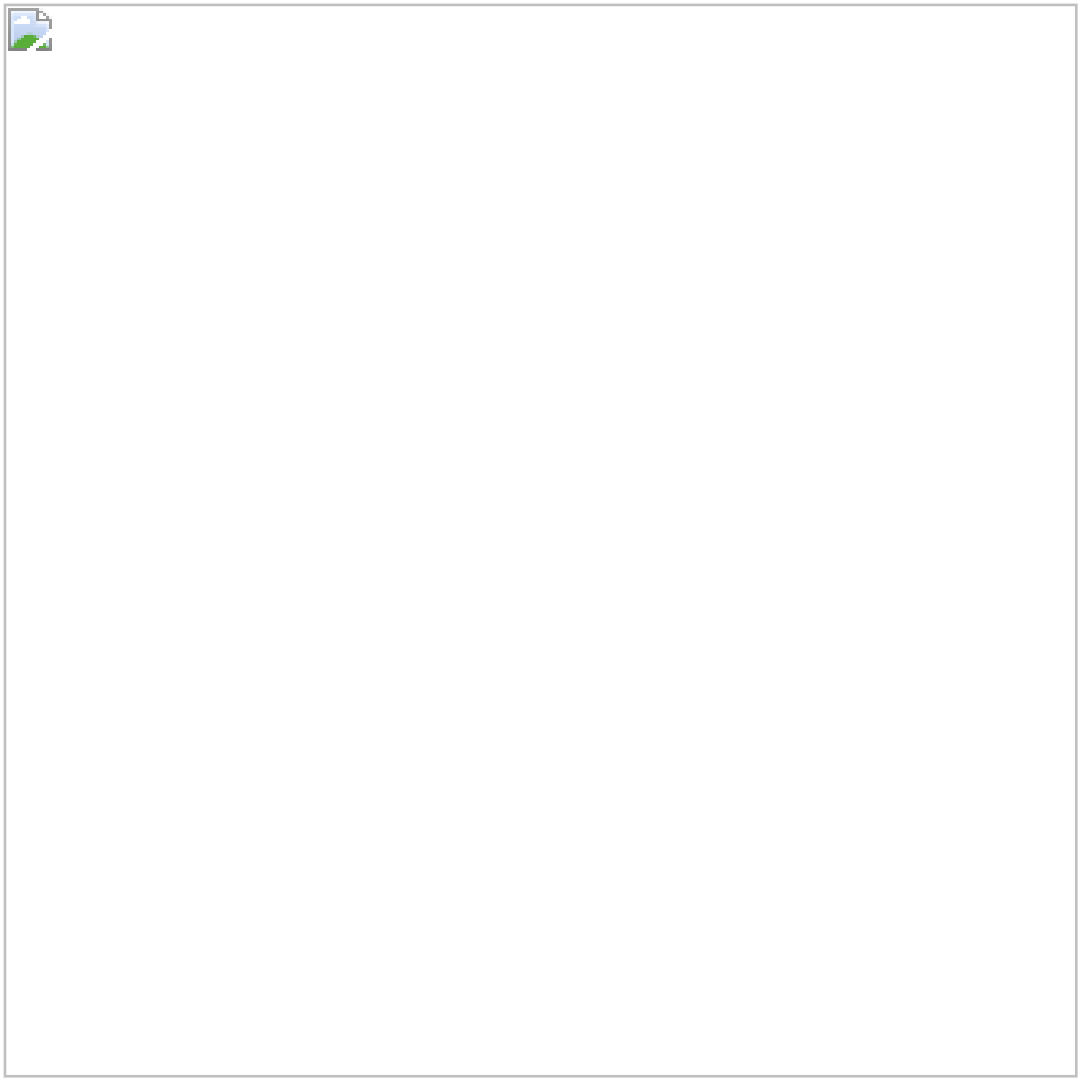

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The Effect of Forest Tenure on Forest Composition in a Miao Area of Guizhou, China

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Guizhou Province is one of the most expansive and important forest regions in China. Traditional Miao people have inhabited the mountains and managed the forest resources of this region for more than 1000 years. In the 1980s, the Chinese government transferred many collectively owned forests to individual household control. Since then, there have been 3 forest tenure types in Miao areas: state forests, collective forests, and household forests. The Collective Forest Tenure Reform was implemented nationwide starting in 2005, and in Guizhou in 2007, to develop and stabilize the forest tenure institutions. To investigate the effect of tenure type on the floristic composition and size structure of local forests, we conducted inventories in replicate forests under each type of tenure in 3 traditional Miao villages in Leishan County. Results showed that tree species richness and diversity were significantly higher in state and collective forests than in household forests; no significant differences were detected among villages. Cunninghamia lanceolata*, an important local timber species, was most abundant in household forests, while higher proportions of associated broadleaf and pine species were recorded in state and collective forests. The lack of significant differences between state and collective forests for most measurement variables suggests that the inherent similarities between these 2 tenure types created by long-term use and management by the Miao have largely overshadowed the effects of more recent management efforts by the state. Each tenure regime offers different benefits, and a portfolio including all 3 tenure types would best provide the ecosystem services and economic opportunities required by forest-dependent communities.*

Keywords: Cunninghamia lanceolata; *forest tenure; forest composition; Guizhou Province; Miao; China.*

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Introduction

Over the past few decades, there has been a growing global effort to better develop sustainable forest management. China has rich biodiversity in its forest ecosystems, but both its forest area per capita and forest cover are below the world average (State Forestry Administration of China 2014). The limited forest resources in China are distributed unevenly. Almost half of the forests are in the southwest and northeast, where most ethnic minority groups reside (Li 2004), including the Miao and Dong people in Guizhou Province, the Dai and Akha people in Yunnan Province, and the Li people in Hainan Province (Davies and Wismer 2007; Sturgeon 2010; Song 2013).

In China in the 1980s, like in many developing countries, state control of forests failed to manage land efficiently (Mayers and Bass 1999; White and Martin 2002). Since the 1980s, the major trend in Chinese forest governance has been toward decentralization, gradually shifting forest management from the government to individual households (Agrawal et al 2008). Other forested nations such as India and Nepal have also reformed forest tenure (Agrawal and Ostrom 2001; Liu 2001). Local community or private forest management by minority people has been recognized as a potential approach for achieving forest sustainability (Wiersum 1997; Pagdee et al 2006).

Guizhou Province was one of the first areas affected when the Chinese government started to implement forest tenure reform for minority people in the early 1980s. With more than 8 million hectares of forest and an average forest cover of 49% (Government of Guizhou 2015), it is one of the most expansive and important forest regions in China. These forests have been used, managed, and conserved by traditional Miao people and their ancestors for more than 1000 years, and currently about half of China's Miao people live in small, isolated settlements in the steep mountain forests in the southeastern part of the state. Historically, the relationship between the Miao and the forests of Guizhou has been characterized by migrations, resettlement, civil unrest, malaria outbreaks, and periodic forest burning by government armies (Jenks 1994; Elvin 2004). Through it

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all, the Miao tended their rice fields, harvested timber to build their houses, collected forest fruits and medicinal plants, and consistently enriched local forests and fallows by planting useful trees species, including *Cunninghamia lanceolata*, a particularly valuable timber tree (Menzies 1988). These low-level yet long-term silvicultural treatments by Miao communities have had a major impact on the forests of Guizhou.

Since the establishment of the People's Republic of China in 1949, government policies related to land tenure and forest management have shifted several times (Richardson 1990; Zhang et al 2000). Perhaps the most influential of these was the Three Fixes policy of 1981, which encouraged private-sector participation in forest management and granted greater rights to individual farmers. This reform converted collective forests to 2 new tenure arrangements: freehold mountain land and contract mountain land. Under the freehold arrangement, farmers could obtain use rights to the land and ownership of trees they planted on it. Under the contract arrangement, they could obtain use rights by signing a contract with a village committee (State Council of China 1981). Both freehold and contract mountain land correspond to what is referred to in this article as household forests. Before the Three Fixes policy, about 42% of China's forests were owned by the state and the remainder were collectively owned. By 1986, management of about 70% of the collectively owned forests had been transferred to individual households (Wang et al 2004; Xu and Jiang 2009).

To ensure the stability and constancy of the previous reform, the central government called for nationwide Collective Forest Tenure Reform in 2005 and started to implement it in Guizhou in 2007. This reform clarified individual households' rights to use and benefit from household forests, which provided incentives to households to manage forests and improve their livelihoods (Sturgeon 2007; He 2012).

The Three Fixes policy and Collective Forest Tenure Reform led to 3 types of forest tenure in China (State Council of China 1981; Yeh 2000; Démurger et al 2009):

- State forests, where both ownership and use rights are held by the central, provincial, prefectural, or county government (Yeh 2000);
- Collective forests, where ownership and use rights are held by local communities; and
- Household forests, which remain collective property but in which individual households have use rights and ownership of trees and forest resources (State Council of China 1981; Démurger et al 2009).

Each tenure type is governed by a specific set of management prescriptions. The management of state forests follows national policies and regulations issued by the Ministry of Forestry and by nature reserve offices; collective forests are managed by a village committee according to local rules or customary law, and benefits and returns are shared by the community or used for collective public goals (Zuo and Chai 2006). Household forests are managed by households according to the needs and aspirations of the family. Rural villages in China today exhibit various combinations of these 3 forest tenure types based on the number of households present at the time the policy was implemented (Long and Zhou 2001).

In 1998, there were serious floods along the Yangtze River. These were caused by many factors, chief among them deforestation in upper Yangtze watersheds (Zong and Chen 2000), which had greatly increased soil erosion and reduced the water storage capacity of local soils (He and Jiao 2000). After the floods, the State Council of China announced that it would take drastic action to protect and restore natural forests (State Council of China 1998). Cutting of natural forests was forbidden in the upper reaches and on both sides of the Yangtze River; this included Guizhou Province (Shi and Zhang 1998). The natural forests around Miao villages in Leishan were almost all state and collective forests. Rules from the nature reserve office, as well as customary village laws, had already prohibited cutting in state and collective forests. This government announcement strengthened the logging ban, which helped protect state and collective forests in Miao areas.

The forest tenure changes created by the Three Fixes policy and Collective Forest Tenure Reform are the most recent in a long series of shifting political conditions and management contexts confronted by Miao communities in Guizhou. What effect has the increasing degree of control by individual households over management activities had on local forests? Are household forests treated the same as collective forests? How do these 2 differ from neighboring state forests? Perhaps most importantly, what do the current floristic composition and size structure of forests under different tenure arrangements near Miao villages suggest about the future of Guizhou's forests?

To address these questions, we conducted inventories in state, collective, and household forests in 3 traditional Miao villages in Leishan Country. Our basic objective was to assess the impact of land-tenure change on forest structure and the diversity of local tree species.

Methods

Site description

Leishan County (107°55′–108°22′E, 26°02′–26°34′N) extends more than 1218.5 km^2 in the Qiandongnan Miao and Dong Autonomous Prefecture of Guizhou Province in southwest China. The region is characterized by steep mountains and plunging river valleys, with the highest elevation of 2178.8 m found on Leigongshan Mountain. The climate is subtropical monsoon, with average

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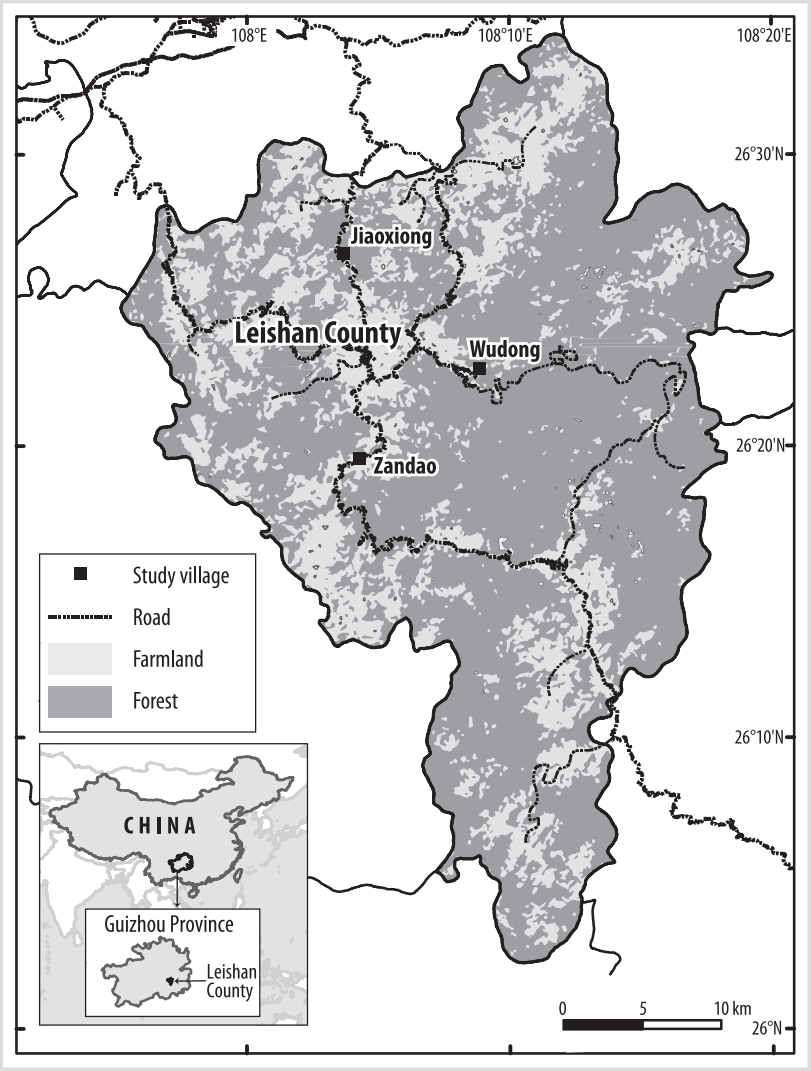
FIGURE 1 Location of the study villages. (Map by Yin Jin and Hannah Stevens)



temperatures of 14–15°C and a mean annual rainfall of 1375 mm. Local forests range from high-elevation alpine scrub to mountain evergreen–deciduous mixed forest and low-elevation evergreen broadleaf forest (Chen 2001).

We conducted forest inventories in 3 Miao villages in Leishan County: Wudong, Zandao, and Jiaoxiong (Figure 1). Each of the villages has representative examples of state forests, collective forests, and household forests. All of the villages are inhabited by the Long Skirt Miao, who are distinguished by their dialect and dress. The women of the Long Skirt Miao, for example, typically wear colorful, long, embroidered skirts (Diamond 1995). The village of Wudong is 350 years old and is composed of 108 families and about 470 people. It has 28.2 ha of agricultural land and 1155 ha of forest land, of which 213 ha is collective forest and the remaining 942 ha is household forest. Zandao has a 400-year history and contains 170 families and about 720 people. There are 49 ha of agricultural land and 736 ha of forest land in Zandao, of which 267 ha is collective forest and the remaining 469 ha is household forest. The third village, Jiaoxiong, is 400 years old and has 126 families and about 400 people. Jiaoxiong has 76 ha of agricultural land and 434 ha of forest land, of which 44 ha belong to the collective and 390 ha are household forest.

Data collection and analysis

We sampled 27 inventory transects—9 in each village, consisting of 3 each in state, collective, and household forests. Transects were located in representative tracts of forest of known history with the help of local forestry staff, village elders, and selected householders. Each transect was 10 m wide and 100 m long (1000 m^2) and

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divided into five 10×20 m (200 m^2) plots; all transects were corrected for slope (Peters 1996). Within each plot, all trees ≥5.0 cm in diameter at breast height (DBH) were measured for diameter and identified as to species with the help of botanists from the Guizhou Academy of Forestry and the Leigongshan Nature Reserve; nomenclature followed Chen (2004). All transect data were collected from May to July 2013.

Size-class histograms showing the distribution of the number of stems of *C. lanceolata* and the number of stems of all broadleaf and pine species were constructed for each forest tenure type; similar histograms were plotted for basal area totals. Two measures of species diversity were derived from the transect data—the Simpson index (Simpson 1949) and the Shannon-Wiener function (Peet 1974)—and the different tree species recorded in each forest tenure type were ranked based on importance values (Cain and Castro 1959), calculated using the density, basal area, and frequency of each taxa.

One-way analysis of variance was used to examine the relationships among tree density, total basal area, number and percentage of *C. lanceolata* trees, species richness (number of tree species per 1000 m^2), and species diversity (the Simpson index and the Shannon-Wiener function) in relation to forest tenure. A series of Tukey's Honestly Significant Difference tests were performed to evaluate the group differences among the transect means of each parameter grouped by village ($n = 3$) and forest tenure type ($n = 9$).

Results

Forest structure

The results of the one-way analysis of variance showed that tree density per transect was not significantly different among villages or forest tenure types (Table 1). Basal area per transect was also not significantly different among collective, state, and household forests, although significant differences ($P < 0.05$) were found among villages for collective forests. Both the number and the percentage of *C. lanceolata* trees, however, varied significantly ($P < 0.05$) among forest tenure types but not among villages. *C. lanceolata* density (total number within a given area) and relative abundance to other species (percentage) were highest in household forests, followed by state forests and then collective forests.

Tree species diversity and richness

Tree species diversity varied significantly between both tenure types and villages ($P < 0.05$), but there were no significant differences among villages within a single tenure type (Table 1). Both the Simpson index and the Shannon-Wiener function showed significant differences among tenure types but not among villages. The Simpson index showed collective forests had the most tree species diversity, followed by state forests and then household forests. The Shannon-Wiener function showed significantly lower diversity in household forests but no significant differences between state and collective forests.

With regard to species richness, the number of tree species per transect was significantly lower in household forests than in state and collective forests; no significant difference was found between state and collective forests in terms of the number of tree species.

Size distribution

The diameter distributions of the trees in all 3 types of forest tenure exhibited a greater number of individuals in the smaller size classes than the larger classes; that is, they conform to a negative exponential or inverse-J distribution (Figure 2). In both state and collective forests, the proportion of *C. lanceolata* stems varied from class to class, with higher percentages characteristically occurring in the larger-diameter (≥20 cm DBH) classes; the smaller classes were dominated by broadleaf and pine species. In household forests, numbers of *C. lanceolata* far exceeded those of other tree species in all diameter classes.

The distribution of basal area by diameter class was essentially bell shaped for all 3 tenure types, with the distribution of *C. lanceolata* basal area in household forests skewed slightly toward the smaller (≤20 cm DBH) classes. In terms of total basal area, forests under all 3 types of tenure were dominated by trees of 15.0–30.0 cm DBH, with most diameter classes containing more *C. lanceolata* than broadleaf or pine tree basal area. Although *C. lanceolata* presented higher basal areas than all other tree species in every tenure regime, this pattern was especially notable in household forests, where *C. lanceolata* predominated in all basal area classes.

Species ranking

The tree species recorded in each forest type were ranked based on their importance value (Table 2). *C. lanceolata* was ranked highest in state and collective forests, followed by *Pinus massoniana* and *Fagus longipetiolata;* the latter 2 species exhibited importance values that are about a third of that calculated for *C. lanceolata*. This pattern of dominance was even more pronounced in household forests, where *C. lanceolata* displayed an importance value almost twice that of the other 2 tenure types. *P. massoniana* was ranked second in household forests, followed by *Betula luminifera* and *F. longipetiolata*.

Discussion

When forest tenure was decentralized throughout China 30 years ago, relationships among local communities and forest management patterns in minority regions dramatically changed (Démurger et al 2009). Evidence

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TABLE 1 Density, basal area, species richness, and diversity by forest tenure type and village.

	State forests			Collective forests
	Wudong	Zandao	Jiaoxiong	Wudong
All trees[a]				
Density (per 1000 m^2)[b]	155.0[c]	137.0[c]	95.0[c]	186.3[c]
Basal area (m^2/1000 m^2)[b]	4.09[c]	2.48[c]	2.20[c]	3.78[c]
Species richness (per 1000 m^2)*	15.7[c]	12.7[c]	7.7[c]	21.0[c]
Simpson index**	0.59[c]	0.48[c]	0.52[c]	0.71[c]
Shannon-Wiener function**	1.66[c]	1.25[c]	1.18[c]	1.91[c]
***Cunninghamia lanceolata* trees**[a]				
Density (per 1000 m^2)**	44.3[c]	87.3[c]	56.0[c]	80.7[c]
Relative abundance (%)**	32.6[c]	65.2[c]	51.5[c]	47.6[c]

TABLE 1 Extended.

	Collective forests		Household forests		
	Zandao	Jiaoxiong	Wudong	Zandao	Jiaoxiong
All trees[a]					
Density (per 1000 m^2)[b]	148.7[c]	118.0[c]	95.3[c]	137.7[c]	156.7[c]
Basal area (m^2/1000 m^2)[b]	1.85[c]	2.41[c, d]	2.04[c]	3.05[c]	2.29[c]
Species richness (per 1000 m^2)*	15.7[c]	4.0[c]	7.7[c]	2.0[c]	4.0[c]
Simpson index**	0.61[c]	0.43[c]	0.29[c]	0.11[c]	0.32[c]
Shannon-Wiener function**	1.60[c]	0.73[c]	0.72[c]	0.20[c]	0.60[c]
***Cunninghamia lanceolata* trees**[a]					
Density (per 1000 m^2)**	47.3[c]	59.7[c]	72.7[c]	128.3[c]	127.0[c]
Relative abundance (%)**	38.8[c]	50.3[c]	78.2[c]	93.5[c]	80.4[c]

[a]Values shown are averages calculated from three 1000-m^2 transects sampled in each forest type at each village.
[b]NS, not significant.
[c, d]Values followed by the same letter are not significantly different from one another (Tukey's Honestly Significant Difference test, $P < 0.05$).
*$P < 0.1$; **$P < 0.05$.

shows that these changes led to a more balanced approach to sustainable forest management for ethnic minority peoples (Nepal 2002). For instance, studies have shown that tenure change has improved the environmental and socioeconomic conditions of the Li people in Hainan (Davies and Wismer 2007). Another case study in Yunnan Province suggested that decentralization of forest management contributed to better forest governance and reforestation over the past few decades by increasing forest cover, with associated increases in the productivity and efficiency of minority households (Xu and Ribot 2004). Our study found a similar pattern for the Miao people of Guizhou.

Two points in particular should be kept in mind when reviewing the transect data from Guizhou. First, all sample communities are at least 350 years old. Miao villagers have been farming, planting trees, and interacting with local forests for a long time, and all of the forest tenure types examined were essentially created from the same original forest type. Both state and collective forests were delineated in landscapes that the Miao have been consistently using for hundreds of years, while household forests are relatively recent (35 years old), created from collective forests. Irrespective of the current tenure regime, all forests were shaped by the same people, who were manipulating the

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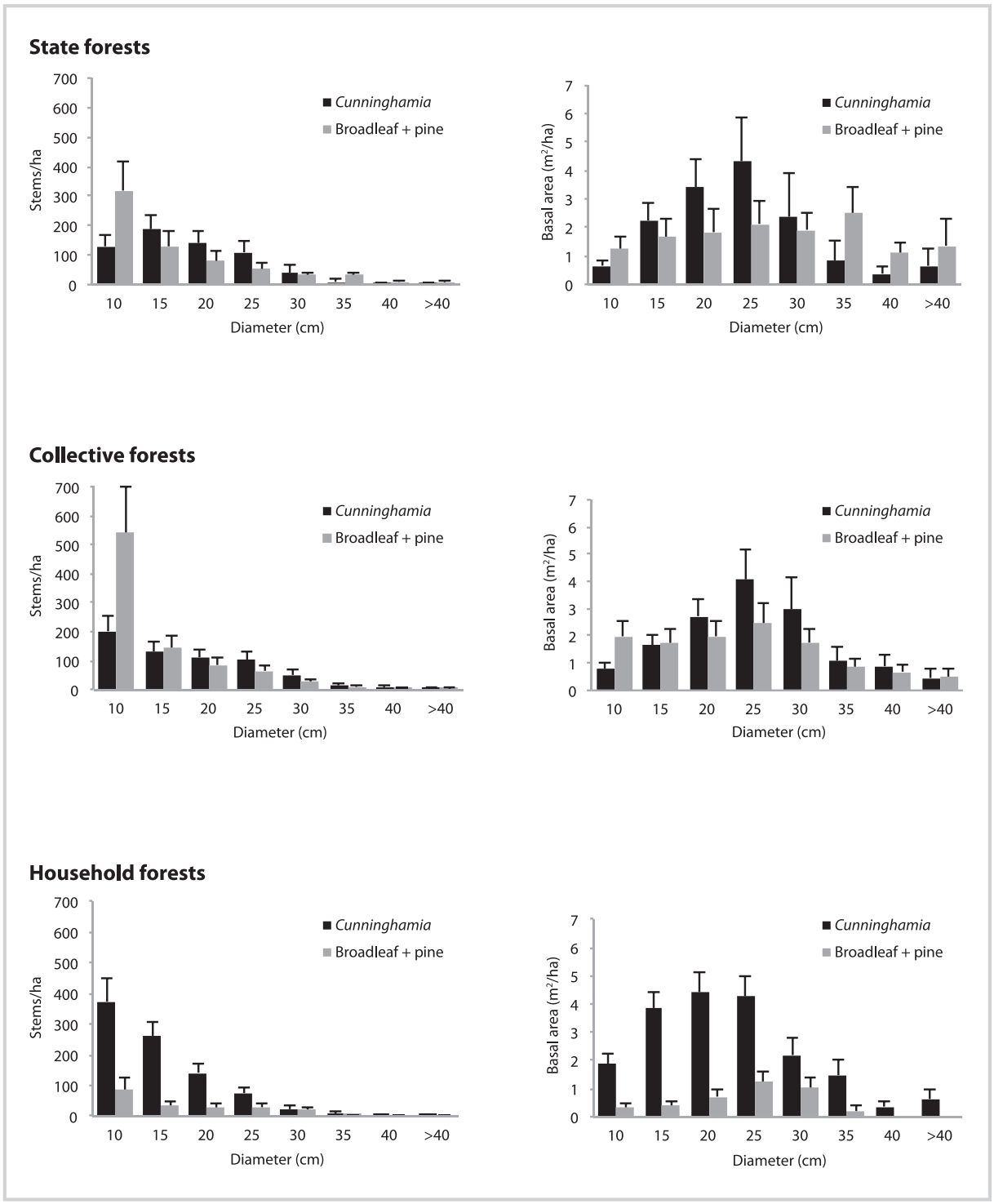
FIGURE 2 Size-class distributions of *C. lanceolata* trees and broadleaf and pine trees in the study villages. Class totals represent mean values and standard errors from 9 inventory transects.



same tree species with the same overall management outlook.

Second, the lack of significant differences at the village level for almost all measurement variables suggests, at least partially, that all communities are doing much the same thing with their forests. In those forests where Miao communities have only minimal interaction—state forests—the structural and floristic similarities created by

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their long-term use seem to largely overshadow the effects of more recent management efforts. Given the distinct differences in both tenure and intended uses of household, collective, and state forests in general, it is surprising there were not more significant differences in species composition and structure. Forests across all tenure types are remarkably homogeneous, with no dramatic differences in size-class distribution. None of the forests showed a dramatic difference in age classes, and there was little evidence of newly regenerating forests or young plantations.

Of particular interest in this regard is the abundance of *C. lanceolata* in all forest tenure types. This endemic conifer, known locally as *shamu,* is one of the most important timber species in China (Menzies and Tapp 2007). The species has a number of desirable properties—such as good form, fast growth, and durable yet workable wood—and it sprouts easily after cutting (Fung 1994). It is easily propagated by seeds, coppicing, or cuttings, and it is the most commonly planted timber species in the mountains of southern Hunan, Guizhou, Guangxi, and Fujian Provinces (Menzies 1988). Miao villagers prefer its wood for building houses and making furniture, coffins, and agricultural tools; the bark is used to roof small outbuildings; and the occasional sale of *shamu* logs provides a welcome source of revenue.

A final *C. lanceolata* characteristic of note is that the species occurs as scattered populations in mixed deciduous and evergreen broad-leaved forest (Richardson 1990) and is not known to occur naturally in high-density aggregations (Chandler 1994). That said, the densities of *C. lanceolata* trees (≥10.0 cm DBH) recorded during our inventories of collective forests and state forests in the vicinity of Miao villages were 443 and 873 trees per hectare, respectively. Given the extreme value and utility of this species, its long-term proximity to human settlements, and the demonstrated management capabilities of the Miao, it seems clear that these forests, even those under state control, have been notably enriched with *C. lanceolata* trees for several centuries.

In comparing state forests and collective forests, few significant differences were encountered in our measurement variables. The overall density of trees in all of these forests was essentially the same, as was tree size (basal area), the number of tree species recorded, and both the number and the percentage of *C. lanceolata* stems (Table 1).

These results may seem somewhat surprising, because the regulations governing forest use in each tenure type are dramatically different. Tree harvesting in state forests is tightly controlled, and villagers are not allowed to fell trees in these areas. In collective forests, however, while forest-related activity requires prior approval by the village council, villagers can fell, thin, prune, and plant trees in these areas as necessary to maintain forest productivity and supply the timber needs of the village. However, the application process for a felling license is complicated and usually takes a long time. The number of trees that can be cut with each license is also small (Lu and Xue 2011). Therefore, there was no big difference between state forests and collective forests in tree cutting.

Furthermore, Miao people have long protected forests as part of their cultural traditions, viewing ancient forests or big trees in particular locations as feng shui forests or divine trees, which they believed could bless their villages (Coggins et al 2012). Feng shui forests and divine trees were mostly found in state and collective forests. There have been traditional customary laws to conserve these forests in Miao areas since ancient times; they still play an important role and are, in many cases, even more effective than central government rules (Yu 2006; Luo et al 2015). The management of state and collective forests was—and still is—largely influenced by local customary laws.

For the preceding reasons, both management frameworks, one centralized and the other community based, seem to be producing similar forests, although the latter maintains a broader representation of broadleaf and pine species and a larger number of *C. lanceolata* trees in the smaller size classes (Figure 2). The large number of *C. lanceolata* stems says a lot about the management skills of Miao villagers and bodes well for the future value, utility, and continued existence of collective forests. The higher percentage of pines and broadleaf trees in collective forests is largely the result of the greater number of *P. massoniana* trees maintained, introduced, or both by Miao villagers (Table 2). This pine, although less desirable than *C. lanceolata,* is also fast growing, produces useful timber, and is a source of commercial resin (Wu and Raven 1999).

At the level of household forests, the main differences among tenure types are most apparent. Although these forests exhibit tree densities and basal areas similar to those of collective and state forests, their species richness and diversity, as measured by both the Simpson index and the Shannon-Wiener function, are significantly less, and the density and relative abundance of *C. lanceolata* trees are the highest of any forest tenure type (Table 1 and Figure 2). Based on the importance values of the constituent species (Table 2), household forests are essentially all 30-year-old plantations of *C. lanceolata* and *P. massoniana* that were planted at the same time, as soon as the law allowed household forests to exist. Freed from the constraints of community consensus and resource sharing, Miao householders, not surprisingly, have opted to maximize the economic value of the forests under their control.

Management implications

What do these differences suggest about the future of the forests in Guizhou? Leishan County, where the study

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TABLE 2 Density, basal area, frequency, and importance value of the 10 most important species in each forest type. (Table 2 continued on next page.)

Rank[a)]	Species	Density (stems/ha)	Basal area (m^2/ha)	Frequency	Importance value
State forests					
1	*Cunninghamia lanceolata*	625.6	14.9	33	0.382
2	*Pinus massoniana*	87.8	4.2	17	0.096
3	*Fagus longipetiolata*	54.4	1.2	17	0.053
4	*Sassafras tzumu*	43.3	1.8	10	0.047
5	*Liquidambar formosana*	45.6	1.2	14	0.046
6	*Rhododendron lapponicum*	73.3	0.9	5	0.037
7	*Cyclobalanopsis glauca*	52.2	0.7	8	0.033
8	*Castanopsis eyrei*	46.7	0.6	7	0.030
9	*Carpinus viminea*	23.3	0.5	8	0.024
10	*Betula luminifera*	17.8	0.3	8	0.020
Collective forests					
1	*Cunninghamia lanceolata*	625.5	14.7	40	0.373
2	*Pinus massoniana*	201.1	5.7	29	0.153
3	*Fagus longipetiolata*	98.9	1.1	10	0.049
4	*Carpinus viminea*	50.0	0.8	16	0.041
5	*Weigela florida*	76.7	0.2	11	0.034
6	*Betula luminifera*	47.8	0.3	14	0.032
7	*Castanopsis eyrei*	56.7	0.6	6	0.028
8	*Rhododendron stamineum*	55.6	0.3	8	0.026
9	*Rhus chinensis*	47.8	0.3	9	0.026
10	*Liquidambar formosana*	22.2	0.5	10	0.025
Household forests					
1	*Cunninghamia lanceolata*	1093.3	21.1	45	0.710

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TABLE 2 Continued. (First part of Table 2 on previous page.)

Rank[a)]	Species	Density (stems/ha)	Basal area (m^2/ha)	Frequency	Importance value
2	*Pinus massoniana*	113.3	3.3	22	0.145
3	*Betula luminifera*	35.6	0.2	3	0.022
4	*Fagus longipetiolata*	7.8	0.1	4	0.017
5	*Myrica rubra*	10	0.1	2	0.010
6	*Pinus armandii*	4.4	0.1	2	0.009
7	*Cerasus duclouxii*	2.2	0.1	2	0.008
8	*Sassafras tzumu*	2.2	0.1	2	0.008
9	*Daphniphyllum macropodum*	3.3	0.1	2	0.008
10	*Weigela florida*	2.2	0.1	2	0.007

[a)]For each forest type, species are ranked according to their importance value. Values shown are based on nine 1000-m^2 transects sampled in each tenure type; nomenclature is based on Chen (2004).

villages are located, exhibits an average forest cover of 70% and is one of the most forested regions in the province (Government of Guizhou 2015). All of these forests, however, are not the same. State forests do a good job of maintaining the existing structure and composition of local forests, while collective forests are better at maintaining the regeneration of broadleaf species and increasing stocking levels of *C. lanceolata*. As local markets, population densities, and resource demands continue to increase within the remote mountain habitats occupied by the Miao, household forests will undoubtedly play an increasingly important role in local livelihoods.

Our results suggest that an appropriate balance should be maintained among different forest tenure regimes in the region. No forest type—state, collective, or household—can by itself provide the full array of ecosystem services, subsistence and commercial resources, and economic opportunities required by local populations. A greater appreciation of the role of the original Miao inhabitants in maintaining and enriching the forests of Guizhou would also be useful, as well as further study of the management systems and land-use practices, both historical and current, that have created the forested landscape that we see today.

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