Bull. Inst. Environ. Sci. Technol. Yokohama Natn. Univ. 17 : 85−105 (1991)

Diversity and Dissimilarity of Three Forest Types in Xishuangbanna, Tropical Southern China [1)]

中国南部西双版納の熱帯における3森林タイプの多様性と相違点

Elgene O. Box,[2)] Kazue Fujiwara,[3)] and Qiu Xue-Zhong[4)]

エルジン O. ボックス・藤原　一繪・邸　学忠

Synopsis

Xishuangbanna is the southernmost, tropical part of Yunnan Province in southwestern China. It is characterized by a tropical monsoonal climate and vegetation ranging from tropical seasonal evergreen forests to tropical "laurel" forests above about 1000 - 1200 m in the mountains. Three forest types were sampled and are described in terms of composition and structure: a tropical seasonal evergreen forest at 700 m, a montane *Castanopsis* "laurel" forest at 1070 m, and a forest on limestone. Although all in the same general area, the three forests were completely different, with only one tree species occurring in even two of the thre e forests. The genera in the three forests are characteristic of their respective bioclimatic zones in East Asia. The boundary between lowland tropical and montane Fagaceae forest, involving changes in temperature and water balance, also corresponds to that found in other mountains of Southeast Asia but seems unusually low and/or abrupt in this area, raising questions of zonation mechanisms.

Introduction

Xishuangbanna, the lowland southernmost part of Yunnan province of southwestern China (see Figure 1), lies on the northern edge of the tropics, just south of the descending Yunnan Plateau, bordering Burma, Laos and Vietnam. With its Dai (cf. Thai) an many other local nationalities, Xishuangbanna is quite different culturally as well as physiographically from the rest of Yunnan and the rest of China. From the north, the Yunnan Plateau (with elevations generally between 1500 and 2000 m) drops off to elevations of 500 - 1000 m for most of Xishuangbanna, resulting in a somewhat sharper transition than otherwise between the subtropical and even warm - temperate zones to the north and the beginning of the upland tropical region to the south. Simao, the gateway to Xishuangbanna, is still subtropical, but tropical species and landscapes appear soon to the south, extend to the east along the Laotian and Vietnamese borders, and curve northward in the west, along the Burmese border, to about 25° N

1) Contribution from the Department of Vegetation Science, Institute of Environmental Science and Technology, Yokohama National University, No. 211.

2) University of Georgia, Geography Department and Institute of Ecology, Athens, Georgia 30602, USA.

3) Yokohama National University, Institute of Environmental Science and Technology, Yokohama 240, Japan.

4) Kunming Institute of Ecology, Academia Sinica, 25 East Jiaochang Road, Kunming, Yunnan, People's Republic of China.

(Accepted Dec.1. 1990.)

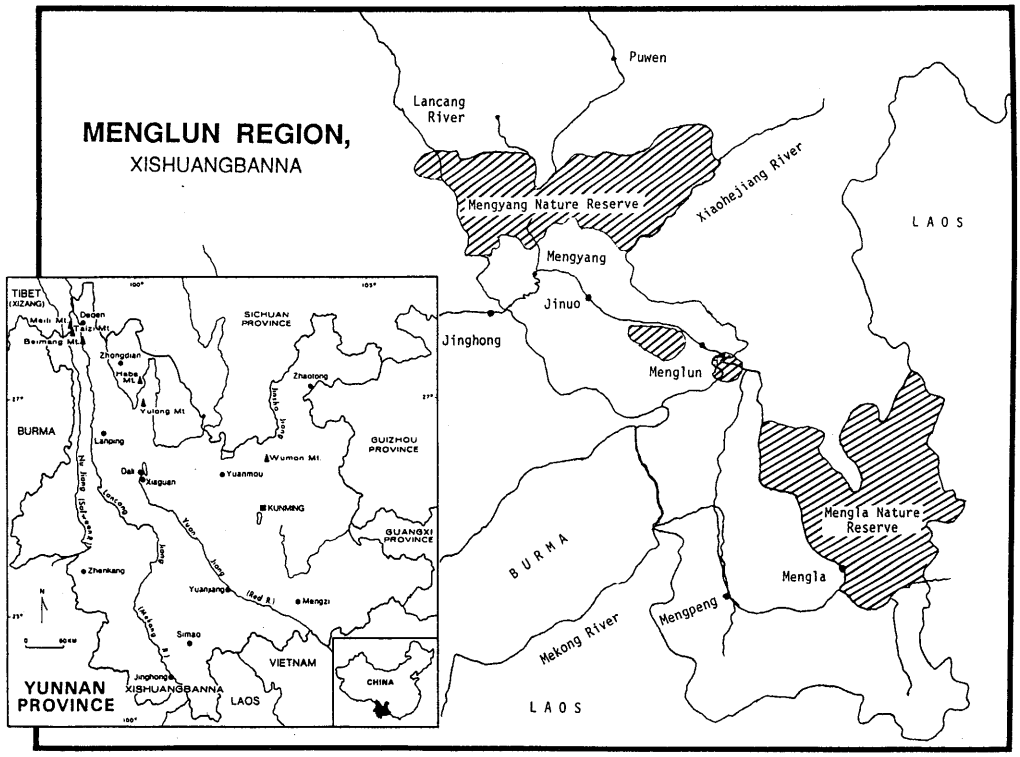

Figure 1. The Menglun Region of Xishuangbanna, southernmost Yunnan Province. Menglun is located near a loop in the Luosuojiang (Xiaohejiang) River, on the highway from Mengyang to Mengla (southernmost Xishuangbanna). Most of the land between rivers is mountainous (see topographic map by Urushibara-Yoshino and Nagatsuka 1989 but note that "Mengla" is in fact Menglun). The Menglun Nature Reserve has two sections (diagonal pattern), including the Man-Ka mountain area northwest of Menglun and the limestone area southeast of Menglun. Larger nature reserves are also shown, near Mengyang (mainly montane forest) and near Mengla (seasonal rain forest) (Yunnan University 1960).

latitude. This region along the Burmese-Yunnan border shows some of the highest values of satellite-sensed surface greenness (AVHRR "greenness index", Box et al. 1989a) and represents perhaps the most northward extension of tropical rainforest in the Northern Hemisphere. The botanical and biogeographical significance of Xishuangbanna, and indeed of Yunnan itself, has long been appreciated (e.g. Brandis 1895, Handel-Mazzetti 1921, Merrill 1923, Wilson 1931, Wang 1939, Jiang 1980).

For studies of both natural vegetation and potential crop species, the Tropical Botanical Garden at Menglun has served for many years as a base of operations and as an experiment station for introductions of new species into the region. Menglun is also centrally located relative to the four long-standing nature conservation areas in Xishuangbanna, namely Da Menglung (near the Burmese border), Mengyang, Menglun, and Mengla (see Figure 1). The area around Menglun contains a variety of landscapes

and vegetation types, ranging from the agricultural Jinghong Basin to the various montane belts (cf. Xu et al. 1989, Urushibara and Nagatsuka 1989, Yoshino 1989). Four main forest types are well represented: seasonal evergreen forest, montane evergreen broad-leaved forest, valley rainforest, and forests on limestone. These forest types are described in an early conservation report (Yunnan Univ. 1960), by Zhu et al. (1986, 1987), and to some extent, in English, by Wang (1961).

Our short time in Xishuangbanna permitted description of only three of the four forest types, all at sites within 30 km of Menglun. The three forests studied were almost totally different in their composition. The purpose of this paper is to present the composition and structure of these forests and attempt an initial understanding of their dynamic status and biogeographic position.

Regional Climate and Vegetation

The study areas around Menglun and other locations are shown in Figure 1. Jinghong, the largest town, is at about 550 m elevation in the center of the Jinghong Basin, reached by road from Simao to the north. The Lancang (Mekong) River runs through the basin and on southeastward into Laos and eventually Vietnam. Mengla is at about 640 m in the hills along the Laotian border in extreme southern Xishuangbanna. The climate of the somewhat drier Jinghong Basin is shown by the climate diagram in Figure 2, which represents the monsoon seasonality for the whole region. Precipitation increases to the southeast, though, from the 1200 mm at Jinghong to over 1500 mm at Mengla (Zhu et al., 1986). The climate diagram shows the high rainfall in summer and significant dry season in winter, with pleasant winter temperatures but significant evapotranspiration. This seasonality and the winter dry season are somewhat more extreme than in comparable areas of southeastern China, closer to the coast. Light frost may occur in winter at Simao (to -1.7° C) and at Mengla (to -0.5° C). Frost does not occur at Menglun or throughout lowland Xishuangbanna, but temperature inversions, with near-freezing temperatures and fog, are common in winter (Nomoto et al. 1989, cf. Yasunari and Tian 1989, Yoshino 1989).

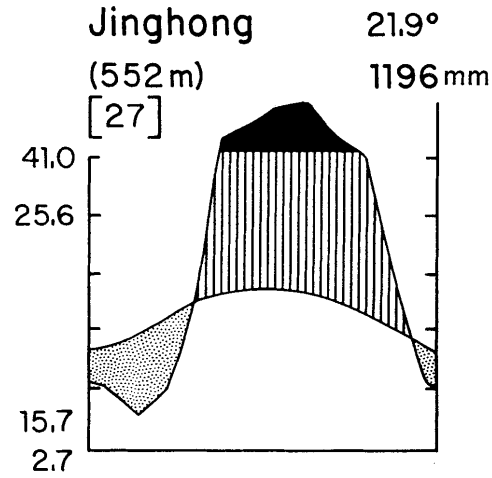

Figure 2. Climate Diagram of Jinghong, the Regional Center of the Jinghong Basin of Xishuangbanna.

The main, general vegetation types of Xishuangbanna (mainly forest types) are shown in Table 1, as recognized in the main vegetation description for Yunnan, the "Vegetation of Yunnan" (Zhu et al. 1987). Perhumid tropical rainforests remained (as of 1981, "Yunnan Vegetation Map" 1987) only along the Yuanjiang (Vietnamese Red) River valley near the Vietnamese border, while "seasonal rainforests" are shown as occurring mainly in upland areas of southernmost Xishuangbanna (mainly *Terminalia-Pometia* type), with a small area of the *Shorea-Dipterocarpus* type along the Burmese border at almost 25° N (see also Wang et al. 1985, Makita and Chujo 1989). The montane rainforest types are shown mainly in southeastern Yunnan (Yuanjiang and Guangxi border areas), while more seasonal semi-evergreen forests (especially *Ficus-Chukrasia* type) and raingreen deciduous forests (especially *Bombax-Albizia* types) are shown in southern Xishuangbanna and along the border with Burma (to almost 25° N). Areas above about 1000-1200 m are covered by evergreen broad-leaved forests (plus degradation stages) and conifer forests (mainly *Pinus kesiya* var. *langbianensis* to the north and *P. yunnanensis* in the south). There are also large agricultural areas and large areas of savanna, plus "economic forests" (tree plantations). Special sclerophyll (*Quercus*) forests and xeric scrub occur in some hot, dry river valleys, but these are mainly to the north on the escarpment. Some large areas of bamboo forest are shown in southernmost Xishuangbanna.

Study Sites

Menglun itself is on the Luosuo River (a tributary of the Lancang) at about 540 m elevation but separated from the Jinghong Basin by low mountains reaching over 1000 m in elevation. Two of the study sites were in this mountain area, near Man-Ka village, while the other site was on limestone in a small conservation area south of Menglun. A preliminary description of these conservation areas is given in "A Survey of Plant Communities of the Nature Conservation Stations in the Tropical and Subtropical Regions of Yunnan Province, China" (Yunnan University 1960), prepared for the Yunnan provincial government.

Climatic characteristics for Simao, Jinghong, and Mengla are summarized in Table 2. From these data the climatic conditions at Menglun and the study sites are estimated, based on normal temperature lapse rates and the precipitation map by Zhu et al. (1986). Temperatures at Menglun may be more or less similar to those at Jinghong, but the greater precipitation gives Menglun a more favorable water balance, even in the lowland. Nevertheless, there is still a dry season of 3-4 months in late winter to early spring, during which time the climatic water deficit must be met by water reserves in the soil. This results in significant differences in moisture stress between deeper and shallower soils. The two sites on Man-Ka mountain are separated by several kilometers but are both on a more or less north-facing slope and differ in elevation by less than 400 meters, one at about 700 m and the other at about 1070 m. The other site, on limestone, is at about the same elevation as Menglun and has similar macroclimatic conditions.

Table 1. Main Vegetation Types of Xishuangbanna.

The vegetation types are summarized from the "Vegetation of Yunnan" (Zhu et al. 1987), which describes vegetation types for all of Yunnan. Names of vegetation types are direct translations from the Chinese as far as possible and generally correspond to English type names. Seasonal rainforest (季節雨林), though, occurs with a short but significant dry season, contains fewer epiphytes and lianas, and is thus usually called 'tropical seasonal evergreen forest' in English, rather than rainforest. Seasonal forests (Chinese: seasonal rain forests, 季雨林), on the other hand, are at most only semi - evergreen, due to stronger seasonality of the rainfall.

Tropical Evergreen Forests
- Perhumid Rainforest: *Dipterocarpus, Hopea, Crypteronia*, etc.
- Seasonal Rainforest (=tropical seasonal evergreen forest)
  - *Shorea - Dipterocarpus* (with *Arenga* understorey)
  - *Antiaris - Pouteria - Canarium* (with *Gironniera, Garcinia*, etc.)
  - *Terminalia - Pometia* (with *Knema, Garcinia, Epiprinus*, etc.)
  - *Parashorea chinensis* (with *Myristica, Barringtonia*, etc.)
- Montane Rainforest
  - *Alstonia - Paramichelia* (with *Castanopsis, Actinodaphne*, etc.)
  - *Dysoxylon - Semecarpus - Phoebe* (with *Xanthophyllum, Schima, Calophyllum*)
  - *Madhuca - Altingia* (with *Semecarpus*)
  - *Manglietia wangii* (with *Ficus* etc.)

Seasonal Forests ("seasonal rain forests")
- Semi - Evergreen Seasonal Forests
  - *Ficus - Chukrasia* (with *Saraca, Dimocarpus*, etc.)
  - *Mesua ferrea* (with *Mangifera, Knema, Ficus, Mallotus, Castanopsis*)
  - *Cassia siamea* (with *Microcos, Mallotus*, etc.)
- Raingreen Forests ("deciduous seasonal rain forests")
  - *Bombax - Albizia* (with *Lysidice, Garuga, Erythrina, Michelia, Dysoxylon*)
  - *Terminalia - Erythrina* (with *Tetrameles, Sapium, Ulmus*, etc.)
  - *Protium - Castanopsis* (with *Gmelina, Dillenia, Aporusa*)
  - *Pterocarya tonkinensis, Tectona grandis*, and *Bauhinia variegata* types
- Limestone Forests: *Tetrameles - Garuga - Ulmus* (with *Cleistanthus, Celtis*, etc.)

Evergreen Broad - Leaved Forests
- Monsoonal Evergreen Broad - Leaved Forests
  (*Castanopsis - Lithocarpus, Persea - Castanopsis, Quercus-Podocarpus*, and *Cyclobalanopsis - Manglietia* types)
- Semi-Moist Evergreen Broad - Leaved Forests
  (*Cyclobalanopsis* and *Castanopsis* types)
- Mid-Montane Mesic Evergreen Broad - Leaved Forests
  (*Lithocarpus, Castanopsis, Cyclobalanopsis*, Lauraceae, etc.)
- Upper-Montane Mossy Forests (*Rhodoleia, Persea, Lithocarpus*, etc.)
- Summit Mossy Dwarf - Forests (elfin woodlands): *Rhododendron, Lithocarpus*, etc.

Evergreen Sclerophyll Forests
- (*Quercus* spp., etc., in hot dry river valleys)
- Needle - Leaved Forests
  (mainly *Pinus kesiya* var. *langbianensis*, also *Calocedrus macrolepis*)
- Bamboo Forests
  (*Dendrocalamus strictus, Bambusa sinospinosa, Lingnania chungii* types)
- Savannas
  - Hot (lowland) areas: medium and tall - grass types with *Bombax, Ficus*, etc.
  - Warm (Low - montane): short, medium, and tall - grass types with *Pinus*, etc.
- Shrublands and Scrub
  - Hot Xeric River - Valley Scrub (*Sophora, Cotinus, Vitex, Desmodium*, etc.)
  - Warm - climate Limestone Scrub (*Myrsine, Rosa, Zanthoxylon*, etc.)
  - Hot Riparian Sand Scrub (*Homonoia riparia*)

Table 2. Climatic Data in Xishuangbanna and Projected Conditions for Menglun and the Relevé Sites.

		Temperatures							Water Balance (annual)			
Location	Zone	Lat.	Elev.	annual	warmest month	coldest month	annual min.	abs. min.	Precip.	PET	MI	Deficit
Simao	transition	22.8	1302	17.7°	21.7°	13.1°	0.9°	−1.7°	1548	1043	1.48	51
Jinghong	tropical	21.9	552	21.7°	25.6°	15.5°	5.7°	2.7°	1197	1283	0.93	148
Mengla	tropical	21.5	639	20.9°	24.6°	15.2°	5.6°	−0.5°	1532	1234	1.24	81
Projected values for Menglun and vicinity:												
Menglun	tropical	21.8	540	20.9°	25.0°	15.2°	5.6°	2.6°	~1500	1230	~1.2	86
Man - Ka	colline	21.9	700	20.2°	24.2°	14.8°	5.2°	2.3°	~1600	1190	~1.3	65
	montane	21.9	1070	17.7°	21.7°	13.6°	4.0°	1.0°	> 1600	1040	> 1.5	60

The long-term average temperatures (annual, warmest and coldest months, annual minimum) and the annual precipitation values for Simao, Jinghong, and Mengla are from "Yunnan Forests" (Zhu & Committee 1986, pp. 15, 21). Absolute minimum temperatures are from Wu (1980) for Simao, Jiang (1988) for Jinghong, and from Wang et al. (1986) for Mengla, probably based on different periods of measurement. Potential evapotranspiration (PET) is estimated by the Holdridge (1959) method. The moisture balance (MI) is annual precipitation divided by annual PET, and climatic water deficit is estimated by standard water-budget methodology (based on Thornthwaite 1957). Menglun lies roughly halfway between Jinghong and Mengla, and Man-Ka mountain is 20-30 km north of Menglun. The annual precipitation (1500 mm) at Menglun was suggested by the map of Zhu & Committee (1986, p. 14). All other climatic values for Menglun and Man-Ka are projected using estimated lapse rates (based on Zhu et al. 1984, cf. Yoshino 1989).

The significance of just a few hundred meters of elevation in tropical mountains can be seen clearly in the moisture-balance estimates for these two Man-Ka sites. The boundary between tropical lowland and montane lucidophyllous forest involves changes in both temperature and water balance, and seems to occur near an annual moisture-index value of about 1.4 (see Table 2; cf. Box et al. 1989b, and Box, in press). In Yunnan this boundary generally occurs between about 1000m and 1200m elevation (Zhu et al. 1986, 1987; Jiang 1980; Wang et al. 1985; Jin 1979, 1983). This corresponds roughly with vertical zonation in other parts of tropical Asia (cf. Whitmore 1984).

The three forests were sampled by the Braun-Blanquet method (Braun-Blanquet 1964; see Fujiwara 1987 or Westhoff & van der Maarel 1973), which gives a complete description of stand composition and structure. No quantitative calculations are necessary in the field, making this method relatively rapid and suitable for wide-ranging, comparative geographic work. Species were identified by Qiu, Wu, and Zhang, based partly on earlier work in the area. Species names follow Yunnan Institute (1984).

The Seasonal Evergreen Forest at Man-Ka

A fairly extensive area of seasonal evergreen forest on a steep north-facing slope

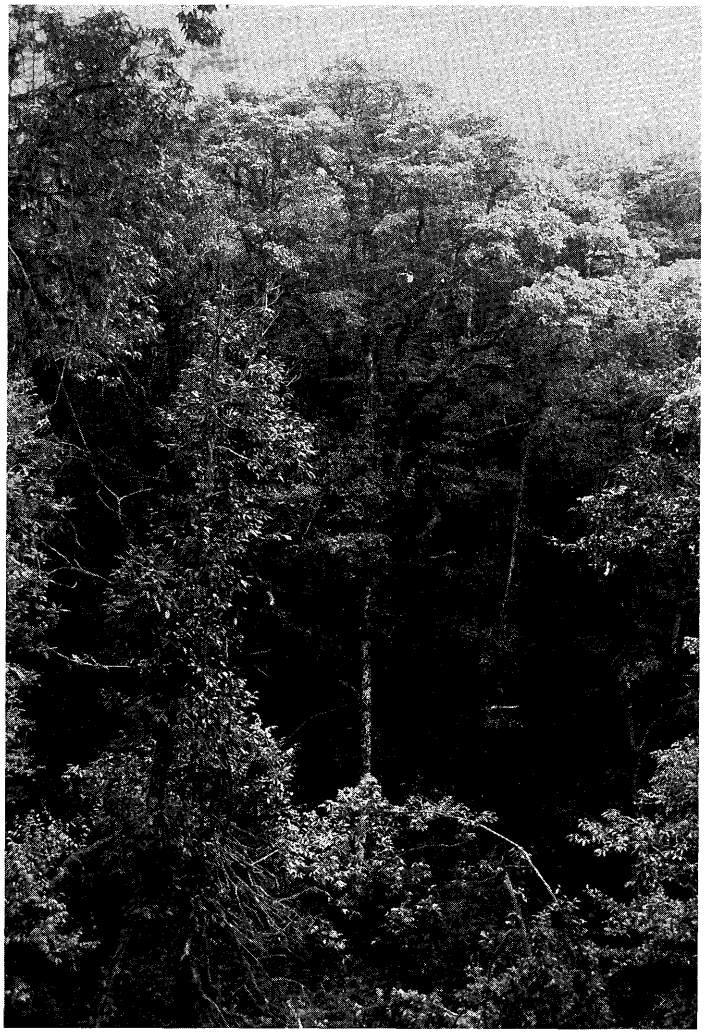

Figure 3. The Seasonal Evergreen Forest at 700 m Elevation on a 40° Slope at Man-Ka Mountain.

near Man-Ka, just off the Xiaolun Highway 20 km north of Menglun, provided an opportunity to study this forest type. The exact site is well studied by the Chinese authors, who have data for the numbers, dimensions, and life form of the individual trees (unpublished). The forest (Figure 3) occurs on a roughly 40° slope and has a canopy height of about 40 m. Five strata could be recognized, as in many tropical forests (e.g. Richards 1952, Whitmore 1984), but the two "shrub" layers, at 6 and 2 meters, are a bit lower than in most tropical rainforests. The composition and structure of the forest are shown in Table 3, as represented by a Braun-Blanquet relevé slightly rewritten to emphasize the different plant growth forms. The overstorey cover, at 75%, is a bit lower than in typical East Asian evergreen broad-leaved forests, but the understoreys all show consequently greater development, all with at least 40% cover.

Table 3. Relevé Sample of "Seasonal Evergreen Forest" at Man - Ka Mountain forest inventory site (about 750 m).

T_1	40m	75%	10 Nov. 1988
T_2	15m	45%	Elevation 750m
S_1	6 m	40%	Slope 40° to N
S_2	2 m	40%	30 x 20 m
H	1 m	50%	KF, Qiu, Wu, Zhang, EB

T_1: 3 • 3 *Polyalthia cheliensis* (Annonac.)(DBH 70cm)
3 • 2 *Amoora* (=*Aglaia*) *dasyclada* (Meliac.)(57cm)(EG)
2 • 2 *Pometia tomentosa* (Sapindac.)(2 m buttress)(EG)
2 • 1 *Machilus* (=*Persea*) *melanophylla* (80cm)(EG)
1 • 1 *Knema erratica* (Myristicac.)
1 • 1 *Gironniera subaequalis* (Ulmac.)(EG)(40cm)
1 • 1 *Polyalthia* sp$_2$. (47cm)

lianas: 1 • 2 *Bauhinia genuflexa* (Leg.)(20cm diam., on ground)
\+ *Cocculus laurifolia* (Menispermac.)(4 cm)
vine: 1 • 2 *Piper flaviflorum* (5 cm)

T_2: 2 • 2 *Gironniera subaequalis* (T_1)
2 • 2 *Pometia tomentosa* (T_1)
2 • 2 *Garcinia cowa* (Guttif.)
2 • 2 *Barringtonia pendula* (Lecythidac.)
1 • 2 *Lasiococca comberi* var. *pseudoverticillata* (Euphorb.)
1 • 1 *Pouteria grandifolia* (Sapotac.)
1 • 1 *Knema furfuracea* (35cm)
1 • 1 *Myristica yunnanensis*
\+ *Polyalthia cheliensis* (T_1)
\+ *Baccaurea ramiflora* (Euphorb.)
\+ *Trigonostemon thyrsoideum* (Euphorb.)
\+ *Chisocheton siamense*(Meliac.)
\+ *Sumbaviopsis albicans* (Euphorb.)
\+ *Tarenna sylvestris* (Rubiac.)

lianas: 1 • 2 *Combretum yunnanensis* (Combretac.)
\+ *Strychnos nitida* (Loganiac.)
\+ *Byttneria grandifolia* (Sterculiac.)(30m horizontally)
epiphyte: + Orchidae sp. (*Paphiopedilium concolor*?)

S_1: 3 • 3 *Lasiococca comberi* var. *pseudoverticillata* (T_2)
2 • 2 *Pometia tomentosa* (T_1)
1 • 2 *Amoora dasyclada* (T_1)
1 • 2 *Barringtonia pendula* (T_2)
1 • 2 *Sumbaviopsis albicans* (T_2)
1 • 2 *Aglaia abbreviata* (Meliac.)
1 • 1 *Pittosporopsis kerrii* (Icacinac.)
\+ • 2 *Tarenna sylvestris*
\+ • 2 *Litsea lancifolia* (Laurac.) (T_2)
\+ • 2 *Salacia aurantica* (Celastrac.)
\+ • 2 *Saporosma ternatum* (Rubiac.)
\+ • 2 *Millettia* sp$_1$. (Leg.)
\+ *Gironniera subaequalis* (T_1)
\+ *Garcinia cowa* (T_2)
\+ *Horsfieldia pandurifolia* (Myrist.)
\+ *Xanthophyllum siamense* (Xanth.)
\+ *Antiaris toxicaria* (Morac.)
\+ *Litsea garrettii* (Laurac.)
\+ *Schefflera* (?) sp.
\+ *Knema erratica* (T_1)
\+ *Chisocheton siamense* (T_2)
\+ *Diospyros nigrocartex* (Ebenac.)
\+ *Aphanamixis grandifolia* (Meliac.)
\+ *Ficus auriculata* (Morac.)
\+ *Stephania brachyandra* (Menispermac.)
\+ *Millettia* sp. $_2$

vines: 1 • 2 *Strychnos nitida* (T_2)
\+ *Combretum yunnanense* (T_2)
\+ *Beaumontia murtonii* (Apocynac.)
\+ *Rhaphidophora hongkongensis* (Arac.)

S_2:	2・3	*Lasiococca comberi* v. *pseudovert.*	2・2	*Strychnos nitida* (T_2)
	2・2	*Cleidion bracteosum* (Euphorb.)	1・2	*Amoora dasyclada* (T_1)
	1・2	*Knema erratica* (T_1)	1・2	*Mitrephora thorelii* (Anonac.)
	+・2	*Pometia tomentosa* (T_1)	+・2	*Sumbaviopsis albicans* (T_2)
	+・2	*Psychotria henryi* (Rubiac.)	+・2	*Beaumontia murtonii*
	+・2	*Xanthophyllum siamense*	+・2	*Litsea lancifolia*
	+・2	*Ixonanthes cochinchinensis*	+・2	*Symplocos cochinchinensis*
	+・2	*Lasianthus kerrii*	+・2	*Salacia polysperma*
	+・2	*Pterospermum menglunense* (end.)	+・2	*Suregada glomerulata* (Euphorb.)
	+・2	*Pandanus pekinensis*	+	*Polyalthia cheliensis* (T_1)
	+	*Myristica yunnanensis* (T_2)	+	*Artocarpus lakoocha* (Morac.)
	+	*Eurya acuminata* (Theac.)	+	*Parabarium* sp.$_1$ (Apocynac.)
	+	*Syzygium polypetaloideum*	+	*Dysoxylon sinensis* (Meliac.)
	+	*Capparis assamica*	+	*Ventilago calyculata* (Rhamnac.)(decid.)
	+	*Stereospermum tetragonum* (Bign.)	+	*Ficus* sp.
	+	*Ardisia quinquegona*	+	*Aphananthe nitida* (Ulmac., decid.)
	+	*Oreocnide obovata* (Urtic.)	+	*Castanopsis* sp.
	+	*Millettia* sp.	+	*Antiaris toxicaria*
	+	*Saprosma ternatum*	+	*Elaeocarpus austro - yunnanensis*
	+	*Acacia pennata*	+	*Lasianthus conspicuus*
	+	*Psychotria yunnanensis*	+	*Flemingia macrophylla* (Legum.)
forb:	+	*Phrynium capitatum* (2 m)		
vine:	1・1	*Piper flaviflorum*		
epiphyte:	+	*Bolbites heteroclita* (fern)		
H:	1・2	*Pometia tomentosa*	1・2	*Amoora dasyclada* (T_1)
	+・2	*Cleidion bracteosum*	+	*Barringtonia pendula* (T_2)
	+・2	*Mitrephora thorelii*	+	*Illigera orbiculata* (Hernandiac.)
	+	*Syzygium polypetaloideum*	+	*Garuga pinnata* (Burserac.)
	+	*Psychotria pilifera*	+	*Piper sarmentosum*
	+	*Piper* sp.$_2$		
vines:	+・2	*Piper flaviflorum* (T_1)	+	*Combretum yunnanense* (T_2)
	+	*Erythropalum scandens* (Olac.)	+	*Epipremnum pinnatum* (Arac.)
	+	*Streptocaulon javentas*	+	*Tetrastigma obovatum* (15m on ground)
ferns:	2・2	*Bolbites heteroclita*	1・2	*Pteropteris* sp.
	+・2	*Pleiocnemia wentii* (height: 1 m)	+・2	*Allantodia aspera*
	+・2	*Abacopteris triphylla*	+	*Angiopteris caudatiformis*
	+	*Pronephrium megacuspe*		
forbs:	2・2	*Phrynium capitatum* (Marant)	+・2	*Goodyera procera*
	+・2	*Aspidistra typica* (Lil.)	+・2	*Pilea bracteata* (Urticac.)
	+	*Pollia secundiflora* (Comm.)		

Level symbols in parentheses indicate level potentials where these could be estimated; EG = evergreen, decid. = deciduous.

The canopy is dominated jointly by *Polyalthia cheliensis* (Annonaceae), *Amoora* (=*Aglaia*) *dasyclada* (Meliaceae), and *Pometia tomentosa* (Sapindaceae), all three from families which are much more common in the tropics than in extra-tropical forests. Additional canopy species are *Machilus* (=*Persea*) *melanophylla* (a species not encountered in *Persea* forests further north), *Knema erratica* (Myristicaceae), *Gironniera subaequalis* (a subtropical to tropical Ulmaceae species occurring also in southeastern China), and a second, undetermined species of *Polyalthia*. *Pometia* (with buttresses measuring 2 m across), *Persea* (80 cm diameter), and *Gironniera* are evergreen, but at least some of the other species may be deciduous. (Many species in Yunnan are unique to the region and are not included in the Chinese floristic manual (Institute of Botany 1972-85), which gives seasonal foliation habit.) In addition, *Bauhinia genuflexa* (Leguminosae, 20 cm diameter), *Cocculus laurifolia* (Menispermaceae), and *Piper flaviflorum* reach the canopy as larger or smaller lianas.

The tree and shrub understoreys include many of the canopy species plus a large number of other woody species, including other vines but only a very few epiphytes (which are especially sensitive to an extended dry season). Both shrub layers are at least co-dominated by *Lasiococca comberi* var. *pseudoverticillata* (Euphorbiaceae). Cover in the herb layer is mainly by *Bolbites heteroclita* and other ferns plus *Phrynium capitatum* (Marantaceae), but some woody seedlings also occur.

The numbers of individual trees over 10 cm in diameter, in each layer, are shown in Table 4. The total numbers of non-vine arborescent and frutescent species in each layer, and the corresponding occurrences of those species in lower layers, are shown in Table 5. Of the seven tree species in the canopy layer, all but *Persea* and the second *Polyalthia* species occur as younger trees or arborescents in lower layers, especially *Pometia*, *Gironniera*, and *Amoora*. This plus the somewhat greater cover in understorey layers suggests that this forest may still be recovering from some disturbance. Furthermore, the canopy composition does not really match that of any of the types identified in Table 1. Compared with evergreen broad-leaved forests dominated by Fagaceae, etc., this Man-Ka forest shows a slightly higher number of species in the canopy and in the herb layer. This may be due to the occurrence of deciduous trees in the overstorey, also permitting more light to reach the forest floor.

Table 5 also suggests some aspects of the potential dynamics of this tropical seasonal forest stand. Five of the seven canopy species show regeneration in lower layers, while seven of the 14 tree species of the T_2-layer show regeneration (some of which may be potential canopy species, cf. Zhu et al. 1987). Only three large tree species have seedlings in the herb layer (*Pometia*, *Amoora*, and *Barringtonia*), but such seedlings are not necessarily numerous, given the long periods of time that seedlings often must wait before being "released" by formation of a canopy gap (cf. Swaine et al. 1987, Turner 1990). *Pometia tomentosa* is a co-dominant of the *Terminalia-Pometia* forest type recognized by Zhu et al. (1987), but *Terminalia* was not found at Man-Ka.

Table 4. Numbers of Individual Trees over 10 cm in Diameter (DBH) in the Seasonal Evergreen Forest Relevé (Man - Ka).

	Diameter breast-height	Tree Overstorey (T_1 layer)	Understorey (T_2 layer)	Shrub Layer (S layer)
Overstorey Trees				
Polyalthia cheliensis	70 cm	3	+	•
Amoora (=*Aglaia*) *dasyclada*	57 cm	2	•	+
Pometia tomentosa	2 m *	1	2	2
Gironniera subaequalis	40 cm	1	3	1
Machilus melanophylla	80 cm	1	•	•
Polyalthia sp$_2$.	47 cm	1	•	•
Knema erratica	—	1	•	•
(* buttress - root diameter)				
Trees in Understorey				
Garcinia cowa		•	2	1
Pouteria grandifolia		•	2	•
Barringtonia pendula		•	1	2
Lasiococca comberi v. *pseudoverticillata*		•	1	2
Knema furfuracea	35 cm	•	1	•
Tarenna sylvestris		•	1	3
Sumbaviopsis albicans		•	1	1
Chisocheton siamense		•	1	1
Baccaurea ramiflora		•	1	•
Trigonostemon thyrsoideum		•	1	•

The relevé area was 500 m^2 on a 40° slope and represents a site for which additional data on individual trees are available (Liu et al., unpublished).
Plus signs indicate occurrence of individuals smaller than 10 cm DBH (diameter at breast height). In addition, one individual each (DBH over 10 cm) of *Aglaia abbreviata, Pittosporops is kerrii, Litsea lancifolia,* and *Saporosma ternatum* occurred in the S_1 layer.

Table 5. Numbers of Potential Tree Species by Forest Layer in the Seasonal Evergreen Forest at Man - Ka.

Layer	Total no. of species	No. of arboresc. species	No. of arb. T_1 species	No. of arb. T_2 species	No. of arb. S_1 species	No. of arb. S_2 species
T_1 (canopy tree)	10	7	—	—	—	—
T_2 (tree understorey)	18	14	3	—	—	—
S_1 (arboresc. / shrub)	30	26	4	6	—	—
S_2 (typical shrub)	45	42	4	2	10	—
H (ground herb)	29	11	2	1	0	6
Total	106	83	5	7	10	6

Of the seven canopy tree species, five occur as younger individuals in lower layers: *Gironniera subaequalis, Pometia tomentosa,* and *Polyalthia cheliensis* in the T_2 and at least one lower *layer,* and *Amoora dasyclada* and *Knema erratica* in the S_1 and S_2 layers. *Pometia* and *Amoora* also have seedlings in the herb layer. Of the 14 tree species in the T_2 layer, seven occur also in lower layers: *Barringtonia, Sumbaviopsis, Lasiococca, Tarenna, Garcinia,* and *Chisocheton* in the S_1 (and lower) layer, and *Myristica* in the S_2 layer (see Table 3 for species names). Among the vines and lianas (not included above), *Piper flaviflorum* (T_1) occurs also in the S_2 and H layers, while *Combretum yunnanensis* and *Strychnos nitida* (T_2) also occur in at least one lower layer.

The Montane Evergreen Broad-Leaved Forest

An evergreen broad-leaved lucidophyllous or "laurel type" forest (see Figure 4) occurred on a 15° NW-facing slope less than 400 m higher than the seasonal evergreen forest. This montane evergreen broad-leaved forest was dominated by *Castanopsis hystrix* and *Lithocarpus fordianus*, with two undetermined *Pasania* (cf *Lithocarpus*) species also in the canopy layer. The canopy was low (15 m) but closed (85%), and the understorey layers showed at most 40% cover, with many dead branches on the ground. The understorey tree layer contained the same genera plus *Millettia leptobotrya* (Leguminosae), *Elaeocarpus sylvestris*, and *Actinodaphne henryi* (Lauraceae), as well as *Wendlandia parviflora* (Rubiaceae, not common further north). The complete composition and structure of this forest are shown in Table 6.

Although most species seem to be local species, the tree-layer dominance by evergreen Fagaceae (with Lauraceae and *Elaeocarpus*) and the general distribution of species diversity (by far greatest in the shrub layer) make this forest quite similar to evergreen broad-leaved "laurel" forests familiar from the warm-temperate and subtropical parts of humid East Asia, including southern Japan and southernmost Korea as well as eastern China (e.g. Fujiwara 1981-86, Song 1988, Box et al. 1990). *Castanopsis* and *Lithocarpus* show regeneration in the herb layer, and the two *Pasania* species are present sparingly in the shrub layer (as is *Lithocarpus*). Other common lucidophyllous forest genera also occur in the shrub layer, including *Osmanthus* (the shrub-layer dominant), *Schima*, *Litsea*, and *Syzygium* (mainly subtropical). On the other hand, many of the shrub-layer genera are not so typical of lucidophyllous forests but

Figure 4. The Montane Evergreen Broad-Leaved Forest (*Castanopsis*) at 1070 m Elevation on Man-Ka Mountain.

rather suggest tropical affinities, for example *Croton*, *Glochidion*, *Aporusa* and other Euphorbiaceae, *Toona* and *Trichilia* (Meliaceae), *Harpullia* and *Nephelium* (Sapindaceae), *Pithecellobium* (Leguminosae), and others. Vines occur sparsely in all layers, notably *Pueraria collettii*, but no epiphytes were recorded. The sparse herb layer (20%) involves woody seedlings plus mainly *Alpinia* and *Woodwardia japonica*.

Table 6. Relevé Sample of "Laurel Forest" at Man-Ka Mountain (about 1070 m).

11 Nov. 1988

T_1	15m	85%	Elevation 1070m
T_2	8m	30%	Slope 15° to NW, 15 x 15m
S	3.5m	40%	many dead branches on ground
H	0.5m	20%	

T_1:	3・4	*Castanopsis hystrix* (30cm, with low shoots)		
	3・3	*Lithocarpus fordianus*		
	2・2	*Pasania* sp.$_2$ (smaller lvs.)	1・2	*Pasania* sp.$_1$ (larger lvs.)
vines:	+・2	*Dalbergia pinnata* (decid.)	+	*Pueraria collettii*
T_2:	2・2	*Castanopsis hystrix*	2・2	*Millettia leptobotrya*
	1・2	*Lithocarpus fordianus*	1・2	*Elaeocarpus sylvestris*
	1・2	*Pasania* sp$_2$. (smaller lvs, 18cm)	1・1	*Actinodaphne henryi* (Laurac.)
	+	*Wendlandia parviflora* (Rubiac.)		
vines:	+	*Pueraria collettii*	+	*Dioscorea fordii* (decid.)
S:	3・3	*Osmanthus polyneurus*	2・2	*Aporusa yunnanennsis* (Euphorb.)
	1・2	*Croton argyratus* (Euphorb.)	+・2	*Mallotus repandus* (Euphorb.)
	+・2	*Aporusa* sp. (larger)	+・2	*Trichilia connaroides* (Meliac.)
	+・2	*Millettia leptobotrya* (Leg.)	+・2	*Harpullia cupaninides* (Sapind., decid)
	+・2	*Desmodium elegans* (Leg.)	+	*Elaeocarpus sylvestris*
	+	*Schima wallichii* (Theac.)	+	*Breynia fruticosa* (Euphorb.)
	+	*Syzygium szemaoense* (Myrtac.)	+	*Pasania* sp$_2$. (smaller lvs.)
	+	*Rubiaceae* sp. (tarennoid)	+	*Litsea cubeba*
	+	*Lithocarpus fordianus*	+	*Actinodaphne henryi*
	+	*Canthium parvifolium* (Rubiac.)	+	*Pasania* sp$_1$. (larger lvs, 28cm)
	+	*Winchia calophylla* (Apocynac.)	+	*Syzygium nienkui*
	+	*Phoebe lanceolata* (Laurac.)	+	*Vernonia parishii* (Comp.)
	+	*Ficus virens*	+	*Eurya groffii*
	+	*Glochidion hirsutum* (Euphorb.)	+	*Schizomussaenda dehiscens* (Rubiac.)
	+	*Evodia lepta* (Rutac.)	+	*Pithecellobium clypearia* (Leg.)
	+	*Mitragyna bruonis* (Rubiac.)	+	*Toona microcarpa* (Meliac.)
	+	*Antidesma diandrum* (=*acidum*)	+	*Litsea* sp. (*atrata*?)
	+	*Phyllanthus asteranthus* (Euphorb.)	(+)	*Nephelium chryseum* (Sapindac.)
	+	*Turpinia pomifera* (Staphyleac.)	(+)	*Aralia thomsonii*
vines:	+	*Smilax lanceifolia* v. *lanceolata*	+	*Smilax hypoglauca*
	+	*Pueraria collettii*	+	*Lygodium flexuosum* (fern)
H:	2・2	*Castanopsis* sp. (seedl.)	1・2	*Lithocarpus fordianus* (seedl.)
	+・2	*Aporusa yunnanensis* (seedl.)	+	*Tricchilia connaroides*
	+	*Vernonia parishii*	+	*Rhus chinensis* v. *roxburghiana*
	+	*Piper pubicatulum*		
	+	*Smilax hypoglauca*	+	*Pueraria collettii*
forbs:	2・2	*Alpinia* sp.	+	*Peliosanthes sinica* (Liliac.)
	+	*Ophiopogon aciformis*		
ferns:	1・2	*Woodwardia japonica*	+・2	*Pteris longipes*
	+・2	*Cyclosorus crinipes*	+	*Pteris biaurita*
	+	*Lygodium flexuosum* (seedl.)		
sedges:	+・2	*Carex baccans*	+	*Scleria hebecarpa*
	+	*Scleria laevis*		
grass:	+	Graminae sp.		

The total number of species (61) is a bit high for a typical East Asian "laurel" forest, but the lower latitude, proximity to other forest types in a transitional region, and some evidence of disturbance may be responsible for this. This forest seemed to represent a subtropical montane analog of East Asian evergreen broad-leaved (lucidophyllous) forests, but with characteristic Yunnan species, some of them tropical.

The Forest on Limestone

A forested outcropping of jagged limestone boulders occurs about 1 km off the main road less than 5 km south of the Menglun botanical garden. The area sampled (20 x 30 m) included the lower slopes of both sides of a ravine which sloped about 15° to the southwest, with slopes to 30° on the sides of the ravine. The composition and structure of the forest are shown in Table 7. The physiognomy of the forest, including its dense network of vines and the wide buttresses of the dominant species, *Tetrameles nudiflora* (Datiscaceae), are shown in Figures 5 and 6.

Table 7. Relevé Sample of "Limestone Forest" near Menglum (about 690 m).

T_1	35m	50%	Limestone (rough, jagged boulders)
T_2	15m	80%	Elevation 690m
S	5m	40%	Slope 15° to SW, both sides of ravine
H	0.8m	30%	(ravine slopes to 30°)

T_1:	3・3	*Tetrameles nudiflora* (Datiscac.) (buttress to 3 m DBH) (decid.)		
	2・2	*Toona ciliata* (Meliac.) (90cm DBH) (decid.)		
	2・1	*Cleistanthus sumatranus* (Euphorbiac.) (EG)		
	2・1	*Celtis wightii* (Ulmac.) (85cm DBH)		
T_2:	5・4	*Cleistanthus sumatranus*		
	1・2	*Lasiococca comberi* var. *pseudoverticillata* (Euphorbiac.)		
S:	2・2	*Celtis wightii*	2・2	*Cleistanthus sumatranus*
	1・2	*Lasiococca comb.* v. *pseud.*	1・2	*Sageretia pauciflora* (Rhamnac.)
	+	*Sumbaviopsis albicans* (Euphorb.)	+	*Cleidion spiciflorum* (Euphorb.)
	+	*Celtis cinnamomea*	+	*Rauvolfia yunnanensis* (Apocynac.)
	+	*Chloranthus* (Chlor.)	+	*Suregada glomerulata* (Euphorb.)
	+	*Helicia nilagirica* (Proteac.)	+	*Tarenna incerta* (Rubiac.)
	+	*Radermachera microcalyx* (Bign.)	+	*Clausenia dunniana* (Rutac.)
vines:	2・2	*Jasminum lanceolatum* (Oleac.)		
	1・1	vine sp. (*Millettia* sp.?)		
	+	*Dregea volubilis* (Asclepiad.)		
H:	2・3	*Cleistanthus sumatranus* (seedl.)	1・2	*Celtis wightii* (seedl.)
	+・2	*Acacia* sp. (seedl.)	+	*Walsura robusta* (Meliac.) (seedl.)
vines:	+・2	*Rhaphidophora hongkonensis*	+	*Rhaphidophora decursiva*
	+	*Rhaphidophora megaphylla*	+	*Tetrastigma planicaulum*
	+	*Hoya pottsii* (Asclep.)		
forns:	1・1	*Tectaria polymorpha*	+・2	*Adiantum philippense*
forbs:	+	*Chlorophytum malayense* (Lil.)	+	*Begonia dryadis* (Begoniac.)
	+	*Polygonatum cirrhifolium*	+	*Arisaema* sp.
	(+)	*Oreocnide rubescens* (Urticac.)		

(EG=evergreen, decid.=deciduous)

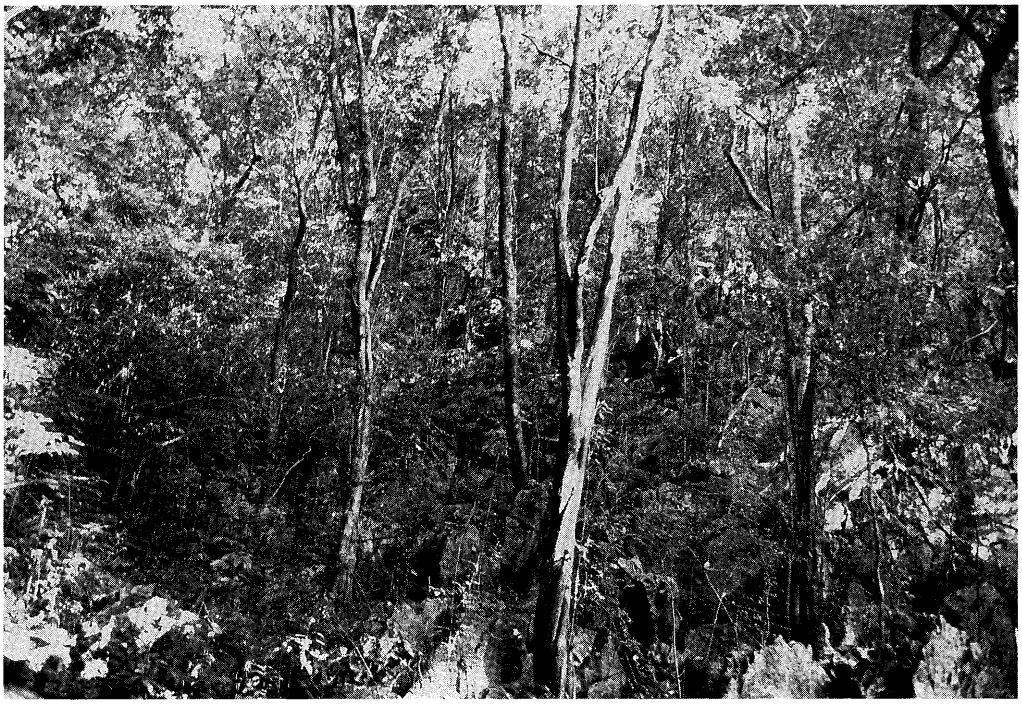

Figure 5. The Limestone Forest near Menglun, with Deciduous and Evergreen Trees on Shallow (Variable) Soil over Jagged Limestone.

Like many forests on limestone, the composition is much simpler than that of the adjacent forest. The canopy is dominated by *Tetrameles nudiflora* (deciduous) and includes only three other species: *Cleistanthus sumatranus* (Euphorbiaceae, with reddish bark, a modular trunk structure, and thin, glossy evergreen leaves), *Toona ciliata* (Meliaceae, deciduous, with trunk diameter to 90 cm at breast height), and *Celtis wightii* (Ulmaceae, 85 cm DBH, perhaps deciduous). The understorey tree layer is almost completely composed of *Celtis wightii* (15 m, 80%), along with some *Lasiococca comberi* var. *pseudoverticillata* (Euphorbiac.), which was also the main species in both shrub layers at the Man-Ka seasonal forest site. *Celtis* and *Cleistanthus* also dominate the shrub and herb layers, accompanied by other species which were mostly not seen in the other two forest samples. The total number of species is only 34, with 14 occurring only in the herb layer and 13 only in the shrub layer.

The occurrence of *Tetrameles* as the canopy dominant, with no apparent regeneration, and the fact that it is considered to be a main dominant species of limestone forests in the region suggest that the forest is mature. It also suggests that this forest is fairly typical of limestone forests in Xishuangbanna, which are described (Zhu et al. 1987, pp. 188) as involving also *Celtis* spp. and *Cleistanthus* (but *Cl. saichikii*), as well as *Sumbaviopsis*, *Clausenia*, *Adiantum*, etc. Although the accompanying species composition differs from the descriptions of Zhu et al. (1987), this forest appears to conform to the *Tetrameles* type of limestone forest. It is unusually tall (35m) compared with the forests of coastal and island limestone areas of East Asia (e.g. Okinawa, southern Taiwan). Otherwise, the dominance by deciduous species,

Figure 6. Large Buttress Roots of *Tetrameles nudiflora* with Tangle of Lianas in the Limestone Forest near Menglun.

concentration of cover at around 15 m height and less understorey are similar to other forests on limestone.

Forest Richness

The species richness of the three forests, by stratum and growth form, is shown in Table 8. The truly tropical, seasonal forest at Man-Ka (700 m) shows more species in all categories except graminoids than either of the other forests. All three forests have much of their total species richness concentrated in the shrub layer(s), with relatively few species in the herb layer. Forests on rough limestone often have fewer species, but not always. Kelly et al. (1988), for example, report that Jamaican forests on limestone, though shorter, generally have as many species as other, comparable Caribbean forests.

Dissimilarity of the Three Forests

The most striking feature of the three forests studied is their almost complete dissimilarity in composition, as shown in Table 9. No species occurs as a tree in all three relevés, and only four species occur in two of the three relevés, all four in the two lower-elevation, truly tropical forests (Man-Ka at 750 m and the limestone forest, at 690 m). One of these species, *Lasiococca comberi* var. *pseudoverticillata*, is the only species which occurs as a tree in more than one of the three relevés. The other three species common to the tropical seasonal and limestone forests are *Sumbaviopsis albicans* (a T_2 tree at Man-Ka but in the shrub layer on the limestone),

Table 8. Numbers of Species in Each Layer of the Three Forests Sampled.

	Seasonal forest	*Castanopsis* forest	Limestone forest
Overstorey trees (T_1)	7	4	4
Understorey trees (T_2)	14	7	2
Shrub layer(s)	26, 42	38	14
Lianas and vines (all)	12	6	8
Epiphytes (all)	2	0	0
Ferns (herb layer only)	7	5	2
Forbs (herb layer only)	5	3	5
Graminoids (herb layer)	0	4	0
Totals	106	61	34

The shrub layer(s) include shrubs, arborescents, and potential taller trees. In the seasonal forest, two shrub layers were recognized.

Table 9. Numbers of Total and Common Genera in the Three Forests near Menglun.

	Total Genera			Common Genera			
Location / Layer	Man - Ka 700m	Man - Ka 1070m	Lime - stone	Man - Ka (both)	Man - Ka 700m & limestone	Man - Ka 1070m limestone	All 3 relevés
Overstorey trees (T_1)	6	3	4	(1)	0	(1)	0
Understorey trees (T_2)	14	7	2	(1)	1+(2)	0	(1)
Shrub layer(s)	25, 40	34	13	4	4	0	0
Lianas and vines (all)	12	5	6	4	4	0	0
Ferns (herb layer only)	7	4	2	0	0	0	0
Forbs (herb layer only)	5	3	5	0	0	0	0
Totals	62	51	30	7	9	1	1

Man-Ka 700m is the seasonal evergreen forest (mainly tropical taxa), while Man-Ka 1070m is the *Castanopsis* forest. Numbers in parentheses indicate numbers of genera common to more than one forest stand sampled but present only in a lower stratum in at least one of the locations. Only one genus, *Lasiococca*, occurs as a tree in more than one of the forest stands.

Suregada glomerulata (also Euphorbiaceae, a shrub in both relevés), and *Rhaphidophora hongkongensis* (Araceae), a shrub-layer vine at Man-Ka (700 m) and one of three *Rhaphidophora* vine species in the herb layer of the limestone forest.

There are also few common genera. Only one genus, *Millettia* (Leguminosae), occurs in all three relevés. No genus other than *Lasiococca* occurs as a tree in more than one relevé, though two canopy genera (*Castanopsis* and *Toona*) occur in the shrub layer of a second relevé (as a single individual). *Castanopsis* and *Elaeocarpus* from the Fagaceae forest at Man-Ka are represented also in the lower shrub

layer of the tropical seasonal forest at Man-Ka, while in the shrub layers, various species of *Litsea*, *Ficus*, *Eurya*, and *Syzygium* occur sparingly (+•2 or less) in both forests. *Piper flaviflorum* is a fairly common canopy and understorey vine in the tropical seasonal forest, while *P. pubicatulum* occurs as scattered individuals in the herb layer of the Fagaceae forest. *Tarenna sylvestris* occurs as an understorey tree in the tropical seasonal forest, while *Tarenna incerta* occurs in the limestone forest. In addition, four other genera occur in both the tropical seasonal and the limestone forests (in addition to the four common species mentioned above): *Cleidion* (Euphorbiaceae), *Oreocnide* (Urticaceae), *Acacia* (Leguminosae, seedlings), and *Tetrastigma* (Vitaceae). *Toona* (different species) is the only genus common to the Fagaceae forest and the limestone forest samples. The common subtropical genera *Psychotria*, *Ardisia*, and *Symplocos* occurred in the tropical seasonal forest but not in the other relevés. No non-woody genus occurred in more than one of the three relevés.

Interpretation

There is generally a certain amount of overlap, of species as well as genera, creating a transition band between different forest zones. In East Asian forests, such genera as *Persea*, *Castanopsis* and other Fagaceae, *Schima*, *Syzygium*, *Psychotria*, *Ardisia*, *Cinnamomum*, and various other woody tree and shrub genera occur widely throughout the subtropical forests and are known to occur also in both warm-temperate and tropical forests to a lesser extent. Of course it is well known (e.g. Richards 1952, Whitmore 1984, Ashton 1967) that tropical forests are quite different taxonomically from extra-tropical forests. Nevertheless, the almost complete dissimilarity in species and even genus composition of the three forests studied seems striking. This is especially so in the case of the two forests at Man-Ka, both on the north side of the mountain (perhaps 5 km apart) and separated by less than 400 meters in elevation.

As already described, the Fagaceae forest at Man-Ka and the limestone forest could both be recognized as fairly typical examples of forest types described by Zhu et al. (1987) in their classification of Yunnan vegetation. The tropical seasonal forest at Man-Ka, however, could not be placed so easily, and we were told by Kunming personnel afterward that it was not a typical forest. The dynamic position of this forest thus becomes an interesting question and is being studied by the Kunming Institute of Ecology. A register of individual trees at the site is available, and litterfall studies are also being conducted.

The tropical seasonal forest (see Table 3) seems to be most closely related to the *Antiaris-Pouteria-Canarium* and *Terminalia-Pometia* types of "seasonal rain forest" described by Zhu et al. (1987)(Table 1), in which *Gironniera subaequalis* and *Pometia tomentosa* are especially important and in which *Garcinia cowa* and *Knema furfuracea* (all in the Man-Ka relevé) also occur. Other main trees at Man-Ka are represented in these two forest types by other species of the same genera, e.g. *Polyalthia*, *Aglaia* (*Amoora*), *Barringtonia*, and *Baccaurea*. On the other hand, the two dominant genera in Table 3, *Polyalthia* and *Amoora*, are not prominent in the types described by Zhu et al. (1987), and the species of these genera which are mentioned by Zhu et al. seem not to be canopy species. *Persea* (80 cm DBH at Man-Ka) is not mentioned at all by Zhu et al.

All of this suggests two things, namely a rather marginal position for the Man-

Ka seasonal forest (near its upper elevational limit) and/or that the Man-Ka seasonal forest may still be recovering from some disturbance. The Man-Ka tropical seasonal forest shows more or less equal similarity, in terms of potential overstorey tree species, to the *Terminalia-Pometia* and the *Antiaris-Pouteria-Canarium* types of Zhu et al. (1987). Perhaps most interesting, though, is that even as a fragment near another forest type, the tropical seasonal forest contains almost no species or even genera from the adjacent *Castanopsis* forest. Some Kunming personnel felt that the *Castanopsis* forest was at an unusually low elevation, perhaps descending along a ridge (shallower, drier soil). This is supported by the strong admixture of tropical elements in the *Castanopsis* (lucidophyllous) forest. In the more truly tropical seasonal forest none of the *Castanopsis* forest dominants remain as important elements, if at all. This rapid replacement of extra-tropical dominants by tropical ones (but not the reverse going northward) seems to be a characteristic of the boundaries of the tropical forest zone.

Acknowledgement

The authors would especially like to express their thanks to Zhang Jian-hou, director of the Tropical Botanical Garden at Menglun, and to Wu Bang-xing, taxonomist, for their taxonomic and logistical assistance during our work around Menglun. Thanks also to Jiang Han-qiao, Jin Zhen-zhou and Liu Lun-hui (Kunming), who provided literature and helpful scientific advice, and who also facilitated our work in Xishangbanna (as well as other parts of Yunnan). Finally, special thanks also to our intrepid interpreter, Miss Zhao Jing, for her tireless assistance.

References

Ashton, P. S. 1967. Climate versus soil in the classification of Southeast Asian tropical lowland vegetation. J. Ecol., 55:67.

Ashton, P. S. 1978. Crown Characteristics of Tropical Trees. In: *Tropical Trees as Living Systems* (P. S. Tomlinson and M. H. Zimmermann, eds.). Cambridge University Press.

Box, E. O., B. N. Holben, and V. Kalb 1989a. Accuracy of the AVHRR Vegetation Index as a predictor of biomass, primary productivity and net CO_2 flux. Vegetatio, 80:71-89.

Box, E. O., K. Fujiwara, Hao Y., Zhong Y., Fu Q., and Xiao B. 1989b. A tropical montane evergreen forest and other vegetation on Hainan Island, southern China. Bull. Inst. Environm. Sci. Techn. Yokohama Nat. Univ., 16:75-94.

Box, E. O., Song Y., A. Miyawaki and K. Fujiwara 1990. An evergreen broad-leaved forest in transitional eastern China. Bull. Inst. Environm. Sci. Techn. Yokohama Nat. Univ., 17.

Box, E. O. (in press). Japanese Vegetation in Global Perspective. In: *Vegetation and Environments of Japan.* (A. Miyawaki et al., eds.). Shibundô /Kluwer.

Brandis, D. 1895. An enumeration of the Dipterocarpaceae. J. Linn. Soc. Bot., 29:1-148.

Central Meteorological Bureau 1979. *Zhongguo Renmin Gongheguo Qihou Tuji.* (Climatic Atlas of the People's Republic of China.) Beijing: Map Press. (In Chinese.)

Champion, H. G., and S. K. Seth 1968. *A Revised Survey of the Forest Types of India.* Delhi: Government Printer.

China Natural Geography Editorial Committee (eds.) 1984. (*China Natural Geography: Climate.*) Beijing: Academia Sinica and Science Press. 161 pp (in Chinese).

Fujiwara, K. 1981-86. (Phytosociological investigation of the evergreen broad-leaved forests

of Japan, I-IV.) Bull. Inst. Environm. Sci. Techn. Yokohama Nat. Univ., 7:67-133, 8: 121-150, 9:159-160, 13:99-149 (in Japanese, with Engl. synopsis in part IV).

Handel-Mazzetti, H. 1921. Übersicht über die wichtigsten Vegetationsstufen und -Formationen von Yunnan und SW-Setschuan. Bot. Jahrb. Engler, 56:578-597.

Holdridge, L. R. 1959. A simple method for determining potential evapotranspiration from temperature data. Science, 130:572.

Institute of Botany 1972-85. (*Iconographia Cormophytorum Sinicorum.*) 5 vols. plus two appendices, each about 1000 pp. Beijing: Science Press. (In Chinese, with Latin indices.)

Iwatsuki, K., and M. Mizutani 1972. (*Coloured Illustrations of Bryophytes of Japan.*) Osaka: Hoikusha. 405 pp (in Japanese, with Latin index).

Jiang Han-qiao 1980. (Distributional features and zonal regularity of vegetation in Yunnan.) Acta Botanica Yunnanica, 2:20-32, 142-151 (in Chinese).

Jiang Ai-liang 1988. Climate and natural production of rubber (*Hevea brasilensis*) in Xishuangbanna, southern part of Yunnan province, China. Intern. J. Biometeorol., 32: 280-282.

Jin Z.-Z. 1979. (The types and characteristics of evergreen broadleaf forests in Yunnan.) Acta Botanica Yunnanica, 1:90-105 (in Chinese).

Jin Z.-Z. 1983. (On the fundamental features of tropical rainforest and monsoon forest in Yunnan.) J. Yunnan Univ. (Nat. Sci. edition), 1,2: 197-205 (in Chinese).

Kelly, D. L., E. V. J. Tanner, V. Kapos, T. A. Dickinson, G. A. Goodfriend, and P. Fairbairn 1988. Jamaican limestone forests: floristics, structure and environment of three examples along a rainfall gradient. J. Tropical Ecology, 4:121-156.

Kunming Institute of Botany (eds.) 1977-86. (*Flora Yunnanica.*) 4 vols. Academia Sinica. Beijing: Science Press. (In Chinese, with Latin index.)

Liu L. and Yu Y. 1983. (The distribution and floristic composition characteristic to tropical forest in Yunnan.) Acta Botanica Yunnanica, 5:187-196 (in Chinese).

Makita, H., and H. Chujo 1989. Vegetation of Yunnan and Hainan Provinces, China. Geogr. Rev. Japan, ser. B., 62:116-126.

Merrill, E. D. 1923. Distribution of the Dipterocarpaceae. Philippine J. Sci., 23:1-33.

Nomoto, S., Du M.-Y., and K. Ueno 1989. Some characteristics of cold-air lakes and fog in the Jinghong and Mengyang Basins, Xishuangbanna, China. Geogr. Rev. Japan, ser. B, 62:137-148.

Richards, P. W. 1952. The *Tropical Rain Forest.* London: Cambridge Univ. Press.

Song Y.-Ch. 1988. Broad-leaved evergreen forests in central Japan in comparison with eastern China. Veröff Geobot. Inst. Rübel (Zürich), 98:197-224.

Swaine, M. D., D. Lieberman, and F. E. Putz 1987. The dynamics of tree populations in tropical forest: a review. J. Trop. Ecol., 3:359-366.

Thornthwaite, C. W., and J. R. Mather 1957. Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance. Publ. in Climatol., 10(3):185-311 (Drexel Inst. Technol., Centerton, New Jersey).

Turner, I. M. 1990. Tree seedling growth and survival in a Malaysian rain forest. Biotropica, 22:146-154.

Urushibara, K., and S. Nagatsuka 1989. Climatic conditions and vertical zonality of soil distribution in South Yunnan, China. Geogr. Rev. Japan, ser. B, 62:127-136.

Wang Chi-Wu 1939. A preliminary study of the vegetation of Yunnan. Bull. Fan Mem. Inst. Biol. Bot., 9:65-123.

Wang Chi-Wu 1961. *The Forests of China, with a Survey of Grassland and Desert Vegetation.* Cabot Foundation publ. no. 5. Cambridge (Massachusetts): Harvard University, 313 pp.

Wang D.-M., Yang Sh.-Z., and Zhu Y.-X. 1985. (The Dipterocarpaceae forests in Yunnan Province.) Acta Phytoecol. Geobotan. Sinica, 9:32-45 (in Chinese, with English summary).

Whitmore, T. C. 1984. *Tropical Rain Forests of the Far East.* 2nd edition. Oxford: Clarendon Press.

Wilson, E. H. 1913. *A Naturalist in Western China.* 2 vols. 251 + 229 pp.

Wu Zh.-Y. and committee (ed.) 1980. *Zhongguo Zhibei* (Vegetation of China). Beijing: Science Press. 1375 pp (in Chinese).

Wu Zh.-Y. and co-workers (eds.) 1984. (*Index Florae Yunnanensis.*) Kunming Institute of Botany, Academia Sinica. Kunming: People's Publishing House. 2 vols., 2259 pp (in Chinese, with Latin index).

Xu W.-D., Sh. Shirasaka, and T. Ichikawa 1989. Farming system and settlements in Xishuangbanna, Yunnan Province, China. Geogr. Rev. Japan, ser. B, 62:104-115.

Yasunari, T., and Tian Sh.-F. 1989. Large-scale atmospheric circulation patterns associated with the cold surges in Yunnan Province, China. Geogr. Rev. Japan, ser. B, 62:161-169.

Yoshino, M. M. 1989. Problems of climates and agroclimates for mountain development in Xishuangbanna, South Yunnan, China. Geogr. Rev. Japan, 62:149-160.

Yunnan Institute of Tropical Botany (eds.) 1984. (*List of Plants in Xishuangbanna.*) Kunming: Yunnan Nationalities Press. 509 pp (in Chinese).

Yunnan University 1960. (A survey of plant communities of the nature conservation stations in the tropical and subtropical regions of Yunnan Province, China.) Prepared for Yunnan Government. 166 pp (in Chinese, with English summary).

Zhu Y.-Ch. and committee (eds.) 1986. *Yunnan Senlin* (Yunnan Forests). Kunming: Yunnan Science-Technology Press; and Beijing: Chinese Forestry Press. 572 pp, with forest map and 123 photos (in Chinese, with Latin species glossary).

Zhu Y.-Ch. and committee (eds.) 1987. *Yunnan Zhibei* (Yunnan Vegetation). Beijing: Science Press. 1024 pp, with veg. map (in Chinese, with Chinese and Latin species indices).