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Species Composition, Diversity and Structure of Secondary Tropical Forests Following Selective Logging in Huong Son, Ha Tinh Province, Vietnam

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Species composition, diversity and structure of Huong Son secondary forests post–logged 2 years (PL2), 12 years (PL12) and 22 years (PL22) were studied in May 2004. Percent composition of families and number of commercial species found in the plot PL2 were lower in comparison with those of the two other plots. The medium Sorensen similarity index, ranging from 29.55 to 40.25%, found for all tree size classes showed a slightly high dissimilarity between plots. Simpson's index for all tree size classes was quite similar among plots though only small difference was found for seedlings in the plot PL2. Shannon–Wiener index (H') in all plots exhibited relatively high, ranging from 1.76 to 3.48, for all size classes combined but revealed slightly low diversity indices for commercial species. Species richness and evenness (H) turned out to be the best indices for demonstrating diversity among plots. The size class distribution with Weibull model showed nearly a continuously inverse J-shaped curve. Except the plot PL2 and the plot PL12 followed a similarly exponential trend, the plot PL22 showed a left skewed shape. However, the result of basal area showed that the PL12 had lower basal area than others. All plots showed having some commercial species with relatively high importance value index along with a proportion contributed by other noncommercial ones, i.e. *Syzygium cinereum* and *Diospyros apiculata*.

INTRODUCTION

Selective logging has been widely argued the most important management intervention in a selective silvicultural system (Ho *et al.*, 2004). It is the most popular and most widely employed approach for commercial timber production in Southeast Asia and its impacts on forest structure, composition and regeneration dynamics are large (Okuda *et al.*, 2003). According to Webb (1997), selective logging is a harvesting system that produces disturbance similar to natural tree–fall gaps. Under optimal conditions, selective logging does not significantly change forest structure (Matthews, 1989), but stimulates natural regeneration and growth with the formation of gaps (Hartshorn, 1989). The impacts of logging include the direct effects of felling of harvested trees and associated damage to the residual stand where a large proportion of the remaining vegetation may be killed or damaged. Damage control during logging is an important factor in retaining the potential for natural regeneration of desired commercial species

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(Webb, 1997). These logging effects will directly influence ecological processes involved in the establishment of seedlings and subsequent regeneration of the stand and can significantly alter species composition and stand structure (Cannon *et al.*, 1998). According to Bundestag (1990), in selective felling, no attention is normally paid to ecological considerations. Rather, the number of trees felled and the quantity of logs removed depend exclusively on the quality of the stand and the commercial value of the available wood types. In fact, the number of stems extracted is typically constrained to some degree by local forest regulations which usually specify the minimum felling diameter, but generally do not specify limits to the proximity of felled trees. Felling intensities vary considerably between the three main rain forest regions. In Southeast Asian forests the intensity may be very high. For example, Malaysian Dipterocarp forests dominated by the commercially valuable like *Dryanobalanops aromatica* or *Shorea curtisii*, the felling rate may reach 72 trees per hectare, equivalent to a stump every 12 m. Intensities of 14–24 trees per hectare are more common. This contrasts with extraction levels of 3–5 trees per hectare in most Amazonian forests and less than one tree per hectare in remote areas of central Africa (Johns, 1997).

In Vietnam, tropical secondary forests have been reduced in both quality and quantity. Natural forests are mainly managed by State Forestry Enterprises which are economic institutions assigned with the responsibility to manage and use about 5 million ha of forestland. Located in central part of the country, Huong Son Forestry and Service Company is well–known by its successful experience in managing natural forests. However, the harvesting of commercial tree species is regulated through a forest management plan that stipulates a minimum extraction diameter for each commercial value groups of species. It has been criticized that forest harvesting has resulted in much damage to remaining forests in terms of dynamics. Some of the important questions to be answered are the adequacy of existing levels of seedlings, saplings and advanced growth of commercial tree species as the basis for the future crops both before and more importantly after logging. Therefore, understanding the status of tropical forests following selective logging has become of importance for sustainable use and management of this type of forest in this area. Besides, examination of the regeneration of commercially valuable species following timber extraction is a basic part of any silvicultural system of selective logging. This information is needed for designing adequate treatments to favor the growth of desired individuals for the next rotation (Dawkins, 1958). The objectives of this study were to describe and assess species composition, diversity and structure of some secondary forests following selective logging system in Huong Son forest, Ha Tinh province, Vietnam.

MATERIALS AND METHODS

Study area

The study site was located in the western part of Huong Son district, Ha Tinh province belonging to natural geographical area in North Truong Son (latitude 18° 15'N to 18° 38'N, longitude 105° 07'E to 105° 24'E). Topography is characterized by altitude ranging from 300 to 500 m high. The mean annual temperate is 23 °C, in summer is 28.5 °C (absolutely maximum is 39.5 °C) and in winter is 14 °C (absolutely minimum is 2.5 °C).

The mean annual rainfall is 2,110 mm. The mean annual humidity is 85%. Dry season lasts from November to next April while rainy season from May to October. Weather changes drastically throughout the year along with heavy rain, storms and twists usually occur. From April to June this area is strongly affected by a kind of hot wind coming from Laos. During this time, temperature can reach 36 °C or higher and humidity reduces to 55%.

Vegetation composition in Huong Son forests includes 165 species belonging to 54 families and 98 genera in which families in which most individuals can be found are Euphorbiaceae, Fagaceae, Lauraceae, Rubiaceae, Magnoliaceae, Dipterocarpaceae and Meliaceae. In comparison with vegetation types of neighboring areas, vegetation in Huong Son is not abundant than that of Quy Chau district, Nghe An province with 192 species belonging to 53 families and 127 genera but more numerous than that of Quang Binh province with 104 species belonging to 43 families and 87 genera (Thiep, 1996).

Site selection and sampling design

In May 2004, three secondary forests logged 2, 12 and 22 years belonging three compartments prior to sampling were selected. In each stand, one plot measuring 0.5 ha (50×100 m) were established. The plots were chosen with the similarity in topography condition but were different from each other concerning time of logging, namely: plot PL2 was logged in 2002 (2–year prior logging), plot PL12 was harvested in 1992 (12–year prior logging) and plot PL22 was felled in 1982 (22–year prior logging). In each plot, two diagonals were setup and quadrats measuring 4 m^2 (2×2 m) for seedlings and 16 m^2 (4×4 m) for saplings were laid along these diagonals.

Seedlings and saplings were counted and judged in quadrats and poles and trees of woody stems with diameter at breast height (D.B.H.) >6 cm were measured in plot (Table 1) and then classified and grouped based on commercial value (Table 2).

Table 1. Criteria for judging seedlings, saplings, poles and trees in Huong Son forest, Ha Tinh province.

Category	Criteria
Seedlings	Height up to 1.5 m
Saplings	Height >1.5 m and D.B.H. <6 cm
Poles	D.B.H. =6～10 cm
Trees	D.B.H. >10 cm

Table 2. Criteria for classifying commercial value groups in Huong Son forest, Ha Tinh province, Vietnam (Ministry of Agriculture and Rural Development, 1999).

Group	Criteria
A	Commercial, big sizes (D.B.H. >45 cm), high and excellent quality
B	Non–commercial, medium sizes (D.B.H. >40 cm), medium or bad quality (miscellaneous wood)
C	Non–commercial, small sizes (D.B.H. >30 cm), bad quality

Data analyses

Species composition

Species composition was measured mainly by estimating number of families and species and families with a percent composition greater than 5%. In this study, Sorensen's coefficient, which is generally applied to qualitative data, was used to measure the similarity in species composition between each match of plots. Similarity index measures the degree to which the species composition of quadrats or sample matches is alike (Kent and Coker, 1992).

$$Ss=\frac{2a}{2a+b+c}$$

where: a is number of species common to both plots

b is number of species in plot 1

c is number of species in plot 2

Species diversity

Diversity was quantified by means of following index: species richness (S), as the number of species recorded at the sampled area (Magurran, 1988), Simpson's index (Ds) and Shannon–Wiener index (H') (Krebs, 1972; Hill, 1973; Smith, 1974).

Simpson's index (Ds) heavily weighed towards the most abundant species in the sample while being less sensitive to species richness. As Ds increases, diversity decreases and therefore Ds is usually expressed as 1 – Ds (complementary form) or 1/Ds (reciprocal form). In this study, 1 – Ds was used:

$$Ds=1-\sum_{i=1}^{s}\frac{(ni(ni-1))}{(N(N-1))}$$

Shannon – Wiener index (H') was calculated as:

$$H'=-\sum_{i=1}^{s} pilnpi$$

Maximum diversity index (H max) was also calculated as:

$$Hmax=\ln S$$

Estimation of tree species evenness or equitability (E) was obtained from the formula:

$$E=\frac{H'}{Hmax}$$

where: S is the number of species

pi is the proportion of individuals found in i^{th} species expressed as fraction of total

ln is the log base n

ni is the number of individuals of species i^{th}

N is the total number of individuals of all species

Forest structure

The use of Weibull distribution probability density function is becoming increasingly popular for modeling the diameter distributions of both even– and uneven–aged forest stands. The Weibull's popularity is derived from its flexibility to take on a number of different shapes corresponding to many different observed unimodal tree–diameter distributions. In addition, the cumulative distribution function of the Weibull exists in closed form and thus allows for quick and easy estimation of the number of trees by diameter class without integration of the probability density function (PDF) once the parameters have been fitted (Bailey and Dell, 1973; Shifley and Lentz, 1985 as cited by Jeffrey and Stephen, 1989).

In this study, the two–parameter Weibull PDF given by Patil *et al.* (1984) was used:

$$f(x)=\left(\frac{\gamma x^{\gamma-1}}{\beta^{\gamma}}\right)\exp\left[-\left(\frac{x}{\beta}\right)^{\gamma}\right] \qquad x,\gamma,\beta>0$$

where: γ, β are the shape and scale parameters, respectively, and x is the random variable. Cohen (1965) derived the maximum likelihood estimators for γ and β as:

$$\left[\frac{\sum_{i=1}^{n} x_i^{\gamma}\ln x_i}{\sum_{i=1}^{n} x_i^{\gamma}}-\frac{1}{\gamma}\right]-\frac{1}{n}\sum_{i=1}^{n}\ln x_i=0 \qquad (1) \qquad \hat{\beta}=\left[\frac{\sum_{i=1}^{n} x_i^{\hat{\gamma}}}{n}\right]^{\frac{1}{\hat{\gamma}}} \qquad (2)$$

Notice that one $\hat{\gamma}$ is determined, solution for $\hat{\beta}$ is straightforward. Many forest sampling schemes call for trees to be grouped by discrete diameter classes during data collection. In this case, (1) and (2) may be rewritten as:

$$\left[\frac{\sum_{i=1}^{n} fix_i^{\gamma}\ln x_i}{\sum_{i=1}^{n} fix_i^{\gamma}}-\frac{1}{\gamma}\right]-\frac{1}{n}\sum_{i=1}^{n} fi\ln x_i=0 \qquad (3) \qquad \hat{\beta}=\left[\frac{\sum_{i=1}^{n} fix_i^{\hat{\gamma}}}{n}\right]^{\frac{1}{\hat{\gamma}}} \qquad (4)$$

In order to understand the suitability of Weibull distribution model, a Chi–Square test was performed.

$$\chi^2=\sum\frac{fi-ft}{ft} \qquad (5)$$

If $\chi^2=\chi_{0.01}^2$ with degree of freedom k=n–m–1, we accept the null hypothesis as the Weibull PDF is fitted for modeling the forest structure.

where: fi is the observed frequency of trees

ft is the expected frequency of trees

xi is the diameter–class midpoint.

k is the degree of freedom

n is the number of class intervals

m is number of parameters to be estimated in the Weibull PDF (m=1)

Another criterion to measure forest structure is importance value index (IV) (Curtis and McIntosh, 1951) by average sum of relative dominance and relative density.

$$\text{Relative dominance (RBA)}=\frac{\text{Basal area of species a}}{\text{Total basal area of all species}}\times 100$$

$$\text{Relative density (RD)} = \frac{\text{Number of individuals of species a}}{\text{Total number of individuals of all species}} \times 100$$

$$\text{Relative importance value (RIV)} = \frac{\text{RBA} + \text{RD}}{2}$$

RESULTS

Species composition

The total number of families and species for plot logged 2 years prior (PL2), plot logged 12 years prior (PL12) and plot logged 22 years prior (PL22) was identified, grouped based on their commercial value and ranked depended on families whose composition greater than 5% (Table 3; Appendix A). In total, there were 31 families in the plot PL2 represented by 49 species. Four of these families individually compose greater than 5% of the total individuals in this plot (Table 3). In the plot PL12, 56 species belonging to 32 families were identified. Six families individually make up greater than 5% of the total individuals in this plot (Table 3). From a total of 30 families and 44 species in the plot PL22, there were five families that individually make up greater than 5% of the total individuals. Sapotaceae and Myrtaceae were two families found in both three plots.

Table 3. Families with a percent composition greater than 5% at three plots following selective logging in Huong Son forest, Ha Tinh province.

Plot	Total families	Total species	Family	Composition (%)	No of species in each family
PL2	31	49	Lauraceae	22.5	4
			Myrtaceae	14.3	1
			Sapotaceae	7.3	1
			Mimosaceae	5.0	1
				49.1[a]	5[b]
PL12	32	56	Dipterocarpaceae	15.6	2
			Sapotaceae	10.7	2
			Myrtaceae	8.8	1
			Alangiaceae	5.8	2
			Ebenaceae	5.8	2
			Fagaceae	5.2	3
				46.2	8
PL22	30	44	Fagaceae	21.6	3
			Lauraceae	21.3	3
			Myrtaceae	8.4	1
			Ebenaceae	7.5	2
			Sapotaceae	7.5	2
				66.3	8

[a] Means for total composition of families combined.
[b] Means for number of commercial species combined.

The total composition of families whose composition greater than 5% found in the plot PL2 was 49.1%, of which Lauraceae accounted for 22.5% followed by Myrtaceae (14.3%). In the plot PL12, the total composition was slightly lower (46.2%), of which Dipterocarpaceae and Sapotaceae comprised 15.6% and 10.7%, respectively. The highest composition of families was found in the plot PL22 (66.3%) with two families, Fagaceae (21.6%) and Lauraceae (21.3%), represented as main families in this plot. In terms of commercial timber species, 5 species were found in the plot PL2, 8 species in the plot PL12 and 8 species in the plot PL22. The fact that the number of species found in each family was quite low may be a good evidence for the intensity of selective logging on species composition in these plots.

Species composition was further analyzed using Sorensen's similarity index (Table 4). It can be seen that there were a slight differences between species composition in terms of size classes and among plots. For example, of 31 seedling species sampled in the plot PL22 and 45 in the plot PL12, 22 of them were similar, giving a percentage similarity of 36.67% whereas of 26 sapling species sampled in the plot PL22 and 28 in the plot PL12, 15 of them were similar, showing a percentage similarity of 35.71%. Regarding pole size, of 23 species sampled in the plot PL22 and 35 in the plot PL12, 16 of them were identical showing a percentage of similarity of 35.56%. In the case of trees, of 42 species in the plot PL22 and 53 in the plot PL12, 32 of them were similar, giving a percentage of similarity of 40.25%. Results of similarity between the plot PL22 and the plot PL2 and between the plot PL12 and the plot PL2 were found to be similar trends.

Table 4. Sorensen's similarity index values for seedlings, saplings, poles and trees at three plots following selective logging in Huong Son forest, Ha Tinh province, Vietnam.

Tree category	No. of species in PL22	No. of species in PL12	No. of species common to both plots	Percent similarity (Sorensen's coefficient)
Seedlings	31	45	22	36.67
Saplings	26	28	15	35.71
Poles	23	35	16	35.56
Trees	42	53	32	40.25
Tree category	No. of species in PL22	No. of species in PL2	No. of species common to both plots	Percent similarity (Sorensen's coefficient)
Seedlings	31	17	13	35.14
Saplings	26	21	14	37.33
Poles	23	31	14	34.15
Trees	42	46	26	37.14
Tree category	No. of species in PL12	No. of species in PL2	No. of species common to both plots	Percent similarity (Sorensen's coefficient)
Seedlings	45	17	13	29.55
Saplings	28	21	11	30.99
Poles	35	31	21	38.89
Trees	53	46	28	36.13

Measures of species richness and diversity

Six common measures of species richness and diversity for seedlings, saplings, poles and trees were shown in Table 5. The simplest measure of diversity was species richness, the total number of species, encountered in the three forest plots studied. Interestingly, the plot PL12 showed the highest tree species richness in both four classes. The plot PL22 ranked the second in the seedling and sapling size classes whereas the plot PL2 tended to have more species in the pole and tree size classes. However, the plot PL2 had the highest number of individuals per species for all size classes than any of the two remaining plots, especially in the seedling class with nearly three times greater than those of the two remaining plots. The plot PL12 showed having higher in the sapling and pole size classes and lower in tree size class compared to those in the plot PL22 but these plots were not significantly different in the seedling class. With respect to Simpson's diversity

Table 5. Diversity index values for seedlings, saplings, poles and trees at three plots following selective logging in Huong Son forest, Ha Tinh province, Vietnam.

Measures of Diversity	Plot		
	PL2	PL12	PL22
Species Richness (S)			
Seedlings	17 (11)[a]	45 (22)	31(17)
Saplings	21 (11)	28 (14)	26 (15)
Poles	31(19)	35 (21)	23 (14)
Trees	46 (27)	53 (29)	42 (22)
No of individuals per species			
Seedlings	1099.3 (937.5)	316.7 (386.4)	316.5 (323.5)
Saplings	250 (244.3)	167.4 (205.4)	132.2 (141.7)
Poles	6.8 (5.9)	5.9 (6.1)	4.7 (5.4)
Trees	14.6 (15.3)	7.7 (8.7)	13.3 (17.9)
Simpson's Diversity (Ds)			
Seedlings	0.75 (0.63)	0.94 (0.89)	0.93 (0.91)
Saplings	0.87 (0.75)	0.91 (0.89)	0.95 (0.91)
Poles	0.92 (0.92)	0.94 (0.89)	0.94 (0.89)
Trees	0.95 (0.92)	0.96 (0.92)	0.93 (0.89)
Shannon-Wiener Diversity (H')			
Seedlings	1.76 (1.36)	3.19 (2.50)	3.01 (2.57)
Saplings	2.49 (1.36)	2.98 (2.38)	3.10 (2.54)
Poles	2.95 (2.66)	3.14 (2.56)	2.86 (2.35)
Trees	3.30 (2.78)	3.48 (2.83)	3.13 (2.58)
Hmax Diversity			
Seedlings	4.09 (3.46)	5.49 (4.46)	4.95 (4.09)
Saplings	4.39 (3.46)	4.81 (3.81)	4.70 (3.91)
Poles	4.95 (4.25)	5.13 (4.39)	4.52 (3.81)
Trees	5.52 (4.75)	5.73 (4.86)	5.39 (4.46)
Evenness Diversity (E)			
Seedlings	0.43 (0.39)	0.58 (0.56)	0.61 (0.63)
Saplings	0.57 (0.39)	0.62 (0.62)	0.66 (0.65)
Poles	0.59 (0.63)	0.61 (0.58)	0.63 (0.62)
Trees	0.60 (0.58)	0.61 (0.58)	0.58 (0.58)

[a] Means for measures of diversity for commercial species were shown in brackets.

index, the plot PL2 shows having the lowest diversity of seedlings. Regarding Shannon–Wiener diversity index, the plot PL2 again had the lowest diversity of seedlings whereas the plot PL12 ranked the first followed by the plot PL22. However, there were slight differences in the saplings, poles and trees for this diversity index. This was also true for the maximum species diversity index (Hmax), in which the plot PL2 represented having lowest diversity of seedlings and saplings. Finally, this trend was found for evenness index since the lowest diversity was found for seedlings. Results of commercial species also showed similar trends. The plot PL2 showed the highest tree species richness, highest numbers of individuals per species but ranked the third in terms of equitability for seedling and saplings.

Forest structure

The size class distributions of both commercial and non–commercial pole and tree species combined were shown in Fig. 1. The frequency distributions of D.B.H. class (at

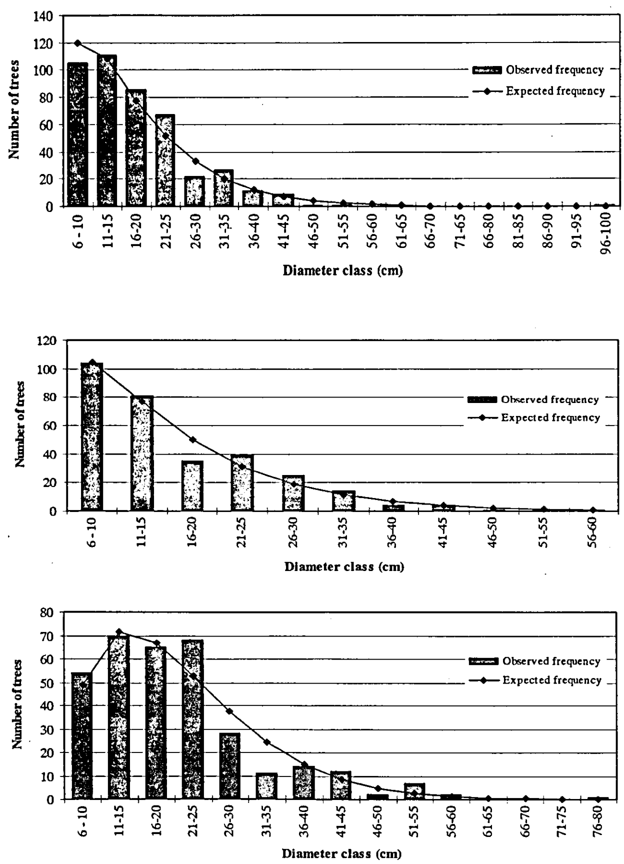

Fig. 1. Diameter class distribution with Weibull model of poles and trees at three plots following selective logging in Huong Son forest, Ha Tinh province, Vietnam. From top to down were PL2, PL12 and PL22, respectively.

5–cm intervals) showed inverse J-shaped curves with many smaller trees and fewer larger ones. For all plots, the Weibull distribution seems to be a best model suited with the observed data. There was a small decrease in 26–30 cm size class and disruptions at higher classes (>50 cm) in the plot PL2. Similar trend was found in the plot PL22 with a pick at 21–25 cm size class followed by some disruptions in the next two size classes but there was an increase in the number of trees in bigger size classes. Only the plot PL12 showed a small disruption in 16–25 cm size class and then followed the same trend with other two plots. All plots showed disruptions and fluctuations in size classes over 50 cm.

The diameter class distribution was closely related with changes in density and basal areas. It can be seen from Table 6 that there were differences in the number of poles and trees in which all plots showed having higher number of trees than poles. The highest density was found in the PL2 with 882 trees per ha then followed by the plot PL22 (662 trees per ha) and the plot PL12 (618 trees per ha). The same tendency was found with basal area. The contribution by poles to basal area estimates was very small. By virtue of high density of medium trees, both the plot PL2 and the plot PL22 had the highest basal area estimates for all size classes considered in comparison with those of the plot PL12.

Table 6. Density and basal area for poles and trees at three plots following selective logging in Huong Son forest, Ha Tinh province, Vietnam.

Parameters	Plot		
	PL2	PL12	PL22
Density (trees ha^{-1})			
Poles	210	208	108
Trees	672	410	560
All combined	882	618	662
Basal area (m^2 ha^{-1})			
Poles	0.98	1.18	0.71
Trees	29.18	16.09	28.05
All combined	30.16	17.27	28.76

Another important criterion for demonstrating forest structure was importance value index (IV) (Table 7 and Appendix B). The importance value of commercial and non–commercial species were computed and ranked for three plots. Only species having greater than 5% in IV was listed. Seven species in the plot PL2 and six species in the plot PL22 both embodied greater than 50% of total species combined while four species in the plot PL12 represented less than 50% of the total species shared. It can be seen that *Syzygium cinereum*, a non–commercial but canopy tree species, appeared in both three plots. It was ranked first in the plot PL2 and was third in the plot PL12 and the plot PL22. In the plot PL22, *Diospyros apiculata*, another non–commercial species was also constituted, although small, as part of major importance value for this plot. No one species had similar importance value indices in each of the three plots studied. Rather, each plot had different tree species at the top of the list of importance value. In PL2, *Cinnamomum obtusifolium* was most important while both *Eberhardtia tonkinensis*

Table 7. Importance value index and importance rank for poles and trees at three plots following selective logging in Huong Son forest, Ha Tinh province, Vietnam.

Plot	Species	Group	Importance Value (%)	Importance rank
PL2	*Cinnamomum obtusifolium*	A	10.35	2
	Cryptocarya lenticellata	A	7.86	3
	Eberhardtia tonkinensis	A	6.79	4
	Cinnamomum parthenoxylum	A	6.47	5
	Engelhardtia roxburghiana	A	6.10	6
	Castanopsis indica	A	5.48	7
	Syzygium cinereum	B	11.69	1
	Others		45.25	
PL12	*Eberhardtia tonkinensis*	A	11.23	1
	Vatica tonkinensis	A	11.04	2
	Alangium ridleyi	A	6.29	4
	Syzygium cinereum	B	8.06	3
	Others		63.38	
PL22	*Quercus platycalyx*	A	14.18	1
	Cryptocarya lenticellata	A	13.19	2
	Lithocarpus tubulosus	A	6.42	4
	Madhuca pasquieri	A	5.55	5
	Syzygium cinereum	B	8.89	3
	Diospyros apiculata	C	5.17	6
	Others		46.16	

and *Vatica tonkinensis* ranked in top places of importance for the plot PL12. Also, *Quercus platycalyx* and *Cryptocarya lenticellata* ranked as first and second places in importance value for the plot PL22.

DISCUSSION

In many tropical countries, timber is extracted from forests through selective logging. This will cause disturbance, usually heavy disturbance, to the remaining forest. The number of harvested trees per hectare is generally low, but the damage to the remaining forest caused during the logging operation can be considerable (Johns, 1988; Johns *et al.*, 1996). In this study, species composition was observed in three plots post–logged in different timing (2 years, 12 years and 22 years). Differences in species composition were found between these plots with altitude ranging from 300 to 500 m. Ho *et al.* (2004) studied the effect of intermediate, short–term (2.5 years after logging) and long–term (about 50 years after logging) logging on tree species in Peninsular Malaysia and found that there were no distinct changes in species composition and the number of Dipterocarp species observed before and after logging. However, there was a variation in species composition observed between plots (at different elevations) within a compartment and between compartments. Lieberman *et al.* (1985) reported that species composition varies subtly in relation to altitude. Consequently, floristic variation discerned between the plots was consistently correlated with environmental factors, among which physiography was clearly important (Manokaran and Swaine, 1994). Our result, therefore, is partly consistent with these studies. The fact that percent composition of families and number of commercial species found in the plot PL2 were lower in comparison with those of the two other plots may be reckoned as this plot was affected by recent selective logging activities. Moreover, the medium Sorensens similarity index, ranging from 29.55 to 40.25%, found for all tree size classes showed a slightly high dissimilarity between plots. Similarity indices in this study were higher than those between forests logged more than 20 years ago and unlogged forests in Indonesia (Robert, 2002) but lower than those between 12– and 26–year old secondary forests in Mexico (Aliza *et al.*, 1997). Establishing clear changes in floristic composition in tropical rain forest is difficult because the majority of species in any area represented by only a few trees (Ho *et al.*, 2004). However, a realistic assessment of changes in species composition can only be obtained from long–term observations over a large area and including sampling of juvenile populations (Manokaran and Swaine, 1994).

Species diversity has been one of the basic concepts of ecology used to characterize communities and ecosystems (Whitmore, 1984). Consequently, two common applied indices, the Simpson's (Ds) and Shannon–Wiener (H') diversity indices were used to characterize the plots. However, both indices are known to be sensitive to changes in the number of species and the distribution of individuals among the species, i.e. evenness or equitability (E) diversity index. A comparison of diversity measures with other studies in Southeast Asia is somewhat difficult due to the heterogeneity in criteria and methods used. The three diversity indices are only available for one study in Malaysia (Newbery *et al.*, 1992), one study in the Philippines (Hamann *et al.*, 1999), one study in Uganda (John, 1987) and a number of studies in Neotropical forests compiled by Bongers *et al.* (1988). Simpson's index for all tree size classes was quite similar among plots though only small difference was found for seedlings in the plot PL2. Deducing from Shannon–Wiener index (H'), all plots exhibited relatively high, ranging from 1.76 to 3.48, for all size classes of all trees combined but revealed slightly low diversity indices for commercial species. However, result of the equitability index (E) showed that these plots have a quite high dominance for both commercial and all trees combined. This is consistent with result reported by John (1987) in Uganda.

Species richness, as the simplest and least ambiguous index of species diversity was compared for plots. Species richness in this study is lower than that reported for Southeast Asia forests, where the number of species per hectare is typically between 100 and 150 (Hamann *et al.*, 1999). It is generally recognized that species richness is positively associated with species abundance (Denslows, 1995) and area and environmental heterogeneity have strong effects on species diversity (Whitmore, 1998). In a Bornean forest, 8 years after selective logging, density and species richness were found lowered as compared to pre–harvest levels but no major changes in family level taxonomic composition were observed (Cannon *et al.*, 1998). In a forest in India selective logging with limited mechanization had little effect on floristic composition 15 years later and within 20 years the forest was expected to resemble an unlogged forest (Pélissier *et al.*, 1998). In one study in the Philippines, Luna *et al.* (1999) stated that 50 years after selective logging, species richness was the same as in unlogged forest although species composition was altered. John *et al.* (2002) reported that harvesting intensity in an upland Amazonian forest has little impact on species richness for herbs, grasses, tree seedlings <2 m tall and vines after 11 years. Even though these studies were accomplished in different tropical forests with various timing and selective logging regimes, our result partly concurs with these considerations since the plot PL12 and the plot PL22 both showed having little changes in species richness for seedlings. On the other hand, the high frequency of individuals per species represented by seedlings and saplings found in plot PL2 and other plots may indicate that these forests have a high potential of dormant seed bank, the possibility of colonization from outside or a low level of seedling and sapling mortality several years after logging. Our result is, however, different from that reported by Ho *et al.* (2004) in Malaysia due to the reduction of population density along with irregular seed production from potential mother trees. Species richness and evenness (H), therefore, turned out to be the best indices for demonstrating diversity among plots.

It is better to calculate species diversity for all plant species, life forms (shrubs and herbs) and vertical layers within each plot (Onaindia *et al.*, 2004). Otherwise, lianas are abundant and diverse group of plants in forests throughout the world, particularly in the tropics (Schnitzer and Bongers, 2002) should be studied since felling of liana–laden trees during harvesting operations can induce excessive stand damage because their crowns are likely to be connected to their neighbors (Putz, 1984) and physically impede the establishment of seedlings and saplings of tree species in logging gaps (William and Francis, 2004). Though detailed inventory of these life forms in these plots was not carried out, our observations found that the number of shrubs and vines appeared in the studied plots slightly become visible in the plots whereas the forest canopy cover, which was measured for poles and trees, was just somewhat different among the plots.

Stand structure and specifically diameter distributions of stands and species is an important stand variable which needs to be considered in the development of sustained–use management systems and is a basis for monitoring stand development after harvesting resources (Geldenhuys, 1992). In this study, it is difficult to assess the impacts of forest logging relied only on volume and level of harvest of a few commercial species because the official extraction data or records do not show the volume or density of trees, poles, saplings or seedlings damaged or killed by tree crushes or by the mechanical handling of logs from the forest to extraction roads. Otherwise, diameter class distribution of trees in a stand may be used as a crude estimator of the relative age structure and state of a forest when no growth data available (Odum, 1971; Lorimer, 1980, as cited by Sokpon and Biaou, 2002) and as an indicator of natural or man– induced history (Lorimer, 1980). Therefore, the Weibull distribution, mentioned above as a most popularity model, was selected for modeling diameter class distribution of the plots studied. All the plots showed nearly a continuously inverse J–shaped curve, in which most diameter classes distributed with two main classes: reserve stocking and maturing stocking, ranging from 6 to 45 cm, in which the latter had a largest number of individuals but all plots lacked mature stocking in higher size classes. Except the plot PL2 and the plot PL12 that followed a similarly exponential trend, the plot PL22 showed a left skewed shape. However, the result of basal area showed that the PL12 had lower basal area than others.

Judging from the importance value index (IV), the plots studied showed a somewhat different trend. In this study, only relative dominance and relative density were combined to create IV for each species in pole and tree size classes in the plots. All plots showed having some commercial species with relatively high IV along with a proportion contributed by other noncommercial ones, i.e. *Syzygium cinereum* and *Diospyros apiculata*. The appearance of high shade–tolerant species such as *Vatica tonkinensis*, *Castanopsis indica*, *Cinanamomum parthenoxylum* and *Cinnamomum obtusifolium*, which could be found in primary forests as described by Thiep (1996), was good evidence for the high adaptability of these species after logging. Dominion is a group of plant species in tropical forests in which some species, generally stipulated as containing from 5–10 species, have total individuals greater than 50% (relative dominance) compared with those of other species in the forest and each species individually occupy about 4–5%. In some cases, if the relative dominance of species is not clearly shown and the number of species was too numerous, a complexion will be created (Trung, 1999). Following the method of combining relative dominance and relative density for each species as already proposed by Thiep (1996), we found seven species in the plot PL12 and six species in the plot PL22 formed two dominions, whereas four species in the plot PL12 created one complexion. This proves that these plots have been changing in better conditions. However, these dominions maybe only occur in small areas (<0.5 ha) since the relative dominance of species will decrease in larger regions. However, ecological species grouping by wood quality is inadequate and should be involved with the ecological species grouping such as a case of study in East Kalimantan, Indonesia (Phillips *et al.*, 1999). The systematic improvement of forests by non–commercial thinning of less valuable tree species can be justified within homogeneous and rich forests, but should be avoided in poorer stands where treatments cannot be economically justified because of their high costs. For all commercial species, detailed studies of regeneration requirements and their availability in the area should be carried out.

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Appendix A. List of woody species identified for seedlings, saplings, poles and trees at three plots following selective logging in Huong Son forest, Ha Tinh province, Vietnam.

Family and species	PL2	PL12	PL22	Group
Alangiaceae				
Alangium kuzzii Craib	×	×		B
Alangium ridleyi King	×	×		A
Anacardiaceae				
Toxicodendron succedanea (L.) Mold.	×		×	B
Annonaceae				
Polyalthia lauii Merr.	×	×	×	B
Araliaceae				
Schefflera heptaphylla (L.) Frodin.		×	×	B
Burseraceae				
Canarium album (Lour.) Raeusch.	×	×	×	A
Canarium bengalense Roxb.		×		A
Dacryodes dungii Dai *et* Yakovl.			×	B
Caesalpiniaceae				
Dialium cochinchinensis Pierre.	×	×	×	A
Erythrophleum fordii Oliv.	×	×	×	A
Capparidaceae				
Crataeva religiosa Forst. f.		×		B
Clusiaceae				
Garcinia cowa Roxb. ex DC.			×	B
Garcinia oblongifolia Champ. *ex* Benth.	×	×		B
Garcinia fagraeoides A. Chev.A. .Chev.	×	×		B
Dipterocarpaceae				
Vatica diospyroides Symingt.		×		A
Vatica tonkinensis A.Chev. *ex*. Tardieu	×	×	×	A
Ebenaceae				
Diospyros apiculata Hiern.	×	×	×	C
Diospyros lanceifolia Roxb.			×	B
Diospyros morrisiana Hance in Walp.		×		B
Elaeocarpaceae				
Elaeocarpus griffithii (Wight) A. Gray	×			A
Euphorbiaceae				
Antidesma bunius (L.) Spreng.	×	×		B
Chaetocarpus castanocarpus (Roxb.) Thwaites			×	B
Endospermum chinensis Benth.	×	×		A
Sapium discolor (Champ. *ex* Benth.) Muell. Arg.		×		A
Fabaceae				
Ormosia balansae Drake	×	×	×	A
Ormosia pinnata (Lour.) Merr.	×	×	×	A

Appendix A. (continued)

Family and species	PL2	PL12	PL22	Group
Fagaceae				
Castanopsis indica (Roxb.) A. DC.	×			A
Lithocarpus ducampii (Hickel & A. Camus) A. Camus		×	×	A
Lithocarpus tubulosus (Hickel & A. Camus) A. Camus		×	×	A
Quercus platycalyx Hickel & A. Camus		×	×	A
Juglandaceae				
Engelhardtia roxburghiana Wall.	×	×	×	A
Lauraceae				
Cinnamomum obtusifolium (Roxb.) Nees.	×	×	×	A
Cinnamomum parthenoxylum (Jack) Meisn.	×	×	×	A
Cryptocarya lenticellata Lecomte	×	×	×	A
Endiandra hainanensis Merr. & Metc. *ex* Allen		×		A
Litsea robusta Bl.		×		B
Litsea verticillata Hance.	×	×		A
Magnoliaceae				
Manglietia fordiana Oliv.	×	×		A
Michelia balansea (DC.) Dandy	×			A
Michelia foveolata Merr. *ex* Dandy	×			A
Michelia hypolampra Dandy		×		A
Meliaceae				
Aglaia gigante (Pierre) Pell.			×	A
Aglaia polystachya Wall.		×		A
Dysoxylum alliaceum (Blume) Blume	×			A
Dysoxylum binectariferum (Roxb.) Hook. f. *ex* Bedd.		×		A
Mimosaceae				
Archidendron eberhardtii IC.Nielsen.	×	×	×	B
Moraceae				
Artocarpus tonkinensis A. Chev. *ex* Gagnep	×	×	×	A
Ficus racemosa L.	×	×		C
Streblus tokinensis (Dub. & Eberth.) Corn.		×		C
Taxotrophis ilicifolia Vidal	×			B
Plantanaceae				
Platanus kerrii Gagnep.		×		B
Polygalaceae				
Xanthophyllum annamensis Gagnep.	×	×	×	A
Myristicaceae				
Horsfieldia amygdalina (Wall.) Warb.	×	×	×	A
Knema globularia (Lam.) Warb.	×	×	×	B
Myrtaceae				
Syzygium cinereum Wall. *ex* Merr. & Perry	×	×	×	B

Appendix A. (continued)

Family and species	PL2	PL12	PL22	Group
Proteacea				
Helicia cochinchinensis Lour.	×	×	×	B
Rosaceae				
Prunus arborea var. montana (Hook. f.) Kalkm.	×	×	×	B
Rubiaceae				
Anthocephalus chinensis Auct., non Walp.	×	×	×	A
Neonauclea sessitifolia (Roxb.) Merr.		×	×	B
Rutaceae				
Acronychia pedunculata L.	×		×	B
Euodia bodinieri Dode	×			A
Zanthoxylum avicenniae (Lamk.) DC.	×		×	B
Sapindaceae				
Amesiodendron chinensis (Merr.) Hu		×		A
Mischocarpus pentapetalus (Roxb.) Radlk.			×	A
Paranephelium spirei Lecomte	×			B
Pavieasia annamensis Pierre	×	×	×	A
Sapotaceae				
Eberhardtia tonkinensis Lecomte	×	×	×	A
Madhuca pasquieri (Dubard) H. J. Lam		×	×	A
Sterculiaceae				
Scaphium macropodum (Miq.) Beumée *ex* K. Heyne	×		×	B
Sterculia lanceolata Cav.	×	×	×	B
Symplocaceae				
Symplocos adenophylla Wall. *ex* G. Don.	×			B
Symplocos cochinchinensis (Lour.) S. Moore		×	×	B
Theaceae				
Camellia caudate Wall.		×		B
Eurya nitida Korth.			×	B
Schima superba Gard. & Champ.	×			A
Schima wallichii (DC.) Korth.	×			A
Tiliaceae				
Grewia hirsuta Vahl			×	B
Ulmaceae				
Gironniera subaequalis Planch.	×	×	×	B
Verbenaceae				
Vitex trifolia L.		×		C

Appendix B. Relative importance value (IV) and importance rank for poles and trees at three plots following selective logging in Huong Son forest, Ha Tinh province, Vietnam.

Specie	Group	Importance Values (IV)			Importance Ranks		
		PL2	PL12	PL22	PL2	PL12	PL22
Cinnamomum obtusifolium	A	10.35	0.57	3.27	2	40	8
Cryptocarya lenticellata	A	7.86	0.85	13.19	3	32	2
Eberhardtia tonkinensis	A	6.79	11.23	2.13	4	1	13
Cinnamomum parthenoxylum	A	6.47	0.94	1.72	5	29	15
Engelhardtia roxburghiana	A	6.10	1.71	3.10	6	15	10
Castanopsis indica	A	5.48	...	...	7	...	...
Elaeocarpus griffithii	A	2.12	...	...	12	...	...
Horsfieldia amygdalina	A	1.84	1.92	3.13	14	14	9
Vatica tonkinensis	A	1.71	11.04	1.86	15	2	14
Pavieasia annamensis	A	1.68	3.33	1.29	16	8	20
Ormosia pinnata	A	1.31	0.44	0.90	18	45	25
Dialium cochinchinensis	A	1.22	0.60	1.04	20	38	23
Manglietia fordiana	A	1.12	1.22	...	22	23	...
Schima wallichii	A	1.11	...	...	23	...	...
Xanthophyllum annamensis	A	1.01	0.38	1.54	25	48	18
Erythrophleum fordii	A	0.95	1.17	1.01	26	25	24
Canarium album	A	0.94	1.55	0.45	27	17	37
Michelia foveolata	A	0.83	...	...	28	...	...
Ormosia balansae	A	0.81	3.38	2.39	30	7	12
Anthocephalus chinensis	A	0.72	0.50	1.54	31	41	19
Michelia balansea	A	0.60	...	...	33	...	...
Litsea verticillata	A	0.55	0.19	...	34	57	...
Endospermum chinensis	A	0.49	0.38	...	37	48	...
Dysoxylum alliaceum	A	0.34	...	...	41	...	...
Artocarpus tonkinensis	A	0.34	1.50	0.74	43	18	30
Euodia bodinieri	A	0.28	...	...	44	...	...
Alangium ridleyi	A	0.27	6.29	...	45	4	...
Schima superba	A	0.17	...	...	47	...	...
Vatica diospyroides	A	...	4.39	...	...	5	...
Lithocarpus ducampii	A	...	2.97	4.10	...	9	7
Amesiodendron chinensis	A	...	2.71	...	...	11	...
Quercus platycalyx	A	...	1.20	14.18	...	24	1
Canarium bengalense	A	...	0.94	...	...	29	...
Aglaia polystachya	A	...	0.67	...	...	36	...
Madhuca pasquieri	A	...	0.57	5.55	...	39	5
Michelia hypolampra	A	...	0.45	...	...	42	...
Lithocarpus tubulosus	A	...	0.45	6.42	...	43	4
Endiandra hainanensis	A	...	0.41	...	...	46	...
Dysoxylum binectariferum	A	...	0.28	...	...	52	...
Sapium discolor	A	...	0.23	...	...	54	...
Aglaia gigante	A	...	...	0.83	...	...	28
Mischocarpus pentapetalus	A	...	...	0.71	...	...	31
Syzygium cinereum	B	11.69	8.06	8.89	1	3	3

Appendix B. (continued)

Specie	Group	Importance Values (IV)			Importance Ranks		
		PL2	PL12	PL22	PL2	PL12	PL22
Archidendron eberhardtii	B	4.66	1.41	0.46	8	20	36
Gironniera subaequalis	B	3.67	4.08	2.44	9	6	11
Helicia cochinchinensis	B	2.35	1.29	1.68	11	21	16
Acronychia pedunculata	B	2.04	...	0.56	13	...	33
Garcinia fagraeoides	B	1.36	1.00	...	17	27	...
Zanthoxylum avicenniae	B	1.28	...	0.70	19	...	32
Prunus arborea var. montana	B	1.21	1.68	1.59	21	16	17
Garcinia oblongifolia	B	1.02	0.38	...	24	47	...
Knema globularia	B	0.82	0.44	0.48	29	44	34
Polyalthia lauii	B	0.69	2.12	0.18	32	12	41
Symplocos adenophylla	B	0.54	...	...	35	...	...
Paranephelium spirei	B	0.50	...	...	36	...	...
Scaphium macropodum	B	0.47	...	0.17	39	...	44
Antidesma bunius	B	0.37	0.66	...	40	37	...
Alangium kuzzii	B	0.34	0.34	...	41	51	...
Toxicodendron succedanea	B	0.22	...	0.18	46	...	40
Sterculia lanceolata	B	0.13	0.84	1.05	48	33	22
Taxotrophis ilicifolia	B	0.12	1.02	...	49	26	...
Diospyros morrisiana	B	...	2.84	...	...	10	...
Platanus kerrii	B	...	1.45	...	...	19	...
Dacryodes dungii	B	...	1.28	1.06	...	22	21
Symplocos cochinchinensis	B	...	0.87	0.81	...	31	29
Schefflera heptaphylla	B	...	0.82	0.29	...	34	38
Camellia caudate	B	...	0.38	...	...	48	...
Neonauclea sessitifolia	B	...	0.25	0.18	...	53	42
Crataeva religiosa	B	...	0.23	...	...	54	...
Litsea robusta	B	...	0.19	...	...	57	...
Diospyros lanceifolia	B	...	...	0.88	...	...	26
Eurya nitida	B	...	...	0.87	...	...	27
Grewia hirsuta	B	...	...	0.47	...	...	35
Chaetocarpus castanocarpus	B	...	...	0.20	...	...	39
Garcinia cowa	B	...	...	0.17	...	...	43
Diospyros apiculata	C	2.54	2.00	5.17	10	13	6
Ficus racemosa	C	0.49	0.96	...	38	28	...
Vitex trifolia	C	...	0.72	...	...	35	...
Streblus tokinensis	C	...	0.23	...	...	54	...