CHANGES IN TREE SPECIES DIVERSITY OVER TIME IN TROPICAL RAINFORESTS OF CENTRAL REGION, VIETNAM

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SUMMARY

To get a better understanding of the tree species diversity in tropical rainforests of Central region, Vietnam, we used a data set from 12 one-hectare permanent sample plots in four provinces. Each plot has a square shape (100 m x 100 m^2) and is divided into twenty five 20 m x 20 m quadrats. All trees equal to or larger than 6 cm diameter at breast height ($DBH \geq 6$ cm) were identified by species and permanently marked using a white metal tag. Diversity indices and rank type diversity profiles were used to assess and compare the tree species diversity between four locations. The results showed that, the most noticeable trend was a decrease in almost all diversity indices. Tree species diversity varied considerably from province to province. In our study, the conclusion was that intrinsic diversity of plots in Ha Tinh, Thua Thien Hue and Binh Dinh is larger than that of the Khanh Hoa plots. Moreover, the total number of species strictly increased with increasing area, which can be explained by the influence of environmental heterogeneity on the species-area relationship. The species-area curves did not reach their asymptote at the one hectare plot size, which means that one could expect to record new tree species if the sample area would be further increased beyond 10,000 m^2.

Keywords: Diversity ordering, rank type diversity profiles, species-area relationship, tree species diversity, tropical rainforests.

I. INTRODUCTION

Species diversity, species richness, and biodiversity are widely used terms in ecology and natural resource management. In general, the species diversity of a community is made up of two components: species richness (or the number of species present) and the evenness, species equitability, or abundance of each species (Pielou, 1966; Patil and Rao, 1994). Hamilton (2005) reports that there have been two approaches to measuring species diversity: the first involves constructing mathematical indices broadly known as diversity indices, and the second requires comparing observed patterns of species abundance to theoretical species abundance models. Species diversity indices take two aspects of the community into account: species richness and evenness (Hamilton, 2005). In this study, species richness, the Shannon-Wiener, Simpson indices, and the diversity profile are computed to evaluate and compare the diversity of the tree species in the four study sites.

The species-area relationship is another crucial tool available in the study of species diversity, conservation biology and landscape ecology (Palmer and White, 1994; Lomolino, 2000). When plotting the number of tree species against sampling size, the curve was originally intended to describe the increase in the number of species found as the size of the sampling area increased (Tjörve, 2003). This curve is one of the oldest, most well-proven patterns in ecology (Tjörve, 2003) and is more suitable for the assessment of diversity than is merely counting the number of species (Lepě & Stursa, 1989). It allows to determine the minimum area that is necessary to document all the species present within a given contiguous region (Barkman, 1989; Gadow and Ying, 2007).

II. STUDY AREA AND DATA COLLECTION

2.1. Study area

Measurements were taken in a tropical rainforest, in four different provinces of Vietnam: Ha Tinh Province, Thua Thien Hue Province, Binh Dinh Province, and Khanh Hoa Province. There were three plots in each of the four provinces; the locations of both provinces and the plots within them are demonstrated in Figure 1.

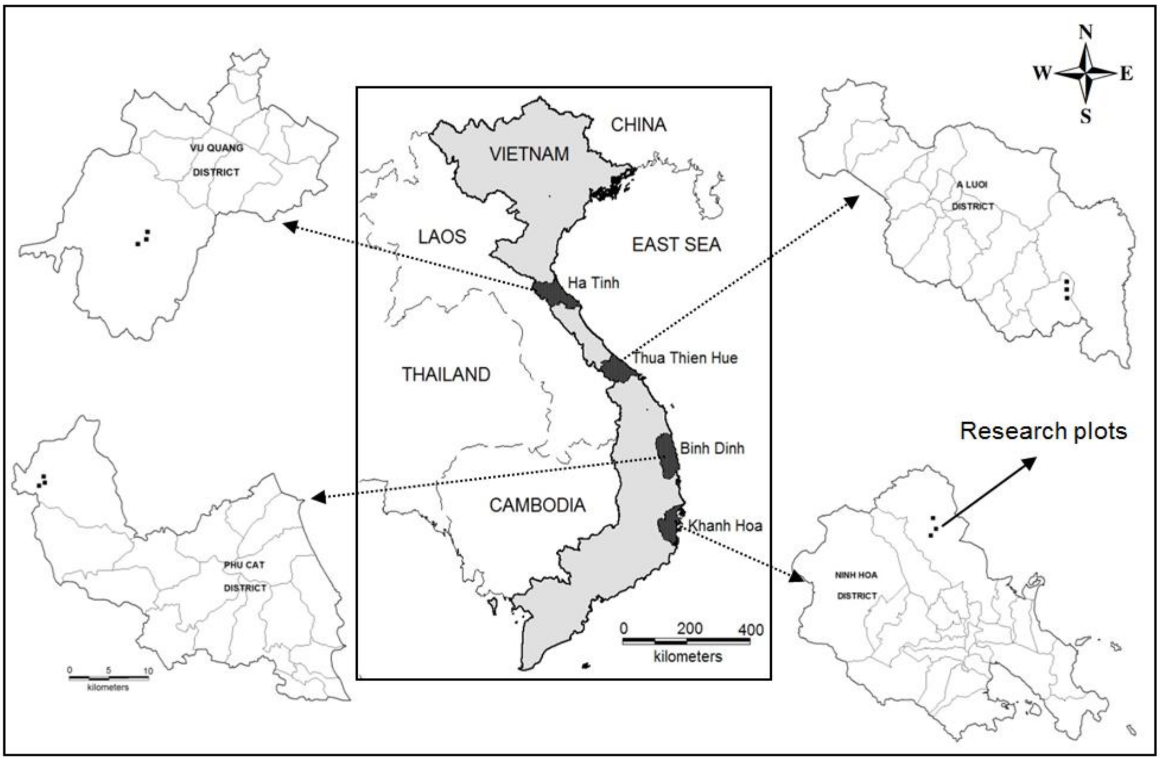

Figure 1. Location of the four study sites and 12 sample plots

2.2. Data collection

In this research, 12 permanent plots (PSPs) in four provinces were selected from the network of PSPs which was established by the Forest Inventory and Planning Institute (FIPI) of Vietnam. Data from 2005 inherited, and re-measurement of these plots was done by the author in 2012, 2013.

Each plot has a square shape (100 m x 100 m^2) and is divided into twenty five 20 m x 20 m quadrats (Figure 2). It was aligned according to a magnetic-north direction and has four major corner posts made of concrete. All trees equal to or larger than 6 cm diameter at breast height (*DBH* ≥ 6 cm) were identified by species and permanently marked using a white metal tag.

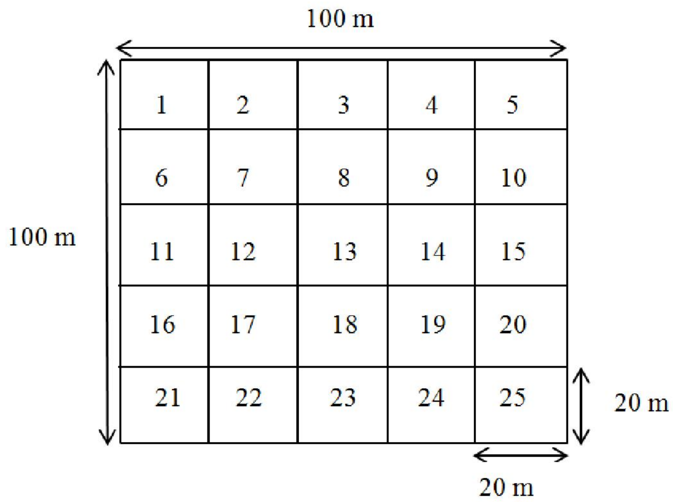

Figure 2. Quadrats numbering scheme

2.2.1. Field methods in 2005

On each plot, all trees in the plot with a diameter at breast height from 6 cm ($DBH \geq 6$ cm) were marked and, identified by species.

2.2.2. Field methods in 2012 and 2013

Measurements were repeated on all 12 plots, either in 2012 (plot 1, plot 2 in Ha Tinh; plot 1, plot 3 in Thua Thien Hue; plot 1, plot 2 in Binh Dinh; plot 1, plot 2 in Khanh Hoa) or in 2013 (plot 3 in Ha Tinh, plot 2 in Thua Thien Hue, plot 3 in Binh Dinh, plot 3 in Khanh Hoa).

2.3. Data analysis

2.3.1. Diversity indices

The following indices are defined in accordance with Gove, Patil, Swindel and Taillie (1994, Chapter 12).

- Species count (Δ_{SC})

$$\Delta_{SC} = \sum_{i=1}^{s}\left\{\frac{1}{\pi_i}\right\}\pi_i = s \qquad (1)$$

- Simpson diversity index (for an infinite community) (Δ_{Si})

$$\Delta_{Si} = \sum_{i=1}^{s}[1-\pi_i]\pi_i = 1 - \sum_{i=1}^{s}\pi_i^{2} \qquad (2)$$

- Shannon-Wiener diversity index (Δ_{Sh})

$$\Delta_{Sh} = \sum_{i=1}^{s}\{-\log\pi_i\}\pi_i = -\sum_{i=1}^{s}\pi_i \log\pi_i \qquad (3)$$

where:

$\pi_i = \frac{n_i}{N}$ is the abundance of the i -*th* species,

n_i is the number of individuals of species i,

N is the total number of all individuals, and

s is the number of species.

2.3.2. Diversity profiles

Diversity profiles have been used to assess tree species diversity in uneven-aged forest stands. Patil and Taillie (1979, 1982) discuss two kinds of rarity measures, the dichotomous type and the rank type, which lead to two different diversity profiles. Examined more closely, these types are defined as follows:

a) Dichotomous type

$$\Delta_{\beta} = \sum_{i=1}^{s}\frac{1-\pi_i^{\beta}}{\beta}\pi_i = \frac{1-\sum_{i=1}^{s}\pi_i^{\beta+1}}{\beta}, \beta \geq -1 \qquad (4)$$

where for β=-1, Δ_{-1} is the species count, for β= 0, $\Delta_0$is the Shannon-Wiener index and for β= 1, $\Delta_1$is the Simpson index.

b) Rank type

The intrinsic diversity profile of a community is given by the pairs (T_j):

$$T_j = \sum_{i=j+1}^{s} \pi_i^{\#} \qquad j = 1, \ldots, s-1 \qquad (5)$$

where: T_s = 0and T_0 = 1. Species rarity relies only on its rank, because $\pi_i^{\#}$is the *i-th* component in the ranked relative abundance vector $\pi^{\#}=(\pi^{\#}_1,\ldots, \pi^{\#}_s)$ with $\pi^{\#}_1 \geq \pi^{\#}_2 \ldots \geq \pi^{\#}_s$. T_j is called the right tail-sum of the ranked relative abundance vector $\pi^{\#}$.

If community C' is intrinsically more diverse than community C, in short $C' \overset{imd}{>} C$, then the Δ_β- profiles preserve that ordering; the reverse is not true. However, ordered T_j-profiles, i.e. without intersections, are equivalent to intrinsic diversity ordering.

2.3.3. Species-area relations

Species-area relations show the increase of a species richness as observed within an increasing area. In each plot examined, area size increased from subplot 1 (400 m^2) to subplot 25 (10000 m^2).

A diverse assortment of functions has been suggested as models for species-area relations; the following three functions were selected:

Exponential curve (Gleason 1922, 1925):

$$s = Z\ln(A) + C \qquad (6)$$

Power curve (Arrhenius 1921):

$$s = CA^{Z} \qquad (7)$$

Logistic curve (Archibald 1949):

$$s = \frac{B}{C + A^{-Z}} \qquad (8)$$

where: s is the number of species,

A is the area, and

B, C, and Z are parameters.

III. RESULTS

3.1. Diversity indices

Changes in species richness as indicated by species count, Shannon-Wiener, and Simpson indices.

The four sites differed drastically in their diversity (Table 1). In the years after the first census, the total species count and number of families in the four locations reduced over time from 295 species and 68 families in 2005 to 288 species and 67 families in 2012/2013. The most striking trend was a decline in almost all diversity indices, with the exceptions of plot 3 in Thua Thien Hue and plot 1 in Khanh Hoa, where the number of occurring tree species rose. The appearance of five new species in plot 3 of Thua Thien Hue (*Actinodaphne pilosa, Aglaia tomentosa, Artocarpus rigidus, Litsea vang* H., and *Peltophorum pterocarpum*) and one (*Alstonia scholaris*) inplot 1 of Khanh Hoa brought the total species count from 80 and 46 in 2005 to 85 and 47, respectively, in 2012.

The province totals show a decrease in the species counts of Ha Tinh, Binh Dinh, and Khanh Hoa but an increase in Thua Thien Hue. The number of families also declined, with the exception of Khanh Hoa, where that number remained unchanged.

Table 1. Diversity indices of 12 plots in four provinces

Province	Plot	Species count (Δ_{SC})		Number of families		Shannon-Wiener index (Δ_{Sh})		Simpson index (Δ_{Si})	
		2005	2012/2013	2005	2012/ 2013	2005	2012/ 2013	2005	2012/ 2013
Ha Tinh	1	60	58	29	28	1.685	1.645	0.964	0.961
	2	66	56	30	29				
	3	81	74	34	32				
Total		113	104	39	37				
ThuaThien Hue	1	79	79	41	40	1.698	1.691	0.972	0.970
	2	86	86	40	40				
	3	80	85	41	40				
Total		106	108	46	45				
Binh Dinh	1	94	90	44	43	1.704	1.693	0.964	0.961
	2	96	91	39	39				
	3	102	101	42	41				
Total		131	125	50	48				
Khanh Hoa	1	46	47	32	33	1.261	1.252	0.901	0.899
	2	59	58	39	39				
	3	54	52	35	34				
Total		83	82	45	45				
Total (four provinces)		295	288	68	67				

The Shannon-Wiener and Simpson indices declined between the two measurements in all provinces. These indices were substantially higher in Binh Dinh and Thua Thien Hue than in Ha Tinh and Khanh Hoa; in addition, there was some contradiction between ThuaThien Hue and Binh Dinh during the two periods, namely that Δ_{SC}, Δ_{Sh}(Binh Dinh) >Δ_{SC}, Δ_{Sh} (Thua Thien Hue), but Δ_{Si} (Binh Dinh) <Δ_{Si} (Thua Thien Hue). Inversely, there is a consistent ordering of all three indices in comparison with Khanh Hoa: Δ (Ha Tinh, Thua Thien Hue, Binh Dinh) > Δ (Khanh Hoa). This inconsistency is an interesting point when comparing stands and can be explained as a lack of intrinsic diversity ordering among the stands being assessed.

3.2. Diversity profile

3.2.1. Changes in dichotomous type

The values of the Δ_β diversity profiles for the four sites in 2005 and 2012/2013 changed slightly (Figure 3.8). On the one hand, ThuaThien Hue's Δ_β diversity profile crossed BinhDinh's profile at β = -0.1 in both 2005 and 2012, explaining why the rankings of both the Δ_{SC} and Δ_{Sh} of the two provinces differ from that of the Δ_{Si}. On the other hand, Figure 3 clearly evidences reduction in Ha Tinh and BinhDinh's total species count, from a respective 113/131 species to 104/125.

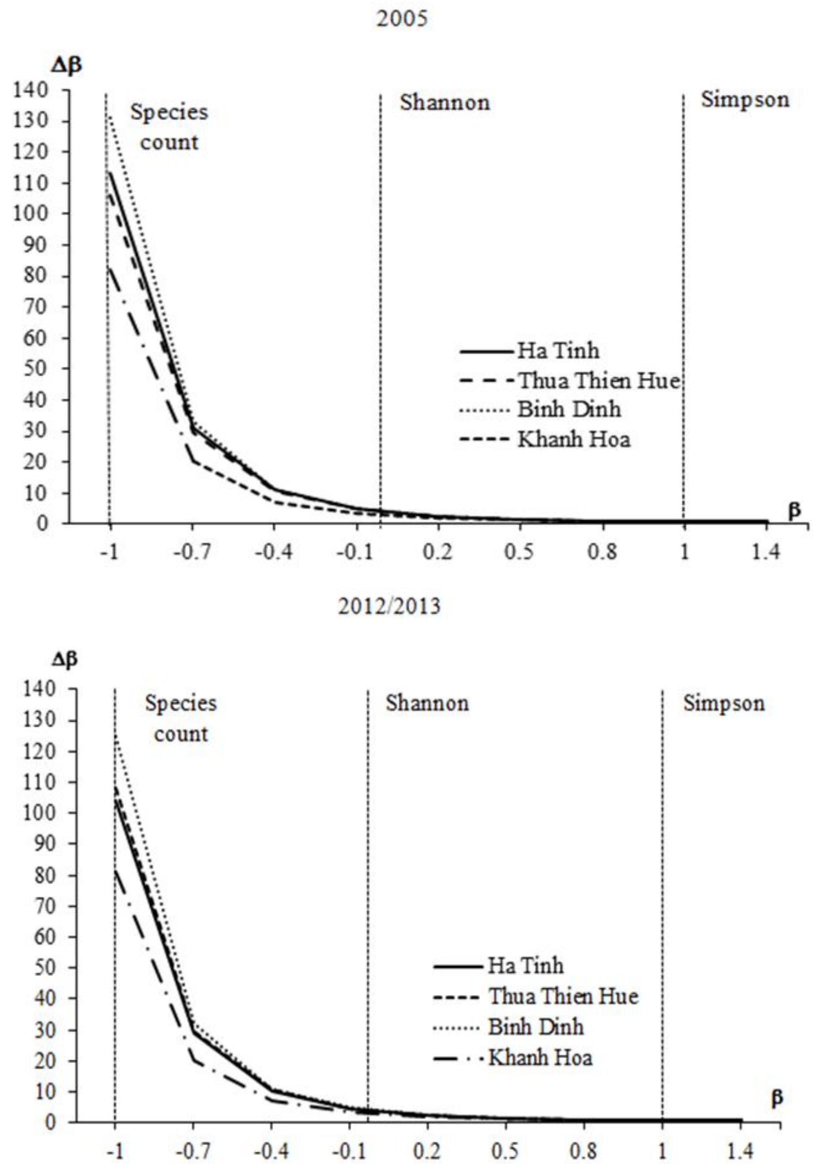

Figure 3. The Δ_β– profiles for four provinces in 2005 and 2012/2013

3.2.2. Rank type

There was little difference between 2005 and 2012/2013 in the T_j-profiles (Figure 4). In both 2005 and 2012/2013, Thua Thien Hue's profile is above Binh Dinh's for *j* from 1 to 14; for *j* larger or equal to 15, Thua Thien Hue's profiles were below Binh Dinh's. The profile of Ha Tinh also intersects those of the latter. Consequently, there is no intrinsic diversity ordering between these three sites. The final conclusion was that the plots in Thua Thien Hue, Binh Dinh and Ha Tinh are intrinsically more diverse than those of Khanh Hoa.

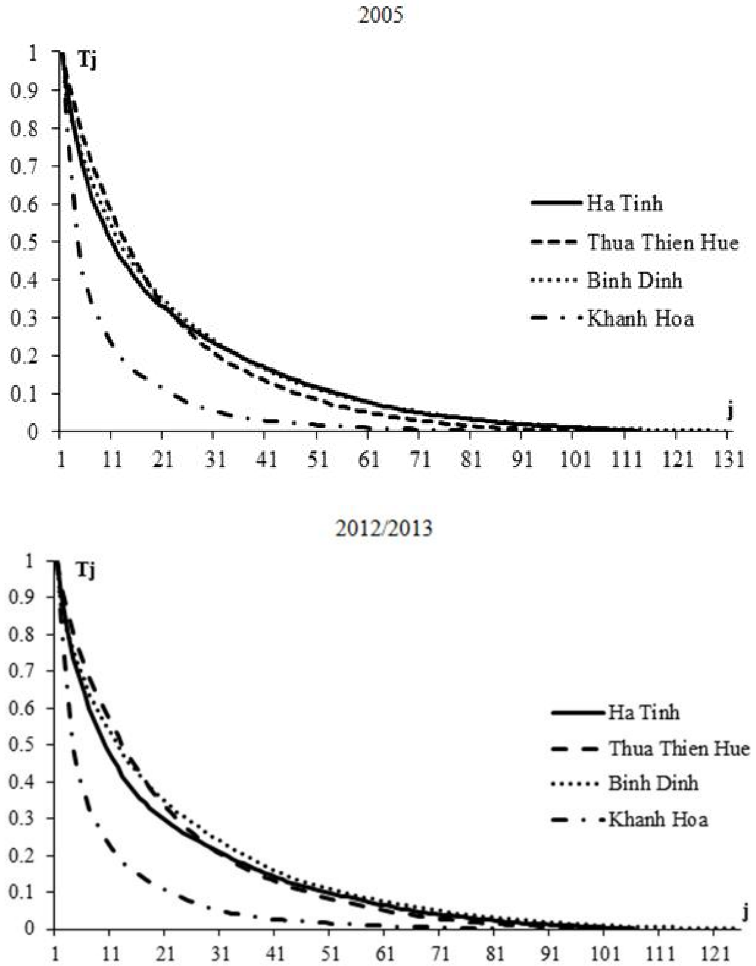

Figure 4b. Right tail-sum T_j-profiles for the four provinces in 2005 and 2012/2013

3.3. Species-area relations

Of the three equations used (Exponential, Power, and Logistic), the species-area data was best fitted by the Power function with an R^2 varying from 0.93 to 0.99 (2005) and 0.86 to 0.99 (2012/2013).

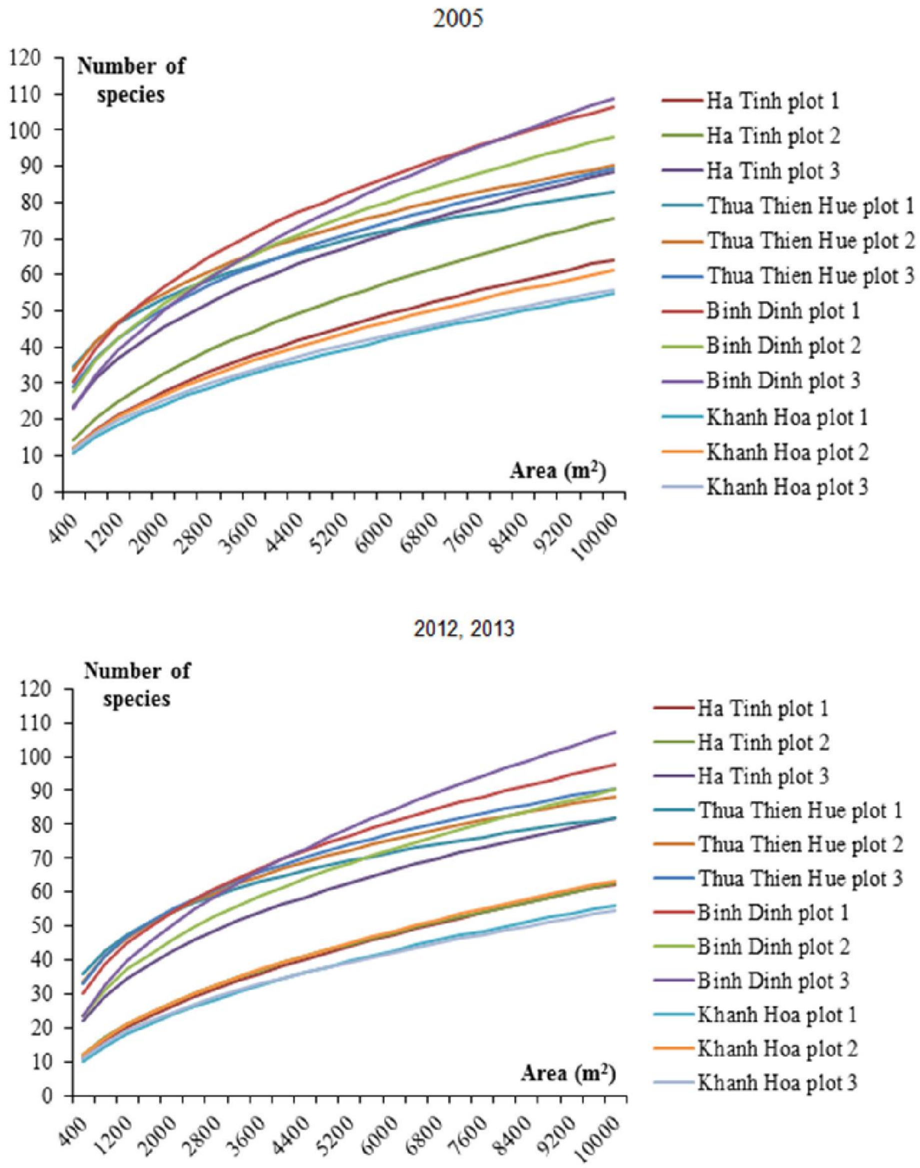

Figure 5. Species-area curves fitted by the Power function for 12 plots from four provinces in the years 2005 and 2012/2013

Figure 5 demonstrates two obvious changes in the 12 curves between 2005 and 2012/2013: first, three of the five lowest estimated curves, namely of Ha Tinh plots 1 and 2 and Khanh Hoa plot 2 became closer; second, the rank between Thua Thien Hue plot 2 and Binh Dinh plot 2 changed. In 2012 and 2013, 12 species-area curves are clearly classified into two groups, where group 1 consists of Ha Tinh plot 3, Binh Dinh, and Thua Thien Hue, group 2 is made up of Ha Tinh plots 1 and 2 and Khanh Hoa. In the graph of the second inventory, the most interesting point was that because of the disappearance of five species (*Bischofia javanica* Bl., *Craibiodendro scleranthum*, *Cratoxylon formosum*, *Elaeocarpus grandifloras*, and *Ficus racemosa*) in Binh Dinh plot 2, the plot's estimated curve was brought down to below that of Thua Thien Hue plot 2, despite the fact that the number of tree species in the latter was lower than that of the former. In similar fashion - and due to the death of two speciesin Ha Tinh plot 1 (*Armesiondendron chinense* and *Microcos* *paniculata*), 10 species in plot 2 (*Actinodaphne pilosa, Annona squamosa, Aphanamixis polystachya, Baccaurea sapida, Croton tiglium, Cryptocarya annamensis, Machilus platycarpa, Michelia mediocris, Oroxylum indicum*, and *Pavieasia annamensis*), and one species in Khanh Hoa plot 2 (*Lithocarpus ducampii*), Ha Tinh plots 1 and 2 and Khanh Hoa plot 2 became closer than in 2005. In addition, the largest number of species per hectare in Binh Dinh plot 3 was 102 in 2005 and 101 in 2013, whereas only 46 (2005) and 47 (2012) species were found in Khanh Hoa plot 1, the result of the high densities of *Syzygium wightianum, Diospyros sylvatica*, and *Enicosanthellum sp.*

As was expected for all sample plots, the number of tree species continuously increased with increasing the area size. The species-area curves for the four locations did not reach their asymptote at the one hectare plot size, which means that one could expect to record new tree species if the sample area would be further increased beyond 10,000 m^2.

IV. CONCLUSION

Tree species diversity in the present study varies greatly from place to place, which may be mainly accounted for by taking variation in biogeography, habitat, and disturbance into consideration (Whitmore, 1998). Differences in terrain, gradient, and slope direction can cause the changes to the soil, water, and microclimate, which in turn are reflected in the varying adaptability of the assorted species.

In the years after the first census, the most noticeable trend was a decrease in almost all diversity indices, with the exceptions of plot 3 in Thua Thien Hue and plot 1 in Khanh Hoa, where the number of occurring tree species rose thanks to the occurrence of several new species in Thua Thien Hue plot 3 and one in Khanh Hoa plot 1. For the ten other plots, the species richness was declined due to the disappearance of species, more precisely the loss of two species in Ha Tinh plot 1, 10 species in plot 2, five species in Binh Dinh plot 2, and one species in Khanh Hoa plot 2. We also used rank type diversity profiles to assess and compare the tree species diversity between four locations. When arranging the intrinsic diversity ordering, the conclusion was that intrinsic diversity of plots in Thua Thien Hue, Binh Dinh and Ha Tinh is larger than that of the Khanh Hoa plots.

While diversity indices have been commonly used in ecological research, they remain problematic in that different indices may rank communities inconsistently (Liu *et al.*, 2007). This issue can be mediated by the use of diversity profile methods, the output of which is a diversity profile in graphical form for each stand being compared. In the present study, we found that diversity profile methods (e.g., dichotomous type, rank type) provided a more stringent test of diversity ordering than did diversity indices; as such, we recommend diversity profiles as the method of preference when comparing tree species diversity among forest stands.

In this study, the total number of species increased in tandem with the area, which can be explained via the influence of environmental heterogeneity on the species-area relationship. Scheiner *et al.* (2000) stated that as area increases, more types of environments are likely to be encountered. If species are non-uniformly distributed with regard to environments, then the number of tree species encountered will increase with area. In this case, the species-area curve will reach an asymptote only if the number of environments reaches an asymptote at some spatial scale.

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SỰ THAY ĐỔI ĐA DẠNG LOÀI CÂY THEO THỜI GIAN CỦA RỪNG MƯA NHIỆT ĐỚI Ở KHU VỰC MIỀN TRUNG VIỆT NAM

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TÓM TẮT

Để hiểu biết rõ hơn về thay đổi đa dạng loài cây theo thời gian của rừng mưa nhiệt đới ở khu vực miền trung Việt Nam, tôi sử dụng dữ liệu từ 12 ô mẫu định vị, mỗi ô có diện tích một ha tại bốn tỉnh. Mỗi ô định vị có hình dạng vuông (100 m x 100 m^2) và được chia thành hai mươi lăm phân ô có kích thước 20 m x 20 m. Tất cả các cây có đường kính từ 6 cm trở lên được xác định tên loài và được đánh dấu bằng biển kim loại màu trắng. Trong nghiên cứu này, các chỉ số đa dạng và hồ sơ đa dạng được dùng để đánh giá và so sánh sự đa dạng loài cây giữa bốn tỉnh. Kết quả cho thấy hầu hết các chỉ số đa dạng đều giảm. Số loài cây khác nhau đáng kể giữa các tỉnh. Kết quả theo hồ sơ đa dạng cho biết đa dạng nội tại của các ô đo đếm tại Hà Tĩnh, Thừa Thiên Huế và Bình Định lớn hơn so với các ô đo đếm tại Khánh Hòa. Mối quan hệ giữa số loài và diện tích cho biết tổng số loài cây tăng theo với diện tích, điều này có thể được giải thích bởi sự ảnh hưởng của các yếu tố môi trường không đồng nhất lên mối quan hệ này. Các đường cong thể hiện mối quan hệ loài-diện tích không đạt tiệm cận ở diện tích một ha, có nghĩa là chúng ta có thể mong đợi tìm được các loài cây mới nếu tăng thêm diện tích ô điều tra.

Từ khóa: Đa dạng loài cây, hồ sơ đa dạng, mối quan hệ loài - diện tích, rừng mưa nhiệt đới, thứ tự đa dạng.

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