

# Evaluating the Influence of Topography on Species Diversity, Distribution and Composition of Forests in Central Vietnam

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## Abstract

**Objectives:** This study focused on evaluating the influence of topography conditions on species richness, diversity, distribution and species composition as dependent variables at different micro topographic attributes in Central Vietnam.

**Methods/Statistical Analysis:** Trees with diameter at breast height  $\geq 6.0$  cm of 90 quadratic plots (1000 m<sup>2</sup>) were inventoried to assess species richness, diversity, and distribution. Scatterplot Matrices: Pairs-sample Test was applied to evaluate the multiple correlations between ranked elevations and slopes with dependent variables. The composition of most abundant, dominant species including Importance Value Index at the midpoint of each topographic attribute was compared with those of the entire topographic attribute. **Findings:** A total of 4297 tree individuals were recorded representing 122 species from 47 families. We found a significant difference of species richness, diversity, stem density and basal area in different topographic attributes ( $p < 0.05$ ). The lower elevation and shallower slope had more species richness and diversity than those in the higher elevation and steeper slope. Elevation had more influence on the distribution of species, stand density, species diversity, basal area and family than those of the slope. The species composition between slopes was not remarkably distinguishable which helps to confirm that slopes do not contribute to species distribution, composition. Fagaceae, Myrtaceae, Lauraceae, Cannabaceae, Meliaceae, Sapindaceae, Dipterocarpaceae, Leguminosae, Burseraceae and Malvaceae were the most dominant. The composition of the most abundant and dominant species at the midpoint plots objected to those of the entire topographic attribute. Difference of species composition between elevations may have subjected due to disturbance or successional processes of different forest ecological habitats in the current study area. **Application/Improvements:** Mapping micro-site natural forest disturbances based topographic conditions of dominant, endemic species for conservation and management of different ecological habitats with support of high-resolution satellite images.

**Keywords:** Composition, Central Vietnam, Species Diversity, Topography

## 1. Introduction

Tropical forests host the most species richness and complex plant communities of all forests<sup>1,2</sup>. Species diversity is an indicator that shows substantial links between the richness and abundance of individual tree species, reflecting the heterogeneity or existence of vegetation<sup>3</sup>.

The diversity of tree species is fundamental to entire forest biodiversity because individuals of tree species

give resources and formation of habitat for the forest ecosystem<sup>4-6</sup>. Factors that influence forest species richness at different scales could be comprising soil, parent materials, air temperature, light and even altitudes<sup>7</sup>. The spatial distribution of trees in the tropical forest ecosystem or forest habitat has been a major interest for plant ecologists because of its potential role in explaining the coexistence of different tree species in species-rich forests<sup>8</sup>. Understanding forest species richness, diversity,

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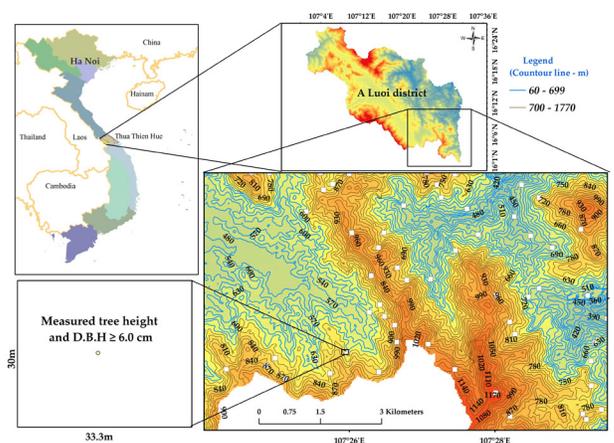
species distribution in the current study area where the taxon spatially aligned and species composition in where different species are favored in a community, is necessary for forest sustainability, species conservation, management of forest ecosystems, and natural forest landscape restoration<sup>9</sup>.

Tree species composition is also a very important indicator for assessing the Importance Value Index (IVI) of a species within a forest stand, providing information on abundance, dominance and frequency thereby providing information on the contribution of the species to vegetation formation<sup>10</sup>. Natural forests in Vietnam have declined dramatically as a result of the Vietnam War, population growth, overexploitation, and the transformation of forested areas into arable land<sup>11</sup>. Forest covers of Vietnam was around 43% in 1943 and declined to below 28% in 1990s<sup>12</sup>. The forests of the Northern and Southern Truong Son Mountain Range have been highlighted as global eco-regions by the World Wide Fund for Nature<sup>13</sup>. The tropical evergreen forests are geographically classified below 700 m a.s.l. (above sea level) in the north and below 1000 m a.s.l. in the south. The subtropical evergreen forests are classified above 700 m a.s.l. in the north and above 1000 m a.s.l. in the south of Vietnam. Vegetation communities are further identified by edaphic condition, the level of disturbance and floristics, and finally by the dominant species.

Numerous researchers have documented that plant species composition and abundance are related to the heterogeneity of soil properties, topography, and stage (i.e. age) of forest succession<sup>14-19</sup>. In Vietnam, some studies have simply described the spatial distribution of trees in forests<sup>20,21</sup>. While the influence of topographic conditions as topographic attributes on tree diversity, composition and distribution has not been studied<sup>22</sup>, no study has been conducted on the influence of topographic features (such as elevations and slopes) on tree species distribution, species diversity and composition.

To fill the gapped knowledge about the tropical evergreen forests in the Northern Central Truong Son Mountain Range in the Central Vietnam, this study aims to evaluate the influence of topographic attributes on species richness, species distribution and to compare the species composition of the most dominant species of the representative plots with those of the entire topographic attribute respectively.

The study area is located in the North Central Truong Son Mountain Range and of the A Luoi district in Vietnam (Figure 1), which borders<sup>23</sup> from 107°E to 107°30' E and from 16°N to 16°30' N in the western part of the Thua Thien Hue province. The climate consists typical tropical monsoon characteristics. The area is frequently influenced by an intertropical convergence zone that typically causes tropical low pressures and typhoons, leading to annual rainfall of about 3500 mm with an average of 200 rainy days per year, most of the rainy days accumulate between September and December<sup>21</sup>. The average annual temperature is 25° C, the average high temperature is 26.1° C, and the average low temperature is 18.5° C. Moisture content varies from 86% to 96%. The typical topography in this mountainous region features complex, steep slopes ranging from 5 to 48°. The elevation of the study area is from 150 to 1162 m a.s.l. thus the landscape of A Luoi is usually affected by landslides<sup>24</sup>.



**Figure 1.** Study area and sample plot design.

The primary and secondary lowland evergreen forests are consisted in the current study area<sup>25</sup>. The most dominant genera of *Dipterocarpus*, *Hopea*, *Parashorea* of Dipterocarpaceae and *Lithocarpus* and *Castanopsis* of Fagaceae and followed by *Syzygium* of Myrtaceae; as well as the genera of Lauraceae, namely *Machilus*, *Litsea* and *Cinamomum*, and of the Cannabaceae was *Girardinia*, *Aphananthe*. Forests in the study area are under management of Sao La Nature Reserve and Management Board of Watershed Forests. Four soil types are present within the research area: Ferralic Acrisols (75%), Arenic Acrisols (14%), Humic Acrisols (6%), and Hyperdystric Acrisols (5%)<sup>26</sup>.

## 2. Materials and Methods

### 2.1 Vegetation sampling and Topographic attribute classification

A total of 90 plots (30 × 33.3 m) were randomly sampled in the natural forests of the study area (Figure 1). The top height (Ht) in meters and the Diameter at Breast Height (DBH) of all living trees with a DBH ≥ 6.0 cm were recorded for the calculation of the mean stand parameters<sup>27,28</sup>. The tree species were recorded in the field in the Vietnamese language and later translated to their scientific names. The names of all tree species were checked to avoid synonyms in the Plantlist<sup>29</sup>. Coordinates, elevations, and slopes of all sample plots were recorded on-site with GPS and calibrated with a Global Digital Elevation Model (DEM) resolution (30 × 30 m) in ArcGIS 10.5. The minimum interval distance between plots was approximately 200 m.

As forests in Vietnam were ecologically classified, we divided the topographic elevation into two levels, H1 (150–696 m a.s.l.) and H2 (700–1162 m a.s.l.). For slope classification, we took into account of studies of<sup>24,30,31</sup> and we decide to divide slopes into two levels, lower slope (S1) ranged from 5 to 20 degrees, and steeper slope (S2) ranged from 20 to 48 degrees.

### 2.2 Species richness and species diversity distribution

In general, higher values of biodiversity indices such as species diversity and species dominance indicate large species richness<sup>32</sup>. The Shannon Index (H) of species was calculated as<sup>33</sup>:

$$\text{Shannon Index}(H) = -\sum_{i=1}^s p_i \ln(p_i)$$

where,  $p^i$  is the proportion of S made up of the  $i^{\text{th}}$  species, and the Evenness (Eq) was calculated based<sup>34</sup> as:

$$\text{Eq} = \frac{H}{\ln(S)}$$

where, H is Shannon Index and  $\ln(S)$  is the natural logarithm of the total number of species in the attribute.

We calculated the mean number of species, number of families, stem density, and basal area of all sampled plots for each topographic attribute to assess the species richness, stem density, dominance, correlation between elevations, and slope and species distribution under different topography.

Statistical 13.3 was used to test for significant differences between the mean numbers of species, number of families and stem density; and the basal area, dominance and abundance of species. In order to present multiple regressions between topographic attributes and forest stand variables, the Scatter Plot Matrices (SPLOMS) with pairs. panels package in R (RStudio Team, 2015) was used<sup>35</sup>. We then compared the means of species, individuals among topographic attributes and stand parameters<sup>36</sup>. The forest parameters of the current study are presented in Table 1.

### 2.3 Species Composition

Along with assessing the species composition for all topographic attributes, we also compared the contributions of dominance and abundance of the most ten species that

**Table 1.** Species richness, diversity, density over respective topographic attributes

Attributes/Parameters	Elevations (m) a.s.l.		Slopes (degree)	
	H1 (150–699)	H2 (700–1162)	S1 (5–20)	S2 (20–48)
No. of Plots (1000 m <sup>2</sup> )	50	40	38	52
Mean topographic attribute(±SD/attr)	527±146a	808±92b	14.3±4.7a	28.1±5.8b
Species richness (±SD) (species/plot)	29.7±3.4a	20.2±3.6b	27.1±5.5a	23.8±5.8b
Families (±SD) (family/plot)	21.3±2.9a	15.8±2.8b	19.6±3.9a	18.0±3.8a
Stand density (±SD) (stem/ha)	527±8.9a	415±13.2b	508±10.6a	455±13.7b
Basal Area (±SD) (m <sup>2</sup> /ha)	21.8±0.6b	26.2±1.0a	21.5±0.8a	25.4±0.8b
Shannon Index (H)	3.2±0.14a	2.7±0.20b	3.1±0.29a	2.9±0.26b
Equality (Eq)	94±0.02a	93±0.03b	98±0.31a	93±0.05a

(Within column, the values followed by the same letter (a, b) are not significantly different ( $p < 0.05$ ) between H1 and H2 of each parameter and values followed by the same letter (a, b) are not significantly different ( $p < 0.05$ ) between S1 and S2 of each parameter)

were present in the representative plots to those of the entire attribute. The species composition of tree species as of species abundance as number of individuals (N/ha), absolute dominance as basal area (m<sup>2</sup>/ha), frequency in percent (%), and IVI of each species where consists of relative density, relative frequency and relative dominance of the attribute were calculated<sup>20,37</sup>. The comparison of

species composition aimed at accessing the contribution of the ten most dominant species which appeared in the representative plots of each topographic attribute with those of the entire attribute with the hope to differentiate different forest ecology habitats where different species were compositionally found in different topographic attribute (Table 2).

**Table 2.** Species composition of the representative plots and of the entire topographic attribute

Species	Family	Representative Plots			Topographic Attributes			
		Abundance (N/ha)	Dominance (m <sup>2</sup> /ha)	IVI	Abundance (N/ha)	Dominance (m <sup>2</sup> /ha)	F(%)	IVI
<i>Syzygium zeylanicum</i> (L.) DC. (5:63)	Myrtaceae	1.00	0.06	24.62	12.60	0.71	66	6.07
<i>Bursera tonkinensis</i> Guillaum (4:57)	Burseraceae	0.80	0.12	33.82	11.40	0.89	46	6.21
<i>Dipterocarpus grandiflorus</i> Blanco (3:46)	Dipterocarpaceae	0.60	0.02	13.06	9.20	0.33	42	4.21
<i>Shorea roxburghii</i> G.Don (2:26)	Dipterocarpaceae	0.40	0.04	14.35	5.20	0.37	34	3.54
<i>Alangium ridleyi</i> King (2:63)	Cornaceae	0.40	0.03	13.34	12.60	0.49	60	5.54
<i>Wrightia annamensis</i> Eberh. & Dubard (2:36)	Apocynaceae	0.40	0.02	10.46	7.20	0.18	44	3.42
<i>Artocarpus rigidus</i> Blume (1:14)	Moraceae	0.20	0.07	18.49	2.80	0.16	14	2.46
<i>Amesiodendron chinense</i> (Merr.) Hu (1:19)	Sapindaceae	0.20	0.05	13.70	3.80	0.31	28	3.07
<i>Artocarpus tonkinensis</i> A.Chev. ex Gagnep. (1:20)	Moraceae	0.20	0.02	9.58	4.00	0.21	24	2.67
<i>Engelhardtia roxburghiana</i> Lindl (1:46)	Juglandaceae	0.20	0.02	8.14	9.20	0.63	46	5.08
H1: Other (34:390)		4.40	0.12	140.44	449.00	17.53	-	231.00
H1: Total (44:2635)		8.80	0.55	300.00	527.00	21.80	-	300.00
<i>Elaeocarpus sylvestris</i> (Lour.) Poir. (7:23)	Elaeocarpaceae	1.75	0.13	37.41	5.75	0.40	20	3.85
<i>Girardinia subaequalis</i> Planch (4:69)	Cannabaceae	1.00	0.08	24.22	17.25	0.80	58	8.02
<i>Lithocarpus ducampii</i> (Hickel & A.Camus) (4:110)	Fagaceae	1.00	0.08	23.92	27.50	2.02	60	12.06
<i>Scaphium macropodum</i> (Miq) Beumee ex K.Heyne (3:52)	Malvaceae	0.75	0.05	17.51	13.00	0.51	68	7.02
<i>Helicia cochinchinensis</i> Lour. (3:30)	Proteaceae	0.75	0.01	13.08	7.50	0.29	33	4.07
<i>Macaranga denticulata</i> (Blume) (2:18)	Euphorbiaceae	0.50	0.04	14.07	4.50	0.12	25	2.66
<i>Knema elegans</i> Warb (2:23)	Myristicaceae	0.50	0.02	12.05	5.75	0.30	23	3.47
<i>Vitex quinata</i> (Lour.) F.N.Williams (2:7)	Lamiaceae	0.50	0.01	11.28	1.75	0.05	15	1.41
<i>Canarium album</i> (Lour.) DC. (2:26)	Burseraceae	0.50	0.01	11.10	6.50	0.35	43	4.27
<i>Cinnamomum verum</i> J.Presl (2:5)	Lauraceae	0.50	0.01	11.09	1.25	0.03	10	0.99
H2: Other (33:363)		3.00	0.35	124.28	324.75	21.38	-	252.16
H2: Total (43:1662)		10.75	0.79	300.00	415.50	26.25	-	300.00
<i>Lithocarpus tubulosus</i> (Hickel & A.Camus) (11:37)	Fagaceae	2.89	0.02	30.11	9.74	0.51	34	5.03
<i>Artocarpus tonkinensis</i> A.Chev. ex Gagnep. (3:18)	Moraceae	0.79	0.00	18.23	4.74	0.28	24	3.26
<i>Aphanamixis grandiflora</i> (3:42)	Euphorbiaceae	0.79	0.01	14.69	11.05	0.41	58	5.19
<i>Endospermum sinensis</i> Benth. (3:21)	Euphorbiaceae	0.79	0.01	13.38	5.53	0.16	29	2.82
<i>Symplocos glauca</i> (Thunb.) Koidz. (3:41)	Symplocaceae	0.79	0.01	10.66	10.79	0.39	47	4.89

Species	Family	Representative Plots			Topographic Attributes			
		Abundance (N/ha)	Dominance (m <sup>2</sup> /ha)	IVI	Abundance (N/ha)	Dominance (m <sup>2</sup> /ha)	F(%)	IVI
<i>Nephelium melliferum</i> Gagnep. (2:39)	Sapindaceae	0.53	0.00	9.79	10.26	0.65	58	5.54
<i>Prunus arborea</i> (Blume) Kalkman (2:23)	Rosaceae	0.53	0.02	9.42	6.05	0.19	34	3.15
<i>Syzygium lanceolatum</i> (Lam.) Wight & Arn (2:73)	Myrtaceae	0.53	0.01	8.07	19.21	0.82	79	7.98
<i>Adina pilulifra</i> (1:11)	Rubiaceae	0.26	0.01	9.72	2.89	0.06	24	1.78
<i>Alphonsea monogyna</i> Merr.&Chun (1:6)	Annonaceae	0.26	0.02	7.94	1.58	0.04	11	1.18
S1: Other (36:311)		3.95	0.70	167.99	426.32	17.99	-	259.17
S1: Total (46:1931)		12.11	0.80	300.00	508.16	21.50	-	300.00
<i>Lithocarpus ducampii</i> (Hickel & A.Camus) (5:128)	Fagaceae	0.96	0.09	31.99	24.62	1.86	67	10.55
<i>Engelhardtia roxburghiana</i> Lindl (3:51)	Juglandaceae	0.58	0.04	16.75	9.81	0.83	46	5.61
<i>Ormosia pinnata</i> (Lour.) Merr (3:29)	leguminosae	0.58	0.03	15.66	5.58	0.28	40	3.51
<i>Sapium discolor</i> (3:11)	Euphorbiaceae	0.58	0.03	14.39	2.12	0.10	13	1.67
<i>Gironniera subaequalis</i> Planch (3:79)	Cannabaceae	0.58	0.01	10.98	15.19	0.62	60	6.72
<i>Archidendron clypearia</i> (Jack) I.C.Nielsen (3:10)	Leguminosae	0.58	0.01	10.29	1.92	0.07	12	1.39
<i>Canarium album</i> (Lour.) DC. (3:39)	Burseraceae	0.58	0.01	9.83	7.50	0.27	42	3.98
<i>Aphananthe cuspidata</i> (Blume) Planch (2:49)	Cannabaceae	0.38	0.04	15.55	9.42	0.52	38	4.81
<i>Diospyros sylvatica</i> Roxb (2:24)	Ebenaceae	0.38	0.01	8.71	4.62	0.33	23	3.16
<i>Aphanamixis grandiflora</i> (2:64)	Meliaceae	0.38	0.00	7.14	12.31	0.44	60	5.84
S2: Other (50:484)		5.96	0.15	158.73	361.92	20.12	-	252.76
S2: Total (60:2366)		11.54	0.42	300.00	455.00	25.44	-	300.00

(Species presented in bracket i.e: (60:2366) indicating number of individual stems in the representative plot and the individual stems in the topographic attribute; N = number of stem of a species per ha; F (%) = Frequency; IVI = Importance Value Index of the representing plot).

### 3. Results

#### 3.1 Vegetation Distribution over Topography

A total of 4297 individual trees were recorded, representing 122 species from 47 families from the total area (9.0 ha). The ten most abundant species at lower elevation (H1), out of 121 species present, were: *Syzygium lanceolatum* (Lam.) Wight & Arn, *Lithocarpus ducampii* (Hickel & A.Camus), *Lithocarpus dealbatus* (Hook.f. & Thomson ex Miq.) Rehder, *Gironniera subaequalis* Planch, *Syzygium zeylanicum* (L.) DC, *Alangium ridleyi* King, *Scaphium macropodum* (Miq) Beumee ex K.Heyne, *Bursera tonkinensis* Guillaum, *Lithocarpus tubulosus* (Hickel & A.Camus) and *Symplocos glauca* (Thunb.) Koidz.

Of these, the three most dominant species were *L. dealbatus*, *L. ducampii* and *B. tonkinensis* Guillaum (Table 3).

The ten most dominant species at higher elevation (H2), out of 109 species present, were: *Lithocarpus ducampii* (Hickel & A.Camus), *Gironniera subaequalis* Planch, *Lithocarpus tubulosus* (Hickel & A.Camus), *Syzygium zeylanicum* (L.) DC, *Lithocarpus dealbatus* (Hook.f. & Thomson ex Miq.) Rehder, *Syzygium zeylanicum* (L.) DC, *Aphanamixis grandiflora*, *Scaphium macropodum* (Miq) Beumee ex K.Heyne, *Alangium ridleyi* King and *Engelhardtia roxburghiana* Lindl. But the most dominant species in H2 were *L. ducampii*, *Shorea roxburghii* G.Don, *Dipterocarpus grandiflorus* Blanco, *Bursera tonkinensis* Guillaum (Table 3).

The ten most abundant species at shallower slope (S1), out of 116 species present, were: *Syzygium lanceolatum*

**Table 3.** The abundant and dominant species in different topographic attributes

Att	Species	Family	N	Abu (N/ha)	Dom (m <sup>2</sup> /ha)
H1	<i>Syzygium lanceolatum</i> (Lam.) Wight & Arn	Myrtaceae	102	20.4	0.8
	<i>Lithocarpus ducampii</i> (Hickel & A.Camus)	Fagaceae	73	14.6	0.9
	<i>Lithocarpus dealbatus</i> (Hook.f. & Thomson ex Miq.) Rehder	Fagaceae	65	13.0	1.0
	<i>Gironniera subaequalis</i> Planch	Cannabaceae	65	13.0	0.4
	<i>Syzygium zeylanicum</i> (L.) DC.	Myrtaceae	63	12.6	0.7
	<i>Alangium ridleyi</i> King	Cornaceae	63	12.6	0.5
	<i>Scaphium macropodum</i> (Miq) Beumee ex K.Heyne	Malvaceae	58	11.6	0.4
	<i>Bursera tonkinensis</i> Guillaum	Burseraceae	57	11.4	0.9
	<i>Lithocarpus tubulosus</i> (Hickel & A.Camus)	Fagaceae	55	11.0	0.5
	<i>Symplocos glauca</i> (Thunb.) Koidz.	Symplocaeeae	55	11.0	0.5
	Total (10)		656	131.2	6.7
	Other (111)		1979	395.8	15.1
H2	<i>Lithocarpus ducampii</i> (Hickel & A.Camus)	Fagaceae	110	27.5	2.0
	<i>Shorea roxburghii</i> G.Don	Dipterocarpaceae	69	17.3	0.8
	<i>Dipterocarpus grandiflorus</i> Blanco	Dipterocarpaceae	61	15.3	0.8
	<i>Bursera tonkinensis</i> Guillaum	Burseraceae	60	15.0	0.6
	<i>Engelhardtia roxburghiana</i> Lindl	Juglandaceae	58	14.5	0.6
	<i>Lithocarpus tubulosus</i> (Hickel & A.Camus)	Fagaceae	58	14.5	0.6
	<i>Gironniera subaequalis</i> Planch	Cannabaceae	54	13.5	0.6
	<i>Syzygium zeylanicum</i> (L.) DC.	Myrtaceae	37	9.3	0.8
	<i>Lithocarpus dealbatus</i> (Hook.f. & Thomson ex Miq.) Rehder	Fagaceae	35	8.8	0.5
	<i>Aphanamixis grandiflora</i>	Meliaceae	35	8.8	0.5
	<i>Alangium ridleyi</i> King	Cornaceae	21	5.3	0.6
	<i>Scaphium macropodum</i> (Miq) Beumee ex K.Heyne	Malvaceae	12	3.0	0.6
	Total (12)		610	152.5	9.2
	Other (97)		1052	263.0	17.0
S1	<i>Lithocarpus dealbatus</i> (Hook.f. & Thomson ex Miq.) Rehder	Fagaceae	72	18.9	1.1
	<i>Syzygium lanceolatum</i> (Lam.) Wight & Arn	Myrtaceae	73	19.2	0.8
	<i>Shorea roxburghii</i> G.Don	Dipterocarpaceae	21	5.5	0.8
	<i>Lithocarpus ducampii</i> (Hickel & A.Camus)	Fagaceae	55	14.5	0.8
	<i>Syzygium zeylanicum</i> (L.) DC.	Myrtaceae	49	12.9	0.8
	<i>Gironniera subaequalis</i> Planch	Cannabaceae	55	14.5	0.6
	<i>Alangium ridleyi</i> King	Cornaceae	55	14.5	0.6
	<i>Engelhardtia roxburghiana</i> Lindl	Juglandaceae	32	8.4	0.6
	<i>Scaphium macropodum</i> (Miq) Beumee ex K.Heyne	Malvaceae	48	12.6	0.5
	<i>Aphanamixis grandiflora</i>	Meliaceae	42	11.1	0.4
	<i>Symplocos glauca</i> (Thunb.) Koidz.	Symplocaeeae	41	10.8	0.4
	Total (11)		543	142.9	7.3
	Other (106)		1388	365.3	14.2

Att	Species	Family	N	Abu (N/ha)	Dom (m <sup>2</sup> /ha)
S2	<i>Lithocarpus ducampii</i> (Hickel & A.Camus)	Fagaceae	128	24.6	1.9
	<i>Bursera tonkinensis</i> Guillaum	Burseraceae	28	5.4	1.1
	<i>Dipterocarpus grandiflorus</i> Blanco	Dipterocarpaceae	41	7.9	0.9
	<i>Shorea roxburghii</i> G.Don	Dipterocarpaceae	30	5.8	0.9
	<i>Engelhardtia roxburghiana</i> Lindl	Juglandaceae	51	9.8	0.8
	<i>Lithocarpus tubulosus</i> (Hickel & A.Camus)	Fagaceae	79	15.2	0.8
	<i>Lithocarpus dealbatus</i> (Hook.f. & Thomson ex Miq.) Rehder	Fagaceae	51	9.8	0.6
	<i>Gironniera subaequalis</i> Planch	Cannabaceae	79	15.2	0.6
	<i>Syzygium zeylanicum</i> (L.) DC.	Myrtaceae	72	13.8	0.6
	<i>Syzygium lanceolatum</i> (Lam.) Wight & Arn	Myrtaceae	89	17.1	0.6
	<i>Aphananthe cuspidata</i> (Blume) Planch	Cannabaceae	49	9.4	0.5
	<i>Aphanamixis grandiflora</i>	Meliaceae	64	12.3	0.4
	<i>Scaphium macropodum</i> (Miq) Beumee ex K.Heyne	Malvaceae	62	11.9	0.4
	Total (13)		823	158.3	10.3
Other (104)		1543	296.7	15.2	

(Att = attribute; N = number of stem of a species in the attribute; Abu = Abundance; Dom = Dominance)

(Lam.) Wight & Arn, *Lithocarpus dealbatus* (Hook.f. & Thomson ex Miq.) Rehder, *Alangium ridleyi* King, *Gironniera subaequalis* Planch, *Lithocarpus ducampii* (Hickel & A.Camus), *Syzygium zeylanicum* (L.) DC, *Scaphium macropodum* (Miq) Beumee ex K.Heyne, *Aphanamixis grandiflora*, *Bursera tonkinensis* Guillaum and *Symplocos glauca* (Thunb.) Koidz. But the most dominant species were *L. dealbatus*, *B. tonkinensis*, *S. lanceolatum* and *Shorea roxburghii* G.Don (Table 3).

At the steeper slope (S2), the ten most dominant species, out of the 117 present, were: *Lithocarpus ducampii* (Hickel & A.Camus), *Syzygium lanceolatum* (Lam.) Wight & Arn, *Gironniera subaequalis* Planch, *Lithocarpus tubulosus* (Hickel & A.Camus), *Syzygium zeylanicum* (L.) DC, *Aphanamixis grandiflora*, *Scaphium macropodum* (Miq) Beumee ex K.Heyne, *Engelhardtia roxburghiana* Lindl, *Lithocarpus dealbatus* (Hook.f. & Thomson ex Miq.) and *Aphananthe cuspidata* (Blume) Planch but the most dominant species were *L. ducampii*, *Bursera tonkinensis* Guillaum, *Dipterocarpus grandiflorus* Blanco and *Shorea roxburghii* G.Don (Table 3).

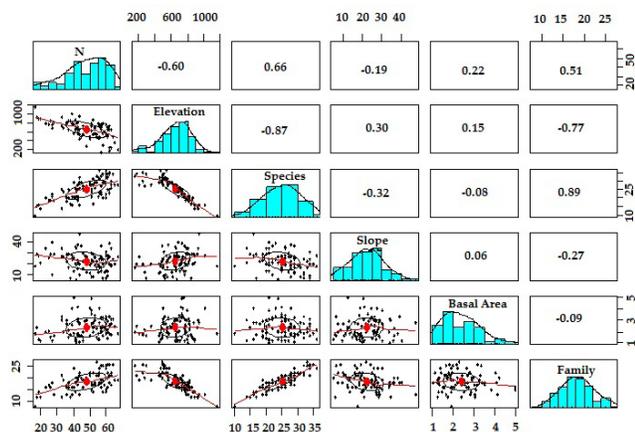
### 3.2 Species diversity and Species distribution

Table 1 shows significant differences ( $p < 0.05$ ) for mean number of tree species, number of families, tree density,

and basal area (BA) per hectare between H1 and H2. The sample results show that the higher elevation zone had lower species diversity, families, and stem density; but higher BA. Meanwhile, there are no significant differences ( $p < 0.05$ ) in mean family richness and Evenness (Eq) between S1 and S2. The mean values of number of species, family plot<sup>-1</sup>, and tree density per hectare at the lower elevation and slope were higher than those of the higher elevation and slope except for number of families in S1 and S2.

The diversity of tree species, family, Shannon Index (H) and Evenness (Eq) of each topographic attribute presented in Table 1 indicating the species diversity in Shannon Index and its Evenness amongst attributes were different and showed the same trend of Shannon Index between elevation and slope. Even though, the mean Evenness between S1 and S2 was not significantly different at ( $p < 0.05$ ).

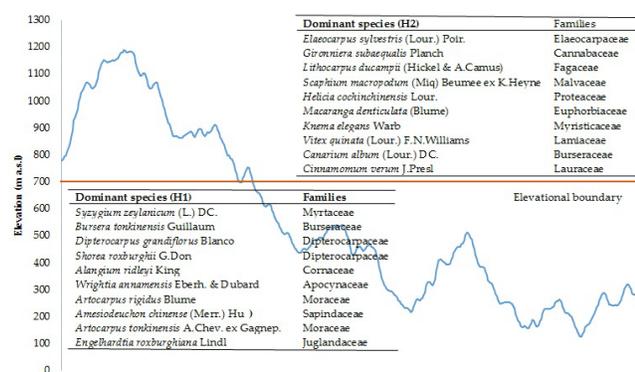
The results presented in Figure 2 show negative correlation of the number of species with elevation at  $-0.87$ , with stem density at  $-0.60$ , and with number of families at  $-0.77$ . A weak positive correlation of  $0.15$  exists between BA and elevation. The results show weak negative correlation of slope with species, stem density and family at  $-0.32$ ,  $-0.19$  and  $-0.27$ , respectively. Slope exhibits a very weak positive correlation with BA ( $0.06$ ).



**Figure 2.** Paired correlation between elevation, slope with species, stem density (N), basal area, family.

### 3.3 Species composition

The most ten dominant species of each topographic attribute were ranked (Table 2) according to species abundance as number of individuals (N/ha), absolute dominance as basal area (m<sup>2</sup>/ha), frequency in percent (%), and IVI of each species. The most dominant species at different elevations are mapped in Figure 3 in which the ten most dominant species of the representative in H1 and H2 were presented based on the elevation levels (m a.s.l.). The species composition provides information on the vegetation formation and contribution of each species through its abundance, dominance, and frequency, which help to explain the ecological habitat status in the study area (Table 2). The IVI is the combination of relative density, relative dominance and relative frequency in percentage, and helps rank the importance of a species in each attribute.



**Figure 3.** Most dominant species accounted in the representative plots of elevation levels (H1 and H2).

## 4. Discussion

### 4.1 Topographic Vegetation Distribution

Obtaining knowledge on species richness, species diversity and the species distribution among different elevations and slopes is a powerful tool in plant ecology to determine species composition<sup>38</sup>. The most abundant and dominant species in H1, H2, S1 and S2 are presented in Table 3. The main species present in each attribute were determined, in primarily evergreen and semi- evergreen forests<sup>21</sup>. The number of species and number of families found in the current study, presented in Table 3, further emphasize the results of<sup>38</sup> and <sup>39</sup>. The above listed dominant families and species found in the current study were naturally distributed in central Truong Son Mountain range, and were reported by many researchers<sup>25,39,40</sup>. At the lower elevation (H1), the most abundant species presented in Table 3 were *S. lanceolatum*, *L. ducampii*, *L. dealbatus*, *G. subaequalis*, *S. zeylanicum*, *A. ridleyi*, *S. macropodum*, *B. tonkinensis*, *L. tubulosus* and *S. glauca*. Of those species, *L. dealbatus*, *B. tonkinensis* and *L. ducampii* were the most dominant.

In the higher elevation (H2), the most abundant species present were *L. ducampii*, *S. roxburghii*, *D. grandifloras*, *B. tonkinensis*, *E. roxburghiana*, *L. tubulosus*, *G. subaequalis*, *S. zeylanicum*, *L. dealbatus*, *A. grandiflora*, *A. ridleyi*, *S. macropodum*. Of these species, *L. ducampii*, *S. roxburghii*, *D. grandifloras* and *S. zeylanicum* were the most dominant and especially in the higher elevation, there were more endemic species from genera of *Dipterocarpus*, *Shorea*, *Engelhardtia* and *Scaphium* which are important and endemic of the northern Truong Son Mountain Range<sup>11,25</sup>.

The abundant and dominant species in both shallower slope (S1) and steeper slope (S2) were not much different among themselves and with H1 and H2 presenting in Table 3. But it is good to note that the steeper slope had more endemic species than those in shallower slope (i.e, three endemic species were found in S1 as *Shorea*, *Engelhardtia* and *Scaphium* but four endemic species found in S2 were *B. tonkinensis*, *Dipterocarpus*, *Shorea*, *Engelhardtia* and *Scaphium*). These patterns help explain that forests in both lower elevation and shallower slope could have more influences by humans than those in the higher elevation and steeper slope<sup>41,42</sup>. The endemic species were found more dominant and abundant in the higher elevation and steeper slope where has low disturbance and better management and protection<sup>43-45</sup>.

The aim of establishment of protected in Vietnam is to protect, research on the main ecosystem, threatened and endemic species of flora and fauna including their habitats<sup>11,46</sup>.

## 4.2 Species diversity and Species distribution

In the tropical area, the species richness, diversity and composition at the higher elevation were lower than at the lower elevation, meaning that the species richness, diversity decreased with an increase of elevation<sup>47</sup>. This relationship explains that forests at the lower elevation could be more environmentally shaped than those at the higher elevation. The lower elevation forests may be less productive due to competition or disturbance from humans and management<sup>48</sup>. The species richness between H1 and H2 was significantly different ( $p < 0.05$ ). Species richness declined with increasing elevation, which is in agreement with <sup>31</sup> and <sup>49</sup>. The species richness was also significantly different ( $p < 0.05$ ) between S1 and S2, where S2 had lower species richness than S1. This indicates that the lower elevation and slope had more species richness, and that elevation had more influence than slope on species richness and diversity<sup>50,51</sup>. The species richness, diversity and composition in the study area could have been influenced significantly by the gradients<sup>52</sup>, not only with the number of species but also the number of families ( $p < 0.05$ ). At the lower elevation and shallower slope, forests could be more fragmented since radiation can reach the forest floor, so more pioneer species can become dominant during succession<sup>53</sup>. The tree density between the different elevations and slopes was significantly different ( $p < 0.05$ ), this result corresponds to the findings of others<sup>54-57</sup>. The BA was significantly different between H1 and H2, as well as between S1 and S2 ( $p < 0.05$ ). Since the Basal Area (BA) is one of the elements contributing to species dominance in the forest stand and over topographic attributes. This finding is in line with the findings of some studies where the BA increased with an increase of elevation<sup>59,60</sup>.

Shannon Index (H) and Evenness (Eq) ranged from 2.7 to 3.2 and from 93 to 98 in all topographic attributes, respectively. The species diversity and Evenness at the lower elevation and slope were higher than for the higher elevation and steeper slope ( $p < 0.05$ ), which corresponds to the species richness. The Shannon Index between H1 and H2 is similar to the findings of Sinha et al. (2018)<sup>61</sup>, and significantly different (95%). While the trend of Evenness

(Eq) at the steeper slope (S2) is higher than those in S1, it is not significantly different. The different consistence may show that the Evenness correlates to the disturbance, which is stronger in less steep topography<sup>48</sup>. Species diversity, basal area and species distribution presented in the current study can be differed from other studies such as <sup>50</sup> within the tropical rain forest of Costa Rica, <sup>31</sup> in the moist temperate forest of Garhwal Himalaya, and <sup>51</sup> in Sierra Nevada, Mexico due to the different temperature and rainfall and different range of elevations of tropical forests in the southeast Asia. Especially in Latin America where the deciduous forests accounted for 47% of forest area<sup>62</sup>.

## 4.3 Species composition

The most dominant species which contribute to the species composition of the representative plots for H1 and H2 was different. However, the *S. zeylanicum* species was the most abundant, numbering five individuals in the representative plot out of 63 individuals (5:63) in the entire topographic attribute of H1, the *B. tonkinensis* was not as dominant as *S. zeylanicum* in the presentative plot of H1 but it is more dominant than *S. zeylanicum* in the entire topographic attribute. As four out of the ten dominant species at the lower elevation (H1) occupied 0.19 m<sup>2</sup> out of 8.80 m<sup>2</sup> per ha in representative plot, and 2.22 m<sup>2</sup> out of 17.53 m<sup>2</sup> per ha in the whole attribute, consisting of the Burseraceae, Dipterocarpaceae and Juglandaceae families<sup>63</sup>. According to, the dominant species below 1000 m a.s.l. (in the south) and 700 m a.s.l. (in the north) are of Fagaceae, Myrtaceae, Lauraceae, Cannabaceae, Meliaceae, Malvaceae, Leguminosae; and Dipterocarpaceae, Burseraceae, Sapotaceae, Magnoliaceae, and Meliaceae; respectively. The dominance of these species confirms the stated forest type of moist and evergreen forests (where the annual rainfall is above 2500 mm and the moisture content is greater than 85%)<sup>64</sup>. Some of the predominant species, such as *S. zeylanicum*, *A. ridleyi*, *W. annamensis*, *A. rigidus*, *A. chinense* and *A. tonkinensis*, were dominant and light demanding at this elevation range, representing a type of secondary forest<sup>21</sup>. These ten species occupied 160% out of 300% of IVI in the representative plot and 42.27% out 300 % of IVI of the entire topographic attribute. The comparison of the Important Value Index of the dominant species in the representative plots with those in the entire topography gave a modest explanation of species composition in the entire topographic attribute. The values for dominance and abundance of both the representative plots and the

topographic attribute is an indicator of species diversity, as lower dominance and abundance values result in high diversity. At the higher elevation (H2), the dominant species were *E. sylvestri*, *G. subaequalis* and *L. ducampii*, which occupied 37.41%, 24.22% and 23.92% out of 175.72% in representative plot and occupied 50.5% out of 90.75% abundance and 3.22 m<sup>2</sup> out of 4.87 m<sup>2</sup> per ha<sup>-1</sup> of the ten most dominant species in this range of elevation. In this plot, there were three *S. macropodium* individuals out of 52, this species is the multiple-use propose of this area<sup>65</sup>.

The composition of *C. album*, *C. verum*, *L. ducampii*, *E. sylvestris*, *G. subaequalis* indicates complex vegetation cover, where approximately 80 to 90 species can be commonly found in the fallow soil type or after being selectively-logged or fragmented. The dominant species in two representative plots of S1 and S2 could explain vegetation cover occurring in the lowland forests below 700 m (in the north) and 1000 m a.s.l. (in the south), especially in the humid region of both the Northern and Southern Truong Son Mountain Range where a combination of Lauraceae, Fagaceae, Moraceae, Anacardiaceae families were commonly found<sup>25,39</sup>.

At steeper slope (S2), *Lithocarpus ducampii* are the most abundant and dominant, accounting for 32% in the representative plot and 10.55% in the topographic attribute. In this ecological range, *Engelhardtia roxburghiana* accounted for 16.75%, followed by *Ormosia pinnata* (15.66%), *Sapium discolor* (14.39%), and *Gironniera subaequalis* (10.98%) in the representative plot. On the other hand, *G. subaequalis* had the second highest abundance in the whole attribute with 15.19 individuals per ha, followed by *Aphanamixis grandiflora* (12.31 individuals) and *Engelhardtia roxburghiana* (9.81 individuals).

## 5. Conclusions

The species richness, species diversity, stand density and basal area were significantly different between lower and higher elevations, as well as between shallower and steeper slopes. The lower elevation and shallower slope had more species richness and diversity than did the higher elevation and steeper slope. The species diversity Evenness (Eq) presented in both the lower elevation (H1) and slope (S1) was higher than those of higher elevation (H2) and slope (S2). The higher elevation and steeper slope had a larger mean basal area, but less individuals per ha, this could result from forest disturbance and successional processes. Elevation had more influence on species, stand density, species diversity, basal area and family distribution than those of the slope. Slope had a weak correlation with the species richness, stand

density and basal area in the study area. Elevation was the key factor influencing species richness, stem density and species dominance in the study area.

Species composition between elevations and slopes was significantly different in term of species dominance and abundance. Difference of species composition could have been subjected to disturbance or successional processes of forest ecosystem in the current study area.

The species composition between slopes was not clearly distinguishable, this could help to confirm that slopes do not contribute to species distribution over topographic attributes.

The species composition of the most abundant and dominant species in the representative plots did not fully represent the species which were dominant and abundant at the entire topographic attribute in the study area. It could result from the low variation of topographic elevation or can be that the location of the representative plots favors for a certain microsite or aspects.

The current study can only report some major parameters of the forests; therefore, further efforts are needed for more information on endemic species and the most dominant species, which would contribute to appropriate conservation, restoration and management strategies in the area.

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