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Forest vegetation of Xishuangbanna, south China

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Abstract Xishuangbanna of southern Yunnan is biogeographically located at a transitional zone from tropical southeast (SE) Asia to subtropical east Asia and is at the junction of the Indian and Burmese plates of Gondwana and the Eurasian plate of Laurasia. The region, though surprisingly far from the equator and at a relatively high altitude, has a rich tropical flora and a typical tropical rain forest in the lowland areas. Based on physiognomic and ecological characteristics, floristic composition and habitats combined, the primary vegetation in Xishuangbanna can be organized into four main vegetation types: tropical rain forest, tropical seasonal moist forest, tropical montane evergreen broad-leaved forest and tropical monsoon forest. The tropical rain forest can be classified into two subtypes, i.e. a tropical seasonal rain forest in the lowlands and a tropical montane rain forest at higher elevations. The tropical seasonal rain forest has almost the same forest profile and physiognomic characteristics as equatorial lowland rain forests and is a type of truly tropical rain forest. Because of conspicuous similarity on ecological and floristic characteristics, the tropical rain forest in Xishuangbanna is a type of tropical Asian rain forest. However, since the tropical rain forest of Xishuangbanna occurs at the northern edge of tropical SE Asia, it differs from typical lowland rain forests in equatorial areas in having some deciduous trees in the canopy layer, fewer megaphanerophytes and epiphytes but more abundant lianas and more plants with microphyll. It is a type of semi-evergreen rain forest at the northern edge of the tropical zone. The tropical montane rain forest occurs at wet montane habitats and is similar to the lower montane rain forest in equatorial Asia in floristic composition and physiognomy. It is a type of lower montane rain forests within the broader category of tropical rain forests. The tropical seasonal moist forest occurs on middle and upper limestone slopes. It is similar to the tropical montane evergreen broad-leaved forest in the region in physiognomy, but differs from the latter in floristic composition. It is a vegetation type on limestone at high elevations. The monsoon forest in Xishuangbanna is a tropical deciduous forest under the influence of a strong monsoon climate and is considered to be a transitional vegetation type between a tropical rain forest and savanna in physiognomy and distribution. The tropical montane evergreen broad-leaved forest is the main montane vegetation type in the region. It is dominated largely by the families Fagaceae, Euphorbiaceae, Theaceae and Lauraceae. It differs from tropical lower montane rain forests in its lack of epiphytes and in having more abundant lianas and plants with compound leaves. It is considered to be a distinct vegetation type from the northern margin of mainland southeastern Asia, controlled by a strong seasonal climate, based on its floristic and physiognomic characteristics.

Key words vegetation, tropical rain forest, tropical seasonal moist forest, tropical montane evergreen broad-leaved forest, tropical monsoon forest, Xishuangbanna, southern Yunnan

1 Introduction

The tropical area of southern China is climatically and biogeographically located at the northern edge of tropical Asia, including southeastern Xizang (Tibet, lower valleys of the southern Himalayas), southern Yunnan, southwestern Guangxi, southern Taiwan and Hainan Island. The largest tropical area still covered by forests is in southern Yunnan. Tropical forests of southern Yunnan were little known until the late 1950s because of poor access except for some brief descriptions by Wang (1939). For a long time there has been discussion as to whether there are true tropical rain forests in southern Yunnan, owing to its location at the northern edge of tropical SE Asia with a monsoon climate. If there were tropical rain forests in the region, it would probably be intermediate between classic tropical rain forests and monsoon forests as defined by Schimper (1903), or be a type of subtropical rain forests which differ in various aspects from the truly tropical rain forests described by Richards (1952). After the China-Russia expedition which penetrated deep into the areas of southwestern China, including southern Yunnan in the late 1950s, some papers on the tropical forests (Fedorov, 1958; Qu, 1960; Wang, 1961) and tropical flora (Fedorov, 1957; Wu, 1965) of this part of China, were published. It was then accepted that biogeographically real tropical rain forests existed in southern Yunnan, but these were considered as a type different from the ones in Indo-Malaysia because of the lack of representative species of Dipterocarpaceae, which dominates the rain forests of tropical SE Asia. The interests of botanists in the areas were rekindled in the 1970s by the finding of a dipterocarp forest in southern Yunnan. From that finding the Indo-Malaysian affinity of the tropical flora of Yunnan

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was taken into consideration. Further biogeographical and ecological studies on the vegetation and flora of tropical southern Yunnan revealed that it comprises indeed part of the Indo-Malaysian flora (Zhu, 1992a, 1992b, 1993a, 1993b, 1993c, 1994a, 1994b, 1997, 2001; Zhu et al., 1996, 1997, 1998a, 1998b, 1998c, 2000, 2001, 2003, 2004; Zhu and Zhou, 2002; Zhu and Roos, 2004). Also Whitmore (1982) felt that the birds in the tropical rain forest of southern Yunnan sang the same songs as those to be heard in the tropical rain forest of Malaysia when he was on a short visit to southern Yunnan and he confirmed that there are true evergreen rain forests present in the southern fringes of China (Whitmore, 1984, 1990).

Xishuangbanna is an administrative region of southern Yunnan. It has a typical monsoon climate. In spite of its relatively high latitude and elevation, Xishuangbanna has still a tropical moist climate in the southern area due to the Hengduan Mountains which form a barrier keeping out the cold air from the north in winter. Its montane topography produces dense fog during the entire dry season to supplement insufficient precipitation. The region is biogeographically located at a transitional zone from tropical SE Asia in the south to subtropical east Asia in the north and from the Sino-Japanese floristic region in the east to the Sino-Himalayan floristic region in the west. Southern Yunnan is therefore a key area in biogeography and of great interest in the study of biodiversity (Myers, 1998).

2 Geography

2.1 Topography

Xishuangbanna lies between 21°09′ and 22°36′N, 99°58′ and 101°50′E (Fig. 1). The region has an area of 19,690 km^2. It borders Myanmar and Laos and has a mountainous topography with the mountain ridges running in a north-south direction and decreasing in elevation southward. Its elevation varies from 480 m at the bottom of the lowest valley in the south (Mekong River) to 2,430 m at the top of the mountain in the north (Fig. 2). The Mekong River runs through the region from northwest to southeast. The western and northern parts of the region with higher basins over 1,000 m elevation, have a mountainous topography and are controlled by a southern-subtropical climate, while the south consists basically of hills with lower basins under 1,000 m elevation and controlled by a tropical climate (Xu et al., 1987).

2.2 Climate

The region has a typical monsoon climate. The annual mean temperature varies from 21.7°C at an elevation of 550 m to 15.1°C at 1,979 m and the 20°C isotherm is equal to the 850 m elevation isoline (Table 1). The hottest month is June with a mean temperature of 17.9 at 1,979 m elevation and 25.3°C at 550 m elevation, while the coldest month is January with a mean temperature varying from 8.8 to 15.6°C. 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, of which more than 80% falls during the rainy season from May to October. The annual precipitation is higher in the eastern part of the region than in the western part. In those areas of lower hills and valleys covered by tropical forests, the annual mean temperature is about 21°C and the annual cumulative temperature (the sum of daily temperature means > 10°C) is 7,600–7,800°C. The annual precipitation is over 1,500 mm, relative humidity is about 80% and frost has never been recorded (Table 2).

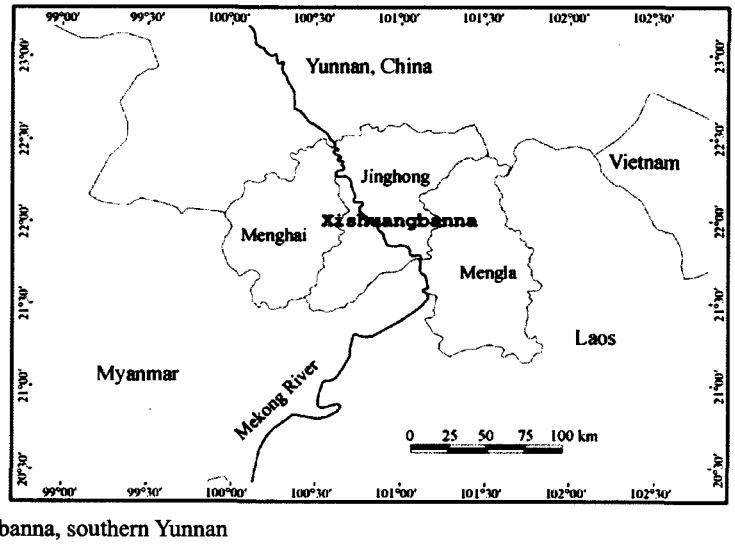

Fig. 1 Location of Xishuangbanna, southern Yunnan

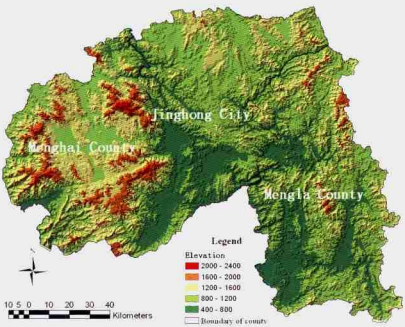

Fig. 2 Topography of Xishuangbanna (from the Landscape Ecology Lab, XTBG)

Table 1 Temperature distributions at different sites (elevations)

Locality	Elevation (m)	AMT (°C)	ACT (°C)	MTH (°C)	MTC (°C)
Mekong River	552.7	21.7	7,948	25.3	15.6
Menglun	600.0	21.4	7,811	25.3	15.6
Mengla	631.9	21.0	7,639	24.6	15.2
Mengyang	740.0	20.8	7,592	24.6	14.7
Jinghong	552.7	21.9	7,950	25.5	15.7
Mangao	1,176.3	18.1	6,578	22.3	11.9
Summit of Nangongshan	1,979.0	15.1	5,062	17.9	8.8

Data from Yunnan Meteorological Bureau ed., Climatic Data of Yunnan Agriculture. Kunming: Yunnan People's Press, 1983. AMT: annual mean temperature; ACT: annual cumulative temperature; MTH: mean temperature of the hottest month; MTC: mean temperature of the coldest month.

Table 2 Rainfall distributions recorded at different sites (elevations)

Locality	AP (mm)	PD (mm)	PR (mm)	PD/PR
Mekong River	1,208.0	178.5	1,029.5	0.17
Menglun	1,556.8	263.5	1,293.3	0.20
Mengla	1,531.9	281.6	1,250.3	0.23
Mengyang	1,193.7	176.0	1,017.9	0.15
Jinghong	1,196.0	178.2	1,017.8	0.18
Mangao	1,390.3	204.8	1,185.5	0.17
Summit of Nangongshan	2,491.5	371.1	2,120.4	0.17

Data from Yunnan Meteorological Bureau ed., Climatic Data of Yunnan Agriculture. Kunming: Yunnan People's Press, 1983. AP: annual precipitation; PD: precipitation during dry season (November to April); PR: precipitation during rainy season (May to October).

Dense fog always exists during the entire dry season on the lower hills and in the valleys, averaging 146 foggy days per year and 1 mm precipitation per foggy day recorded in Mengla County in southern Xishuangbanna, 116 foggy days per year in Menglun in the central area of the region and 126 foggy days per year in Mangao in the northwest of the region. This compensates for the insufficient precipitation so that a tropical moist climate can form locally in spite of its relatively low mean annual precipitation.

2.3 Soils

There are three main soil types in the region. Laterite soils developed from siliceous rocks, such as granite and gneiss and occur between 600–1,000 m elevation with a deep solum but a thin humus horizon. The lateritic red soil from the rock substrate of sandstone occurs in the area above 1,000 m elevation. Limestone hills have soil from rock substrate of hard limestone of Permian origin with a pH of 6.75. The tropical rain forest of Xishuangbanna occurs mainly on laterite soils with pH values of 4.5–5.5. A small portion of the tropical rain forest occurs on limestone soils.

2.4 Geological history

Southern Yunnan is at the junction of the Indian and Burmese plates of Gondwana and the Eurasian plate of Laurasia according to its geological history (Audley-Charles, 1987; Hall, 1998). Before the Mesozoic era, the area was part of the Tethys margin

and more recently some fragments from Gondwanaland were combined. Since the Tertiary era the region had gone through several stages of rising and descending movements with intermittent uplifts of the Himalayas and gradually formed the modern topography during the mid-Tertiary era (Shi et al., 1998, 1999).

During the late Cretaceous era, the region was under a dry-and-hot climatic condition, as determined from fossil records from Mengla in which a relatively high proportion of *Ulmipollenites* and *Ephedripites* were found (Sun, 1979). From the Paleocene to the Eocene era, the region went through a rising stage with the uplift of the Himalayas and influenced by a dry climate with high deposition of salt minerals. From the Miocene to the Neocene era, the elevation of the region declined to some extent and formed a series of basins in a wet-and-warm climate. Since the Quaternary era, the region went through rapid upheavals again, with alternative climatic changes of wet and dry periods (Liu et al., 1986).

Paleobotanical studies are insufficient in the region, especially for the Tertiary period. From pollen depositions in Mengla from the late Cretaceous to the early Tertiary era, except pollens of *Ulmipollenites*, *Ephedripites*, Sun (1979) found the presence of gymnosperm fossils such as *Tsugaepollenites*, *Araucariacites*, *Taxodiaceaepollenites*, *Abietineaepollenites* and *Pinuspollenites* and angiosperms such as *Engelhardtioidites*, *Faguspollenites*, *Ilexpollenites*, *Symplocospollenites*, *Rhamnacidites*, *Cupuliferuipollenites*, *Caprifoliidites*, *Quercoidites*, *Fraxinoipollenites* and *Liquidambarpollenites*. This evidence indicates that the representative vegetation in the period was a subtropical montane evergreen broad-leaved forest, which is similar to the present vegetation in subtropical Yunnan.

Song et al. (1976, 1983) defined the region and neighboring northern Mainland SE Asia as the palaeo-phytogeographical region of *Quercus-Betula* vegetation of the plateau of the Miocene-Neocene era, suggesting that the vegetation in Xishuangbanna could have been a subtropical montane evergreen broad-leaved forest during this period. From other available references (Editorial Group for Cenozoic Plants from China, 1978; Song, 1984; Wang, 1996), the vegetation of regions bordering on southern Yunnan was considered to be subtropical evergreen broad-leaved forests during the Tertiary era. A 40,000 year palynological record from northeast Thailand indicates that the region supported a Fagaceae-coniferous forest, similar to contemporary vegetation from subtropical southwest China. Climatic conditions were cooler and probably drier in the Pleistocene era than in present day northern Thailand (Penny, 2001). Xishuangbanna is geographically near to northern Thailand. It is possible that Xishuangbanna had vegetation and climatic conditions similar to northern Thailand in the Pleistocene era.

The present tropical rain forest in Xishuangbanna is at the limits of elevation and latitude of tropical rain forests in the northern hemisphere. It is believed that the tropical moist climate in southern Yunnan did not form until the Himalayas were lifted up to a certain elevation after the late Tertiary era. Thus, the tropical rainforests in the region were developed after the Tertiary era. The fundamental topography and climate of the region have been strongly affected by the uplift of the Himalayas and the formation of the eastern monsoon climate (Shi et al., 1998, 1999).

3 The vegetation

Terminology and classification of tropical vegetation have not been generalized world-wide because different disciplines were used by different investigators. For example, physiognomic and ecological characteristics, initiated by Drude (1913) and Warming (1909), were used as the main basis for vegetation classification by most American researchers, while floristic aspects (Braun-Blanquet, 1932) were used by continental European scientists. Our classification was based on physiognomic and ecological characteristics, floristic composition and habitats combined. Physiognomic and ecological characteristics were used mainly for classification at the vegetation type level (Richards, 1983), while floristic composition and habitats combined was used mainly at the formation level. Thus the primary vegetation of Xishuangbanna can be classified into four main vegetation types, i.e. tropical rain forests, tropical seasonal moist forests, tropical montane evergreen broad-leaved forests and tropical monsoon forests, including two vegetation sub-types, four formation groups and eighteen formations.

I. Tropical rain forest (Vegetation type)
- I-1. Tropical seasonal rain forest (Vegetation sub-type)
  - Ravine seasonal rain forest (Formation group)
    - a. *Pometia tomentosa* + *Terminalia myriocarpa* forest (Formation)
    - b. *Shorea wantianshuea* forest (Formation)
    - c. *Pometia tomentosa-Celtis philippensis* var. *wightii* forest (Formation)
  - Lower hill seasonal rain forest (Formation group)
    - a. *Antiaris toxicaria* + *Pouteria grandiflora* forest (Formation)
    - b. *Celtis philippensis* var. *wightii-Lasiococca comberi* var. *pseudoverticillata* forest (Formation)
- I-2. Tropical montane rain forest (Vegetation sub-type)
  - a. *Mastixia euonymoides-Phoebe megacalyx* forest (Formation)
  - b. *Parachmeria yunnanensis-Gymnanthes remota*

forest (Formation)

II. Tropical seasonal moist forest (Vegetation type)
Tropical seasonal evergreen moist forest (Formation group)
a. *Osmanthus polyneurus-Dracaena cochinchinensis* forest (Formation)
b. *Lasiococca comberi* var. *pseudoverticillata-Cleistanthus sumatranus* forest (Formation)
Tropical seasonal semi-evergreen moist forest (Formation group)
a. *Bombax insignis* + *Colona floribunda* forest (Formation)
b. *Bombax insignis-Garcinia bracteata* forest (Formation)

III. Monsoon forest (Vegetation type)
a. *Pterocarya tonkinensis* forest (Formation)
b. *Bombax ceiba* forest (Formation)
c. *Anogeissus acuminata* forest (Formation)
d. *Lannea coromandelica* + *Sterculia pexa* forest (Formation)

IV. Tropical montane evergreen broad-leaved forest (Vegetation type)
a. *Schima wallichii* + *Castanopsis hystrix* forest (Formation)
b. *Schima wallichii* + *Lithocarpus fohaiensis* forest (Formation)
c. *Castanopsis echinocarpa* forest (Formation)

3.1 Tropical rain forest

The tropical rain forest (vegetation type) in Xishuangbanna was classified into two subtypes, i.e. a tropical seasonal rain forest and a tropical montane rain forest (Qu, 1960; Wu, 1980, 1987; Zhang and Cao, 1995; Cao et al., 1996; Jin, 1979, 1983, 1997; Jin and Ou, 1997; Zhu, 1992, 1993a, 1997; Zhu et al., 1998). The tropical seasonal rain forest is a rain forest in the lowlands usually below 900 m in elevation, while tropical montane rain forest occurs locally at higher elevations.

The tropical seasonal rain forest of Xishuangbanna, in terms of physiognomy and structure, is similar, 1: to the evergreen seasonal forest of tropical America of Beard (1944, 1955) which was reclassified by Richards (1952) as a subformation of tropical rain forest, 2: to the humid evergreen type of the African tropical rain forest of Hall and Swaine (1976, 1981), 3: to the mesophyll vine forest of the Australian rain forest of Webb (1959) or 4: to the semi-evergreen rain forest of Walter (1971). However, it resembles largely the semi-evergreen rain forests of SE Asia of Whitmore (1984). Since the rain forest in Xishuangbanna occurs at its limits of latitude and elevation and has a clear change of physiognomy between different seasons, Chinese botanists prefer the term tropical seasonal rain forest (Cao et al., 1996; Jin, 1983, 1997; Wu, 1980, 1987; Zhang and Cao, 1995; Zhu, 1992, 1997; Zhu et al., 1998). All the same, this forest belongs to the tropical rain forest formation of SE Asia and is a type of semi-evergreen rain forest at the northern edge of the tropical zone.

3.1.1 Tropical seasonal rain forest

With conspicuous similarity in ecological and floristic characteristics to the tropical rain forest of SE Asia, the tropical seasonal rain forest of Xishuangbanna is considered to be a type of tropical Asian rain forest. In southern Yunnan, this forest occurs in wet valleys and on lower slopes of hills or mountains below 1,000 m elevation. The same forest type also occurs in northern Thailand (Smitinand, 1966) and North Vietnam (Thin, 1997) although different names are used. The tropical seasonal rain forest represents SE Asian tropical rain forest at its limits of latitude and elevation.

Like the equatorial lowland rain forest, the tropical seasonal rain forest has 3–4 indistinct tree layers, of which the top layer consists largely of emergent trees more than 30 m tall (the tallest up to 60 m) and has about 30% of crown coverage; the second layer, up to 30 m high with almost continuous crowns and the greatest density of stems (70%–80% coverage), is the main canopy layer; the third layer, 5–18 m tall, with a crown cover of about 40%, consists of small trees and juveniles of species from the upper layers. At some sites, the third layer can be further divided into two sub-layers: an upper sub-layer (10–18 m tall) and a lower sub-layer (5–9 m tall). In physiognomy the tropical seasonal rain forest is dominated by evergreen mesophanerophytes with simple, leathery and entire mesophyllous leaves and characterized by having abundant woody climbers and vascular epiphytes. Buttresses and cauliflory are also common. The forest is mainly evergreen despite the fact that there are some deciduous trees in the emergent layer.

In floristic composition, the tropical seasonal rain forest is dominated by Euphorbiaceae, Lauraceae, Rubiaceae, Moraceae, Annonaceae, Meliaceae, Asclepiadaceae, Apocynaceae, Orchidaceae, Urticaceae, Rutaceae, Acanthaceae and Papilionaceae. Some families such as Sapindaceae, Anacardiaceae, Burseraceae, Elaeocarpaceae, Ebenaceae and Combretaceae have less species richness than the former ones, but they are dominant in the tree layers of the rain forest. Still, some other families, which just have a few species, such as Dipterocarpaceae (2 species), Barringtoniaceae (1 species), Tetrameleaceae (1 species), Myristicaceae (9 species), Guttiferae (8 species), Icacinaceae (9 species), Ixonanthaceae (1 species) and Sapotaceae (6 species) are of greater phytosociological importance in the forest.

The tropical seasonal rain forest in Xishuangbanna occurs mainly in wet valleys and on lower hills below

900–1,000 m elevation. Based mainly on habitats and floristic composition, the tropical seasonal rain forest of Xishuangbanna is further classified into two types (formation groups in term of vegetation classification category), i.e. a lower hill seasonal rain forest and a ravine seasonal rain forest (Wu, 1980, 1987; Jin, 1997; Jin and Ou, 1997; Zhu, 1992, 1997; Zhu et al., 1998). The ravine seasonal rain forest, occurring at wetter ravine habitats, has a relatively high species diversity, more epiphytes and fewer deciduous trees than the lower hill seasonal rain forest. The ravine seasonal rain forest comes closer to the classic tropical rain forest, whereas the lower hill seasonal rain forest tends to be a type transitional to the tropical montane forest.

1) Ravine seasonal rain forest

The ravine seasonal rain forest occurs in the wet valleys and on lower slopes as well as shaded slopes (usually northeast facing). It has fewer than 10% deciduous trees, both in number of species and in individuals. The forest is floristically characterized by *Pometia tomentosa*. Three ravine seasonal rain forest formations are recognized in Xishuangbanna.

a) *Pometia tomentosa* + *Terminalia myriocarpa* forest

This forest occurs mainly in wetter parts of valleys and on lower mountains of non-limestone below 1000 m elevation in the south of the region, mainly in Mengla County.

This forest is typically stratified with three tree layers, reaching up to 35–45 m high (Fig. 3). The top tree layer has a coverage of 25%–30%, of which some trees are so huge that they soar above the canopy as emergent trees. The representative tree species of the layer are *Terminalia myriocarpa*, *Pometia tomentosa*, *Homalium laoticum* var. *glabrescens*, *Elaeocarpus varunua*, *Sapium baccatum*, *Neonauclea griffithii*, *Garuga floribunda*, *Tetrameles nudiflora*, *Semecarpus reticulatus*, *Pterospermum lanceaefolium* etc. The second tree layer with continuous crowns reaches up to 18–30 m high and is wholly evergreen. The representative tree species are *Garcinia cowa*, *Knema cinerea* var. *glauca*, *Myristica yunnanensis*, *Barringtonia macrostachya*, *Baccaurea ramiflora*, *Mitrephora wangii*, *Lasiococca comberi* var. *pseudoverticilata*, *Symphyllia silhetiana*, *Nephelium lappaceum* var. *pallens*, and *Caryota ochlandra*. The lower tree layer occupies a vertical space of 6–18 m high and has a coverage of less than 50%. The common species are *Pittosporopsis kerrii*, *Goniothalamus griffithii*, *Syzygium latilimbum*, *Cleidion bracteosum*, *Trigonostemon thyrsoideum*, *Aglaia perviridis*, *Beilschmiedia purpurascens*, *Phoebe lanceolata* and *Horsfieldia tetratepala* (Table 3).

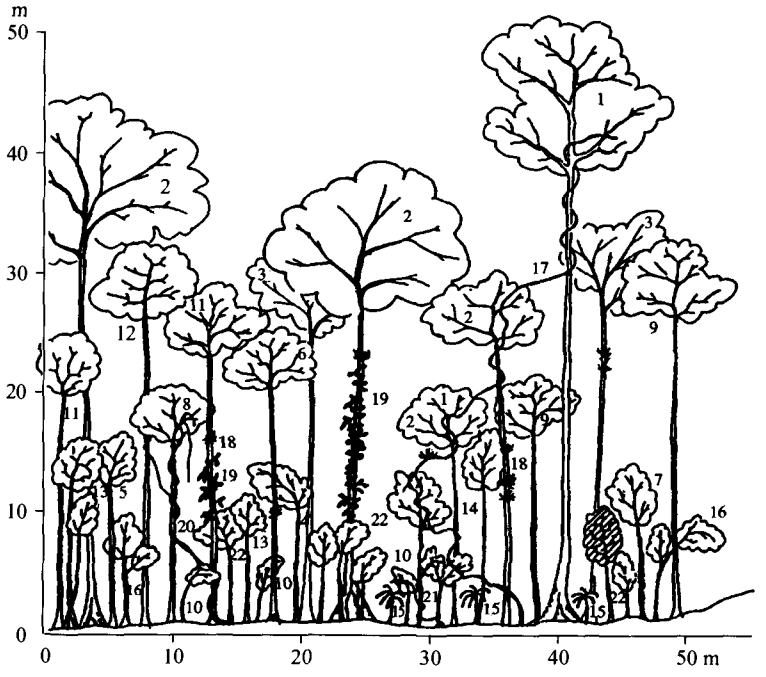

Fig. 3 The profile diagram of *Pometia tomentosa* + *Terminalia myriocarpa* forest. 1. *Terminalia myriocarpa*; 2. *Pometia tomentosa*; 3. *Garruga floribunda* var. *gamblei*; 4. *Knema furfuracea*; 5. *Baccauria ramiflora*; 6. *Garcinia cowa*; 7. *Syzygium latilimbum*; 8. *Barringtonia macrostachya*; 9. *Lasiococca comberi* var. *pseudoverticillata*; 10. *Pittosporopsis kerrii*; 11. *Pseuduvaria indochinensis*; 12. *Pterospermum lanceaefolium*; 13. *Drypetes cumingii*; 14. *Alphonsea monogyna*; 15. *Musa acuminata*; 16 *Trigonostemon thyrsoideum*; 17. *Ventilago calyculata*; 18. *Neottoptreis nidus*; 19. *Rhaphidophora hongkongensis*; 20. *Combretum latifolium*; 21. *Fissistigma* sp.

Table 3 Importance values of tree species of *Pometia tomentosa* + *Terminalia myriocarpa* forest

Location: Menglun, Mengla County			
Elevation (m):	700	650	
Area of plot (m×m):	50×50	50×50	
Number of tree species (>5 cm DBH):	48	49	
Number of individuals:	96	108	
Species	IVI	IVI	Average IVI
Pometia tomentosa	40.40	41.31	40.86
Garruga floribunda var. *gamblei*	8.10	23.78	15.94
Terminalia myriocarpa	17.94	11.6	14.77
Terminalia bellirica	13.77	7.29	10.53
Horsfieldia tetrapetala	–	19.54	9.77
Ficus altissima	–	18.40	9.20
Ficus racemosa	15.50	–	7.75
Ailanthus fordii	11.61	3.12	7.37
Syzygium latilimbum	9.36	4.72	7.04
Horsfieldia pandurifolia	6.43	7.25	6.84
Baccaurea ramiflora	6.63	6.38	6.51
Caryota ochlandra	8.77	4.19	6.48
Milletia laptobotrya	10.43	2.39	6.41
Barringtonia macrosthachys	9.71	2.79	6.25
Garcinia cowa	2.91	9.43	6.17
Neonauclea tsiana	–	11.99	6.00
Lagestroemia tomentosa	–	11.0	5.50
Picrasma javanica	3.94	5.59	4.77
Drypetes cumingii	9.38	–	4.69
Gironniera yunnanensis	8.34	–	4.17
Pterospermum menglunense	–	8.33	4.17
Garcinia xanthochymus	8.06	–	4.03
Chisocheton siamensis	7.54	–	3.77
Lasiococca comberi var. *pseudoverticillata*	–	7.05	3.53
Celtis timorensis	–	6.92	3.46
Alphonsea monogyne	4.09	2.51	3.30
Laportea basirotunda	3.89	2.46	3.18
Radermachera microcalyx	3.13	2.40	2.77
Cyclobalanopsis rex	5.34	–	2.67
Pygeum macrocarpus	2.80	2.46	2.63
Antidesma bunis	5.24	–	2.62
Diospyros nigrocartex	2.80	2.38	2.59
Knema furfuracea	2.70	2.31	2.51
Cleidion bracteosum	–	5.00	2.50
Ficus macleliandii	–	4.95	2.48
Pittosporopsis kerrii	2.60	2.31	2.46
Ficus oligodon	–	4.78	2.39
Pouteria grandifolia	4.63	–	2.32
Polyalthia cheliensis	4.34	–	2.17
Vitex quinata var. *puberula*	–	4.08	2.04

1. Only species with an average Importance Value Index (IVI) over 2 are shown in the table.

2. Average Importance Value Index

$$\frac{\text{Cumulative importance value from all plots}}{\text{The number of plots}}$$

Importance value index = Relative abundance + Relative dominance (Basal area) + Relative frequency

(The same as in Tables 4–7, 10 and 12)

The sapling-shrub layer consists of saplings, young lianas and shrubs, of which saplings predominate not only in number of individuals but also in number of species. The most frequently occurring shrubs are *Lasianthus* spp., *Ardisia tenera*, *Ardisia virens*, *Psychotria yunnanensis*, *Mycetia hirta*, *Ixora fulgens*, *Duperrea pavetiaefolia*, *Miliusa chunii*, *Miliusa velutina*, *Saprosma ternatum*.

The herb layer usually has a coverage of less than 30% and the common species are *Bolbites heteroclita*, *Tectaria variolosa*, *Phrynium capitatum*, *Rhynchotechum obovatum*, *Phlogacanthus curviflorus* var. *brevicalyx*, *Eranthemum polyanthum*, *Rungia robusta*, *Gomphostemma* spp., *Piper* spp.

Woody lianas are very luxuriant in this forest type. The dominant species are *Randia bispinosa*, *Fissistigma* spp., *Tetrastigma* spp., *Parameria laevigata*, *Combretum latifolium*, *Salacia polysperma*, *Tinomiscum tonkinensis*, *Erythropalum scandens*, *Parabarium* spp., *Calamus* spp. etc. Epiphytes are abundant on tree trunks and branches and the frequently occurring species are *Rhaphidophora hongkongensis*, *Rh. decursiva*, *Hoya* spp., *Piper mullesua*, *Dischidia* spp. as well as many species of Orchidaceae and Gesneriaceae. Strangling plants such as *Ficus* spp. are common in this forest type.

This forest formation, up to now, has the largest cover and is the main ravine seasonal rain forest formation.

b) *Shorea wantianshuea* forest

This forest type has been found only in limited habitats of Mengla County, in the far south of the region, covering about 800 hm^2. The formation contains only one consociation with a single dominant species *Shorea wantianshuea* of Dipterocarpaceae. The dipterocarp forest occurs intermittently along the Nanna River and its tributaries, the Nanhang and Nansha Rivers at 700–950 m above sea level. In comparison with the former formation this forest type is richer in species and appears more similar to a typical tropical rain forest. Its floristic composition is also more similar to that of tropical SE Asia. This forest type belongs to the dipterocarp forests of SE Asia and is a type of northern margin of the latter.

This dipterocarp forest, reaching up to 60 m high, is the tallest forest in south China (Fig. 4). The top tree layer with very uneven crown canopy reaches 30–60 m high and has a coverage of about 30%. As an emergent tree, the single dominant species *Shorea wantianshuea* is the tallest tree, with crown branches

near the top and its semi-orbicular crown soars high. Other top tree species, such as *Pometia tomentosa*, *Terminalia myriocarpa*, *Sapium baccatum*, *Neonauclea griffithii*, *Machilus tenuipilis*, *Semecarpus reticulatus*, *Cyclobalanopsis chrysocalyx*, *Sloanea dasycarpa*, *Canarium bengalense* and *Amoora tetrapetala* usually occupy a space of 30–45 m high above the continuous crown canopy of the second tree layer and under the crown of *Shorea wantianshuea*. The second tree layer reaches up to 18–30 m high. *Garcinia cowa* predominates in this layer and other representative species are *Ficus langkokensis*, *Symphyllia silhetiana*, *Knema furfuracea*, *Pseudouvaria indochinensis*, *Barringtonia macrostachya*, *Gironniera subaequalis*, *Knema cinerea* var. *glauca*, *Pterospermum menglunensis*, *Diospyros xishuangbannaensis* and *Nephelium lappaceum* var. *pallens*. The third tree layer is 6–20 m high and can be roughly divided into two sub-layers. The upper sub-layer occupies the 10–20 m high space and has as common species *Baccaurea ramiflora*, *Dichapetalum genonioides*, *Eurya austro-yunnanensis*, *Beilschmiedia purpurascens*, *Diospyros atrotricha* and *Memecylon cyanocarpus*. The lower sub-layer is 6–10 m high. The species *Pittosporopsis kerrii* predominates and other common species are *Phoebe lanceolata*, *Cleidion bracteosum*, *Syzygium latilimbum*, *Trigonostemon thyrsoides*, *Diospyros nigrocortex*, *Mezzettiopsis creaghii* and *Litsea garrettii* (Table 4).

The sapling-shrub layer is 1.5–5 m high and has a coverage of 20%–30%. The most frequently occurring shrub species are *Saprosma ternatum*, *Ixora amplexicaulis*, *Urophyllum sinensis*, *Drypetes hoaensis*, *Lasianthus sikkimensis*, *Lasianthus wallichii*, *Mycetia gracilis*, *Randia yunnanensis* and *Psychotria yunnanensis*.

The herb layer has a coverage which varies from 10% to 70% depending on microhabitats. The most frequently occurring species are *Acanthus leucostachys*, *Phrynium placentarium*, *Rhynchotechum obovatum*, *Amischotolype hookeri*, *Elatostemma megacephalum*, *Pters quilleana*.

Lianas are very abundant in the dipterocarp forest. The dominant lianas are *Tetracera scandens*, *Randia bispinosa*, *Parameria laevigata*, *Bythneria iniergrifolia*, *Calamus gracilis* and *Combretum latifolium*.

Epiphytes are also abundant in the forest. Frequently occurring species are *Rhaphidophora hongkongensis*, *Ficus sagittata*, *Neottopteris somonsiana*, *Rh. decursiva*, *Rh. crassicaulis*, *Arthropteris palisolii*, *Piper mullesua*, *Aeschynanthus* spp., *Micrechites polyantha* and a number of Orchidaceae species. Strangling plants, such as *Ficus subulata*, *Ficus gibbosa* var. *cuspidifera*, are common. Some root parasitic plants, such as *Aphyllorchis caudata*, *Balanophora* spp., also occur in the forest.

Table 4 Importance Values of tree species of *Shorea wantianshuea* forest

Location: Bubeng, Mengla County
Elevation: 700–800 m
Cumulative plot area (hm^2): 1.04 (2,500 m^2 + 2,500 m^2 + 2,400 m^2 + 3,000 m^2)
Number of tree species: 125
Number of individuals (>5 cm DBH): 892

Species	Average IVI
Shorea wantianshuea	68.10
Pittosporopsis kerrii	13.10
Garcinia cowa	12.50
Pometia tomentosa	12.20
Baccaurea ramiflora	9.10
Ficus lankokensis	6.18
Lasioccoca comberi var. *pseudoverticillata*	6.07
Lithocarpus fohaiensis	5.75
Cinnamomum bejolghota	5.19
Knema furfuracea	4.64
Castanopsis indica	4.17
Sapium baccatum	3.97
Pseuduvaria indochinensis	3.67
Chisocheton siamensis	3.58
Barringtonia macrostachya	3.47
Gironniera subaequalis	3.38
Aglaia perviridia	3.36
Semecarpus reticulata	3.32
Phoebe lanceolata	3.32
Diospyros atrotricha	3.29
Cleidion bracteosum	3.05
Syzygium latilimbum	3.04
Knema cinerea var. *glauca*	3.04
Mayodendron igneum	2.95
Garruga floribunda var. *gamblei*	2.93
Machilus tenuipilis	2.79
Pterospermum monglunensis	2.37
Litsea dilleniaefolia	2.29
Diospyros xishuangbannensis	2.16
Neonauclea griffithii	2.11

c) *Pometia tomentosa-Celtis philippensis* var. *wightii* forest

This forest occurs near the bottom of valleys and on lower slopes in somewhat less wet habitats, with rock outcrops usually covering more than 30% of the limestone 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 top tree layer. *Sumbaviopsis albicans* is the dominant species in the upper sublayer of the third layer as is *Cleidion spiciflorum* in the lower sublayer (Table 5).

The understory with a cover of 50%, consist almost entirely of saplings. Only a few shrub species were recorded. Common species are *Psychotria siamica*, *Sauropus macranthus* and *Miliusa tenuistipitata*. The

herb layer has a cover of 30% and *Tectaria cordatum*, a fern species, and *Piper polysyphorum* are the most common species. *Ventilago calyculata* var. *trichoclad* and, *Loeseneriella lenticellata* are common lianas. *Rhaphidophora hongkongensis* and *Pothos chinensis* are frequent epiphytes. This community is transitional towards the lower hill seasonal rain forest in physiognomy and floristic composition.

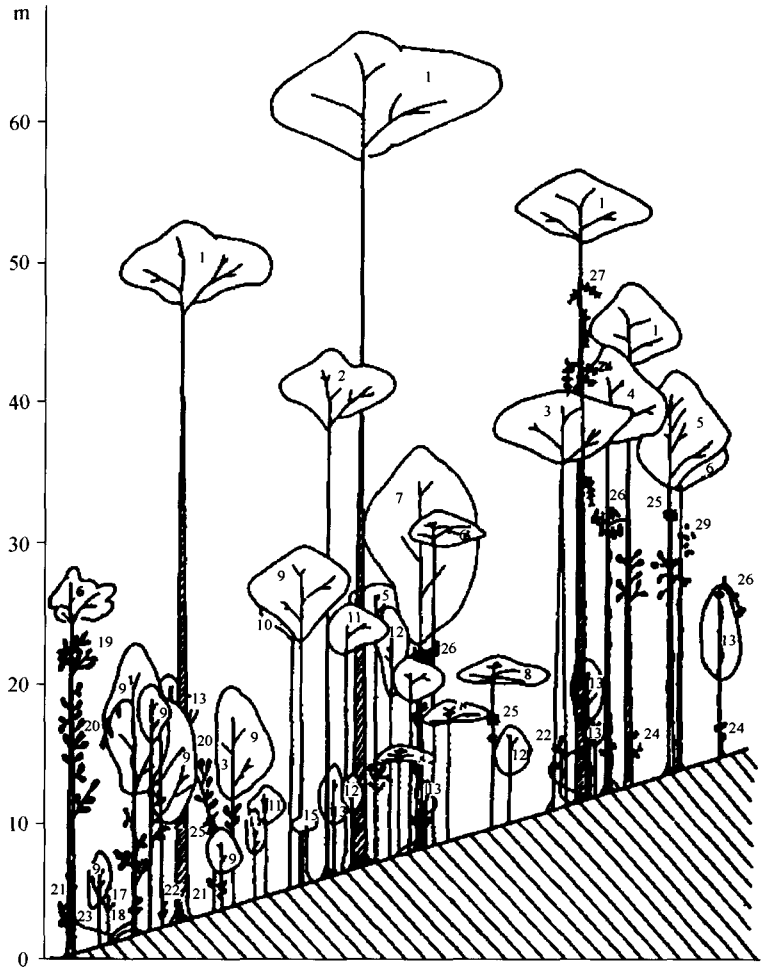

Fig. 4 The profile diagram of dipterocarp rain forest. 1. *Shorea wantianshuea*; 2. *Canarium bengalese*; 3. *Pometia tomentosa*; 4. *Elaeocarpus varunum*; 5. *Semecarpus reticulatus*; 6. *Antidesma calviscens*; 7. *Nephelium lappaceum* var. *pallens*; 8. *Garcinia cowa*; 9. *Pseuduvaria indochinensis*; 10. *Vitex quinata* var. *pubescens*; 11. *Diospyros atrotricha*; 12. *Drypetes hoaesis*; 13. *Diospyros xishuangbannensis*; 14. *Dysoxylum lenticellatum*; 15. *Pittosporopsis kerrii*; 16. *Baccaurea ramiflora*; 17. *Diospyros nigrocartex*; 18. *Uvaria tonkinensi*; 19. *Ficus subulata*; 20. *Rhaphidophora hongkongensis*; 21. *Arthropteris palisotii*; 22. *Ficus sagittata*; 23. *Rhaphidophora crassicaulis*; 24. *Piper mullesua*; 25. *Neottopteris somonsiana*; 26. *Salacia cochinchinensis*; 27. *Parameria laevigata*; 28. *Symphorema invulucrata*; 29. *Ficus gibbosa* var. *cuspidifera*.

2) Lower hill seasonal rain forest

The lower hill seasonal rain forest occurs in the less wet habitats on lower hills and lower sun-facing (usually southwest) slopes. Deciduous trees make up 10–30 per cent of the number of species or in importance value. Its canopy is about 30–45 m high with a relatively clear stratification. The top layer with a crown cover of 40%–50% is 30–45 m tall. The second layer is still the main canopy layer with a crown cover of 70%–80% and 15–28 m tall. The third layer with a cover of circa 50%–60% is 3–15 m tall. Two lower hill seasonal rain forest formations were recognized in Xishuangbanna.

a) *Antiaris toxicaria* + *Pouteria grandiflora* forest

This forest formation occurs mainly on lower hills and lower mountains surrounding wide depressions below 800 m elevation. The areas have now been opened up to use for agriculture on a large scale and so the primitive forests of this formation have been largely destroyed. There are only a few more or less disturbed

forests remaining in so-called "Holy hills" close to villages, such as Mangyanguan of Menglong, Mangjin and Chengzi of Menglun, Manfa and Mangyuan of Menghan.

Table 5 Importance values of tree species of *Pometia tomentosa-Celtis philippensis* var. *wightii* forest

Location: Mengxing, Mengla County			
Elevation (m):	700	740	
Area of plot (m×m):	50×50	50×50	
Number of species (>5 cm DBH):	23	19	
Number of individuals:	118	164	
Species	IVI	IVI	Average IVI
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	–	13.6
Neonauclea tsaiana	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	–	17.7	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	–	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

The forest reaches up to 35–45 m high. The top tree layer with discontinuous crowns and a coverage of 20%–30%, emerges above the continuous crown canopy of the second tree layer (Fig. 5). The representative tree species of this layer are *Antiaris toxicaria*, *Chukrasia tabularis*, *Pouteria grandiflora*, *Ficus altissima*, *Ixonanthes cochinchinensis*, *Canarium album*, *Amoora dasyclada* and *Gironniera subaequalis*. The second tree layer reaches up to 15–28 m high and has a continuous crown canopy. The most representative tree species are *Knema globularis*, *Polyalthia cheliensis*, *Acronychya pedunculata*, *Xanthophyllum siamensis*, *Microcos paniculata*, *Garcinia xanthochymus*, *Mangifera siamemsis*, *Arytera litoralis*, *Turpinia montana*, *Mitrephora thorelii* and *Knema furfuracea*. The lower tree layer is 5–15 m high. The common species are *Suregoda glomerulata*, *Aporusa dioica*, *Aporusa villosa*, *Memecylon polyanthum*, *Glycosmis cochinchinensis*, *Ardisia depressa*, *Hyptianthera stricta*, *Millettia leptobotrya* and *Ostodes paniculata* (Table 6).

The sapling-shrub layer is 1–5 m high and has a coverage of 30%–40%. This layer consists of saplings, young lianas and shrubs. The most abundant shrub

Table 6 Importance values of tree species of *Antiaris toxicaria* + *Pouteria grandiflora* forest

Location: Menglun, Mengla County			
Elevation (m):	680	650	
Area of plot (m×m):	50×50	50×50	
Number of species (>5 cm DBH):	46	52	
Number of individuals:	207	182	
Species	IVI	IVI	Average IVI
Antiaris toxicaria	3.91	80.36	42.14
Barringtonia macrostachya	44.50	–	22.25
Tetrameles nudiflora	40.50	–	20.25
Polyalthia cheliensis	2.70	29.41	16.06
Gironniera subaequalis	23.97	5.58	14.78
Chisocheton siamensis	18.51	–	9.26
Xanthophyllum siamensis	7.89	10.22	9.06
Garcinia xanthochymus	3.06	14.20	8.63
Millettia leptobotrya	11.49	5.06	8.28
Cinnamomum tamala	16.36	–	8.18
Alphosea monogyna	–	13.13	6.57
Pittosporopsis Kerrii	11.66	–	5.83
Amoora dasyclada	–	10.31	5.16
Aphananthe cuspidata	4.32	5.76	5.04
Harpulia cupanioides	1.66	8.35	5.01
Dysoxylum lukii	–	9.45	4.73
Ficus langkikensis	8.61	–	4.31
Arytera litoralis	–	7.83	3.92
Knema globularis	–	7.76	3.88
Randia acuminatissima	7.65	–	3.83
Knema furfuracea	3.57	3.96	3.77
Baccaurea ramiflora	5.93	1.52	3.73
Phoebe puwenensis	6.71	–	3.36
Garcinia cowa	2.79	3.65	3.22
Antidesma montana	6.26	–	3.13
Millettia pachyloba	6.23	–	3.12
Pterospermum lanceaefolium	6.06	–	3.03
Metadiba trichotoma	5.70	–	2.85
Microcos paniculata	–	5.67	2.84
Mitrephora thorelii	3.79	1.68	2.74
Mallotus philippinensis	–	5.04	2.52
Nephelium lappaceum var. *pallens*	1.81	3.01	2.41
Sysygium tetragonum	–	4.64	2.32
Sapium baccatum	–	4.13	2.07

species are *Prismatomeris tetranda, Canthium horridum, Euodia lepta, Clausena dentata, Pandanus furcatus* and *Psychotria henryi.*

The herb layer is about 1 m high and has a coverage of 20%–80%. The most frequently occurring herbaceous plants are *Geophila herbacea, Lepidagathis incurva, Hypoestes triflora, Oplismenus compositus, Pleocnemia winittii* and *Tectaria variolosa.*

Lianas are abundant in the forest and most of them are woody lianas. The predominant species are *Randia bispinosa, Connarus yunnanensis, Salacia polysperma, Combretum latifolium, Ventilago calyculata, Strychnos nitida, Fissistigma maclurei, Neuropeltis racemosa, Acacia intsia* var. *caesia* and *Thunbergia grandiflora.* Epiphytes are not abundant. The common species, which can be found in most stands, are *Pothos chinensis, Cymbidium pendulum, Pseudodrynaria coronans* and *Lepisorus* spp.

b) *Celtis philippensis* var. *wightii-Lasiococca comberi* var. *pseudoverticillata* forest

This is the most common community on lower limestone slopes. The top tree layer is dominated by *Celtis philippensis* var. *wightii*, with some scattered deciduous emergent trees (Fig. 6). *Lasiococca comberi* var. *pseudoverticillata* is the dominant species in the second layer. *Sumbaviopsis albicans* and *Cleidion spiciflorum* still dominate the third layer (Table 7).

The understory with a cover of 30%–50% consists of saplings. Fewer true shrub species were recorded. The herb layer is rather undeveloped and consists mainly of seedlings and a lot of creeping lianas. The most common creeping liana species are *Derris caudatilimba* and *Loeseneriella yunnanensis.* Big woody lianas such as *Combretun* spp., *Tetrastigma* spp. and *Ventilago* spp. occur often. Epiphytes are less frequent than in the ravine seasonal rain forest.

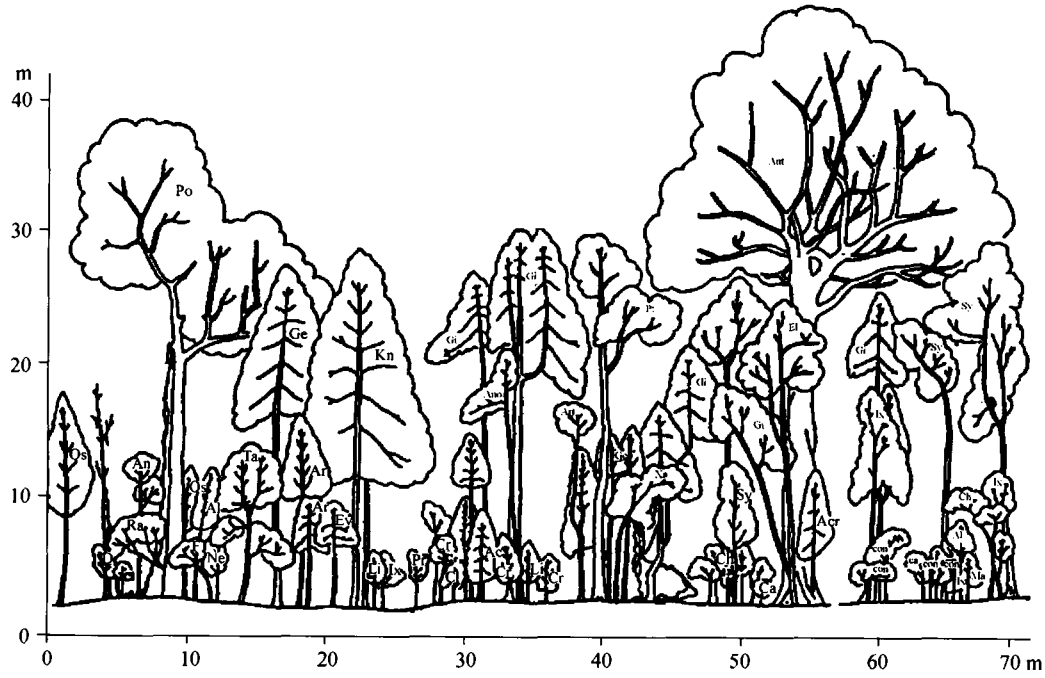

Fig. 5 The profile diagram of *Antiaris toxicaria* + *Pouteria grandiflora* forest. Gi.: *Gironniera subaequalis*; Cl.: *Clausena dentata*; Pt.: *Pterospermum lanceaefolium*; Ac.: *Acronychia pedunculata*; Ra.: *Randia yunnanensis*; Can.: *Canthium horridum*; Ne.: *Nephenium lappaceum* var. *pallens*; Ano.: *Annonaceae*; Os.: *Ostodes paniculata*; Ix.: *Ixonanthe cochinchinensis*; El.: *Eleocarpus sphaerocarpus*; Ge.: *Suregoda glomerulata*; Al.: *Alangium kurzii*; Cap.: *Capparis membranifolia*; Ant.: *Antiaris toxicaria*; Art.: *Artocarpus tonkinensis*; Pr.: *Prismatomeris tetrandra*; Kn.: *Knema furfuracea*; Po.: *Pouteria grandifolia*; An.: *Antidesma calvescens*; Sy.: *Symlocos cochinchinensis*; Ta.: *Tarenna sylvestris*; Ev.: *Evodia simplicifolia*; Ch.: *Chisocheton siamensis*; Xa.: *Xanthophyllum siamense*; K.: *Knema globularia*; Li.: *Litsea garrettii*; Ca.: *Canarium album*; Ar.: *Ardisia yunnanensis*; D.: *Dalbergia stipulata*; Cro.: *Croton argyratus* (From Wu C Y ed. Vegetation of Yunnan, Fig. 5-1, 1987).

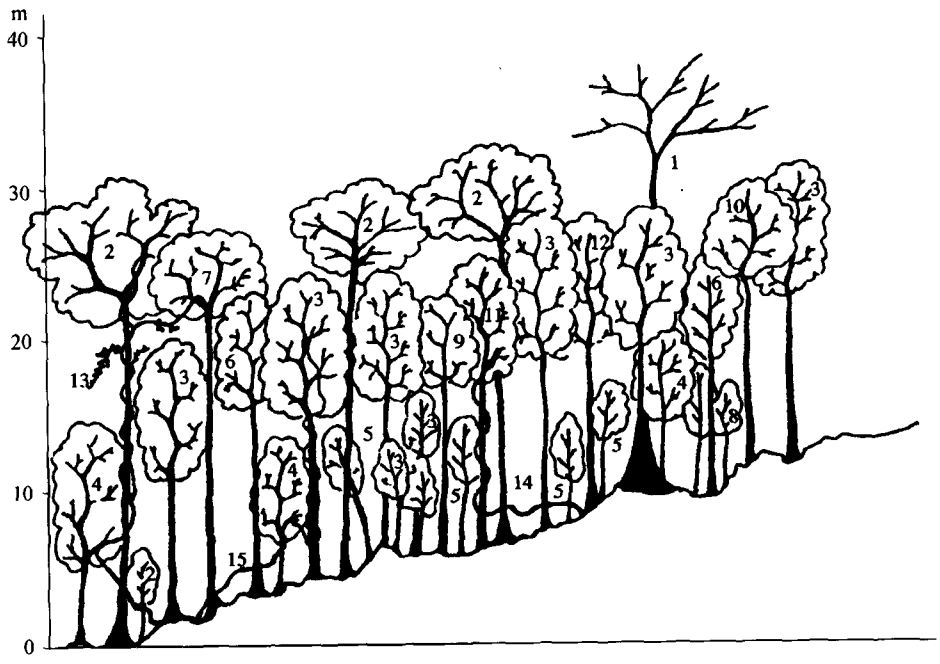

Fig. 6 The profile diagram of *Celtis philippensis* var. *wightii- Lasiococca comberi* var. *pseudoverticillata* forest. 1. *Tetrameles nudiflora*; 2. *Celtis philippensis* var. *wightii*; 3. *Lasioccoca comberi* var. *pseudoverticillata*; 4. *Sumbaviopsis albicans*; 5. *Cleidion spiciflorum*; 6. *Alphonsea 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*

Table 7 Importance values of tree species of *Celtis philippensis* var. *wightii-Lasiococca comberi* var. *pseudoverticillata* forest

Location:	Mengyen	Menglun	Menglun	Mengyen	
Elevation (m):	800	1,000	1,060	825	
Area of plot:	50 m×50 m	20 (10 m×10 m)	5 (10 m×10 m)	40 m×60 m	
Number of species (>5 cm DBH):	27	23	12	11	
Number of individuals:	102	271	44	142	
Species	IVI	IVI	IVI	IVI	Average IVI
Lasiococca comberi var. *pseudoverticillata*	67.12	126.10	101.00	151.10	111.30
Celtis philippensis var. *wightii*	23.64	44.18	30.37	97.20	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	8.80
Cleidion spiciflorum	10.67	6.67	7.57	9.30	8.55
Alphosea mollis	10.81	–	18.42	–	7.30
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	–	–	–	12.80	3.20
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	–	–	–	8.90	2.23
Beilschmiedia yunnanensis	6.66	2.12	–	–	2.20
Caryota urens	–	–	8.42	–	2.11

3.1.2 Tropical montane rain forest

The tropical montane rain forest in Xishuangbanna is similar to the lower montane rain forest of tropical Asia (Whitmore, 1984, 1990). It occurs in wet montane habitats between 900–1,800 m elevation in the region. In species richness the tropical montane rain forest is dominated by Lauraceae, Euphorbiaceae, Papilionaceae, Fagaceae, Rubiaceae, Theaceae, Liliaceae, Rosaceae and Araceae, while Magnoliaceae, Mastixiaceae, Lauraceae, Fagaceae, Theaceae, Nyssaceae, Euphorbiaceae and Elaeocarpaceae are the dominant families in the tree layers. In physiognomy the tropical montane rain forest is dominated by evergreen mesophanerophytes and microphanerophytes with simple, leathery and entire mesophyllous leaves and characterized by having more or less frequent woody lianas and abundant epiphytes, abundant herbaceous phanerophytes but few buttresses and cauliflory. Compared with the seasonal rain forest of the region, the montane rain forest has less abundant megaphanerophytes and large woody lianas, but more abundant micro and nanophanerophytes, herbaceous phanerophytes and more plants with simple, leathery and non-entire and microphyllous leaves (Zhu et al., 2004). Although the tropical montane rain forest is somewhat different from the lowland rain forest in floristic and physiognomic characteristics, it is still considered to be a type of tropical rain forest by most researchers (Beard, 1944, 1955; Grubb, 1964; Robbins, 1968; Whitmore, 1984, 1990; Richards, 1952, 1996).

Based mainly on their habitats, species composition and forest profiles, the vegetation of the montane rain forest is classified into two formations (Wang et al., 2001; Zhu et al., 2004):

1) *Mastixia euonymoides-Phoebe megacalyx* forest

This forest occurs mainly in wetter montane valleys. The forest has usually two tree layers (Fig. 7). The upper layer is up to 35 m high with a crown cover of 70%–80% and is dominated by *Mastixia euonymoidos, Manglietia hookeri, Michelia cavalerieri* and *Nyssa wenshanensis* var. *longipedunculata*. On some sites *M. euonymoidos* grew sufficiently tall so as to be considered as emergent. The lower tree layer was further divided into two sub-layers at some sites. The upper sub-layer is 10–20 m high with a crown cover of 60%–70% and dominated by *Phoebe megacalyx, Syzygium brachythyrsum* and *Dysoxylum binecteriferum*. The lower sub-layer is 5–10 m high with a cover of 40%–50%. The most frequent species are *Ardisia thyrsiflora, Cylindrochelupha kerrii, Ostodes kuangii* and *Brasaiopsis lepidota* (Table 8).

The shrub layer is up to 1–5 m high and dominated by juvenile trees. The most frequent shrub species are *Psychotria symplocifolia, Brassaiopsis fatsioides, Mycetia gracilis, Brachytome hirtellata* var. *glabrescens* and *Oxyspora vagans*.

The herbaceous layer is well developed with a cover of 50%–70%. Abundant species are *Ophior-*

Table 8 Importance values of tree species of *Mastixia euonymoides-Phoebe megacalyx*

Location: Mengsong, Jinghong County
Elevation (m): 1,650–1,780
Area of plot: 5 (25 m×20 m)
Number of species (>5 cm DBH): 62
Number of individuals: 261

Species	RA	RD	RF	IVI
Mastixia euonymoides	0.76	1.64	23.46	25.86
Phoebe megacalyx	9.13	4.10	6.00	19.22
Syzygium brachythyrsum	9.51	4.10	3.01	16.62
Dysoxylum binecteriferum	9.51	4.10	2.35	15.95
Manglietia hookeri	0.38	0.82	14.14	15.34
Michelia cavalerieri	1.90	2.46	8.73	13.09
Nyssa wenshanensis var. *longipedunculata*	1.52	2.46	7.12	11.10
Linociera insignis	4.94	3.28	1.66	9.88
Ardisia thyrsiflora	4.56	4.1	0.87	9.53
Cinnanmomum javanicum	2.66	3.28	3.21	9.15
Helicia pyrrhobotrya	4.18	3.28	0.58	8.05
Callophylum polyanthum	2.66	3.28	1.72	7.66
Ostodes kuangii	3.80	2.46	1.38	7.64
Xanthophyllum yunnanensis	3.42	3.28	0.88	7.58
Brasaiopsis lepidota	2.28	2.46	1.90	6.64
Cylindrochelupha kerrii	3.80	2.46	0.29	6.55
Cryptocarya rolletii	3.04	3.28	0.17	6.49
Alcimandra cathcartii	1.52	2.46	2.29	6.27
Litsea vang var.lotbta	1.52	3.28	0.13	4.93
Litsea lancifolia var. *pedicellata*	2.28	2.46	0.12	4.86
Randia sp.	2.66	1.64	0.52	4.82
Michelia hedyosperma	1.14	1.64	1.93	4.71
Drypetes salicifolia	0.76	1.64	2.30	4.70
Hovenia acerba var. *kiukiangensis*	0.76	0.82	2.82	4.40
Lithocarpus hancei	0.76	0.82	2.56	4.14
Litsea verticillata	1.52	1.64	0.03	3.19
Mastixia pentandra var. *chinensis*	1.14	1.64	0.28	3.06
Reevesia thyrsoidea	1.14	1.64	0.26	3.04
Randia wallichii	1.14	1.64	0.25	3.03
Dimocarpus yunnanensis	0.76	1.64	0.45	2.85
Macaranga henryi	1.52	0.82	0.17	2.51
Machilus shweliensis	0.38	0.82	1.27	2.47
Alsodaphne andersonii	0.38	0.82	0.91	2.11

*1. Only species with an IVI over 2 are shown in the table.
RA: relative abundance; RD: relative dominance; RF: relative frequency; IVI: importance value index
Importance value index= relative abundance + relative dominance (Basal area) + relative frequency
(The same as in Tables 9, 11 and 14–17)

rhiziphyllum macrobotryum, *Allantodia dilatata*, *Ctenitopsis* spp., *Microsorium dilatatum*, *Porandra scandens*, *Rhynchotechum obovatum* and *Strobilanthus* spp.

There are a few lianas although some big woody individuals belonging to species such as *Epigeum auritum*, *Bousigonia angustifolia*, *Clamus bambariensis* and *Gnetum montanum* are present.

Epiphytes are abundant. They include *Pothos chinensis*, *Neottopteris nidus*, *Rhaphidophora hongkongensis*, *Aeschynanthus bracteatus*, *Pholidota imbricata* and *Asplenium normale*.

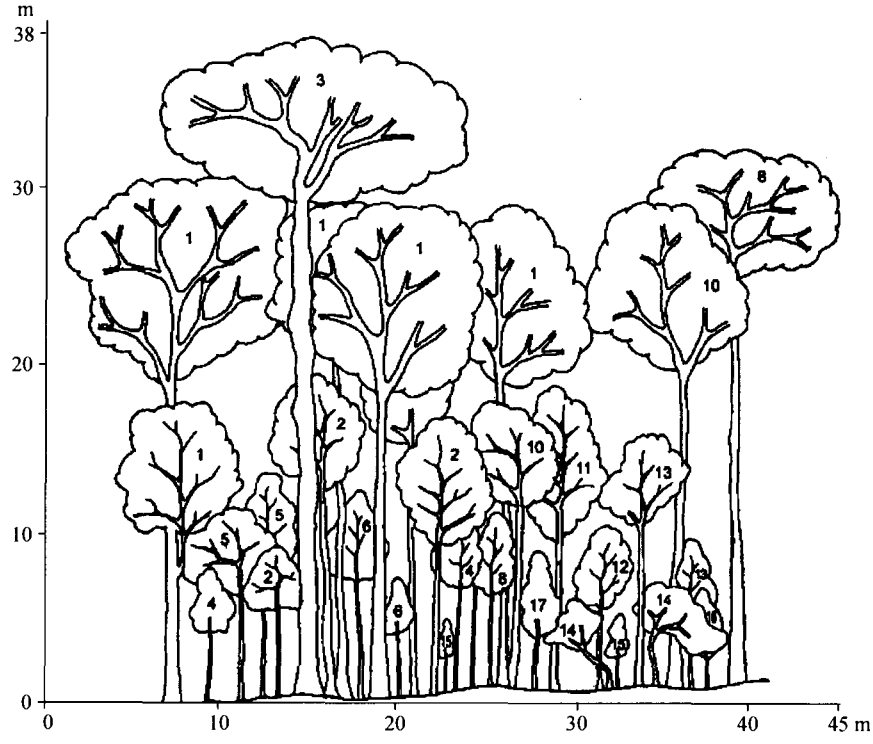

Fig. 7 The profile of *Mastixia euonymoides-Phoebe megacalyx* forest. 1. *Alcimandra cathcartii*; 2. *Phoebe megacalyx*; 3. *Masitixia euonymoides*; 4. *Helicia pyrrhobotrya*; 5. *Symplocos hookeri*; 6. *Cylindrochelupha kerrii*; 7. *Linociera insignis*; 8. *Callophylum polyanthum*; 9. *Macaranga henryi*; 10. *Syzygium brachythyrsum*; 11. *Cyclobalanopsis* sp.; 12. *Xanthophyllum yunnanensis*; 13. *Dysoxylum binecteriferum*; 14. *Cryptocarya rolletii*; 15. *Oxyspora vagans*; 16. *Castanopsis argyrophylla*; 17. *Litsea lancifolia* var. *pedicellata*

2) *Parachmeria yunnanensis-Gymnanthes remota* forest

This forest occurs on shady slopes and on tops of hills. The forest is 25–30 m high with a very even canopy. It also has two tree layers (Fig. 8). The upper layer with a crown cover of 80% is dominated by *P. yunnanensis*, *Nyssa wenshanensis*, *Cinnamomum javanicum* and *Callophylum polyanthum*. The lower layer, at 5–20 m with a cover of 70%–80%, is dominated by *G. remota*, *Syzygium brachythyrsum*, *Xanthophylum yunnanensis* and *Wendlandia pingpiensis* (Table 9).

The shrub layer is 1–5 m high with a cover of 30%–40% and dominated by juvenile trees. Frequent shrub species are *Euodia lepta*, *Fargesia plurisetosa*, *Lasianthus lucidus*, *Psychotria symplocifolia*, *Oxyspora vagans* and *Lasianthus inodorus*.

The herbaceous layer is usually less developed than in the preceding forest type. Frequent species are *Davallia mairesii*, *Pteris insignis*, *Ophiopogon graminifolia*, *Colysis pothifolia* and *Strobilanthus* spp.

There are few lianas but some big woody lianas occur such as *Connaris paniculatus*, *Celastrus monospermum*, *Epigeum auritum*, *Bousigonia angustifolia*, *Gnetum montanum* and *Alyxis balansae*. Epiphytes are fewer than in the *Mastixia euonymoides-Phoebe megacalyx* forest.

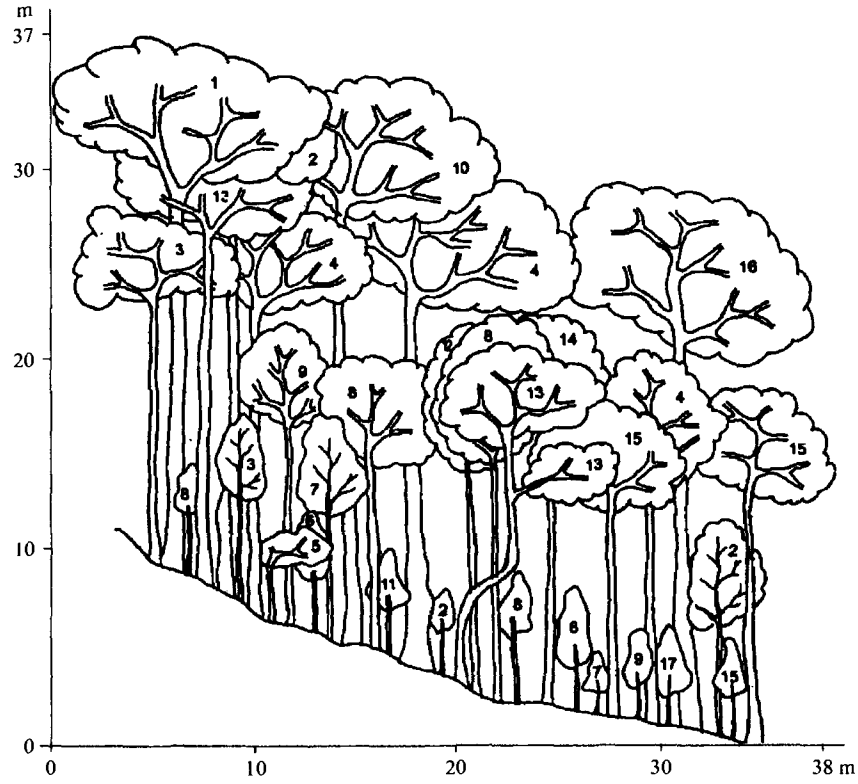

Fig. 8 The profile of *Parakmeria yunnanensis- Gymnanthes remota* forest. 1. *Parakmeria yunnanensis*; 2. *Callophylum polyanthum*; 3. *Xanthophyllum yunnanensis*; 4. *Nysssa wenshanensis* var. *longipedunculata*; 5. *Cylindrochelupha kerrii*; 6. *Microtropis teragona*; 7. *Wendlanida pingpiensis*; 8. *Gymnanthes remota*; 9. *Syzygium brachythyrsum*; 10. *Michelia floribunda*; 11. *Dimocarpus yunnanensis*; 12. *Mastixia pentandra* subsp. *chinensis*; 13. *Reevesia thyrsoidea*; 14. *Dysoxylum binecteriferum*; 15. *Gomphandra tetrandra*; 16. *Acer decandrum*; 17. *Ostodes kuangii*.

3.2 Tropical seasonal moist forest

Tropical seasonal moist forests occur on the middle and upper limestone slopes, ranging from 650–1,300 m in elevation. This vegetation type abuts the seasonal rain forest in limestone valleys and lower slopes and was called monsoon forest by some Chinese authors (Wu, 1980, 1987). The term seasonal moist forest is preferred here because the forest is not equivalent to Schimper's monsoon forest (Schimper, 1903), despite the fact that it is affected by seasonal dryness and contains a variable percentage of deciduous trees (Zhu et al., 1998). The seasonal dryness in the region is compensated to some extent by dense fog accompanied by low temperatures during the same months (November to April) (Whitmore, 1984). Some deciduous trees shed leaves towards the end of the dry season, while others such as *Cratoxylon cochinchinensis* shed their old leaves as new ones develop. This suggests that the occurrence of deciduous trees in the region is more frequently associated with local, dry habitats than with the seasonal dryness of the climate. Therefore, using the term monsoon forest for the evergreen or semi-evergreen forest on limestone soil is confusing because Schimper's monsoon forest is more or less completely leafless during the dry season. The term "tropical seasonal moist forest" is used here for this type of forest in Xishuangbanna because of its physiognomy, habitat and the confusion with the term "monsoon forest" (Zhu et al., 2003; Zhu, 2005).

In physiognomy, the seasonal moist forest is still dominated by evergreen mesophanerophytes and microphanerophytes with simple, leathery and entire mesophyllous leaves and has many woody lianas. Compared with the seasonal rain forest of the region, the seasonal moist forest has less abundant megaphanerophytes, but more abundant herbaceous chamephytes and more-plants with compound, leathery leaves.

The tropical seasonal moist forest is basically evergreen, with two distinct tree layers. *Lasiococca comberi* var. *pseudoverticillata* and *Osmanthus polyneurus* are the dominant species in the top layer and *Dracaena cochinchinensis* and *Cleistanthus sumatranus* are usually the dominant species in the second layer. The understory consists of saplings and creeping lianas. Two forest formation groups are recognized based on habitat, physiognomy and floristic composition: a tropical seasonal evergreen moist forest and a tropical seasonal semi-evergreen moist forest.

Table 9 Importance values of tree species of *Parachmeria yunnanensis-Gymnanthes remota* forest

Location: Mengsong, Jinghong County
Elevation (m): 1,650–1,700
Area of plot: 5 (25 m×20 m)
Number of species (>5 cm DBH): 71
Number of individuals: 293

Species	RA	RD	RF	IVI
Gymnanthes remota	15.0	4.20	3.97	23.53
Parachmeria yunnanensis	1.0	2.52	11.08	14.62
Xanthophylum yunnanensis	7.2	3.36	2.22	12.75
Syzygium brachythyrsum	7.2	3.36	1.65	12.18
Wendlandia pingpiensis	6.8	3.36	1.19	11.38
Nyssa wenshanensis	1.0	1.68	8.13	10.84
Cinnamomum javanicum	3.1	3.36	3.83	10.26
Callophylum polyanthum	3.4	3.36	3.38	10.15
Nyssa wenshanensis var. *longipedunculata*	2.0	1.68	5.93	9.66
Mastixia pentandra subsp. *chinensis*	4.1	1.68	3.72	9.49
Manglietia insignis	0.7	0.84	6.17	7.70
Acer decandrum	2.0	3.36	2.26	7.67
Cyclobalanopsis sp.	1.4	1.68	2.81	5.86
Ostodes kuangii	4.4	0.84	0.53	5.80
Cyclobalanopsis sp.	0.3	0.84	3.97	5.16
Machilus shweliensis	1.4	2.52	1.11	5.00
Engelhardtia spicata	0.3	0.84	3.78	4.96
Alcimandra cathcartii	0.7	1.68	2.58	4.94
Michelia floribunda	1.4	1.68	1.79	4.83
Podocarpus niriifolius	0.7	0.84	3.22	4.75
Caraibiodendron stellatum	1.0	0.84	2.55	4.42
Lithocarpus gagnepainianus	1.7	0.84	1.85	4.40
Dimocarpus yunnanensis	2.0	1.68	0.55	4.28
Gomphandra tetrandra	2.7	0.84	0.69	4.26
Cinnamomum bejolghota	1.4	2.52	0.28	4.17
Lithocarpus pseudoreinwardtii	2.0	1.68	0.24	3.96
Linociera ramiflora	0.7	1.68	1.16	3.52
Castanopsis histrix	0.3	0.84	2.24	3.43
Litsea sp.	0.3	0.84	2.21	3.39
Cyclobalanopsis sp.	2.0	0.84	0.48	3.37
Lindera metcalfiana var. *dictyophylla*	1.4	1.68	0.23	3.27
Castanopsis argyrophylla	0.7	0.84	1.47	2.99
Lithocarpus fohaiensis	0.3	1.68	0.90	2.92
Reevesia thyrsoidea	0.7	1.68	0.52	2.88
Ardisia thyrsiflora	1.0	1.68	0.15	2.86
Randia griffithii	0.7	1.68	0.47	2.84
Schima wallichii	0.7	0.84	1.27	2.80
Symplocos wikstroemiifolia	1.0	1.68	0.07	2.77
Dysoxylum benecteriferum	1.0	1.68	0.06	2.76
Pygeum henryi	0.7	1.68	0.33	2.69
Litsea sp.	0.3	0.84	1.26	2.44
Cylindrokelupha kerrii	0.7	1.68	0.06	2.43
Eurya aurea	0.7	1.68	0.06	2.42
Linociera insignis	0.7	1.68	0.04	2.40
Eriobotrya obovata	0.7	0.84	0.84	2.37
Rhododendron moumaiensis	1.0	0.84	0.44	2.30
Acer huianum	0.3	0.84	1.03	2.21
Alangium chinensis	0.3	0.84	0.92	2.10

(To be continued)

(Continue Table 9)

Table 10 Importance values of tree species of *Osmanthus polyneurus-Dracaena cochinchinensis* forest

Location:	Longpa, Jinghong	Longpa, Jinghong	
Elevation (m):	1,320	1,420	
Area of plot (m×m):	25×20	25×20	
Number of species (>5 cm DBH):	15	21	
Number of individuals:	37	42	
Species	IVI	IVI	Average IVI
Osmanthus polyneurus	74.83	90.86	82.84
Dracaena cochinchinensis	106.49	–	53.25
Tarenna sylvistris	24.14	11.53	17.75
Syzygium 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	7.30
Alphonsea mollis	7.31	6.55	6.93
Myrsine semiserrata	+	13.52	6.76
Mallotus philippinensis	7.08	5.62	6.35
Garcinia bracteata	–	12.30	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 anguta var. *hookeri*	8.08	–	4.04
Eriolaena kwangsiensis	7.79	–	3.90
Micromelum integerrimum var. *mollisimum*	7.34	–	3.67
Diospyros yunnanensis	–	7.10	3.55
Clausena excavata	6.96	–	3.50
Ulmus lanceifolia	–	6.70	3.35
Fortunella polyandra	–	5.89	2.95
Schoepfia fragrans	–	5.85	2.93
Wrightia laevis	–	5.62	2.81

3.2.1 Tropical seasonal evergreen moist forest

This tropical seasonal evergreen moist forest occurs on the upper slopes, the shady slopes or the tops of lower hills with more than 90% of rock outcrops from 600 m to 1,300 m elevation and usually abuts the seasonal rain forest on the lower slopes and in valleys. This forest is almost entirely evergreen, with two distinct tree layers. The top 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. Some deciduous emergent trees such as *Tetrameles nudiflora*, *Garuga pinnata* and *Chukrasia tabularis* are sparsely dotted throughout the forest.

Two main forest formations were recorded:

1) *Osmanthus polyneurus-Dracaena cochinchinensis* forest

This forest usually occurs on the upper slopes of mountains or hills above 1,000 m elevation. *Osmanthus polyneurus* is the dominant species in the top layer and *Dracaena cochinchinensis* is usually dominant in the second layer (Fig. 9).

The understory consists of saplings and creeping lianas. The most common lianas are *Loeseneriella yunnanensis* and *Hiptage benhalensis*. Herbaceous species of the family Urticaceae such as *Procris crenata*, *Elatostema* spp. and *Pilea* spp., are abundant. Epiphytes on rock are also frequent (Table 10).

2) *Lasiococca comberi* var. *pseudoverticillata-Cleistanthus sumatranus* forest

This forest type occurs only on the dry slopes and the tops of the lower hills in Menglun between 600–800 m. There are two tree layers, of which the upper layer is 16 to 23 m tall and has a cover of 50%; the lower layer is 5–16 m tall and has a cover of more than 70% (Fig. 10). It is basically a community with the predominant species *Lasiococca comberi* var. *pseudoverticillata* in the upper tree layer and *Cleistanthus sumatranus* in the lower tree layer. It abuts the 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 throughout the forest. The understory is similar to the former community (Table 11).

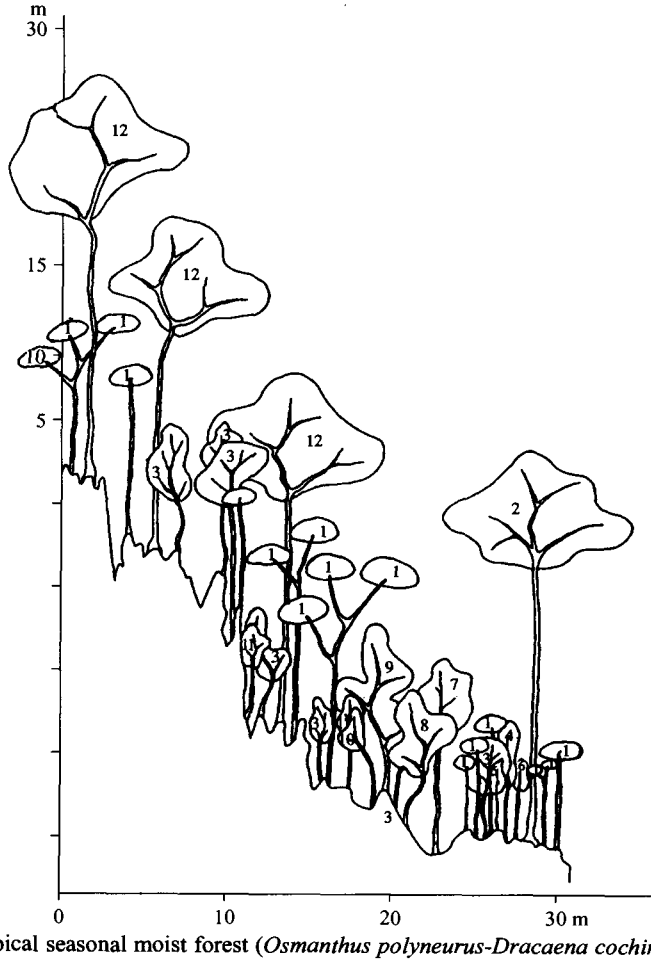

Fig. 9 The profile diagram of tropical seasonal moist forest (*Osmanthus polyneurus-Dracaena cochinchinensis* community). 1. *Dracaena cochinchinensis*; 2. *Amoora tetrapetala*; 3. *Tarenna sylvestris*; 4. *Garcinia bracteata*; 5. *Mallotus philippinensis*; 6. *Diospyros yunnanensis*; 7. *Syzygium balsameum*; 8. *Photinia angusta* var. *hookeri*; 9. *Alphonsea mollis*; 10. *Engelhadtia spicata*; 11. *Clausena excavata*; 12. *Osmanthus polyneurus*.

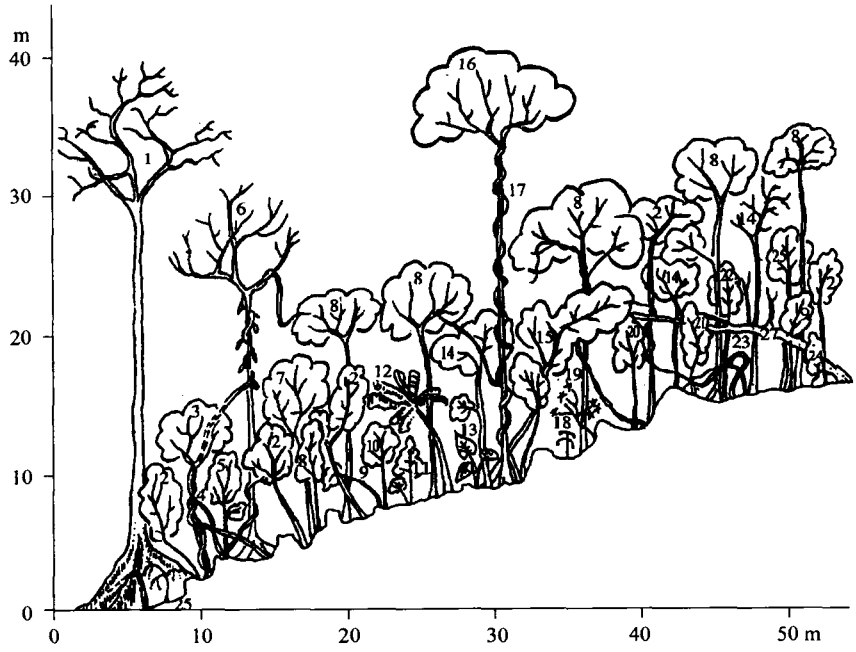

Fig. 10 The forest profile diagram of tropical seasonal moist forest (*Lasiococca comberi* var. *pseudoverticillata-Cleistanthus sumatranus* community). 1. *Tetrameles nudiflora*; 2. *Cleistanthus sumatranus*; 3. *Laportea urentissima*; 4. *Pothos repens*; 5. *Sumbaviopsis albicans*; 6. *Garruga floribunda* var. *gamble*; 7. *Mallotus paniculata*; 8. *Lasiococca comberi* var. *pseudoverticillata*; 9. *Cleidion brevipetiolatum*; 10. *Sterculia lanceolata*; 11. *Murraya tetramera*; 12. *Musa acuminata*; 13. *Alocasia macrorhizza*; 14. *Colona floribunda*; 15. Unknown; 16. *Celtis 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 (From Xu & Jiang ed. Reports on the Nature Reserve of Xishuangbanna, pp.136: Fig. 5, 1987).

Table 11 Importance values of tree species of *Lasiococca comberi* var. *pseudoverticillata-Cleistanthus sumatranus* forest

Location: Menglun, Mengla County
Elevation: 750 m
Area of plot: 50 m×50 m
Number of species (>5 cm DBH): 29
Number of individuals: 445

Species	RA	RD	RF	IVI
Cleistanthus sumatranus	45.60	7.80	12.66	66.10
Croton crassifolius	8.50	7.80	37.50	53.90
Lasiococca comberi var. *pseudoverticillata*	27.19	7.80	4.90	39.90
Celtis philippensis var. *wightii*	4.70	6.30	21.3	32.30
Garuga pinnata	2.00	7.80	6.90	16.80
Tetrameles nudiflora	0.20	1.60	11.70	13.50
Glycosmis ferruginea	1.80	6.30	0.50	8.60
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	6.00
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

3.2.2 Tropical seasonal semi-evergreen moist forest

This formation group occurs on much drier lower and middle slopes. The forest is semi-evergreen with deciduous trees making up 30–60 per cent of the number of species and 35–70 per cent of the importance value index. Top layer trees are usually deciduous with umbrella crowns and thicker bark. The dominant species in the top layer is usually *Bombax insignus*, 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.

Two main forest formations were also recorded:

1) *Bombax insignis* + *Colona floribunda* forest

This forest occurs on the lower and middle dry slopes and covers a relatively large area. *Bombax insignis* is the dominant species. 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 12). The understory consists of saplings, lianas and shrubs. Common shrub species are *Murraya koenigii*, *Colebrookea oppositifolia* and *Allo-*

phylus hirsutus. Common lianas are *Amalocalyx yunnanensis*, *Porana spectabilis* and *Acacia pinnata*. Epiphytes are rare.

2) *Bombax insignis-Garcinia bracteata* forest

This forest occurs on the lower and drier, gentle slopes. *Bombax insignis*, as emergent trees, reaches up to 35 m. *Garcinia bracteata* and *Dracaena cochinchinensis* are the co-dominant species in the second layer. The understory is similar to the former community (Table 13).

Table 12 Importance values of tree species of *Bombax insignis* + *Colona floribunda* forest

Location:	Huiwa	Yingchan	Mengyen	
Elevation (m):	980	1,200	1,000	
Area of plot (m×m):	30×30	25×30	40×50	
Number of species (>5 cm DBH):	19	20	16	
Number of individuals:	70	38	57	
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
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	12.90	–	7.95
Spondias pinnata	–	19.07	–	6.36
Ehretia tsangii	–	7.29	9.00	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	–	3.40
Helicia cochinchinensis	–	9.69	–	3.23
Litsea glutinosa	9.32	+	–	3.10
Sterospermum tetragonum	–	9.30	–	3.10
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 toosendan	–	8.86	–	2.95
Engelhartia roxburghiana	–	8.65	–	2.88
Alphonsea mollis	–	–	8.00	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

(To be continued)

(Continue Table 12)

Table 13 Importance values of tree species of *Bombax insignis-Garcinia bracteata* community

Location: Mengyen, Mengla
Elevation (m): 800
Area of plot: 50 m×50 m
Number of species (>5 cm DBH): 27
Number of individuals: 115

Species	RA	RD	RA+RD
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

*1. Only species with RA+RD over 2 are shown in the table.
2. RA: Relative abundance; RD: Relative dominance

3.3 Monsoon forest

The monsoon forest is a tropical deciduous forest under the influence of a strong monsoon climate as defined by Schimper (1903). In southern Yunnan and SE Asia, monsoon forests have often a mosaic distribution with the seasonal rain forests. Monsoon forests seem an intermediate type between seasonal rain forests and savanna. In Xishuangbanna, monsoon forests occur on the banks of the Mekong River and at wide basins where there is an evidently annual dryness, controlled

by a strong monsoon climate (Zhu, 2005). The monsoon forest is usually 20–25 m tall with 1–2 tree layers. The upper tree layer with an umbrella crown is composed of deciduous trees, or the tree layers are all deciduous. Woody lianas and epiphytes are scarce. Frequent tree species are *Bombax ceiba*, *Ficus altissima*, *Chukrasia tabularis* var. *velutina*, *Erythrina stricta*, *Pterocarya tonkinensis*, *Albizia chinensis*, *Bischoffia javanica*, *Bauhinia variaegata*, *Anogeissus acumunata*, *Stereospermum tetragonum* and *Mitragyna brunonis*.

The monsoon forest is often a single dominant tree community. Four main formations are recognised in Xishuangbanna region:

3.3.1 Pterocarya tonkinensis forest

This forest occurs mainly at alluvial banks of rivers, such as the Mengxun, Nanla and Luosuo, between 480–650 m elevation, in Mengla County. The forest is up to 25 m tall and has a tree layer with a canopy cover of 80%. The tree layer is dominated by *Pterocarya tonkinensis* and occasionally *Anthocephalus chinensis*, *Trewia nudiflora* and *Lagerstroemia tomentosa* are present in the forest. Underneath the tree layer is a sapling-shrub layer with a cover of 30%–50% and a herbaceous layer with a cover of 10%–20%. Woody lianas and epiphytes are rare in the forest. Frequent shrub species are *Homonoia riparia*, *Cipadesa baccifera*, *Solanum torvum*, *Desmodium multiflorum*, *Maesa indica* and *Phyllanthus flexuosus*. The most frequently occurring herb species are *Arthraxon lanceolatus*, *Piper longum*, *Eupatorium coelesticum*, *Colebrookea oppositifolia*, *Cyclosorus molliusculus* and *Dicliptera riaria* (Fig. 11) (Li et al., 1999).

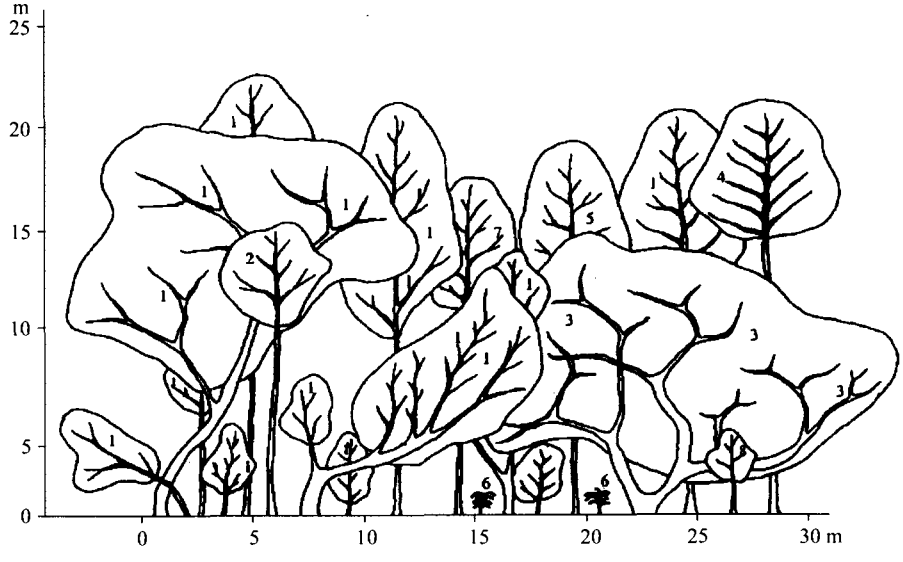

Fig. 11 The profile diagram of *Pterocarya tonkinensis* forest. 1. *Pterocarya tonkinensis*; 2. *Albizia odoratissima*; 3. *Dillenia indica*; 4. *Anthocephalus chinensis*; 5. *Trewia nudiflora*; 6. *Pandanus furcatus*; 7. *Alstonia scholaris*; 8. *Lagerstroemia tomentosa*.

3.3.2 Bombax ceiba forest

The *Bombax ceiba* forest occurs mainly on alluvial banks of the Langcan and Luosuo Rivers. It is 15–20 m tall and has only one tree layer with a cover of 90%. The tree layer consists entirely of *Bombax ceiba*. The shrub-sapling layer is 1–2 m tall with a cover of 10%–30%. The herbaceous layer is 0.5–1 m tall with a cover of more than 70% during the rainy season. Frequent shrub species are *Maesa indica*, *Securinega virosa*, *Solanum verbacifolium*, *Solanum spirale*, *Solanum torvum* and *Urena lobata* var. *chinensis*. Frequent herb species are *Eupatorium odoratum*, *Alocasia macrorrhizos*, *Cyathula prosrata*, *Ageratum conyzoides*, *Sambucus chinensis*, *Conyza canadensis* and *Amorphophalus virosus* (Li et al., 1993).

3.3.3 Anogeissus acuminata forest

This forest occurs mainly on the alluvial banks of the Langcan River and the lower slopes of the river valley below 900 m in Jinghong County. This forest is 25–30 m tall and has two tree layers. The upper layer has a canopy cover of 40% and is dominated by *Anogeissus acuminata*. Other frequent trees in the upper layer are *Dalbergia obtusifolia*, *Sterculia villosa*, *Dalbergia yunnanensis*, *Grewia eriocarpa*, *Lannea coromanderica*, *Eriolaena kuangsiensis* and *Dalbergia fusca* var. *enneandra*. The lower tree layer is 10–15 m tall with a cover of more than 80%. It is dominated by the bamboo species *Dendrocalamus strictus*. The shrub-sapling layer is 1.5 m tall and has a cover of 30%. The frequent shrub species are *Dendrolobium*

triangulare, *Leea crispa*, *Helicteris glabriuscula*, *Flemingia strobilifera*, *Pouzolzia sanguinea* and *Callicarpa cathayana*. The herbaceous layer is 0.5 m tall and has a cover of 20%–30%. Frequent herb species are *Oryza meyeniana* subsp. *granulata*, *Boesenbergia fallax*, *Globba racemosa*, *Commelina undulata*, *Nervilia fordii*, *Desmodium falcate*, *Oplismenus compositus* and *Cucurligo capitullata*. Lianas, such as *Loeseneriella lenticellata*, *Cissus* sp., *Pueraria phaseoloides*, *Cryptolepis buchanani*, *Celastrus paniculatus* and *Aspidopterys floribunda*, occur often (Wang and Zhu, 1990).

3.3.4 Lannea coromandelica + Sterculia pexa forest

This forest occurs also on alluvial banks and the lower slopes of Langcan (the upper Mekong River). It is 20–25 m tall and has 1–2 tree layers. The upper tree layer is mainly composed of deciduous trees and has a canopy cover of 80%. The dominant trees are *Lannea coromandelica*, *Sterculia pexa*, *Stereospermum colais*, *Albizia odoratissima* and *Colona floribunda*. The lower tree layer has a cover of 20%–30% and is dominated by *Pistacia weinmannifolia*, *Dalbergia obtusifolia*, *Eriolaena kwangsiensis*, *Phyllanthus emblica*, *Bauhinia acuminata*, *Grewia eriocarpa* and *Cipadessa cinerascens*. On some sites, the bamboo species *Dendrocalamus membranaceus* is dominant in the lower tree layer (Table 14).

The sapling-shrub layer is 1–3 m tall and has a cover of 10%–20%. The layer is dominated by saplings such as *Sterculia pexa* and *Dalbergia obtusifolia*. Frequently occurring shrub species are *Woodfordia fruticosa*, *Vernonia parishii* and *Helicteres angustifolia*. The herbaceous layer is 0.5–1 m tall with a variable cover of 20-80%. Frequent herb species are *Microstegium ciliatum*, *Chromolaena odorata*, *Selaginella* sp., *Heteropogon contortu*, *Adiantum philippense*, *Lysimachia lobelioides* and *Rostellularia diffusa*. Frequent lianas are *Loeseneriella yunnanensis*, *Ampelocissus sikkimensis*, *Pueraria alopecuroides* and *Cryptolepis buchananii*.

3.4 Tropical montane evergreen broad-leaved forest

The main montane vegetation type in Xishuangbanna is the tropical montane evergreen broad-leaved forest. It is usually distributed on mountain slopes and summits above 1,000 m elevation and valleys above 1,300 m. The forest is dominated largely by the families Fagaceae, Euphorbiaceae, Theaceae and Lauraceae. Physiognomically, the forest is characterized by abundant trees with mesophyllous leaves (making up circa 70% of the trees) and leathery leaves (also making up about 70% of the trees). The term "monsoon evergreen broad-leaved forest" was used for this forest type by some Chinese authors (Jin, 1979; Wu, 1980; 1987). However, "monsoon forest" was widely used for deciduous forests in the strong monsoon climate of SE Asia (Schimper, 1903). This forest in Xishuangbanna is evidently not a monsoon forest of the same type as in SE Asia because it is an evergreen forest. It is also different from the tropical montane rain forest of SE Asia because it usually lacks epiphytes. The term tropical montane evergreen broad-leaved forest is here used for this type of forest in Xishuangbanna in consideration of its physiognomy, habitat and to avoid confusion with the "monsoon forest" and the "tropical montane rain forest" of SE Asia and Xishuangbanna (Zhu et al., 2005).

Table 14 The importance values of tree species of *Lannea coromandelica* + *Sterculia pexa* forest

Location: Langcanjiang, Jinghong County

Elevation (m): 630–820

Area of plot: 5 (25 m×20 m)

Number of species (>5 cm DBH): 25

Number of individuals: 333

Species	RA	RD	RF	IVI
Lannea coromandelica	6.25	11.41	35.28	52.94
Sterculia pexa	6.25	7.81	31.80	45.86
Stereospermum colais	6.25	7.21	4.14	17.60
Pistacia weinmannifolia	3.75	9.91	2.33	15.99
Albizia odoratissima	6.25	4.20	5.39	15.85
Eriolaena kwangsiensis	6.25	3.90	4.70	14.86
Dendrocalamus membranaceus	2.50	10.51	0.93	13.94
Cipadessa cinerascens	3.75	7.81	1.79	13.35
Eriolaena spectabilis	5.00	5.11	2.64	12.75
Phyllanthus emblica	5.00	3.90	1.26	10.16
Colona floribunda	5.00	3.60	1.26	9.86
Dalbergia obtusifolia	5.00	2.70	2.07	9.77
Grewia eriocarpa	6.25	3.00	0.45	9.70
Grewia abutilifolia	5.00	3.30	1.00	9.31
Sterculia villosa	3.75	3.30	1.57	8.62
Woodfordia fruticosa	3.75	3.00	0.36	7.11
Casearia graveolens	3.75	1.81	0.72	6.27
Dalbergia fusca	2.50	2.10	0.68	5.28
Bauhinia acuminata	2.50	2.40	0.32	5.23
Hymenodictyon flaccidum	3.75	0.90	0.11	4.76
Mallotus philippinensis	2.50	0.60	0.40	3.50
Bombax ceiba	1.25	0.60	0.50	2.35

This tropical montane evergreen broad-leaved forest occurs on montane slopes between 900–1,800 m and usually has two conspicuous tree layers, of which the

upper tree layer is 15–30 m tall with dense crowns and the lower tree layer is 3–18 m tall with a cover of about 50%. These forests are dominated by the Fagaceae, Theaceae and Lauraceae families, but diversified in species composition on different sites. The understory is mainly composed of saplings and seedlings of the tree layer species. Shrub and herbaceous species are usually less abundant.

Compared with tropical seasonal rain forests at lower elevation in the region, the tropical montane evergreen broad-leaved forest has fewer epiphytes, fewer mega-mesophanerophytes, fewer plants with compound leaves, but more abundant micro-nanophanerophytes and hemicryptophytes, more plants with microphyllous leaves and more plants with entire leaf margins.

The tropical montane evergreen broad-leaved forest is diverse in species composition and somewhat different in the most dominant or sub-dominant species although they are at similar elevations and have a similar physiognomy. Three forest formations are recognized and named by their dominant and sub-dominant species as follows: *Schima wallichii+Castanopsis hystrix* forest, *Schima wallichii+Lithocarpus fohaiensis* forest and *Castanopsis echinocarpa* forest.

3.4.1 Schima wallichii + Castanopsis hystrix forest

The *Schima wallichii* + *Castanopsis hystrix* forest occurs mainly in Mengsong, in the west of the region. The upper tree layer is dominated by *Schima wallichii* (Theaceae) and *Castanopsis hystrix* (Fagaceae). The lower tree layer is composed of species from diverse families such as *Wendlandia tinctoria* (Rubiaceae), *Ardisia neriifolia* (Myrsinaceae), *Ormosia fordiana* (Papilionaceae) and *Symplocos yunnanensis* (Symplocaceae) (Table 15).

The shrub layer is 1–3 m tall and dominated by juvenile tree species. Shrub species, such as *Wikstroemia indica*, *Evodia lepta*, *Alchornea davidii*, *Eriosolena composita* and *Psychotria symplocifolia* were recorded. The herbaceous layer is quite developed and has a cover of 50%–60%. Common species are *Carex baccans*, *Microstegium* sp., *Strobilanthus* spp., *Smilax hypoglauca*, *Ophiopogon revolutus* and *Lophatherum gracile*. Common lianas are *Craspedolobium schochii*, *Mussaenda hossei*, *Embelia ribes* and *Smilax lanceolata*.

3.4.2 Schima wallichii + Lithocarpus fohaiensis forest

This forest occurs mainly in Caiyanghe in the north of the region. The upper tree layer is co-dominated by *Schima wallichii* and *Lithocarpus fohaiensis*. The lower tree layer is dominated by *Vaccinium exaristatum* (Table 16).

The understory is also composed mainly of juvenile tree species. Common shrub species are *Evodia lepta*, *Vernonia volkameriaefolia* and *Ardisia virens*. Common herbaceous species are *Carex baccans*, *Arthraxon lanceolatus*, *Sarcandra hainanensis*, *Alpinia blepharocalyx* and *Smilax hypoglauca*. The common liana plants are *Rourea minor*, *Craspedolobium schochii* and *Jasminum lanceolarium*.

Table 15 Importance values of tree species in *Schima wallichii + Castanopsis hystrix* forest
Location: Mengsong, Xishuangbanna
Elevation: 1,320–1,380 m
Area of plot: 5 (25 m×20 m)
Number of species (>5 cm DBH): 36
Number of individuals: 221

Species	RA	RD	RF	IVI
Schima wallichii	14.93	36.34	7.14	58.41
Castanopsis hystrix	15.38	23.90	5.71	44.99
Machilus tenuipilis	9.05	3.71	5.71	18.47
Castanopsis mekongensis	4.52	6.62	5.71	16.86
Anneslea fragrans	4.98	5.95	5.71	16.64
Betula alnoides	3.17	5.88	2.86	11.91
Lithocarpus truncatus	4.07	3.50	4.29	11.85
Wendlandia tinctoria	4.98	0.83	5.71	11.52
Ardisia neriifolia	4.07	4.25	2.86	11.18
Lindera metcalfiana var. *dictyophylla*	7.69	0.40	2.86	10.95
Gordonia chrysandra	4.07	1.55	4.29	9.91
Xanthophyllum siamense	1.81	1.80	4.29	7.89
Metadina trichotoma	2.26	0.58	4.29	7.13
Daphniphyllum majorum	2.71	0.87	1.43	5.02
Illicium micranthum	2.71	0.79	1.43	4.93
Michelia floribunda	1.81	0.11	2.86	4.78
Helicia nilagirica	0.91	0.18	2.86	3.94
Xanthophyllum yunnanense	0.91	0.12	2.86	3.88
Ormosia fordiana	0.91	0.06	2.86	3.82
Lithocarpus fenestratus	0.91	0.66	1.43	2.99
Pithesellobium clypearia	0.91	0.51	1.43	2.84
Elaeocarpus austroyunnanensis	0.45	0.68	1.43	2.56
Symplocos yunnanensis	0.91	0.05	1.43	2.38
Linociera ramiflora	0.45	0.17	1.43	2.05
Cyclobalanopsis myrsinaefolia	0.45	0.14	1.43	2.02

3.4.3 Castanopsis echinocarpa forest

The *Castanopsis echinocarpa* forest occurs mainly in the Nangong mountains in the southeast of the region.

The upper tree layer is strongly dominated by *Castanopsis echinocarpa*. The lower tree layer is dominated by Euphorbiaceae and Myrtaceae species such as *Aporusa yunnanensis*, *Glochidion lanceolarium*, *Syzygium cumini* and *Syzygium leptanthum* (Table 17).

The understory is composed mainly of juvenile tree species. A few shrub species were recorded. Common shrubs are *Vernonia parishii*, *Croton kongensis*, *Glochidion eriocarpum* and *Millettia pachycarpa*. The herbaceous layer is undeveloped with a cover of 10%–30%. Common species are *Smilax hypoglauca*, *Carex baccans* and *Polygonatum cirrhifolium*. The liana plants are dominated by *Craspedolobium schochii* and epiphytes are few.

Table 16 Importance values of tree species of *Schima wallichii* + *Lithocarpus fohaiensis* forest
Location: Caiyanghe, Simao
Elevation: 1,450–1,500 m
Area of plot: 5 (25m×20 m)
Number of species (>5 cm DBH): 26
Number of individuals: 380

Species	RA	RD	RF	IVI
Schima wallichii	3.95	17.75	6.52	28.22
Lithocarpus fohaiensis	13.42	9.26	5.43	28.12
Vaccinium exaristatum	14.21	5.41	5.43	25.05
Lithocarpus fenestratus	8.68	9.15	4.35	22.18
Machilus tenuipilis	8.16	2.74	5.43	16.33
Castanopsis hystrix	3.42	11.38	1.09	15.89
Castanopsis echinocarpa	5.53	4.85	3.26	13.64
Castanopsis ceratacantha	5.00	3.81	4.35	13.16
Castanopsis calathiformis	4.74	4.92	2.17	11.83
Anneslea fragrans	2.89	3.13	5.43	11.46
Ternstroemia gymnanthera	1.84	5.60	3.26	10.70
Betula alnoides	1.32	6.46	1.09	8.86
Helicia nilagirica	4.21	2.40	2.17	8.79
Wendlandia tinctoria	3.16	1.49	3.26	7.91
Litsea sp.	2.89	1.45	3.26	7.61
Symplocos yunnanensis	2.37	0.78	3.26	6.41
Engelhardtia roxburghiana	1.32	2.78	2.17	6.27
Tricalysia fruticosa	2.11	0.41	3.26	5.78
Diospyros kaki var. *sylvestris*	1.05	0.79	2.17	4.02
Michelia floribunda	1.05	0.11	2.17	3.33
Pygeum topengii	0.53	0.38	2.17	3.08
Decaspermum fruticosum	0.53	0.06	2.17	2.76
Millettia cubittii	0.26	1.30	1.09	2.65
Choerospondias axillaris	0.26	1.29	1.09	2.64

*1. Only species with an IVI over 2 are shown in the table.
RA: relative abundance; RD: relative dominance; RF: relative frequency: IVI: importance value index
Importance value index= Relative abundance + Relative dominance (Basal area) + Relative frequency

Table 17 Importance values of tree species of *Castanopsis echinocarpa* forest
Location: Nangong mountains, Xishuangbanna
Elevation: 1,170–1,200 m
Area of plot: 5 (25 m×20 m)
Number of species (>5 cm DBH): 26
Number of individuals: 474

Species	RA	RD	RF	IVI
Castanopsis echinocarpa	57.38	73.57	8.77	139.72
Schima wallichii	8.23	10.05	8.77	27.05
Castanopsis mekongensis	6.96	4.58	8.77	20.31
Syzygium leptanthum	5.27	2.21	8.77	16.26
Wendlandia tinctoria	5.70	1.56	8.77	16.03
Aporusa yunnanensis	4.43	0.88	7.02	12.33
Lithocarpus fenestratus	2.53	2.00	5.26	9.80
Glochidion lanceolarium	0.84	0.21	7.02	8.07
Sapium baccatum	1.90	1.93	3.51	7.34
Metadina trichotoma	0.84	0.14	3.51	4.49
Cylindrokelupha yunnanensis	0.42	0.09	3.51	4.02
Vaccinium exaristatum	1.05	0.26	1.75	3.07
Winchia calophylla	0.42	0.72	1.75	2.89
Millettia pulchra var. *yunnanensis*	0.63	0.38	1.75	2.76
Cratoxylon cochinchinense	0.84	0.11	1.75	2.71
Machilus rufipes	0.42	0.11	1.75	2.29
Syzygium cumini	0.21	0.26	1.75	2.23
Choerospondias axillaries	0.21	0.26	1.75	2.22
Elaeocarpus austroyunnanensis	0.21	0.18	1.75	2.14
Engelhardtia colebrookeana	0.21	0.13	1.75	2.09
Canarium album	0.21	0.12	1.75	2.08
Horsfieldia glabra	0.21	0.07	1.75	2.03
Diospyros kaki var. *sylvestris*	0.21	0.06	1.75	2.03
Millettia leptobotrya	0.21	0.04	1.75	2.01
Phyllanthus emblica	0.21	0.04	1.75	2.01
Cylindrokelupha delatensis	0.21	0.04	1.75	2.00

4 Conclusions and discussion

Based on physiognomic and ecological characteristics, floristic composition and habitat combined, the primary vegetation of Xishuangbanna can be classified into four main vegetation types, i.e. tropical rain forests, tropical seasonal moist forests, tropical montane evergreen broad-leaved forests and tropical monsoon forests, including two vegetation sub-types, four formation groups and eighteen formations.

The tropical rain forest in Xishuangbanna was classified into two subtypes, i.e. a tropical seasonal rain forest in the lowlands and a tropical montane rain forest at higher elevations.

The tropical seasonal rain forest has almost the same forest profile and physiognomic characteristics

as equatorial lowland rain forests. It is undoubtedly a type of truly tropical rain forest. Since the tropical seasonal rain forest in Xishuangbanna occurs at the extreme condition of rainfall and temperature usually required by tropical rain forest, it differs from lowland rain forests in equatorial areas by having some deciduous trees in the canopy layer, fewer megaphanerophytes and epiphytes but more abundant lianas as well as more plants with microphylls. It is believed that these differences are a result of the slight seasonal dryness as well as the relatively low temperature found at this relatively high latitude and elevation. The tropical seasonal rain forest is a type of semi-evergreen rain forest from the northern edge of the tropical zone.

The tropical montane rain forest occurs at wet montane habitats between 900–1,800 m in the region. It is physiognomically dominated by evergreen mesophanerophytes and microphanerophytes with simple, leathery and entire mesophyllous leaves and characterized by having more or less frequent woody lianas and abundant epiphytes, abundant herbaceous phanerophytes but few buttresses and cauliflory. The montane rain forest is dominated, in terms of species richness, by the families Lauraceae, Euphorbiaceae, Fagaceae, Papilionaceae, Rubiaceae and Theaceae. In terms of phytosociological importance, the dominant families are Lauraceae, Magnoliaceae, Euphorbiaceae, Fagaceae, Mastixiaceae and Nyssaceae. Compared with the seasonal rain forest of the region, the montane rain forest has less abundant megaphanerophytes and large woody lianas, but more abundant micro and nanophanerophytes, herbaceous phanerophytes and more plants with simple, leathery and non-entire and microphyllous leaves.

The tropical montane rain forest in Xishuangbanna is largely similar to the lower montane rain forest in equatorial Asia, which was included under the category of tropical rain forest by Whitmore (1990). We agree with Whitmore's classification and consider the tropical montane rain forest in Xishuangbanna a type of lower montane rain forest within the broader category of tropical rain forest (here a sub-type of the tropical rain forest in the region).

The tropical seasonal moist forest occurs on middle and upper limestone slopes. It was called monsoon forest by some Chinese authors. The term seasonal moist forest is preferred here because the forest is not equivalent to Schimper's monsoon forest (Schimper 1903), despite the fact that it is affected by seasonal dryness and contains a variable percentage of deciduous trees. It is also different from the tropical montane evergreen broad-leaved forest in the region in floristic composition. The seasonal moist forest is physiognomically dominated by evergreen mesophanerophytes and microphanerophytes with simple, leathery and entire mesophyllous leaves and has frequent woody lianas. Compared with the seasonal rain forest of the region, the seasonal moist forest has less abundant megaphanerophytes, but more abundant herbaceous chamephytes and more plants with compound, leathery leaves. This limestone forest, which abuts the seasonal rain forest on lower slopes and at limestone valleys, is a vegetation type on limestone at higher elevations in southern Yunnan.

The monsoon forest of Xishuangbanna is a tropical deciduous forest under the influence of a strong monsoon climate in southern Yunnan. It has often a mosaic distribution with the seasonal rain forest. The monsoon forest is considered to be a transitional vegetation type between the tropical rain forest and savanna in physiognomy and distribution.

The tropical montane evergreen broad-leaved forest is the main montane vegetation type in Xishuangbanna. It is usually distributed on mountain slopes and summits above 1,000 m elevation and valleys above 1,300 m. The forest is dominated largely by the families Fagaceae, Euphorbiaceae, Theaceae and Lauraceae. Physiognomically, the forest is characterized by abundant trees with mesophyllous leaves and leathery leaves. The term "monsoon evergreen broad-leaved forest" was used for this forest type by some Chinese authors. However, the name "monsoon forest" is widely used for deciduous forest in the strong monsoon climate of SE Asia. This forest in Xishuangbanna is evidently not a monsoon forest of the same type as in SE Asia because it is an evergreen forest. They are also different from tropical lower montane rain forests in equatorial SE Asia due to a lack of epiphytes and in having more abundant lianas and plants with compound leaves. The tropical montane evergreen broad-leaved forests in southern Yunnan, which occur in relatively dry montane habitats and are influenced by strong seasonal dryness, cannot be suitably classified in either the lower montane rain forest as in equatorial southeastern Asia or in the tropical montane rain forest occurring in wet valleys in southern Yunnan. It is better to treat these tropical montane evergreen broad-leaved forests as a distinct vegetation type at the northern margin of mainland southeastern Asia, controlled by strong seasonal climate based on their floristic and physiognomic characteristics.

Compared with tropical seasonal rain forests at lower altitudes in the region, the tropical montane evergreen broad-leaved forest has fewer epiphytes, fewer mega-mesophanerophytes, fewer plants with compound leaves, but more abundant micro-nanophanerophytes and hemicryptophytes, more plants with microphyllous leaves and more plants with entire leaf margins.

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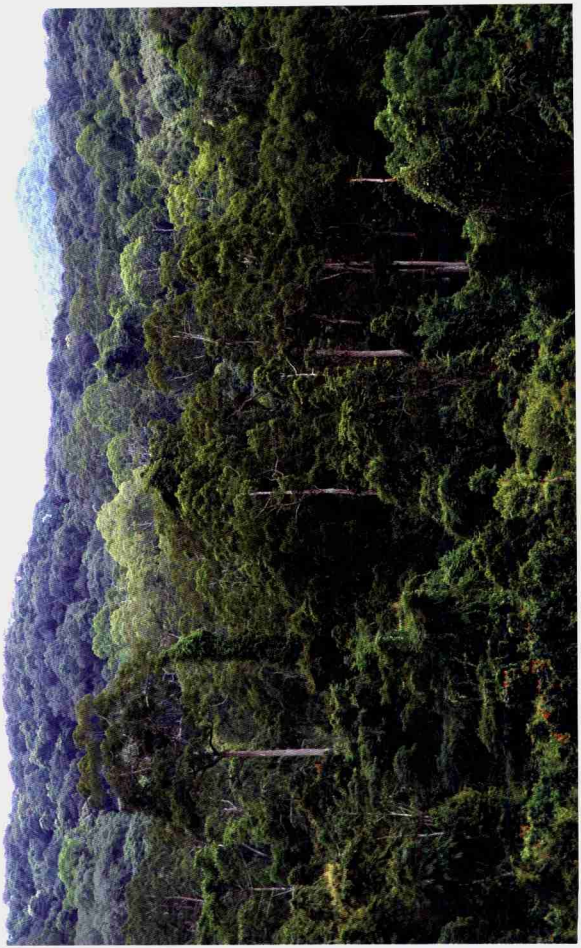
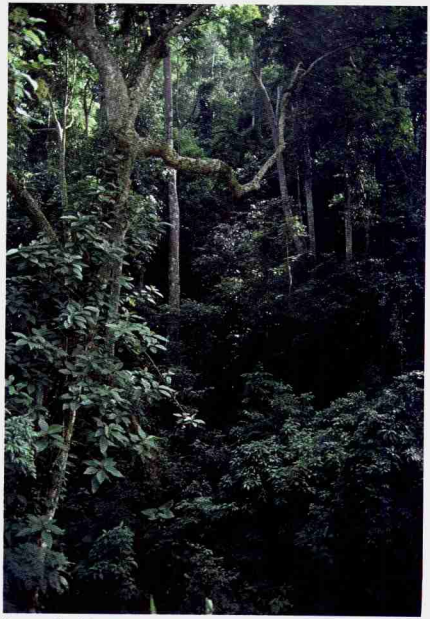


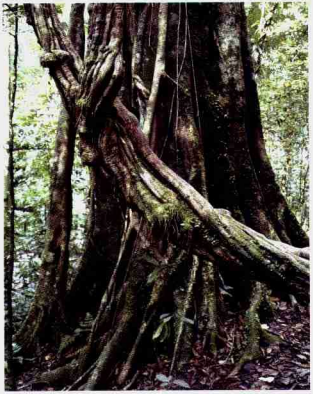
Physiognomy of the tropical rain forest in Xishuangbanna

Overlook of the tropical rain forest in Xishuangbanna



Forest profile of the ravine seasonal rain forest

Buttress — *Tetrameles nudiflora* in the ravine seasonal rain forest



Huge woody liana — *Ventilago calyculata*

The dominant tree species of *Terminalia myriocarpa* in the ravine seasonal rain forest

The dominant tree species of *Pometia tomentosa* in the ravine seasonal rain forest

Inside of tropical ravine seasonal rain forest

Understory of tropical ravine seasonal rain forest

Frequent understory species *Pittosporopsis kerrii*

Big woody liana — *Tetrastigma planicaulum*

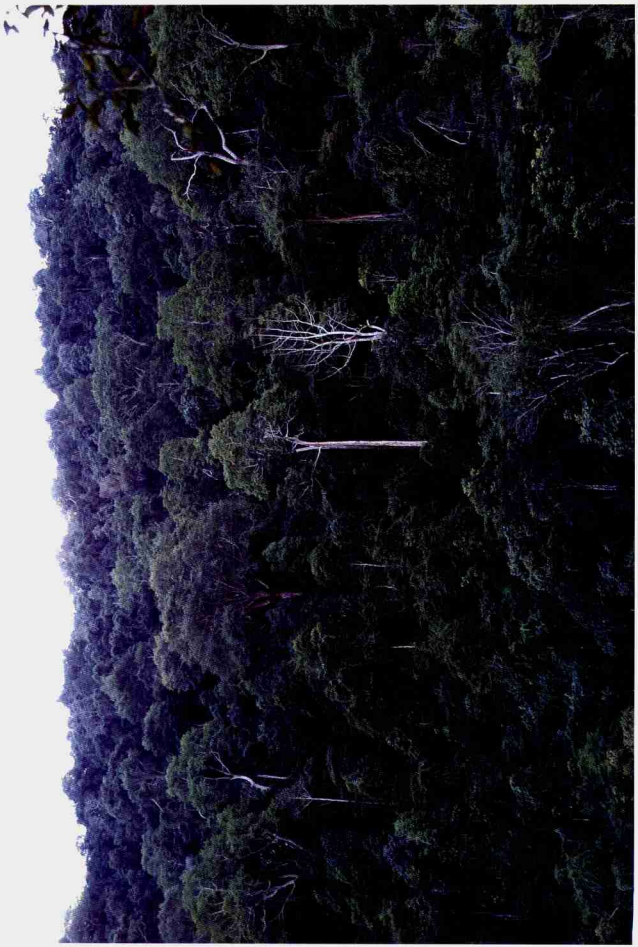
Big woody liana — *Tinomiscum tonkinensis*

Strangler plant in the ravine seasonal rain forest

Dominant herbaceous plant *Phrynium capitatum* in the ravine seasonal rain forest

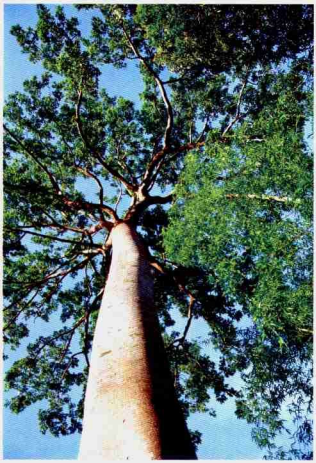
Frequent epiphytic plant *Neottopteris nidus*

Frequent epiphytic plant *Rhaphidophora hongkongensi*



Lower hill seasonal rain forest

Understory of lower hill seasonal rain forest



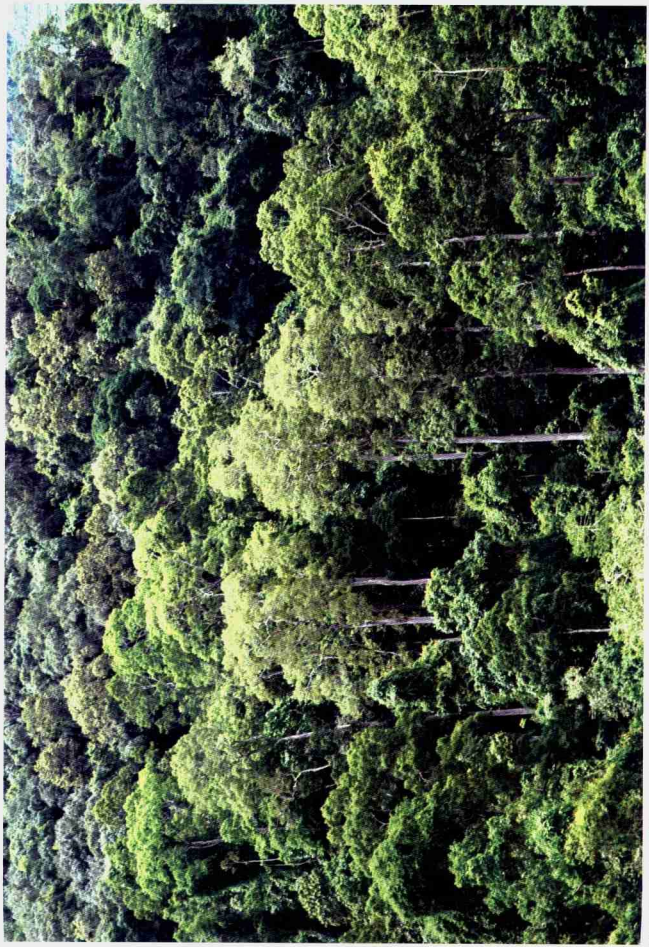
Dominant tree species *Antiaris toxicaria* in the lower hill seasonal rain forest

Big woody liana in the lower hill seasonal rain forest

Frequent herbaceous plant *Rhynchotechum obovatum*

Frequent herbaceous plant *Elatostema* spp.

Frequent epiphytic plant *Rhaphidophora megaphylla*



Dipterocarp rain forest (*Shorea wantianshuea* forest)

Dominant tree species *Shorea wantianshuea* in the dipterocarp rain forest

Fruits of *Shorea wantianshuea*

Frequent tree species *Pseuduvaria indochinensis* in the dipterocarp rain forest

Profile of the dipterocarp rain forest

Big woody lianas in the dipterocarp rain forest

Epiphytic plants in the dipterocarp rain forest

Frequent herbaceous plant *Phlogacanthus curviflorus* in the dipterocarp rain forest

Frequent herbaceous plant *Acanthus leucostachyus* in the dipterocarp rain forest

Tropical seasonal rain forest on limestone

Profile of the tropical seasonal rain forest on limestone

Huge trees in the tropical seasonal rain forest on limestone

Inside of the tropical seasonal rain forest on limestone

Tropical seasonal evergreen moist forest on limestone

The characteristic species *Celtis philippensis* var. *wightii*, exclusive to limestone

Profile of the tropical seasonal evergreen moist forest on limestone

Dominant tree species *Lasiococca comberi* var. *pseudoverticillata* in the tropical seasonal evergreen moist forest on limestone

Understory of the tropical seasonal evergreen moist forest on limestone

Stilt roots in the forest on limestone

Frequent herbaceous plant *Erathemum pulchellum* in limestone forest

Frequent herbaceous plant *Colebrookea oppositifolia* in limestone forest

Elatostema salvinoides exclusive to limestone

Tropical seasonal semi-evergreen moist forest on limestone

Physiognomy of the tropical seasonal semi-evergreen moist forest on limestone

Osmanthus polyneurus-Dracaena cochinchinensis forest on limestone

Dracaena cochinchinensis forest on limestone summit

Frequent herbaceous plant *Paraboea rufescens* on limestone

Andrographis laxiflora var. *glomeruliflora*, exclusive to limestone

Frequent species *Agapetes burmanica* on limestone summit

Tropical montane evergreen broad-leaved forest

Profile of the tropical montane evergreen broad-leaved forest

Oak trees in the tropical montane evergreen broad-leaved forest

Understory of the tropical montane evergreen broad-leaved forest

Woody liana in the tropical montane evergreen broad-leaved forest

Schefflera octophylla in the tropical montane evergreen broad-leaved forest

Chloranthus holotegius in the tropical montane evergreen broad-leaved forest

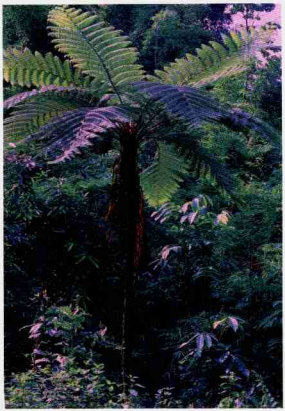
Frequent herbaceous plant *Sonerila tenera* in the tropical montane evergreen broad-leaved forest

Tropical montane rain forest

Profile of the tropical montane rain forest

Lianas in the tropical montane rain forest

Frequent tree species *Phoebe megacalyx* in the tropical montane rain forest



Tree fern in the tropical montane rain forest

Tree species of *Alstonia scholaris* in the tropical montane rain forest

Brassaiopsis palmipes in the tropical montane rain forest

Bombax ceiba forest

Flowers of *Bombax ceiba*

Pterocarya tonkinensis forest

Anogeissus acuminata forest

Lannea coromandelica + *Sterculia pexa* forest

Deciduous tree species *Mayodendron igneum* in monsoon forest

Deciduous tree species *Erythrina stricta* in monsoon forest

Frequent tree species *Phyllanthus emblica* in monsoon forest

Congea tomentosa

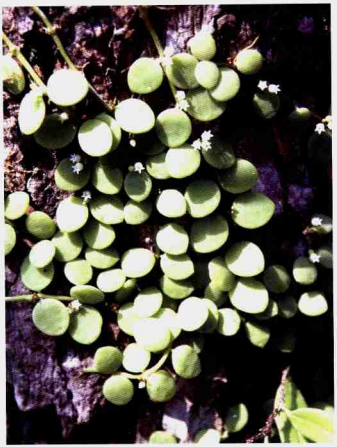
Balanophora harlandii

Caryota ochlandra

Tacca chantrieri

Beaumontia grandiflora

Quisqualia indica



Epiphytic plant *Dischidia mino*

Barringtonia macrostachya

Selaginella picta

Alocasia macrorrhizos with large leaves

Cauliflory plant—*Ficus auriculata*

Costus speciosus

Alocasia bicolor in limestone forest

Cycas simplicipinna

The rare and endangered plant *Zippelia begoniaefolia* in the dipterocarp rain forest

Abelmoschus crinitus

Hodgsonia macrocarp

Chesalia curviflora

Stixis suaviolens

Thunbergia grandiflora

Aglaonema pierreanum

Tetracera xui

Liana species *Cissus javana*

Liana species *Mucuna interrupta*

The rare and endangered plant *Quisqualis caudata*

Polygonatum cirrhifolium

Eulophia nuda

Vanda brunnea

Survey in the tropical rain forest of Xishuangbanna

Canopy walk-way in the dipterocarp rain forest in Mengla County