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The Structure, Species Composition and Diversity of the Limestone Vegetation in Xishuangbanna, SW China

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Abstract

The limestone vegetation in Xishuangbanna, tropical southwest China, includes three main vegetation types, six formations, and nine communities, which are described in detail with enumerations of forest profiles and species composition. Species diversity is discussed based on Shannon-Wiener's indexes for each forest formation. Comparison between the limestone seasonal rain forests and the ones on non-limestone reveals that the limestone seasonal rain forest has a lower species diversity index value per unit area but higher community diversity than the rain forest on non-limestone.

Introduction

Limestone vegetation is one of the principal vegetation types in tropical Yunnan of southwest China. Because of the great diversity of habitat and topography, limestone vegetation is extremely diverse in community types and very rich in endemic taxa. However, limestone vegetation is even less well known than that not on limestone, owing to the rugged topography. About 19% (3600 km^2) of Xishuangbanna, the southern-most part of Yunnan, is limestone. Most of the limestone area is still covered by forests and although these have been studied (Liu, 1987; Xu et Jian 1987), little has been published in English. This paper is based mainly on three years' field work on plots and is a phytosociological study of the limestone vegetation.

General Geography

Location and topography

Xishuangbanna lies between 2109' and 2236' N, 9958' and 10150' E. The region, which borders Burma and Laos, is a mountainous area at the northern margin of mainland southeast Asia and the southern end of the Hengdwan Mountains (part of the Himalayas). Basically, the area has a mountain-valley topography with the mountains running north-south with lower elevations towards the south. Altitude varies from 480 m at the bottom of the lowest valley in the south to 2429 m at the top of highest

mountain in the north.

The limestone occurs mainly in the south-eastern part of Xishuangbanna as a basically north-south-trending tract and ranges in altitude from 600 m to 1600 m (Fig. 1). There are two main types of limestone topography. One is typical karst hills, which have rocky tops without soil, and slopes partially covered by thin soil. The other is usually much bigger mountains, which also have rocky tops without soil, but have slopes, especially the lower ones, covered by thick soil with fewer limestone outcrops. Because of the diversity of topography and the great site to site variance of soil depth and cover of outcrops, there is a wide range of micro-habitats, i.e. there is a great spatial heterogeneity in the limestone.

Climate

The region of Xishuangbanna has a typical tropical monsoon climate. In the limestone area, climatic change with altitude is conspicuous. The annual mean temperature is 22°C (600 m alt.) to 18.4°C (1600 m), and the annual temperature accumulation (the sum of daily temperature means where they are > 10°C) is 8000°C (600 m) to 6600°C (1600 m); the monthly mean temperature is 15.9°C (600 m) to 12.3°C (1600 m) for the coldest month and 25.7°C (600 m) to 22°C (1600 m) for the hottest month. The annual precipitation varies from 1200 mm to 1556 mm of which more than 80 percent falls during the rainy season which starts in May and lasts till the end of October.

The Hengdwuan Mountains to the north of the region act as a huge barrier keeping out the cold air from the north in winter. Dense fog always exists for the whole of the dry season on the lower hills and in the valleys (average 146 foggy days per year and 1 mm precipitation per foggy day recorded in Mengla County in the south of the region), which compensates for the insufficient precipitation, so that a tropical moist climate occurs locally in spite of the fact that the region is controlled by strong monsoon climate and at a relatively high latitude and elevation.

Methods

Limestone vegetation is extremely diverse, especially because there are many communities, which are in different stages of succession. After initial floristic investigation (Zhu *et al.*, 1996), the main and representative primary forest types (which occupied relatively large areas and are climax communities judged by field observation) were selected for establishing plots. For each selected forest type, one to several plots were laid out. The number of plots (or the total sampling area) for a forest type was

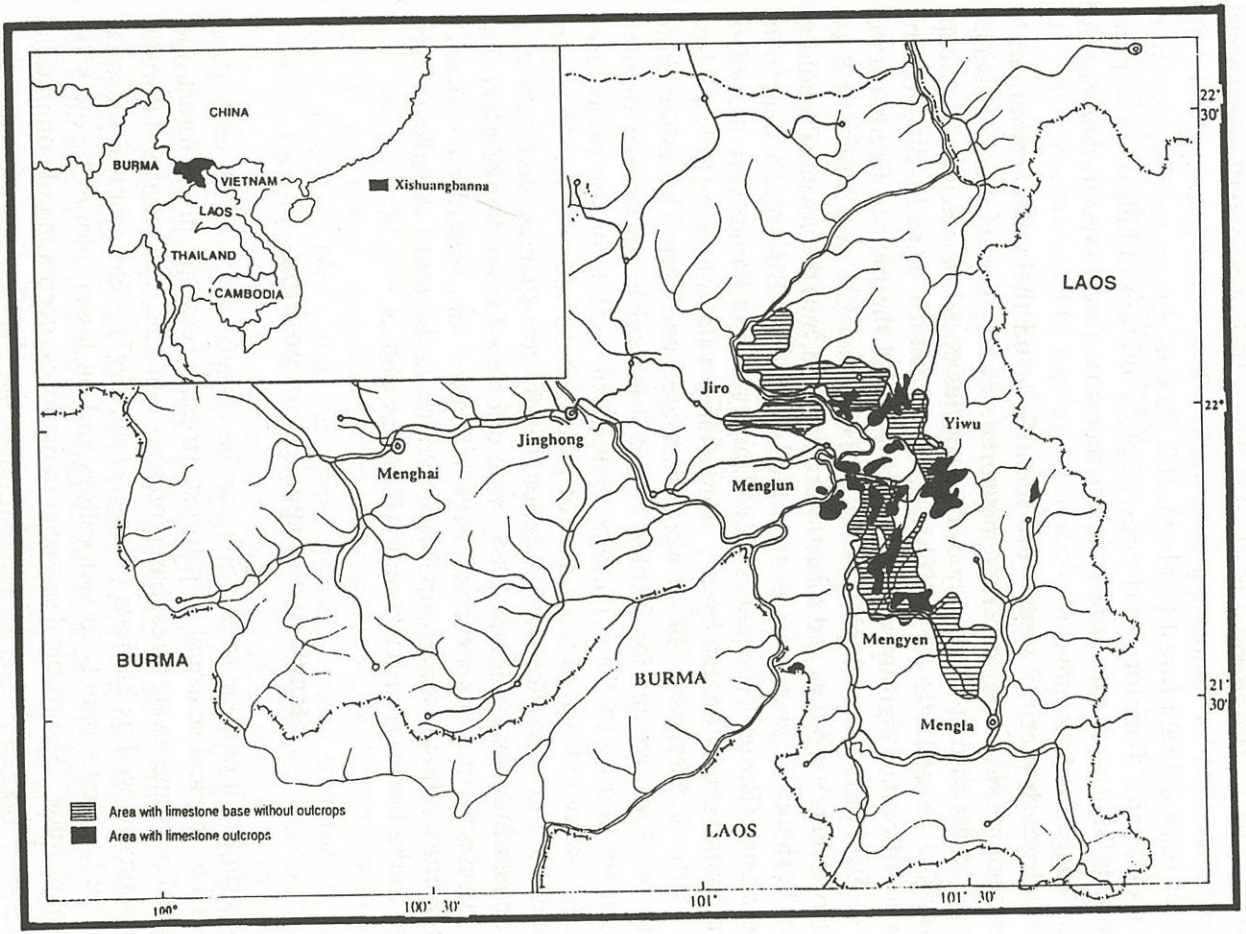

Figure 1. Distribution of limestone in Xishuangbanna, SW China.

determined mainly depending on floristic variance of the forest type. Sixteen plots were used for the analysis described in this paper. Different sized plots were used for different forest types in different topographical sites owing to considerations of phytocoenological minimal area and in some situations for facilitating field work. Plots were basically 2000–2500 m^2 for seasonal rain forest (7 plots), 500–2000 m^2 for seasonal moist forest (7 plots) and 100 m^2 for dwarf forest (2 plots) on tops of hills or mountains. (It is difficult to fix plot size even for the same forest type because of the very rugged topography).

In each plot, all trees were identified and their dbh. (minimum 5 cm), height and crown coverage measured. Each plot was roughly divided into 5 strips so that frequency of tree species could be calculated (except plots 102–16 and 102–15 in Tables 1 and 7, which were investigated by another botanist's group without subdivision of the plots). Furthermore, in 3–5 subplots (in each plot) of 5 x 5 m (for seasonal rain forest) or 3 x 3 m (for others), saplings and shrubs were counted, and the cover of seedlings and herbaceous plants were estimated by Braun-Blanquet's degree of abundance (Braun-Blanquet, 1932). Epiphytes and lianas were identified and abundance estimated by eye. Importance value indexes (IVI) devised by Curtis & McIntosh (1951) were calculated and shown in tables from data of plots except for Tables 1 and 7 in which percentage of total dominant density (%Dens.) and percentage of total dominant breast area (%BA) were calculated from data of plots 102–16 and 102–15. Shannon-Wiener's indexes (Shannon-Wiener, 1949) for species diversity and Evenness Indexes of Pielou (1966) were calculated from data of plots. For all species in plots, specimens were collected and identified. Species authorities follow Flora Reipublicae Popularis Sinicae. Specimens are kept in the herbaria at KUN and HITBC as well as at SYS.

Structure and species composition

The primary limestone vegetation can be classified into three vegetation types i.e. tropical seasonal rain forest, tropical seasonal moist forest and tropical montane dwarf forest based on physiognomic, structural and floristic characters as well as habitats (Wang *et al.*, 1997). The tropical seasonal rain forest occurs mainly in wet valleys and on lower slopes below 850–900 m altitude. The tropical seasonal moist forest occurs mainly on middle slopes and tops of lower hills. However, the distribution of vegetation types is greatly affected and modified by local micro-habitats. Topography seems to have the stronger effect on distributional patterns of vegetation than elevation. For example, the tropical seasonal rain forest occurs

occasionally on the upper valleys near 1000 m altitude in some particular sites because of the temperature inversion appearing in the mountain areas. The tropical montane dwarf forest occurs on the tops of hills or mountains. Each vegetation type is further subdivided into formations.

1. Tropical Seasonal Rain Forest

Like equatorial lowland rain forest, tropical seasonal rain forest has 3–4 indistinct tree layers. The top layer is mainly emergent trees more than 30 m tall (tallest up to 45 m) and has c. 30% of crown coverage; the second layer, up to 30 m tall with almost continuous crowns (70–80% coverage) and a greatest density of stems, is the main canopy layer; the third layer, 5–18 m tall, and with crown cover of c. 40%, consists of small trees and juveniles of species from the upper layers. In some sites, the third tree layer can be further divided into two sublayers: upper sublayer (10–18 m tall) and lower sublayer (5–9 m tall). Buttresses and cauliflory are common, and both big woody climbers and vascular epiphytes are abundant. The forest is mainly evergreen in spite of the fact that there are some deciduous trees in the emergent layer. This forest type occurs in wet valleys and lower slopes of hills or mountains and below 1000 m altitude.

Tropical seasonal rain forest contains two main formations:

1a. Ravine seasonal rain forest

This occurs in the wettest valleys and lower slopes as well as shaded slopes (usually northeast facing). It has fewer than 10% deciduous trees, either in number of species or in individuals and all exist in upper layer. Floristically the formation is characterized by *Pometia tomentosa* (Fig. 2). The similar forest type, which occurs on non limestone habitats in the region, was called "wet seasonal rain forest" in early Chinese botanical references (Qu, 1960), but the term "ravine seasonal rain forest" was preferred by recent authors owing to its valley habitat (Jin and Ou, 1997; Zhu *et al.*, 1998). There are 90 tree species, 16 shrub species, 32 herbaceous species, 26 liana and 5 epiphyte species in the plots (cumulative area of 7400 m^2). Two communities have been recorded:

(i) *Pometia tomentosa-Alphonsea monogyna* community. This community occurs in the wettest bottom of valleys or on lower slopes, with *Pometia tomentosa* as dominant species of the upper tree layer. Its canopy is usually 35–40 m tall. *Alphonsea monogyna* is the dominant species and *Pseuduvaria indochinensis* the sub-dominant species in second tree layer. *Horsfieldia pandurifolia* is the dominant in the upper sublayer of the third tree layer (9–20 m tall) and *Cleidion spiciflorum* is the dominant in lower sublayer of the third tree layer (5–10 m tall). The understorey, with a

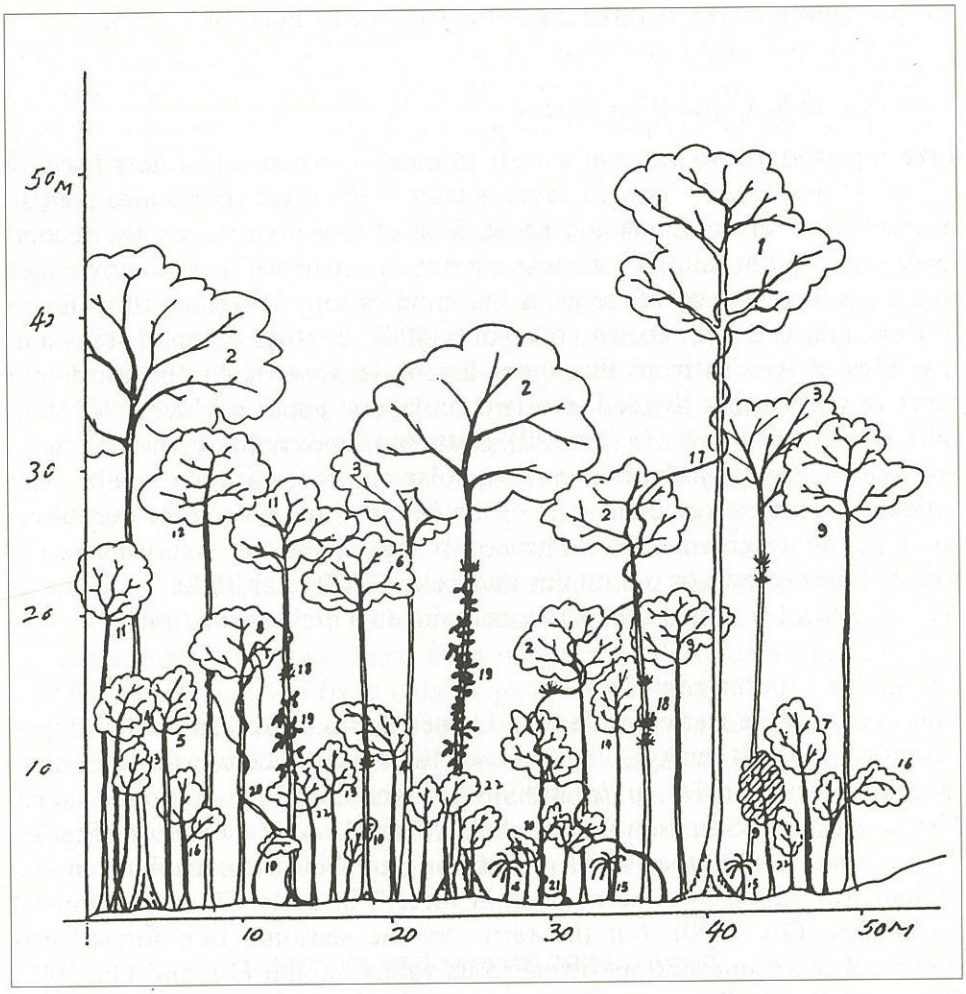

Figure 2. Forest profile of ravine seasonal rain forest

1. *Terminalia myriocarpa;* 2. *Pometia tomentosa;* 3. *Alphonsea monogyna;* 4. *Knema furfuracea;* 5. *Baccaurea ramiflora;* 6. *Garcinia cowa;* 7. *Syzygium latilimbum;* 8. *Barringtonia macrostachya;* 9. *Lasioccoca comberi* var. *pseudoverticillata;* 10. *Pittosporopsis kerrii;* 11. *Pseuduvaria indochinensis;* 12. *Pterospermum lanceaefolium;* 13. *Drypetes cumingii;* 14. *Horsfieldia pandurifolia;* 15. *Musa acuminata;* 16. *Trigonostemon thyrsoideum;* 17. *Ventilago calyculata;* 18. *Neottopteris nidus;* 19. *Rhaphidophora hongkongensis;* 20. *Combretum latifolium;* 21. *Fissistigma sp.;* 22. *Cleidion spiciflorum.*

cover of 30–40%, consists mainly of saplings and young woody lianas. *Pseuderanthemum polyanthum* and *Leea compactiflora* are the commonest shrub species. The herb layer is developed with a cover of 60%. The commonest species are the ferns *Ctenitopsis fusipes* and *Bolbites heteroclida,* the herb *Ophiopogon latifolius* and *Piper boemerifolium, and* the lianas *Derris cudatilimbum, and Strychnos nitida.* Its physiognomy and profile are almost exactly the same as those of wet seasonal rain forest on non-limestone in the region (Zhu, 1992, 1997). Most species of the community are also found in non-limestone seasonal rain forest, but the latter has many species not present on the limestone (Table 1).

Table 1. *Pomentia tomentosa-Alphonsea monogyna* community

Plot no.:102-16	Location: Meng-yue, Mengla
Altitude (m): 700-720	Area of plot (m): 80 x 30
Aspect: NE	Slope (degree): 0-5
Height of canopy: 40 m	Coverage of vegetation: >90%
No. of species (≥ 5 cm d.b.h.): 45	No. of stems: 140

Name of species	%Dens.	%BA	%Dens.+%BA
Pometia tomentosa	10.71	20.41	31.12
Amoora tetratepala	0.71	21.36	22.07
Alphonsea monogyna	15.00	2.76	17.26
Horsfieldia pandurifolia	6.43	5.71	12.14
Ficus altissima	0.71	9.98	10.69
Garuga floribunda var. *gamblei*	0.71	8.56	9.27
Cleidion spiciflorum	7.86	0.77	8.63
Diospyros hassellii	6.43	2.19	8.62
Pseuduvaria indochinensis	6.43	1.53	7.96
Glycosmis ferruginea	2.14	4.55	6.69
Litsea pierrei var. szemaois	2.86	3.25	6.11
Debregeasia squamata	3.57	0.85	4.42
Celtis timorensis	1.43	2.52	3.95
Prunus zippenliana	2.86	0.72	3.58
Picrasma javanica	2.14	0.74	2.88
Garcinia cowa	2.14	0.70	2.84
Erythrina stricta	1.43	1.33	2.73
Cryptocarya acutifolia	0.71	1.92	2.63
Macropanax dispermus	2.14	0.36	2.50
Canarium album	0.71	1.71	2.42
Litsea dilleniaefolia	1.43	0.75	2.18
Elaeocarpus austroyunnanensis	1.34	0.67	2.10
Lasiococca comberi var. *pseudoverticillata*	1.43	0.45	1.88

Cont:

Name of species	%Dens.	%BA	%Dens.+%BA
Diospyros nigrocortex	1.43	0.45	1.88
Antidesma montana	1.43	0.30	1.73
Tapiscia yunnanensis	0.71	0.94	1.65
Pterospermum lanceaefolium	1.43	0.20	1.63
Laportea sinuata	1.43	0.15	1.58
Tetrameles nudiflora	0.71	0.67	1.38
Semecarpus reticulatus	0.71	0.64	1.35
Macaranga indica	0.71	0.57	1.28
Toona ciliata	0.71	0.43	1.1
Dysoxylum lukii	0.71	0.40	1.11
Phaeanthus saccopetaloides	0.71	0.38	1.09
Dysoxylum binectariferum	0.71	0.27	0.98
Drypetes perreticulata	0.71	0.17	0.88
Canarium pimela	0.71	0.14	0.80
Phoebe puwenensis	0.71	0.11	0.82
Chisocheton sinensis	0.71	0.11	0.82
Trigonostemon thyrsoideum	0.71	0.11	0.82
Antidesma bunius	0.71	0.07	0.78
Sarcospermum arboreum	0.71	0.03	0.74
Sumbaviopsis albicans	0.71	0.02	0.73
Drypetes cumingii	0.71	0.02	0.73
Dichapetalum gelonioides	0.71	0.02	0.73
Total	100	100	200

(ii) *Pometia tomentosa-Celtis philippensis* var. *wightii* community. This community occurs near the bottoms of valleys and on lower slopes in somewhat less wet habitats, with rock outcrops usually covering more than 30% of the ground. It usually has *Celtis philippensis* var. *wightii and Lasioccoca comberi* var. *pseudoverticillata* as co-dominant species in the second tree layer and *Pometia tomentosa* as a dominant species in the upper tree layer. *Sumbaviopsis albicans* is the dominant in the upper sublayer of the third layer and *Cleidion spiciflorum* in the lower sublayer (Table 2). The understorey with a cover of 50% consists almost entirely of saplings. Only a few shrub species are recorded and the common ones are *Psychotria siamica, Sauropus macranthus* and *Miliusa tenuistipitata.* The herb layer has a cover of 30%, and the commonest are *Tectaria cordatum* (a fern), *Pilea balansae* and *Piper polysyphorum. Ventilago calyculata* var. *trichoclada* and *Loeseneriella lenticellata* are the commonest lianas. *Rhaphidophora hongkongensis* and *Pothos chinensis* are frequent epiphytes. This community is transitional toward lower hill seasonal rain forest in physiognomy and floristic composition.

Table 2. *Pometia tomentosa–Celtis philippensis* var. *wightii* community

Plot no.:	HW9203	HW9202	
Location:	Menglun	Menglun	
Altitude (m):	700	740	
Area of plot (m):	50 x 50	50 x 50	
Aspect:	NE	NE	
Slope (degree):	25	10	
Height of canopy (m):	35	30	
Coverage of vegetation (%):	100	100	
No. of tree species (≥5 cm DBH):	23	19	
No. of stems:	118	164	
Name of species	IVI[1)]	IVI	Average
Celtis philippensis var. *wighttii*	41.3	56.1	48.7
Lasiococca comberi var. *pseudoverticillata*	45.1	39.8	42.6
Cleidion spiciflorum	18.7	40.2	29.4
Sumbaviopsis albicans	24.7	30.7	27.7
Pometia tomentosa	11.8	18.5	15.1
Ficus altissima	27.2	–[2)]	13.6
Neonauclea tsiana	12.5	12.2	12.4
Caryota urens	14.3	11.4	12.8
Amoora tetrapetala	6.9	15.6	11.3
Drypetes perreticulata	12.7	8.2	10.4
Mitrephora maingayi	8.8	10.2	9.5
Tetrameles nudiflora	–	117.7	8.8
Terminalia bellerica	13.7	–	6.9
Garcinia xanthochymus	3.0	9.0	6.0
Mitrephora wangii	9.9	–	4.9
Duabanga grandiflora	8.7	–	4.3
Alphonsea monogyne	8.2	+[3)]	4.1
Chukrasia tabularis var. *velutina*	7.6	–	3.8
Dysoxylum hainanensis	+	7.7	3.8
Randia wallichii	5.9	+	2.9
Pterospermum lanceifolium	5.4	–	2.7
Pseudostreblus indica	+	5.6	2.8
Ficus benjamina	+	5.3	2.6
Morus macroura	4.0	–	2.0
Ficus glaberrima	3.2	–	1.6
Dysoxylum lenticellatum	3.2	–	1.6
Glycosmis ferruginea	–	3.0	1.5
Ficus cyrtophylla	–	3.0	1.5
Diospyros hassellii	–	3.0	1.5
Horsfieldia tetratepala	+	2.9	1.5
Laportea sinuata	2.9	–	1.4
Total	300	300	300

[1)] IVI=%Density + % Frequency + %Dominance

[2)] —: not recorded in the plot

[3)] +: only saplings (<5 cm d.b.h.) or seedlings were recorded in the plot

1b. Lower hill seasonal rain forest

Lower hill seasonal rain forest occurs in even less wet habitats mainly on lower hills and sometime on lower sun-facing (usually southwest) slopes. It has the same altitudinal range as formation 1a, but is never found in valleys. Deciduous trees make up 10–30% of the number of species or individuals and exist in upper layer and as emergents. The similar forest type occurs on non-limestone habitats in the region, and was also called "dry seasonal rain forest" (Qu., 1960), but the term "lower hill seasonal rain forest" was preferred recently considering its habitat.(Jin and Ou, 1997; Zhu *et al.*, 1998). It has a canopy about 30 m tall and relatively clear stratification. The upper layer with a crown cover of 40–50%, is 20–30 m tall. The second layer, which is the main canopy layer, has a crown cover of 70–80% and 10–20 m tall. The third layer with a cover of c. 50–60% is 3–10 m tall. There are some scattered emergents such as *Chukrasia tabularis* var. *velutina, Tetrameles nudiflora* and *Garuga floribunda* var. *gamblei* (Fig. 3). There are 67 tree species, 12 shrub species, 13 herbaceous species, 32 liana and 4 epiphyte species in the plots (cumulative area of 7400 m^2).

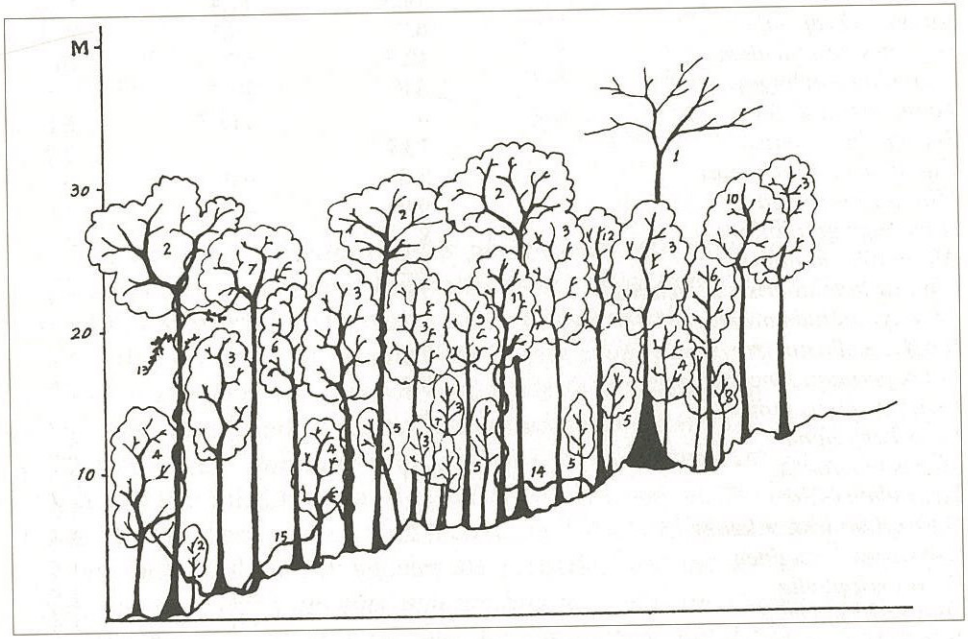

Figure 3. Forest profile of lower hill seasonal rain forest

1. *Tetrameles nudiflora;* 2. *Celtis philippensis* var. *wightii; 3. Lasioccoca comberi* var. *pseudoverticillata;* 4. *Sumbaviopsis albicans;* 5. *Cleidion spiciflorum;* 6. *Alphonsea mollis;* 7. *Amoora tetrapetala;* 8. *Tarenna sylvestis;* 9. *Garcinia bracteata;* 10. *Metadina trichotoma;* 11. *Alphonsea monogyna;* 12. *Beilschmiedia yunnanensis;* 13. *Combretum latifolium;* 14. *Ventilago calyculata;* 15. *Tetrastigma henryi.*

There are several other communities that occur on non limestone habitats in the region but only one community was recorded in the limestone:

Celtis philippensis var. *wighti—Lasiococca comberi* var. *pseudoverticillata* community. This is the commonest community on lower slopes of limestone. The upper tree layer is dominated by *Celtis philippensis* var. *wightii,* with some scattered deciduous emergents. *Lasiococca comberi* var. *pseudoverticillata* is the dominant in the second layer. *Sumbaviopsis albicans* and *Cleidion spiciflorum* are still the dominants in the third layer (Table 3). The understorey with a cover of 30–50%, consists of saplings. Fewer true shrub species were recorded. The herb layer is very undeveloped and consists of seedlings and a lot of creeping lianas. The commonest creeping lianas are *Derris caudatilinba* and *Loeseneriella yunnanensis.* Big woody lianas, such as *Combretum* spp., *Tetrastigma* spp. *Ventilago* spp. etc., are frequent. Epiphytes are less frequent than in the ravine seasonal rain forest.

Table 3. *Lasiococca comberi* var. *pseudoverticellata–Celtis philippensis* var. *wightii* community

Plot no.:	94-03-01	93-12-03	9203	102-13		
Location:	Mengyen	Yingchan	Yingchan	Mengyen		
Altitude (m):	800	1000	1060	825		
Area of plot (m):		50 x 50	20(10 x 10)	5(10 x 10)	40 x 60	
Aspect:	SW	NW	SW	W		
Slope (degree):		40	5-15	10	10	
Height of canopy (m):		30	30	30	25	
Coverage (%):		>90	90	95	90	
No. of species (≥5cm d.b.h.)		27	23	12	11	
No. of stems	102	271	44	142		
Name of species		IVI	IVI	IVI	IVI	Average
Lasiococca comberi var. *pseudoverticellata*		67.12	126.1	101	151.1	111.3
Celtis philippensis var. *wightii*		23.64	44.18	30.37	97.2	48.85
Chukrasia tabularis var. *velutina*		15.37	11.42	30.24	–	14.26
Garuga floribunda var. *gamblei*		9.66	32.16	8.97	–	12.70
Tetrameles nudiflora		40.67	–	–	–	10.17
Sumbaviopsis albicans		11.81	9.33	7.64	6.39	8.8
Cleidion spiciflorum		10.67	6.67	7.57	9.3	8.55

Cont:

Name of species	IVI	IVI	IVI	IVI	Average
Alphosea mollis	10.81	–	18.42	–	7.3
Tarena sylvestis	–	14.1	7.57	–	5.42
Bombax insignis	17.00	–	–	–	4.25
Metadina trichotoma	–	2.27	13.85	–	4.03
Amoora tetrapetala	–	4.99	8.34	–	3.33
Laportea sinuata	5.84	7.55	–	–	3.35
Syzygium szemaoensis	–	–	–	12.8	3.2
Fortunella polyandra	–	12.7	+	–	3.14
Garcinia bracteata	9.91	2.11	+	–	3.01
Polyalthia cheliensis	11.71	–	+	–	2.93
Alphonsea monogyna	6.31	3.45	–	–	2.44
Croton crassifolium	3.09	–	–	6.23	2.33
Symphyllia silhetiana	–	–	–	8.9	2.23
Beilschmiedia yunnanensis	6.66	2.12	–	–	2.20
Caryota urens	–	–	8.42	–	2.11
Walsura robusta	–	–	7.57	–	1.89
Ficus conccina	6.24	–	–	–	1.56
Celtis bodinieri	5.95	–	–	–	1.49
Lagerstroemia tomentosa	5.79	–	–	–	1.45
Dracaena cochinchinensis	4.02	1.68	–	1.43	
Ficus racemosa	5.34	–	–	–	1.34
Murraya tetramera	–	5.10	+	–	1.28
Ficus glaberrima	2.96	2.14	–	–	1.28
Ficus virens 4.59	–	–	–	1.15	
Vitex quinata var. *puberula*	3.14	–	–	–	0.79
Syzygium melanophylla	–	–	–	3.0	0.75
Dysoxylum lenticellata	2.94	–	–	–	0.74
Mitrephora thorelii	2.94	–	–	–	0.74
Wrightia tomentosa	2.90	–	–	–	0.73
Ehretia tsangii	2.89	–	–	–	0.73
Mitrephora maingayi	–	2.38	–	–	0.6
Derris robusta	–	–	–	2.21	0.55
Diospyros yunnanensis	–	1.75	–	–	0.44
Mitrephora wangii	–	1.71	–	–	0.43
Amoora calcicola	–	1.68	+	–	0.42
Aglaia testicularis	–	1.66	–	–	0.42
Randia acuminatissima	+	–	–	1.55	0.39
Xeromphis spinosa	–	–	–	1.40	0.35
Total 300	300	300	300	300	

2. Tropical Seasonal Moist Forest

Tropical seasonal moist forest was recognized as a vegetation type based on its profile and its occurrence mainly on the middle and upper slopes ranging from 650–1300 m altitude on limestone. It usually has two distinct tree layers with the canopy 20–25 m tall although some scattered big trees can reach more than 30 m tall in some sites. Woody lianas are abundant and vascular epiphytes with small, thick leaves are common. Buttresses and cauliflory are relatively rare. This forest type is somewhat diverse in physiognomy and floristic composition because of the great diversity of micro-habitats on the mid and upper slopes of the limestone. This vegetation type was called "monsoon forest" in Chinese botanical references (Liu, 1987). The term seasonal moist forest is preferred because the forest is not equivalent to Schimper's monsoon forest in many ways in spite of the fact that it is affected by seasonal dryness and contains a variable percentage of deciduous trees.

Two main formations can be recognized:

2a. Tropical seasonal evergreen moist forest

This formation occurs on upper slopes, shady slopes or tops of lower hills with more than 90% of rock outcrops from 650 m to 1300 m alt. The forest is evergreen, with two distinct tree layers. The upper layer with a crown cover of 40–60% is 15–25 m tall and the second layer with a crown cover of 70–80% is 3–15 m tall. Woody climbers are very abundant. Vascular epiphytes with small, thick leaves are frequent. There are 50 tree species, 8 shrub species, 10 herbaceous species, 10 liana and 11 epiphyte species in the plots (cumulative area of 3500 m^2). It is intermediate between lower hill seasonal rain forest and montane dwarf evergreen forest.

Two main communities have been recorded:

(i) *Osmanthus polyneurus–Dracaena cochinchinensis* community. This community usually occurs on the upper slopes of mountains or hills above 1000 m altitude (Fig. 4). *Osmanthus polyneurus* is the dominant species in the top layer and *Dracaena cochinchinensis* is usually the dominant in the second layer (Table 4). The understorey consists of saplings and creeping lianas. The commonest lianas are *Loeseneriella yunnanensis* and *Hiptage benhalensis.* Herbaceous species of the family Urticaceae, such as *Procris crenata, Elatostema* spp. and *Pilea* spp., are abundant. Lithophytes are also frequent.

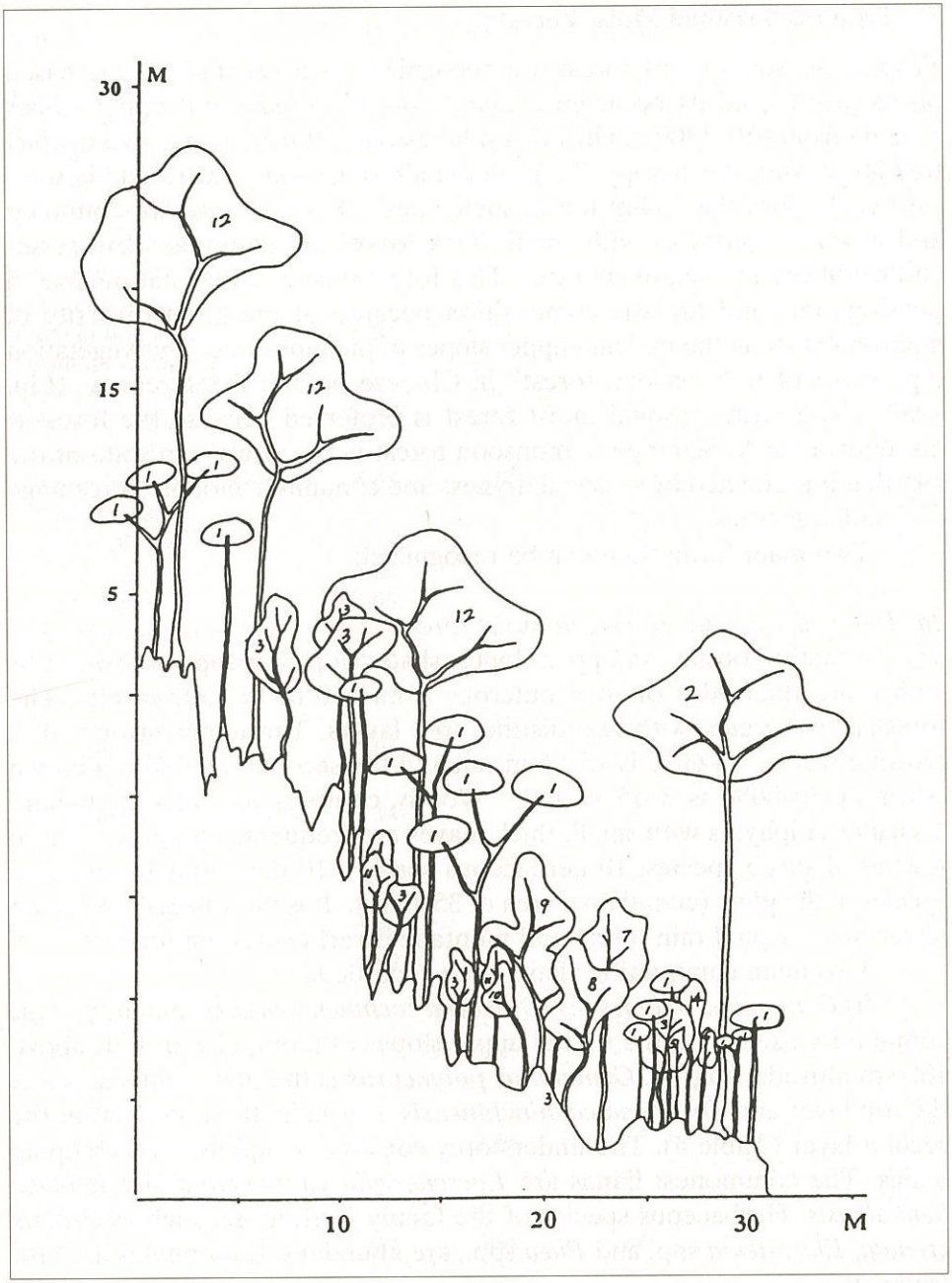

Figure 4. Forest profile of Osmanthus–Dracaena community

1. *Dracaena cochinchinensis;* 2. *Amoora tetrapetala;* 3. *Tarenna sylvestris*; 4. *Garcinia bracteata*; 5.*Mallotus philippinensis;* 6. *Diospyros yunnanensis*; 7. *Syzygium balsameum*; 8. *Photinia angusta* var. *hookeri*; 9. *Alphonsea mollis*; 10. *Engelhardtia spicata*; 11. *Clausena excavata*; 12. *Osmanthus polyneurus*

Table 4. *Osmanthus polyneurus–Dracaena cochinchinensis* community

Plot no.:	9207	9208	
Location:	Long-pa, Mengla	Long-pa, Mengla	
Altitude (m):	1320	1420	
Area of plot (m):	25 x 20	25 x 20	
Aspect:	E 30	NW	
Slope (degree):	40	25	
Height of canopy (m):	20	20	
Coverage of vegetetion (%):	85	90	
No. of tree species (>5 cm d.b.h.):	15	21	
No. of stems:	37	42	
Name of species	IVI	IVI	Average
Osmanthus polyneurus	74.83	90.86	82.84
Dracaena cochinchinensis	106.49	+	53.25
Tarenna sylvistris	24.14	11.53	17.75
Syzygiun sp.	–	24.22	12.11
Wightia tomentosa	7.79	14.9	11.35
Sterculia villosa	–	19.75	9.88
Murraya tetramera	6.99	11.07	9.03
Schefflera glomerulata	–	16.31	8.16
Mitrephora calcarea	9.56	5.99	7.82
Engelhardtia spicata	6.96	7.46	7.3
Alphonsea mollis	7.31	6.55	6.93
Myrsine semiserrata	+	13.52	6.76
Mallotus philippinensis	7.08	5.62	6.35
Garcinia bracteata	+	12.3	6.15
Celtis timorensis	+	11.74	5.87
Ficus curtipes	–	9.34	4.67
Garruga pinnata	9.27	–	4.64
Ficus orthoneura	9.26	–	4.64
Kopsis officinalis	–	8.18	4.09
Photinia arguta var. hookeri	8.08	–	4.04
Eriolaena kwangsiensis	7.79	–	3.9
Micromelum integerrimum var.*mollisimum*	7.34	–	3.67
Diospyros yunnanensis	–	7.1	3.55
Clausena excavata	6.96	+	3.5
Ulmus lanceifolia	+	6.7	3.35
Fortunella polyandra	–	5.89	2.95
Schoepfia fragrans	–	5.85	2.93
Wrightia laevis	–	5.62	2.81
Total	300	300	300

(ii) *Lasiococca comberi* var. *pseudoverticillat–Cleistanthus sumatranus* community. This occurs only on dry slopes and the tops of lower hills in Menglun between altitudes 650–800 m. There are two tree layers, of which the upper layer is 16 to 23 m tall and has a coverage of 50%; the lower layer is 5–16 m tall and has a coverage more than 70 %. *Lasiococca comberi* var. *pseudoverticillata* is the predominant species in the upper tree layer and *Cleistanthus sumatranus* in the lower tree layer (Fig. 5). It abuts lower hill seasonal rain forest, which is on the lower slopes and in valleys. Some deciduous emergent trees, such as *Tetrameles nudiflora, Garuga pinnata,* and *Chukrasia tabularis,* are sparsely dotted through the forest (Table 5). The understorey is similar to the former community.

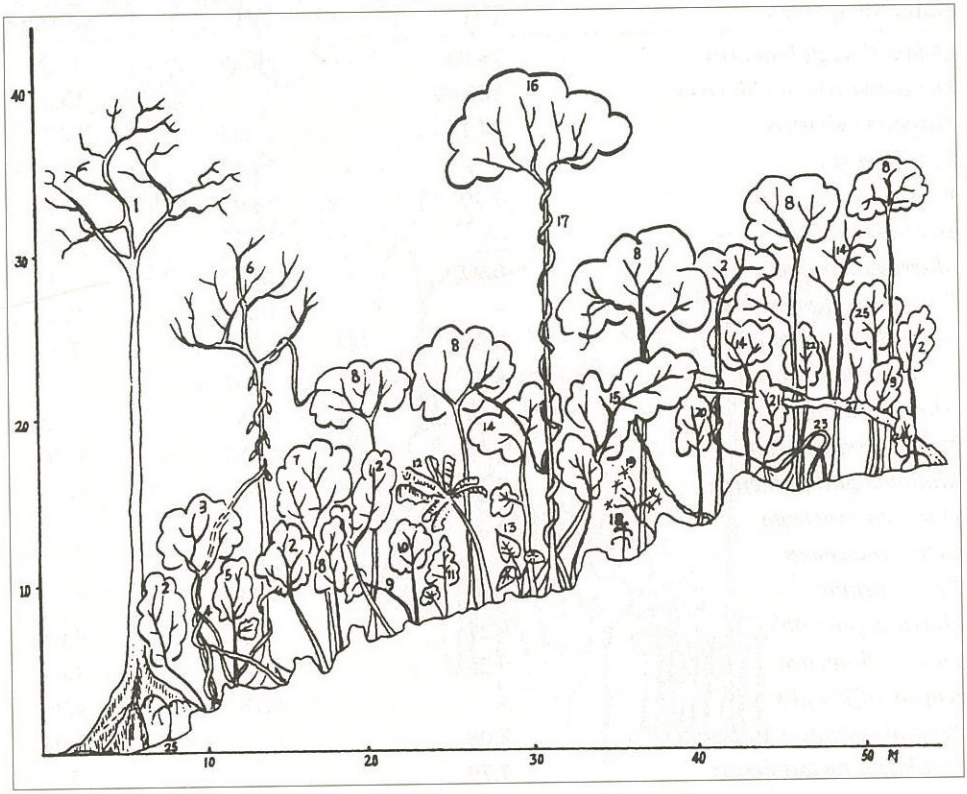

Figure 5. Forest profile of Lasiococca–Cleistanthus community

1. *Tetrameles nudiflora;* 2. *Cleistanthus sumatranus;* 3. *Laportea urentissima;* 4. *Pothos repens;* 5. *Sumbaviopsis albicans;* 6. *Garruga floribunda var. gamblei;* 7. *Mallotus paniculata;* 8. *Lasioccoca comberi* var. *pseudoverticillata;* 9. *Cleidion spiciflorum;* 10. *Sterculia lanceolata;* 11. *Murraya tetramera;* 12. *Musa acuminata;* 13. *Alocasia macrorhizza;* 14. *Colona floribunda;* 15. *Unknown;* 16. *Celtis philippensis* var. *wightii;* 17. *Santaloides roxburghii;* 18. *Sumbaviopsis albicans;* 19. *Dracaena cochinchinensis;* 20. *Aglaia parviridis;* 21. *Saurauia tristyla;* 22. *Mitrephora thorelii;* 23. *Salacia polysperma;* 24. *Leea crispa;* 25. *Mallotus philippinensis;* 26. *Caryota monostachya;* 27. Dead tree.

Table 5. *Lasiococca comberi* var. *pseudoverticellata–Cleistanthus sumatranus* community

Plot no.: 950506		Location: Menglun		
Altitude (m): 750		Area of plot (m): 50 x 50		
Aspect: NW		Slope (degree): 30		
Height of canopy: 22 m		Coverage of vegetation: >95%		
No. of species (≥5 cm DBH): 29		No. of stems: 445		
Name of species	%Dens.	%Freq.	%B.A.	IVI
Cleistanthus sumatranus	45.6	7.8	12.66	66.1
Croton crassifolius	8.5	7.8	37.5	53.9
Lasiococca comberi var. *pseudoverticellata*	27.19	7.8	4.9	39.9
Celtis philippensis var. wightii	4.7	6.3	21.3	32.3
Garuga pinnata	2.0	7.8	6.9	16.8
Tetrameles nudiflora	0.2	1.6	11.7	13.5
Glycosmis ferruginea	1.8	6.3	0.5	8.6
Mayodendron igneum	1.34	6.26	0.95	7.96
Tarena sylvestris	1.35	4.69	0.27	6.31
Alphonsea monogyna	0.67	4.69	0.79	6.15
Cipadessa baccifera	1.12	4.69	0.19	6.0
Beilschmeidia yunnanensis	0.67	3.13	0.29	4.09
Trigonostemon lyi	0.67	3.13	0.04	3.84
Ehretia tsangii	0.45	3.13	0.09	3.67
Syzygium cuminii	0.45	3.13	0.04	3.62
Amoora tetrapetala	0.22	1.56	1.14	2.92
Ficus orthoneura	0.22	1.56	0.66	2.44
Wrightia tomentosa	0.22	1.56	0.13	1.91
Amoora stellata	0.22	1.56	0.10	1.88
Zanthoxylum planispinum	0.22	1.56	0.1	1.88
Ficus concinna	0.22	1.56	0.07	1.85
Laportea basirotunda	0.22	1.56	0.07	1.85
Amoora calcicola	0.22	1.56	0.17	1.95
Mitrephora calcarea	0.22	1.56	0.03	1.81
Murraya microphylla	0.22	1.56	0.02	1.8
Lagestroemia tomentosa	0.22	1.56	0.01	1.79
Harpullia cupanioides	0.22	1.56	0.01	1.79
Stereospermum tetragonum	0.22	1.56	0.01	1.79
Lepisanthes sp.	0.22	1.56	0.01	1.79
Total	100	100	100	300

2b Tropical seasonal semi-evergreen moist forest

This formation occurs on much drier lower and middle slopes and in wide valleys within the range of 600–1200 m altitude. The forest is semi-evergreen with deciduous trees making up 30–60 % of the number of species and 35–70 % of the sum of cumulative importance value index (from plot data in Tables 6 and 7). The upper layer trees are usually deciduous with umbrella crowns and rough and thicker bark. The dominant species in the upper layer is usually *Bombax insignis,* but in some sites *Colona floribunda, Tetrameles nudiflora* or *Erythrina lithosperma* are either dominant or co-dominant. The second tree layer is evergreen. Small woody climbers are abundant but vascular epiphytes are less frequent. There are 80 tree species, 12 shrub species, 21 herbaceous species, 25 liana and 10 epiphyte species in the plots (cumulative area of 6150 m^2).

Two communities have been recorded:

(i) *Bombax insignis-Colona floribunda* community. This occurs on lower and middle dry slopes and covers a relatively large area. *Bombax insignis* is dominant. In some sites *Colona floribunda, Erythrina lithosperma* are co-dominant species in the top layer. *Pistacia weinmanifolia* is usually dominant in the second layer (Table 6). The understorey consists of saplings, lianas and shrubs. Common shrub species are *Murraya koenigii, Colebrookea oppositifolia* and *Allophylus hirsutus.* Common lianas are *Amalocalyx yunnanensis, Porana spectabilis* and *Acacia pinnata.* Epiphytes are rare.

Table 6. *Bombax insignis–Colona floribunda* community

Plot no.:	HW9201	93-12-01	94-03-02	
Location:	Huiwa	Yingchan	Mengyen	
Altitude (m):	980	1200	1000	
Area of plot (m):	30 x 30	25 x 30	40 x 50	
Aspect:	SW	SE	SW	
Slope (degree):	37	10	45	
Height of canopy (m):	20	20	22	
Coverage of vegetetion (%):	95	95	75	
No. of spp.(≥5 cm D.B.H.)	19	2	16	
No. of stems	70	38	57	
Name of species	IVI	IVI	IVI	Average
Bombax insignis	22.82	–	98.89	40.57
Colona floribunda	36.36	67.23	6.25	36.61
Erythrina lithosperma	25.20	40.14	–	21.78

Cont:

Name of species	IVI	IVI	IVI	Average
Lagerstroemia venusta	64.28	–	–	21.43
Pistacia weinmannifolia	43.48	–	19.26	20.91
Dracaena cochinchinensis	–	–	41.27	13.76
Hymenodictyon excelsum	10.84	–	23.41	11.42
Kydia calycina	–	27.13	–	9.04
Schima wallichii	–	9.08	–	9.02
Celtis philippensis var. *wightii*	–	–	25.97	8.66
Mallotus philippinensis	10.95	12.9	–	7.95
Spondias pinnata	–	19.07	–	6.36
Ehretia tsangii	–	7.29	9.0	5.43
Phyllanthus embelica	–	14.79	–	4.93
Millettia tetraptera	–	–	14.05	4.68
Ficus orthoneura	–	–	12.44	4.17
Grewia eriocarpa	11.75	–	–	3.92
Premna fulva	11.37	–	–	3.79
Sarcosperma kachinensis	–	11.26	–	3.75
Derris robusta	10.87	–	–	3.62
Lithocarpus microspermus	–	10.27	–	3.4
Helicia cochinchinensis	–	9.69	–	3.23
Litsea glutinosa	9.32	+	–	3.1
Sterospermum tetragonum	–	9.3	–	3.1
Tetrasmeles nudiflora	–	–	9.23	3.08
Sterculia villosa	–	–	9.15	3.05
Lepisanthes senegalensis	–	–	8.94	2.98
Eriolaena kwangsiensis	–	8.86	–	2.95
Melia toosenden	–	8.86	–	2.95
Engelhartia roxburghiana	–	8.65	–	2.88
Alphonsea mollis	–	–	8.0	2.67
Ficus hispida	–	7.74	–	2.56
Toona ciliata	–	7.73	–	2.48
Wrightia tomentosa	7.07	–	–	2.36
Acrocarpus fraxinifolius	–	6.71	–	2.24
Ulmus lanceifolius	+	6.54	–	2.18
Phoebe puwensis	–	6.63	–	2.12
Cipadessa baccifera	6.18	–	–	2.06
Croton crassifolius	5.40	–	–	1.80
Cratoxylon cochinchinensis	5.02	–	–	1.70
Mayodendron igneum	4.94	–	–	1.66
Zanthoxylum planispium	4.76	+	–	1.59
Dolichandrone stipulata	4.74	–	–	1.58
Radermachera microcalyx	4.62	–	–	1.54
Elaeocarpus varunum	–	–	4.61	1.54
Beilschmiedia yunnanensis	+	–	4.61	1.54
Ficus glaberrima	–	–	4.61	1.54
Total	300	300	300	300

(ii) *Bombax insignis-Garcinia bracteata* community. This occurs on lower drier gentle slopes or in wide valleys. *Bombax insignis* as emergent trees reaches up to 35 m tall. *Garcinia bracteata* and *Dracaena cochinchinensis* are co-dominant species in the second layer (Table 7). The understorey is similar to the former community.

Table 7. *Bombax insignis–Garcinia bracteata* Community

Plot no.: 102-15	Location: Mengyen, Mengla		
Altitude (m): 800	Area of plot (m): 50 x 50		
Aspect:	Slope (degree): 8-12		
Height of canopy: 40m	Coverage of vegetation: >90%		
No. of species (≥5 cm d.b.h.): 27	No. of stems: 115		
Name of species	%Dens.	%BA	%Dens. + %BA
Bombax insignis	7.83	23.08	30.91
Garcinia bracteata	14.78	7.92	22.70
Dracaena cochinchinensis	11.30	9.02	20.32
Laportea sinuata	10.43	6.87	17.30
Tetrameles nudiflora	2.61	12.43	15.04
Glycosmis ferruginea	8.69	5.69	14.38
Celtis bodinieri	5.22	5.81	11.03
Sumbaviopsis albicans	6.09	2.73	8.82
Dysoxylum lukii	4.35	3.45	7.80
Phaeanthus saccopetaloides	4.35	3.36	7.71
Vitex quinata var. *puberula*	2.61	3.35	5.96
Ficus racemosa	2.61	2.70	5.31
Cleidion spiciflorum	3.48	1.42	4.90
Tarenna sylvestris	2.61	2.09	4.70
Wrightia tomentosa	2.61	2.00	4.61
Wrightia pubescens	0.87	1.36	2.23
Ficus virens	0.87	0.95	1.82
Diospyros yunnanensis	0.87	0.90	1.77
Garuga floribunda var *gamblei*	0.87	0.82	1.69
Clausena excavata	0.87	0.82	1.69
Croton crassifolius	0.87	0.78	1.65
Hymenodictyon excelsum	0.87	0.68	1.55
Garuga pinnata	0.87	0.49	1.36
Alphonsea mollis	0.87	0.34	1.21
Unknown sp.	0.87	0.34	1.21
Cipadessa baccifera	0.87	0.27	1.14
Polyalthia cheliensis	0.87	0.27	1.14
Total	100	100	200

3. Montane Dwarf Forest

Tropical montane dwarf forest occurs on the tops of hills and summits of mountains at an altitude range between 900–1600 m. The forest has only one dwarf tree layer with canopy height of 7–15 m. Epiphyte ochids and non-vascular epiphytes are abundant. Small woody climbers are also abundant in some sites. The forest is usually characterized by *Agapetes burmanica,* which has swollen roots for water storage.

Two formations were recognised.

3a. Montane evergreen dwarf forest

This occurs on shady tops of hills and summits of relatively higher mountains above 1000 m altitude. *Pistacia weinmannifolia* and *Myrsine semiserrata* are usually dominant or co-dominant. Lithophytic orchids are very abundant on rocks; creeping climbers are also abundant. Only a representative community was plotted and analysed because of difficult field work in the very rugged topography.

Photinia angusta—Pistacia weinmannifolia community. This occurs mainly on limestone summits above 1200 m altitude. *Photinia angusta* and *Pistacia weinmannifolia* are co-dominant species (Table 8).

Table 8. *Photinia angusta-Pistacia weinmannifolia* community

Plot no.: 93-12-02	Location:Ying-chan,Mengla
Altitude (m): 1380	Area of plot (m): 10 x 10
Aspect: SW	Slope (degree): 20
Topography: on top of a hill	Height of canopy: 7 m
Coverage of vegetation: 95%	
No. of species (≥5 cm d.b.h.): 4	No. of stems: 6

Name of species	%Dens.	%Freq.	%BA	IVI
Photinia arguta var. *hookeri*	33.33	33.33	43.72	110.38
Pistacia weinmanifolia	33.33	33.33	43.72	110.38
Myrsine semiserrata	16.67	16.67	8.69	42.03
Pterospermum proteum	16.67	16.67	3.87	37.21
Total	100	100	100	300

Understorey	*Abund.	Freq.	Understorey	Abund.	Freq.
Agapetes burmanica	3.2	80	*Derris caudatilimbum*	+	40
Eria hainanensis	2.2	100	*Peperomia heyniana*	+	20
Hedychium villosum	+	80	*Bauhinia carcinophylla*	+	20
Fagopyrum tataricum	+	80	*Kalanchoe laciniata*	+	20
Tetrastigma delavayi	2.1	40	*Pyrrosia adnascena*	+	20
Pilea platanifolia	+	40	*Eria javanica*	+	20
Clematis kerrii	+	40	*Campylotropsis pinatorum*	+	20

* Braun-Blanquet's degree of abundance

3b. Montane semi-evergreen dwarf forest

The formation occurs only on some dry tops of hills. Deciduous trees make up 40 % of the number of species and 60 % of the sum of cumulative importance value index. Epiphytes are rare but woody climbers are still abundant. Also only a representative community was plotted and analysed.

Ficus neriifolia—Dracaena cochichinensis community. This occurs on dry and gentle tops of hills with an altitude of 900–1200 m. Deciduous species *Ficus neriifolia* is dominant (Table 9).

Table 9. *Ficus neriifolia-Dracaena cochichinensis* community

Plot no.: 93-12-04	Location: Yingchan,Mengla
Altitude (m): 930	Area of plot (m): 10 x 10
Aspect: S	Slope (degree): 15
Height of canopy: 15m	Coverage of vegetation: 85%
No. of species (≥5 cm d.b.h.): 5	No. of stems: 14

Name of species	%Dens.	%Freq.	%BA	IVI
Ficus neriifolia var. *trilepis*	42.86	40.00	44.50	127.36
Sterculia villosa	14.29	20.00	21.14	55.43
Dracaena cochinchinensis	28.57	20.00	3.78	52.35
Celtis philippensis var. *wightii*	7.14	10.00	20.23	37.37
Pistacia weinmannifolia	7.14	10.00	10.32	27.46
Total	100	100	100	300

Understorey	*Abund.	Freq.	Understorey	Abund.	Freq.
Schefflera glomerulata	2.2	80	*Phymatodes cuspidata*	+	80
Combretum punctatum	2.2	60	*Bauhinia carcinophylla*	+	40
Boehmeria siamensis	2.2	80	*Peperomia dindygulensis*	+	40
Pilea platanifolia	+	100	*Hedychium villosum*	+	20
Hoya pottisii	+	80			

* Braun-Blanquet's degree of abundance

Species diversity

From the data, tree species diversity indexes were calculated and results presented in Table 10. The highest value of diversity index is for the *Pometia-Alphonsea* community of ravine seasonal rain forest, which occurs mainly on bottoms of wet valleys, while the lowest value appears in the communities of the montane dwarf forest, which occurs on upper slopes

Table 10. Species diversity of limestone vegetation

Forest type	Plot	Area (m^2)	Alt. (m)	Habitat	Sl (°)	NS	NI	H'	E
I. Tropical seasonal rain forest									
a. Ravine seasonal rain forest									
a1 *Pometia-Alphonsea* Com.	102-16	2400	700	Wet valley terrace	0-5	45	140	3.2627	0.8571
a2 *Pometia- Celtis* Com.	HW9203	2500	700	Wet slope	25	23	118	2.4269	0.774
	HW9202	2500	740	Shade lower slope	10	19	164	2.0464	0.693
b. Lower hill seasonal rain forest									
b1 *Lasiococca-Celtis* Com.	940301	2500	800	Shade slope	40	27	102	2.5277	0.7669
II. Tropical seasonal moist forest									
a. Evergreen moist forest									
a1 *Lasiococca-Cleistanthus* Com.	*950506*	*2500*	*750*	*Sun-facing* Slope	*30*	*29*	*445*	*1.7393*	*0.5165*
b. Semi-evergreen moist forest									
b1 *Bombax-Garcinia* Com.	102-15	2500	800	Light slope	8-12	27	115	2.8613	0.8682
III. Montane dwarf forest									
a. Evergreen dwarf forest	931202	100	1380	Top of hills	20	4	6	1.3297	0.9592
b. Semi-evergreen dwarf forest	931204	100	930	Upper hill slope	15	5	17	1.3761	0.855

Sl : Slope; NS : Number of species (≥5 cm dbh); NI: Number of individuals (≥5 cm dbh); H': Shannon-Wiener's diversity indices (Shannon-Wiener, 1949); E: Evenness indices of Pielou (1966)

and tops of hills. The communities on sun-facing steep slopes, which are usually consociations or associations with co-dominant species, such as the *Lasiococca comberi* var. *pseudoverticillat -Cleistanthus sumatranus* community, have relatively lower diversity index values than the communities on sun-facing gentle slopes.

Compared with seasonal rain forests on non-limestone, the limestone seasonal rain forests show lower index values (Table 11) and this agrees with Cao's results (Cao and Zhang, 1997). The communities of seasonal

Table 11. Comparison of species diversity between the limestone seasonal rain forest and the seasonal rain forest on non-limestone

Forest type	Plot	Area (m^2)	Alt. (m)	Habitat	Sl (°)	NS	NI	H'	E
1. Tropical seasonal rain forest on limestone									
a. Ravine seasonal rain forest	102-16	2400	700	Wet valley terrace	0-5	45	140	3.2627	0.8571
	HW9203	2500	700	Wet slope	25	23	118	2.4269	0.774
	HW9202	2500	740	Shade lower slope	10	19	164	2.0464	0.693
b Lower hill seasonal rain forest	940301	2500	800	Shade slope	40	27	102	2.5277	0.7669
Tropical seasonal rain forest on non-limestone									
a. Ravine seasonal rain forest	940102	2500	650	Wet valley slope	5-10	49	108	3.586	0.9263
	940103	2500	675	Wet valley slope	30	57	194	3.573	0.8727
	940101	2500	700	Wet valley slope	25	48	96	3.599	0.9297
b Lower hill seasonal rain forest	931206	2500	650	Lower hill slope	10	52	182	3.3765	0.8545
	9201	2500	680	Lower hill slope	30	46	207	3.1594	0.825

Sl: slope; NS : Number of (≥5 cm dbh); NI: Number of individuals (≥5 cm dbh); H': Shannon-Wiener's diversity indices (Shannon-Wiener, 1949); E: Evenness indices of Pielou (1966)

rain forest on non-limestone have almost identical values for diversity index and evenness, while the communities of limestone seasonal rain forest show a clear disparity in the values. This implies that the limestone seasonal rain forest has higher community diversity than the rain forest on non-limestone substrates.

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