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Comparison of Secondary and Primary Forests in the Ailao Shan Region of Yunnan, China

STEPHEN S. YOUNG[1] and WANG ZHI-JUN

Institute of Ecology, Kunming Branch, Academia Sinica, Kunming, Yunnan (People's Republic of China)

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ABSTRACT

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In southern China, when the original broadleaf evergreen forest is destroyed, pines are generally the first secondary tree species to invade the site. In Yunnan Province (southwestern China), *Pinus yunnanensis* is the principal secondary tree species. We examined two different secondary pine stands, one on the eastern slope and the other on the western slope of the Ailao Shan (mountains) of Yunnan in the Xujiaba Nature Reserve. Data was collected to determine the structure and composition of secondary forests after the destruction of the primary broadleaf evergreen forest.

When compared, the primary broadleaf evergreen forest exhibits a much higher biodiversity and overall density than the secondary pine forests. When the two secondary stands are compared with each other, differences in structure and composition indicate that the Ailao Shans may produce a major climatic border between China's southwestern and southeastern monsoon systems. In addition, bird species were recorded in the stands and observations indicate that the Ailao Shans also mark a significant migratory border.

Yunnan is an important biological region in China because it harbors over 50% of the country's plant and animal species. The proper management and protection of Xujiaba and other Nature Reserves in the Province will help maintain Yunnan's biological wealth. The protection of forest cover will also minimize environmental degradation, such as soil erosion, which is being experienced in other developing regions. As China aggressively modernizes, forest management based on ecological data is vital in order to protect remaining forests and help develop a sustainable rural economy.

INTRODUCTION

The purpose of this study was to generate and analyze ecological data and use it toward the management of a nature reserve in southwestern China. The importance of using ecological data to manage forest ecosystems is at the heart of developing management strategies based on sustainability.

[1]Present address: 2 Seymour Court, Troy, NY 12180, U.S.A.

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With management concerns in mind, a joint survey was conducted by Chinese and American researchers during the autumn of 1986 to study the structure and composition of regenerating secondary forests that appear after the primary broadleaf evergreen forest is destroyed. The study was carried out by the Ecology Institute of the Kunming Branch of Academia Sinica (Chinese Academy of Sciences) at the Xujiaba Nature Reserve in the Ailao Shan (mountains) of central-west Yunnan (Fig. 1). The information generated from this study will be useful for the future management and conservation of Xujiaba. In addition, the data collected supports the theory that the Ailao Shans are a major climatic border between China's two principal monsoonal systems, the southwestern and southeastern monsoons, and a migratory border for birds.

Although much of China has lost its forest cover, southwestern China has been able to maintain some important healthy forests. Much of this region lies atop the high Yunnan-Guizhou plateau and is either mountainous or hilly. This rough topography has kept the population low by isolating the region from migrating populations, and thus has allowed the primary broadleaf evergreen forest to survive in a number of areas, particularly within Yunnan province.

Yunnan Province

Located in the far southwest, Yunnan Province resides in China's second most forested area after the northeast (Hsiung and Johnson, 1981). Unfortunately, these remaining forests currently face tremendous pressures because of recent increases in population as China aggressively modernizes. In the early 1950's, approximately 55% of the province was forested, yet by 1975 the forest cover had dropped to 30% and continues to decline (Smil, 1983).

Yunnan is bordered by Vietnam and Laos to the south and by Burma to the west (Fig. 1). The province is divided into two regions, the Eastern Yunnan Plateau, which is part of the Yunnan-Guizou Plateau and is located east of the Ailao Shans, and the Western Yunnan Valleyland, which is located west of the Ailao Shans. Similar to the famed Guilin area of southern China, the Eastern Plateau exhibits a spectacular karst topography of pinnacles, caverns and subterranean streams while the Western Valleyland consists of deep valleys and high mountain ranges, generally running northwest–southeast. The Ailao Shans provide the topographic border between these two geographic regions.

With an unequalled wealth of over 55% of China's animal species and over 50% of the country's plant species (Zheng, 1981; Anonymous, 1984), people in China nickname Yunnan the 'Kingdom of Plants and Animals'. Ranging from tropical rain forests in the south to the coniferous and high-alpine forests in the northwest, over 14 different forest ecosystems have been classified within the province (You, 1986). The sclerophyllous evergreen broadleaf forest and the associated secondary pine forest cover the majority of the province.

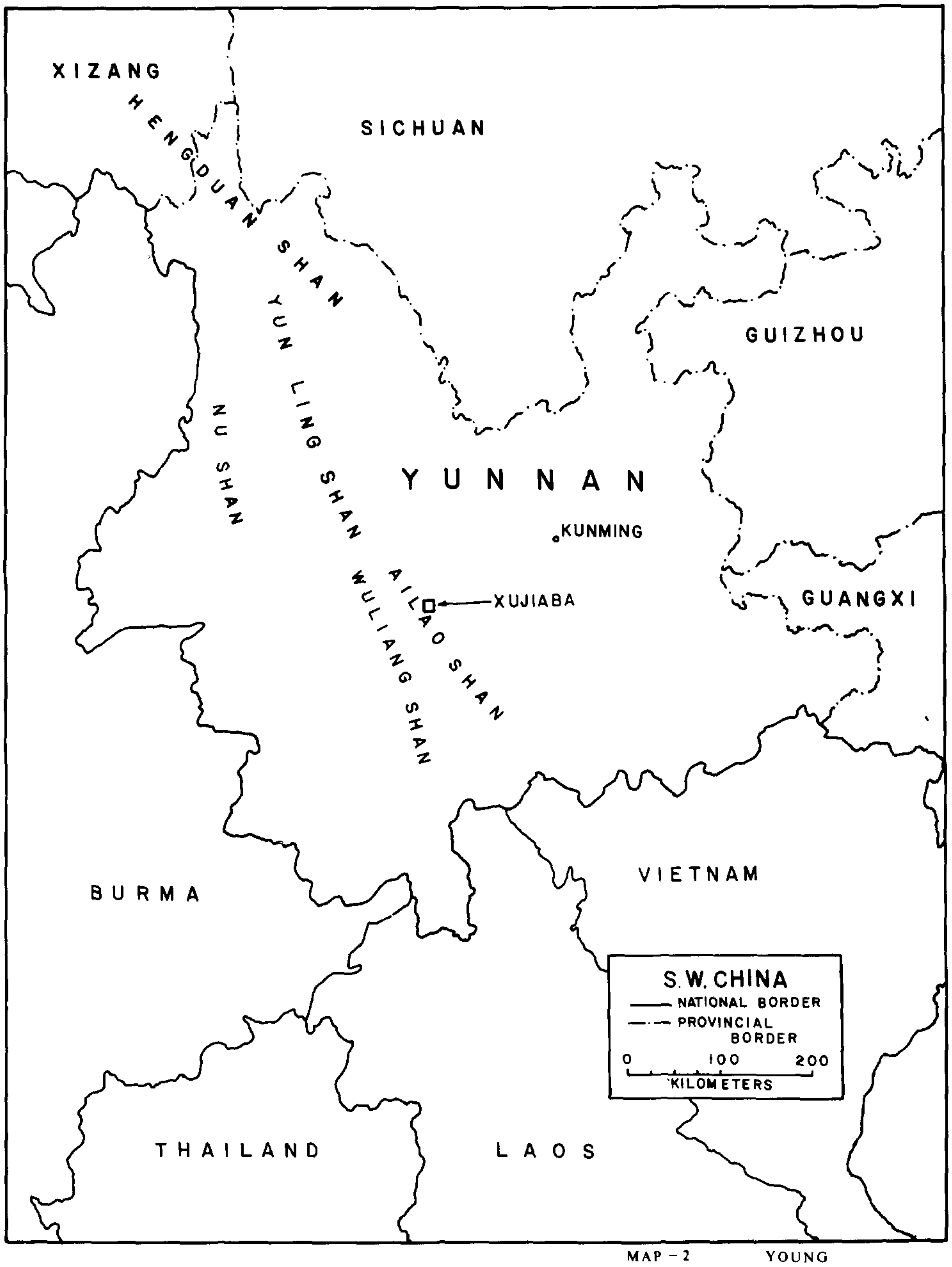

Fig. 1. Map showing location of study area in the Ailao Shan region.

The study area

Within the sclerophyllous evergreen broadleaf forest of central Yunnan a team of Chinese and American ecologists studied two secondary stands of Yunnan pine. The study was conducted at the Xujiaba Nature Reserve which covers 5100 ha on the northern crest of the Ailao Shans in Jingdong County, Yunnan (Fig. 1). Xujiaba consists of nine ecosystems with primary broadleaf evergreen forests covering 85–90% of the area (You, 1985).

Today, in the Xujiaba area, the mountainsides have been virtually stripped of their original vegetation leaving cropland (primarily rice and maize), pas-

Fig. 2. Looking towards the Western Valleyland from the western side of Xujiaba. Most of the slopes in the Ailao Shan region have been deforested and put into cultivation and pastureland with a few patches of secondary forest. Most of the primary forests can only be found on the crests of the mountains.

tureland and secondary forests on the slopes, with the primary broadleaf evergreen forest growing only on mountain crests (Fig. 2). When the primary broadleaf evergreen forests are cut down in this region, and throughout central Yunnan, *Pinus yunnanensis* is generally the first major secondary tree species to invade the site (C.-W. Wang, 1939, 1961; H.-W. Li, 1985; You, 1985). Adjacent to the broadleaf evergreen forests of Xujiaba on both the eastern and western sides, there exist scattered secondary forests of Yunnan pine.

Methods

The authors examined these secondary stands of Yunnan pine on both the eastern and western sides of Xujiaba. Site evaluation occurred in August (1986) and data was collected in October and November (1986) from eight 1-ha plots (four on each side of the mountain). In each 1-ha plot, 16 subplots (10 m×10 m) were established (Fig. 3).

In each subplot, data collected included: trees (⩾3 m): species, diameter at breast height (DBH), height, age, mortality; and shrubs (⩾1/2 m, <3 m): species and mortality. Within the subplots, all trees and shrubs were counted and recorded. In addition, the elevation, slope and exposure of all subplots were noted (Table 1). The choice of the eight 1-ha plots was based on close proximity to the natural broadleaf evergreen forests of Xujiaba.

The stands on both slopes showed signs of human interference, with evidence of some cut stumps and animal browse. Most of the secondary forests are managed with an occasional cutting. Herders also bring goats through the

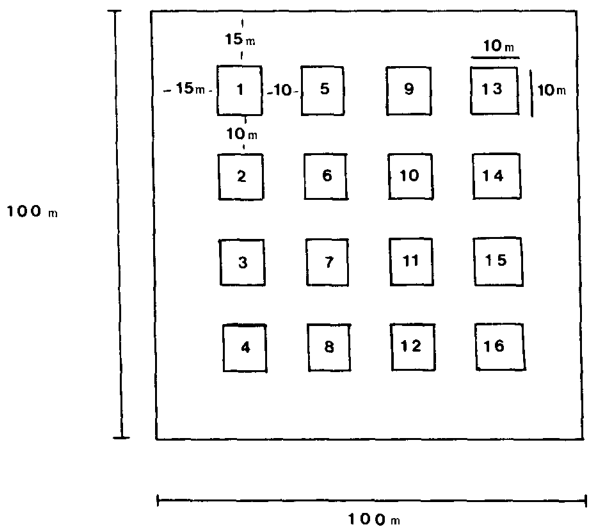

Fig. 3. Each of the eight 1-ha plots was divided into 16 subplots, as shown above. Subplots 1, 5, 9 and 13 were always on the uphill side with the highest elevation.

TABLE 1

Exposure and slope of subplots (degrees) and elevation (m)

	West plots				East plots			
	1	2	3	4	1	2	3	4
Exposure								
Average	200	215	190	210	150	185	130	165
Maximum	230	250	250	290	320	250	330	290
Minimum	160	170	150	120	20	80	20	70
Variation	70	80	100	170	300	170	310	220
Slope								
Average	20	15	20	25	15	10	20	30
Maximum	40	25	40	50	20	20	60	50
Minimum	15	5	10	5	5	5	5	15
Variation	25	20	30	45	15	15	55	35
Elevation								
Average	2285	2330	2370	2295	2370	2360	2365	2390
Maximum	2300	2360	2400	2300	2390	2380	2390	2400
Minimum	2260	2300	2340	2280	2340	2340	2350	2380
Variation	40	60	60	20	50	40	40	20

stands on their way to pastureland. The sites studied had a minimum of human interference and all of them experienced similar human use. No site was examined that had a severe human impact. The areas studied were once covered by evergreen broadleaf forest about 25–35 years ago, and all of the sites consisted of natural regeneration with no planting.

VEGETATIONAL ANALYSIS

Comparison of the primary and secondary forests

A total of 1.28 ha (12 800 m^2) of secondary Yunnan pine forest was intensively studied in the Ailao Shans, with 0.64 ha on the eastern slope and 0.64 ha on the western slope. The basic structure of the stands is typical of Yunnan province (Jiang, 1984; B. Li, 1984; Liu, 1984; Yang, 1984). *Pinus yunnanensis* dominated a mix of broadleaved evergreen species such as *Alnus nepalensis, Gaultheria forrestii, Lyonia ovaifolia* var. *lanceolata, Quercus aliena,* and *Castanopsis orthacantha* (Tables 2, 3 and 4).

The age of the pines averaged 17 years, with the oldest being 38 years. Height averaged 6 m with the tallest being 15 m, and DBH averaged 8 cm with a maximum of 95.5 cm. The pines exhibited good timber structure with round and

TABLE 2

Tree and shrub species present in the sample squares

A.	*Pinus yunnanensis*
B.	*Pinus kesiya* var. *langbianensis*
C.	*Pinus armandii*
D.	*Rhododendion delavayi*
E.	*Alnus nepalensis*
F.	*Alnus ferdinandi-coburghii*
G.	*Daphne cannabina*
H.	*Populus bonatii*
I.	*Camellia forrestii*
J.	*Vaccinium duclouxii*
K.	*Ternstroemia gymnanthera*
L.	*Gaultheria forrestii*
M.	*Machonia mairei*
N.	*Smilax ferox*
O.	*Yushania niitakayamensis*
P.	*Lyonia ovalifolia*
Q.	*Lyonia ovalifolia* var. *lanceolata*
R.	*Lithocarpus leucostachyus*
S.	*Quercus aliena*
T.	*Myrica rubra*
U.	*Myrica nana cheval*
V.	*Hypericum patulum* (possibly misidentified)
W.	*Aralia chinensis*
X.	*Polygala arillula*
Y.	*Castanopsis orthacantha*
Z.	*Craibiodendron yunnanensis*

Note: These are all of the arborescent species sighted in the subplots. The corresponding letters are used in Tables 3 and 4.

straight boles. Regeneration of *P. yunnanensis* occurred in 41% of the subplots surveyed. Regeneration was determined by examining the top right corner (25 m^2) of each subplot for 1- and 2-year-old *P. yunnanensis* seedlings. Although the stands in a few areas had closed canopies, in most cases they were open with a shrub layer and herbaceous ground cover. Except for a couple of places of thick hardwood shrub growth, the forest proved easy to walk through, with sunlight often penetrating to the forest floor.

A total of 26 arborescent species were recorded, with an average of 6 different species per subplot (100 m^2). When these secondary Yunnan pine forests are compared to the nearby primary broadleaf evergreen forests of Xujiaba, some very clear differences become evident.

The most comprehensive vegetational analysis of the Xujiaba Nature Reserve was carried out by You Chang-Xia (You, 1985). In his study he examined 41 subplots (20 m$\times$20 m) and recorded all of the plant species from herbs to

TABLE 3

West slope, 64 subplots (10 m × 10 m): Total number of stems and frequency; trees and shrubs

Species[a]:	A	B	C	D	E	F	G	H	I	J	K	L	M
Tree[b]													
Alive	264	16	14	43	64	0	1	5	2	20	7	0	9
Dead	11	1	0	0	0	0	0	0	0	0	0	0	0
Total	275	17	14	43	64	0	1	5	2	20	7	0	9
Shrub[c]													
Alive	97	15	14	175	29	8	0	48	2	40	56	640	26
Dead	11	0	0	0	0	0	0	0	0	0	0	0	0
Total	108	15	14	175	29	8	0	48	2	40	56	640	26
Frequency[d]													
Tree	47	8	6	15	28	0	1	3	2	2	5	0	0
Shrub	30	5	8	34	10	1	0	8	1	4	10	41	11
Total	57	10	11	43	30	1	1	8	2	4	10	41	12

[a]See Table 2 for species codes.
[b]Total number of trees: 920; alive: 906; dead: 14.
[c]Total number of shrubs: 2497; alive: 2486; dead: 11.
[d]Frequency is the number of subplots (out of 64) where the species were sited.

trees. Of the nine different ecosystems found in Xujiaba, the most extensive one is the primary *Lithocarpus* association which covers 75–80% of the Xujiaba region (You, 1985). In his survey, You studied 20 different subplots (each 20 m × 20 m) scattered throughout the *Lithocarpus* association. He recorded data from a total of 8000 m^2 of forest. Within the *Lithocarpus* association he found 97 different arborescent species from 69 different genera, with each subplot averaging 32 different species.

Comparing You's study to the Yunnan pine stands, it is evident that the primary *Lithocarpus* association has a much greater biodiversity than the secondary pine forest. Even though You's study covered a smaller area of forest (0.8 ha compared to 1.2 ha of Yunnan pines), You found over 3.5 times as many arborescent species.

Although the Yunnan pine stands and the *Lithocarpus* association are in close proximity and that the Yunnan pine stands regenerated from cut *Lithocarpus* forest, the two forest types do not share many arborescent species. Of the 26 species found in the Yunnan pine stands, only five of them (*Daphne cannabina, Camellia forrestii, Vaccinium duclouxii, Smilax ferox* and *Lyonia ovalifolia*) were also found in the rich forests of the nearby primary *Lithocarpus* association studied by You. Only an additional three genera (*Lithocarpus, Castanopsis* and *Rhododendron*) were also found in the *Lithocarpus* association.

In addition to the stark contrast in species diversity, the two forest ecosys-

N	O	P	Q	R	S	T	U	V	W	X	Y	Z
0	0	63	101	0	15	1	0	0	0	3	278	0
0	0	0	0	0	0	0	0	0	0	0	2	0
0	0	63	101	0	15	1	0	0	0	3	280	0
5	122	205	328	0	24	10	0	268	0	0	374	0
0	0	0	0	0	0	0	0	0	0	0	0	0
5	122	205	328	0	24	10	0	268	0	0	374	0
0	0	13	12	0	11	1	0	0	0	2	22	0
2	12	23	15	0	10	4	0	30	0	0	16	0
2	12	25	17	0	14	5	0	30	0	2	22	0

tems show great differences in cover and density. You's plots had an average cover of 98%, with the lowest being 95%, while the plots in the Yunnan pine forests rarely ever reached 50% and dropped as low as 5%. The differences in forest cover reflected the density. Looking at the total number of stems recorded and the per-ha average, the *Lithocarpus* forest (21 400 stems ha^{-1}) is over 20 times as dense as the Yunnan pine forest (1032 stems ha^{-1}) in the tree layer. The shrub layer is surprisingly similar, with 5655 stems ha^{-1} for the *Lithocarpus* association and 6030 stems ha^{-1} for the Yunnan pine stands. Unfortunately, You's (1985) study did not include information pertaining to DBHs or basal area. But, for the Yunnan pine stands, an overall basal area of 2668 m^2 ha^{-1} on the western slope and 642 m^2 ha^{-1} on the eastern side indicates that the stands are indeed quite open (Table 5).

The primary broadleaf evergreen *Lithocarpus* association grows as a thick forest with a dark and moist interior where sunlight rarely penetrates to the forest floor, while the nearby Yunnan pine stands are an open, park-like forest with sunlight often bathing the dry forest floor. These two forest types exhibit very few similarities and share few species, even though they grow in close proximity and the Yunnan pine forest developed where the *Lithocarpus* forest once stood (Figs. 4 and 5).

The principal tree species of the *Lithocarpus* forest association based on density and frequency include: *Lithocarpus xylocarpus, L. jindongensis, Castanopsis wattii, Schima noronhae, Vaccinium duclouxii, Hartia sinensis, Michelia floribunda* and *Rhododendron leptothrium* (You, 1985). The genera of *Lithocarpus* and *Castanopsis* are found in many broadleaf evergreen forests throughout Yunnan, though the exact species vary.

TABLE 4

East slope, 64 subplots (10 m×10 m): Total number of stems and frequency; trees and shrubs

Species[a]:	A	B	C	D	E	F	G	H	I	J	K	L	M
Tree[b]													
Alive	78	0	1	0	87	0	0	6	0	0	2	0	0
Dead	93	0	0	0	25	0	0	0	0	0	0	0	0
Total	171	0	1	0	112	0	0	6	0	0	2	0	0
Shrub[c]													
Alive	275	0	19	55	208	0	22	22	59	132	154	1860	0
Dead	497	0	0	2	23	0	0	0	0	4	0	0	0
Total	772	0	19	57	231	0	22	22	59	136	154	1860	0
Frequency[d]													
Tree	32	0	1	0	30	0	0	2	0	0	1	0	0
Shrub	43	0	6	12	33	0	3	8	8	8	16	49	0
Total	55	0	7	12	45	0	3	10	8	8	16	49	0

[a]See Table 2 for species codes.
[b]Total number of trees: 319; alive: 200; dead: 119.
[c]Total number of shrubs: 4751; alive: 4163; dead: 588.
[d]Frequency is the number of subplots (out of 64) where the species were sited.

Comparing the secondary stands

An important aspect of this study is that the authors examined secondary stands on both the eastern and western slopes of the Ailao Shans. As mentioned earlier, this mountain range forms the topographical border between the Eastern Yunnan Plateau and the Western Yunnan Valleyland. In addition, the mountain range is considered to be the principal border in Yunnan between the southwestern and southeastern monsoons (Qu, 1963; Zhang, 1963; Cheng, 1982; Ren et al., 1985; Zhang, 1985).

China's climate is strongly affected by monsoons, with marked changes of low and high pressure in summer and winter. The alternating monsoons with their northward and southward movements of moist and dry air masses have played a vital role in the formation and evolution of China's landscape and continue to be one of the most important factors affecting agriculture and forestry.

The southeastern monsoon carries water inland from the Pacific Ocean, while the milder southwestern monsoon delivers water from the Indian Ocean. Western Yunnan and southeastern Tibet are affected by the southwestern monsoon while the rest of China is influenced by the southeastern monsoon (Ren et al., 1985). To the east of Ailao Shan a vast plateau opens up, while to the west, tall mountain ranges appear. The Ailao Shans form a climatic border by effectively

N	O	P	Q	R	S	T	U	V	W	X	Y	Z
0	0	0	17	4	0	0	0	0	0	0	0	5
0	0	0	0	0	0	1	0	0	0	0	0	0
0	0	0	17	4	0	1	0	0	0	0	0	5
0	85	0	772	33	0	138	84	59	2	0	0	194
0	0	0	41	0	0	19	0	0	0	0	0	2
0	85	0	813	33	0	147	84	59	2	0	0	196
0	0	0	5	2	0	1	0	0	0	0	0	3
0	2	0	44	5	0	18	8	10	1	0	0	10
0	2	0	44	6	0	18	8	10	1	0	0	10

TABLE 5

Basal area (m^2 ha^{-1}) and density (no. ha^{-1}) of the Yunnan pine stands

	All trees		Yunnan pines	
	Basal area	Density	Basal area	Density
West				
Total recorded for all 64 subplots:	1708	920	692	275
Average (no. ha^{-1})	2668	1438	1081	430
East				
Total recorded for all 64 subplots:	411	319	327	171
Average (no. ha^{-1})	642	498	511	267

blocking cold polar air masses from moving west from the open plateau. An understanding of this monsoonal border in Yunnan will aid in the reforestation of the region by identifying appropriate species for the different climatic conditions.

When comparing the Yunnan pine stands on both sides of the mountain range, the most significant finding was a large number of dead Yunnan pine trees on the eastern slope (Fig. 6) and the lack of mortality on the west. During the spring of 1986, Yunnan province experienced an unusually cold period,

Fig. 4. Area of gap regeneration in the primary *Lithocarpus* forest in Xujiaba on the northern crest of the Ailao Shans. This area is the most open region of the *Lithocarpus* forest.

Fig. 5. Lunch break in the secondary Yunnan pine forest on the western side of Xujiaba. This is the most closed (dense) area of the secondary Yunnan pine stands on the western and eastern sides of Xujiaba.

Fig. 6. Dying Yunnan pines on the eastern slope of Ailao Shan.

caused by a polar continental air mass coming from the north through the southeastern monsoon. This cold spell was responsible for the death of Yunnan pine trees in different parts of the province. This die-off provided an unusual situation where it was possible to study the relative extent of the southeastern monsoon in Yunnan province. By studying the Yunnan pine stands on the eastern and western sides, the study attempted to help define Yunnan's principal border between the two monsoonal systems.

No signs of fire, insects or other infestations were evident in the pine stands. The death of other tree species shows that it was not a species-specific die-back which is often caused by insects or disease. The only other ecological study to be carried out in the pine stands on the eastern side was done by You Cheng-Xia (You, 1985). In his study there were no references to a die-back among Yunnan pine trees. Local residents near Xujiaba all claim that the trees started to die after the cold spell.

The data collected (Tables 2, 3 and 4) indicate that the eastern slope did experience a significant die-back compared to the western slope, although both stands are only 6 km apart and both are adjacent to the crest where the primary broadleaf evergreen forests of Xujiaba thrive. The east experienced an overall die-back of 37% of the trees and 12% of the shrubs, while the west had a die-back of 1.5% of the trees and 0.4% of the shrubs. On the east, three different tree species experienced death, the most significant being *P. yunnanensis* with a 54% die-off and *Alnus nepalensis* having a 22% die-off. On the west, *P. yunnanensis* had a 4% die-off and two other tree species experienced die-offs of 6 and 0.7%. From the point of view of the shrub layer, on the east, *Pinus yunnanensis* led the way with a die-off of 64% followed by *Myrica rubra* at 13%, while on the west, *P. yunnanensis* had a die-off of 11% in the shrub layer.

In addition to differences in mortality, the composition of the stands varies, with the east having a lower biodiversity and greater dependency on a few dominant trees. Of the nine species found in the tree layer on the east (dead as well as live stems), the top five species (*P. yunnanensis, A. nepalensis, Lyonia ovalifolia* var. *lanceolata, Populus bonatii, Craibodendron yunnanensis*) make up 97% of the total number of stems found in the sample squares, with the top two having 89%. On the western slope, of the 17 different tree species found, the top five (*Castanopsis orthacantha, P. yunnanensis, Lyonia ovalifolia* var. *lanceolata, A. nepalensis* and *L. ovalifolia*) make up 85% of the total number of stems recorded, with the top two making up only 60%.

Considering the basal area of the dominant species and the overall basal area of the study plots (Table 5), again the eastern side shows a heavier reliance on a few species. On the east, *P. yunnanensis* (alive and dead) accounts for 78% of the total basal area while on the west it accounts for only 40% of the total.

The two Yunnan pine stands exhibited similarities in age, elevation, slope and soils. They are both near the broadleaf evergreen forests and are about 6 km apart. The only significant difference between the two stands, other than a possible leeward effect and differences in exposure (only about 90° because both the eastern and western stands face in a southerly direction — see Table 1), is that one is on the eastern crest of the Ailao Shans and faces the Eastern Plateau while the other stand is on the western crest and faces the Western Valleyland. The differences in structure and mortality that are found when comparing the two sites indicates that there is a difference in climate. However, specific climatological studies must be performed to truly determine the climatic border. The ecological data only indicates the presence of a significant climatic divide.

Comparison of bird populations

Not only do the tree species show a difference between the eastern and western pine stands, but the birds who inhabit the stands also show a clear difference. Over a period of 8 days in November (1986) ornithological observations were made in Yunnan pine stands on both the western and eastern sides of the Ailao Shans. Four days were spent on each side with a total of 25 h of observation time on each slope. The regions used for the vegetational analysis were the same areas used for the bird sightings. The study focused on identifying the species and only after a bird was positively identified was it recorded.

TABLE 6

Species of birds sighted in the Yunnan pine stands

Western slope

R: *Accipiter virgatus affinis*
R: *Glaucidium cuculoides rufescens*
W: *Jynx torquilla chinensis*
R: *Motacilla alba alboides*
R: *Anthus sylvanus*
R: *Coracina novaehollandiae siamensis*
R: *Pericrocotus ethologus yvettae*
R: *Pericrocotus brevirostris affinis*
R: *Lanius cristatus cristatus*
R: *Lanius schach tricolor*
R: *Cossa erythrorhyncha erythrorhyncha*
R: *Troglodytes troglodytes talifuensis*
W: *Tarsiger cyanurus rufilatus*
R: *Phoenicurus frontalis*
R: *Saxicola torquata przewalskii*
R: *Turdus dissimilis*
R: *Monticola solitaria pandoo*
R: *Pomatorhinus erythrogenys odicus*
R: *Pomatorhinus ruficollis albipectus*
R: *Garrulax ellioti*
R: *Garrulax affinis saturatus*
R: *Garrulax squamatus*
R: *Garrulax sannio comis*
R: *Garrulax poecilorhynchus ricinus*
R: *Garrulax albogularis albogularis*
R: *Minla cyanuroptera wingatei*
R: *Alcippe cinereiceps manipurensis*
R: *Heterophasis melanoleuca desgodinsi*
R: *Yuhina occipitalis obscurior*
R: *Paradoxornis webbianus styani*
R: *Rhipidura albicollis albicollis*
R: *Rhipidura hypoxantha*
R: *Parus monticolus yunnanensis*
R: *Aegithalos concinnus talifuensis*
R: *Sitta magna ligea*
R: *Sitta yunnanensis*
R: *Certhia himalayana yunnanensis*
R: *Aethopyga saturata petersi*
R: *Aethopyga gouldiae dabryii*
R: *Aethopyga nipalensis koelzi*
R: *Zosterops palpebrosa siamensis*

R: Resident; T: Traveler; W: Winter migrant.

TABLE 7

Species of birds sighted in the Yunnan pine stands

Eastern slope	
R:	*Streptopelia orientolis agricola*
W:	*Jynx torquilla chinensis*
R:	*Dendrocopos major stresemanni*
W:	*Dendrocopos hyperythrus subrufinus*
R:	*Dendrocopos canicapillus obscurus*
R:	*Cissa erythrorhyncha erythrorhyncha*
R:	*Nucifraga caryocatactes macella*
W:	*Prunella immaculata*
W:	*Tarsiger cyanurus rufilatus*
R:	*Saxicola torquata przewalskii*
R:	*Turdus dissimilis*
R:	*Pomatorhinus erythrogenys odicus*
R:	*Pomatorhinus ruficollis albipectus*
R:	*Garrulax sannio comis*
W:	*Accipiter nisus nisosimilis*
W:	*Dendronanthus indicus*
R:	*Alcippe cinereiceps manipurensis*
W:	*Motacilla cinerea robusta*
R:	*Parus monticolus yunnanensis*
R:	*Aegithalos concinnus talifuensis*
R:	*Sitta yunnanensis*
R:	*Certhia himalayana yunnanensis*
T:	*Zosterops erythropleura*
R:	*Carduelis ambigua ambigua*
T:	*Emberiza aureola aureola*
R:	*Emberiza cia yunnanensis*
W:	*Emberiza pusilla*

R: Resident; T: Traveler; W: Winter migrant.

Looking at bird species sighted in the Yunnan pine stands (Tables 6 and 7), a higher diversity of species is found once again on the western slope. A total of 41 different species was observed on the western slope (Table 6) and 27 on the eastern slope (Table 7), with 13 species being common to both. Besides the higher diversity of species on the west, the type of species was also different. On the western slope, 95% of the birds are considered residents of the area and 5% are winter migrants. On the eastern slope, 62% are residents, with 30% winter migrants and 8% traveling through on their winter migration. Classification of the species as resident, migrant or traveling through was based on years of bird observations made throughout the northern regions of the Ailao Shans (Wang, 1986; Wang et al., 1987).

The larger migratory population on the east is a function of topography; the eastern slope opens up to a wide and vast plateau, while the western slope opens to a region consisting of deep valleys and tall ridges. Thus, the eastern slope is more accessible for migratory birds from the north. This difference is significant when considering that the sites are only about 6 km apart. The Ailao Shans create not only a topographic and climatic border, but also a migratory one. Even with the higher influx of migratory birds, however, the diversity and number of species still remains less on the eastern side.

Of particular interest was the sighting of the tropical species *Pericrocotus ethologus yvettae* and *P. brevirostris affinis* only on the western slope. Their presence on the western side indicates a warmer climate, and reinforces the theory of the western slope being influenced by the milder southwestern monsoon. Both these species are found on the western and eastern slopes during the summer months (though greater in number on the west), but only on the western slope during other times of the year (Wang et al., 1987). These two species are common to Yunnan's tropical regions and are known to migrate north to the Ailao Shan region in the summertime.

CONCLUSION

This study represents an important step in the management and conservation of Yunnan's forest ecosystems, by developing an integrated approach to forest ecology research, by using ecological data to quantitatively compare primary and secondary forests, by increasing the ecological data base of the Xujiaba Nature Reserve, and by helping to define a principal ecological border in Yunnan.

A vital aspect of this study is the style in which it was undertaken. This study was an interdisciplinary look at Xujiaba's ecology. The investigators looked at the bird population as well as the tree composition of secondary forests. Then, the resulting data were compared with data from another forest type to support important management conclusions. In addition to using the data to study the forest ecosystem, it was also used to look at climatic and migratory patterns. While this is standard ecological methodology, it is not often followed in Yunnan. Research is typically very intense but narrow, with only a little interdisciplinary work. The various natural sciences must work together as in this study and share information if Xujiaba and other natural forest ecosystems are to be well protected and managed.

Of principal concern for the management of Xujiaba is the result of the comparison between the secondary forest and the primary forest. This paper demonstrates that the primary *Lithocarpus* association of Xujiaba has a greater species diversity and is denser than the associated secondary pine forests of Xujiaba, which illustrates the need to protect the remaining primary forests in order to preserve species diversity and forest cover. Yunnan harbors over half of China's plant and animal species, and it is the primary forests that maintain this wealth. Thus, a key management objective is the conservation of the primary vegetation.

Since 1980 the Xujiaba region has been recognized as an important natural area. In 1983 a research station was constructed within the Reserve and ecologists began to intensively study the forests of Xujiaba. As more and more data is collected and analyzed, a better understanding of the forest will emerge, and from this knowledge the Nature Reserve can be more effectively managed. For example, as shown in this study it is most important (from the standpoint of biodiversity) to preserve the primary forest. With additional ecological information, a hierarchy of importance within the whole Nature Reserve can be developed and management priorities established. Eventually a hierarchy within the entire Province must be developed, so that management and conservation priorities reflect the needs of the larger broadleaf evergreen forest biome, not just the isolated reserves.

An important aspect of Xujiaba and many natural areas in Yunnan is their use by humans. Currently there are a number of extractive practices going on in Xujiaba. Thus, it is imperative to accelerate ecological research in order to incorporate a utilization priority list into the management hierarchy. The most sensitive areas (areas of rare plant species, endangered wildlife habitat, etc.) must be effectively monitored and protected while the more common forest types should be utilized.

Such practices as the collection of medicinal herbs, resins, oils, building materials, fodder, foods and fuelwood should continue in forests that can sustain these uses. More intensive practices should be carried out in the secondary forests that surround the primary forests of Xujiaba. Managed for production, these secondary forests could ease the pressure on the primary forests. In addition, there are several areas of deforested marginal land that are no longer in forest and are not being utilized agriculturally. Plantations of economically important species should be established in these marginal areas to relieve pressure on the primary forests.

In the protection of Xujiaba it is important to show how a standing forest can provide a livelihood for local people and thus encourage them to maintain the forest cover. All too often the forest is closed to human use, and people develop the notion that to make an economic livelihood the forest must be cut down. As mentioned above, the forests can supply many products, as well as indirect benefits which provide ground cover for catchment areas, soil erosion protection, climate modification, windrows, wildlife, and tourism.

A conservation program that does not take into consideration human needs is bound to fail eventually, especially in Yunnan where 87% of the population lives in rural areas (Liang, 1983). There are a number of documented cases of successful sustainable uses of the natural forest ecosystem (Chernela, 1982; Heltne, 1982; Boom, 1985; Myers, 1986). There is also a growing database on the ethnobotanical uses of forest plants (Duke, 1980; Balick, 1984; Pei, 1985), and such research should be accelerated. These uses must be encouraged and studied in areas where absolute protection is not necessary.

This study's vegetational analysis, bird sightings and other reports indicate that the Ailao Shans form an important border (topographic, climatic and migratory) in Yunnan. The success of reforestation lies in finding economical species to grow in a suitable climate and thus the knowledge of climatic borders is very important. In addition, the development of regional natural areas must take into consideration the migration of certain species so that habitats may be protected in both winter and summer areas. More studies are needed to precisely map this principal ecological border as well other major borders throughout Yunnan.

The broadleaf evergreen forest biome in China is the country's richest and potentially most productive (Anonymous, 1982), yet also one of the most abused ecosystems (Smil, 1984). Through an ecological understanding of the system, strategies can be developed and policies established which can tap the productivity and diversity of the forest ecosystem so that both humans and forest can survive and prosper. This biome has great potential to help China successfully modernize while maintaining a healthy ecosystem.

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