PHYLOGENETIC AND FLORISTIC CHANGES OVER 48 YEARS IN A TROPICAL RAINFOREST REMNANT IN XISHUANGBANNA, SW CHINA

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Abstract. Tropical rainforests represent the most species-rich and at the same time the most fragmented terrestrial biome on Earth. Fragmentation of tropical rainforests is having wide-ranging consequences for the maintenance of local species diversity and community assembly patterns. In this paper we focus on Manyangguang holy hill in Xishuangbanna, SW China with the aim of examining both floristic and community phylogenetic structure changes after decades of fragmentation. A new taxonomic diversity algorithm (within-family diversity) was developed to assess floristic changes in the fragmented forest. Community phylogenetic structure was then compared before and after fragmentation. We found that high species turnover occurred in the fragmented forest and taxonomic diversity changed greatly among families, with changes occurring randomly throughout the phylogenetic tree. While shade-tolerant species have been lost, and ruderal and alien species have been added, the overall phylogenetic diversity has increased with species being more phylogenetically distant. The community phylogenetic structure changed distinctly from clustering to dispersion, which was related to the relatively drier conditions in the forest after fragmentation, resulting in an increase of phylogenetically remote heliophytes and the loss of closer-related sciophytes from the forest.

Key words: holy hills, taxonomic diversity, phylogenetic diversity, community phylogeny, phylogenetic structure, competitive exclusion.

INTRODUCTION

Tropical rainforests represent the most species-rich biome on Earth and are currently considered the most fragmented terrestrial ecosystem worldwide (Gibbs *et al.* 2010, FAO 2011). For example, in Xishuangbanna, China (21°09' - 22°36'N, 99°58 '- 101°50'E), from 1976 to 2003 more than 20% of the original tropical rainforests have been converted to farmlands, rubber plantations, and villages (Li, Ma *et al.* 2009), thus further aggravating rainforest fragmentation. Local climatic conditions in the fragmented rainforest usually change slowly towards being relatively drier (Li *et al.* 2000), which adversely affects primary rainforest species (Zhu *et al.* 2010). Research on forest fragmentation has become a major focus worldwide (Henle *et al.* 2004, Safi *et al.* 2011, Arroyo-Rodriguez *et al.* 2012, Habel & Zachos 2012). Some researchers found decreased biodiversity in fragmented forests (Hautier *et al.* 2009, Goddard *et al.* 2010, Safi *et al.* 2011), while

others indicated that a large proportion of biodiversity was maintained in fragmented tropical landscapes (Arroyo-Rodriguez & Toledo-Aceves 2009, Fahrig *et al.* 2011, Arroyo-Rodriguez *et al.* 2012).

What are the main causes or processes effecting changes or maintenance of biodiversity in fragmented forests? Numerous ecological and evolutionary processes, such as niche separation, dispersal, competition, and predation, have been demonstrated to be related to local biodiversity, although their relative importance is not well understood (Fahrig 2003, Greer & Collins 2008). Among these factors, environmental filtering and competitive exclusion are acting in all communities, but lead to opposite predictions about the phenotypic similarity and phylogenetic relatedness of co-occurring species (Webb *et al.* 2002, Helmus 2007). If closely related species share similar physiological limitations and exhibit evolutionary niche conservatism, environmental filtering will tend to cause closely related species to co-occur. In contrast, competitive exclusion should limit the coexistence of closely related species if spe-

cies compete for the same limited resources (Cavender-Bares *et al.* 2004, 2009).

Research on community phylogenetic relationships gives us a good understanding of species assemblages as an indication of the extent of divergence or convergence among co-existing species, providing useful insight into the relative importance of different ecological processes in the community (Webb *et al.* 2002, Cavender-Bares *et al.* 2004, 2009; Kembel & Hubbell 2006, Cahill *et al.* 2008). Phylogenetic clustering, phylogenetic dispersion, and phylogenetic random, which describe patterns of phylogenetic relatedness in the community, are the most frequently used terminologies to quantify community phylogenetic structure (Webb *et al.* 2002). Phylogenetic clustering is often interpreted as evidence for the environmental filtering of phylogenetically conservative species. In the absence of strong biotic interactions, the ecological similarity of closely related species should cause such species to occupy similar environments, and hence to cluster spatially (Webb *et al.* 2002, Silvertown *et al.* 2006, Swenson *et al.* 2007, Cavender-Bares *et al.* 2009). Phylogenetic dispersion can result from several different processes, and the most likely of these is generally competitive exclusion (Elton 1946, Webb *et al.* 2002, Cavender-Bares *et al.* 2009). Similarities in resource use due to shared ancestry would cause closely related species to compete more strongly than distantly related ones in natural communities. Lastly, phylogenetic random patterns have been interpreted as evidence for the importance of stochastic processes among species during community assembly (Webb *et al.* 2002, Kembel & Hubble 2006).

In this paper, we focused on "holy hills" in Xishuangbanna, SW China, which were once part of a continuous rainforest but then became seriously fragmented. However, the hill-top forests were protected for religious reason. We checked historical plant surveys on Manyangguang holy hill with the aim of examining both floristic changes and changes in community phylogenetic structure after decades of fragmentation. We asked the following questions: First, what are the main floristic changes in the fragmented forest? Second, is species loss and gain restricted to certain clades or does it occur randomly throughout the phylogeny? Third, are there any changes in the phylogenetic structure of the community and what are the correlations between phylogenetic and floristic changes in the fragmented forest?

MATERIALS & METHODS

Study site. The study was conducted on Manyangguang holy hill (in Xishuangbanna, SW China, 21°35'N, 100°40'E; 630m a.s.l.; soil type: laterite). It belonged to a continuous tropical seasonal rainforest until the 1950s, then gradually reduced to 30.04 ha in 1988, 18.37 ha in 1999, and 13.85 ha in 2008 on the hill top surrounded by farmlands, rubber plantations and Manyangguang village (Fig. 1). The forest patch is of important religious significance to the local Dai people and is therefore protected. The mean annual temperature across the rainy and dry seasons is 21.3°C, annual relative humidity is 85%, and annual precipitation is 1426.9 mm, with more than 80% of the rainfall during the rainy season from May to October (Zhu *et al.* 2010).

Historical plant survey. The botanical team of the Chinese Academy of Sciences conducted the first plant inventory survey by intensive repeated transect walks on the hill in 1959/1960. The comprehensive plant survey was in the context of the initiation and establishment of an ecological research station of the Chinese Academy of Sciences at the foot of Manyangguang holy hill. Voucher specimens for all plant species were collected and preserved in the Herbarium of Xishuangbanna Tropical Botanical Garden (HITBC). We checked the herbarium specimens and historical materials and revised the floristic data from that year. A total of 258 species of seed plants (from 75 families) were recognized on the hill in 1959/1960. To make a comparison of the floristic changes on Manyangguang holy hill after serious fragmentation and decades of time, the botanical team of the Chinese Academy of Sciences conducted another intensive plant survey in 2008. The survey methods in 2008 were the same as in 1959/60. A total of 332 species of seed plants (from 79 families) were identified on the hill in 2008. Voucher specimens were collected and preserved in HITBC.

Species definition and identification of the two plant surveys followed Flora of China (Flora of China Editorial Committee 1985), Angiosperm Phylogeny Group III classification (APG III 2009) and the Plant List website (Available at http://www. theplantlist.org/). The combined species checklist of 402 species in 88 families from the 1959/1960 and 2008 plant surveys was used as the species pool in the subsequent phylogenetic analyses (see supporting information Table S1).

Within-family diversity. Detecting floristic changes in a forest is important for local diversity conservation.
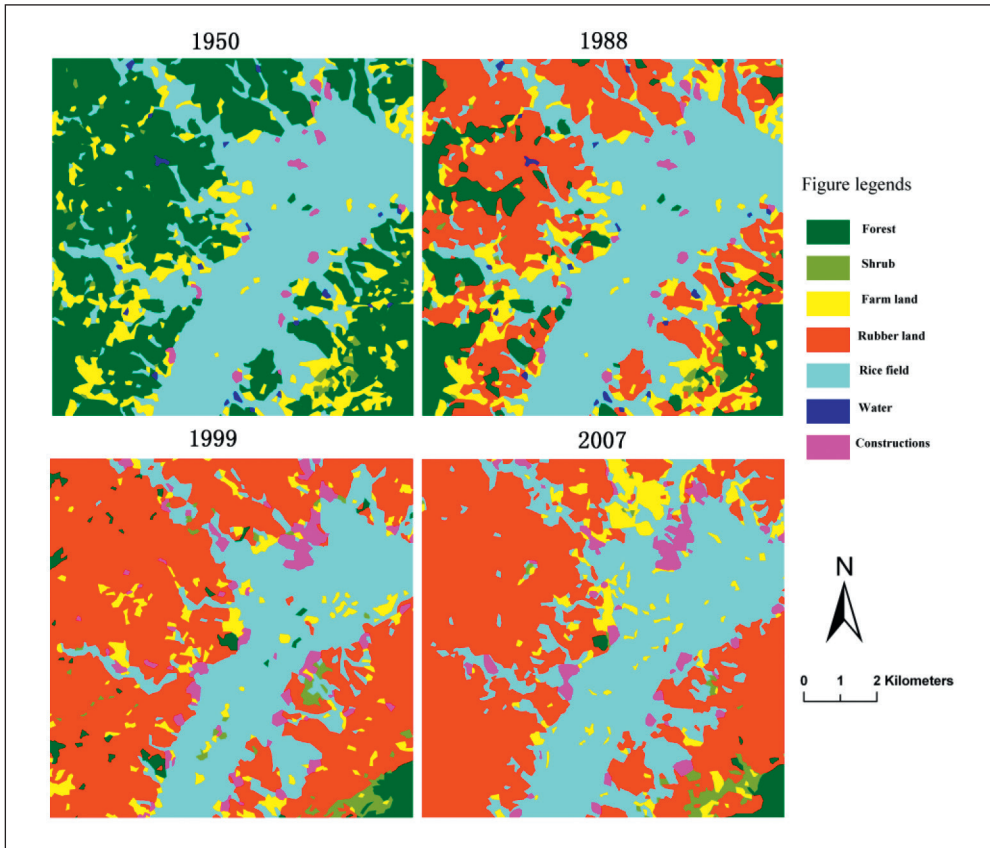
FIG. 1. Forest cover around Manyangguang holy hill from 1950 to 2007. Source: GIS Laboratory of Xishuangbanna Tropical Botanical Garden.

Traditional measures of biodiversity, such as the Shannon (1949) and Simpson (1949) indices, consider the relative species richness and abundance in a forest without regard to the taxonomic complexity in each family. In this paper we develop a new algorithm, within-family diversity (WFD), to measure the taxonomic complexity of the forest's component families, and also for taxa monitoring and local biodiversity conservation:

$$\text{WFD} = \sum_{i=1}^{g} P_i \left(In S_i - In P_i \right),$$

S_i is the species count in genus i in the forest, P_i is the proportion of S_i divided by the total species number of that family in the forest, and g is the genera count in the family, so that $\sum_{i=1}^{g} P_i = 1$. As an applied example, if, in the study area, there is a family comprising only one genus and one species, WFD

equals 0. A higher WFD value means a higher taxonomic diversity within the family.

Reconstruction of the super-tree. A hypothesized phylogenetic tree for the 402 species (in 88 families) from the 1959/1960 and 2008 plant surveys on Manyangguang holy hill was reconstructed using Phylomatic 3 (Webb & Donoghue 2005), using the APG III phylogenetic classification of angiosperm families as backbone (APG III 2009). Species from the same genus and family were treated polytomously for the lack of detailed information on phylogenetic relationships within families and genera. The branch lengths of the phylogenetic tree were assigned using the "bladj" module of the Phylocom 4.2 (Webb *et al.* 2008), which created a pseudochronogram with branch lengths based on node ages in-

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ferred by Wikström *et al.* (2001). The resulting super-tree was used for subsequent phylogenetic analyses.

Phylogenetic analyses. Phylogenetic structure was assessed by comparing taxon composition with that of the regional species pool. The regional species pool hypothetically constitutes all the potential taxa that can colonize the region and here in our study we used the combined species checklist of 402 species (in 88 families) from the 1959/1960 and 2008 plant inventory surveys in the study area as the species pool. We used null model 0 of Phylocom 4.2 (Webb *et al.* 2008) to generate null phylogenies. The null model shuffles species names on the phylogeny, randomizing phylogenetic relationships among species.

We regarded the two plant surveys (in 1959/1960 and 2008) as two independent communities and a series of indices were used to examine the changes in community phylogenetic structure over time (Faith 1992, Webb *et al.* 2002, 2008). Faith's (1992) phylogenetic diversity (PD) was calculated to describe the proportion of the total branch lengths in the super-tree associated with the taxa in a community using the "pd" command in Phylocom 4.2. Mean pairwise distance (MPD) and mean nearest neighbor distance (MNND) were calculated to analyze the phylogenetic distance of co-existing species in a community. The net relatedness index (NRI) and nearest taxon index (NTI) are the standardized measures of MPD and MNND, respectively, and are used to measure tree-wide and terminal phylogenetic relatedness among co-existing species, i.e. whether a community is phylogenetically clustered, even, or dispersed when compared with randomly generated phylogenies (Hubbell 2001, Webb *et al.* 2002, 2008; Kembel & Hubbell 2006).

$$NRI = -\frac{MPD - MPD_{null}}{sd(MPD_{null})}$$

$$NTI = -\frac{MNND - MNND_{null}}{sd(MNND_{null})}$$

NRI and NTI were calculated by implementing the "comstruct" command with 1000 randomizations and null model 0 in Phylocom 4.2. If the mean NRI and NTI values differ from zero according to a one-sample t test ($P < 0.05$) we can conclude that the community is significantly phylogenetically clustered or dispersed on average, since both NRI and NTI have expected values (zero) for phylogenetically random communities, positive for phylogenetically clustered communities, and negative for phylogenetically dispersed communities.

RESULTS

High species turnover. We found a high species turnover on Manyangguang holy hill between the 1960 and 2008 surveys: 70 species had gone extinct but there were also 144 species newly recorded in 2008. The high species turnover between 1960 and 2008 has greatly changed taxonomic diversity within families. Aside from the 9 extinct families (Begoniaceae, Commelinaceae, Daphniphyllaceae, Dilleniaceae, Gesneriaceae, Hernandiaceae, Lecythidaceae, Polygonaceae, Urticaceae) and 13 newly recorded families (Aristolochiaceae, Cardiopteridaceae, Juglandaceae, Lythraceae, Musaceae, Olacaceae, Oleaceae, Opiliaceae, Plantaginaceae, Rosaceae, Santalaceae, Theaceae, Zingiberaceae), WFD decreased in 16 families, increased in 27, and remained the same in 23 families over the past five decades (Table 1).

Changes in community phylogenetic structure. Given this irregularity of species loss and gain, we employed phylogenetic-based analyses and found that the communities in both 1960 and 2008 were not randomly assembled by stochastic processes (NRI, NTI ≠ 0; Webb *et al.* 2002; Table 2). The community phylogenetic structure has changed distinctly after decades of fragmentation: (1) the community in 2008 had higher PD, higher MPD, and lower MNND than that in 1960; and (2) the community in 1960 had a significantly clustered phylogenetic structure (NRI, NTI > 0, $P < 0.05$), while the community in 2008 exhibited both significant tree-wide phylogenetic dispersion (NRI < 0, $P < 0.05$) and marginally significant terminal phylogenetic clustering (NTI > 0, $P = 0.085$).

DISCUSSION

Tropical rainforests are the most increasingly fragmented terrestrial ecosystem in the world (Gibbs *et al.* 2010). In this paper we focused on Manyangguang holy hill, a forest fragment in Xishuangbanna, SW China, to examine the changes in community assembly after decades of fragmentation. A high species turnover in the fragmented forest, including the invasion of alien species (e.g., *Eupatorium odoratum* and *Tithonia diversifolia* in Asteraceae, *Malvastrum coromandelianum* in Malvaceae, etc.), the loss of climax and shade-tolerant species (e.g., *Garuga floribunda* var. *gamblei* in Burseraceae, *Pometia tomentosa* in Sapindaceae, *Sloanea dasycarpa* in Elaeocarpaceae, etc.), and the addition of light-demanding species (pioneers and heliophiles (e.g., *Streblus asper* in Mora-

TABLE 1. Within-family diversity (WFD) changes of co-occurring families present in both 1959/1960 and 2008 on Manyangguang holy hill in Xishuangbanna, SW China.

Family	WFD change	Family	WFD change
Melastomataceae	-1.50	Piperaceae	0.00
Phyllanthaceae	-1.46	Proteaceae	0.00
Celastraceae	-1.04	Sapotaceae	0.00
Annonaceae	-1.02	Simaroubaceae	0.00
Araceae	-0.93	Staphyleaceae	0.00
Connaraceae	-0.81	Myristicaceae	0.00
Anacardiaceae	-0.74	Primulaceae	0.18
Passifloraceae	-0.69	Meliaceae	0.19
Symplocaceae	-0.69	Myrtaceae	0.37
Orchidaceae	-0.58	Malvaceae	0.40
Solanaceae	-0.53	Dioscoreaceae	0.41
Sapindaceae	-0.36	Elaeocarpaceae	0.41
Burseraceae	-0.35	Smilacaceae	0.41
Capparaceae	-0.35	Poaceae	0.43
Lauraceae	-0.28	Araliaceae	0.58
Lamiaceae	-0.25	Vitaceae	0.61
Menispermaceae	0.00	Moraceae	0.61
Malpighiaceae	0.00	Apocynaceae	0.66
Salicaceae	0.00	Convolvulaceae	0.81
Amaranthaceae	0.00	Cyperaceae	0.81
Aquifoliaceae	0.00	Euphorbiaceae	0.99
Arecaceae	0.00	Rutaceae	1.08
Clusiaceae	0.00	Fabaceae	1.36
Combretaceae	0.00	Bignoniaceae	1.39
Cornaceae	0.00	Cucurbitaceae	1.39
Elaeagnaceae	0.00	Cannabaceae	1.56
Fagaceae	0.00	Sabiaceae	1.74
Gnetaceae	0.00	Acanthaceae	1.79
Ixonanthaceae	0.00	Rubiaceae	1.86
Loganiaceae	0.00	Polygalaceae	2.20
Loranthaceae	0.00	Icacinaceae	2.25
Magnoliaceae	0.00	Rhamnaceae	2.66
Pandanaceae	0.00	Asteraceae	5.23

Notes: Sorted by WFD change values. Positive values indicate increased taxonomic diversity within a family between 1959/1960 and 2008, negative values indicate decreased diversity, and 0.00 indicates no change in diversity within a family.

TABLE 2. Phylogenetic comparison between the forest in 1960 and in 2008, Manyangguang holy hill in Xishuangbanna, SW China.

Community	ntaxa	BL	totalBL	PD	MPD	mean NRI	*P* value	MNND	mean NTI	*P* value
1959/1960	75	151	166	0.91	13.20	0.64	0.004	2.59	0.17	0.019
2008	79	157	166	0.95	13.46	-0.88	0.049	2.52	0.34	0.085

Notes: Using the "pd" command and the "comstruct" command with 1000 randomizations and null model 2 in Phylocom 4.2 (see Methods for description); ntaxa: the sum of families present in the community; BL: the branch lengths of the community based on node ages; totalBL: combined total branch length of the supertree; PD: phylogenetic diversity in the community, which accounts for the proportion of BL to totalBL; MPD, MNND: mean pairwise phylogenetic distance and mean nearest neighbor distance (both in millions of years, Ma); mean NRI, mean NTI: mean value of net relatedness index and nearest taxon index; Significant *P* values: the significance of the community phylogenetic structure differed from zero according to one-sample *t*-test.

ceae, *Toona ciliata* in Meliaceae, *Trewia nudiflora* in Euphorbiaceae, etc.), have distinctly changed the flora on Manyangguang holy hill, reducing the number of sciphilous species while increasing the number of heliphilous species. Our results are consistent with findings that, after a long period of fragmentation, species composition changes rapidly to pioneer and heliphilous species (Laurance *et al.* 2006). This is related to the altered environmental conditions in the forest fragments, with more large trees dying because of the desiccation of canopy trees (Briant *et al.* 2010) and hyper abundance of sunlight-tolerant species (Tabarelli *et al.* 2010) in the forest edges.

Finding approaches to assess floristic changes in fragmented forest is of increasing importance. By the application of the new diversity algorithm (WFD), we found taxonomic diversity had changed greatly among families on Manyangguang holy hill between the 1960 and 2008 surveys. The extinct and newly recorded families on the hill can be seen as the two extremes of decreased and increased WFD change values. Thus families with decreased taxonomic diversity accounted for 45.5%, families with increased diversity accounted for 28.4%, and families with no taxonomic diversity changes accounted for 26.1% of the total over the past five decades. By incorporating the WFD change values into the super-tree (Fig. 2) we found that species losses and gains were not restricted to closely related clades but occurred randomly throughout the phylogenetic tree. Species recorded in 2008 but not in 1960 (e.g., Asteraceae, Oleaceae, Olacaceae, Musaceae, Rosaceae species) belong to distantly related clades, as do the species to

first go extinct on Manyangguang holy hill (e.g., Melastomataceae, Urticaceae, Commelinaceae, Gesneriaceae, Hernandiaceae, Lecythidaceae species). The WFD change values provide information on the floristic dynamics in each forest family and would be practical for forest monitoring and local biodiversity conservation.

The phylogeny of the plant community changed much over time between 1960 and 2008. Higher PD in 2008 indicated that the phylogenetic diversity on Manyangguang holy hill did not decrease but increased, due to the addition of ruderal and alien species, even though many primary shade-tolerant species were lost. Our result is congruent with a study that showed that fragmented forests can still maintain high phylogenetic diversity (Arroyo-Rodriguez *et al.* 2012), though this is a temporal phenomenon. The species loss and gain in the Manyangguang fragment affected the phylogenetic distance between co-existing species, making them more phylogenetically distant as indicated by the higher MPD and lower MNND in 2008. The 1960 community was significant phylogenetically clustered (NRI, NTI > 0, *P* < 0.05). At local scales, phylogenetic clustering is often interpreted as evidence for the impact of environmental filtering on phylogenetic conservatism because the ecological similarities of closely related species, in the absence of strong biotic interactions, cause closely related species to occupy similar environments and hence to cluster spatially (Tofts & Silvertown 2000, Webb *et al.* 2002, Silvertown *et al.* 2006, Swenson *et al.* 2007, Cavender-Bares *et al.* 2009). The forest in 1960 was still part of a continu-

ous tropical seasonal rainforest far from human activities, and we considered the phylogenetic clustering in 1960 (compared with the forest in 2008) to be the result of environmental filtering exposing more phylogenetically-related species assemblages. Significant tree-wide phylogenetic dispersion (NRI < 0, P < 0.05) was found in 2008. Phylogenetic dispersion can result from several different processes, but is most likely the result of competitive exclusion (Cahill *et al.* 2008, Cavender-Bares *et al.* 2009).

Several studies have suggested competition as the likely causal mechanism for phylogenetic dispersion in communities (Slingsby & Verboom 2006, Helmus 2007, Cahill *et al.* 2008, Copper *et al.* 2008) because similarity in resource use due to shared ancestry would cause closely related species to compete more strongly than distantly related ones in natural communities (Elton 1946, Webb *et al.* 2002). The forest in 2008 had been severely fragmented and was surrounded by a mix of farmlands, rubber plantations,
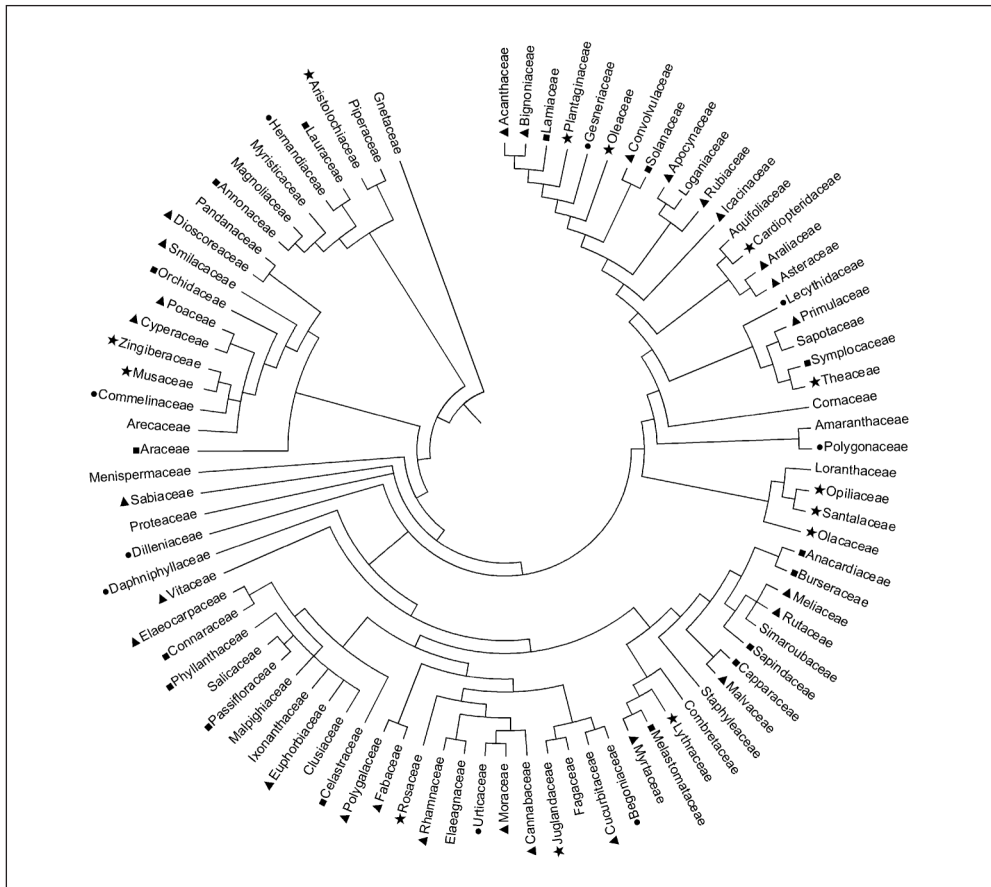

FIG. 2. Super phylogenetic tree for the combined 88 families (402 species) from the 1959/1960 and 2008 plant surveys on Manyangguang holy hill, in Xishuangban, SW China.

Notes: Reconstructed with Phylomatic using the APG III phylogenetic classification of Angiosperm families as backbone. Circles indicate the extinction of families between 1959/1960 and 2008; pentagrams indicate the occurrence of a family in 2008 that was not present in 1959/1960; triangles indicate an increase of within-family diversity of the family between 1959/1960 and 2008; squares indicate a decrease of within-family diversity of the family between 1959/1960 and 2008; no marks indicate families with no diversity changes.

TABLE 3. Climatic data on Manyangguang holy hill in Xishuangbanna, SW China.

Year	Mean temperature (°C)		Mean humidity (%)	
	Dry season	Rainy season	Dry season	Rainy season
1959-1960	18.1	24.3	73	92
2008	19.4	25.8	65	87

Source: Annual reports of Manyangguang field station in Xishuangbanna, SW China.

and Manyangguang village. When comparing climatic conditions on Manyangguang holy hill in 1960 and 2008 (Table 3), we found that it had slowly changed to become relatively drier, with higher temperature and lower humidity. These characteristics are not optimal for primary rainforest shade-tolerant plants, and create more interspecific competition for humid habitats and hence the exclusion of phylogenetically-related species (e.g., *Mayodendron igneum*, Begoniaceae; *Barringtonia macrostachya*, Lecythidaceae; *Litsea martabanica*, Lauraceae) and the emergence of more heliophytes to the forest (e.g., *Blumea balsamifera, Laggera alata, Eupatorium odoratum*, Asteraceae; *Malvastrum coromandelianum*, Malvaceae), which were present on the super-tree with more phylogenetically-distant clades assembled in the forest in 2008 (Fig. 2). We also found that the phylogenetic structure in 2008 has marginally terminal clustering (NTI > 0, P = 0.0758), which meant that terminal taxa in 2008 had a slight trend to occur together with other closely related taxa (heliophytes), which would further increase interspecific competition and reinforce phylogenetic dispersion, leading to more heliophytes and less sciophytes on Manyangguang holy hill.

Our study is partially congruent with Arroyo-Rodriguez *et al.* (2012), in which the authors indicated that in a highly fragmented rainforest the local extirpation of tree species did not occur across entire lineages and that ecosystem functions and stability may be maintained despite the loss of a number of tree species. On Manyangguang holy hill, the severe fragmentation has driven many primary forest species to local extinction, changed the community phylogenetic structure of species assemblages to be more phylogenetically distant and to have more heliophytes, thus reducing the primary rainforest's inherent ecosystem functions and stability. Forest fragmentation and its effect on biodiversity are of major concerns in tropical ecology and biodiversity conservation (Turner & Corlett 1996, Laurance & Bierregaard 1997, Laurance *et al.* 2006). We suggest protecting the present rainforest from further fragmentation and saving native primary plants from competition with ruderal/alien grasses in order to restore its primary forest status and ecosystem functions.

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TABLE S1. Within-family diversity (WFD) changes of co-occurring families present in both 1959/1960 and 2008 on Manyangguang holy hill in Xishuangbanna, SW China.

Family	Species checklist	Inventory in 1959/1960	Inventory in 2008
Acanthaceae	*Asystasia gangetica*	+	-
Acanthaceae	*Chroesthes pubiflora*	-	+
Acanthaceae	*Dicliptera chinensis*	-	+
Acanthaceae	*Lepidagathis incurva*	+	+
Acanthaceae	*Phaulopsis dorsiflora*	-	+
Acanthaceae	*Pseuderanthemum polyanthum*	-	+
Acanthaceae	*Rhaphidospora vagabunda*	-	+
Acanthaceae	*Thunbergia grandiflora*	+	+
Acanthaceae	*Thunbergia lacei*	-	+
Amaranthaceae	*Cyathula prostrata*	+	+
Anacardiaceae	*Choerospondias axillaris*	+	-
Anacardiaceae	*Mangifera siamensis*	+	+
Anacardiaceae	*Mangifera sylvatica*	+	+
Anacardiaceae	*Semecarpus reticulatus*	+	+
Anacardiaceae	*Spondias pinnata*	+	-
Annonaceae	*Dasymaschalon rostratum*	+	-
Annonaceae	*Fissistigma polyanthum*	+	+
Annonaceae	*Miliusa sinensis*	+	-
Annonaceae	*Mitrephora maingayi*	+	+
Annonaceae	*Polyalthia simiarum* subsp. *cheliensis*	+	+
Apocynaceae	*Alstonia rostrata*	+	+
Apocynaceae	*Amalocalyx microlobus*	-	+
Apocynaceae	*Cryptolepis sinensis*	-	+
Apocynaceae	*Cynanchum corymbosum*	-	+
Apocynaceae	*Dischidia tonkinensis*	+	+
Apocynaceae	*Ervatamia officinalis*	+	+
Apocynaceae	*Gymnema sylvestre*	-	+
Apocynaceae	*Heterostemma wallichii*	+	-
Apocynaceae	*Hoya pottsii*	+	+
Apocynaceae	*Ichnocarpus polyanthus*	+	+
Apocynaceae	*Parabarium spireanum*	+	+
Apocynaceae	*Parameria laevigata*	+	-
Apocynaceae	*Rauvolfia verticillata*	-	+
Apocynaceae	*Strophanthus wallichii*	-	+
Apocynaceae	*Toxocarpus villosus*	-	+
Apocynaceae	*Trachelospermum cordatum*	+	-
Apocynaceae	*Urceola rosea*	+	+
Apocynaceae	*Wrightia laevis*	-	+
Apocynaceae	*Wrightia pubescens*	+	+
Aquifoliaceae	*Ilex godajam*	+	+

Family	Species checklist	Inventory in 1959/1960	Inventory in 2008
Araceae	*Amorphophallus virosus*	+	+
Araceae	*Colocasia esculenta*	+	-
Araceae	*Epipremnum pinnatum*	+	-
Araceae	*Pothos chinensis*	+	+
Araceae	*Pothos scandens*	+	+
Araceae	*Rhaphidophora megaphylla*	+	+
Araliaceae	*Aralia armata*	+	+
Araliaceae	*Heteropanax fragrans*	-	+
Araliaceae	*Macropanax dispermus*	+	+
Araliaceae	*Schefflera octophylla*	+	+
Arecaceae	*Caryota monostachys*	+	+
Aristolochiaceae	*Aristolochia tagala*	-	+
Asteraceae	*Ageratum conyzoides*	+	+
Asteraceae	*Bidens pilosa*	-	+
Asteraceae	*Blumea balsamifera*	-	+
Asteraceae	*Conyza canadensis*	-	+
Asteraceae	*Crassocephalum crepidioides*	-	+
Asteraceae	*Eupatorium coelestinum*	-	+
Asteraceae	*Eupatorium odoratum*	-	+
Asteraceae	*Laggera alata*	-	+
Asteraceae	*Siegesbeckia orientalis*	-	+
Asteraceae	*Synedrella nodiflora*	-	+
Asteraceae	*Synotis cappa*	-	+
Asteraceae	*Tithonia diversifolia*	-	+
Asteraceae	*Vernonia cinerea*	-	+
Asteraceae	*Vernonia volkameriifolia*	-	+
Begoniaceae	*Begonia* sp.	+	-
Bignoniaceae	*Dolichandrone stipulata*	-	+
Bignoniaceae	*Mayodendron igneum*	-	+
Bignoniaceae	*Radermachera microcalyx*	+	+
Bignoniaceae	*Stereospermum colais*	+	+
Burseraceae	*Canarium tonkinense*	+	+
Burseraceae	*Garuga floribunda* var. *gamblei*	+	-
Burseraceae	*Garuga pinnata*	+	+
Cannabaceae	*Aphananthe cuspidata*	+	+
Cannabaceae	*Celtis biondii*	-	+
Cannabaceae	*Celtis timorensis*	-	+
Cannabaceae	*Gironniera subaequalis*	+	+
Cannabaceae	*Trema orientalis*	-	+
Capparaceae	*Capparis sabiaefolia*	+	+
Capparaceae	*Capparis tenera*	+	+
Capparaceae	*Stixis suaveolens*	+	+

Family	Species checklist	Inventory in 1959/1960	Inventory in 2008
Cardiopteridaceae	*Cardiopteris quinqueloba*	-	+
Celastraceae	*Celastrus hindsii*	+	-
Celastraceae	*Celastrus paniculata*	+	+
Celastraceae	*Pristimera arborea*	+	-
Celastraceae	*Salacia polysperma*	+	+
Clusiaceae	*Garcinia cowa*	+	+
Clusiaceae	*Garcinia lancilimba*	+	+
Clusiaceae	*Garcinia xanthochymus*	+	+
Combretaceae	*Combretum latifolium*	+	+
Commelinaceae	*Belosynapsis ciliata*	+	-
Commelinaceae	*Commelina diffusa*	+	-
Commelinaceae	*Murdannia macrocarpa*	+	-
Connaraceae	*Connarus yunnanensis*	+	+
Connaraceae	*Rourea minor*	+	+
Connaraceae	*Santaloides roxburghii*	+	-
Convolvulaceae	*Ipomoea pileata*	+	+
Convolvulaceae	*Neuropeltis racemosa*	+	+
Convolvulaceae	*Poranopsis discifera*	-	+
Cornaceae	*Alangium kurzii*	+	+
Cucurbitaceae	*Hodgsonia macrocarpa*	+	+
Cucurbitaceae	*Zehneria indica*	-	+
Cyperaceae	*Carex baccans*	-	+
Cyperaceae	*Cyperus iria*	+	+
Cyperaceae	*Scleria chinensis*	+	+
Daphniphyllaceae	*Daphniphyllum paxianum*	+	-
Dilleniaceae	*Dillenia indica*	+	-
Dilleniaceae	*Tetracera scandens*	+	-
Dioscoreaceae	*Dioscorea alata*	-	+
Dioscoreaceae	*Dioscorea bulbifera*	-	+
Dioscoreaceae	*Dioscorea garrettii*	+	-
Dioscoreaceae	*Dioscorea glabra*	+	+
Elaeagnaceae	*Elaeagnus conferta*	+	+
Elaeocarpaceae	*Elaeocarpus braceanus*	-	+
Elaeocarpaceae	*Elaeocarpus prunifolioides*	+	+
Elaeocarpaceae	*Elaeocarpus sphaerocarpus*	-	+
Elaeocarpaceae	*Sloanea dasycarpa*	+	-
Euphorbiaceae	*Alchornea tiliifolia*	-	+
Euphorbiaceae	*Antidesma acidum*	-	+
Euphorbiaceae	*Antidesma fordii*	+	-
Euphorbiaceae	*Antidesma montanum*	+	+
Euphorbiaceae	*Antidesma sootepense*	+	+
Euphorbiaceae	*Baccaurea ramiflora*	+	+

Family	Species checklist	Inventory in 1959/1960	Inventory in 2008
Euphorbiaceae	*Breynia fruticosa*	-	+
Euphorbiaceae	*Bridelia insulana*	-	+
Euphorbiaceae	*Croton argyratus*	+	+
Euphorbiaceae	*Glochidion arborescens*	-	+
Euphorbiaceae	*Glochidion eriocarpum*	-	+
Euphorbiaceae	*Macaranga denticulata*	+	-
Euphorbiaceae	*Mallotus barbatus*	+	+
Euphorbiaceae	*Mallotus millietii*	-	+
Euphorbiaceae	*Mallotus paniculatus*	+	+
Euphorbiaceae	*Mallotus philippinensis*	-	+
Euphorbiaceae	*Mallotus repandus*	-	+
Euphorbiaceae	*Manihot esculenta*	-	+
Euphorbiaceae	*Ostodes paniculata*	+	+
Euphorbiaceae	*Phyllanthus emblica*	+	-
Euphorbiaceae	*Phyllanthus flexuosus*	-	+
Euphorbiaceae	*Sumbaviopsis albicans*	+	-
Euphorbiaceae	*Suregada glomerulata*	+	+
Euphorbiaceae	*Trewia nudiflora*	+	+
Fabaceae	*Acacia pennata*	-	+
Fabaceae	*Adenanthera pavonina* var. *microsperma*	+	+
Fabaceae	*Albizia lucidior*	+	+
Fabaceae	*Aspidopterys obcordata*	+	+
Fabaceae	*Atylosia barbata*	+	+
Fabaceae	*Bauhinia touranensis*	-	+
Fabaceae	*Caesalpinia cucullata*	+	+
Fabaceae	*Caesalpinia millettii*	+	+
Fabaceae	*Cajanus grandiflorus*	-	+
Fabaceae	*Cissus subtetragona*	-	+
Fabaceae	*Craspedolobium schochii*	-	+
Fabaceae	*Cylindrokelupha kerrii*	-	+
Fabaceae	*Dalbergia pinnata*	+	+
Fabaceae	*Dalbergia rimosa*	+	+
Fabaceae	*Dalbergia stipulacea*	+	+
Fabaceae	*Entada phaseoloides*	+	+
Fabaceae	*Eurysolen gracilis Prain*	+	-
Fabaceae	*Millettia dorwardii*	-	+
Fabaceae	*Millettia leptobotrya*	+	+
Fabaceae	*Mucuna macrocarpa*	+	+
Fabaceae	*Mucuna pruriens*	-	+
Fabaceae	*Ormosia fordiana*	+	+
Fabaceae	*Ormosia yunnanensis*	-	+
Fabaceae	*Pithecolobium clypearia*	+	+

Family	Species checklist	Inventory in 1959/1960	Inventory in 2008
Fabaceae	*Pueraria alopecuroides*	+	+
Fabaceae	*Rottboellia exaltata*	+	-
Fabaceae	*Spatholobus pulcher*	+	+
Fabaceae	*Tadehagi triquetrum*	+	+
Fagaceae	*Castanopsis indica*	+	+
Gesneriaceae	*Aeschynanthus acuminatus*	+	-
Gnetaceae	*Gnetum montanum*	+	+
Hernandiaceae	*Illigera parviflora*	+	-
Icacinaceae	*Apodytes dimidiata*	-	+
Icacinaceae	*Iodes cirrhosa*	+	+
Icacinaceae	*Iodes vitiginea*	+	+
Icacinaceae	*Mappianthus iodoides*	-	+
Icacinaceae	*Pittosporopsis kerrii*	-	+
Ixonanthaceae	*Ixonanthes cochinchinensis*	+	+
Juglandaceae	*Engelhardia spicata*	-	+
Lamiaceae	*Callicarpa longifolia*	+	+
Lamiaceae	*Clerodendrum bungei*	-	+
Lamiaceae	*Clerodendrum henryi*	-	+
Lamiaceae	*Clerodendrum japonicum*	+	+
Lamiaceae	*Clerodendrum villosum*	+	+
Lamiaceae	*Colebrookea oppositifolia*	-	+
Lamiaceae	*Premna fulva*	+	-
Lamiaceae	*Vitex quinata* var. *puberula*	+	+
Lauraceae	*Actinodaphne henryi*	+	-
Lauraceae	*Beilschmiedia linocieroides*	+	+
Lauraceae	*Cinnamomum austroyunnanense*	+	+
Lauraceae	*Litsea cubeba*	-	+
Lauraceae	*Litsea glutinosa*	+	+
Lauraceae	*Litsea liyuyingi*	+	+
Lauraceae	*Litsea martabanica*	-	+
Lauraceae	*Litsea panamanja*	-	+
Lauraceae	*Litsea umbellata*	+	-
Lauraceae	*Phoebe lanceolata*	+	+
Lauraceae	*Phoebe macrocarpa*	+	-
Lauraceae	*Phoebe puwenensis*	+	+
Lecythidaceae	*Barringtonia macrostachya*	+	-
Loganiaceae	*Strychnos nitida*	+	+
Loranthaceae	*Scurrula ferruginea*	+	+
Lythraceae	*Lagerstroemia tomentosa*	-	+
Magnoliaceae	*Manglietia forrestii*	+	+
Malpighiaceae	*Hiptage acuminata*	+	+
Malvaceae	*Acronychia pedunculata*	+	+

Family	Species checklist	Inventory in 1959/1960	Inventory in 2008
Malvaceae	*Colona floribunda*	+	-
Malvaceae	*Helicteres viscida*	+	+
Malvaceae	*Malvastrum coromandelianum*	-	+
Malvaceae	*Microcos paniculata*	+	+
Malvaceae	*Pterospermum lanceifolium*	+	+
Malvaceae	*Sida acuta*	-	+
Malvaceae	*Solanum erianthum*	-	+
Malvaceae	*Solanum photeinocarpum*	-	+
Malvaceae	*Solanum torvum*	-	+
Malvaceae	*Sterculia brevissima*	-	+
Malvaceae	*Sterculia lanceolata*	+	+
Malvaceae	*Urena lobata*	+	+
Melastomataceae	*Bredia velutina*	+	-
Melastomataceae	*Melastoma affine*	-	+
Melastomataceae	*Melastoma imbricatum*	+	+
Melastomataceae	*Memecylon polyanthum*	+	-
Meliaceae	*Amoora dasyclada*	+	+
Meliaceae	*Amoora yunnanensis*	-	+
Meliaceae	*Aphanamixis polystachya*	+	-
Meliaceae	*Chisocheton siamensis*	+	+
Meliaceae	*Chukrasia tabularis* var. *velutina*	+	+
Meliaceae	*Cipadessa baccifera*	+	+
Meliaceae	*Dysoxylum binectariferum*	-	+
Meliaceae	*Dysoxylum densiflorum*	-	+
Meliaceae	*Melia toosendan*	-	+
Meliaceae	*Munronia henryi*	+	-
Meliaceae	*Toona ciliata*	+	-
Meliaceae	*Trichilia connaroides*	-	+
Menispermaceae	*Aspidocarya uvifera*	+	-
Menispermaceae	*Cocculus orbiculatus* var. *mollis*	+	-
Menispermaceae	*Hypserpa nitida*	-	+
Menispermaceae	*Pericampylus glaucus*	-	+
Menispermaceae	*Stephania dolichopoda*	+	+
Menispermaceae	*Tinomiscium petiolare*	+	+
Moraceae	*Antiaris toxicaria*	+	+
Moraceae	*Artocarpus lakoocha*	+	-
Moraceae	*Artocarpus nitidus* subsp. *lingnanensis*	-	+
Moraceae	*Ficus altissima*	+	+
Moraceae	*Ficus benjamina*	-	+
Moraceae	*Ficus callosa*	-	+
Moraceae	*Ficus esquiroliana*	+	+
Moraceae	*Ficus geniculata*	+	+

Family	Species checklist	Inventory in 1959/1960	Inventory in 2008
Moraceae	*Ficus gibbosa* var. *cuspidifera*	+	-
Moraceae	*Ficus glaberrima*	+	-
Moraceae	*Ficus hirta*	-	+
Moraceae	*Ficus hispida*	-	+
Moraceae	*Ficus hookeri*	+	-
Moraceae	*Ficus langkokensis*	+	+
Moraceae	*Ficus orthoneura*	+	-
Moraceae	*Ficus sagittata*	+	+
Moraceae	*Ficus vasculosa*	-	+
Moraceae	*Maclura cochinchinensis*	-	+
Moraceae	*Maclura pubescens*	-	+
Moraceae	*Streblus asper*	-	+
Moraceae	*Streblus indicus*	+	+
Musaceae	*Musa acuminata*	-	+
Myristicaceae	*Horsfieldia glabra*	+	+
Myristicaceae	*Knema erratica*	+	+
Myristicaceae	*Knema furfuracea*	+	+
Myristicaceae	*Knema globularia*	+	+
Myrtaceae	*Decaspermum fruticosum*	+	+
Myrtaceae	*Decaspermum gracilentum*	+	+
Myrtaceae	*Psidium guajava*	-	+
Myrtaceae	*Syzygium polypetaloideum*	+	-
Myrtaceae	*Syzygium latilimbum*	+	+
Myrtaceae	*Syzygium oblatum*	+	+
Myrtaceae	*Syzygium tetragonum*	+	+
Olacaceae	*Erythropalum scandens*	-	+
Oleaceae	*Jasminum nervosum*	-	+
Opiliaceae	*Lepionurus sylvestris*	-	+
Orchidaceae	*Aerides multiflorum*	+	+
Orchidaceae	*Arundina graminifolia*	+	-
Orchidaceae	*Dendrobium primulinum*	+	+
Orchidaceae	*Pholidota imbricata*	+	+
Pandanaceae	*Pandanus furcatus*	+	+
Passifloraceae	*Adenia parviflora*	+	-
Passifloraceae	*Passiflora edulis*	-	+
Passifloraceae	*Passiflora foetida*	+	+
Phyllanthaceae	*Aporusa dioica*	+	+
Phyllanthaceae	*Aporusa yunnanensis*	+	+
Piperaceae	*Piper boehmeriifolium*	+	+
Piperaceae	*Piper mullesua*	+	+
Piperaceae	*Piper sarmentosum*	+	+
Plantaginaceae	*Scoparia dulcis*	-	+

Family	Species checklist	Inventory in 1959/1960	Inventory in 2008
Poaceae	*Arthraxon lanceolatus*	+	+
Poaceae	*Chrysopogon aciculatus*	+	+
Poaceae	*Indosasa hispida*	-	+
Poaceae	*Microstegium ciliatum*	-	+
Poaceae	*Oplismenus compositus*	+	+
Poaceae	*Panicum cordatum*	+	+
Poaceae	*Panicum repens*	+	+
Poaceae	*Paspalum conjugatum*	+	+
Poaceae	*Phyllostachys* sp.	+	-
Poaceae	*Pseudechinolaena polystachya*	+	+
Poaceae	*Setaria palmifolia*	-	+
Poaceae	*Thysanolaena maxima*	-	+
Polygalaceae	*Securidaca inappendiculata*	-	+
Polygalaceae	*Xanthophyllum siamense*	+	+
Polygonaceae	*Polygonum chinense*	+	+
Primulaceae	*Ardisia arborescens*	+	-
Primulaceae	*Ardisia solanacea*	-	+
Primulaceae	*Ardisia villosa*	+	+
Primulaceae	*Ardisia virens*	+	+
Primulaceae	*Embelia parviflora*	-	+
Primulaceae	*Embelia undulata*	+	+
Primulaceae	*Maesa indica*	+	+
Primulaceae	*Maesa macilentoides*	+	+
Primulaceae	*Myrsine seguinii*	+	+
Proteaceae	*Helicia cochinchinensis*	+	+
Rhamnaceae	*Gouania leptostachya*	-	+
Rhamnaceae	*Ventilago calyculata*	+	+
Rhamnaceae	*Ventilago madaraspatana*	-	+
Rhamnaceae	*Ziziphus fungii*	-	+
Rhamnaceae	*Ziziphus oenopolia*	-	+
Rosaceae	*Pygeum topengii*	-	+
Rosaceae	*Rubus alceifolius*	-	+
Rosaceae	*Rubus pirifolius* var. *cordatus*	-	+
Rubiaceae	*Aidia yunnanensis*	+	+
Rubiaceae	*Borreria latifolia*	-	+
Rubiaceae	*Canthium horridum*	+	+
Rubiaceae	*Canthium simile*	-	+
Rubiaceae	*Chassalia curviflora*	+	+
Rubiaceae	*Geophila herbacea*	+	+
Rubiaceae	*Hedyotis capitellata* var. *mollissima*	+	-
Rubiaceae	*Hedyotis costata*	-	+
Rubiaceae	*Hedyotis scandens*	-	+

Family	Species checklist	Inventory in 1959/1960	Inventory in 2008
Rubiaceae	*Hedyotis verticillata*	+	+
Rubiaceae	*Hyptianthera stricta*	-	+
Rubiaceae	*Ixora yunnanensis*	-	+
Rubiaceae	*Lasianthus hookeri* var. *dunniana*	+	+
Rubiaceae	*Morinda angustifolia*	-	+
Rubiaceae	*Morinda cochinchinensis*	+	+
Rubiaceae	*Mussaenda hossei*	+	+
Rubiaceae	*Mussaenda macrophylla*	-	+
Rubiaceae	*Mussaenda sessilifolia*	+	-
Rubiaceae	*Paederia cavaleriei*	-	+
Rubiaceae	*Pavetta hongkongensis*	+	+
Rubiaceae	*Prismatomeris tetrandra*	+	+
Rubiaceae	*Psychotria henryi*	+	-
Rubiaceae	*Psychotria siamica*	+	-
Rubiaceae	*Psychotria yunnanensis*	-	+
Rubiaceae	*Randia bispinosa*	+	+
Rubiaceae	*Saprosma ternata*	+	+
Rubiaceae	*Tarenna yunnanensis*	+	-
Rubiaceae	*Tarennoidea wallichii*	-	+
Rubiaceae	*Uncaria laevigata*	+	+
Rubiaceae	*Uncaria sinensis*	+	+
Rutaceae	*Clausena dentata* var. *dunniana*	+	-
Rutaceae	*Clausena excavata*	+	+
Rutaceae	*Evodia austrosinensis*	+	+
Rutaceae	*Evodia lepta*	+	+
Rutaceae	*Evodia simplicifolia*	-	+
Rutaceae	*Glycosmis pentaphylla*	-	+
Rutaceae	*Micromelum integerrimum*	-	+
Rutaceae	*Zanthoxylum dissitum*	-	+
Sabiaceae	*Meliosma arnottiana*	+	+
Sabiaceae	*Meliosma rigida*	-	+
Sabiaceae	*Sabia limoniacea*	-	+
Salicaceae	*Flacourtia rukam*	+	-
Salicaceae	*Idesia polycarpa*	-	+
Santalaceae	*Scleropyrum wallichianum*	-	+
Sapindaceae	*Allophylus hirsutus*	-	+
Sapindaceae	*Arytera littoralis*	+	+
Sapindaceae	*Harpullia cupanioides*	+	+
Sapindaceae	*Homalium ceylanicum* var. *laoticum*	+	+
Sapindaceae	*Mischocarpus pentapetalus*	+	-
Sapindaceae	*Nephelium lappaceum*	+	+
Sapindaceae	*Pometia tomentosa*	+	-

Family	Species checklist	Inventory in 1959/1960	Inventory in 2008
Sapindaceae	*Sapindus rarak*	+	+
Sapotaceae	*Pouteria grandifolia*	+	+
Simaroubaceae	*Ailanthus giraldii*	+	+
Smilacaceae	*Smilax bracteata*	-	+
Smilacaceae	*Smilax glabra*	+	+
Smilacaceae	*Smilax hemsleyana*	+	+
Solanaceae	*Capsicum frutescens*	+	+
Solanaceae	*Datura stramonium*	+	-
Solanaceae	*Solanum indicum*	+	+
Solanaceae	*Solanum spirale*	+	+
Staphyleaceae	*Turpinia cochinchinensis*	+	+
Symplocaceae	*Symplocos cochinchinensis*	+	+
Symplocaceae	*Symplocos hookeri*	+	-
Theaceae	*Camellia assamica* var. *assamica*	-	+
Urticaceae	*Dendrocnide sinuata*	+	-
Urticaceae	*Oreocnide rubescens*	+	-
Urticaceae	*Poikilospermum lanceolatum*	+	-
Vitaceae	*Cayratia trifolia*	-	+
Vitaceae	*Cissus glaberrima*	+	+
Vitaceae	*Cissus javana*	+	+
Vitaceae	*Leea compactiflora*	-	+
Vitaceae	*Leea indica*	+	-
Vitaceae	*Tetrastigma cruciatum*	-	+
Vitaceae	*Tetrastigma obovatum*	+	-
Zingiberaceae	*Amomum villosum*	-	+
Zingiberaceae	*Zingiber xishuangbannaense*	-	+
Total 88 families	402 species	258 species	332 species