropical forests, Malaysia and tropical Atlantic moist forests, Brazil (Takyu M. *et al.*, 2003), while, in this study only stem density increased with increasing altitude. The decrease pattern of basal area with increasing altitude was widely found in tropics as limitation of soil nutrient supply at higher and cooler sites (Ohsawa M., 1995; Kitayama K. and Aiba S., 2002; Aiba S. and Kitayama K., 1999; Moser R. *et al.*, 2011; Moser G. *et al.,* 2007).

The increase of total tree height with increasing altitude in the present study was inconsistent with other tropical evergreen broadleaf forests in Southeast Asian (Kitayama K. and Aiba S., 2002; Takyu M. *et al.*, 2003) and in Ecuadoran tropical forests (Moser G. *et al.*, 2007). Soil fertility declining Kitayama K. and Aiba S., 2002; Unger M. *et al*, 2012), energy limitation (Ohsawa M., 1995) less sunlight competition (Aiba S. *et al.*, 2004) and probably wind velocity increase (Lieberman D. *et al.*, 1996; Bruijnzeel L.A. and Veneklaas E.J., 1998) in > 1,000 m elevational zones might be responsible for total tree height decline at higher altitude.

The result in this study is also contrary to the research results in Doi Inthanon National Park, Thailand (S.Teejuntuk *et al.*, 2002) and on Bukit Belalong, Brunei (Colin A. Pendry and John Proctor, 1997) which showed the increasing in the density of trees with altitude. However, the study in the Sierra de Manantlán (J. Antonio Vázquez G. *et al.*, 1998) about altitudinal gradients in tropical forest composition, structure, and diversity pointed out the same result with the research that tree density decreases with increasing altitude.

3.2. Frequency distributions of diameter

The density-diameter graph of trees in two altitude levels is shown in Figure 2. Density-diameter distribution has often been used to represent the population structure of forest (Khan *et al.*, 1987; Kumar *et al.*, 2009). In general, there was virtually no difference in the frequency distributions of the DBH across the two altitudes; 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 stand (which in turn indicates good regeneration). Kumar *et al.* (2009) also reported lower density values with increasing girth classes. In addition, plot 1, 2 and plot 5 were lacking large stems (Figure 2). Trees with a DBH greater than 70 cm were only found in plots 3, 4 and plot 6.

3.3. Relationship between height and diameter

All R^2 values of five models were significant (Sig. ≤ 0.05) and logarithmic function had the biggest value of R^2 (Table 2). Therefore, the logarithmic function was used to analyze the height-diameter relationships variation. The height-diameter fits are shown in Figure 3 separated by altitude. For a given DBH greater than 50 cm, trees at the below 1000 m sea level are taller than trees at higher altitudes.

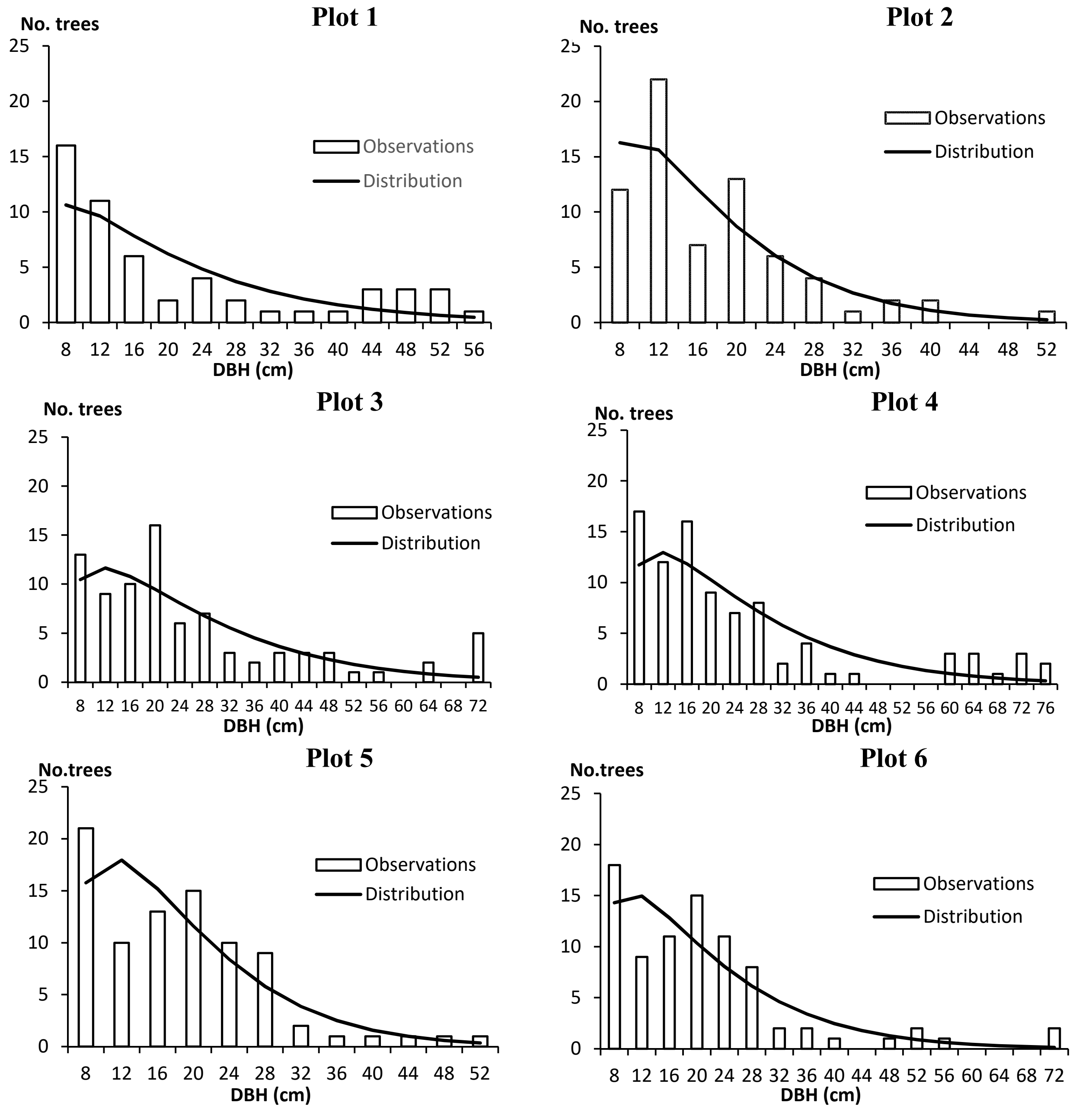
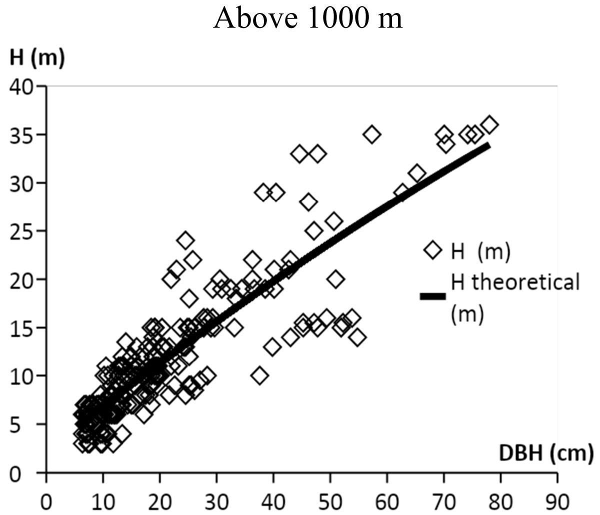


Figure 2. Frequency distributions of diameter for six plots fitted by Weibull distribution

Table 2. Parameter estimates and R^2 values for height-diameter models fitted by five functions

Altitude		Model Summary					Parameter Estimates		
	Equation	R^2	F	df1	df2	Sig.	Constant	b1	b2
> 1000 m	Linear	0.764	668.2	1	206	0.000	2.84	0.42	
	Logarithmic	0.766	527.2	1	206	0.000	-16.86	9.97	
	Quadratic	0.719	334.9	2	205	0.000	2.17	0.48	-0.001
	Compound	0.665	408.4	1	206	0.000	5.26	1.03	
	Power	0.758	645.0	1	206	0.000	1.02	0.80	
< 1000 m	Linear	0.870	1699.8	1	255	0.000	4.16	0.48	
	Logarithmic	0.930	2497.8	1	255	0.000	-19.25	11.74	
	Quadratic	0.907	1675.7	2	254	0.000	-0.49	0.88	-0.006
	Compound	0.690	567.5	1	255	0.000	6.32	1.03	
	Power	0.906	2457.9	1	255	0.000	1.03	0.87	



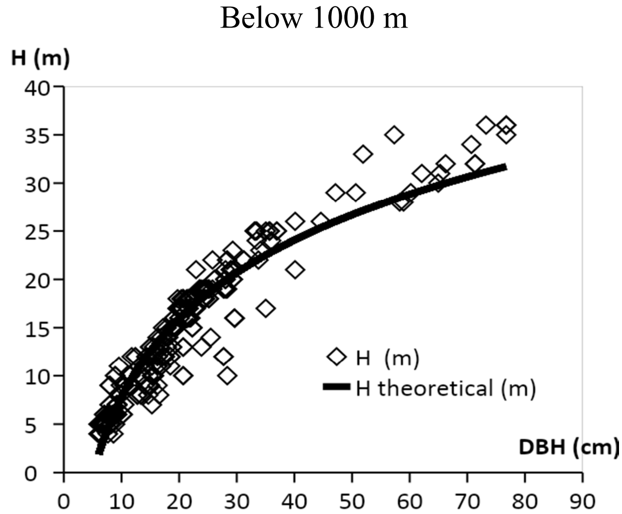


Figure 3. Height-DBH relationships within two altitude levels as according to the Logarithmic function

3.4. Tree species diversity indices

Species count ranged from 18 to 35 species in six plots (Table 3). Basically, species count, Shannon-Wiener, and Simpson indices of below 1000 m asl were slightly higher than above 1000 m asl (Table 3).

Table 3. Diversity indices for six plots in two altitude levels

Altitude	Plot	Species count ($\triangle_{SC}$)	Shannon-Wiener index ($\triangle_{Sh}$)	Simpson index ($\triangle_{Si}$)
> 1000 m	1	18	2.69	0.91
	2	26		
	3	16		
	Total	38		
< 1000 m	4	18	3.08	0.94
	5	32		
	6	35		
	Total	45		

The decline in the number of tree species diversity associated with an increasing in elevation was evidently a reflection the presence of dominant species group including *Michelia mediocris, Dacrycarpus imbricatus, Archidendron balansae, Dipterocarpus retusus, Paramichelia baillonii, Madhuca pasquieri* in the forest stand. The same result also was found in a Biosphere Reserve in central India (Sahu, P.K. *et al.*, 2008) and in the Volcan Barva, Costa Rica tropical forest, Shannon's diversity and species richness (number of species per plot) were also negatively associated with altitudinal gradient (Lieberman *et al.*, 1996). Ren *et al.* (2006) figured out that in Dongling Mountains, Beijing, tree species richness decreased with increasing elevation. The decrease in tree species diversity at higher elevation strata also could be due to ecophysiological constraints, such as reduced growing season, low temperature and low productivity (Korner, 1998; Gairola *et al.*, 2008). Other factors such as soil fertility and topography may also affect the patterns of species richness between two altitudinal levels (Gairola *et al.*, 2008).

3.5. Structure of regeneration

The regeneration pattern of the species is shown in Figure 4. In < 1,000 m, the density of regeneration trees was slightly higher than that of above 1,000m. Presence of sufficient number of regeneration trees in a given population indicates successful regeneration (Saxena and Singh, 1984), which is frequently influenced by the biotic interactions and physical factors in the community. A study of about altitudinal gradients in tropical forest composition, structure, and diversity in the Sierra de Manantlán (J. Antonio Vázquez G., Thomas J. Givnish, 1998) also suggested that the number of regeneration trees in tropical forests might decrease with the altitude increasing.

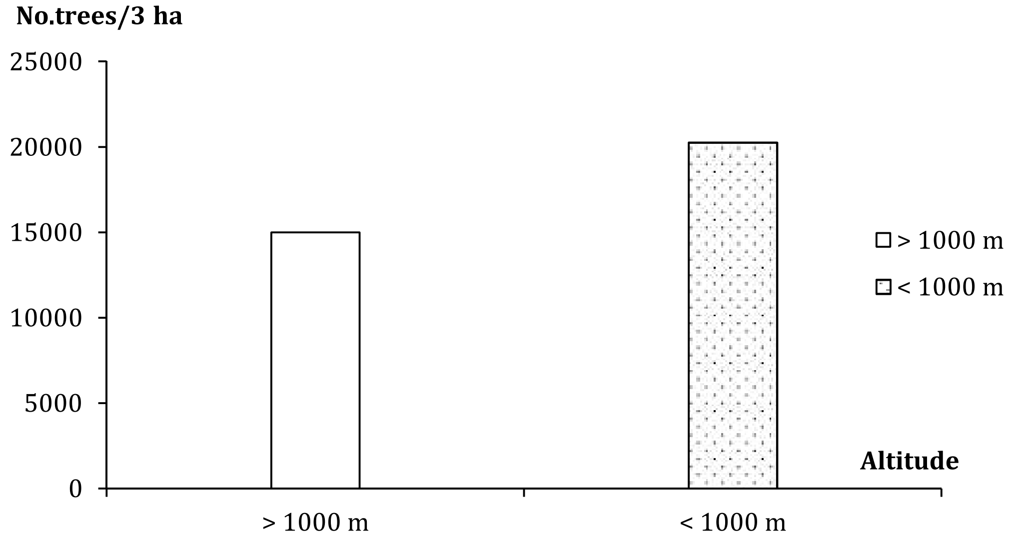


Figure 4. Number of regeneration trees in 2 altitude levels

In addition, the highest number of regeneration trees focused on the first height class (> 1m) in both < 1,000 m and > 1,000 m (Figure 5) and then the number of regeneration trees decreased with increasing height classes.

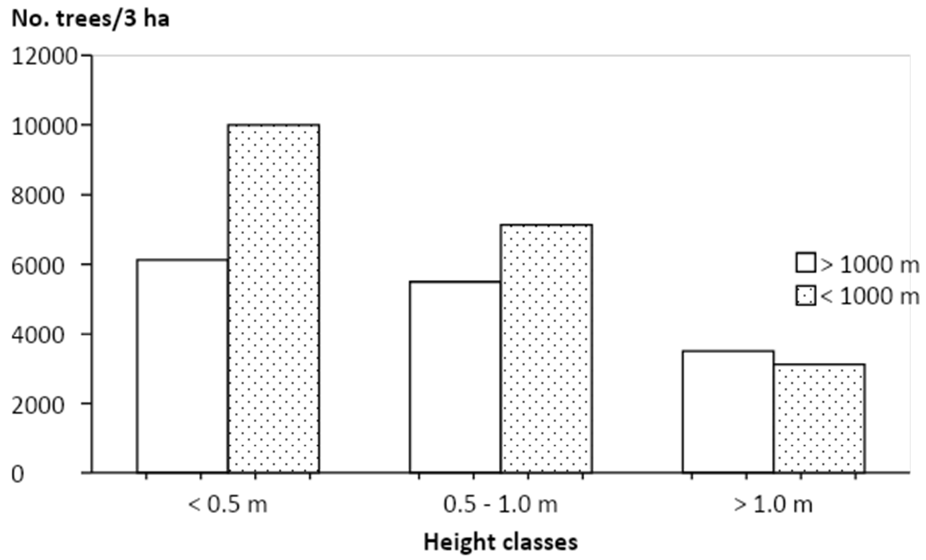


Figure 5. Number of regeneration trees according to height classes in 2 altitude levels

In general, most of regeneration trees in two altitude levels had good and medium quality (Figure 6), and originated from seeds (Figure 7). The presence of good regeneration potential shows suitability of a species to the environment. Climatic factors and biotic interference influence the regeneration of different species in the vegetation.

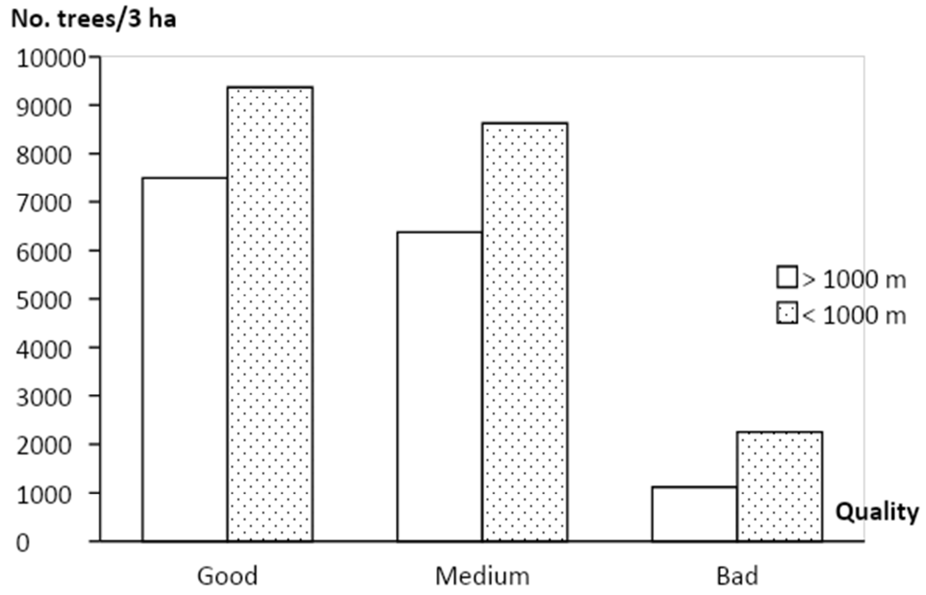


Figure 6. Number of regeneration trees according to quality in 2 altitude levels

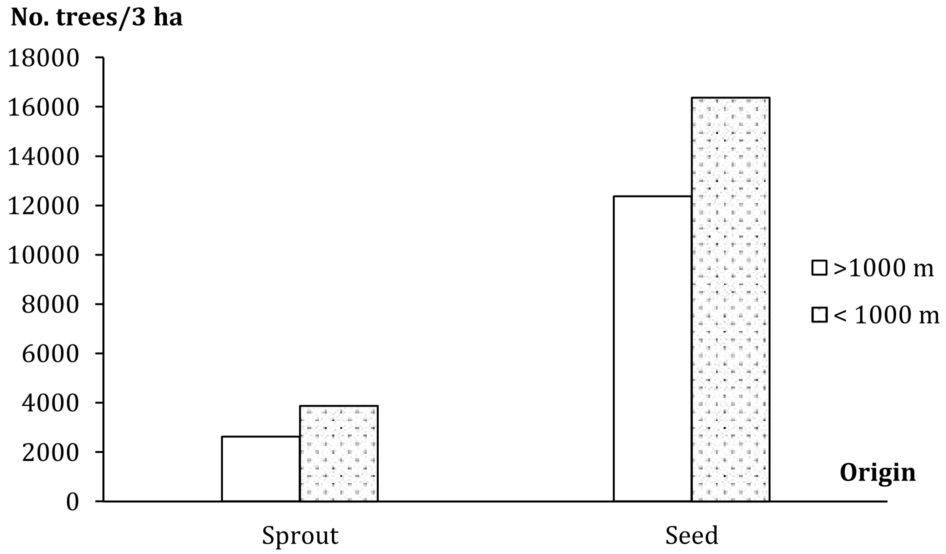


Figure 7. Number of regeneration trees according to origin in 2 elevations

4. CONCLUSION

The forests of Xuan Nha Nature Reserve located in the evergreen broadleaved forest. The pattern of increase of mean diameter, mean height, and basal area was found in evergreen broad-leaved forests in Xuan Nha Nature Reserve. The tree density displayed a slight decreasing trend with increasing altitude.

The frequency distributions of diameter across the two altitude levels were all skewed to the left of the graph, with the total number of stems dramatically declining with the ascending DBH classes.

Regarding to the height-diameter relationship, the logarithmic equation was the most appropriate function to describe this relationship.

The parameter of tree species diversity was slightly higher in < 1,000 m elevational zone compared to higher ones.

The density of regeneration trees in < 1,000 m was slightly higher than that of > 1,000 m. Below 1,000m, the highest number of regeneration trees focused on the first height class (> 1m), for both altitude above 1,000 m and below 1,000 m. Generally, most of regeneration trees in two altitude levels had good and originated in seeds in two altitude levels.

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ĐẶC ĐIỂM CẤU TRÚC RỪNG TRẠNG THÁI III_{A3} GIỮA HAI ĐỘ CAO TẠI VÙNG LÕI KHU BẢO TỒN THIÊN NHIÊN XUÂN NHA, HUYỆN VÂN HỒ, TỈNH SƠN LA

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Trường Đại học Lâm nghiệp

TÓM TẮT

Nghiên cứu được tiến hành để tìm hiểu những thay đổi về cấu trúc rừng và đa dạng loài cây trong rừng lá rộng thường xanh trong vùng lõi của Khu bảo tồn thiên nhiên Xuân Nha. Lập sáu ô tiêu chuẩn (diện tích mỗi ô là 1.000 m^2), nằm ở hai đai cao (< 1.000 m và > 1.000 m) để điều tra. Tất cả các cây có đường kính ngang ngực ≥ 6 cm được xác định tên loài, đo đường kính và chiều cao. Kết quả cho thấy, độ cao > 1.000 m có đường kính trung bình, chiều cao trung bình và tiết diện ngang lớn hơn so với độ cao < 1.000 m. Mật độ lâm phần và đa dạng loài cây ở độ cao > 1.000 m thấp hơn một chút so với độ cao < 1.000 m. Hầu như không có sự khác biệt về phân bố số cây theo cỡ đường kính ở hai đai cao. Tất cả các phân bố này đều có dạng lệch trái với số cây giảm mạnh khi cỡ đường kính tăng lên. Về mối quan hệ giữa chiều cao thân cây và đường kính ngang ngực, hàm logarith được chọn để mô tả mối quan hệ này. Với cả hai độ cao trên 1.000 m và dưới 1.000 m, số cây tái sinh đều tập trung chủ yếu ở cấp chiều cao thứ nhất. Nhìn chung, phần lớn các cây tái sinh ở hai đai cao có phẩm chất tốt và trung bình và có nguồn gốc từ hạt.

Từ khóa: Đa dạng loài cây, đai cao, đặc điểm cấu trúc rừng, Khu bảo tồn Xuân Nha, vùng lõi.

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