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## Research article

# Assessment of the diversity and distribution of the threatened tree species in a logged forest in Vietnam

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### Abstract

Conservation of biodiversity and of endangered tree species in tropical forests represents a challenge in the era of deforestation and overlogging. Assessments of biodiversity and of conservation species are essential to estimating the conservation value of ecosystems in order to develop appropriate management measures. This paper discusses the floristic composition, the diversity, and the regeneration of the conservation species in a logged forest in southern Vietnam. Twenty five one hectare plots have been set up using circular sub-plots of 8 metres diameter and at a distance of 10m from the centre point of other sub-plots. The sampling is approximately 50% in each plot. Ten years after the last logging, the species richness appears low, when compared with the close protected area, but the diversity is quite high and conservation species still occur. Twelve conservation species have been studied from the point of view of their distribution and regeneration. Some are close to extinction but some others show promise in terms of regeneration. Six floristic groups have been identified and, among them, two are of interest from a conservation point of view. This logged forest still has a high conservation value, and the process that aims at developing protection measures is clearly relevant.

**Keywords:** Species richness, Diversity, Conservation species, Logged forest, Vietnam

La conservation de la biodiversité et des espèces d'arbres en danger représente un défi en cette période de déforestation et de surexploitation. L'évaluation de la biodiversité et des espèces de conservation est nécessaire afin d'estimer la valeur de conservation des écosystèmes en vue de développer des mesures appropriées de gestion. Cet article traite de la composition floristique, de la diversité et de la régénération des espèces de conservation dans une forêt exploitée au sud du Vietnam. Vingt cinq dispositifs de un hectare ont été mis en place en utilisant des placettes circulaires, de 8m de diamètre, qui sont espacées de 10m les unes des autres. L'échantillonnage est approximativement de 50% dans chacun des dispositifs. Dix ans après la dernière exploitation, la richesse spécifique apparaît faible, quand elle est comparée à celle d'une zone protégée qui lui est proche, mais la diversité est assez élevée et les espèces de conservation sont encore présentes. Douze espèces de conservation ont été étudiées du point de vue de leur distribution et de leur régénération. Certaines sont proches de l'extinction mais d'autres sont très prometteuses en termes de régénération. Six groupes floristiques ont été identifiés et, parmi eux, deux ont un fort intérêt du point de vue de la conservation. Cette forêt exploitée a encore une forte valeur de conservation et le processus qui vise à prendre des mesures de protection est tout à fait adéquat.

**Mots clés:** Richesse spécifique, Diversité, Espèces de conservation, Forêt exploitée, Vietnam

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## Introduction

Vietnam is one of the world's 10 most biologically diverse countries. Situated at the crossing of three different routes of flora migration, namely the Himalaya-South China route in the North-west, the India-Myanmar route in the West and the Malaysia-Indonesia route in the South, Vietnam has a very high number of plant species [1]. But for many reasons, such as rapid changes in land use, over-harvesting, and long wars, the forests of Vietnam have severely declined, both in quantity and quality [2]. Forests covered 12.3 million ha or 37% of the country's area, in 2005, but 18% was plantation and 70% of the remaining forest was of poor quality (Vietnam Environmental Monitors). Forests have been logged and even overlogged, mostly during the '80s. Consequently, forest resources have been highly damaged and many species within Vietnam run the risk of extinction, of which around 150 are critically endangered and vulnerable [3]. These species are called conservation species in this paper. In 1992, the Vietnamese government banned log exports, and then banned logging in many state-managed forests in 1997. A National Biodiversity Action Plan was adopted, in 1995, to guide and focus the nation's conservation effort, and a further plan, covering the period 2006-2015 with a vision for 2020, is being implemented. However, Vietnam has to face two major problems, biodiversity conservation and wood supply. As a result, the terrestrial protected areas system represented only 6.17% of the total country [4] which is insufficient for sustainable conservation. In this context, the question is how logged forests can participate in biodiversity conservation.

Logged forests are generally seen as having a much lower conservation value than protected forests. After logging, the species richness is generally reduced and the composition changed in favor of pioneer trees [5, 6, 7]. However, human-induced disturbances in tropical forests span a wide gradient, depending on land-use type and intensity [8]. For Ashton [9], little information is as yet available on the impact of successive felling cycles in biodiverse tropical rain forests, and such research is now a critical requirement. In spite of the damage caused by logging, secondary forests may act as reservoirs for recolonization and as corridors between remaining primary forest fragments. From a biodiversity conservation perspective, it is important to know how secondary forests compare with primary forests in terms of species richness and species similarity [10]. It is in this context that Tan Phu forest (Fig. 1) has been chosen for study, since it represents one of the last lowland forests in southern Vietnam and has been logged intensively during the last decades.

This paper aims to answer three questions:

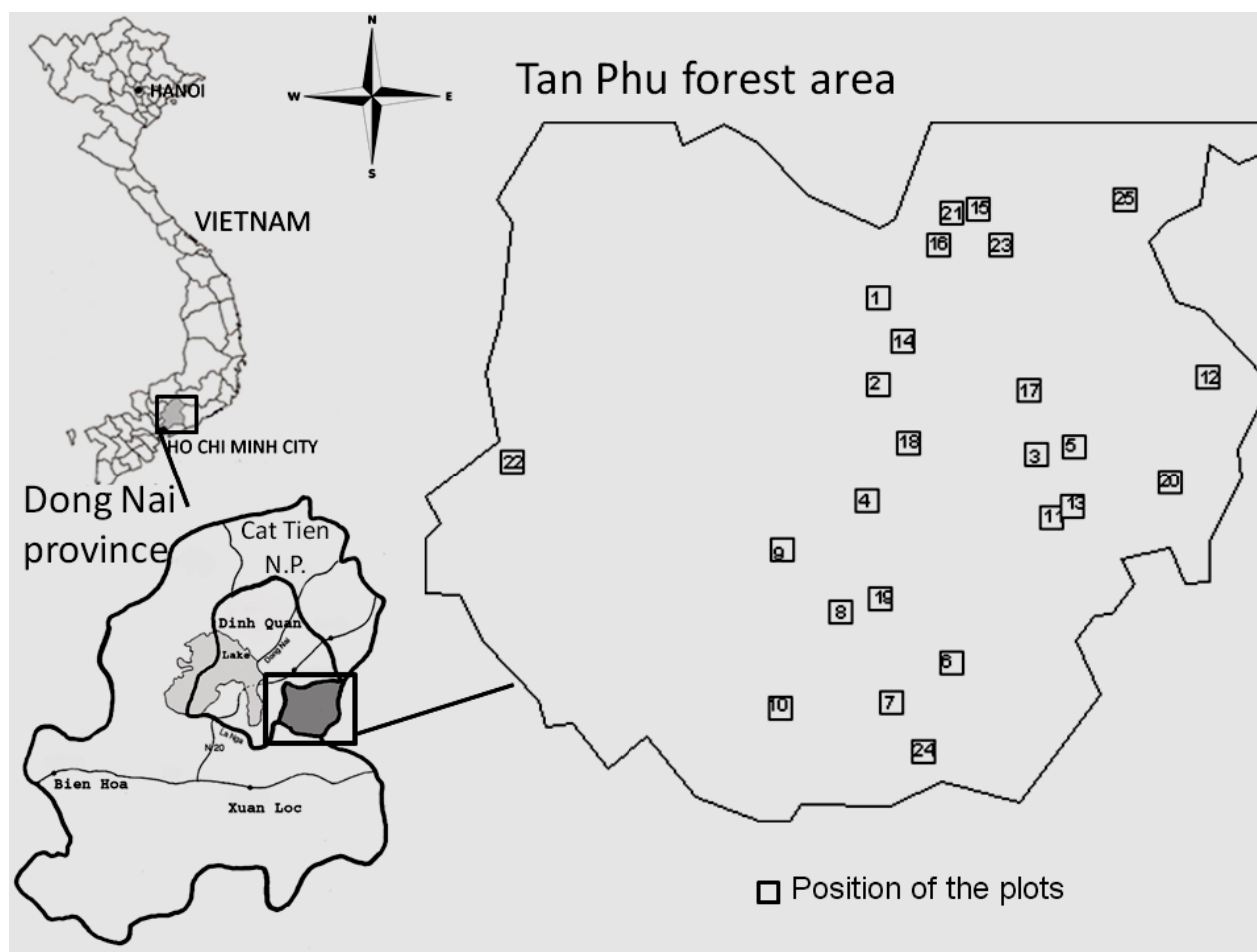
1. What is the floristic structure after logging?
2. What is the biodiversity value of Tan Phu forest in comparison with that of the nearby protected area?
3. How are the conservation species distributed within Tan Phu forest and how do they regenerate?

## Methods

### Study area

Tan Phu forest (Fig. 1) is located in southern Vietnam and covers 13 900 ha. Annual rainfall, measured at Talai, is 2,715 mm/yr. Rainfall is mostly spread between mid-May and mid-November. Mean annual temperature is 26°C with an amplitude of 3.7 °C. Soils are sandy and clayic, organic matter is poor (0.2 to 3%), rate of iron (0.1 to 12 mg/100g) and aluminum (0.1 to 2 mg/100g) are high, and pH is acid (5.65 to 4.08). The original forests have been described by Maurand [11]. In the past, forests were characterized by a large number of species belonging to *Dipterocarpaceae* and *Fabaceae*, associated in a complex mixture, and by two other families, *Lythraceae* and *Clusiaceae*. The main species were *Afzelia xylocarpa*, *Anisoptera costata*, *Dalbergia bariensis*, *Dipterocarpus alatus*, *Dipterocarpus dyeri*, *Heritiera cochinchinensis*, *Hopea odorata*, *Mesua ferrea*, *Sindora cochinchinensis*, *Shorea vulgaris*, *Vatica odorata* and *Xylia xylocarpa*. It is also stated in the

Indochina forest department records that logging started in the 1940s. However, there is no detailed data on logging before 1978. For the period 1978-1986, logged trees, over 60 cm in diameter, came from *Anisoptera costata*, *Dipterocarpus alatus*, *Dipterocarpus dyeri*, *Heriteria cochinchinensis*, *Hopea odorata*, *Lagerstroemia calyculata*, *Litsea pierrei*, *Shorea roxburghii*, *Shorea thorelii*, *Sindora cochinchinensis*, and *Xylia xylocarpa*. Successive and intense logging continued until 1996, and then logging was banned by the Vietnamese government.

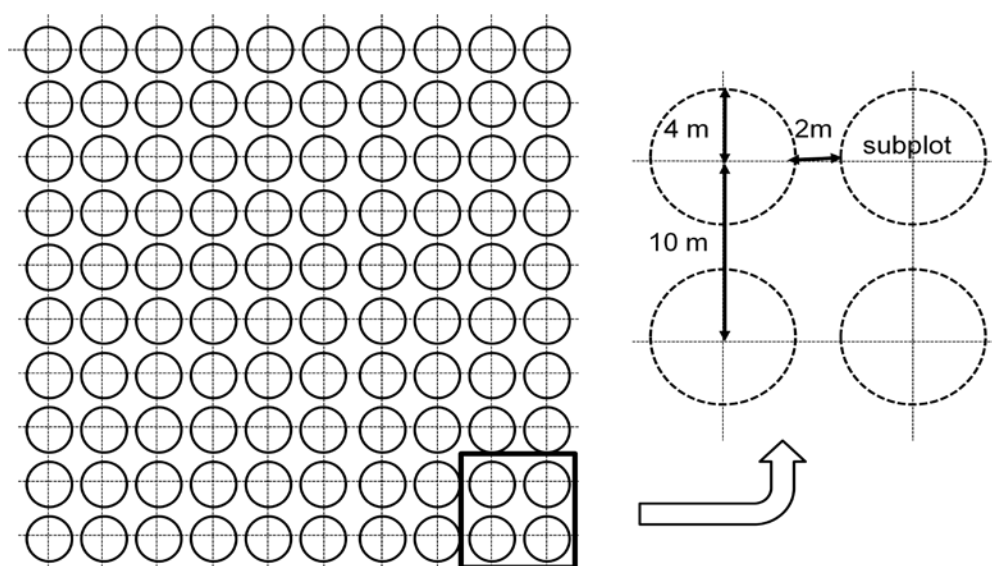


**Fig. 1: Location of the study area in Dong Nai Province –Vietnam**

### *Sampling strategy*

We developed a sampling strategy incorporating both the structure and floristic composition of forest stands. First, we conducted a preliminary survey to identify different types of forest and to locate replicate stands for each situation. Based on this survey, forest inventory plots were established across the forest area. The classic method using square sub-plots was tested, but the high density of climbers and shrubs in the undergrowth made setting up sub-plots slow and difficult. We found an alternative method using circular sub-plots which are positioned on the centre point of a 10m square network (Fig. 2). This does not require delimitation of the area. Trees (diameter  $\geq 10$  cm at dbh) are sampled if the distance from the center of the circle is less than or equal to 4 metres. This was a systematic method of sampling that covered close to 50% of the area and was less time-consuming. Regeneration (diameter  $< 10$  cm and height  $> 2$ m) was sampled if the

distance from the center of the circle was no greater than 1.2 metre. Tree species were identified using the Flora of Ho [12]. In total, 25 plots, each with 100 circular sub-plots, were established in Tan Phu forest. Plots were mainly located in the eastern part of the forest area as the western part is partly covered by plantation and partly devoted to agriculture (Fig. 1).



**Fig. 2. Sampling methodology using circular subplots**

### *Data analysis*

#### *Estimation of species richness*

The species richness estimators, ICE (Incidence-based Coverage Estimator) and ACE (Abundance-based Coverage Estimator) are modifications of the Chao and Lee [13] estimators discussed by Colwell and Coddington [14]. These have been calculated using EstimateS software [15].

#### *Shannon-Wiener index (H)*

A widely used measure of biological diversity is Shannon's index. This index is also referred to as "Shannon's information measure" or "entropy" [16].

#### *Simpson's Index of Diversity 1 - D*

The index represents the probability that two individuals randomly selected from a sample will belong to different species.  $D$  is the squared sum of the proportion of species relative to the total number of species. The value of the index ranges between 0 and 1, and the greater the value, the greater the sample diversity [17].

#### *Abundance Jaccard index*

This coefficient of similarity is an index of the extent to which two plots have both species and their abundances in common [18]. EstimateS software [15] was utilized for calculations.

#### *Distribution*

Distribution of the frequency of trees and their regeneration is performed with the module `s.value`, package `ADE4`, of the R software. R version 2.10.1 (2009-12-14). The R foundation for Statistical Computing.

## Results

### 1. Description and conservation value of the floristic groups in Tan Phu forest

A graphic representation of the Jaccard similarity index table is presented in Fig. 3. The closest plots are 1 and 22 with a percentage of shared abundance equal to 62%. The most different ones are plots 4 and 12 which share only 15% of their abundance. According to the hierarchic classification, six floristic groups of plots can be identified and their similarity indices are presented in Table 1.

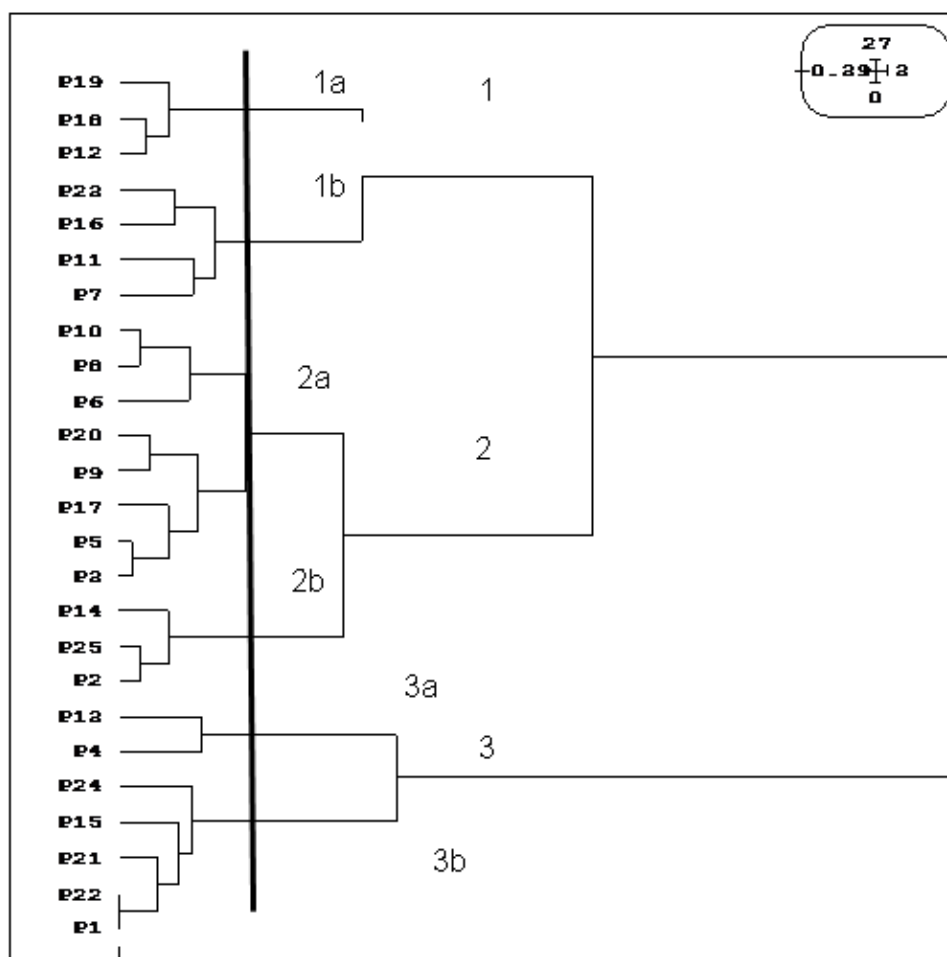


Fig. 3. Hierarchic classification of the 25 forest plots based on their similarity index

The floristic composition of each group is presented in the following appendices:

1a: This group is mainly characterized by *Shorea roxburghii* (which represents 16.74% of the total abundance of the species), *Syzygium zeylanicum* (9.14%), *Parinari annamensis* (7%), *Irvingia malayana* (4.39%), and *Calophyllum dongnaiensis* (3.68%). This group is composed of seven conservation species, all of which are *Dipterocarpaceae* species which represent 21.85% of the total abundance. *Shorea roxburghii* is the dominant one.

1b: This is characterized by *Diospyros maritima* (8.46%), *Memecylon sp.* (6.63%), *Irvingia malayana* (5.55%), *Vitex tripinnata* (5.06%), *Vatica odorata* (4.31%), *Syzygium chanlos* (3.56%) and *Hopea odorata* (3.48%). It has 10 conservation species and among this 8 *Dipterocarpaceae* which represent 15.25% of the total abundance (N = 85) and 2 Fabaceae species at a very low rate (0.91%).

2a: This is composed of *Syzygium chanlos* (8.18%), *Vatica odorata* (6.28%), *Dipterocarpus dyeri* (4.60%), *Diospyros lanceafolia* (4.09%) and *Grewia paniculata* (4.05%). The conservation value is close to those of 1b with 8 *Dipterocarpaceae* species which represent 13.54% and *Sindora cochinchinensis* (0.75%).

2b: This is composed of *Diospyros lanceafolia* (5.83%), *Acronychia pedunculata* (5.58), *Litsea pierrei* (3.93), *Xerospermum noronhianum* (3.93), *Dipterocarpus dyeri* (3.68%), and *Syzygium chanlos* (3.04%). It contains a total of 6 *Dipterocarpaceae* species (6.14%) and *Sindora cochinchinensis* (0.51%)

3a: This is characterized by *Lagerstroemia calyculata* (16.72%), *Xerospermum noronhianum* (12.74%), *Diospyros sp.* (8.60%) and *Dipterocarpus alatus* (6.79%). In addition, it has four other *Dipterocarpaceae* species (for a total of 8.44%) and 2 *Fabaceae* species (0.99%).

3b: This is composed of *Cratoxylon formosum* (11.29%), *Acronychia pedunculata* (9.53%), *Grewia paniculata* (9.47%), *Vitex tripinnata* (6.85%) and *Lagerstroemia calyculata* (5.42%). *Dipterocarpaceae* and *Fabaceae* species are non-dominant, respectively 4.31% and 2.15%, but at the same time, 11 conservation species are represented.

Globally, the 3 most abundant families are *Dipterocarpaceae* (11.7%), *Myrtaceae* (10.5%) and *Clusiaceae* (7.1%). *Lythraceae* represents 3.6% and *Fabaceae* only 1%.

Table 1: Specific richness (S), Shannon index (H), Simpson index (D) and Jaccard similarity index calculated for the different floristic groups and diversity value for the total of plots

Floristic groups	Area	S	H	D	Jaccard index					
					1a	1b	2a	2b	3a	3b
1a	1.5ha	86	5	0.94	--	0.56	0.55	0.42	0.4	0.46
1b	2ha	85	5.39	0.97		--	0.54	0.45	0.5	0.51
2a	4ha	107	5.67	0.97			--	0.54	0.49	0.55
2b	1.5ha	89	5.54	0.97				--	0.42	0.5
3a	1ha	73	4.73	0.93					--	0.45
3b	2.5ha	111	5.27	0.95						--
Total plots	12.5ha	176	6.02	0.98						

## 2. Biodiversity value of the Tan Phu forest

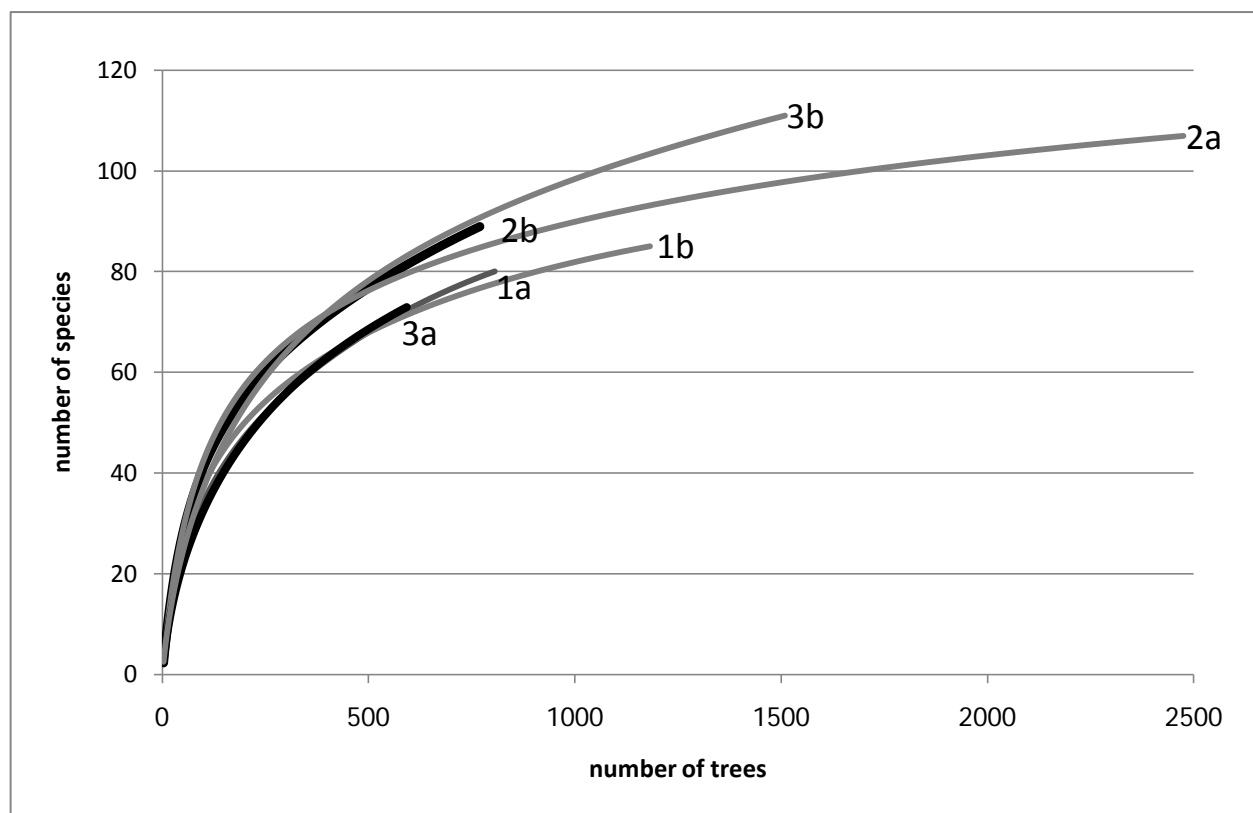
The total number of species found for all the 25 plots, equivalent to 12.5 ha, in the Tan Phu forest is 176 and, in terms of diversity, the Shannon index is 6.02 and the Simpson index is 0.98 (Table 1). By using ACE and ICE estimators, the total species richness can be estimated at 207 and 205, respectively. Observation of the species richness accumulation curves (Fig. 4) shows that the species richness is the highest in 3b and 2b with 111 species on 2.5 ha and 89 species on 1.5 ha, respectively. The Shannon index varies from 4.73 in 3a to 5.67 in 2a and the Simpson index changes from 0.93 in 3a to 0.97 in 1b, 2a, and 2b. The similarity is highest between 1a and 1b and lowest between 1a and 3a (Table 1).

In terms of conservation, 12 threatened species are found in the Tan Phu forest; these are *Azelia xylocarpa*, *Anisoptera costata*, *Dalbergia bariensis*, *Dipterocarpus alatus*, *Dipterocarpus dyeri*,

*Hopea odorata*, *Shorea guiso*, *Shorea roxburghii*, *Shorea thorelii*, *Sindora cochinchinensis*, *Vatica odorata*, and *Xylia xylocarpa*.

### 3. Distribution and regeneration of the conservation species

Distribution of the frequency of trees and regeneration of each conservation species are presented in Fig. 5. Four *Dipterocarpaceae* species are well represented in Tan Phu. These are, namely, *Dipterocarpus alatus* (1.4% of the trees), *Dipterocarpus dyeri* and *Shorea roxburghii* (2.6%), and *Vatica odorata* (2.97%). These are present in more than half of the total number of plots. The regeneration is numerous for *Vatica odorata* (3.67%) but limited for the other species and in particular for *Dipterocarpus alatus* (0.48%), which is found in only four plots. *Hopea odorata* and *Anisoptera costata* are less represented, respectively 1% and 0.6% of the trees and 0.4% and 0.48% of the regeneration. Of these two species, trees are present in 18 and 17 plots, respectively, but the regeneration occurs only in 9 and 6 plots. The last two *Dipterocarpaceae* species, namely *Shorea guiso* and *S. thorelii*, are rare (0.27%) and their regeneration is nearly absent (0.02% observed in just one single plot). The *Fabaceae* species are also barely represented. *Sindora cochinchinensis* alone is better represented with 0.6% of the adults (in 15 plots) and 0.48 of the regeneration (in 10 plots). *Azalia xylocarpa* (0.05% of the total number of trees), *Dalbergia bariensis* (0.02%), and *Xylia xylocarpa* (0.29%) are rare. The regeneration is absent for *A. xylocarpa* and nearly absent for *X. xylocarpa* (0.03%) but is non-negligible for *D. bariensis* (0.07%) in comparison with the adult's occurrence.



**Fig. 4. Species accumulation curves for the different floristic groups identified in the Tan Phu forest**

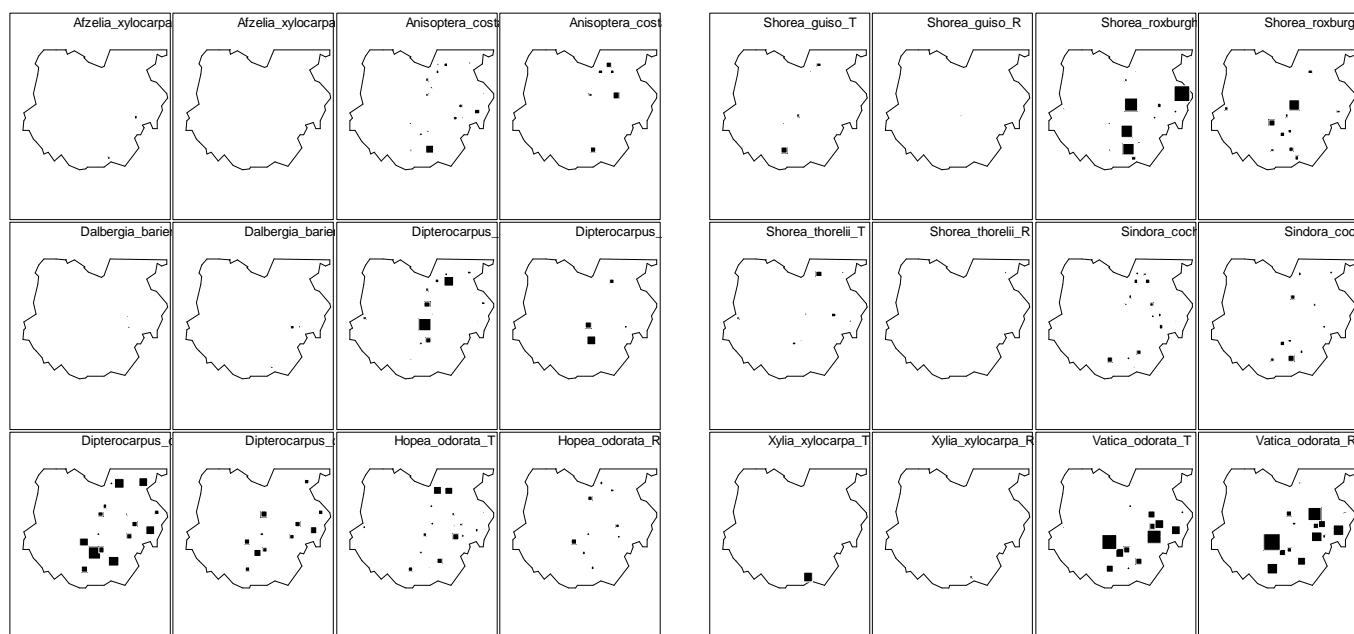


## Discussion

### *Floristic structure after logging*

In Tan Phu, six groups of forest can be identified, and the Jaccard indices range from 40% to 56%. In the neighboring protected area of Cat Tien National Park, similarity indices range from 0 to 37% [19]. These indices are comprised of between 36.13% and 40.25% in a logged forest in Ha Tinh province in central Vietnam [20]. Forest types in Tan Phu share a large number of species; these are more homogeneous than other protected or logged forests in Vietnam. Some species, like *Acronychia pedunculata*, *Buchanania arborescens*, *Carallia brachiata*, *Careya arborea*, *Combretum parvifolium*, *Diospyros maritima*, *Elaeocarpus tectorius*, *Garcinia ferrea*, *Grewia tomentosum*, *Iringia malayana*, *Parinari annamensis*, *Syzygium chanlos*, *S. grandis*, *Vitex tripinnata*, and *Xylopiavialana*, occur in 80% of the plots in Tan Phu forest.

Groups 1a, 1b, and 2a could be classified as *Dipterocarpaceae* forests. The percentage of *Dipterocarpaceae* trees varied from 21.8% to 13.54%, and these correspond to different levels of species arrangements after logging. Okuda *et al.* [21] have reported a total density percentage of 9.2% *Dipterocarpaceae* in a primary forest in Malaysia. Tran *et al.* [20] have reported a maximum of 15.6% *Dipterocarpaceae* trees in some forests in central Vietnam. Compared with other forests in Vietnam and even in the region, Tan Phu forest can be considered as an important pool of *Dipterocarpaceae*. Groups 2b and 3a correspond to a *Lythraceae* or *Myrtaceae* forest mixed with *Sapindaceae*, *Ebenaceae*, and *Dipterocarpaceae* species. These are degraded forests in which the dominant species moved from *Dipterocarpaceae* and *Fabaceae* to *Myrtaceae* or *Lythraceae* families after logging. Group 3b could be classified as *Guttifereae-Rutaceae-Tiliaceae* forest and corresponds to the extreme degradation of both *Dipterocarpaceae* and *Fabaceae* forests (figure 6).



**Fig. 5. Distribution of the frequency of trees (T) and regeneration (R) for the conservation species in Tan Phu. The size of the square reflects the importance of the frequency in the considered plot.**

### *Biodiversity value of Tan Phu forest and in comparison with Cat Tien National Park*

The observed species richness ranges from 86 to 89 within 1.5 ha in a *Dipterocarpaceae-Myrtaceae* forest (1a) and in a *Dipterocarpaceae-Ebenaceae* forest (2b), respectively. It is equivalent to 85 within 2 ha of a *Myrtaceae-Ebenaceae-Dipterocarpaceae* forest (1b) and it reaches 107 within 4 ha of a *Myrtaceae-Dipterocarpaceae* forest (2a). By comparison, only 18 species occur in a 1 ha plot of *Dipterocarpaceae* forest in Cat Tien National Park. *Dipterocarpaceae* forests are much richer in Tan Phu than in Cat Tien National Park. Anyway, considering that the number of tree species of 10 cm dbh is within the range of 100–150 species typically recorded in Southeast Asian lowland rainforests [22], the observed species richness is low both in the logged and protected forests. Observed species richness is 73 within a 1 ha *Lythraceae-Sapindaceae-Ebenaceae* forest (3a) in Tan Phu. By comparison, Blanc *et al.* [19] have reported 57 to 91 species in 1 ha plots of *Lythraceae-Ebenaceae* forest in Cat Tien National Park (figure 1); there is no difference between logged and protected forest. In Tan Phu, the highest species richness is observed on 2.5 ha of a *Guttiferae-Rutaceae-Tiliaceae* forest (3b) where it is equivalent to 111 species. In this latest forest type, the species are mostly pioneer species like *Cratogeomys formosum*, *Acronychia pedunculata*, *Grewia paniculata*, and *Vitex tripinnata*. In Tan Phu, degraded forests composed of pioneer species and having a low rate of *Dipterocarpaceae* have higher species richness. In total, the observed species richness reaches 176 on 12.5 ha in Tan Phu and the estimated species richness is comprised of between 205 and 207. In Cat Tien National Park, the same number of species has been recorded in only 5 ha. The total species richness can be considered higher in Cat Tien than in Tan Phu forest. For Chittibabu and Parthasarathy [23] and Zhu *et al.* [24], although species richness could be higher in some fragments, the species diversity is generally lower in the logged forests than in the protected forest. In Tan Phu, the forest types share a large number of common species, but some important species, like *Heritiera cochinchinensis* and *Mesua ferrea*, may have already disappeared.

The diversity ranges from 0.94 to 0.97 and from 5.00 to 5.67, respectively, for the Simpson and Shannon indices in *Dipterocarpaceae* forests (1a, 1b, 2a). In the neighboring protected forest, the values are 0.51 and 1.98. The diversity of the *Dipterocarpaceae* forest in Tan Phu is the result of logging. The diversity increases due to both the reduction of native species and to the appearance of pioneer species. The *Lythraceae-Sapindaceae-Ebenaceae* forest (3a) has the lowest value, equivalent to 0.93 and 4.73, respectively, for the Simpson and Shannon indices. Blanc *et al.* [19] found values ranging from 0.84 to 0.96 and 4.15 to 5.62, respectively, for the same indices in a similar forest type in Cat Tien National Park. Diversity of *Lythraceae* forest could be considered equivalent in both logged and protected forest. Finally, in heavily degraded forests (3b), the diversity could be linked to the invasion of some pioneer species and to the reduction of native species. The Simpson and Shannon indices are equivalent to 0.95 and 5.27, respectively. Cumulatively, the diversity values are 0.98 and 6.02 respectively for the Simpson and Shannon indices. The diversity observed in Tan Phu is high and could be linked to the decreasing abundance of native species and to an increasing abundance of pioneer species.

### *Distribution and regeneration of the conservation species*

The *Dipterocarpaceae* family is the most important one and represents 11.7% of the total number of trees. This family is dominant in two of the six floristic groups and represents 21.85% of the trees. Eight *Dipterocarpaceae* species, found in Tan Phu, are considered as conservation species. In comparison, Blanc *et al.* [19] have inventoried only five species of *Dipterocarpaceae*, which represents less than 10% of the abundance in the Cat Tien National Park. *Dipterocarpaceae* could also account for 15.6% in some forests in Central Vietnam [20], but it concerns only two species. Tan Phu can be considered as an important area for the conservation of *Dipterocarpaceae*. However, except for *Vatica odorata* and to a certain degree *D. dyeri* and *S. roxburghii*, the regeneration is limited. *S. guiso* and *S. thorelii* are even at risk of extinction in Tan Phu.

*Fabaceae* species represent only 1% of the abundance in Tan Phu and account for four conservation species. By comparison, Blanc *et al.* [19] have found 12 species of *Fabaceae* in Cat Tien National Park. Except for *Sindora cochinchinensis* which has the highest occurrence and represents 0.6% of the adult trees, the three other species, namely *Azelia xylocarpa*, *Dalbergia bariensis*, and *Xylia xylocarpa*, are rare and their regeneration is limited. These three species are close to extinction.



**Fig. 6 : Some forest types occurring in Tan Phu area in the south of Vietnam. Left to right: *Dipterocarpaceae* forest (2a), *Lythraceae* forest (3a), *Guttiferae-Rutaceae-Tiliaceae* forest (3b). Photo credit: Jérôme Millet**

### Implications for conservation

In the study area, logging has produced a gradient of degradation of the original *Dipterocarpaceae* and *Fabaceae* forests. This leads to six actual different floristic compositions in which the abundance of native species has decreased to the benefit of pioneer species. As a result, *Dipterocarpaceae* species are still dominant in two forest types but are progressively less abundant in the four others, while *Fabaceae* species have nearly disappeared. Overall, the logged forest of Tan Phu presents a low species richness when compared with the neighboring protected forest of Cat Tien, but the floristic groups observed often have high species richness and diversity values due to the appearance of many pioneer species. The invasion of pioneer species also creates a high percentage of similarity among the groups. From a conservation point of view, the studied forest stands continue to enclose important conservation species, particularly in the *Dipterocarpaceae* family. Some of these species are abundant and continue to regenerate (for instance, *Dipterocarpus dyeri*, *Shorea roxburghii*, and *Vatica odorata*), but some others, like *Anisoptera costata*, *D. alatus*, *Hopea odorata*, *Shorea guiso*, and *S. thorelii*, are scattered and few regenerations are observed. The four *Fabaceae* species, which are *Azelia xylocarpa*, *Dalbergia bariensis*, *Sindora cochinchinensis*, and *Xylia xylocarpa*, are rare and, except for *S. cochinchinensis*, are close to extinction. In this regard, some species like *Heritiera cochinchinensis* and *Mesua ferrea* observed in the past have not been identified in this study and may have disappeared. The logged forest of Tan Phu still has a high conservation value, but urgent action should be undertaken to preserve the conservation species. Two *Dipterocarpaceae* forests (1b & 2a) identified in the study should be protected in order to preserve most of the *Dipterocarpaceae* species. The conservation species closest to extinction should be considered under afforestation programs.

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## References

- [1] Trung, T.V. 1998. Ecosystems of tropical forests in Vietnam. *Science and Technics Publishing House. Ha Noi.*
- [2] Dang, N. V., Mai, T. D., Chu, H. C., Huy, T. D., Kinh, N. H. 2001. Forestry in Vietnam (1945-2000), development progress and experienced lessons. *Agricultural Publishing House. Ha Noi.*
- [3] Nghia, N.H. 2000. Some threatened tree species of Vietnam. *Agricultural Publishing House, Ha Noi.*
- [4] World Database on Protected Areas. <http://www.wdpa.org/Statistics.aspx>, access on October, 2010.
- [5] Primack, R.B. and Lee, H.S. 1991. Population dynamics of pioneer (macaranga) trees and understorey (Mallotus) trees (Euphorbiaceae) Primary and selectively logged Bornean rain forests. *Journal of tropical ecology* 7 : 439-458.
- [6] Cannon, C.H., Peart, D.R., Leighton, M. 1998. Tree species diversity in commercially logged Bornean rainforest. *Science* 281, 1366-1368.
- [7] Parrotta, J.A., Francis, J.K., Knowles, O.H. 2002. Harvesting intensity affects forest structure and composition in an upland Amazonian forest. *Forest Ecology and Management* 169: 243-255.
- [8] Makana, J.R. and Thomas, S.C. 2006. Impacts of selective logging and agricultural clearing on forest structure, floristic composition and diversity, and timber tree regeneration in the Ituri Forest, Democratic Republic of Congo. *Biodiversity and Conservation* 15:1375–1397
- [9] Ashton, P.S. 2008. Changing values of Malaysian forests: the challenge of biodiversity and its sustainable management. *Journal of Tropical Forest Science* 20: 282–291.
- [10] Brearley, F.Q., Prajadinataa, S., Kidd, P.S., Proctor, J. 2004. Structure and floristics of an old secondary rain forest in Central Kalimantan, Indonesia, and a comparison with adjacent primary forest. *Forest Ecology and Management* 195 385–397
- [11] Maurand, P., 1943. L'indochine forestière. *Imprimerie d'Extrême Orient, Hanoi.* 121p
- [12] Ho, P.H. 2000. Cay Co Viet Nam. An Illustrated Flora of VietNam. 3 volumes. *Youth Publishing House, Ho Chi Minh City.*
- [13] Chao, A and Lee, S.M. 1992. Estimating the number of classes via sample coverage. *Journal of the American Statistical Association* 87 : 210-217.
- [14] Colwell, R. K., Coddington J. A. 1994. Estimating terrestrial biodiversity through extrapolation. *Philosophical Transactions of the Royal Society (Series B)* 345, 101-118.
- [15] Colwell, R. K. 1997. EstimateS : statistical estimation of species richness and shared species from samples. Version 5. User's guide and application published at : <http://viceroy.eeb.uconn.edu/estimates>.
- [16] Shannon, C. E. 1948. A mathematical theory of communications. *Bell System Technical Journal* 27 : 379-423, 623-656.
- [17] Simpson, E. H. 1949. Measurement of diversity. *Nature* 163 : 688
- [18] Magurran, A. E. 2004. *Measuring biological diversity*. Blackwell.
- [19] Blanc, L., Maury-Lechon, G., Pascal, J.P. 2000. Structure, floristic, composition and natural regeneration in the forests of Cat Tien National Park, Vietnam: an analysis of the successional trends. *Journal of biogeography*, 27, 141-157.

- [20] Tran, H., Iida, S., Inoue, S. 2005. Species composition, diversity and structure of secondary tropical forests following selective logging in Huong Son, Ha Tinh Province, Vietnam. *Journal Fac. Agr., Kyushu Univ.*, 50 (2), 551-571.
- [21] Okuda, T., Suzuki, M., Adachi, N., Quah, E.S., Hussein, N.A., Manokaran, N. 2003. Effect of selective logging on canopy and stand structure and tree species composition in a lowland dipterocarp forest in peninsular Malaysia. *Forest ecology and management* 175 297-320.
- [22] Whitmore T.C., 1990. An introduction to tropical rain forests. Clarendon Press, Oxford, UK.
- [23] Chittibabu, C.V., Parthasarathy, N. 2000. Attenuated tree species diversity in human-impacted tropical evergreen forest sites in Kolli hills, Eastern Ghats, India. *Biodiversity and Conservation* 9: 1493–1519.
- [24] Zhu, H., Xu, Z.F., Wang, H., Li, B.G. 2004. Tropical rain forest fragmentation and its ecological and species diversity changes in southern Yunnan. *Biodiversity and Conservation* 13: 1355–1372.
- [25] World Conservation Union (IUCN). *The IUCN Red List of Threatened Species*. Available from <http://www.iucnredlist.org>

## Appendix 1. floristic composition of the forest groups

Floristic Groups	Family	Composition %	Main Species	%	Conservation status [25]		
1a	Dipterocarpaceae	21.85	<i>Shorea roxburghii</i> G. Don	16.74	EN / VU		
			<i>Dipterocarpus dyeri</i> Pierre	1.66	CR / NT		
			<i>Vatica odorata</i> Symington	1.31	VU		
			<i>Dipterocarpus alatus</i> Roxb.	1.3	EN / NT		
			<i>Hopea odorata</i> Roxb.	0.35	VU / NT		
			<i>Shorea thorelii</i> Pierre	0.24	CR		
			<i>Anisoptera costata</i> Korth.	0.23	EN / VU		
			<i>Syzygium zeylanicum</i> DC.	9.14			
			Myrtaceae	18.28			
			Guttifereae	7.48	<i>Calophyllum calaba</i> L.	3.68	
			Chrysobalanaceae	7	<i>Parinari anamensis</i> Hance	7	
			Irvingiaceae	4.39	<i>Irvingia malayana</i> Warb.	4.39	
			1b	Dipterocarpaceae	15.25	<i>Vatica odorata</i> Symington	4.31
<i>Hopea odorata</i> Roxb.	3.48	VU / NT					
<i>Shorea roxburghii</i> G. Don	2.82	EN / VU					
<i>Dipterocarpus alatus</i> Roxb.	2.24	EN / NT					
<i>Anisoptera costata</i> Korth.	1.57	EN / VU					
<i>Dipterocarpus dyeri</i> Pierre	0.58	CR / NT					
<i>Dipterocarpus intricatus</i>	0.16	LC					
<i>Shorea guiso</i> Bl.	0.08	CR					
Ebenaceae	12.1	<i>Diospyros maritima</i> Bl.				8.46	
Myrtaceae	6.88	<i>Syzygium chanlos</i> Merr. & Perry				3.56	
Melastomaceae	6.63	<i>Memecylon</i> sp.				6.63	
Verbenaceae	5.63	<i>Vitex tripinnata</i> Merr.				5.06	
Irvingiaceae	5.55	<i>Irvingia malayana</i> Warb.				5.55	
Fabaceae	0.91	<i>Sindora cochinchinensis</i> Baill.				0.83	LR / VU
		<i>Dalbergia bariensis</i> Pierre				0.08	EN

2a	<i>Myrtaceae</i>	14.77	<i>Syzygium chanlos Merr. &amp; Perry</i>	8.18	
	<i>Dipterocarpaceae</i>	13.54	<i>Vatica odorata Symington</i>	6.28	VU
			<i>Dipterocarpus dyeri Pierre</i>	4.61	CR / NT
			<i>Hopea odorata Roxb.</i>	0.83	VU / NT
			<i>Shorea guiso Bl.</i>	0.52	CR
			<i>Anisoptera costata Korth.</i>	0.52	EN / VU
			<i>Shorea roxburghii G. Don</i>	0.36	EN / VU
			<i>Shorea thorelii Pierre</i>	0.27	CR
			<i>Dipterocarpus alatus Roxb.</i>	0.12	EN / NT
	<i>Ebenaceae</i>	7.54	<i>Diospyros lancaefolia</i>	4.09	
	<i>Tiliaceae</i>	4.05	<i>Grewia paniculata</i>	4.05	
	<i>Fabaceae</i>	0.83	<i>Sindora cochinchinensis Baill.</i>	0.75	LR / VU
2b	<i>Myrtaceae</i>	9.64	<i>Syzygium chanlos Merr. &amp; Perry</i>	3.04	
	<i>Ebenaceae</i>	9.26	<i>Diospyros lancaefolia Roxb.</i>	5.83	
	<i>Dipterocarpaceae</i>	6.14	<i>Dipterocarpus dyeri Pierre</i>	3.68	CR / NT
			<i>Dipterocarpus alatus Roxb.</i>	1.52	EN / NT
			<i>Anisoptera costata Korth.</i>	0.51	EN / VU
			<i>Shorea thorelii Pierre</i>	0.17	CR
			<i>Hopea odorata Roxb.</i>	0.13	VU / NT
			<i>Vatica odorata Symington</i>	0.13	VU
	<i>Sapindaceae</i>	5.83	<i>Xerospermum noronhianum Bl.</i>	3.93	
	<i>Rubiaceae</i>	5.71	<i>Metadina trichotoma Bakh.</i>	3.55	
	<i>Rutaceae</i>	5.71	<i>Acronychia pedunculata Roxb.</i>	5.58	
	<i>Lauraceae</i>	4.94	<i>Litsea pierrei Merr.</i>	3.93	
	<i>Fabaceae</i>	0.89	<i>Sindora cochinchinensis Baill.</i>	0.51	LR / VU
3a	<i>Lythraceae</i>	16.72	<i>Lagestroemia calyculata Pierre</i>	16.72	
	<i>Sapindaceae</i>	13.57	<i>Xerospermum noronhianum Bl.</i>	12.74	
	<i>Ebenaceae</i>	11.75	<i>Diospyros sp.</i>	8.6	
	<i>Dipterocarpaceae</i>	8.44	<i>Dipterocarpus alatus Roxb.</i>	6.79	EN / NT
			<i>Hopea odorata Roxb.</i>	0.83	VU / NT
			<i>Dipterocarpus dyeri Pierre</i>	0.33	CR / NT
			<i>Shorea guiso Bl.</i>	0.33	CR

			<i>Anisoptera costata</i> Korth.	0.16	EN / VU
	<i>Fabaceae</i>	0.99	<i>Sindora cochinchinensis</i> Baill.	0.66	LR / VU
			<i>Afzelia xylocarpa</i> (Kurz) Craib.	0.33	EN
3b	<i>Guttifereae</i>	12.93	<i>Cratoxylon formosum</i> Dyer	11.29	
	<i>Rutaceae</i>	10.77	<i>Acronychia pedunculata</i> Roxb.	9.53	
	<i>Tiliaceae</i>	9.53	<i>Grewia tomentosa</i> Jussieu	9.47	
	<i>Verbenaceae</i>	7.9	<i>Vitex tripinnata</i> Merr.	6.85	
	<i>Lythraceae</i>	5.42	<i>Lagerstroemia calyculata</i> Pierre	5.42	
	<i>Dipterocarpaceae</i>	4.31	<i>Dipterocarpus dyeri</i> Pierre	1.7	CR / NT
			<i>Dipterocarpus alatus</i> Roxb.	0.52	EN / NT
			<i>Shorea thorelii</i> Pierre	0.65	CR
			<i>Shorea roxburghii</i> G. Don	0.45	EN / VU
			<i>Anisoptera costata</i> Korth.	0.45	EN / VU
			<i>Shorea guiso</i> Bl.	0.26	CR
			<i>Hopea odorata</i> Roxb.	0.19	VU / NT
			<i>Vatica odorata</i> Symington	0.06	VU
	<i>Fabaceae</i>	2.15	<i>Xylia xylocarpa</i> Taubert	1.37	VU
			<i>Sindora cochinchinensis</i> Baill.	0.33	LR / VU
			<i>Afzelia xylocarpa</i> (Kurz) Craib.	0.13	EN

LC : Least Concern. VU: Vulnerable. NT : Near threatened. EN : Endangered. CR : Critically Endangered