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HOMOGENEITY OF NATURAL FORESTS AT THE STAND SCALE: EVIDENCES FROM A LUOI DISTRICT, THUA THIEN HUE PROVINCE, VIETNAM

Toai Minh Pham Vietnam National University of Forestry; - Corresponding author
Dien Pham Van Vietnam National University of Forestry;

ABSTRACT In order to identify homogeneity of natural forests at stand scale we selected and conducted a study on a natural forest vegetation in A Roang commune, A Luoi district, Thua Thien Hue province in North Central Coast region of Vietnam. The homogeneity character was assessed on 02 primary plots of 10,000m2 each. In which, each primary plot was divided into 25 secondary plots of 400m2 each. Four indicators reflecting the homogeneity of natural forest vegetation was tested including: (i) the relative distribution of tree stumps on forest floor; (ii) spatial pattern of canopy trees (DBH ≥ 10 cm) in the forest stands; (iii) the relative deviation of structure and growth factors of forest vegetation among secondary plots and (iv) aggregation of secondary plots bases on similarity levels. The results showed that, the primary plot 1 could be considered as one biological community with the similarity of 77% or lower while the primary plot 2 was two differently biological communities with the similarity of 70%. If similarity increases, the homogeneity of forest vegetation will be decreased. In general, it is difficult to find the forest vegetation which has absolutely homogeneity or if the similarity is required equal or greater than 90%.

KEYWORDS : homogeneity, natural tropical forest, stand scale, Thua Thien Hue province

1. INTRODUCTION

Silviculture practiced on the stand scale (Hudson 2009) and an efficient forest management requires detailed knowledge of forest stands, including tree species and their spatial distribution on forest floor. Therefore, stand scale concepts use to emphasize on the homogeneity in growing land as well as its typical conditions. In order to identify homogeneity of a forest stand, forest area is usually divided into compartment and sub-compartments in which each sub-compartment will be considered as a stand. Due to the homogeneity requirement, area of each sub-compartment should not be too big and its optimum size is normally determined by the spatial distribution and the variability of the forest to be surveyed (Köhl et al. 2006) . In case of the tropical evergreen forest, an average size of each sub-compartment should be about 10 hectares for convenient application of silviculture (Quan and Dien 2013).

With regards to a natural forest stand, due to dispersal limitation of seeds, many tree species are clustered distributed within a small area (He and Duncan 2000, Wiegand et al. 2007a). In addition, as a result of differences in availability resource patch for establishment, competition such as rock out crop, terrain sharp, aspect and slope (Bolstad et al. 1998, Ohmann and Spies 1998, Zhang and Zhang 2011), soil fertility, temperature, light energy and moisture (Watt 1934, Ellenberg 1974, Davis and Goetz 1990, Currie 1991, Diekmann and Lawesson 1999, Zhang and Zhang 2011), variation in spatial pattern of forest vegetation is formed (Loosmore and Ford 2006). The homogeneity or heterogeneity of natural forest stand scale greatly affects on forest management activities, particularly on field operational activities.

So far, a number of scientists have assumed that biometrical characteristics within each forest plot or sample plot are relative homogeneous (Barnoaiea 2007). In term of silviculture practice, some questions need to be considered such as how such homogeneity is determined? if the homogeneity is not satisfactorily achieved then which silvicultural solutions need to be taken within each forest plot? Especially, we also usually assume that the growing condition and forest characteristics on a sub-compartment is homogeneous and try to establish a sample plot that satisfies the homogeneity requirements. This assumption will be addressed within this article.

The article aims at testing homogeneity indicators of natural forest (as broadleaved evergreen natural tropical forest) at the stand scale in North Central Coast region of Vietnam, with a case study from A Luoi district, Thua Thien Hue province. Indicators were tested include: (1) relative distribution of tree stumps on forest floor; (2) spatial pattern of canopy trees in forest stands; (3) relative deviation of structured and growth factors of forest vegetation among sub-plots; (4) aggregation of secondary plots based on similarity levels.

2. RESEARCH AREA AND METHODS

2.1. Research area

This study was conducted in A Roang commune, A Luoi district, Thua Thien Hue province (Figure 1). It has tropical monsoon climate with two distinct seasons: the rainy season lasts from September to December and the dry season lasts from January to August. The average rainfall is 3,500mm. The average temperature is 25°C. The soil group in this area is Ferralsols.

The coordination of sample plot 01 and 02 is 16°7´48,44"N latitude and 107°25´46,75"E longitude; 16°7´33,65"N latitude and 107°25´39,95"E longitude, respectively. Sample plots locate within 660m-680m above sea level with an average slope of 20°-25°.

Figure 1. Location of reseach area in Thua Thien Hue province, Vietnam

2.2. Research method

2.2.1. Establishing sample plot and data collection

Figure 2. Arrangement of secondary sample plots on the primary sample plot Two primary sample plots (OTC) were established within natural forest stands at A Roang commune, A Luoi district, Thua Thien Hue province.

OTC has an area of 10,000m^2 (100m x 100m). Each sample plot was divided into 25 secondary sample plots of 400m2 (20mx20m) each, as shown in Figure 2.

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On each secondary sample plot, tree species that have diameter at breast height (DBH) of equal and more than 10.0cm are identified. Their DBH and height as well as their location on secondary sample plot are measured. In which, name of tree species were identified with the support of local tree finder; tree location and height were identified by Leica Disto D5 and compass; DBH was measured using diameter taper.

2.2.2. Data analysis

The homogeneity indicators of the vegetation are measured as follows:

- Indicator 01: The relative distribution of tree stumps on forest floor demonstrated in a two dimension diagrams and parameters is identified including: (i) the relative location of each tree stump; (ii) the relative DBH size of the tree on the primary sample plot. These parameters were analyzed using CRANCOD 1.4 software (www.pommerening.org).

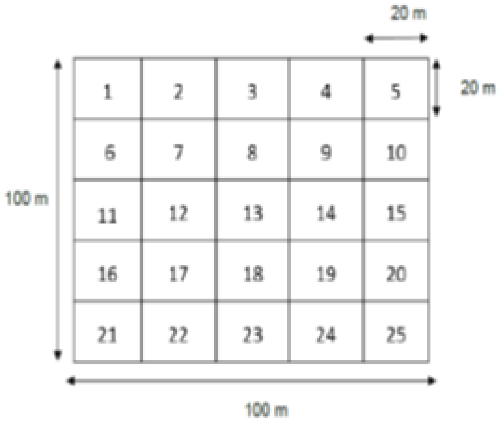

Figure 2. Arrangement of secondary sample plots on the primary sample plot

Indicator 02: The spatial pattern of canopy trees (with DBH ≥ 10cm) within the stand scale is demonstrated by g-function (density at a specific distance) and L-function (cumulative density to a specific distance) and then tested by "zero model" at complete spatial randomness (CRS). This test is conducted in two stages. Stage 01 applies 199 times of Monte Carlo simulation in order to establish the confidence interval between five biggest and five smallest values. If the result falls beyond the confidence interval, the difference obtained from the simulation fails to reach the 5% significance level. Stage 02 evaluates the significance of the difference obtained from the simulation, the test for Goodness of fit (GoF) is conducted for a distance from 0 to 30m. The significant differences from simulation is not accepted if the p-value of the GoF test is less than 0.05 and this result will be used for analyzing in the spatial pattern model (the model consists of g- and L-functions). The analyzing process is conducted on Programita 2014 software (www.pommerening.org).

- Indicator 03: The relative deviation of structure and growing factors of forest vegetation between secondary plots is measured in accordance with the guidance provided in the book of forest yield (Hinh 2012). Poisson probability distribution is assumed to test the distribution of trees on forest floor and to establish a colored diagram (consists of 8 color levels) for visual illustration.

- Indicator 04: The assembly of secondary plots as one biological community under different similarity levels is evaluated through classification of secondary plots. The grouping of secondary plots on the primary sampling plots is based on six forest vegetation parameters (including number of species, number of individual trees, DBH, top height, basal area, volume of secondary plots). The non-metric multidimensional scaling (NMDS) model and branching diagram technique are analyzing in R statistical software.

3. RESULTS

3.1. Distribution of trees on forest floor

The homogeneity of natural forests is demonstrated by a visual image indicating stump location as well as relative size of tree diameter on the horizontal plane of forest floor. This is a qualitative evaluation but in fact it can be considered as a semi-quantitative indicator. From Figure 3, the study found out that:

-Distributions of trees on forest floor in both OTCs are heterogeneous since there is no canopy tree in some scattered areas. Size of these "forest gaps" could be reached 300 -400m^2.

-The size of trees on the plots is so diversify as many big trees are found in some places while medium or small tree sizes can only be found in other different places.

-A number of forest gaps are found in the South East of OTC#1 and the center of OTC#2.

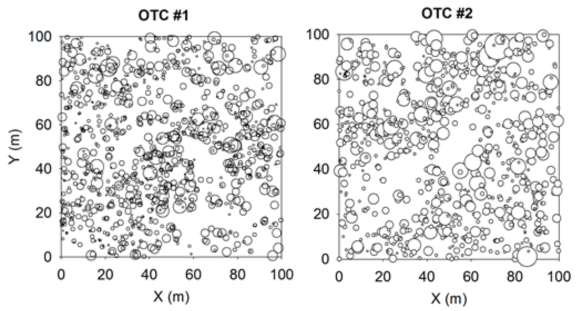

Figure 3. Distribution diagram of trees on OTC#1 and OTC#2
(The size of the circle is representative for tree's DBH)

3.2. Spatial distribution of canopy trees

The distribution of canopy trees (DBH ≥ 10 cm) on two OTCs is compared with the complete spatial randomness (CSR) model to test the heterogeneity within long distance. Testing result obtained from OTC#1 shows that canopy trees tend to distribute as clusters within a radius of less than 02m (Figure 4a, g-function). However, analysis result of L-function suggests that the tree density does not decrease, even up to a long distance of 50ms (Figure 4b). In OTC#2, both the g-function the L-function analysis show cluster distribution within a distance of less than 20m.

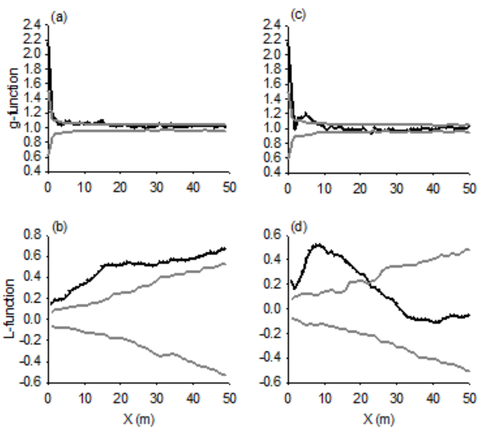

Figure 4. Spatial distribution of canopy trees (DBH ≥ 10 cm) in OTC#1 (Figure a-b) and OTC#2 (Figure c-d) as obtained from g- and L-functions
(The testing model (black line) and the confidence interval at 95% (grey line)

3.3. Variations of statistical indicators of forest vegetation

Within the entire stand (OTC), the variations of parameters including diameter at breast high (DBH, cm), top height (Hvn, m), basal area (G, m2 ha-1) and the total forest volume (M, m3 ha-1) are significant. Variation coefficients gradually increase from Hvn (34.6 to 35.4%) to DBH (53.9 to 61.1%) to G (119.69 to 143.89%) and to M (164.59 to 220.18%) (As can be seen in Table 1). This means that the homogeneity of natural forests is so low.

Table 1. Variations of statistical indicators of forest vegetation

Plot	Criteria	DBH (cm)	Hvn (m)	(m^2/individual)	(m^3/individual)
OTC#1	Average value	16.9	13.2	0.0289	0.2245
	Variation coefficient (%)	53.9	34.6	119.69	164.59
OTC#2	Average value	18.1	13.8	0.0352	0.3105
	Variation coefficient (%)	61.1	35.4	143.89	220.18

The homogeneity of forest stands is not only reflected in the difference among trees but also in the variations of structure and growing factors among secondary plots (Table 2).

As can be seen in Table 2, variation level between minimum and maximum values of all parameters are significant. Variation coefficient of many factors are noticeable and their highest values belong to forest volume (47.54% to 50.18%).

Table 2. Variation of vegetation parameters across secondary plots

Plot	Parameters	Value			Variation (%)
		Min.	Max.	Mean	
OTC#1	-Number of species on secondary plots (number of species)	7.0	26.0	17.8	29.40
	-Number of trees on secondary plots (number of trees)	17.0	70.0	40.0	39.40
	- DBH (cm)	13.1	23.0	17.4	14.00
	- Hvn (m)	9.1	15.7	13.2	11.20
	- G (m2)	0.58	2.31	1.15	38.09
	- M (m3)	3.84	19.18	8.97	47.54
OTC#2	- Number of species on secondary plots (number of species)	9.0	25.0	18.0	23.70
	-Number of trees on secondary plots (number of trees)	11.0	58.0	34.2	33.40
	- DBH (cm)	15.6	22.0	18.2	8.50
	- Hvn (m)	11.5	15.3	13.8	6.70
	- G (m2)	0.38	2.37	1.21	37.27
	- M (m3)	2.24	29.63	10.62	50.18

Comparison of table 1 and 2 shows that, the variation coefficient (%) of parameters within the entire stand are greater than across secondary plots. This phenomenon is caused by the contribution of each different individual tree (from 855 to 1,000 stems ha-1) than of each different secondary plot (25 plots per OTC).

The homogeneity of natural forest stands is further tested using Poisson distribution assumption (Table 3 and 4)

Results mentioned in Table 3 and Figure 5 show a cluster distribution of trees on the forest floor for both OTCs while Table 4 and Figure 6 show that the cluster distribution (reserve) of trees on OTC is even.

Table 3. Analysis of trees distribution on forest floor

Plot	Avg. value	S^2	W	Conclusion
OTC#1	39.96	247	6.19	Cluster distribution
OTC#2	34.2	130	3.81	Cluster distribution

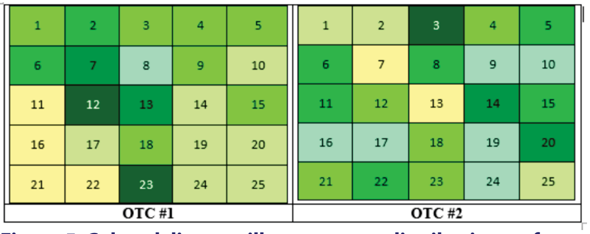

Figure 5. Colored diagram illustrates tree distribution on forest floor
(The darker the color, the higher the tree density)

Table 4. Cluster distribution of trees on forest floor

OTC	Avg. value	S^2	W	Conclusion
OTC #1	0.2362	0.0097	0.041	Even distribution
OTC #2	0.3065	0.0090	0.029	Even distribution

Figure 6. Colored diagram illustrates cluster distribution on forest floor
(The darker the color, the higher the tree density)

The homogeneity of forest stands is additionally defined through the similarity or dissimilarity in the growing of species in secondary plots (Table 5). This Table shows that the number of species increases at lower frequency (less than 5%) (27-33 species). The variation of the number of species at different frequency does not follow a certain pattern. There are 07 to 10 species occurred equal and greater than 50% frequency level. These findings show that the frequency of occurrence of species in secondary plots varies from the lowest frequency of 04% to the highest value of 92%.

Table 5. Frequency of occurrence of species in secondary plots

Frequency of occurrence (%)	Number of species	
	OTC#1	OTC#2
< 5	33	27
5 - 10	7	13
10 - 15	8	8

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15 - 20	4	5
20 -25	8	9
25 - 30	5	4
30 - 35	2	3
Frequency of occurrence (%)	Number of species	
	OTC#1	OTC#2
35 - 40	4	2
40 - 45	6	6
45 - 50	4	0
> 50	7	10
Total number of species	88	87

The above results depict a clear picture of the homogeneity of natural forest stands. There exist, however, conflicting evidence such as the distribution diagram of forest trees using different measurement methods. The results, therefore, suggest that in order to arrive at a positive confirmation, multiple criteria (06 criteria) need to be used in assigning secondary plots.

3.4. Aggregation of secondary plots based on similarity levels

Grouping secondary plots using six criteria is considered as a method that secure high level of confidence to answer the question of how homogeneous forest vegetation on primary plots (or on forest stand in general) is.

NMDS results (as showed in Figure 7a, 7b) indicate that the dissimilarity level in OTC#1 is lower than that in OTC#2. Secondary plots with high homogeneity in OTC#1 include secondary plot number 16 and 21; 12 and 23 etc. Secondary plots with high homogeneity in OTC#2 are numbers 5 and 12; 4 and 9 etc.

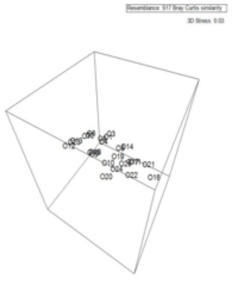

Figure 7a. NMDS diagram of OTC#2

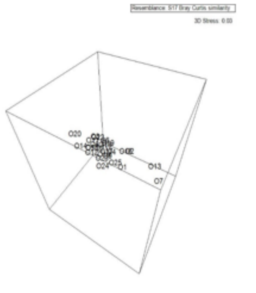

Figure 7b. NMDS diagram of OTC#1

The branch diagram provides a better evidence of the assembly of secondary plots as one biological community (Figure 8 and 9).

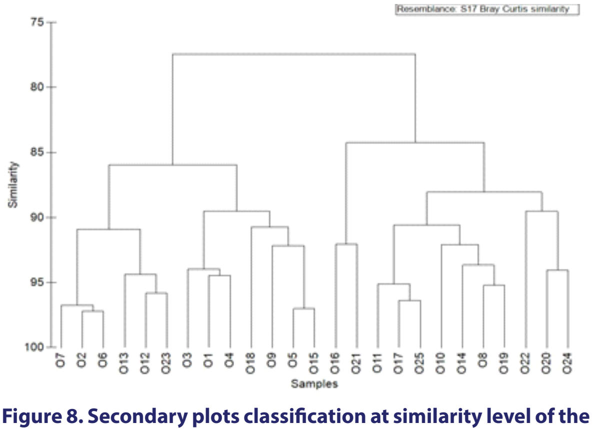

Figure 8. Secondary plots classification at similarity level of the vegetation (OTC#1)

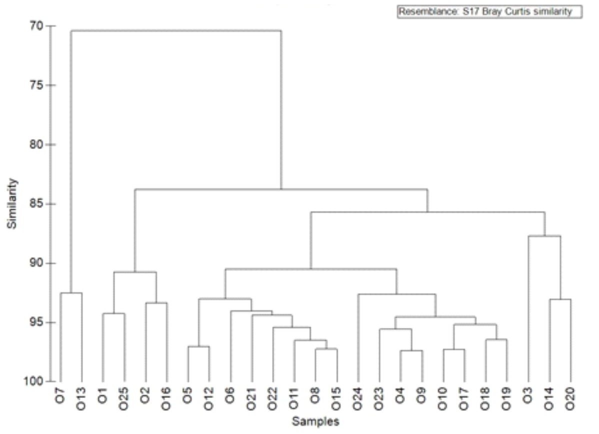

Figure 9. Secondary plots classification at similarity level of the vegetation (OTC#2)

In OTC#1, if the similarity level is approximately 77%, secondary plots belong to one biological community. If the similarity level is at 85%, there are two communities while there are 5 communities at the similarity level of 90%, and 17 communities at the similarity level of 95%.

In OTC#2, at similarity levels of 70%, 84%, 86% and 90%, secondary plots are classified into 2, 3, 4, 5 communities, respectively. When the similarity levels reaches 95%, the number of communities is estimated about 16.

4. DISCUSSIONS

At a given scale of observation, it has been found that the distributions of trees on forest floor in both sample plots in are heterogeneous. This can be considered as a typical distribution pattern of tree species in tropical rain forest , especially 80.4% of tree species in a Malaysian tropical rain forest and 88.4% of tree species in an evergreen broadleaved forest in Eastern China have aggregated distribution and regular distribution of tree species is rarely found.

The heterogeneous growing conditions (including shadow, rock, streams, humidity and soil nutrition etc.) and/or dispersal limitation causes scattered distribution of forest trees . The heterogeneity is easily noticed in large sized of sample plot where forest trees do not spread evenly all over the OTC. For a sample plot of less than 01 hectare in size, prior studies have proved the influence of heterogeneous environment factors on the distribution of forest trees in which relative high density of rock out crop and disturbance levels of studied stands results a number of forest gaps are found in the South East of OTC1 and the center of OTC#2. The comparison between the two density functions: g-function (density at a particular distance) and L-function (cumulative density to a specific distance) has shown that the distribution of forest trees is relatively homogeneous in OTC#1 while heterogeneous in OTC#2.

High variation values of statistical indicators in both OTCs suggest the fact that growing parameters vary across individual trees. In other words, the similarity of growing indicators across forest trees may not exist. If we compare stand parameters indicated in Table 1 and Table 2, study could notice that variation of tree vegetation among individual trees is much higher than that of secondary plots. Consequently, it is more appropriate to use the variation across secondary plots to indicate the spatial homogeneity of the forest vegetation.

Regarding aggregation of secondary plots based on similarity levels, the above analysis shows that the higher the similarity levels is, the lower the homogeneity level can be found. In other words, the homogeneity of forest stands depends on the similarity level selected as criterion. Results documented confirm that the homogeneity of OTC#2 is lower than that of OTC#1. These results are consistent with conclusions in the research conducted in Dong Nai province .

On each plot, the silvicultural techniques produce identical impacts on trees . The heterogeneity of the vegetation on a forest stand requires necessary remedies in establishing standard plot as well as designing and applying suitable techniques. When setting up standard plot small sized standard plot responds better than larger sized plots with regard to homogeneity requirements. As a result, when there is no reason to set up large sized plot, it is advisable to consider establishing small standard plots and increase the number of plots.

The homogeneity on a standard plot can be easily determined using the distribution diagram of trees on the floor. However, it is recommended that comprehensive indicators be used to confirm homogeneity. In addition, when designing and applying silvicultural techniques on site observation is required. It is more accurate to obtain statistical figures and analysis by individual secondary plots.

5. CONCLUSIONS

This research studies the homogeneity of natural broadleaved evergreen forest vegetation at stand scales through four dimensions (i) the relative distribution of tree stump on forest floor. (ii) Spatial pattern of grown-up tree in forest stands. (iii) The relative deviation of structured and growth factors of forest vegetation between secondary plots and (iv) Aggregation of secondary plots based on similarity levels. These dimensions are summative and do not only reflect the general characteristics of forest vegetation in physical term but also in ecological aspect and growth.

- Dimension 1: measurement shows the heterogeneity of tree sizes and distribution.

- Dimension 2: measurement indicates that grown-up tree distribution is relatively complicated. The homogeneity of OTC≠1 is higher than that of OTC≠2.

- Dimension 3: measurement shows that the variation of major characteristic indicators of vegetation are significant but lower for secondary plots. This is a reason for even distribution is documented for small plot such as secondary plot while cluster distribution is found for forest trees on the forest floor. Frequency of occurrence of species on secondary plots also varies.

- Dimension 4: measurement indicates that the homogeneity of vegetation at forest stand scale is best determined by characteristics similarity. This study uses six characteristics of forest vegetation (number of species, number of trees, diameter at chest high, tip height, cross section and production volume for secondary plots) to evaluate the assembly on secondary plots for each standard primary plot. OTC≠1 is considered a biological community with the similarity level of less than 77% while OTC≠2 is divided into two communities at the similarity level of 70%. Results show that the homogeneity of OTC≠1 is higher than that of OTC≠2 to existence of rocks. When similarity increases, vegetation homogeneity drops.

Vegetation homogeneity at stand scale at the research site is hardly achieve at the similarity of 90% and above. It suggests that care should be taken when establishing standard plots or applying silvicultural techniques. Subsequent research is required to improve production effectiveness.

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