ORIGINAL RESEARCH PAPER VOLUME-6 | ISSUE-8 | AUGUST - 2017 | ISSN No 2277 - 8179 | IF : 4.176 | IC Value : 78.46

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

DIVERSITY AND ECOLOGICAL ASSOCIATION OF TREE SPECIES IN SPECIAL-USE FORESTS OF VIETNAM: A CASE STUDY IN HUONG SON, HA NOI

Forest Science

Dien Pham Van Vietnam National University of Forestry, Xuan Mai, Chuong My, Hanoi, Vietnam, Corresponding Author

Toai Pham Minh Vietnam National University of Forestry, Xuan Mai, Chuong My, Hanoi, Vietnam

Mung Thi Ha Vietnamese Academy of Forest Sciences, Duc Thang, Bac Tu Liem, Hanoi, Vietnam

Huy Quoc Le Vietnamese Academy of Forest Sciences, Duc Thang, Bac Tu Liem, Hanoi, Vietnam

Hai Hong Nguyen Vietnam National University of Forestry, Xuan Mai, Chuong My, Hanoi, Vietnam

Ha Tran Thi Thu Thai Nguyen University of Agriculture and Forestry, Thai Nguyen, Vietnam

ABSTRACT

The tree layer is an important component of a forest ecosystem. In order to identify the most important characteristics of tree communities including importance value (IV, %); species dominance pattern; species diversity indices and ecological associations of tree species, we conducted 18 sample plots of 1,000 m^2 each in Huong Son special-use forests, Ha Noi that typically distributed in the study site including six fields. The results showed that among 18 sample plots, there are 6 ones encompassing 35.8% of their species found with an IV of higher than 5% could be considered as ecologically significant species of the forest stands. Four species were found to be dominant in three sample plots with an IV of more than 30%, resulting in a geometric steep slope pattern in the top niche of the dominance diversity (D-D) curve. The species diversity H' found vary from 1.66 to 2.90 with a low value at sample plots with a geometric dominance diversity pattern and a higher value at plots with a lognormal dominance diversity series. There were up to 11 pairs of tree species found with a similarity of 80%. The results also showed that the 120-tree species found in the studied site were divided into four ecological groups. These results could imply independent, mutual, or comparative relationships among the species.

KEYWORDS

Importance value, ecological association, dominance, diversity index, special-use forest.

1. INTRODUCTION

Biodiversity of an ecosystem is not only benefits for human health but also essential for the environment and natural resources (Tuxill and Bright 1998, Naeem et al. 1999, Bullock et al. 2008, UNEP and FAO 2016). The potential pathways of biodiversity restoration or degradation are strongly effected by activities of human society (Bullock et al. 2008). By being cognizant and morally alive, humanity can work to save its own body and soul (O'Riordan and Stoll-Kleemann 2002). Thus, maintenance of biodiversity in order to manage forest ecosystems is an increasing concern (Jobidon et al. 2004, Clarke et al. 2010).

An ecological association of tree species is obvious characteristic of forest vegetation (Campbell and David 2000). The survival, variation and distribution of a certain species in space and time depend not only on the abiotic factors such as terrain sharp, soil fertility, temperature, light energy and moisture, etc. (Watt 1934, Ellenberg 1974, Bolstad et al. 1998, Ohmann and Spies 1998, Diekmann and Lawesson 1999, Bullock et al. 2008, Clarke et al. 2010, Zhang and Zhang 2011) but also on interaction with others in the community in different ways. Biological interactions are extremely complex and diverse and cannot always be distinguished from each other (Dien and Hoan 2016). Studying the ecological associations among species, groups of species and event communities would provide us with valuable information on the interaction patterns of plants with each other and with environmental elements and also the impacts of plants on natural ecosystems (Huy 2012, Dien and Hoan 2016).

As a part of the special-use forest (SUF) system in Vietnam, the Huong Son special-use forest is an important natural reserve for biodiversity, landscape and cultural conservation as well as supports for local livelihood improvement through ecotourism and spirit activities. However, the forests and their biodiversity have been negatively affected by both human activities and naturally environmental disturbances (Cong and Huy 2009). Therefore, the protection and conservation of its forests, biodiversity and the natural landscape have been considered as an important activities at the area in current time (Anh et al. 2008). There has been some research on forest and biodiversity inventory for potential values of the protected area; however, the results were not addressed scientifically regarding the examination of vegetation, biodiversity patterns, and ecological association. In this study, with its results regarding dominance patterns, species diversity indices and ecological associations can enhance knowledge on forest ecosystems and provide suitable information for sustainable management and conservation activities.

2. STUDY SITE AND METHODS

2.1. Study site

The Huong Son SUF is located in Huong Son commune, My Duc district, Ha Noi, Vietnam. Six fields of the SUF were selected for studying including Gieng Chen, Thung Sau, Ben Da - Rung Vai, Hinh Bong, Thung Mang, and Tuyet Son.

The area mainly consists of limestone mountains and low terrain mountain; the highest peak is 381m above sea level (Cong and Huy 2009). The topography of the SUF is strongly fragmented, which makes the ecosystem and landscape very diverse (Anh et al. 2008, Cong and Huy 2009). The Huong Son SUF has a tropical monsoon climate with an average annual temperature of 23-30^{0}C and annual rainfall of 1,800-2,000mm and about 140-150 rainy days in a year. The rainy season lasts from April to October containing about 81-91% of an annual rainfall. The dry season lasts from November to March of next year (Anh et al. 2008).

The task of the Huong Son SUF is to "protect limestone forest types and famous landscapes of the region" (Sung 1994) since this is considered as a museum of nature and life with typical limestone mountains, famous caves, rivers, forests and horticulture fields mixed with Buddhist pagodas and temples in a very complex and diverse landscapes. The core zone of SUF is estimated about 4,355 hectares and a buffer zone is about 1,191 hectares. There are 85 families, 577 genera and 873 species of flora, in which 25 rare plant species are listed in the Red Book of Vietnam (Anh et al. 2008). There are about 288 species of fauna belonging to 84 families and 26 genera, including 40 rare animal species (Anh et al. 2008, Cong and Huy 2009), especially insects are so diversify in the SUF with about 374 species of 65 families and 13 genera.

The forests were seriously degraded due to improper practices and over-exploitation activities. Recently, with management efforts, the forest ecosystems are being protected and well recovered (Anh et al. 2008, Cong and Huy 2009, Dien and Hoan 2016).

Figure 1. Map of the study site

2.2. Data collection

As above mentioned, natural forest in the study area is classified as the tropical broad-leaved evergreen forest type that is naturally distributed on limestone mountain of Huong Son SUF. In order to access its diversity and ecological association of tree species, we selected six fields including Gieng Chen, Thung Sau, Ben da - Rung Vai, Hinh Bong, Thung Mang, and Tuyet Son that are representative for the site to set up sample plots. In each field, three (03) sample plots of 1,000 m^2 (25m x 40 m) each were typically established at up-hill, low and middle upper locations. In totally, 18 sample plots of 1,000 m^2 each were established in the study site.

Within each sample plot, all tree with DBH ≥ 6cm were marked and their name, total height (H, m) and diameter at breast height (DBH, cm) were recorded. In which, species names were identified by tree finder; DBH and H were measured for each tree using silvicultural equipment. In addition, canopy cover, degree of disturbance, topography features were identified and described using silvicultural methods.

2.3. Data analyses

Importance value index (IV) as proposed by Curtis and McIntosh (1950) was used to express the dominance and biological success of any species. IV was reported that it is a better expression of relative ecological importance of a species than an absolute measure such as frequency, density, or dominance. It was calculated for each species by the formula:

$$IV(\%) = \frac{N(\%) + G(\%)}{2} \quad (1)$$

*Where: IV- Importance value index, N% - Percentage of the number of tree species, G% - Percentage of basal area of tree species. Basal area (BA) = pi * DBHm^2 /4.*

Species dominance diversity pattern

Species dominance diversity patterns and ascertainment of the resource apportionment among the species at a site were analyzed by the dominance diversity (D-D) curves' method (Whittaker 1970, Pandey et al. 2002). In this case, the IV was used as a measure of the niche for a species and resource apportionment, and thus it was treated as an expression of the relative niche size. This bases on the assumption that there is some correspondence between the share in community resources and community space utilized by a species (Whittaker 1970, Pandey et al. 2002, Huy 2012).

The methods of Naveh and Whittaker (1980), Verma (2000) and Pandey et al. (2002) were used in examining the concepts of niche space partitioning and resource sharing among plant species of the communities under study for the dominance diversity analysis. Two patterns suggested for the analysis of species dominance as following:

+ *Geometric series*: The D-D curve is typical for sites where one species highly dominates. The highly dominant species possess high IV values and it is classified to occupy the top niches and takes a large share of the available resources. The dominant species is the most competitive, followed by the other species, which are subsequently proportionally less competitive and thus take proportionally less of the total resources. Communities with this pattern usually have low species diversity (Preston 1948, Naveh and Whittaker 1980). This is the so-called niche preemption hypothesis (Whittaker 1970, Pandey et al. 2002). The curve represents a geometric series with a very steep slope. This geometric series would also suggest that the vegetation of the site is not stable, and other species can often invade the community (Pandey et al. 2002, Huy 2012).

+ *Lognormal series*: This type of D-D curve occurs on sites where no single species possesses high IV values and strongly dominates. Plant communities showing a lognormal distribution are thought to more equally share the resources in a gradual ranking order from the most important species to the least important one. This lognormal distribution also suggests that at the site species are fairly equally competitive. Such communities have high diversity and the vegetation of the site is considered rather stable (Verma 2000, Pandey et al. 2002, Huy 2012).

Species biodiversity indices

The vegetative diversity patterns of the studied sites were measured and analyzed using four plant diversity indices including species richness (SR), Shannon-Wiener diversity (H'), Margalef (d), and Simpson (D).

Species richness (SR): diversity can be defined as the number of species found in a plot, a measure known as species richness. The species richness of trees was calculated as the number of species per study plot area.

Shannon-Wiener Diversity (H'): The diversity index (H') has not only a variety component but also an equitability component; it accounts for the distribution of individuals among the species present. This means that information content is maximal if each individual belongs to a different species and minimal if all belong to the same species. Species diversity (H') was calculated following Shannon and Wiener (1963) as:

$$H' = -\sum_{i=1}^{s} \{N_i/N\} \log 2\{N_i/N\} \quad (2)$$

Where: S - the number of individual of one species in the sample, Ni - the total number of individuals of species i, and N - the number of individuals of all species in the studied sample.

Margalef's diversity indicator (d) as proposed by Margalef (1958) was used as following:

$$d = \frac{S-1}{\log N} \quad (3)$$

Where: d - Margalef's index, S - the total number of species and N - the total number of individuals in the plot

Simpson diversity index was calculated as following Simpson's equation (1949):

$$D = 1 - \sum_{i=1}^{s} p_i^2 \quad (4)$$

Where: D - the Simpson index, P - the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N) and S - the number of species.

Ecological association

The ecological associations of tree species in the communities were identified using three tools: dendrogram cluster, graph NMDS (non-metric multidimensional scaling) and graph PCA (principal component analysis) (Curtis and McIntosh 1950). These indicators were determined using R software ver.3.4.0. In which, trees are classified into group 1 if PC1 value ≥ 0 and PC2 value ≥ 0; into group 2, 3, 4 if PC1 value ≥ 0 and Pc2 value < 0; Pc1 value < 0 and PC2 value ≥ 0; Pc1 value < 0 and Pc2 value < 0, respectively.

3. RESULTS

3.1. Important value index of tree species

IV results of forest communities in Huong Son special-use forest estimated from 18 sample plots of six sites (Table 1) show that there are 43 species (35.8% of total species) found with IVs of more than 5%, in which 13 species were found in the Gieng Chen site, 11 species in Thung Sau, 17 species in Ben Da-Rung Vai, 12 species in Hinh Bong, 12 species in Thung Mang and 13 species in Tuyet Son. The number of

ecologically significance species was found to be highest in plot 3 (11 species) and lowest in plot 1 (2 species).

Table 1. Important value index of 43 ecologically significance species in forest community

N0	Local name	Scientific name	IV (%)			Occurrence	
			Min.	Average	Max.	No. of Field	No. of Plot
1	Boi loi nhot	*Litsea glutinosa*	5.2	5.2	5.2	1	1
2	Bua	*Garcinia oblongifolia*	5.3	5.3	5.3	1	1
3	Buoi	*Citrus grandis*	6.3	11.1	15.5	3	3
4	Buong	*Sinocalamus flagellifera*	6.1	16.3	32.4	4	7
5	Chay rung	*Artocarpus tonkinersis*	6.7	6.7	6.7	1	1
6	Da rung	*Ficus vasculora*	9.2	16.7	24.1	2	2
7	Dai	*Plumeria rubra*	12.0	12.0	12.0	1	1
8	Dau gia	*Baccaurea harmandii*	14.9	14.9	14.9	1	1
9	Do vang	*Streblus macrophyllus*	6.5	17.4	24.2	5	14
...	...	...	...	...	...	...	...
36	Thong gai	*Podocarpus ifolius*	5.2	5.3	5.5	2	2
37	Trai	*Shoera thoreli*	7.2	10.2	13.3	2	2
38	Vai	*Litchi chinensis*	9.4	9.4	9.4	1	1
39	Xanh	*Ficus benjamina*	12.2	14.0	12.9	2	2
40	Xoan ta	*Melia azedarach*	7.2	8.1	9.0	2	2
41	Sang gao	*Siphonodon celastrinens*	9.6	13.0	19.4	4	7
42	De he	*Sp*	6.7	6.7	6.7	1	1
43	Phuong vi	*Delomix regia*	5.3	7.4	9.6	1	3

The highest values of IV were found for Gao *(Bombax malabarica)* with 47.4% at the plot 6 in Thung Sau field, followed by IVs of three other species, Buong *(Sinocalamus flagellifera)* with 32.4% and Sung *(Ficus racemora)* with 35.5% in plot 14 (Thung Mang field) and Gao *(Bombax malabarica)* with 38.1% in plot 16 (Tuyet Son field).

3.2. Species dominance diversity patterns

Species dominance patterns were represented by dominance diversity curves (figure 2). These curves were developed on the basis of IV as a function of niche size and are indicators of species/resource apportionment in relation to the stability of environmental conditions at the site of a community.

The results of the D-D curve analysis in figure 2 showed that, as far as the dominant species are concerned, the curves of Thung Sau, Thung Mang, and Tuyet Son suggest a geometric series with a steep slope for dominant species with high IV values of more than 30% in the top of the D-D niche space. This would suggest that niche preemption is taking place among the dominant species in this forest community.

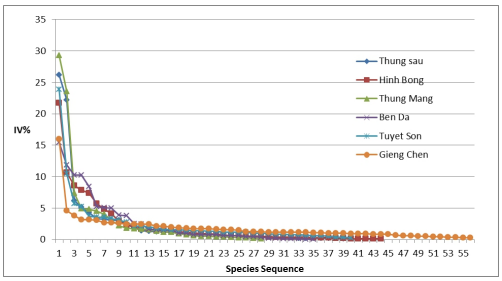

Figure 2. Dominance diversity curves of all fields in the Huong Son SUF

3.3. Diversity indices of tree species

Analysis results of relevant diversity indices were presented in Table 2.

Species richness. The results showed that the species richness (SR) ranged from 12 to 35, the lowest SR found in plot 18 in Tuyet Son and the highest found in plot 1 in Gieng Chen (35 species).

Shannon-Wiener Diversity (H'). The values of the Shannon Diversity Index (H') range from 1.66 to 2.90. The highest values of H' were found in the Gieng Chen site (2.90; 2.70, and 2.30), where its D-D curves recorded with lognormal series, low dominance, and a gradual shift from the high to the lowest IV species in the D-D sequence, followed by the H' of the Ben Da-Rung Vai site (2.06; 2.19; 2.01). The lowest H' values were found in the Thung Sau and Hinh Bong sites; their D-D curves were recorded with geometric series and a steep slope with high dominant species (IVs are higher than 30%). The large differences in Shannon H' among the study plots/sites reflect differences in ecological site conditions and disturbance regimes.

Table 2. Diversity indices of tree species

Field	Sample plot	SR	H'	d	D
Gieng Chen	1	35	2.90	6.17	0.90
	2	27	2.70	4.98	0.87
	3	24	2.30	4.65	0.81
Thung Sau	4	22	2.18	3.77	0.80
	5	20	1.75	3.20	0.64
	6	13	1.70	2.12	0.74
Ben Da - Rung Vai	7	17	2.06	2.94	0.82
	8	24	2.19	4.49	0.81
	9	15	2.01	2.45	0.81
Hinh Bong	10	30	2.11	2.45	0.72
	11	27	2.38	2.45	0.86
	12	18	1.66	2.45	0.70
Thung Mang	13	28	2.28	2.95	0.83
	14	22	1.71	3.80	0.62
	15	15	2.07	5.88	0.88
Tuyet Son	16	21	1.67	2.40	0.90
	17	18	2.61	4.06	0.91
	18	12	2.58	3.97	0.74

Margalef Diversity indicator (d). The lowest value of 4.88 was found in plot 6 of Thung Sau, the highest value of 15.05 was found in plot 1 of Gieng Chen. The value of Margalef's diversity index reflects the species abundance of a forest plant community. The higher the number of species found at a field and the more equal the number of individuals of each species, the higher the value of the Margalef's Diversity would be in the field.

Simpson Index (D). Values of Simpson's index (D) ranged from 0.62 to 0.91, with an average value of 0.8. The study site recorded with the highest (0.91) was plot 17 in Tuyet Son and the lowest (0.62) was plot 14 in Thung Mang.

3.4. Ecological association of tree species

Ecological association of tree species was represented by dendrogram cluster (figure 3), PCA graph (figure 4), and NMDS graph (figure 5).

Figure 3 showed that the higher the similarity, the lower the pair of tree species in terms of ecological association. With the similarity increased from 40%, 60% to 80%, the pairs of tree species found for ecological association decreased from 64 to 37 down to 11, respectively. The pairs of tree species found with higher similarity have closer relationships with each other than have others with lower similarity. Based on the findings, we can put results into practice.

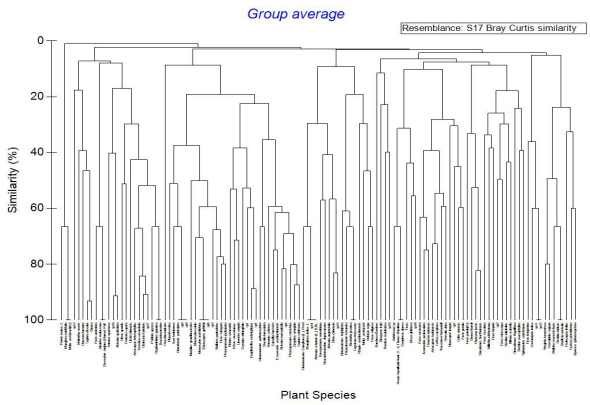

Figure 3. Ecological association of tree species in forest communities

Note: Latin names of 120 tree species indicated in X axis of figure 3 are listed from left to right (number 01 to 120) as follows:

Table 3. List of tree species names indicated in X axis of figure 3)

1	*Prunus mume*	25	*Plumeria rubra*	49	*Camellia forrestre*	73	*Bambusa bambos*	97	*Ficus vasculora*
2	*Mangifera minitifolia*	26	*Acer tonkinense*	50	*Excoecaria cochinchinensis*	74	*Diospyros kaki*	98	*Millettia ichthyotona*
3	*Melia azedarach*	27	*Cinnademia paniculata*	51	*Alstonia marcophylla*	75	*Bombax malabarica*	99	*Ficus hispida*
4	*Sp13*	28	*Sp8*	52	*Sp5*	76	*Sp18*	100	*Sp2*
5	*Melientha snavis*	29	*Sp9*	53	*Pterospermum venustum*	77	*Antidesma sp*	101	*Ficus microcarpa*
6	*Clausena lansium*	30	*Machilus grandibracteata*	54	*Zizyphus oenophia*	78	*Uvaria hamiltonii*	102	*Streblus inlicifolius*
7	*Sapium discolor*	31	*Memecylon edule*	55	*Sapium sebiferum*	79	*Symplocos glauca*	103	*Dillenia scabrella*
8	*Shoera*	32	*Memecylon acutellatum*	56	*Cinnamomum camphora*	80	*Ficus*	104	*Sinocalamus flagellifera*
9	*Ficus aurienlata*	33	*Elaeocarpus griffithii*	57	*Mangifera indica*	81	*Litsea glutinosa*	105	*Streblus macrophyllus*
10	*Aleurites moluccana*	34	*Sp6*	58	*Sp14*	82	*Sp10*	106	*Siphonodon celastrinens*
11	*Annona squamosa*	35	*Sp3*	59	*Alstonia scholaris*	83	*Ficus racemora*	107	*Ficus benjamina*
12	*sp16*	36	*Mallotus paniculatus*	60	*Xerospermum noronhiana*	84	*Acronychia pedunculata*	108	*Castanopsis indica*
13	*Alstonia spathulata*	37	*Ficus variegata*	61	*Dracontommelen dupereamum*	85	*Ormosia balansae*	109	*Sp11*
14	*Citrus grandis*	38	*Pterospermum jackianum*	62	*Alstonia angutisfolia*	86	*Artocarpus tonkinersis*	110	*Sp12*
15	*Pouteria sapota*	39	*Ricinus communis*	63	*Rhus chinensis*	87	*Coffea carephora*	111	*Wrightia tomemtosa*
16	*Litchi chinensis*	40	*Rhus succedanea*	64	*Sp15*	88	*Baccaurea harmandii*	112	*Ceasalpinia sappan*
17	*Artocarpus heterophyllus*	41	*Linociera sangda*	65	*Cinnamomum bejolghota*	89	*Sterculia alata*	113	*Mallotus macrostchyus*
18	*Averrhoa carrambola*	42	*Garcinia oblongifolia*	66	*Prismatomeris tetrandra*	90	*Dimocapus longan*	114	*Streblus indicus*
19	*Chukrasia tabularis*	43	*Sp1*	67	*Bischofia javanica*	91	*Sp7*	115	*Gleditsia australis*
20	*Sp17*	44	*Engelhardtia roxburghiana*	68	*Capsicum frutcscens*	92	*Celtis sinensis*	116	*Podocarpus ifolius*
21	*Psidium gayava*	45	*Sp4*	69	*Rhapis cochinchinensis*	93	*Ficus pumila*	117	*Cratoxy prumiflorum*
22	*Styphnolobium japonica*	46	*Cinnamomum pathenoxylom*	70	*Melia azedarach*	94	*Ficus pumila*	118	*Aporosa sphaerosperma*
23	*Dracontommelen*	47	*Steculia lanceolata*	71	*Delomix regia*	95	*Shoera thoreli*	119	*Ficus vasculora*
24	*Oroxylon indicum*	48	*Vernonia arborea*	72	*Ficus religiosa*	96	*Chausena laevis*	120	*Millettia ichthyotona*

Based on the results of figure 3 and PC values, tree species can be categorized into 4 groups as mentioned in table 4.

Table 4. Ecological association groups of tree species in Huong Son SUF

No.	Tree species	No.	Tree species	No.	Tree species	No.	Tree species
GROUP 1							
1	*Annona squamosa*	16	*Melientha snavis*	31	*Linociera sangda*	46	*Oroxylon indicum*
2	*Alstonia spathulata*	17	*Ficus pumila*	32	*Pterospermum venustum*	47	*Cinnamomum pathenoxylom*
3	*Sp16*	18	*Artocarpus heterophyllus*	33	*Psidium gayava*	48	*Sp8*
4	*Ficus microcarpa*	19	*Mallotus paniculatus*	34	*Diospyros kaki*	49	*Steculia lanceolata*
5	*Clausena lansium*	20	*Styphnolobium japonica*	35	*Mangifera minitifolia*	50	*Sp9*
6	*Bombax malabarica*	21	*Dracontommelen*	36	*Melia azedarach*	51	*Cinnademia paniculata*
7	*Chukrasia tabularis*	22	*Prunus mume*	37	*Ficus variegata*	52	*Ficus aurienlata*
8	*Bambusa Bambos*	23	*Sp4*	38	*Pterospermum jackianum*	53	*Sp13*
9	*Sp17*	24	*Engelhardtia roxburghiana*	39	*Plumeria rubra*	54	*Acer tonkinense*
10	*Sp18*	25	*Sp3*	40	*Elaeocarpus griffithii*	55	*Prismatomeris tetrandra*
11	*Vernonia arborea*	26	*Alstonia marcophylla*	41	*Sp6*	56	*Aleurites moluccana*
12	*Pouteria sapota*	27	*Sapium sebiferum*	42	*Memecylon acutellatum*	57	*Dysoxylon juglans*
13	*Averrhoa carrambola*	28	*Rhus succedanea*	43	*Camellia forrestre*		
14	*Sp1*	29	*Sp5*	44	*Excoecaria cochinchinensis*		
15	*Ricinus communis*	30	*Zizyphus oenophia*	45	*Ficus*		
GROUP 2							
1	*Sinocalamus flagellifera*	5	*Sp15*	9	*Xerospermum noronhiana*	13	*Ficus religiosa*
2	*Sp2*	6	*Dracontommelen dupereamum*	10	*Sp14*	14	*Bischofia javanica*
3	*Alstonia angutisfolia*	7	*Rhapis cochinchinensis*	11	*Alstonia scholaris*	15	*Capsicum frutcscens*
4	*Rhus chinensis*	8	*Cinnamomum camphora*	12	*Mangifera indica*	16	*Cinnamomum bejolghota*
GROUP 3							
1	*Shoera thoreli*	8	*Symplocos glauca*	15	Sp10	22	*Ficus pumila*
2	*Shoera*	9	*Sp11*	16	*Sincalamus bacthaiensis*	23	*Streblus inlicifolius*
3	*Sapium discolor*	10	*Sp12*	17	*Ficus vasculora*	24	*Millettia ichthyotona*
4	*Memecylon edule*	11	*Citrus grandis*	18	*Sp7*	25	*Siphonodon celastrinens*
5	*Machilus grandibracteata*	12	*Litsea glutinosa*	19	*Ficus benjamina*		
6	*Antidesma sp*	13	*Castanopsis indica*	20	*Garcinia oblongifolia*		
7	*Uvaria hamiltonii*	14	*Chausena laevis*	21	*Ficus hispida*		

GROUP 4							
1	*Aporosa sphaerosperma*	7	*Dimocapus longan*	13	*Dillenia scabrella*	19	*Gleditsia australis*
2	*Ormosia balansae*	8	*Celtis sinensis*	14	*Streblus macrophyllus*	20	*Delomix regia*
3	*Ficus racemora*	9	*Baccaurea harmandii*	15	*Litchi chinensis*	21	*Wrightia tomemtosa*
4	*Acronychia pedunculata*	10	*Coffea carephora*	16	*Mallotus macrostchyus*	22	*Melia azedarach*
5	*Cratoxy prumiflorum*	11	*Podocarpus ifolius*	17	*Ceasalpinia sappan*		
6	*Sterculia alata*	12	*Artocarpus tonkinersis*	18	*Streblus indicus*		

Table 3 shows that 57 tree species belong to Group 1 while 16, 25 and 22 species are classified into Group 2, 3 and 4, respectively.

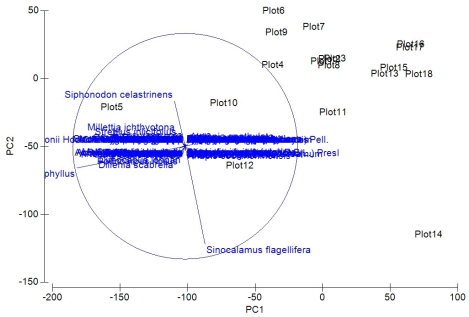

Figure 4. PCA graph represents ecological associations of tree species

The PCA result also reflected the relationship among and between species with No. 6, 7, 9, 11 and 14, etc., plots being independent of each other. This also indicated that there were few species occurring in other plots if they already occurred in these plots. In other words, the relationship among the species in this group was weak and had little meaning.

Another important issue that emerged was to learn if the plots were identical with each other. To answer this question, the study analyzed four diversity indices of the tree species using the multi-criteria method (MCA). The results were shown in figure 4.

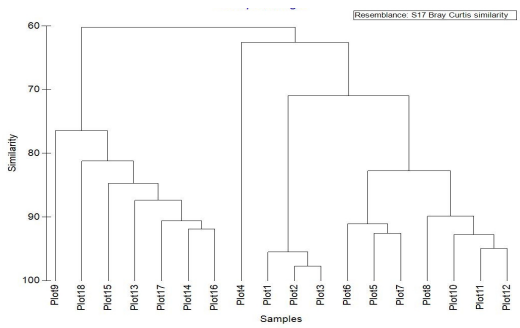

Figure 5. Dendrogram represents the relationships between the plots

With a similarity level below 60%, all plots were considered as a population. When the similarity level increased, the plots also fragmented and "separated" out. With the similarity level of 90-96%, some plot groups were close together, meaning that their characteristics were similar, and their species occurred simultaneously. According to figure 6, plots with close relationships were 2 with 3, 5 with 7, 11 with 12, and 14 with 16.

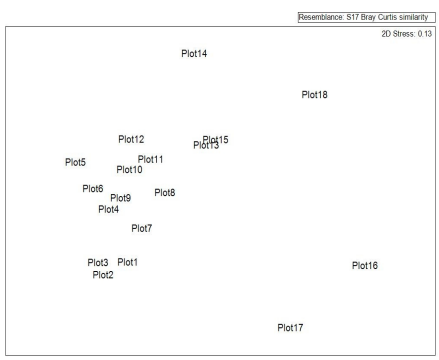

Figure 6. NMDS of sampling plots

However, if the similarity level was higher than 97%, there would be no pairing. This suggests that uniformity in this area is difficult to achieve. Divergence among sample plots was also evidenced in figure 6. The NMDS result showed that the discrete between plots was clear. The stress index used in this case was S = 0.13 at a very good level for reducing the dimension while maintaining the accuracy needed.

4. DISCUSSIONS

The importance value index of a species represents the relative dominance of the species in a community, which further indicates how important the species is with respect to its associates in terms of resource utilization. According to Thai Van Trung (1978), in a forest community, a species with an IV ≥ 5% should be considered as an ecologically significant species of the forest stand. However, if a species' IV exceeded 30% of the community in total, it had a high dominant status and geometric steep slope pattern in the top niche of the dominance diversity (D-D) curve (Whittaker 1970, Pandey et al. 2002). In this study, number of tree species belonged to ecological significant groups are nearly the same among six fields. However, three species uncluding Buong *(Sinocalamus flagellifera),* Sung *(Ficus racemora)* and Gao *(Bombax malabarica)* have IV ≥ 30% but this pattern can only be found in plot 6, 14 and 16 where high disturbance recorded. Of the total 120 species found in the Huong Son SUF, 43 tree species have their IVs ≥ 5.0% accounting for 35.8% total of trees. This is a common feature of tropical evergreen rain forest when tree species are diversified and they share the importance value (Armstrong et al. 2011).

At the Gieng Chen and Ben Da - Rung Vai fields, the situations were clearly different from that of the three fields above with regard to community richness, slope of the dominance-diversity curve and the pattern. The D-D curve strongly suggests a lognormal series in the richer community with less dominance and a gradual shift from the high to the lowest IV species in the D-D sequence. In these sites, no tree species was found with an IV of higher than 30%. At the current management status, the site conditions and forest vegetation appear rather stable.

The significant variability of the tree species diversity index among sample plots of each field and among six fields were found and suggested a mosaic patterning of species distribution in the study site. A site with a plant community showing a geometric series usually has low species diversity, high dominance and weak niche differentiation among those species (Preston 1948, Naveh and Whittaker 1980, Cong and Huy 2009, Huy 2012). It would also be suggested that the site has an inefficient use of its resources, the forest vegetation is not stable, and other species often invade this community.

The values of Shannon's Diversity Index in the present study were considered from low to medium with ecological site conditions and disturbances of the very rocky landscapes and ecosystems. These are consistent with findings of Anh et al. (2008) and Cong and Huy (2009). For the tropical rain forest, the H' values would range at high values from 5.06-5.40 compared to low values from 1.16-3.40 in temperate forest (Braun 1950, Risser and Rice 1971, Singhal et al. 1986, Huy and Seghal 2004).

Association of tree species, in either the positive or negative direction, can also occur as a direct consequence of biotic interactions such as mutualism, competition and predation (Legendre and Blanchet 2008) as well as habitat heterogeneity of habitat or environmental condition among sites (Campbell and David 2000, Caceres and Legendre 2009). Identification of this particular pattern of each stand or site can provide important information for further management activities toward sustainable ways. The study demonstrates that there are a significantly different number of tree species in each association group (57 tree species belong to group 1 while 16, 25 and 22 species are classified into group 2, 3 and 4, respectively). The species belonging the same group could usually have strong relationships with each other. Species in group 1 have an antagonistic relationship with species in group 3 while they have no relation to other species in group 2 and group 4. Species in

group 2 have an antagonistic relationship with species in group 4 and no relation to the species of group 1 and group 3.

5. CONCLUSIONS

Huong Son SUF is an important natural reserve in terms of biodiversity, landscape, and cultural conservation of Vietnam. Of the total 120 tree species found in the studied site, 43 tree species accounting for 35.8% were found with IVs of higher than 5% and considered as ecologically significant species of the forest stand. Three species possessed IVs of exceeding 30% of the community as a total in three plots of the Thung Sau, Thung Mang, and Tuyet Son sites which led to a high dominant status and geometric steep slope pattern in the top niche of their dominance diversity (D-D) curves.

The species richness and all diversity indices (H', d and D) revealed highest values in Gieng Chen field where its D-D curve was recorded with lognormal series and less dominance, it was followed by the H' value of the Ben Da-Rung Vai field (2.06; 2.19 and 2.01). The lowest values were found in the Thung Sau and Hinh Bong fields, where their D-D curves were recorded with geometric pattern and steep slope. The significant variability of the tree species diversity indices among sample plots of each field suggested a mosaic patterning of species distribution in the study site.

Results of ecological association analysis showed that similarity level was less than 80%. It means that uniformity of natural forests regarding the characteristics of the vegetation is not achieved. Of the total 120 tree species, 57 tree species belong to group 1 while 16, 25 and 22 species are classified into group 2, 3 and 4, respectively.

ACKNOWLEDGEMENT

We would like to thank the Research Center for Forest Ecology and Environment, Vietnamese Academy of Forest Science, Vietnam for providing relevant data for our research.

We would also like to thank the Vietnam National University of Forestry for promoting us in the whole process of writing and completing this qualitative paper.

REFERENCES

1. Anh, H. V., L. Q. Huy, and L. T. Cong. 2008. Development of biodiversity database for Huong Son special-use forest, Chuong My, Hanoi. Forest Science 1:569-678.
2. Armstrong, A. H., H. H. Shugart, and T. E. Fatoyinbo. 2011. Characterization of community composition and forest structure in a Madagascar lowland rainforest. Tropical Conservation Science 4:428-444.
3. Bolstad, P. V., W. Swank, and J. Vose. 1998. Predicting Southern Appalachian over story vegetation with digital terrain data. Landscape Ecology 13:271-283.
4. Braun, E. L. 1950. The ecology of the forest of Eastern North America, their development, composition and distribution. Deciduous forest of Eastern North America. McGraw Hill, New York-Blakiston, USA.
5. Bullock, C., C. Kretsch, and E. Candon. 2008. The economic and social aspects of biodiversity - Benefits and costs of biodiversity in Ireland. Dublin, Isreland.
6. Caceres, M. D., and P. Legendre. 2009. Associations between species and groups of sites: indices and statistical inference. Ecology 90:3566-3574.
7. Campbell, O. W., and R. P. David. 2000. Habitat associations of trees and seedlings in a Bornean rain forest. Journal of Ecology 88:464-478.
8. Clarke, I., Z. Stokes, and R. Wallace. 2010. Habitat restoration planning guide for natural resource managers. Government of South Australia, through Department of Environment and Natural Resources, Adelaide.
9. Cong, L. T., and L. Q. Huy. 2009. Quantification of plant species diversity in Huong Son special use forest, Chuong My, Hatay. Forest Science 4.
10. Curtis, J. T., and R. P. McIntosh. 1950. The interactions of certain analytic and synthetic phytosociological characters. Ecology 31:434-455.
11. Diekmann, M., and J. E. Lawesson. 1999. Shifts in ecological behaviour of herbaceous forest species along a transect from northern Central to North Europe. Folia Geobot 34:127-141.
12. Dien, P. V., and P. X. Hoan. 2016. Forest ecology (in Vietnamese). Agricultural publishing house, Hanoi, Vietnam.
13. Ellenberg, H. 1974. Zeigerwerte der Gefasspflanzen Mitteleuropas. Scripta Geobot. 9:1-97.
14. Huy, L. Q. 2012. Growth, demography and stand structure of Scaphium macropodum in differently managed forests in Vietnam. Utrecht University, Netherlands.
15. Huy, L. Q., and R. N. Seghal. 2004. Invasion of Parthenium hysterophorus in chir-pine forests and its allelopathic effects. International Workshop on Protocols and Methodologies in Allelopathy. International Allelopathy Society, India.
16. Jobidon, R., G. Cyr, and N. Thiffault. 2004. Plant species diversity and composition along an experimental gradient of northern hardwood abundance in Picea mariana plantations. Forest Ecology and Management 198:209-221.
17. Legendre, P., and F. G. Blanchet. 2008. Species association. Page 11. University of Alberta, Edmonton.
18. Margalef, R. 1958. Temporal succession and spatial heterogeneity in phytoplankton. Pages 323-347 in B. Traverso, editor. Perspectives in Marine biology. Univ. Calif. Press, Berkeley.
19. Naeem, S., F. S. Chair, C. III, R. Costanza, P. R. Ehrlich, F. B. Golley, D. U. Hooper, J. H. Lawton, R. V. O'Neill, H. A. Mooney, O. E. Sala, A. J. Symstad, and D. Tilman. 1999. Biodiversity and Ecosystem Functioning: Maintaining Natural Life Support Processes. Ecological Society of America.
20. Naveh, Z., and R. H. Whittaker. 1980. Structural and floristic diversity of shrublands and woodlands in northern Israel and other Mediterranean areas. Plant ecology 41:171-190.
21. O'Riordan, T., and S. Stoll-Kleemann. 2002. Enhancing biodiversity and humanity. Cambridge University Press, England.
22. Ohmann, J. L., and T. A. Spies. 1998. Regional gradient analysis and spatial pattern of woody plant communities in Oregon forests. Ecological Monographs 68:151-182.
23. Pandey, P. k., S. C. Sharma, and S. K. Banerjee. 2002. Biodiversity studies in a moist temperate Western Himalayan forest. Indian Journal of Tropical Biodiversity 10:19-27.
24. Preston, F. W. 1948. The commonness, and rarity, of species. Ecology 29:254-283.
25. Risser, P. G., and E. L. Rice. 1971. Diversity in tree species in Oklahoma upland forests. Ecology 52:876-880.
26. Simpson, E. H. 1949. Measurement of diversity. Nature 163:688.
27. Singhal, R. M., V. R. S. Rawat, P. Kumar, S. D. Sharma, and H. B. Singh. 1986. Vegetation Analysis of Woody Species of some forests of Chakrata Himalayas-india. Indian Forester 112:819-832.
28. Sung, C. V. 1994. Natural Reserves System in Vietnam.
29. Trung, T. V. 1978. Vietnamese forest vegetation (in Vietnamese). Scientific and Technological Publishing House, Hanoi.
30. Tuxill, J., and C. Bright. 1998. Protecting Nature's Diversity: Mending Strands In the Web of Life. Futurist 32:46-51.
31. UNEP, and FAO. 2016. Biodiversity and human health. Cancun, Mexico.
32. Verma, R. K. 2000. Analysis of species diversity and soil quality under Tectona grandis Lf and Acacia catechu (Lf) Wild plantations raised on degraded bhata land. Indian Journal of Ecology 27:97-108.
33. Watt, A. S. 1934. The vegetation of the Chiltern Hills, with special reference to the beechwoods and their seral relationships. J. Ecol. 22:230-257.
34. Whittaker, R. H. 1970. Communities and ecosystems. Macmillan, London: Collier Macmillan, New York, USA.
35. Zhang, J., and F. Zhang. 2011. Ecological relations between forest communities and environmental variables in the Lishan Mountain Nature Reserve, China. Afr J Agric Res 6.