ANALYZING OF NEAREST NEIGHBORHOOD CHARACTERISTICS OF TROPICAL BROADLEAVED FOREST STANDS

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SUMMARY
Spatial structure is one of the major parameters for describing forest stand structure. We applied a new method to quantitative analysis spatial structure of forest stand based on nearest neighbour distance between tree groups. Three 1-ha plots (100 m x 100 m) were designed on the tropical broadleaved forests to validate the distribution of structural parameters. All tree with diameter at breast high (DBH) ≥ 6 cm were mapped, measured tree DBH and classified species. We calculated and described structural parameters such as Mingling, DBH dominance and Uniform Angle Index by using Crancod and Microsoft Excel softwares. The results showed that: most of studied species were found highly mixed with other species. In DBH dominance analysis, most of dominant tree species in Ha Tinh and Binh Dinh plots were less competition in tree DBH comparing to nearest neighbours. However, three species had positive advantage in tree size, therefore bearing higher competitive capacity for nutrient resources. About spatial distribution, most of tree species in three studied plots were from regular to clumped patterns but mainly focused at random pattern. The spatial structural parameters offer direct information and valuable about spatial structure of forest stand. Those information can be used in thinning of sustainable forest management, modelling and restoration.
Keywords: Broadleaved forest, dominance, mingling, nearest neighborhood, uniform angle index.

I. INTRODUCTION

Structural characteristics of forest stand can be describe as the distribution characteristics of individuals of the same species, which is typically represented by different diameters and tree ages (Li et al., 2002). In a given space, population structure is vulnerable to isolation from other populations within the same community, therefore, for any tree species in a mixed forest, interspecific and intraspecific differences in tree size, species mingling and distribution patterns may be the most important characteristics of population structure. Distribution patterns directly reflect the way individuals assemble or scatter in space, which may in turn be associated with conditions of competition and utilization of environmental resources among adjacent trees. Tree size is directly related to the degree of maturation of a tree population and to the competitive advantage of the population within the community, it may also be directly related to the survive viability and ecological niche of the population. Intraspecific aggregation involves isolation between species in the same community, and the process is close to seed dispersal, regeneration capacity and growth.

A number of methods for describing forest structural attributes have been largely developed for decades. However, an exact description of small-scale structural attributes is considered to be increasingly importance (Corral-Rivas et al. 2010). Recently, new individual tree indices, such as uniform angle index, species mingling and dominance (Gadow et al. 1998; Aguirre et al. 2003; Hui et al. 2011), have been developed. The basic idea of these indices is to characterize the neighborhood of a reference tree by its using n-nearest neighbors. The techniques of nearest neighbor statistics allow us determining the relationship within neighborhood groups of trees such as species and size class at small scales. This method has several advantages over using expression frequency to depict the attributes among individuals when compared to the traditional methods (Pommerening 2002). For instance, greater inhomogeneity in species and homogeneity in size classes indicate greater structural diversity (Gadow et al. 2012).

In this study, our overall goal is to characterize spatial attributes of neighborhood trees by applying the current techniques of nearest neighbor statistics. For a better understanding of structural units, we combined three structural units for each species in analyses, such as mingling - uniform angle index, mingling - dominance and dominance - uniform angle index.

II. RESEARCH METHODOLOGY

2.1. Study site and data collection

Three1-ha plots was designed in 2012 on tropical broadleaved forest stands in Ha Tinh (at coordinates of 18°20'52,13" N; 105°20'16,43" E), Binh Dinh (at coordinates of 14°8'40.94" N; 108°54'2.30" E) and Khanh Hoa (at coordinates of 12°39’48,89" N; 109°4’40,35" E) provinces. In each study plot, a grid of 25 subplots (20 m x 20 m) was then created in which all trees with diameter at breast height - DBH ≥ 6 cm were mapped. Tree position (x, y coordinates) was recorded by using a laser distance measurer (Leica Disto D5) and compass; other characteristics such as species and DBH were also investigated.

2.2. Data analysis

We applied current techniques of nearest neighbor statistics which are based on the assumption that the spatial structure of a forest stand determined by the distribution of specific structural relationships within neighborhood groups of trees. A forest stand is composed by neighborhood structural units of n-trees. We used three structural indices proposed by Gadow & Hui (2002) such as species mingling, dominance and uniform angle index to describe homogeneity or heterogeneity of trees through a variety of species, diameter classes and spatial arrangements with equations from 2.1-2.3 (Gadow et al. 1998, Aguirre et al. 2003, Hui et al. 2011, Pommerening et al. 2011).

Species mingling (M): Describes the species composition and spatial pattern of forest trees. It is defined as the proportion of the n nearest neighbours that are different species from the reference tree (Fig. 1a).

$$M_i = \frac{1}{4}\sum_{j=1}^{4} v_j \qquad (2.1)$$

v_j = 1 if neighbor *j* is not the same species as reference tree *i*, otherwise v_j = 0.

Dominance (U): Describes the size differentiation between a reference tree and its four nearest neighbors. It is defined as the proportion of n nearest neighbors that are smaller than reference tree (Fig. 1b).

$$U_i = \frac{1}{4}\sum_{j=1}^{4} v_j \qquad (2.2)$$

v_j = 0 if neighbor *j* is smaller than reference tree *i*, otherwise v_j = 1.

Uniform angle index (W): Describes the degree of regularity for the four nearest neighbors as reference tree. It is defined as the proportion of angle (α) smaller than the standard angle α_0 (Fig. 1c).

$$W = \frac{1}{4}\sum_{j=1}^{4} w_j \qquad (2.3)$$

W_i = 1 if $\alpha_j<\alpha_0$, otherwise W_i = 0, α_0= 360°/(n+1).

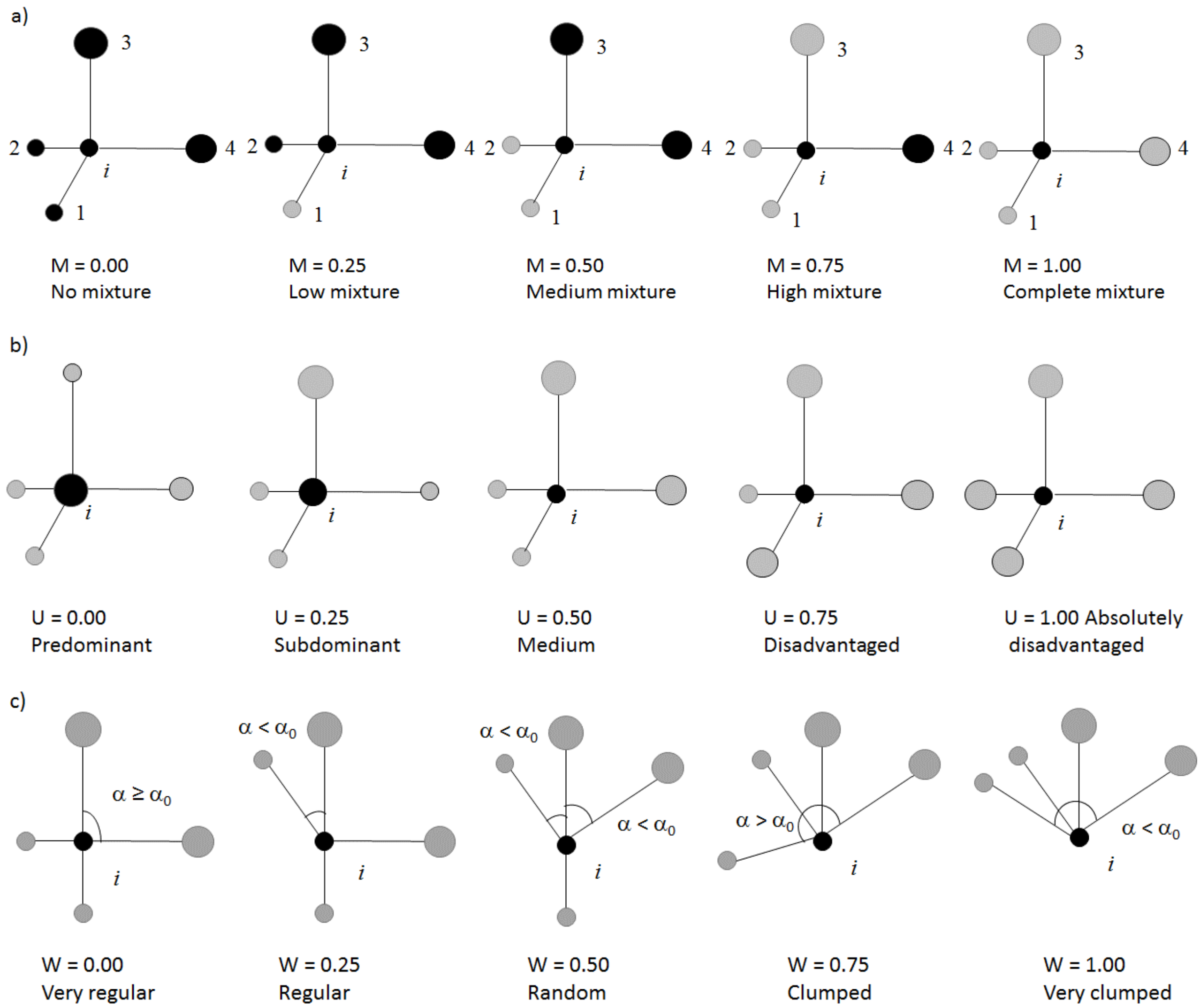

Figure 1. Definition of the spatial parameters: Mingling (a), Dominance (b) and Uniform Angle Index (c)

The methods described above were implemented by using software Crancord (http://crancord.org/). To eliminate the edge effect of the estimates in M_i, W_i and U_i calculation, we applied the nearest neighbor edge correction method proposed by Pommerening & Stoyan (2006).

III. RESULTS

3.1. Forest stand properties

The forest characteristics were described in Table 1. In Ha Tinh plot, the forest stand was dominated by five tree species, including *Vatica odorata, Gironniera subaequalis, Nephelium melliferum, Calophyllum calaba* and *Calophyllum calaba*. These species gained 42% of tree abundance, 44.7% of total basal area and 43% of important value index (IVI). The Ha Tinh plot was high diversity compared to two other plots. In Binh Dinh plot, six most dominant species among 97 tree species in total contribute 35% in individual abundance, 50% in total basal area and 46% of total IVI. This is highest diversity among three studied plots containing most dominant trees such as *Parashorea chinensis, Parashorea chinensis, Ilex rotunda, Intsia bijuga, Hopea pierei, Melanorrhoea laccifera* and *Wringtia annamensis*. The most dominant species in Khanh Hoa plot, including *Syzygium wightianum, Diospyros sylvatica, Nephelium* *melliferum* and *Ormosia balansae* in total of 47 tree species, contributed more for this community, with 64% in individual abundance, 71% in total basal area and 68% in IVI.

Table 1. Characteristics of tree species in the studied plots

Plot	Species	N	G	IVI	Shannon	Simpson
Ha Tinh	*Vatica odorata*	43	2.1106	11.98	3.34	0.96
	Gironniera subaequalis	37	2.3440	11.82		
	Nephelium melliferum	32	1.7777	9.51		
	Calophyllum calaba	19	0.9069	5.22		
	Knema cortiosa	22	0.6857	5.00		
	53 others	208	9.6709	56.47		
Binh Dinh	*Parashorea chinensis*	163	11.1659	21.38	3.70	0.96
	Ilex rotunda	50	2.3573	5.29		
	Intsia bijuga	17	3.3772	4.85		
	Hopea pierei	48	1.7652	4.49		
	Melanorrhoea laccifera	26	1.7552	3.38		
	Wringtia annamensis	46	0.79184	3.24		
	91 others	649	20.98	57.34		
Khanh Hoa	*Syzygium wightianum*	226	11.0721	28.18	2.62	0.87
	Diospyros sylvatica	191	9.3845	23.86		
	Nephelium melliferum	54	2.3009	6.27		
	Polyalthia nemoralis	34	2.1977	4.95		
	Ormosia balansae	42	1.7623	4.84		
	43 others	302	10.4872	31.87		

N - species abundance, G - basal area (m^2), DBH - diameter at breast height, IVI - important value index, Shannon - Shannon - Wiener index.

3.2. Structural characteristics

Analyzed results of Ha Tinh plot was shown in Fig. 2. All five species showed species mixture (Mingling) concentrated at high levels from high mixture to complete mixture, M= 0.75 - 1 in *V. odorata*, M = 0.5 - 1 in *G. subaequalis*, M = 0.75 - 1 in *N. melliferum*, M= 0.5 - 0.75 in *C. calaba* and M = 0.75 - 1 in *K. cortiosa*. These evidences shown that these dominant species were highly mixed with other tree species in adjacent neighbours.

About DBH dominance to nearest neighbour, *V. odorata* (U = 0 - 0.75) and *N. melliferum* (U = 0.50) were dominant to medium advantages. While *G. subaequalis* (U = 0.75 - 1) and *C. calaba* (U = 1) were disadvantaged to completely disadvantaged, *C. calaba* and *K. cortiosa* were advantaged (U= 0). The results showed that these species were less advantage in DBH comparing to their nearest neighbours, except *K. cortiosa*.

UAI shows spatial distribution of reference individuals to their nearest neighbours. All five dominant species were regular to clumped pattern with W = 0.25 - 0.75 (*V. odorata, G. subaequalis, N. melliferum*, *C. calaba* and *K. cortiosa*).

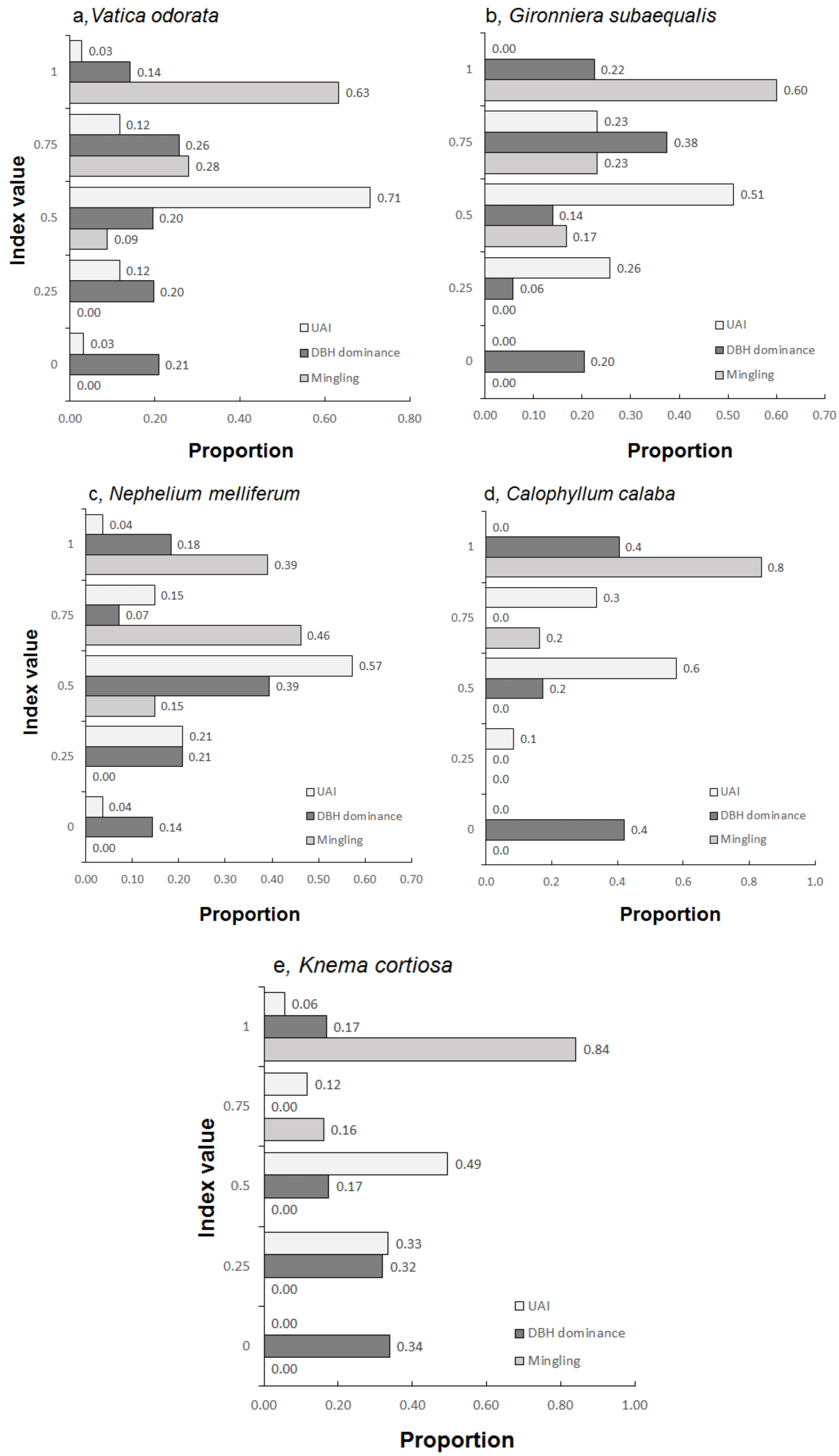

Figure 2. Structural characteristics of five dominant species at Ha Tinh plot

The results of six dominant species were shown in Fig. 3. All tree species showed high levels of mixing with other species in nearest neighbours. Complete mixture contained *P. chinensis* (M = 0.75 - 1), *I. rotunda* (M = 0.75 - 1), *I. bijuga* (M = 1) and *H. pierei* (M = 0.75 - 1). *M. laccifera* (M = 0.5 - 0.75) and *W. annamensis* (M = 0.25 - 1) varied from low mixture to Complete mixture.

Four species were less competitive in tree size with nearest neighbours, their DBH dominaces were medium to complete disadvantage such as *P. chinensis* (U = 0.5 - 1), *I. rotunda* (M = 0.5 - 1), *I. bijuga* (M = 0.75 - 1) and *M. laccifera* (M = 0.75 - 1). While two remaining species, *H. pierei* (M = 0 - 0.75) and *W. annamensis* (M = 0 - 0.5) had tree size advantages from predominance to disadvantage comparing to adjacent neighbours.

In spatial distribution, most species ranged from regular to clumped distribution, however highly concentrated at random pattern (M = 0.5) including *P. chinensis* (M = 0.25 - 0.75), *I. rotunda* (M = 0.25 - 0.75), *I. bijuga* (M = 0.5) and *H. pierei* (M = 0.5 - 0.75) and *W. annamensis* (M = 0.25 - 0.75). Only *M. laccifera* (M = 1) was very clumped distribution to their neighborhoods.

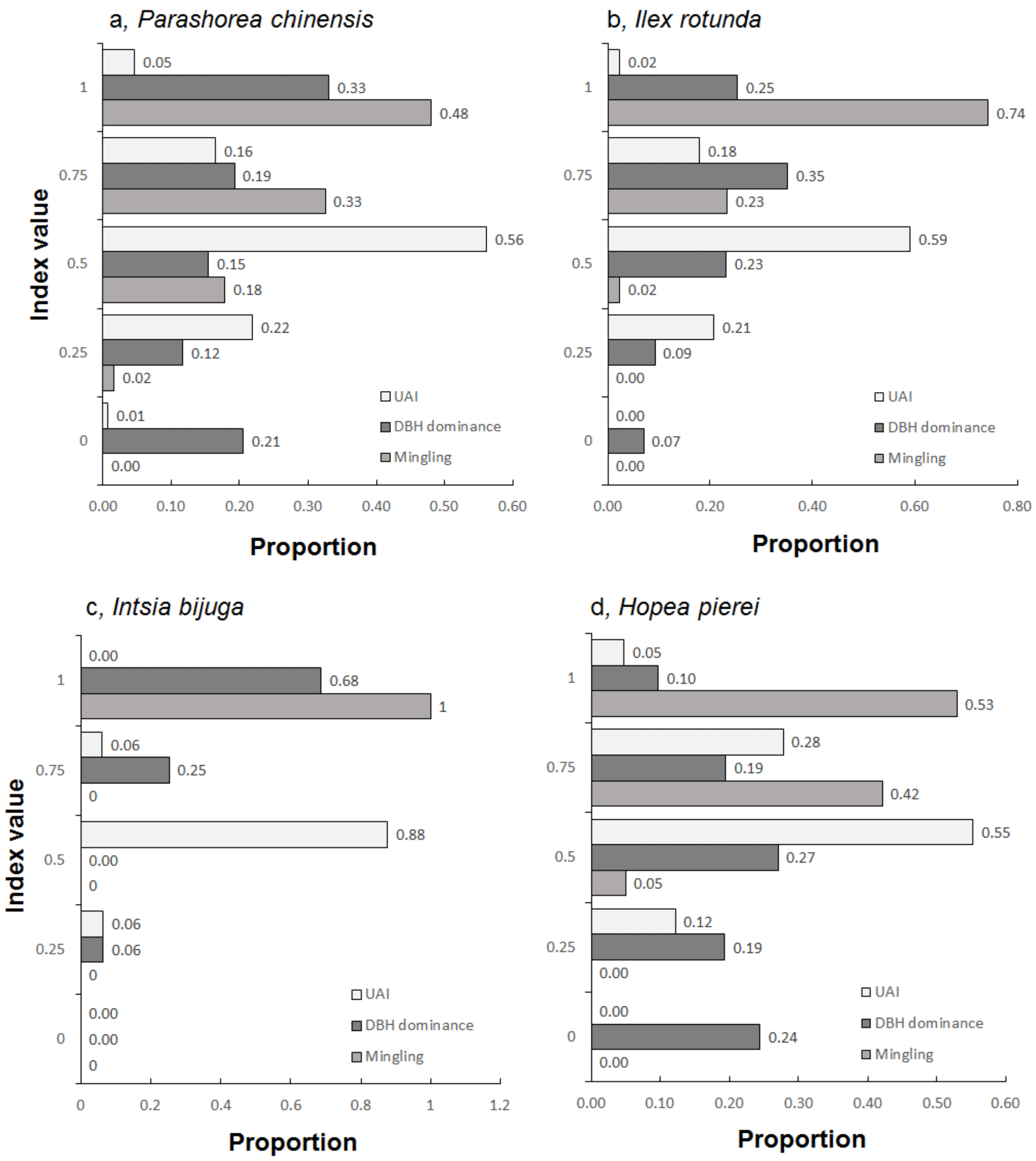

Figure 3. Structural characteristics of six dominant species at Binh Dinh plot

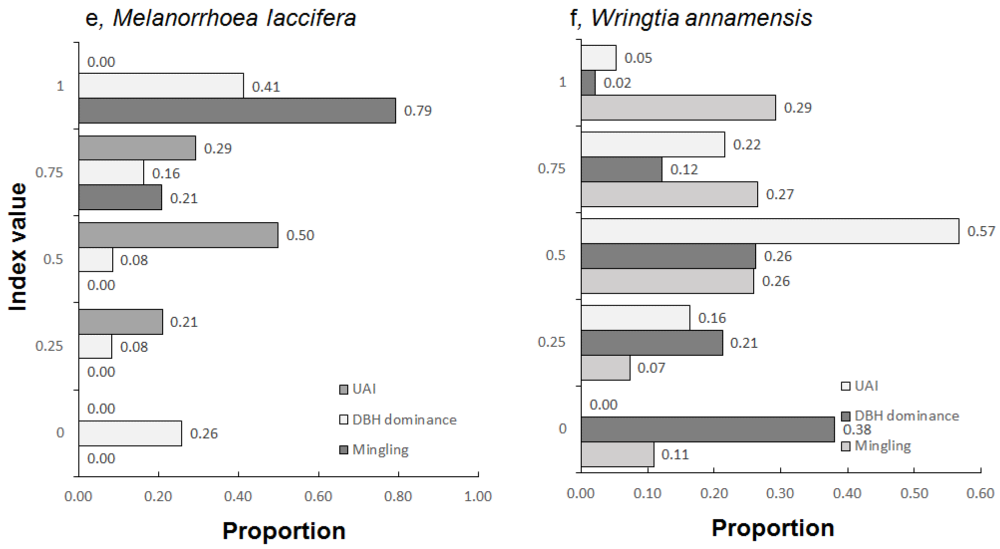

Figure 3 (cont). Structural characteristics of six dominant species at Binh Dinh plot

In Khanh Hoa studied plot (Fig. 4), three dominant species were mixed with nearest neighbours from medium to high mixture including *S. wightianum* (M = 0.5 - 1), *D. sylvatica* (M = 0.5 - 1) and *N. melliferum* (M = 0.5 - 1). However, those species were concentrated at medium level meaning that, in nearest trees, there are less interspecific neighbours. *P. nemoralis* (M = 0.75) and *O. balansae* (M = 1) were shown high to complete mixing with other species in neighbourhood.

Proportions of high advance in DBH dominance were high in *S. wightianum* (U = 0 - 1), *D. sylvatica* (U = 0 - 1) and *N. melliferum* (U = 0 - 1) inferring competitive advantage comparing to these nearest neigbours. However, these proportion values were low in *P. nemoralis* (U = 0 - 0.75), *O. balansae* (U = 0 - 1).

Spatial patterns were from regular to clumped distribution but mainly at medium level (W = 0.5) such as *S. wightianum* (W = 0.25 - 0.5), *D. sylvatica* (W= 0.25-0.75), *N. melliferum* (W = 0.25 - 0.75), *P. nemoralis* (W = 0.5 - 0.75) and *O. balansae* (W = 0.5 - 0.75). That mean most of the dominant species were medium to clumped distribution to neighbours.

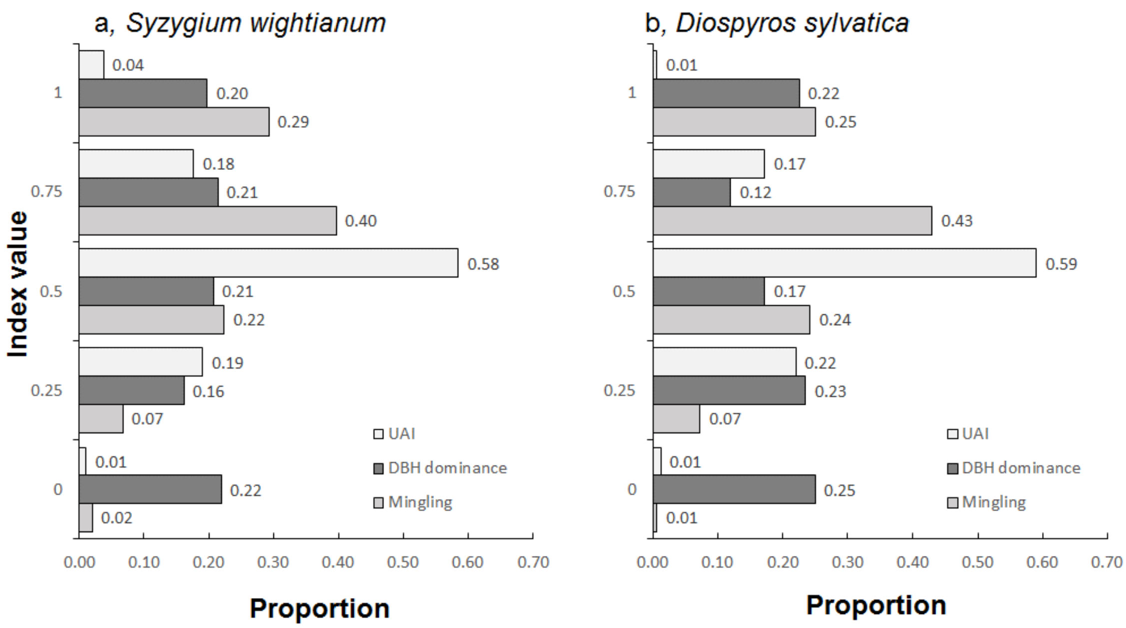

Figure 4. Structural characteristics of five dominant species at Khanh Hoa plot

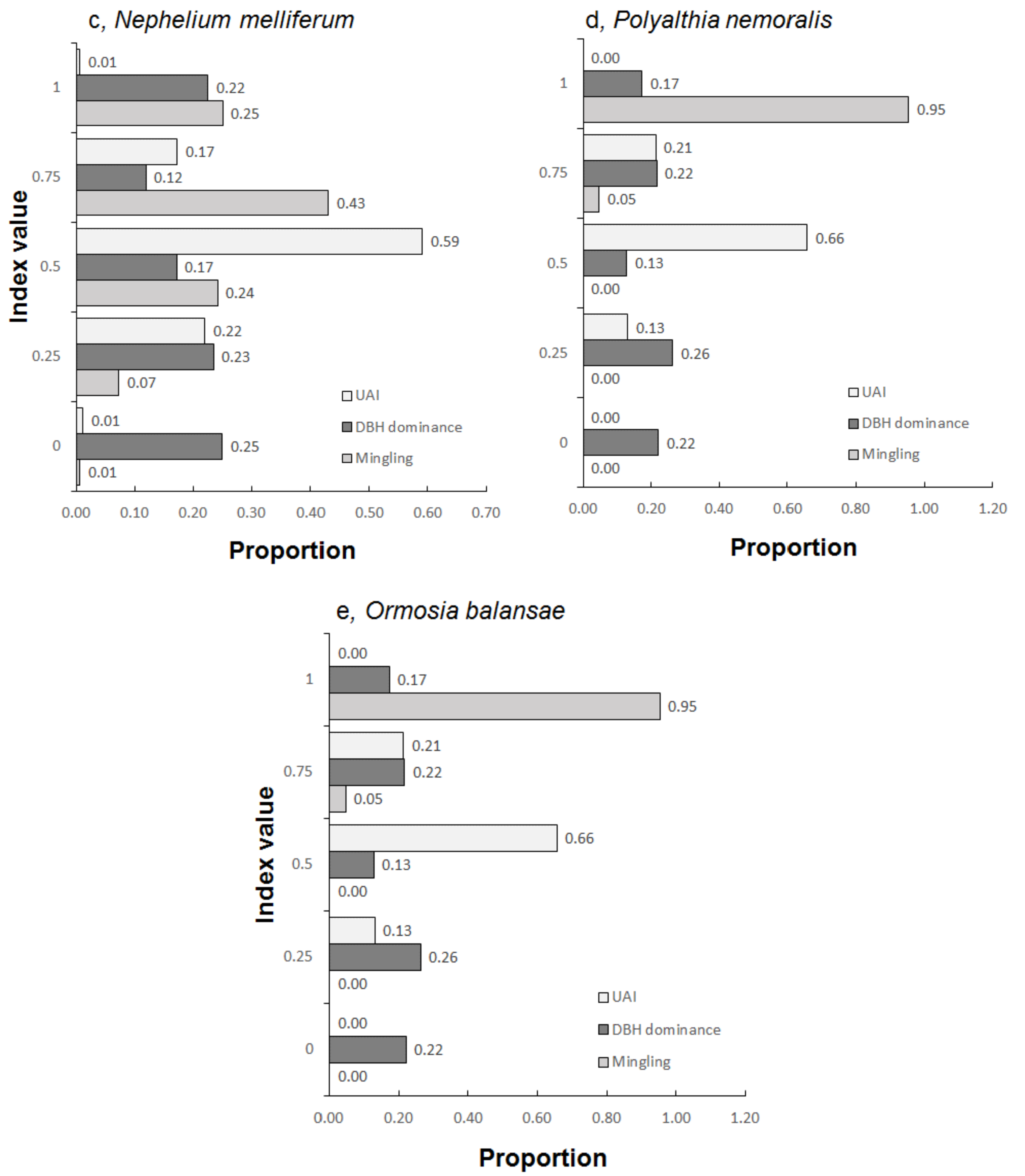

Figure 4 (cont). Structural characteristics of five dominant species at Khanh Hoa plot

3.3. Discussion

The relationship between tree individuals and their nearest neighbors is highly potential to elucidate competitive interaction for limited environmental resources, the mutual dependence and species coexistence (Gadow et al. 1998). The structural parameters were considered closely to species association between each individual and its four nearest neighboring trees by the relationship between mixture, size differentiation and distribution pattern, thus, this approach is advantageous compared to the univariate analysis of structural parameters (Li et al. 2014).

The results shown evidences that most of studied species were found highly mixed with other species. In DBH dominance analysis, most of dominant tree species in Ha Tinh and Binh Dinh plots were less competition in tree DBH comparing to nearest neighbours. However, three species, including *S. wightianum*, *D. sylvatica* and *N. melliferum* in Khanh Hoa plot, had positive advantage in tree size, therefore bearing higher competitive capacity for nutrient resources. About spatial distribution, most of tree species in three studied plots were from regular to clumped patterns but mainly focused at random pattern, excepting *M. laccifera* in strong clumped distribution, comparing to nearest neighbours.

These finding may be a reflection of dispersal limitation and development processes of these forest communities. The tendency of species aggregation is common and especially in high tree species diversity forests (Wright 2002), as a pattern of mixed species would lead to a reduction of species diversity due to competitive interaction. This is supported by a finding of Hubbell & Foster (1986) that, in species-rich communities, two individual of the same species may share only a few common species among their nearest neighbors. Moreover, functionally similar species may produce ecological equivalence among species traits which was explained by neutral theory (Hubbell 2006). High diversity species meaning high mixture may also involve seft-thinning process where number of saplings are decreased as average tree size increases over time, consequently increasing chance to replace by other species. Regular pattern can be resulted by interspecific competition between tree species making greater distance between interspecific individuals.

IV. CONCLUSION

The important practical advantage of this approach is that stand spatial attributes can be determined simply by evaluating the immediate neighbourhoods of a given number of reference trees. Therefore, management methods can be based on considering spatial attributes (size, species and distribution pattern) of each tree, allowing comparison of spatial structure between actual and ideal stand distributions. Our study revealed that selective thinning can improve the health and spatial structure of forest stands and ensure the success of forest management in structurally complex forests.

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PHÂN TÍCH ĐẶC ĐIỂM CÂY LÂN CẬN GẦN NHẤT CỦA RỪNG LÁ RỘNG NHIỆT ĐỚI

Nguyễn Hồng Hải

Trường Đại học Lâm nghiệp

TÓM TẮT

Cấu trúc không gian là một trong những chỉ tiêu quan trọng để mô tả cấu trúc lâm phần. Chúng tôi áp dụng một phương pháp mới để phân tích định lượng cấu trúc không gian của rừng dựa vào quan hệ của các nhóm cây lân cận nhau. 03 ô tiêu chuẩn 1-ha (100 m x 100 m), được thiết lập trên trạng thái rừng lá rộng thường xanh, được sử dụng để đánh giá các tham số cấu trúc. Tất cả các cây gỗ có đường kính ngang ngực ≥ 6 cm được xác định loài, đo đếm đường kính ngang ngực và vị trí tương đối trong ô tiêu chuẩn. Chúng tôi tính toán và mô tả các tham số cấu trúc như trộn lẫn, ưu thế đường kính và chỉ số đồng góc bằng phần mềm Crancod và Microsoft Excel. Kết quả cho thấy rằng: các loài cây được phân tích đều trộn lẫn mức độ cao với các loài cây khác. Phân tích ưu thế đường kính cho thấy: cây ưu thế ở Hà Tĩnh và Bình Dịnh kém cạnh tranh hơn về đường kính với cây lân cận gần nhất. Tuy vậy, có 03 loài có ưu thế đường kính nên có ưu thế cạnh tranh về không gian dinh dưỡng. Về phân bố không gian, hầu hết các loài cây ưu thế ở 03 ô tiêu chuẩn có phân bố từ dạng đều đến cụm với cây lân cận, tập trung chủ yếu ở dạng đều. Các tham số cấu trúc không gian cung cấp những thông tin trực tiếp và có giá trị về cấu trúc không gian của lâm phần. Những thông tin này có thể được sử dụng cho việc tỉa thưa trong quản lý rừng bền vững, mô hình hóa và phục hồi rừng.

Từ khóa: Chỉ số đồng góc, lân cận gần nhất, rừng lá rộng nhiệt đới, trộn lẫn, ưu thế.

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