Diversity and composition of understory vegetation in the tropical seasonal rain forest of Xishuangbanna, SW China

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Abstract: Tropical forests vegetation and community research have tended to focus on the tree component, and limited attention has been paid to understory vegetation. Species diversity and composition of the understory of tropical seasonal rain forest were inventoried in a 625m^2 area (for sapling layer) and a 100m^2 area (for herb/seedling layer) in three 1ha plots. We found 3068 individuals belonging to 309 species, 192 genera and 89 families. The most important family as determined by the Family Importance Value (FIV) was Rubiaceae in both sapling and herb/seedling layers. In terms of Importance Value Index (IVI), the shrub *Mycetia gracilis* (Rubiaceae) was the most important species in the sapling layer and the pteridophyte *Selaginella delicatula* (Selaginellaceae) was the most ecological significant species in the herb/seedling layer. Much more vascular plant species were registered in the understory than in the tree layer totaled among the three plots. The species diversity did not differ significantly among the tree layer, sapling layer and herb/seedling layer. Given that we still know little about the understory plant community for growth forms other than trees, the results from the present study indicate that more attention should be paid to the understory vegetation during the decision-making process for biodiversity conservation in the tropical forests. Rev. Biol. Trop. 59 (1): 455-463. Epub 2011 March 01.

Key words: herb, non-dipterocarp tropical forest, sapling, shrub, species richness, seedling, understory plants.

The understory is an integral component of forest ecosystems generally supporting a large fraction of total community floristic diversity (Gentry & Dodson 1987, Gentry & Emmons 1987, Mayfield & Daily 2005, Tchouto *et al*. 2006) and providing habitats and food sources for many kinds of animals (Gentry & Emmons 1987, Hirao *et al*. 2009). Understory vegetation could also influence community dynamics and succession patterns (Newbery *et al*. 1999, Royo & Carson 2006) and contribute to nutrient cycling (Nilsson & Wardle 2005). Understory composition usually varies considerably among different forest types (Hart & Chen 2008). Several factors have been suggested to account for this variation, including overstory structure and composition (Hart & Chen 2008, Sangar *et al*. 2008), soil nutrient and moisture availability (Poulsen & Pendry 1995, Newbery *et al*. 1996), succession history (LaFrankie *et al*. 2006), forest management strategies (Hart & Chen 2008, Ares *et al*. 2009), and fragmentation (Benitez-Malvido & Martinez-Ramos 2003, Rasingam & Parthasarathy 2009).

Tropical rain forests are among the most species rich communities on Earth. Many studies on vascular plants in tropical forests have focused on trees with diameter at breast height (DBH) ≥10cm, whereas the understory remains the least understood. In fact, the understory of tropical forests may also be species-rich (Tchouto *et al*. 2006). In a tropical wet forest in Rio Palenque of Ecuador, 32 species were recorded in the overstory (DBH≥10cm);

in contrast, 176 species (herbs, shrubs, and saplings) were enumerated in the underlayer within a 0.1ha plot (Gentry & Dodson 1987). In a permanent plot of 30ha in the tropical forest in Western Ghats of India, 148 tree species (GBH≥30cm) and 155 species of understory plants were recorded (Annaselvam & Parthasarathy 1999). Thus, it is important to include the understory vegetation in a biodiversity inventory. Otherwise, the plant species richness would be underestimated.

Xishuangbanna, located in the Northern margin of the tropical Asia, maintains large areas of tropical forests. However, tropical forests in this area are rapidly being destroyed due to increased human activities (Li *et al*. 2008), such as rubber plantation (Ziegler *et al*. 2009). In the fragmented forests, species composition of overstory has been changed and species richness has declined (Zhu *et al*. 2004). Although the understory is more sensitive to forest fragmentation and biological invasion than the overstory (Muthuramkumar *et al*. 2006) and herbaceous plant species have higher extinction rates than woody species (Levin & Levin 2001), we still lack an understanding how understory vegetation will change in face of the clearance and fragmentation occurring in this area. Even worse, we have limited information on the understory vegetation in the old-growth tropical forests in this area. If forests should differ in the understory composition, they would differ greatly in terms of the number of flowers and fruits and show different patterns of forest dynamics (Gentry & Emmons 1987, Harms *et al*. 2004, LaFrankie *et al*. 2006).

In this study, we compared the plant diversity and composition of understory vegetation (shrubs, tree saplings (DBH<2cm, height>1m), tree seedlings (height<1m), and herbs) among three sites based on a biodiversity inventory carried out in old-growth tropical seasonal rain forests in Xishuangbanna, SW China. The results of alpha and beta diversity of adult lianas (Lü *et al*. 2009) and trees (Lü *et al*. 2010) are already available. This study is the first attempt to study the diversity patterns in the understory vegetation of tropical forests in Xishuangbanna. These data will increase our understanding of the tropical forests in this area by presenting a full view of the understory.

MATERIALS AND METHODS

Study area: This study was conducted in three localities in Xishuangbanna (21°08’-22°36’ N-99°56’-101°50’ E), SW China, those were referred as: Menglun (21°57’ N-101°12’ E; 730m), Mengla (21°32’ N-101°33’ E; 581m) and Manyang (21°27’ N- 101°36’ E; 643m). Xishuangbanna borders Myanmar in the Southwest and Laos in the Southeast, and has mountainous topography, with mountain ridges running in a North–South direction, decreasing in elevation Southward (Cao *et al*. 2006). This area has a typical monsoon climate with three distinct seasons: a humid hot rainy season (May-October), a foggy cool-dry season (November-February) and a hot-dry season (March-April). The mean annual temperature is 21.7°C and there is little variation between years. The average annual rainfall is 1 550mm, with 87% occurring in the rainy season and 13% in the dry season. During the dry season, fog occurs almost every day and is heaviest from midnight until mid-morning. The mean relative humidity is 87%. The soil is classified as Latosol (pH 4.5-5.5) developed from purple sandstone (Cao *et al*. 2006). The canopies of the forests in this study are dominated by the trees *Pometia tomentosa* and *Terminalia myriocarpa* (Lü *et al*. 2010). While all these forests are old-growth ones, the forest in Manyang plot had been disturbed (about 10 stems DBH>40cm had been logged by local people) before it was included in the nature reserve.

Field sampling: Fieldwork was undertaken during December 2004 to April 2005. Each 1ha plot was divided into 100 subplots (10m×10m) to facilitate the inventory. The understory vegetation was stratified into two categories, sapling layer (individuals with height≥1m but DBH<2cm) and herb/seedling layer (individuals with height<1m). In each plot, all individuals taller than 1m and with

DBH less than 2cm were measured (DBH and height), labeled and identified to species within 25 quadrats of 5m×5m (bottom right of corresponding 10m×10m subplot, with the total area of 625m^2) spaced systematically within each 1ha plot. Within each 5m×5m quadrat, seedlings (woody plants less than 1m tall) and herbs were sampled in the same way in a 2m×2m grid (bottom right of corresponding quadrat, with the total area of 100m^2). Nomenclature of species follows Li *et al*. (1996).

The number of species and individuals of saplings, seedlings, and herbs were recorded in each 5m×5m quadrat and 2m×2m grid. The most commonly used species diversity indices such as Shannon (H'), Simpson (λ), Fisher's α, Hill's diversity indices (N1 and N2) and evenness (E) were calculated. We also calculated the Sorenson Index (SI) and Jaccard Coefficient (J), which are good indicators of floristic similarity between two communities. A modified importance value index (IVI) for each species was calculated by summing its relative density and relative frequency in each plot, following Rasingam & Parthasarathy (2009). The modified family importance value (FIV) for each family was estimated as the sum of relative diversity and relative density of the individuals in that family. Species diversity and composition were compared among the three different sites in order to examine the variation of understory composition in tropical seasonal forests.

RESULTS

Species richness and diversity: A total of 1277 individuals with DBH<2cm and height>1m (sapling layer) was recorded. They belonged to 214 species, 145 genera and 55 families (Table 1). In addition, 1791 individuals of vascular plants <1m (tree seedlings, shrubs, herbs and hemi-epiphytes) belonging to 184 species, 136 genera and 76 families (herb/seedling layer) were recorded. Overall, 309 species of vascular plants belonging to 192 genera and 89 families were recorded in the

TABLE 1

Number of stems, species, genera and families in the understory of tropical seasonal rain forest in Xishuangbanna, SW China

	Density (individuals/ha)	Species (species/ha)	Genera (genera/ha)	Families (families/ha)
Sapling layer				
Menglun	510	124	103	45
Mengla	381	112	93	44
Manyang	386	81	64	31
Average	426	106	87	40
Subtotal	1277	214	145	55
Herb/seedling layer				
Menglun	579	69	59	42
Mengla	564	102	85	59
Manyang	648	108	84	57
Average	597	93	76	53
Subtotal	1791	184	136	76
Understory (Sapling layer + Herb/seedling layer)				
Menglun	1089	160	121	60
Mengla	945	171	133	73
Manyang	1034	149	108	62
Average	1023	160	121	65
Total	3068	309	192	89

understory of three 1ha plots. All the species registered in this study are native to this area.

The number of vascular plant species per hectare was similar for both sapling and herb/seedling layers, whereas the number of individuals per hectare was higher in the herb/seedling layer than the sapling layer (Table 1). The number of species in the sapling layer varied from 81 (Manyang) to 124 (Menglun), in the herb/seedling layer from 69 (Menglun) to 108 (Manyang). In terms of most of the diversity indices, the sapling layer was the most diverse in Mengla (Table 2) and was the least diverse in Manyang. The herb/seedling layer was least diverse in Menglun caused by the lowest species richness. Mengla was more diverse than Manyang when Shannon-Wiener and Hill's diversity indices were considered. However, Manyang was more diverse than Mengla when Margalef's and Fisher's indices of species richness were considered. The higher evenness in the herb/seedling layer of Mengla may contribute to this contrasting pattern.

In terms of both SI and J, the composition of sapling layer in Menglun and Mengla was the most similar pair at family level (Fig. 1A, B). In contrast, Mengla and Manyang were the most similar pair at species level. For the herb/seedling layer, the composition of Mengla and Manyang was the most similar at all the three taxonomic levels (Fig. 1C, D).

Understory composition and structure: No species accounted for more than 4% of the combined importance value (Table 3) of the sapling layer. With 49 individuals the shrub *Mycetia gracilis* (Rubiaceae) was the most frequent species, and consequently, holding the highest importance value. The 10 most important species in the sapling layer accounted for 20% of the combined importance value. In contrast, this proportion was 35% in the herb/seedling layer. Three pteridophyte species, *Selaginella delicatula* (Dasv.) Alston (Selaginellaceae), *Tectaria fengii* Ching et C. H. Wang (Aspidiaceae) *and Bolbitis heteroclita* (Presl) Ching. (Bolbitidaceae), were the top three species with the highest IVIs due to the highest number and frequency of individuals (Table 3). In terms of IVI, only two species (the shrub *Mycetia gracilis* Craib and the tree *Pseuduvaria indochinensis* Merr.) appeared in the top tens in both sapling and herb/seedling layers. Averaged across the three 1ha plots, three-fourths of the species were represented by less than five individuals in both the sapling and herb/seedling layers, accounting for 37% and 23% of the total stems in each layer,

TABLE 2

Species diversity indices for sapling layer and herb/seedling layer in the three 1 ha forest plots of tropical seasonal rain forest in Xishuangbanna, SW China

	S	S/N	H'	□	D	Fisher's □	N1	N2	E
					Sapling layer				
Menglun	123	0.24	4.24	0.02	19.73	51.47	69.46	41.63	0.88
Mengla	112	0.29	4.30	0.02	18.68	53.46	73.66	49.93	0.91
Manyang	81	0.21	3.87	0.03	13.43	31.25	48.18	32.73	0.88
					Herb/seedling layer				
Menglun	69	0.12	3.37	0.06	10.69	20.42	29.12	15.85	0.80
Mengla	102	0.18	4.08	0.03	15.94	36.38	59.11	39.22	0.88
Manyang	108	0.17	3.65	0.06	16.53	36.99	38.46	16.29	0.78

S=total number of species censused. S/N=the rate of species increase per individual recorded. H□=Shannon-Wiener index, $H\square=-\sum(n_i/N_i)\ln(n_i/N_i)$. □=Simpson's concentration index, $\square=\sum(n_i/N_i)^2$. D=Margalef's index of species richness, D=(S-1)/lnN. □=Fisher's index of diversity, $S/N=\square\ln(1+N/\square)$. N1=Number 1 of Hill diversity indices, $N1=e^{H\square}$. N2=Number 2 of Hill diversity indices, N2=1/□. E=Pielou's evenness index, E=H□/lnS.

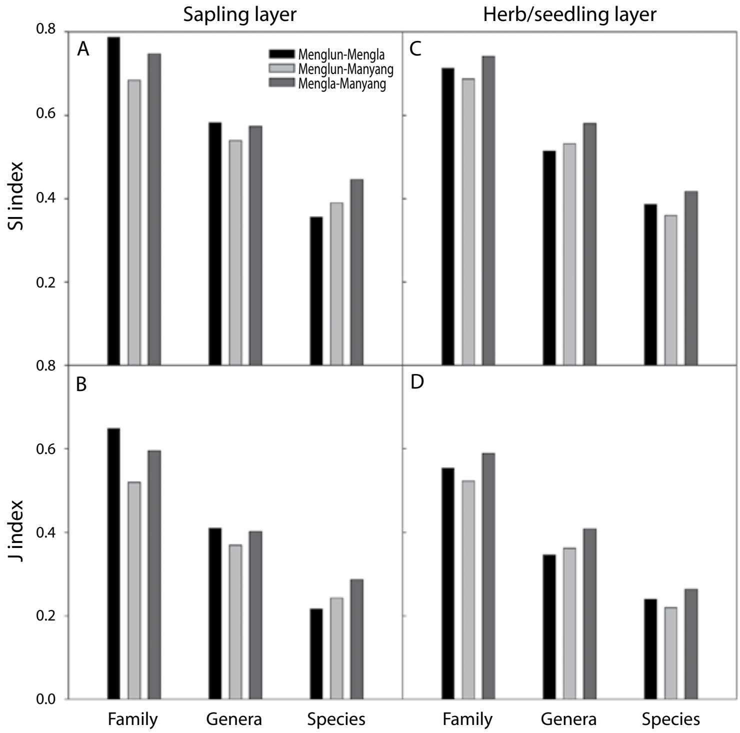

Fig. 1. Sorensen Index (SI) and Jaccard's Coefficient (J) for sapling layer (**A** and **B**) and herb/seedling layer (**C** and **D**) between pairs of plots of the three tropical seasonal rain forest plots in Xishuangbanna, SW China.

respectively. On average, there was only one species in the sapling layer and five species in the herb/seedling layer with >20 individuals in each plot, accounting for 1% and 41% of total stems in each stratum, respectively.

The 10 most important families made up 58% of the combined importance value in the sapling layer and 46% of the total in the herb/seedling layer. Rubiaceae was the most species-rich and the most important family in both sapling and herb/seedling layers (Table 4). Aspidiaceae, with the highest density, was the second most important family in the herb/seedling layer. Selaginellaceae, within which only one species recorded in the three plots, was ranked third in importance in the herb/seedling layer due to a very high density of this species. With respect to FIV, Rubiaceae, Euphorbiaceae, Lauraceae, Annonacae and Meliaceae were the five families found in the top ten in both sapling and herb/seedling layers (Table 4).

DISCUSSION

In terms of the tree layer (DBH≥10cm), the tropical seasonal forests in Xishuangbanna share several similar ecological characteristics, including forest profiles, physiognomic characteristics, species richness, density of stems for individual tree species and diameter size-classes with equatorial lowland rain forests (Zhu 1997). However, tropical forests with similar ecological characters in the tree layer may demonstrate major differences in understory structure and composition (LaFrankie *et al*. 2006). With 309 species recorded in the area of 1 875m^2 in three 1ha plots, the understory

TABLE 3
Density, frequency and importance value index (IVI) of the top 10 important species in the sapling layer and herb/seedling layer in three 1-ha tropical seasonal rain forest plots in Xishuangbanna, SW Chi

Species	Family	Density (individuals/ha)				Frequency	IVI
		Menglun	Mengla	Manyang	Total		
Shrub layer							
Mycetia gracilis Craib	Rubiaceae	13	25	11	49	23	6.57
Drypetes indica (Müll. Arg.) Pax & K. Hoffm.	Euphorbiaceae	51	0	1	52	12	5.50
Lasianthus sikkimensis Hook.	Rubiaceae	0	1	39	40	10	4.32
Pseuderanthemum malaccense (C. B. Clarke) Lindau	Acanthaceae	10	10	14	34	13	4.21
Randia acuminatissima Merr.	Rubiaceae	8	7	9	24	19	4.14
Pittosporopsis kerrii Craib	Icacinaceae	13	4	7	24	18	4.02
Walsura robusta Roxb.	Meliaceae	9	10	11	30	14	4.01
Mezzettiopsis creaghii Ridl.	Annonaceae	18	1	7	26	15	3.81
Sterculia lanceaefolia Roxb.	Sterculiaceae	1	4	15	20	16	3.47
Pseuduvaria indochinensis Merr.	Annonaceae	12	9	1	22	14	3.39
Herb layer							
Selaginella delicatula (Dasv.) Alston	Selaginellaceae	68	1	127	196	27	14.61
Tectaria fengii Ching et C. H. Wang	Aspidiaceae	103	37	15	155	30	12.72
Bolbitis heteroclita (Presl) Ching.	Bolbitidaceae	9	13	44	66	26	7.21
Mycetia gracilis Craib	Rubiaceae	2	19	30	51	25	6.23
Pseuduvaria indochinensis Merr.	Annonaceae	12	26	8	46	23	5.69
Phrynium capitatum Willd.	Marantaceae	22	27	3	52	19	5.48
Amomum villosum Lour.	Zingiberaceae	2	12	54	68	10	5.15
Diospyros xishuangbannaensis C.Y. Wu et H. Chu	Ebenaceae	0	37	2	39	18	4.62
Barringtonia macrostachya (Jack) Kurz	Lecythidaceae	27	7	2	36	17	4.31
Chasalia curviflora Thw.	Rubiaceae	14	10	11	35	17	4.26

vegetation in the tropical seasonal rain forest in Xishuangbanna was much more diverse than the tropical evergreen forest in Anamalais (155 species in three thousand $4m^2$ quadrats in a 30ha plot; Annaselvam & Parthasarathy 1999) and Kolli Hills (52 species in eight hundred $4m^2$ quadrats in a 8ha plot; Chittibabu & Parthasarathy 2000) and tropical lowland forests of Little Andaman Island (108 species in eight hundred $1m^2$ quadrats in eight 1ha plots, Rasingam & Parthasarathy 2009) in India. In the tropical wet forest of Rio Palenque in Ecuador, 176 species were recorded in the understory (height<3m) in a 0.1ha plot (Gentry & Dodson 1987). Similarly, 121 herb species were enumerated in three $50m^2$ plots in the tropical forests of Brunei (Poulsen & Pendry 1995). In the tropical forests of Cameroon, 99-229 species per hectare in the herbacous layer (1cm≤DBH<1.5cm) were registered (Tchouto *et al*. 2006). The comparisons made between these data and our own highlights the high species diversity in the understory of tropical seasonal rain forest. Also, it is worth mentioning that it is difficult to do direct comparison of a number of features and statistics among the studies focused on understory due to the variation in criteria and methods used and also difficult to give comparisons among different strata in a particular forest due to the different sampling intensity for each stratum.

The H' index ranged (3.87-4.24) in sapling layer and (3.37-4.08) in the herb/seedling layer, suggesting higher variation of species diversity

TABLE 4
The top ten families with highest family importance value (FIV) in the sapling layer and herb/seedling layer of tropical seasonal rain forest in Xishuangbanna, SW China

Family	No. of species (species/ha)	Density (individuals/ha)	FIV
Shrub layer			
Rubiaceae	25	234	30.00
Euphorbiaceae	24	126	21.08
Annonaceae	12	94	12.97
Lauraceae	17	54	12.17
Meliaceae	7	75	9.14
Moraceae	9	43	7.57
Sapindaceae	5	50	6.25
Myrsinaceae	4	50	5.78
Sterculiaceae	6	35	5.54
Papilionaceae	7	22	4.99
Herb layer			
Rubiaceae	15	162	17.20
Aspidiaceae	5	214	14.67
Selaginellaceae	1	196	11.49
Lauraceae	11	49	8.71
Zingiberaceae	7	84	8.49
Urticaceae	5	87	7.58
Meliaceae	8	55	7.42
Annonaceae	5	63	6.23
Euphorbiaceae	8	31	6.08
Araceae	7	20	4.92

in the herb/seedling layer than in the sapling layer among the three plots. Compared to other studies, the high H' index and low λ index of the understory indicate that the species diversity of the understory in this forest is mainly constituted by rare species. This can also be seen from the distribution pattern of species and abundance in various frequency classes of individuals in the plots. For all the three plots, the evenness of sapling layer were relatively high (0.88-0.91) indicating that no species clearly dominates each plot. However, in the herb/seedling layer, the evenness index was higher in Mengla than Menglun and Manyang. Menglun plot was dominated by *Tectaria fengii* with 103 individuals, while Manyang plot was dominated by *Selaginella delicatula* with 127. In contrast, no species with more than 40 individuals was recorded in Mengla. The higher dominance in Manyang may be partly related to a more open canopy compared with other two plots due to the lower density of large trees (DBH ≥70cm). There are 17 and 19 stems with DBH≥70cm in Menglun and Mengla, while only 10 stems in Manyang (Lü *et al*. 2010).

In this study, we found that the species richness of understory plants (309 species) is higher than the overstory (207 species, DBH≥10cm) enumerated in the same plots (Lü *et al*. 2010). Even when other widely used diversity indices were considered, there was no statistical significant difference among the tree layer, sapling layer and herb/seedling layer (One-way ANOVA, p>0.05). This suggests either the sapling layer or the herb/seedling layer may have equal number of species with the tree layer in this forest. Our results are partly in line with those of Tchouto *et al*. (2006), who found that the shrub layer was the most species rich in all the strata of the Campo-Ma'an rain forest in Cameroon and consequently suggested that the diversity of trees may not reflect the overall diversity of the tropical forest. Results from the present study and those from Tchouto *et al*. (2006) confirm that species richness of the understory is usually as high as even higher than that of the tree layer, indicating that understory deserves more attention during biodiversity inventories in the future.

Rubiaceae, Euphorbiaceae, Annonaceae, Lauraceae, Meliaceae, and Sapindaceae are the dominant families with the highest FIVs in the sapling layer. Similarly, they also dominate the tree layer (Lü *et al*. 2010). It is understandable because a high proportion of the large tree species exist as saplings in the understory. In contrast, the family composition of the herb/seedling layer differed considerably with that of the tree layer and sapling layer due to the dominance of ferns. Pteridophytes have been found to be dominant in the herb layer of both neotropical and paleotropical forests (Poulsen & Nielsen 1995, Poulsen & Pendry 1995). Although Acanthaceae, Poaceae and Asteraceae have been suggested to be the predominant families of ground herbs in tropical rainforests

(Richards 1996), this was not the case in our study. We suspect this may result from the competition between ferns and other herbs. The five families, Euphorbiaceae, Annonaceae, Lauraceae, Sapindaceae and Meliaceae, were among the dominant ones not only in the tree layer (Lü *et al*. 2010) but also in both sapling and herb/seedling layers. This indicates that the seedlings and saplings of these families contributed strongly to the composition of the understory in this forest.

In summary, this study has demonstrated that the understory could contribute a lot to the total species richness of tropical seasonal rain forests. The sapling layer (individuals with height>1m but DBH<2cm) and herb/seedling layer (individuals with height<1m) may hold as many species as the tree layer (DBH≥10cm). All these results suggest that the understory vegetation should be given full consideration for the assessment of biodiversity patterns in tropical forests. The increased interest in forest understory has resulted in many different methods used to census understory composition. Differences in censusing methods result in substantially different results and confound comparisons among studies. Consequently, a standard protocol for understory censuses, especially for tropical forests, is critically needed.

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RESUMEN

La investigación de la vegetación y las comunidades presentes en bosques tropicales han tendido a centrarse en el componente arbóreo, y se ha prestado poca atención a la vegetación del sotobosque. La diversidad de especies y la composición del sotobosque de los bosques tropicales estacionales fueron inventariados en un área de 625m^2 (identificación de árboles jóvenes) y un área de 100 m^2 (capa de plántulas/hierbas) en tres parcelas de 1 ha. Hemos encontrado 3 068 individuos pertenecientes a 309 especies, 192 géneros y 89 familias. La familia más importante según lo determinado por el Valor de Importancia por Familia (FIV-Family Important Value) fue Rubiaceae, tanto en la capa de árboles jóvenes como para la de plántulas y hierbas. En términos del Índice de Valor de Importancia (IVI-Importance Value Index), el arbusto *Mycetia gracilis* (Rubiaceae) fue la especie más importante en la capa de árboles jóvenes y la pteridofitas *Selaginella delicatula* (Selaginellaceae) fue la especie más importante ecológica en la capa de plántulas e hierbas. Mucho más especies de plantas vasculares fueron inventariadas en el sotobosque que en el estrato arbóreo de las tres parcelas juntas. La diversidad de especies no difirió significativamente entre la capa de árboles, la de árboles jóvenes y la de plántulas y de hierbas. Teniendo en cuenta que aún sabemos poco sobre la comunidad de plantas del sotobosque, los resultados del presente estudio indican que debe prestarse más atención a la vegetación del sotobosque durante el proceso de toma de decisiones para la conservación de la biodiversidad en los bosques tropicales.

Palabras clave: hierba, bosque tropical no-dipterocárpico, muestreo, arbusto, riqueza de especies, plátulas, plantas de sotobosque.

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