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ORIGINAL ARTICLE

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Tree species composition and diversity of tropical mountain cloud forest in the Yunnan, southwestern China

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Abstract Species composition, physiognomy, and plant diversity of the less known cloud forests in Yunnan were studied based on data collected from 35 sample plots at seven sites. In floristic composition, the cloud forests are mainly comprised of Fagaceae, Ericaceae, Vacciniaceae, Aceraceae, Magnoliaceae, Theaceae, Aquifoliaceae, Illiciaceae, Lauraceae, and Rosaceae. Physiognomically, the forests are dominated by tree and shrub species. Lianas are rare in the forests. The plants with microphyllous or nanophyllous leaves comprise 44.32–63.46% of the total species, and plants with an entire leaf margin account for more than 50% of the tree and shrub species. There are few tree and shrub species with a drip tip leaf apex and papery leaves. Evergreen species make up more than 75% of the total tree and shrub species. In a 2,500 m^2 sampling area, the number of vascular species ranged between 57 and 110; Simpson's diversity index ranged from 0.7719 to 0.9544, Shannon–Winner's diversity index from 1.8251 to 3.2905, and Pielou's evenness index from 0.5836 to 0.8982 for trees. The cloud forests in Yunnan are physiognomically similar to the tropical cloud forests in America and Southeast Asia. They very much resemble the mountain dwarf mossy forest in Hainan Island, southeastern China, and the Mountain ericaceous forests in the Malay Peninsula. The cloud forests in Yunnan are considered to be developed, as are the tropical upper montane cloud forests in Asia.

Keywords Cloud forest · Species composition · Physiognomy · Plant diversity · Yunnan

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Introduction

Cloud forests include all forests in the humid tropics that are frequently covered by clouds or mist. They make up only 2.5% of the total area of the world's tropical forests (Bubb et al. 2004). The ecosystems within the cloud forests are among the world's most threatened (Aldrich et al. 1997). These ecosystems typically harbor a high proportion of endemic species and are often situated on mountaintops or ridgelines (Foster 2001; Hilbert et al. 2001). They have the unique additional value of capturing water condensed from clouds and fog. The water is vitally important to local communities and people living downstream (Bubb et al. 2004).

Yunnan province of southwestern China is exceptionally interesting to botanists because of its diversified biota and its geological and biogeographical history (Zhu et al. 2005). The region is geographically in a transitional zone between tropical Southeast Asia and temperate East Asia. In this region, the "top mountain dwarf mossy forest", some times called "mountain cloud forest", "mountain mossy evergreen broad-leaved forest", "summit dwarf forest", "mossy elfin forest" or "dwarfing mossy forest on the summit" (Peng et al. 2001; Wu 1987; Yang et al. 2005; Zhu and Yang 1987) have some of the characteristics of a "cloud forest". The area covered by cloud forests is smaller than regions covered by other types of vegetation in Yunnan. Previous investigations of plant species composition in Yunnan mainly focused on lowland tropical rain forests and lower montane forests below 900 m (Zhu et al. 2005). Little research has been carried out on these rare forest ecosystems. In China, tropical montane cloud forests have only been investigated in Hainan (Bubb et al. 2004). The cloud forests in Yunnan are mainly distributed within the climatic transition zone from Southern Subtropic to Northern Tropic. They are similar to typical tropical montane cloud forests in tropical Asia, but differ from the so-called "top mountain dwarf mossy forests" in subtropical and warmer temperate zones of

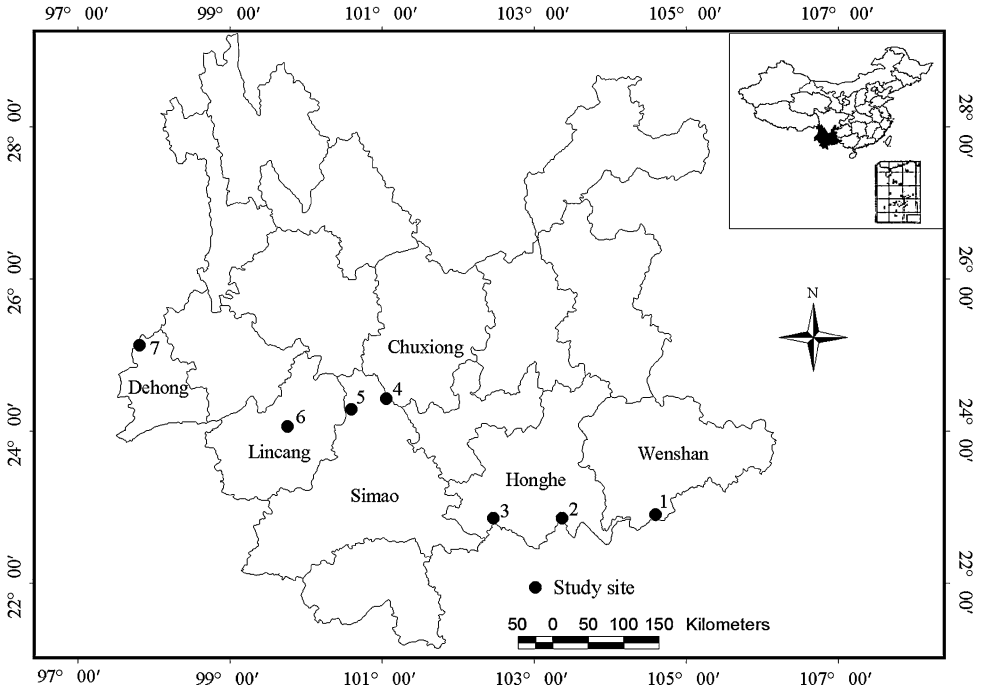

Fig. 1 Map showing the sites and locations of sampling plots in Yunnan of southwestern China. *1* Laojingshan National Nature Reserve; *2* Fengshuilin National Nature Reserve; *3* Huangliangshan National Nature Reserve; *4* Ailaoshan National Nature Reserve; *5* Wuliangshan National Nature Reserve; *6* Daxiushan National Nature Reserve; *7* Sudian National Forest area

China. The tropical forests are currently under threat, however the cloud forests are particularly threatened by anthropogenic pressure and climate changes (Bubb et al. 2004), together with habit fragmentation and disturbance. In this preliminary study, we focused on the species composition, physiognomy and plant diversity of the cloud forests in Yunnan China, aiming to obtain further knowledge about the less known forests.

Materials and methods

Study sites

The study sites are located in the well-protected Sudian National Forest Area and six national nature reserves, which are named in order of their location from east to west, as Laojingshan National Nature Reserve, Fengshuilin National Nature Reserve, Huangliangshan National Nature Reserve, Wuliangshan National Nature Reserve, Ailaoshan National Nature Reserve, and Daxiushan National Nature Reserve (Fig. 1). The seven study sites are all covered by well-conserved, undisturbed primary forests. These study sites are distributed in the region within longitude 97° to 105°E and latitude 22° to 25°N, bordered on the west by Myanmar and on the southeast by Vietnam. The region has a mountainous topography with the mountain ridges running north to south and becoming lower in elevation southward. Altitude ranges from 2,400 m at the Fengshuilin nature reserve to 3,900 m at the top of the Sudian national forest. The Upstream Irawaddy River (also known as Da Ying Jiang River), Salween River (Nu Jiang River), Mekong River (Lan Cang Jiang River), and Red River flow through the region roughly from northwest to southeast.

The study region in Yunnan has a typical monsoon climate. The summer is rainy and hot, and the winter is warm. Climatic data from weather stations located near the study sites are presented in Table 1.

Materials and methods

Five almost contiguous plots of 25 × 20 m in size were laid out at each site in order to acquire data following typical sampling methods. All trees in each of the plots were identified and their DBH (≥5 cm) and heights were measured. In each plot, five 2.5 × 2 m sub-plots were set to survey the floristic composition underneath the forest. In these sub-plots, saplings, shrubs and herbaceous plants were counted and their names were recorded. Lianas in these plots were identified and their abundance was estimated. Importance value indices (IVI) of Curtis and McIntosh (1951) were calculated (Curtis and McIntosh 1951). Rank/abundance diagrams (Magurran 1988) of species in each site were plotted. Physiognomy (life forms and leaf size) was analyzed. Leaf size of both evergreen and deciduous tree and shrub species was categorized, with class limits as follows: Leptophyll < 25 mm^2; Nanophyll (25–225 mm^2); microphyll (225–2,025 mm^2); mesophyll (2,025–18,225 mm^2); Macrophyll (18,225–164,025 mm^2); Megaphyll $> 164{,}025$ (Wang 1987). For plants with compound leaves, we used the size of the leaflets. Shannon–Winner index (H') and Simpson index (D) for tree species diversity were measured

Table 1 The climatic data of the study sites

Study sites	Laojingshan National Nature Reserve	Fengshuilin National Nature Reserve	Huanglianshan National Nature Reserve	Ailaoshann National Nature Reserve	Wuliangshan National Nature Reserve	Daxiushan National Nature Reserve	Sudian National Forest area
Mean annual temperature (°C)	12–23.1	17.8	16.6	10.7	18.3	14.0	22.6
The warmest monthly mean temperature (°C)	6.5–13.5	21.4	19.8	16.4	/	/	28.5
The coldest monthly mean temperature (°C)	17–28.5	11.9	11.4	4.7	/	/	15.5
The extreme highest temperature (°C)	/	33.1	31.5		37.7	/	/
The extreme lowest temperature (°C)	/	−0.9	−1.6	−8	−1.4	/	/
The annual temperature accumulation (> 10°C)	4,500–7,500	5,000–6,000	5,475	2,944.2	6,422	4,875	/
Mean annual precipitation (mm)	1,318	2,330	2,019	1,841	1,100	1,457.3	2,829
Mean relative humidity (%)	/	85	> 80	86	77	75	82
Altitude of climatic station (m)	1,260	1,230	1,634	2,450	1,162	1,930	270
Climatic type	South Subtropics	North tropic	North tropical	South Subtropics	South Subtropics	South Subtropics	North tropical
Longitude (east longitude)	104°34′–104°41′	103°13′–103°23′	103°13′–103°23′	100°10′–101°30′	100°30′–100°45′	99°33′–99°44′	97°31′–97°46′
Latitude (north latitude)	22°54′–22°57′	22°46′–22°54′	22°50′–23°	23°36′–24°44′	24°17′–24°42	24°01′–24°11′	25°17′
Altitude of study site (m)	2,700–2,900	2,400–2,600	2,400–2,500	2,600–2,700	2,600–2,700	Above 2,600	Above 2,800

according to $H' = -\sum (p_i \times \ln p_i)$, $D = 1 - \sum p_i^2$. The Pielou evenness index was calculated according to the formula $J = H'/\ln S$ (Ma 1994). Simpson's diversity index measures the probability that two individuals randomly selected from a sample will belong to the same species. Shannon–Winner's diversity index is based on information theory and it can be used as a measure of the uncertainty in predicting the species with an individual. Pielou's evenness index is a measure that how evenly distributed abundance is among the species that exist in a community. All of the diversity indices were calculated from the plot date (trees with their DBH ≥5 cm). Specimens were collected and identified. Species nomenclatures follow Flora Reipublicae Popularis Sinicae. Specimens are kept in The Herbarium of Xishuangbanna Tropical Botanical Garden (HITBC).

Results

Species composition

Cloud forests usually have a three-layer profile, i.e., a tree layer, a shrub layer, and an herb layer. The tree layer reaches 5–10 m tall except for the forest in the Fengshuilin National Nature Reserve, which has a tree layer about 15 m tall. The shrub layer is mainly composed of bamboo, which is 1–3 m tall. The herb layer is often 15–30 cm tall and is dominated by *Carex*, *Ainsliaea*, and *Crawfurdia* species. The study sites are diverse in composition and the most dominant tree species varies somewhat between sites. Seven forest communities were recognized in these seven sites and named by their dominant and subdominant species. The important tree species in these forest communities are enumerated in Table 2.

The *Lithocarpus variolosus–Rhododendron sinogrande* forest was plotted in the Laojingshan National Nature Reserve. The tree layer is dominated by *Lithocarpus variolosus*, *Rhododendron sinogrande* and *Acer franchetii*. The shrub layer is 1–3 m tall and is dominated by *Yushania polytricha, Gaultheria forrestii, Camellia forrestii* and some juvenile tree species. The herbaceous layer is not well developed. Most places were covered by moss. The common species are *Carex perakensis, Gentiana rigescens, Ainsliaea henryi* and *Diphasiastrum complanatum*. The lianas species are seldom found, but *Clematis montana* and *Tripterospermum pinbianense* are recorded. Epiphytes, such as *Araiostegia perdurans* and *Lepisorus loriformis* can be seen frequently in the forest.

The *Castanopsis echidnocarpa–Acer laxiflorum* forest was plotted in the Fengshuilin National Nature Reserve. The upper tree layer is dominated by *Castanopsis echidnocarpa*, *Acer laxiflorum*. The lower tree layer is composed of *Camellia tsingpienensis*, *Beilschmiedia roxburghiana* and *Microtropis discolor*. The shrub layer is primarily composed of dense *Yushania polytricha*, which with the cohabiting *Symplocos poilanei, Rubus quinquefoliolatus, Plagiopetalum serratum* and other shrub

Table 2 Importance values of tree species in the seven cloud forests

Species	LRF	CAF	MRF	LPF	RLF	RLTF	ILF
Acanthopanax evodiaefolius				9.21	7.43		
Acer franchetii	42.96						
Acer heptalobum				3.54			
Acer kwangnanense			6.41				
Acer laxiflorum		31.15					
Acer sp.							5.93
Alcimandra cathcartii		8.09	1.28				
Alnus nepalensis					3.69	2.97	
Aucuba chlorascens		2.02					
Beilschmiedia roxburghiana		13.92					
Buddleja forrestii							4.26
Buddleja officinalis						2.57	
Camellia caudata			1.44				
Camellia crassipes		3.95					
Camellia forrestii	11.69		4.13				
Camellia sp1.		4.56	2.38				
Camellia tsingpienensis		25.69					
Camellia sp2.			6.52				
Castanopsis echidnocarpa		57.64	3.79				
Castanopsis wattii						4.89	
Cinnamomum subavenium							28.04
Clethra delavayi				15.13	19.96		18.11
Daphne papyracea	3.63						
Daphniphyllum himalaense		5.58	10.86				
Daphniphyllum paxianum					2.31		
Dichroa yunnanensis					1.42		
Elaeocarpus sp.		4.12	5.14				
Eriobotrya bengalensis				2.33			
Eriobotrya obovata			11.67				
Erythroxylum sinense		10.11	7.5				
Euonymus laxicymosus			5.8				
Eurya obliquifolia.		1.74					
Eurya oblonga		5.85					
Eurya sp.						7.52	
Eurya yunnanensis			7.94	2	7.9		
Gaultheria forrestii							3.07
Gaultheria fragrantissima					2.78		
Gaultheria leucocarpa					7.34		
Hartia sinensis			2.29				
Hydrangea aspera					1.43		
Ilex corallina			6.18	19.02			
Ilex sp.	5.1	5.99					2.07
Ilex szechwanensis	16.27	5.67		7.29	25.71		
Ilex wardii							8.39
Illicium macranthum	8.59	18.87	3.48		8.79		51.52
Kalopanax septemlobus	3.42						
Laurocerasus sp.							12.86
Lindera communis						11.96	
Lithocarpus crassifolius				75.67			
Lithocarpus hancei	8.66	3.49	8.38	7.68	42.65		
Lithocarpus hypoglaucus				3.72			43.86
Lithocarpus pachylepis			4.9				
Lithocarpus pachyphyllus						2.54	
Lithocarpus truncatus						54.27	
Lithocarpus variolosus	84.18					21.12	
Lithocarpus xylocarpus					2.92		
Litsea cubeba						5.57	
Litsea sericea					1.42		
Lyonia doyonensis				10.87	9.55		6.82
Lyonia ovalifolia	15.86		10.8	16.08	3.26		
Lyonia villosa						15.35	
Machilus gamblei		2.49	8.1				
Machilus viridis					1.44	2.55	
Magnolia delavayi					1.68		
Manglietia grandis			28.14				
Manglietia insignis		25.02					
Michelia floribunda		19.13					

Table 2 (Contd.)

Species	LRF	CAF	MRF	LPF	RLF	RLTF	ILF
Michelia wilsonii						2.9	
Microtropis discolor		10.72	5.77				
Myrsine seguinii		1.76	1.3				
Neocinnamomum caudatum		6.34					
Neolitsea chuii			10.45				
Neolitsea homilantha			9				
Neolitsea lunglingensis					1.42		
Osmanthus fragrans				2.57		2.67	20.99
Ostodes katharinae		2.79					
Phoebe forrestii					1.39		
Phoebe nanmu							2.28
Pieris formosa	6.88			15.96		13.7	2.07
Pinus armandi				4.05	2.95	2.73	
Rehderodendron gonshanense			23.56				
Rhododendron decorum	3.46		14.32				2.81
Rhododendron irroratum			6.95	50.69	85.6	10.21	
Rhododendron leptothrium						82.47	
Rhododendron microphyton				1.81	1.42	16.68	2.7
Rhododendron sinogrande	66.16						41.83
Rhododendron stamineum						22.13	
Rhododendron tutcherae			4.14				
Rhodoleia championii					2.36		
Rubiaceae sp.			1.58			5.4	
Salix daliensis	3.74						
Schefflera chinensis			16.08				
Schefflera delavayi				1.83			
Schefflera fengii	4.08	6.06	6.06	1.66	1.81		
Schefflera octophylla			1.46				
Schefflera shweliensis				4.2	5.88		22.07
Schima noronhae				1.66	7.09		
Schima wallichii			13.51				
Skimmia arborescens		9.04	3.38				
Sorbus aronioides				1.66			
Sorbus poteriifolia					2.72		
Stranvaesia davidiana				5.92	24.54		
Symplocos anomala				1.8			
Symplocos botryantha	15.32	1.73	14.69	7.07	3.03		11.08
Symplocos ramosissima			15.78				
Symplocos sp.		6.48					
Ternstroemia yunnanensis			3.5	3.96			
Tetracentron sinense.			1.34				
Tsuga dumosa						7.29	
Vaccinium duclouxii				20.96			
Viburnum cylindricum				1.66	8.11	2.51	9.24
Total	300.00	300.00	300.00	300.00	300.00	300.00	300.00

The sampling areas in each study site are 2,500 m^2

LRF: *Lithocarpus variolosus–Rhododendron sinogrande* forest; slope degree: 20–30; aspect: east. CAF: *Castanopsis echidnocarpa–Acer laxiflorum* forest; slope degree: 10–20; aspect: east. MRF: *Manglietia grandis.–Rehderodendron gonshanense* forest; slope degree: 15–25; aspect: west. LPF: *Lithocarpus crassifolius–Rhododendron irroratum* forest; slope degree: 20–30; aspect: west. RLF: *Rhododendron irroratum–Lithocarpus hancei* forest; slope degree: 20–30; aspect: southeast. RLTF: *Rhododendron delavayi–Lithocarpus truncate* forest; slope degree: 20–30; aspect: southwest. ILF: *Illicium macranthum–Lithocarpus hypoglaucus* forest; slope degree: 10–20; aspect: east

species, is almost impenetrable. The herbaceous layer is composed of *Ainsliaea henryi, Ophiopogon bodinier, Polygonatum nodosum*. The common liana species are *Holboellia latifolia, Tetrastigma henryi, Jasminum laurifolium*. The epiphytes are abundant and diverse. The common species are *Agapetes rubrobracteata, Lysionotus serratus, Oreocharis aurea and Elatostema monandrum*.

The *Manglietia grandis–Rehderodendron gongshanense* forest occurs in an upper montane region, above 2,400 m in altitude, in the Huangliangshan National Nature Reserve. *Manglietia grandis*, *Rehderodendron gonshanense*, *Schefflera chinensis*, *Rhododendron decorum* and five other species have IVI values more than 10. The undergrowth is composed mainly of the species *Pleioblastus amarus*. *Microtropis tetragona*, *Symplocos adenopus*, and *Rhododendron tutcherae* are other common shrub species. The herbaceous layer is mainly composed of *Carex perakensis*, *Ophiopogon bodinieri*, *Monachosorum henryi* and *Plagiogyria communis*. Liana species, such as *Tripterospermum pingbianense*, *Tetrastigma henryi* and *Stauntonia brunoniana* are recorded. The epiphytes are composed of *Agapetes rubrobracteata*, *Vaccinium sciaphilum*, *Vittaria flexuosa*, etc.

The *Lithocarpus crassifolius–Rhododendron irroratum* forest occurs in the Ailaoshan National Nature Reserve and was plotted at an elevation of approximately 2,600–2,700 m. The tree layer is 6–7 m tall and is dominated by *Lithocarpus crassifolius* and *Rhododendron irroratum*, which contribute 126.36 to the total IVI. The understory is dominated by *Sinarundinaria nitida* and *Yushania niitakayamensis*, which reach 1–2 m tall. In some plots, the bamboos almost disappear and the ground is covered by a deep moss mat. Common shrub species such as *Lindera supracostata, Heterosmilax chinensis* and *Gaultheria forrestii* were recorded. The herbaceous layer is composed of *Ainsliaea henryi, Carex perakensis, Ophiopogon bodinieri* and *Gentiana rigescens*. The lianas species are seldom found. *Tetrastigma henryi, Tripterospermum volubile* and *Euonymus vagans* are recorded. The epiphytes are rich with *Elatostema monandrum, Araiostegia perduran* and *Mecodium polyanthos*.

The *Rhododendron irroratum–Lithocarpus hancei* forest was plotted in the Wuliangshan National Nature Reserve. *Rhododendron irroratum* with an IVI of 85.60, is the predominant species. The shrub layer is sparse and is composed of juvenile tree species and shrub tree species such as *Heterosmilax chinensis* and *Sinarundinaria nitida*. The common herbaceous species are *Ainsliaea henryi, Dryopteris sublacera, Carex perakensis*. Liana species, *Schisandra neglecta, Tetrastigma henryi and Euonymus vagans* are recorded. The epiphytes are rich with *Lepisorus oligolepidus, Metapolypodium kingpingense, Araiostegia perdurans* and *Elatostema monandrum*.

The *Rhododendron delavayi–Lithocarpus truncatus* forest was plotted in the Daxueshan National Nature Reserve. The tree layer is mainly composed of Ericaceae and Fagaceae species such as *Rhododendron delavayi, Rhododendron stamineum, Rhododendron irroratum, Lithocarpus truncatus, and Lithocarpus variolosus*. The common shrub species are *Hypericum henryi*, *Gaultheria forrestii, Daphne papyracea* and *Viburnum foetidum*. There is a relatively dense herbaceous layer. *Carex perakensis, Fragaria nilgerrensis, Ainsliaea henryi and Gentiana rigescens* are common species. Common lianas are *Holboellia latifolia, Tripterospermum cordatum* and *Euonymus fortunei*. The epiphytes such as *Dendrobium moniliforme, Oberonia caulescens, Bulbophyllum odoratissimum* and *Lepisorus confluens* are recorded.

The *Illicium macranthum–Lithocarpus hypoglaucus* forest was plotted in the Sudian National Forest Area, which borders Burma. The study site has the highest elevation among the seven study sites. The tree layer is co-dominated by *Illicium macranthum, Lithocarpus hypoglaucus* and *Rhododendron sinogrande*. The shrub layer is mainly composed of juvenile tree species, and the common shrub species are *Gaultheria forrestii, Mahonia bracteolata, Viburnum foetidum* and *Symplocos poilanei*. The common herbaceous species are *Tupistra longipedunculata, Ophiopogon bodinieri, Viola cordifolia, Dryopteris wallichiana* and *Fargesia contracta*. The bamboos are less developed in this forest. Common Lianas are *Stauntonia brunoniana, Euonymus vagans* and *Lonicera ferruginea*. The common epiphytes are *Agapetes rubrobracteata, Pyrrosia* sp. and *Orchidaceae* sp.

Physiognomy

In a 2,500 m^2 sample area, the total number of vascular species varies from 57 to 110 in the different study sites (Table 3). The cloud forests are dominated by tree and shrub species (phanerophytes). There are few herb and aerophyte species. Parasitic species are rarely found.

In leaf size spectra, the plants with microphylls and nanophylls contribute to 44.3–63.5% of the total species (Table 4). Plants with an entire leaf margin account for more than 50% of the tree and shrub species. There are uncommon tree and shrub species with a drip tip leaf apex and papery leaves. Evergreen species make up more than 75% of the total tree and shrub species (Table 5). Liana species are rare in all of the forest communities.

Plant diversity

In a 2,500 m^2 sampling area, the total vascular species varies from 57 to 110 and the Simpson's index varies from 0.7719 to 0.9544, Shannon–Winner's diversity index from 1.8251 to 3.2905 and Pielou's evenness index from 0.5836 to 0.8982 for trees. Simpson's index, Shannon–Winner's diversity index and Pielou's evenness index (Table 6) are higher in the *Manglietia grandis–Rehderodendron gonshanense* forest and the *Castanopsis echidnocarpa–Acer laxiflorum* forest than in the other five forests. The *Lithocarpus variolosus–Rhododendron sinogrande* forest has the lowest Simpson's index and Species richness index, but the lowest Pielou's evenness index is in the *Rhododendron irroratum–Lithocarpus hancei* forest in the Wuliangshan National Nature Reserve.

Rank/abundance diagrams of species based on a 2,500 m^2 sampling area from each forest type are given in Fig. 2a–f. The species sequence curve of the *Rhododendron irroratum–Lithocarpus hancei* forest has a longer tail than that of the other forest types, indicating that there are more species with only one or two individuals in this forest type. The *Manglietia grandis–Rehderodendron gonshanense* forest has an almost straight line and a longer tail than that of the other forest types, indicating its high evenness.

Discussion and conclusions

Because of the mountainous topography, Yunnan has more cloud forests than any other province in China. They typically occur in a narrow altitude zone where the atmospheric environment is characterized by a nearly perennial cloudy, windy, and moist climate. Canopy trees usually exhibit gnarled trunks and branches and reduced

Table 3 Life form spectra of the seven forests

Forest types	Liana	Tree	Shrub	Herb	Aerophyte	Parasitic	Total
Lithocarpus variolosus–Rhododendron sinogrande							
No. of species	2	20	11	20	3	1	57
%	3.9	35.1	19.3	35.1	5.3	1.8	100
Castanopsis echidnocarpa–Acer laxiflorum							
No. of species	4	35	25	18	11	0	93
%	5.0	37.6	26.9	19.4	11.8	0.0	100
Manglietia grandis–Rehderodendron gonshanense							
No. of species	4	55	12	18	9	0	98
%	4.8	56.1	12.2	18.4	9.2	0.0	100
Lithocarpus crassifolius–Rhododendron irroratum							
No. of species	4	37	13	19	13	2	88
%	5.7	42.0	14.8	21.6	14.8	2.3	100
Rhododendron irroratum–Lithocarpus hancei							
No. of species	3	36	16	27	8	0	90
%	3.7	40.0	17.8	30.0	8.9	0.0	100
Rhododendron delavayi–Lithocarpus truncates							
No. of species	9	30	17	42	11	1	110
%	9.7	27.3	15.5	38.2	10.0	0.9	100
Illicium macranthum–Lithocarpus hypoglaucus							
No. of species	6	25	19	18	5	0	73
%	9.1	34.2	26.0	24.7	6.8	0.0	100

Table 4 Leaf size classes of the seven forests

Forest type	Lept.	Nano.	Micr.	Meso.	Macro.	Total[a]
Lithocarpus variolosus–Rhododendron sinogrande						
No. of species	0	0	33	18	1	52
%	0.0	0.00	63.5	34.6	1.9	100
Castanopsis echidnocarpa–Acer laxiflorum						
No. of species	0	1	38	49	0	88
%	0.0	1.1	43.2	55.7	0.0	100
Manglietia grandis–Rehderodendron gonshanense						
No. of species	0	3	40	47	0	90
%	0.0	3.3	44.4	52.2	0.0	100
Lithocarpus crassifolius–Rhododendron irroratum						
No. of species	2	3	37	33	1	76
%	2.6	4.0	48.7	43.4	1.3	100
Rhododendron irroratum–Lithocarpus hancei						
No. of species	0	1	43	39	0	83
%	2.7	1.2	51.8	47.0	0.0	100
Rhododendron delavayi–Lithocarpus truncatus						
No. of species	0	4	56	38	1	99
%	0.0	4.0	56.6	38.3	1.0	100
Illicium macranthum–Lithocarpus hypoglaucus						
No. of species	0	1	37	30	1	69
%	0.0	1.5	53.6	43.5	1.5	100

[a] Conifer and fern excluded
Lept. Leptophyll 0–25 mm^2, *Nano*. Nanophyll 26–225 mm^2, *Micr*. Microphyll 226–2,025 mm^2, *Meso*. Mesophyll 2,026–18,225 mm^2, *Macr*. Macrophyll 18,226–164,025 mm^2

tree stature. The cloud forests also have a high proportion of biomass as epiphytes (bryophytes, lichens, and ferns). Soils are wet and are frequently waterlogged. They have high organic content in the form of humus and peat (Wu 1987). In floristic composition, these forests are dominated by the following families: Fagaceae, Ericaceae, Vacciniaceae, Aceraceae, Magnoliaceae, Theaceae, Aquifoliaceae, Illicieae, Lauraceae, and Rosaceae.

These cloud forests were commonly called "top mountain dwarf mossy forest". It is a subtype of evergreen broad-leaved forest, found in Yunnan (Wu 1987). It is sometimes categorized as a "mountainous humid evergreen broad-leaved forest", a broader forest category that is more or less influenced by orographic rainfall (Liu et al. 2000). The term "top mountain dwarf mossy forest" was used by some Chinese authors to describe forests that are strongly influenced by clouds at tropical and subtropical mountain summits. The so-called "top mountain dwarf mossy forest" is dominated by Ericaceae species, and some of the forests are semi-evergreen (Zhu and Yang 1987). The "top mountain dwarf mossy forest" in Hainan province is composed of Fagaceae, Ericaceae, Theaceae, Myrsinaceae, Illiciaceae, Rosaceae and Symplocaceae species (Wu 1980). It is not only similar to the cloud forests in Yunnan in terms of floristic composition but also similar in physiognomy (Wu 1980).

The seven forest communities are physiognomically similar to the elfin woodland forests in tropical America (Beard 1944), and also are similar to the upper montane forest (cloud forest or mist forest, altitude 2,500–3,000 m)

Table 5 Leaf margins, leaf types and leaf habits of tree and shrub species from these seven forests

Forest type	Leaf margin		Leaf apex		Leaf texture		Leaf habit		Total species
	Entire	No-entire	Caudal	No-caudal	Leathery	Papery	Evergreen	Deciduous	
Lithocarpus variolosus–Rhododendron sinogrande									
No. of species	19	12	2	29	24	7	25	6	31
%	61.3	38.7	6.5	93.6	77.4	22.6	80.7	19.4	
Castanopsis echidnocarpa–Acer laxiflorum									
No. of species	30	30	8	52	39	21	51	9	60
%	50.0	50.0	13.3	86.7	65.0	35.0	85.0	15.0	
Manglietia grandis.–Rehderodendron gonshanense									
No. of species	44	23	6	61	48	19	57	10	67
%	65.7	34.3	9.0	91.0	71.6	28.4	85.1	14.9	
Lithocarpus crassifolius–Rhododendron irroratum									
No. of species	29	20	5	44	39	10	37	12	49
%	59.2	40.8	10.2	89.8	79.6	20.4	75.5	24.5	
Rhododendron irroratum–Lithocarpus hancei									
No. of species	34	18	3	49	38	14	41	11	52
%	65.4	34.6	5.8	94.2	73.1	26.9	78.9	21.2	
Rhododendron delavayi–Lithocarpus truncatus									
No. of species	27	18	2	43	36	9	34	11	49
%	60.0	40.0	4.4	95.6	80.0	20.0	75.6	24.4	
Illicium macranthum–Lithocarpus hypoglaucus									
No. of species	23	21	3	41	31	14	34	10	44
%	52.3	47.7	6.8	93.2	70.5	31.8	77.3	22.7	

Conifer, fern, aerophyte species and parasitic plant excluded

Table 6 Trees species diversity indices of the seven forest types

Forest types	D	H'	J	S
Lithocarpus variolosus–Rhododendron sinogrande	0.7719	1.8251	0.6583	16
Castanopsis echidnocarpa–Acer laxiflorum	0.9213	2.8166	0.8453	28
Manglietia grandis–Rehderodendron gonshanense	0.9544	3.2905	0.8982	39
Lithocarpus crassifolius–Rhododendron irroratum	0.8536	2.2837	0.6853	28
Rhododendron irroratum–Lithocarpus hancei	0.7545	2.0039	0.5836	31
Rhododendron delavayi–Lithocarpus truncatus	0.8325	2.1585	0.6983	22
Illicium macranthum–Lithocarpus hypoglaucus	0.8617	2.3307	0.7780	20

D Simpson species diversity index, H' Shannon–Wiener species diversity index, *J* Pielou evenness index, *S* species richness index

on Mt. Kenya in East Africa (Niemelă and Pellikka 2004). Similar forests occur in the Maliau Basin, Sabah (Borneo) at an altitude about 1,000 m (Jones 2000), Mt. Pulog, Philippines at 2,400–2,700 m (Buot-Jr and Okitsu 1999), John Crow Mountains above 950 m in Jamaica (Grubb and Tanner 1976), Island of Saint Lucia (Isaac and Bourque 2001), Oxaquic and Aquic Dystropepts, southern Ecuador, at altitudes from 2,100 m, up to 2,650/2,750 m (Bussmann 2001), Sierra de Luquillo at altitudes above 800 m (Kepler and Patkes 1972), east Malagasy, Madagascar, between 1,000 and 2,200 m (Hawkins 1999). The forest structure, floristic composition and physiognomy of the cloud forests in Yunnan more closely resemble the upper montane forest of Mount Kinabalu, Borneo (Aiba and Kitayama 1999). There are at least 17 plant families, which are common to the seven forest communities and the upper montane forest of Mount Kinabalu, Borneo. The forests, which were called top mountain dwarf mossy forests in Yunnan, are very similar to the mountain ericaceous forests in the Malay Peninsula (Peng et al. 2001; Wu 1987). The nomenclature of montane forests, including TMCF, is confusing. Stadtmüller (1987) has listed at least 35 different names that have been used to typify cloud forests. The wildly adopted broad definition of cloud forests is "forests that are frequently covered in clouds or mist". More or less "azonal" cloud forest types include: (1) lower montane forest (tall forest, little affected by low clouds except to nourish epiphytes); (2) lower montane cloud forest; (3) upper montane cloud forest; (4) subalpine cloud forest; and (5) lower–elevation dwarf (or "elfin") cloud forest. Following those classifications, two new classifications for the cloud forests of Yunnan should be added: "montane moist evergreen broad-leaved forest" and "montane mossy ever-green broad-leaved forest" (20–30 m tall). The seven forest communities that were studied could be suitably classified into the category of upper montane cloud forests.

Numerous literature indicated that the presence of Cyatheaceae is typical of tropical cloud forests. In the humid tropics, the distribution of cloud forests coincides to a very great degree, with the contiguous distribution of the Cyatheaceae (Stadtmuller 1987). In China, Cyatheaceae was recorded in Taiwan, Fujian, Hainan,

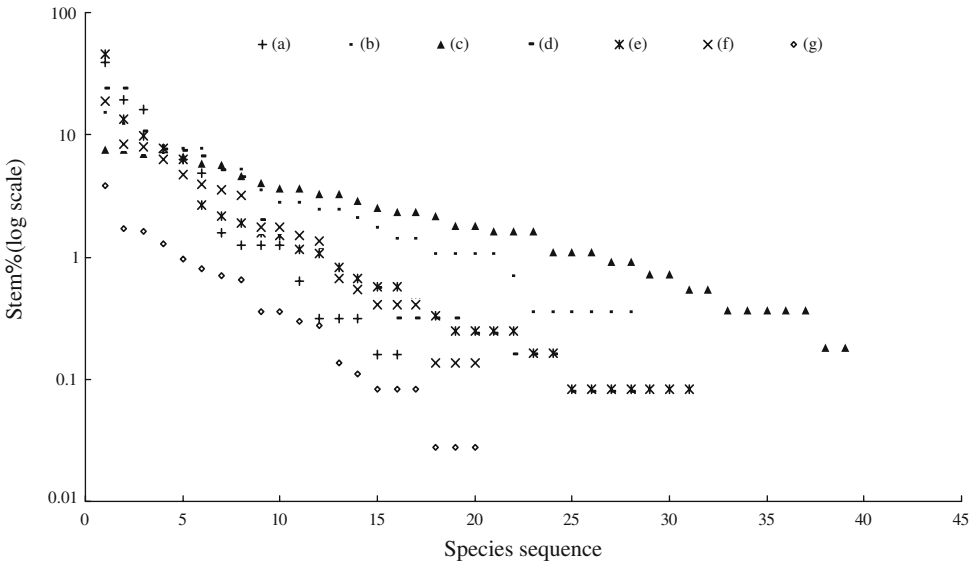

Fig. 2 Rank/abundance diagrams of tree species from seven forest types (a) *Lithocarpus variolosus–Rhododendron sinogrande* forest, (b) *Castanopsis echidnocarpa–Acer laxiflorum* forest, (c) *Manglietia grandis–Rehderodendron gonshanense* forest, (d) *Lithocarpus crassifolius–Rhododendron irroratum* forest, (e) *Rhododendron irroratum–Lithocarpus hancei* forest, (f) *Rhododendron delavayi–Lithocarpus truncate* forest, (g) *Illicium macranthum–Lithocarpus hypoglaucus* forest

Guangdong, Guangxi, Tibet, Guizhou, Sichuan, Yunnan (Zhang and Su 2005). In the seven study sites, there are also Cyatheaceae species, but not in our study plots.

Tropical mountain cloud forests are high on the list of the world's most threatened and least-studied ecosystems. It is widely believed that the majority of these forests that still remain are small areas of remnant fragments of the original extent (Aldrich et al. 1997; Still et al. 1999; Williams-Linera 2002). Many cloud forests occurred as an "island" of evergreen forest on mountain top or along ridges. Of all the types of tropical forest, tropical montane cloud forests are especially sensitive to global warming because the cloud base is expected to increase in altitude and consequently reduce mist, which will lead to the replacement of cloud forests by lower altitude ecosystems and the extinction of cloud forests currently found on mountain peaks where they are unable to spread upslope (Bubb et al. 2004; Hilbert et al. 2001). There is also evidence that regional land-use change can have a significant influence. Cloud forests possess the most abundant of epiphytes, and the climate change effects conspicuously first be seen in the epiphyte communities of cloud forests (Nadkarni et al. 2002). Climate change and land-use change in Yunnan have already been observed (Yang et al. 2005; You et al. 2005). The cloud forest of Yunnan mainly distributed on transit zone of North Tropic to South Subtropic, and it may be more sensitive to climate change and land-use change.

Due to the Massenerhebung effect or mass elevation effect (Foster 2001; Stadtmüller 1987) and influence of the Qinghai-Tibetan Highland, the altitude at which the cloud forest located descends from northwest to southeast. The top mountain dwarf mossy forest of Yunnan is mainly found from 2,400 to 3,000 m elevation and moss evergreen broad leaved forest been found from 1,800 to 2,600 m. It is climatically and biogeographically located at the northern edge of tropical Asia and briefly mentioned in some works, and also little known to the scientific community currently because of poor access to the region. Some of them have been well protected, especially those that are located in the nature reserve areas, but others are at great risk of being destroyed by the pressures of herd, fuel wood, and the development of the economy.

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