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Research Article

Vegetation, floristic composition and species diversity in a tropical mountain nature reserve in southern Yunnan, SW China, with implications for conservation

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Abstract

Complete floristic and vegetation surveys were done in a newly established nature reserve on a tropical mountain in southern Yunnan. Three vegetation types in three altitudinal zones were recognized: a tropical seasonal rain forest below 1,100 m; a lower montane evergreen broad-leaved forest at 1,100-1,600 m; and a montane rain forest above 1,600 m. A total of 1,657 species of seed plants in 758 genera and 146 families were recorded from the nature reserve. Tropical families (61%) and genera (81%) comprise the majority of the flora, and tropical Asian genera make up the highest percentage, showing the close affinity of the flora with the tropical Asian (Indo-Malaysia) flora, despite the high latitude (22°N). Floristic changes with altitude are conspicuous. The transition from lowland tropical seasonal rain forest dominated by mixed tropical families to lower montane forest dominated by Fagaceae and Lauraceae occurs at 1,100-1,150 m. Although the middle montane forests above 1,600 m have 'oak-laurel' assemblage characteristics, the temperate families Magnoliaceae and Cornaceae become dominant. Both the tree species diversities and the numbers of genera and families are higher in the lowlands and middle montane zones than in the lower montane. The lower diversity in the lower montane zone could reflect less precipitation and frequent fires in the historical past. The species compositions of samples within each altitudinal zone show greater horizontal turnover (β diversity) in the lowlands. Conservation efforts should focus on the species-rich lowland and middle montane forests.

Key words: Vegetation; flora; altitudinal changes; tropical mountains

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Introduction

The tropical area of southern China is located on the climatic and biogeographical northern edge of the Asian tropics. The largest tropical area still covered by forests is in southern Yunnan of Southwest China. Floristic and ecological studies have shown that this region has an Indo-Malaysian flora and supports true evergreen rain forest with the same forest profile and physiognomic characteristics as equatorial lowland rain forests elsewhere [1-6]. However, the tropical rain forest has been greatly changed in southern Yunnan. The major land-use change has been an increase in monoculture rubber tree plantations and a decrease in the tropical rain forest. The tropical rain forests with the highest species richness undoubtedly lost their tree species diversity after rubber plantations replaced them with a single rubber tree species. Limiting further expansion of rubber plantations will be necessary for conservation of the rain forest flora and fauna.

A new prefectural-level nature reserve, the Bulong Nature Reserve, was established in December 2008 in southern Yunnan, adjacent to the border with Myanmar, to protect its high species diversity and particular floristic composition from the great threat of expanding rubber plantations. We investigated the vegetation and flora of the Bulong Nature Reserve to inform its administration and management. This reserve has a mountainous topography, with the lowest elevation at 485 m on the Mekong River and the highest summit at 2,196.6 m. Our comprehensive floristic and vegetation survey in the reserve fills the gap in our knowledge of elevation changes in the flora and vegetation on the northern margins of the tropics.

Methods

Study Area

Southern Yunnan(Xishuangbanna) (21°09'-22°36' N, 99°58'-101°50' E; Fig. 1) borders Myanmar and Laos and has a mountainous topography, with the mountain ridges running in a north-south direction and decreasing in elevation southward. The region has a monsoon climate. The annual mean temperature varies from 21.3°C at an elevation of 630 m to 15.1°C at 1,979 m, and the 20°C isotherm is at 850 m. At this latitude temperatures vary seasonally and winter frosts occur regularly above 900-1,000 m. The annual precipitation increases from 1,193 mm at Mengyang at 740 m elevation to 2,491 mm at the summit of Nangongshan at 1,979 m elevation, and more than 80% falls during the rainy season from May to October. Most soils below 1,000 m are deep laterites developed from siliceous rocks, such as granite and gneiss, with a thin humus horizon. Lateritic red soils develop on sandstone above 1,000 m.

Sampling of vegetation

We conducted an intensive floristic inventory and a plot-based vegetation survey in the nature reserve in 1998-2011. Five 25 × 20 m plots were established in each of six forest types. All trees were identified and their d.b.h. (minimum 5 cm) measured and height estimated by eye. The importance value index (IVI) suggested by Curtis and McIntosh [7] was calculated for each forest type. The Shannon-Wiener index ($H' = -\Sigma(P_i * \ln P_i)$) and Simpson's diversity index ($D = 1 - \Sigma Pi^2$) [8] for species diversity were also calculated. We did not include the secondary coniferous

forest in this study. Based on the species list from the floristic inventories, patterns of seed plant distribution were quantified at the generic and the family levels following Wu *et al*. [9-10]. Specimens were identified, and voucher materials are lodged in the herbarium of the Xishuangbanna Tropical Botanical Garden (HITBC). Species authorities follow the Flora of China [11].

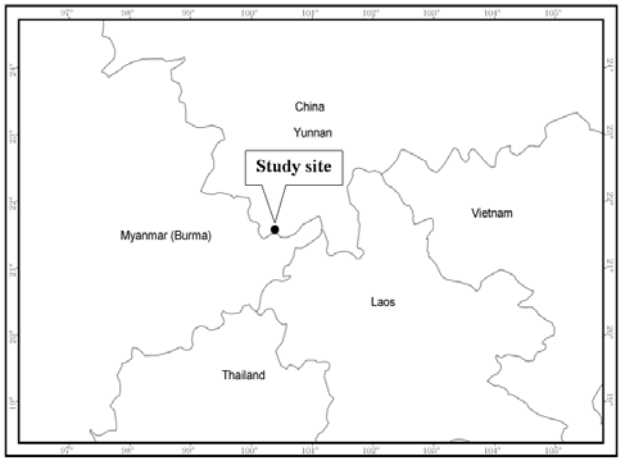

Fig. 1 Location of the study site

Results

The flora

A total of 1,657 species of seed plants in 757 genera and 146 families was recorded from the nature reserve. The families with highest species richness were Fabaceae (108 species), Euphorbiaceae (79), Rubiaceae (79), Lauraceae (65), Orchidaceae (55), and Lamiaceae (50) (Appendix 1). The composition of geographical elements at the family level was assessed (Appendix 2). Families of pantropical distribution have the highest proportion in the flora, including 71 families, contributing 48.6% of the total. At the generic level, tropical elements of all types make up 80.6% of the flora, while temperate ones (Type 8-14) contribute only 14.5% (Appendix 3).

The vegetation

Three altitudinal vegetation zones were recognized based on floristic composition and forest physiognomy: the lowland forest zone below 1,100 m, the lower montane forest zone at 1,100-1,600 m, and the middle montane forest zone above 1,600 m (Fig. 2). Two subtypes were recognized in each zone, giving a total of six forest types. Following the vegetation classification of Xishuangbanna [3, 12], they are named by their dominant tree species as: *Sapium baccatum* - *Baccaurea ramiflora* forest and *Pouteria grandifolia* - *Walsura yunnanensis* forest in the lowland; *Castanopsis fleuryi* + *Castanopsis mekongensis* forest and *Schima wallichii* + *Castanopsis hystrix* forest in the lower montane; and *Mastixia euonymoides* - *Phoebe megacalyx* forest and *Parakmeria yunnanensis* - *Gymnanthes remota* forest in the middle montane (Appendix 4).

The forest in the lowland zone is dominated by species of the predominantly tropical families Euphorbiaceae, Sapotaceae, Lauraceae, Meliaceae, Rubiaceae and Sapindaceae. It has three

to four indistinct tree layers, with emergent trees >30 m tall, a main canopy up to 30 m high, with almost continuous crowns (70-80% cover) and the greatest density of stems; and a subcanopy layer 5-18 m tall, with a crown cover of about 40%, consisting of small trees and juveniles of species from the upper layers. The forest is mainly evergreen, except for some deciduous trees in the emergent layer.

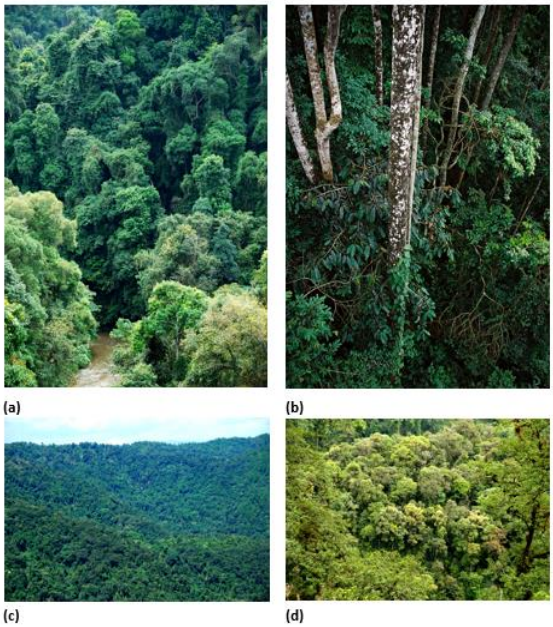

Fig. 2. Three altitudinal vegetation zones in the study area. (a) Physiognomy of the lowland forest, (b) Profile of the lowland forest, (c) Physiognomy of the lower montane forest, (d) Physiognomy of the middle montane forest. Photos by Zhu Hua

The forest in the lower montane zone is dominated largely by species of the families Fagaceae, Theaceae, Euphorbiaceae, and Lauraceae. The forest usually has two conspicuous tree layers, an upper one that is 15-30 m tall with dense crowns and a lower that is 3-18 m tall with a cover of about 50%. The *Schima wallichii + Castanopsis hystrix* forest on the zone occurs mainly on steep slopes (20-30^{o}), and the *Castanopsis fleuryi + Castanopsis mekongensis* forest mainly on gentle slopes (<20^{o}).

The forest in the middle montane zone is dominated by species of the families Lauraceae, Magnoliaceae, Cornaceae, Euphorbiaceae and Fagaceae. It usually has two tree layers. The upper layer is up to 35 m high with a crown cover of 70-80%. The *Mastixia euonymoides - Phoebe megacalyx* forest in this zone occurs mainly in wetter montane valleys, and the *Parakmeria yunnanensis - Gymnanthes remota* forest on shady slopes and the tops of hills.

Species diversity

The number of tree species>5 cm dbh (diameter at breast height) in a 0.25 ha sampling plot was 76-90 in the lowland forest, 36 in the lower montane forest, and 62-70 in the middle montane forest (Appendix 5). The Shannon-Weiner index showed a similar pattern, but the Simpson index was similar for all forest types. Rank-abundance diagrams show the presence of many rare species in all the communities, but a higher proportion in the lowlands (Fig. 3 and 4). Conversely, one or a few species are clearly dominant.

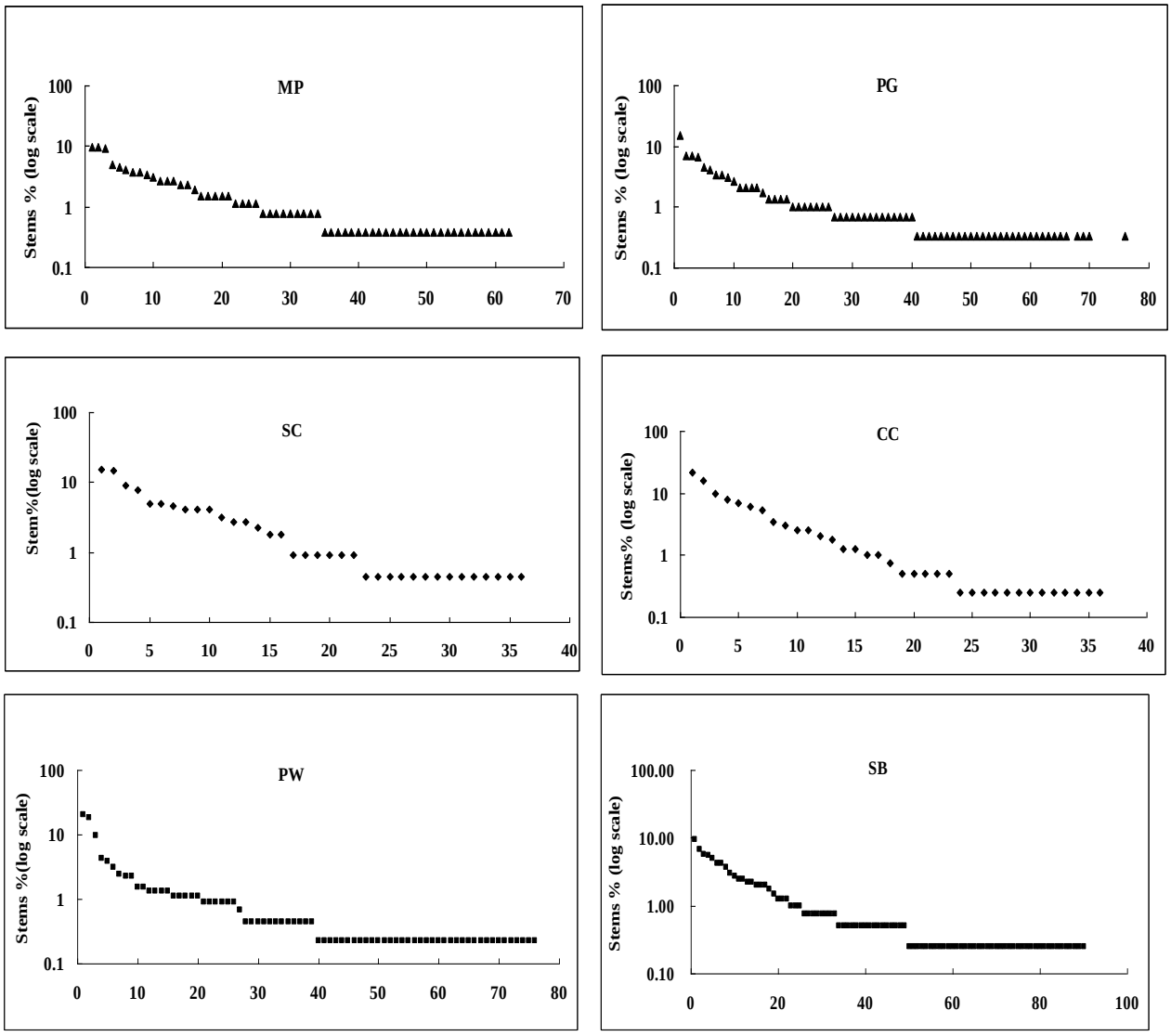

Fig.3. Species sequences ranked by % of number of stems of the six forest formations: MP: *Mastixia euonymoides- Phoebe megacalyx* forest; PG: *Parachmeria yunnanensis- Gymnanthes remota* forest; SC: *Schima wallichii+ Castanopsis hystrix* forest; CC: *Castanopsis fleuryi + Castanopsis mekongensis* forest; PW: *Pouteria grandifolia - Walsura yunnanensis* forest; SB:*Sapium baccatum - Baccaurea ramiflora* forest.

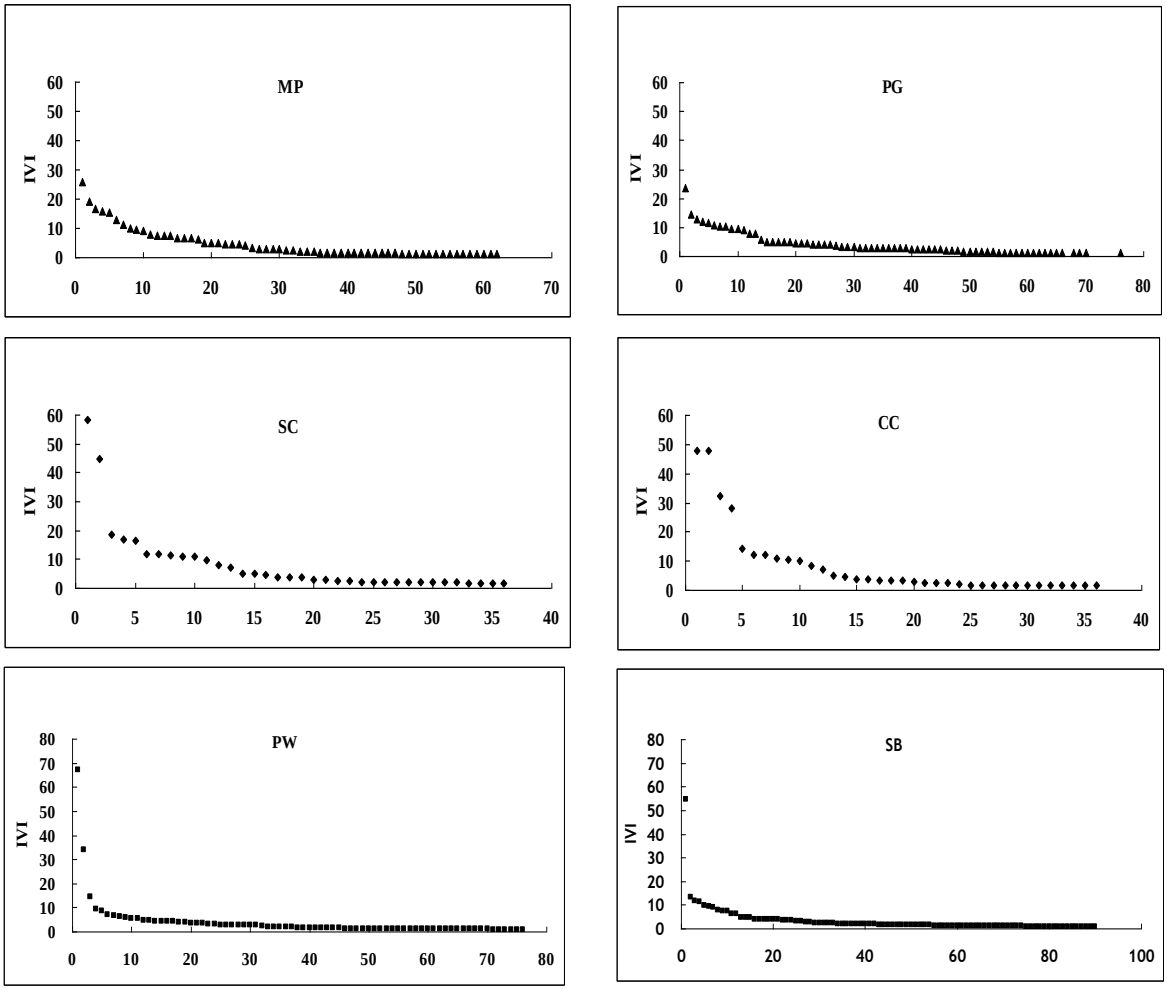

Fig.4. Species sequences ranked by IVI (Importance Value Index) of the six forest formations: MP: *Mastixia euonymoides- Phoebe megacalyx* forest*;* PG: *Parachmeria yunnanensis- Gymnanthes remota* forest*;* SC: *Schima wallichii+ Castanopsis hystrix* forest*;* CC: *Castanopsis fleuryi + Castanopsis mekongensis* forest*;* PW: *Pouteria grandifolia - Walsura yunnanensis* forest*;* SB:*Sapium baccatum - Baccaurea ramiflora* forest.

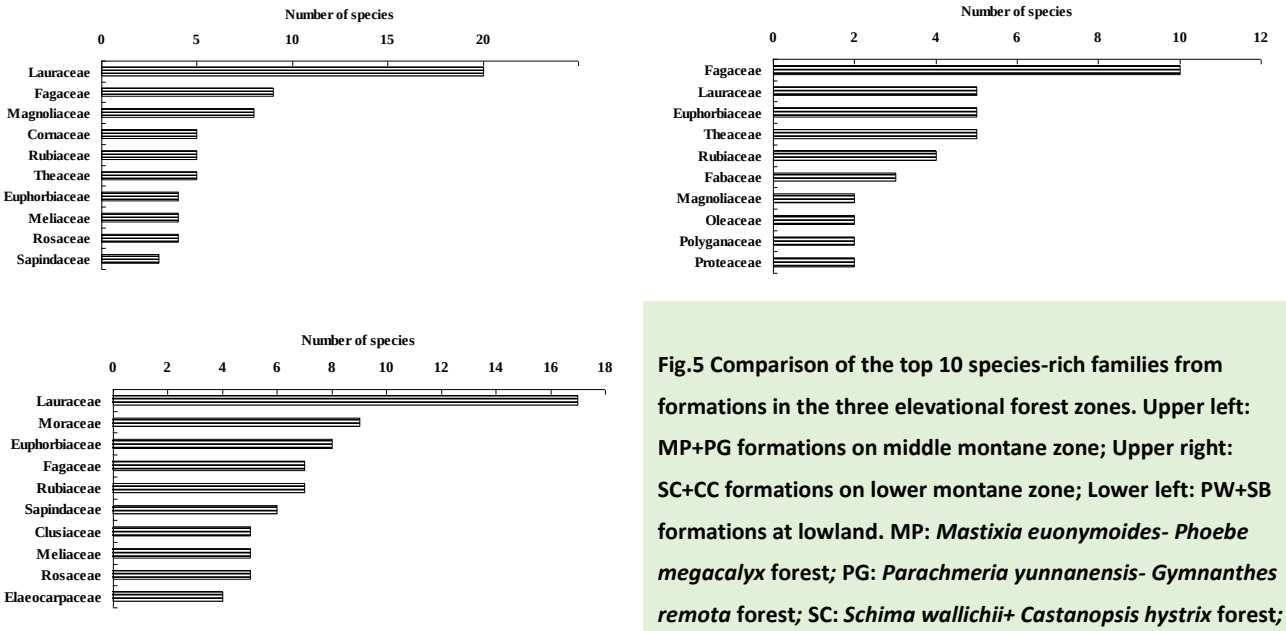

Fig.5 Comparison of the top 10 species-rich families from formations in the three elevational forest zones. Upper left: MP+PG formations on middle montane zone; Upper right: SC+CC formations on lower montane zone; Lower left: PW+SB formations at lowland. MP: *Mastixia euonymoides- Phoebe megacalyx* forest; PG: *Parachmeria yunnanensis- Gymnanthes remota* forest; SC: *Schima wallichii+ Castanopsis hystrix* forest; CC: *Castanopsis fleuryi + Castanopsis mekongensis* forest; PW: *Pouteria grandifolia - Walsura yunnanensis* forest; SB:*Sapium baccatum - Baccaurea ramiflora* forest.

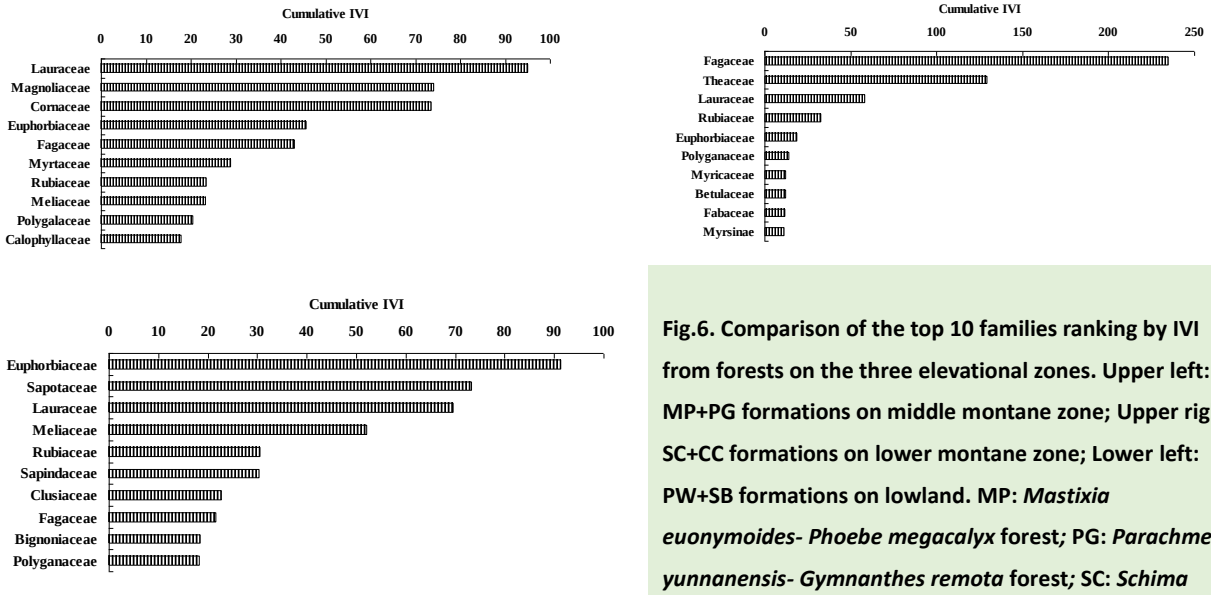

Fig.6. Comparison of the top 10 families ranking by IVI from forests on the three elevational zones. Upper left: MP+PG formations on middle montane zone; Upper right: SC+CC formations on lower montane zone; Lower left: PW+SB formations on lowland. MP: *Mastixia euonymoides- Phoebe megacalyx* forest; PG: *Parachmeria yunnanensis- Gymnanthes remota* forest; SC: *Schima wallichii+ Castanopsis hystrix* forest; CC: *Castanopsis fleuryi + Castanopsis mekongensis* forest; PW: *Pouteria grandifolia - Walsura yunnanensis* forest; SB:*Sapium baccatum - Baccaurea ramiflora* forest.

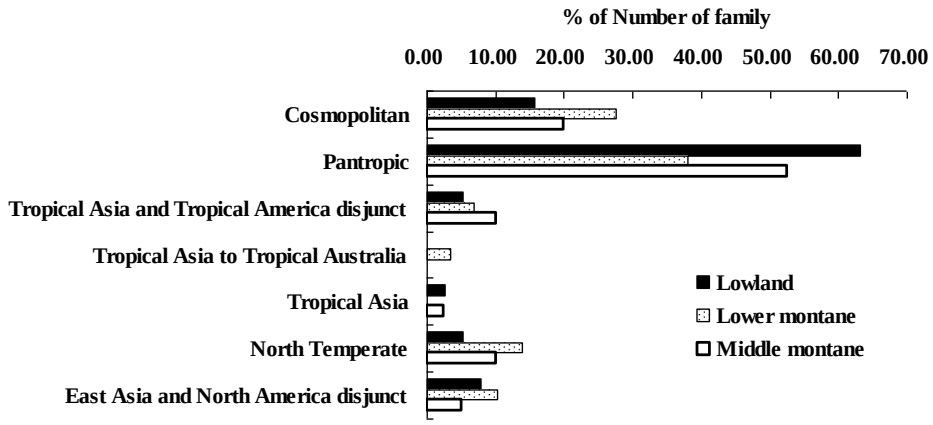

Fig.7. Biogeographical patterns of families along altitudes

Floristic changes with altitude

In terms of numbers of species, family dominance changes with altitude, except for the continued prominence of the Lauraceae, with tropical lowland families declining in importance (Fig. 5). Family dominance by importance value shows a similar, but even stronger trend (Fig. 6). Tropical families contribute 71% of the total in the lowlands, 48% in the lower montane and 65% in the middle montane (Fig. 7). Temperate and Cosmopolitan families have the highest proportion in the lower montane zone (Fig. 7). At the specific level, floristic variation among forest types is conspicuous, although the variation is less within the same elevation zone (Appendix 6).

Discussion

Geographical elements at the generic level can reveal the evolutionary history and floristic affinities of a local flora [10]. In the flora of the Bulong Nature Reserve, tropical elements together make up 80% of the flora, and the Tropical Asia elements are 26% of the flora. Despite the high latitude and cool winters, therefore, the flora of the nature reserve is evidently tropical in nature and has a close affinity to the tropical Asian (Indo-Malaysia) flora.

Ashton [13] suggested that a substantial floristic change occurs between 800 and 1,200 m on tropical mountains in Southeast Asia. The lower elevation marks the upper limit of tropical lowland rain forest, and above the upper elevation the floristically distinct lower montane forest appears. Lowland rain forests have a mixed rain forest species flora, while the lower montane forests are dominated by an ‘oak-laurel’ assemblage. Nakashizuka et al. [14] suggested for altitudinal classification in the Malay Peninsula that the lowlands is below 700m

above sea level, the transition 700-1,100 m, the lower montane 1,100-1,500 m and the upper montane 1,500-1,700m.

In our case in southern Yunnan, 1,000-1,100m is the transition from the tropical seasonal rain forest in the lowlands, dominated by mixed tropical families in species richness and IVI, to the lower montane forest, dominated mainly by Fagaceae and Lauraceae (Fig. 5 and 6). The transition in southern Yunnan is comparable with the transition between the lowland and lower montane forest in tropical Asia [13, 15-17], but at a higher upper elevation due to the so-called “Massenerhebung”, or 'mass elevation effect' [18], wherein forest zones occur at substantially higher elevations on major massifs than on isolated and coastal mountains. In the middle montane forest in southern Yunnan, although there are ‘oak-laurel’ assemblage characteristics, the temperate families Magnoliaceae and Cornaceae become dominant. It is not surprising that the East Asia temperate elements appear in the montane forest at the northern margins of SE Asia. Despite the floristic differences, the middle montane forest in southern Yunnan is similar in physiognomy to the lower montane forest in SE Asia. It is equivalent to the upper facies of the lower montane forest in SE Asia.

Altitudinal changes in biogeographical patterns were reported in Sulawesi in Indonesia [19-20], where there is a progression from dominant tropical families in the submontane zone to tropical Fagaceae (*Castanopsis, Lithocarpus*) in the lower/mid-montane. Sapotaceae in particular make a significant contribution to submontane forest and Magnoliaceae to mid-montane forest. Our studies show similar biogeographical patterns with altitude. Lauraceae has the highest species richness in the lowland and middle montane forests, and Fagaceae is highest in the lower montane forest, but is second in the middle montane forest. The temperate family Magnoliaceae becomes dominant in the middle montane, while the tropical families Moraceae and Euphorbiaceae have higher species richness in the lowland forest. If we rank the families by their IVIs (Figure 6), the Lauraceae, Fagaceae and Euphorbiaceae are the most dominant families in the middle montane, lower montane and lowlands, respectively. Magnoliaceae and Cornaceae are the second most dominant families in the middle montane forest, while Theaceae becomes the second most dominant in the lower montane, and the tropical family Sapotaceae comes second in the lowland.

A general trend found in tropical forests is a decrease in plant species diversity with increasing elevation [21-25]. Not only the numbers of species, but also the numbers of genera and families per sample declined linearly with elevation in Mexico [23]. However, total species richness has a non-linear relationship with elevation, with maximum species richness in the interval between 900 and 1,200m on Mount Kinabalu, Borneo [26]. In our case, not only the tree species diversities, but also the numbers of genera and families, are higher in the middle montane and lowland forests than in lower montane. Values of the Shannon-Wiener index differ considerably between the two lowland forest types, while they are similar for the two middle montane types. This is similar to the results from Mexican montane forest where the species composition of samples within an altitudinal zone showed greater horizontal turnover (β diversity) at lower elevations [23].

Gentry found a nearly linear increase in lowland Neotropical plant species richness with precipitation [21]. The lower tree species diversity in the lower montane forests in southern Yunnan could reflect lower precipitation, especially during the dry season (November to April). However, frequent fires have occurred in the region in the past 2,000 years; phytolith and charcoal records reveal that 12 fire episodes have occurred [27]. The lower montane forest is more frequently affected by fire because of lower precipitation during the dry season. The lower species diversity and the predominance of Fagaceae in these lower montane forests may therefore be successional features, with the forest largely secondary after frequent fire disturbances.

Sapium baccatum is considered a pioneer species. The *Sapium baccatum* - *Baccaurea ramiflora* forest in the lowland zone shows that the vegetation of the nature reserve was also historically disturbed by anthropogenic activities such as traditional swidden practices. Before the Bulong Nature Reserve was established, the region had undergone rapid deforestation, with a massive increase in monoculture rubber tree plantations since the 1980s, as in other parts of the Prefecture [28]. By 2010, rubber covered 22.14% of Xishuangbanna's landscape and the spread continues [28]. Tea plantations are also spreading rapidly in the mountains above 1,300 m in Xishuangbanna. This massive agricultural expansion resulted in disturbance in and around the reserve area before formal protection.

Bulong Nature Reserve is a prefecture-level nature reserve (i.e. lower than the national and provincial levels). Out of the total area of 35,485 ha, state-owned land makes up 24,648 ha and collective-owned land is 10,836 ha. Collective-owned land occurs inside the reserve for historical reasons, with some local people resident there. Although rubber and tea plantations are formally prohibited in the nature reserve, harvesting of wood and medicinal plants still occurs on the collective-owned land, presenting a challenge for the management of the reserve.

Implications for conservation

The lowland forests have the highest species diversity, while the forests in the lower montane zone have the lowest. Within each zone, the variation in Shannon-Wiener's index between forest types declines with elevation. Rank-abundance diagrams show the presence of many rare species in all the communities, but a higher proportion in the lowlands. The species composition of the samples within an altitudinal zone indicates greater horizontal turnover (β diversity) in the lowlands.

Both the tree species diversities and the number of genera and families are higher in the middle montane and lowland forests than in the lower montane. The lower species diversity and the predominance of Fagaceae in these lower montane forests suggest that they could be largely secondary. Conservation should focus on the species-rich lowland and middle montane forests.

Acknowledgments

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Appendix 1Families with more than 10 species in the nature reserve

Family	Number of genus	Number of Species	Family	Number of genus	Number of Species
Fabaceae	42	108	Cucurbitaceae	10	18
Euphorbiaceae	29	79	Menispermaceae	11	17
Rubiaceae	35	79	Sapindaceae	11	17
Lauraceae	12	65	Vitaceae	5	17
Orchidaceae	29	56	Araliaceae	7	16
Lamiaceae	21	50	Melastomataceae	9	16
Asteraceae	28	48	Convolvulaceae	8	15
Poaceae	32	43	Elaeocarpaceae	2	15
Moraceae	7	41	Myrtaceae	3	15
Rosaceae	14	32	Sterculiaceae	7	15
Fagaceae	4	31	Commelinaceae	8	14
Araceae	15	30	Malvaceae	7	15
Urticaceae	11	27	Piperaceae	2	14
Annonaceae	10	26	Smilacaceae	3	14
Apocynaceae	17	26	Celastraceae	5	14
Asclepiadaceae	16	25	Amaranthaceae	8	13
Acanthaceae	20	24	Anacardiaceae	10	13
Meliaceae	11	23	Gesneriaceae	6	13
Zingiberaceae	10	23	Cyperaceae	8	12
Myrsinaceae	4	22	Polygonaceae	2	12
Theaceae	10	22	Oleaceae	6	11
Rutaceae	9	21	Rhamnaceae	6	11
Liliaceae	12	20	Orobanchaceae	7	11

Appendix 2Geographical elements of seed plants at the family level in the flora

Geographical elements at family level	Number of family	%
1Cosmopolitan	38	26.03
2 Pantropic	71	48.63
3 Tropical Asia and Tropical America disjunct	8	5.48
4 Old World Tropic	2	1.37
5 Tropical Asia to Tropical Australia	4	2.74
6 Tropical Asia to Tropical Africa	1	0.68
7 Tropical Asia	3	2.05
8 North Temperate	15	10.27
9 East Asia and North America disjunct	4	2.74
Total number of families	146	100.00

Appendix 3Geographical elements of seed plants at the generic level in the flora

Geographical elements at generic level	Number of genera	%*
1Cosmopolitan	30	3.96
2 Pantropic	167	22.06
3 Tropical Asia and Tropical America disjunct	28	3.70
4 Old World Tropic	88	11.62
5 Tropical Asia to Tropical Australia	86	11.36
6 Tropical Asia to Tropical Africa	43	5.68
7 Tropical Asia	198	26.16
8 North Temperate	46	6.08
9 East Asia and North America disjunct	20	2.64
10 Old World Temperate	9	1.19
11 Temperate Asia	2	0.26
12 Mediterranean, W Asia to C Asia	3	0.40
13 Center Asia	0	0.00
14 East Asia	30	3.96
15 Endemic to China	7	0.92
Total number of genera	757	100.00

Appendix 4 Importance values Index (IVI) of tree species in six forest types (illustrated top 20 species with high IVI)

Vegetation zones											
Middle montane forest zone				*Lower montane forest zone*				*Lowland forest zone*			
Forest types											
Mastixia euonymoides-Phoebe megacalyx forest		*Parakmeria yunnanensis-Gymnanthes remota forest*		*Schima wallichii+ Castanopsis hystrix forest*		*Castanopsis fleuryi + Castanopsis mekongensis forest*		*Pouteria grandifolia - Walsura yunnanensis forest*		*Sapium baccatum - Baccaurea ramiflora forest*	
Altitude: 1650-1780 m Height of canopy: 35 (m) Sampling area: 2500 m^2 No. of sp.: 62 No. of stems: 263		Altitude: 1650-1700 m Height of canopy: 30(m) Sampling area: 2500 m^2 No. of sp.: 70 No. of stems: 293		Altitude: 1320-1380 m Height of canopy: 30 (m) Sampling area: 2500 m^2 No. of sp.: 36 No. of stems: 221		Altitude: 1150-1400 m Height of canopy: 20 (m) Sampling area: 2500 m^2 No. of sp.: 36 No. of stems: 399		Altitude: 950-1050 m Height of canopy: 35 (m) Sampling area: 2500 m^2 No. of sp.: 76 No. of stems: 450		Altitude: 930-1010 m Height of canopy: 35 (m) Sampling area: 2500 m^2 No. of sp.: 90 No. of stems: 402	
Species name	IVI*	Species name	IVI*	Species name	IVI*	Species name	IVI*	Species name	IVI*	Species name	IVI*
Mastixia euonymoides	25.86	*Gymnanthes remota*	23.53	*Schima wallichii*	58.41	*Castanopsis fleuryi*	47.95	*Pouteria grandifolia*	66.98	*Sapium baccatum*	54.59
Phoebe megacalyx	19.22	*Parakmeria yunnanensis*	14.62	*Castanopsis hystrix*	44.99	*Castanopsis mekongensis*	47.68	*Walsura yunnanensis*	34.10	*Baccaurea ramiflora*	13.21
Syzygium brachythyrsum	16.62	*Xanthophyllum yunnanensis*	12.75	*Machilus tenuipilis*	18.47	*Schima wallichii*	32.31	*Aidia yunnanensis*	14.57	*Mayodendron igneum*	11.62
Dysoxylum binectariferum	15.95	*Syzygium brachythyrsum*	12.18	*Castanopsis mekongensis*	16.86	*Lithocarpus truncatus*	27.95	*Polyalthia simiarum*	9.52	*Walsura yunnanensis*	11.36
Manglietia hookeri	15.34	*Wendlandia pingpiensis*	11.38	*Anneslea fragrans*	16.64	*Lithocarpus fenestratus*	14.10	*Xanthophyllum yunnanense*	8.73	*Mischocarpus pentapetalus*	9.91
Michelia cavaleriei	13.09	*Nyssa wenshanensis*	10.84	*Betula alnoides*	11.91	*Myrica esculenta*	12.21	*Xanthophyllum siamense*	6.97	*Macropanax undulatus*	9.56
Nyssa wenshanensis var. *longipedunculata*	11.1	*Cinnamomum javanicum*	10.26	*Lithocarpus truncatus*	11.85	*Castanopsis calathiformis*	12.04	*Garcinia cowa*	6.78	*Garcinia cowa*	8.93

Linociera insignis	9.88	*Calophyllum polyanthum*	10.15	*Wendlandia tinctoria*	11.52	*Lindera metcalfiana* var. *dictyophylla*	10.92	*Castanopsis megaphylla*	6.29	*Ostodes katharinae*	7.65
Ardisia thyrsiflora	9.53	*Nyssa wenshanensis* var. *longipedunculata*	9.66	*Ardisia neriifolia*	11.18	*Aporusa yunnanensis*	10.32	*Laurocerasus phaeosticta*	5.84	*Phoebe lanceolata*	7.57
Cinnamomum javanicum	9.15	*Mastixia pentandra* subsp. *chinensis*	9.49	*Lindera metcalfiana* var. *dictyophylla*	10.95	*Wendlandia tinctoria* subsp. *intermedia*	10.21	*Dichapetalum gelonioides* .	5.59	*Litsea cangyuanensis*	7.26
Helicia pyrrhobotrya	8.05	*Cyclobalanopsis chapensis*	9.23	*Gordonia chrysandra*	9.91	*Persea robusta*	8.39	*Semecarpus reticulata*	5.38	*Cryptocarya yunnanensis*	6.23
Calophyllum polyanthum	7.66	*Manglietia insignis*	7.7	*Xanthophyllum siamense*	7.89	*Ternstroemia gymnanthera*	6.95	*Mayodendron igneum*	4.77	*Nephelium chryseum*	6.22
Ostodes kuangii	7.64	*Acer decandrum*	7.67	*Metadina trichotoma*	7.13	*Horsfieldia glabra*	4.99	*Canthium simile*	4.70	*Dichapetalum gelonioides*	4.75
Xanthophyllum yunnanensis	7.58	*Ostodes kuangii*	5.8	*Daphniphyllum majorum*	5.02	*Elaeocarpus austroyunnanensis*	4.42	*Acronychia pedunculata*	4.32	*Aporusa yunnanensis*	4.74
Brassaiopsis lepidota	6.64	*Cyclobalanopsischrysocalyx*	5.16	*Illicium micranthum*	4.93	*Iteadaphne caudata*	3.70	*Mischocarpus pentapetalus*	4.22	*Pittosporopsis kerrii*	4.60
Cylindrokelupha kerrii	6.55	*Machilus shweliensis*	5	*Michelia floribunda*	4.78	*Pygeum topengii*	3.69	*Gomphandra tetrandra*	4.18	*Persea tenuipilis*	4.09
Cryptocarya rolletii	6.49	*Engelhardtia spicata*	4.96	*Helicia nilagirica*	3.94	*Cylindrokelupha yunnanensis*	3.42	*Macropanax undulatus*	4.14	*Oreocnide rubescens*	4.02
Alcimandra cathcartii	6.27	*Alcimandra cathcartii*	4.94	*Xanthophyllum yunnanense*	3.88	*Anneslea fragrans*	3.38	*Syzygium balsameum*	3.96	*Aidia yunnanensis*	4.01
Litsea vang var. *lobata*	4.93	*Michelia floribunda*	4.83	*Ormosia fordiana*	3.82	*Styrax tonkinensis*	3.19	*Carallia brachiata*	3.85	*Morus macroura*	3.99
Litsea lancifolia var. *pedicellata*	4.86	*Podocarpus neriifolius*	4.75	*Lithocarpus fenestratus*	2.99	*Castanopsis ceratacantha*	2.78	*Ficus altissima*	3.65	*Beilschmiedia robusta*	3.84
Randia sp.	4.82	*Craibiodendron stellatum*	4.42	*Pithecellobium clypearia*	2.84	*Rhamnoneuron balanae*	2.72	*Lithocarpus fohaiensis*	3.65	*Laurocerasus phaeosticta*	3.79

IVI*: Importance value index [7]

Appendix 5 Species diversity of six forest formations across vegetation zones

Forest type	Sampling altitude	Number of species	Number of stems	Shannon-Wiener's diversity indexes	Simpson index
Mastixia euonymoides- Phoebe megacalyx forest (MP)	1650-1780 m	62	263	3.54547	0.95986
Parachmeria yunnanensis- Gymnanthes remota forest (PG)	1650-1700 m	70	293	3.55984	0.95259
Schima wallichii+ Castanopsis hystrix forest (SC)	1320-1380 m	36	221	2.96255	0.92781
Castanopsis fleuryi + Castanopsis mekongensis forest (CC)	1120-1400 m	36	399	2.68935	0.89819
Pouteria grandifolia - Walsura yunnanensis forest (PW)	950-1120 m	76	450	3.17335	0.90883
Sapium baccatum - Baccaurea ramiflora forest (SB)	930-1010 m	90	402	3.82538	0.96763

Appendix 6 The similarity coefficients at species level among the six forest formations

Forest type	MP	PG	SC	CC	PW	SB
Mastixia euonymoides- Phoebe megacalyx forest (MP)	100	40.32	11.11	2.78	4.84	8.06
Parachmeria yunnanensis- Gymnanthes remota forest (PG)		100	27.78	19.44	10	8.57
Schima wallichii+ Castanopsis hystrix forest (SC)			100	33.33	8.33	22.22
Castanopsis fleuryi + Castanopsis mekongensis forest (CC)				100	16.67	36.11
Pouteria grandifolia - Walsura yunnanensis forest (PW)					100	55.26
Sapium baccatum - Baccaurea ramiflora forest (SB)						100

Similarity coefficient between A and B = the number of species shared by both A and B divided by the lowest number of specie of A or B, multiplied by 100%.