18 The Spatial and Temporal Dynamics of Land Use in Xizhuang Watershed of Yunnan, Southwest China

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Abstract

This paper documents the impacts of state-driven reforestation on land use, land cover, and the livelihoods of upland farmers in Xizhuang watershed, southwest China. An analysis of aerial photographs and ASTER satellite imagery from 1987 and 2002 showed that the area of forest has significantly increased and the amount of farmland has decreased. The monocultural reforestation of pine has had serious biophysical and socioeconomic consequences. This case study shows that the government's forestry agency and the local government authority have been implementing decisions for forest plantation and conservation that affect peoples' livelihoods with little local participation.

Introduction

Land use and land cover changes have been extensively researched (Lambin et al. 2001, Verburg 2000). These studies show that forests are rapidly decreasing as the area of cultivated land increases both worldwide and in China. For example, deforestation is estimated to have caused the loss of 1.16 billion hectares of forest worldwide while the area of farmland has increased by about 1.24 billion hectares in the past 300 years (Lambin et al. 2001). However, many areas experience forest transitions when economic development stimulates a decline in forest cover and later, through feedback processes, there is often a recovery in forest cover. A number of scientists (Rudel et al. 2005, Mather 1990, McNeely 2003, and Zhang et al. 2000) have assessed the potential of forest recovery for biodiversity conservation, the sequestering of carbon, and other environmental benefits. Increased afforestation can adversely effect agricultural intensification. Lambin et al. (2000) state that long-term population growth and economic development usually do not take place without the growth of agricultural production.

Forest ecosystems provide important environmental goods and services for local farmers and off-site and lowland dwellers. This case study analyses the underlying dynamics of land use change at the micro-watershed level as a contribution to the development of policies on conservation. It explores the spatial and temporal dynamics of land use in the Xizhuang watershed from 1987 to 2002. It addresses the questions of:

- where does forest recovery happen and at what rate does land-use change progress?
- what drives local afforestation?
- what are the social consequences of forest recovery to local communities? and
- what are local people's coping strategies for such forest transition?

The Xizhuang Watershed

The Xizhuang watershed lies 20 km to the northwest of Baoshan city in the western part of Yunnan province (Figure 18.1). It covers 3,437 ha and is a sub-catchment of the Nujiang river (Salween river). Its elevation ranges from 1750 to 3100 masl. It is located in the southern Hengduan Mountains. The climate in the foothills is subtropical and temperate in the mountain areas. The average annual precipitation is 1013 mm with clearly defined dry and wet seasons. The main soil type is red soil (Li and Sha 2002). The natural vegetation is semi-moist broadleaf forest that disappeared many decades ago and has been replaced by coniferous forest with a mix of alder (*Alnus nepalensis*).

The main settlement in the area is Damaidi village. Most farmers plant two crops per year with maize in the summer and wheat or barley in the winter. Tea is the traditional cash crop.

Xizhuang watershed covers the whole of the administrative villages of Lijiashi and Qingshui, and part of another village. The total population of the watershed is 4,273 with a population density of 124/km^2 in 2002. Population growth and urbanisation in nearby Baoshan has increased the importance of the Xizhuang watershed for the supply of water for agricultural, domestic, and industrial use. A drinking water company is located downstream and a cement factory also relies on water from this watershed. An irrigation canal provides crucial irrigation for Banqiao township. The Baimiao reservoir also has a water intake from the Xizhuang watershed.

Materials and Methods

The authors integrated socioeconomic and spatial information collected from household interviews, participatory social mapping, land use mapping, and a policy review.

Spatial data

Table 18.1 shows the land types found in the Xizhuang watershed according to the classification system adopted in 2002 by the Chinese Land Resources Ministry.

Spatial database — A spatial database was developed using aerial photographs taken in February 1987 at a scale of 1:40,000 by the Yunnan Land Survey Bureau. These were digitally scanned and geo-referenced, data was segmented in e-Cognition by using 'Segmentation' with the parameter of default 10. (Segmentation is the subdivision of an image into separated regions to automatically extract the desired objects of interest in an image for a certain task.) After the polygons were extracted, they were manually interpreted to delineate land cover categories and projected into Transverse Mercator projection (Krasovsky datum).

Satellite imagery — A December 2002 ASTER satellite image of the watershed with a resolution of 15m was rectified using 1:10,000 digital topographic maps. Then more than 20 ground control points were collected with a maximum root mean square (RMS) error of control within 1 pixel. Supervised classification of the image was completed by selecting training sites. GPS readings at more than 40 points were carried out to test the accuracy of the supervised classification. This showed a 90% reliability.

Classification evaluation — The classification of aerial photos and satellite image was evaluated by the researchers and local people. Draft maps were printed and the classification was discussed with local people in the field. Supervised classification of the image was

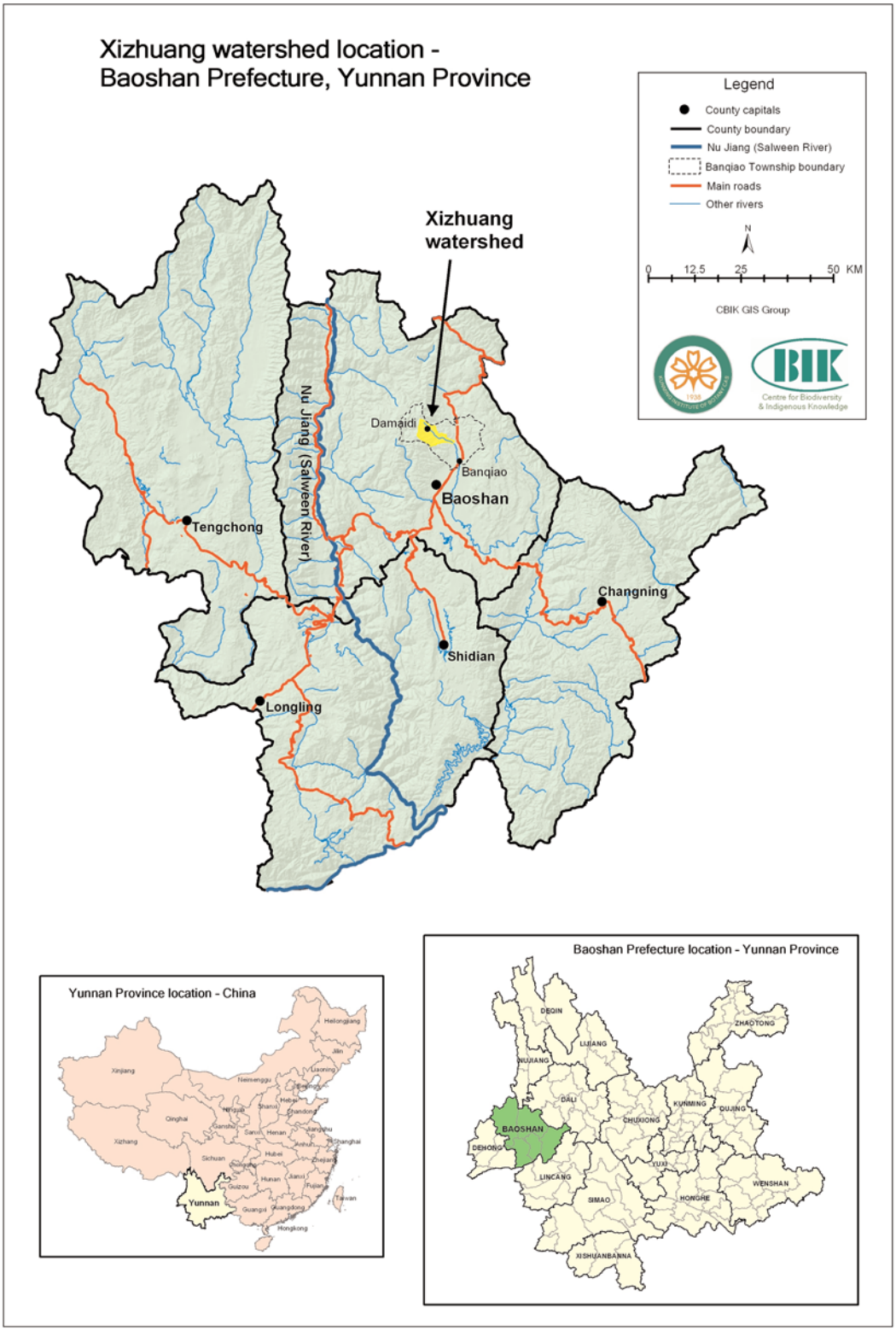

Figure 18.1: **Location of Xizhuang watershed**

Table 18.1: **Land types in Xizhuang watershed**	
I. Agricultural Land	
	11. Paddy (rice)
	12. Upland fields (rainfed crops – in Xizhuang = wheat and corn)
	13. Gardens (in Xizhuang = tea gardens)
	14. Forest land (dense): conifer forest with crown density more than 20%
	15. Forest land (sparse): crown density of 10-20%
	16. Grassland
II. Construction land	
	23. Rural settlements
	24. Individual industrial use land (in Xizhuang = quarries)
	27. Roads
III. Unused land	
	31. Shrubland or young plantations
	35. Barren land
	36. Rivers

completed by selecting training sites. GPS readings at more than 40 points were carried out to test the accuracy of the supervised classification. This showed a 90% reliability in lieu of a statistically-based accuracy assessment. The final classifications for both dates were examined carefully and compared against all available reference data and the authors' extensive knowledge of the study area.

Analysis of the land use and land cover changes was carried out by comparing the 1987 aerial photos and the 2002 satellite image.

Socioeconomic survey

A socioeconomic survey was carried out for the study area by:

- collecting secondary data from government agencies on population, the area of cultivated fields, and food production;
- interviewing key informants, including government officials and local people, about historical events and land use change trends. The relations between the government and local people under different land tenure systems were analysed to show how tenure rights have affected villagers' access to forest resources; and
- participatory mapping where the survey team worked with local people to produce time lines, land use sketch maps, land use transects, and land tenure maps. Topographic and land-use maps were used in the field to facilitate these discussion with farmers, officials and community members on past land-use practices, land-use conflicts, and future plans.

Index of land use change

The degree of individual land use dynamics was calculated through the numerical change in particular land use dynamics multiplied by the length of time of the study. The following formula (Wang 2000, Yang 2001) was used:

In the formula LC represents the degree of land use change, Ua the amount of the particular land use at the beginning of year 'a' and Ub the amount at the end of year 'b', and T the

$$LC = \frac{Ub - Ua}{Ua} \times \frac{1}{T} \times 100\%$$

length of time. When the unit of T is set as a year LC indicates the degree of annual individual land use change.

The degree of integrated land use change is defined by the integrated numeric change of all the categories of land use during the length of time of the study in the area. The formula used to work this out is:

$$LC = \frac{\sum_{i=1}^{n} \Delta LU_{i-j}}{2\sum_{i=1}^{n} LU_i} \times \frac{1}{T} \times 100\%$$

LUi represents the area of category i at the beginning year of the study, DLUi-j represents the amount of land use category i converted to other land uses, and T represents the length of the study. When the unit of T is set as a year, LC indicates the degree of annual integrated land use change (Chen 1998).

Results and Discussion

History of the watershed

Baoshan has a long history. Many inland people migrated from eastern China to the Baoshan valley after the Yuan Dynasty (1279-1368). After this most of the natural forests were destroyed through shifting cultivation and were replaced by pine forests. Box 18.1 shows the main recent events. The field survey and interviews recorded the three major causes of deforestation in recent times as:

- shifting cultivation, the intensive planting of opium and buckwheat, and overgrazing in the early part of the twentieth century;
- logging for firewood to supply iron and steel production; and
- the pre-1980s granting of individual household rights to forest resource use.

The population in Xizhuang watershed has doubled in the past four decades. Population growth has been greater in upland areas because of less enforcement of the one child policy. These upland areas are the ones that have the least arable land. Table 18.2 shows that there is only 0.04 hectares of farmland per person in Lijiashi in the upper watershed, 0.03 hectares per person in Qingshui in the middle watershed, and 0.02 hectares per person on Xizhuang in the lower watershed. This compares with the average of 0.04 hectare per person for lowland farmers in the nearby Baoshan valley.

Most families depend on agriculture for between 50 and 60% of their livelihoods (Figure 18.2). Many local women spend around 15% of their working time collecting firewood, pine needles, leaf litter, and non-timber forest products. Leaf litter is used for fuel and fertiliser. It is put into pigstys for bedding and after mixing with pig manure is composted for fertiliser. Some families sell fuelwood, pine needle ropes (for lighting), and other non-timber forest products. Most households raise about US$200 per year from these products. Livestock, particularly pigs, provide a substantial income for local farmers. Higher agriculture outputs mostly depend on using expensive high yielding crop varieties, chemical fertilisers, and pesticides.

Box 18.1: **Historical events in Xizhuang watershed**

1942-1944	Much logging for house road and bridge building during World War II
Pre-1953	Practicing shifting cultivation (buckwheat 80%, potato 20%) with 3-5 year fallow cycle, and raising goats on pastureland
1957-58	Large areas of forest cut during the "Great Leap Forward" including to build Baimiao Reservoir
1962	First trial of aerial seeding of pine for large-scale afforestation
1965	Establishment of people's communes, collectivisation and much terrace construction
1966-67	Pit-planting of 1000 kg of seeds of *Pinus armandii* per year
1968	Micro-hydro-power station established
1974	Forest survey carried out
1982	Introduction of household responsibility system; but more forest loss
1984	Big floods in Qingshui village
1985	Large-scale mud-flows and first aerial seeding of *Pinus yunnanesis*
1988	Road building gives access to outside
1991	Supplementary aerial seeding carried out
1994	Wasteland auctions where collective degraded lands were leased to the public
1996	Construction of new road
1998	Renewal of household responsibility system

Table 18.2: **Population and farmland resources in Xizhuang watershed (1998 census)**

	Lijiashi village	Qingshui village	Xizhuang village*	Total
Population	1533	2493	1818	5844
Labour	767	1262	904	2934
Arable land (ha)	66.5	81.5	39	187
Arable land per capita (ha/person)	0.043	0.033	0.021	0.034 (average)
Tea gardens (ha)	4.987	5.207	0.973	11.167
Grain production (tonnes/year)	1860	3393	671	5924

Note: Only one third of Xizhuang Administrative village is located within the watershed.

The importance of the Xizhuang watershed area for maintaining good quality water supplies has led to Baoshan municipal government and local communities making great efforts to reforest areas of the watershed. Logging operations have been greatly reduced since the early 1980s in state forest in the watershed's upper catchment areas. Only 500m^3 of firewood is allowed to be removed each year. In 1985 and 1991 the Forestry Bureau carried out aerial seeding to replant a number of degraded areas. In recent years villagers in lower catchment areas have planted trees. The local village administrations, particularly Lijiashi, are regulating the collection of timber, fuelwood and non-timber forest products. Forest guards have been appointed to watch over the forests. They patrol twice a day and serve as a link between villagers and local forest stations. This link includes local people requesting their local forest

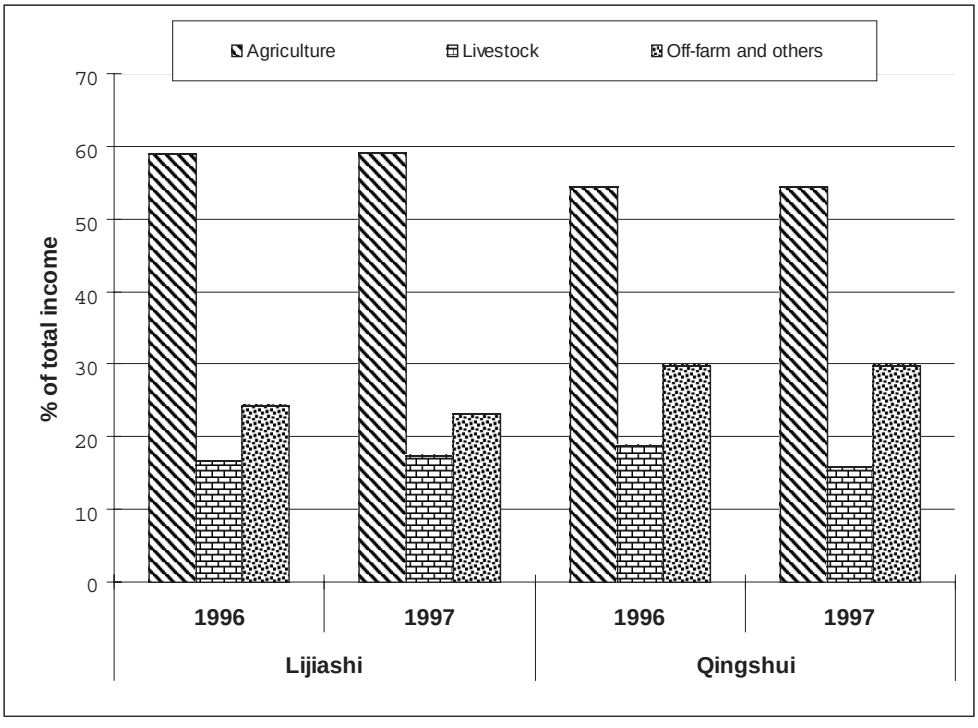

Figure 18.2: **Sources of income in Lijiashi and Qingshui villages**

office to provide them with seedlings for planting. The guards' salaries are paid by villages from forest tax revenues.

Land use dynamics, 1987-2002

Figure 18.3 shows the pattern of land use in the Xizhuang watershed in 1987 and 2002. Changes over the 15 year period show that land use has become more fragmented. Forest land remains the principle cover in the watershed increasing from 44% of the area in 1987 to 54% in 2002. The second most cover is upland fields which reduced from 29% of the area in 1987 to 16% in 2002.

The changes in land use from 1987 to 2002 have been quite diverse (Table 18.3). The change index ranges from only 1.0 for rural settlements to 36.6 for barren land. The most change was a 13% decrease in dry-land cropping land and a 10% increase in dense forest.

Table 18.4, and Figures 18.4 and 18.5 show that 519 hectares of upland fields have been converted into forest land whilst the reverse has happened (forest lands to upland fields) over 160 hectares. Another significant change is the 46 hectares of forest land converted to grassland. Rice paddies have decreased to only one plot by the outlet of the watershed and have mostly been converted into upland fields, forest, and tea gardens. Housing has occupied upland fields and tea gardens.

So much land has become pine forest as many upland fields have been afforested through aerial seeding and by planting with pine seedlings. The analysis also shows that most of the tea in 1987 has been removed and most of the area under tea in 2001 has been planted since

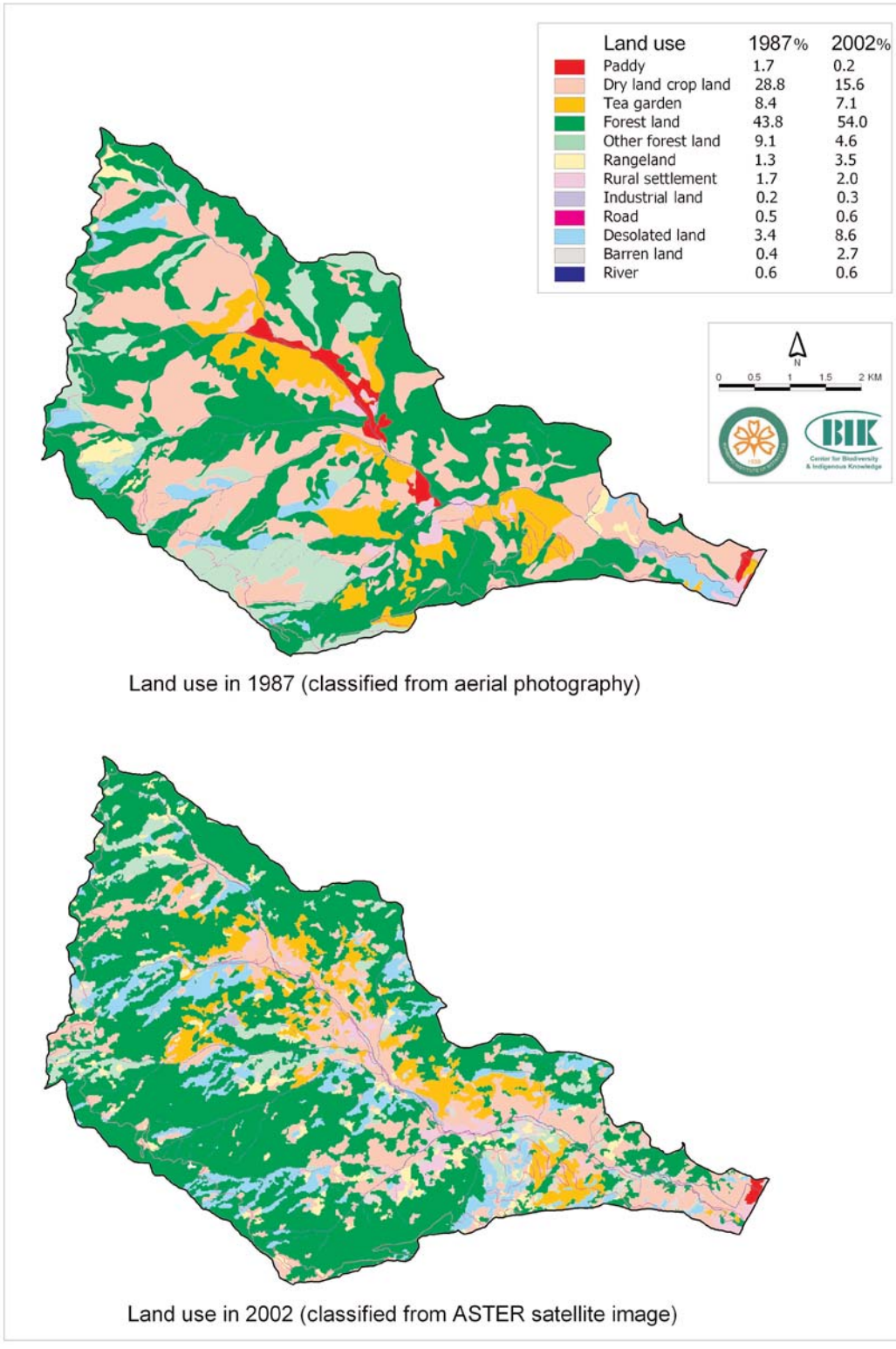

Figure 18.3: **Pattern of land use in the Xizhuang watershed in 1987 and 2002**

Table 18.3: **Land use change between 1987 and 2002 in the Xizhuang watershed**

Land use	Type	Area (ha)		Area change (ha)	Percent total area		% change	Annual land use change index
		1987	2002		1987	2002		
Paddy	11	58.5	5.6	-52.9	1.7	0.2	-1.5	6.0
Upland field	12	991.7	537.9	-453.8	28.8	15.7	-13.2	3.1
Tea garden	13	290.1	244.2	-45.9	8.4	7.1	-1.3	1.0
Forest (dense)	14	1505.0	1858.2	+353.2	43.8	54.1	+10.3	1.6
Forest (sparse)	15	313.1	158.4	-154.7	9.1	4.6	-4.5	3.3
Grassland	16	44.0	121.4	+77.4	1.3	3.5	+2.2	11.7
Settlement	23	58.9	67.6	+8.7	1.7	2.0	+0.3	1.0
Industry land	24	5.7	9.4	+3.7	0.2	0.3	+0.1	4.3
Road	27	15.9	21.9	+6.0	0.5	0.6	+0.2	2.5
Shrub or young plantation	31	118.3	297.5	+179.2	3.4	8.7	+5.2	10.1
Barren land	35	14.4	93.4	+79	0.4	2.7	+2.3	36.6
River	36	22.2	22.2	0	0.6	0.6	0	0
Total area		3437.8	3437.8		100	100		

then. This reflects how many of the old tea gardens (particularly collective ones) were not productive either due to poor management or old varieties, and were uprooted. Individual farmers then began to plant new varieties of tea on their own fields.

Causes of forest recovery

Forest management in Yunnan

Forest management in Yunnan reflects the long history of political struggle and shifting power between the state and local communities (Xu and Ribot 2004). The three main phases have been the period preceding the 1949 Revolution, the 1950 to 1978 era of collectivisation, and the post-1978 period of economic reform and decentralisation.

Most forest lands were privately owned before the 1949 revolution. Some forests were 'owned' in common by communities including the temple, headwater, sacred, and tribal forests. The nature of these common forest properties is significant as Yunnan is traditionally administered by local chiefs (*tusi*). There were also some public forests where part of the income was used for building and maintaining local schools, roads, and bridges.

The land reform laws of June 1950 governed forest resource management for three decades. Between 1950 and 1952 all farmlands and forestlands were nationalised. The state retained management control of large forestlands, but allocated farmlands and traditionally managed forestlands to individuals, particularly the poor. In these areas, the customary institutions were largely respected. The collectivisation process was initiated between 1952 and 1956. Most farmlands and forestlands were collectivised, although private ownership was still recognised in principle. This was followed in 1958 by the establishment of the People's Commune. This

Figure 18.4: **Land use change area 1987-2002**

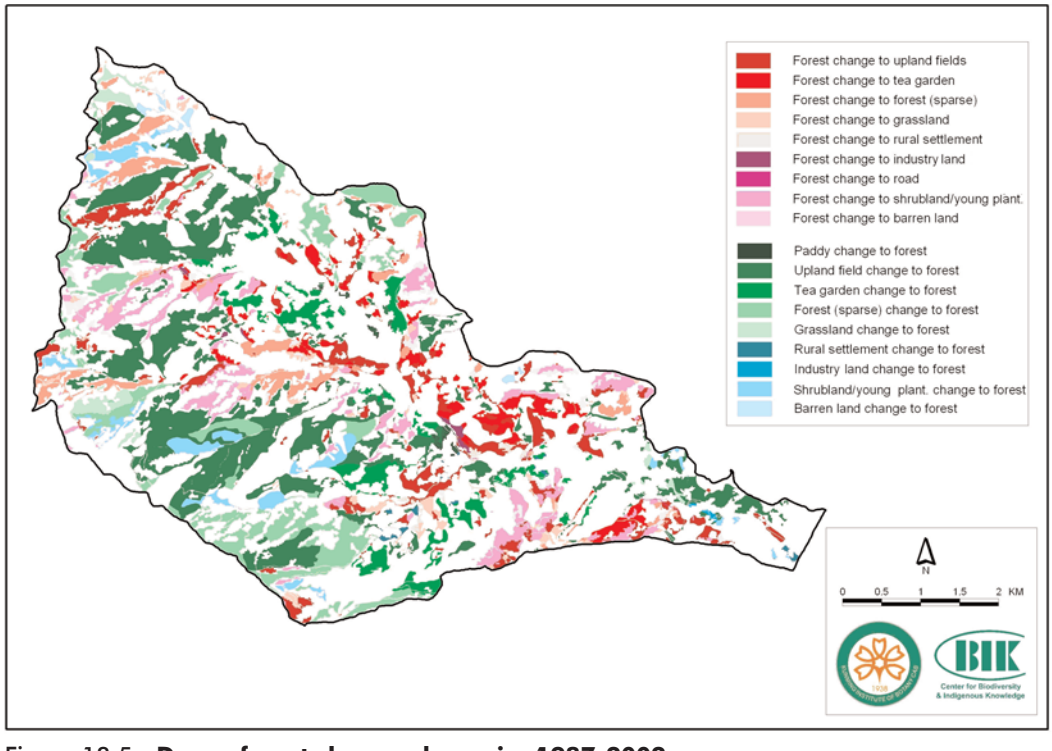

Figure 18.5: **Dense forest change dynamics 1987-2002**

had a profound impact on forest ownership and customary institutions. State and collective ownership replaced private ownership and customary public ownership particularly in peripheral mountainous areas.

The collectivisation policies, especially those enacted during the 1958 Great Leap Forward, resulted in large-scale deforestation. The economic liberalisation reforms began in 1978 with the establishment of the Household Responsibility System. Between 1978 and 1982 agricultural lands such as paddy fields were contracted out to individual farmers, but forests remained under state control. Since the boundaries between state forests and private agricultural lands were often unclear, conflicts occurred between government agencies and local collectives and individuals. To stake their claim to contested forestlands, individuals often cleared forestland to make fields.

Forestry sector reforms began in March 1981 when the state issued its 'Decision on Some Issues Concerning Forest Protection and Forestry Development', otherwise known as the 'Forestry Three Fixes'. This aimed to shift forest management from the state back to local communities and individuals. It provided for both private and collectively-held plots to be leased to individual households. This was the first time in Yunnan's history that local communities received certificates of forestland ownership.

However, these attempts to decentralise forest management and improve security of tenure over forestlands did not solve the problem of forest degradation. The transfer of forest use rights and management responsibility to local farmers did not lead to the regeneration of forests as environmental degradation, soil erosion, and flooding continued. On 1 October 1998, after the most extensive flooding ever witnessed in the Yangtze basin, the Yunnan provincial government introduced a natural forest protection policy in response to a state ban on logging, officially called the Natural Forest Protection Program (NFPP) policy. This ban was immediately followed by the Sloping Land Conversion Program (SLCP), 1999. The SLCP was designed to address the problem of the environmentally damaging cultivation of steep hill slopes. This planned to convert farmland on slopes of more than 25 degrees into forest or grassland. Farmers were encouraged to do this with the distribution of seedlings and government subsidies for grain, education, and healthcare fees. The logging ban and the SLCP have put many indigenous communities in a dire situation as they traditionally rely on forests for their livelihoods.

State afforestation

Following the forestry three fixes policy, the local forestry bureau in 1985 carried out aerial seeding of pine tree seeds over the most degraded forest lands. In some places local people planted pine and eucalyptus seedlings on their forestlands in areas difficult to reach by aerial seeding. Supplementary aerial seeding was carried out in 1991.

The harvesting of timber and fuelwood and grazing in the forestlands is highly regulated. Villagers have to apply for a quota to cut timber. Fuelwood collection is only allowed in certain forests for two weeks during the winter. Villagers have to pay for these forest products at the rate of \$14/m^3 for timber for domestic use, \$42/m^3 for timber for commercial use, and \$1.2 per backload of fuelwood. The township forestry station has been responsible for issuing these quotas since the system began in 1983.

Table 18.4: **Changed and unchanged land use 1987-2002 (hectares) in the Xizhuang watershed**

YEAR		2002											
1987	Category	Paddy	Upland field	Tea garden	Forest (dense)	Forest (sparse)	Grassland	Settlement	Industry land	Roads	Shrub or new plantation	Barren land	Rivers
	Paddy	1.6	37.5	5.1	6.7	0	0.2	4.3	0	1.3	0.3	1.5	0
	Upland field	0	211.9	91.1	519.5	25.7	40.2	11.5	4.4	1	59.3	27	0
	Tea garden	2.6	61.3	48.2	108	11.7	14	6.7	0	1.7	20.1	15.9	0
	Forest (dense)	0	160	85.6	893.6	102.1	45.9	9.7	5	0.9	166.3	36.1	0
	Forest (sparse)	0	24.1	12.5	215.3	6.3	7.3	0.6	0	0	45	2.2	0
	Grassland	0	6.5	0	29.8	5.2	2.4	0	0	0	0	0.1	0
	Settlement	1.4	7.2	1.1	5.5	1.5	3.2	32.8	0	0.7	1	4.4	0
	Industry	0	1.9	0	1.3	1.8	0	0	0	0.3	0	0.4	0
	Road	0	0	0	0	0	0	0	0	15.9	0	0	0
	Shrub or new plantations	0	26.7	0.8	69.8	3.6	6.1	2	0	0.2	5.5	3.8	0
	Barren land	0	0.9	0	8.8	0.6	2.1	0	0	0	0.2	1.8	0
	River	0	0	0	0	0	0	0	0	0	0	0	22.2

Note: the hectare figures under the same category for the two years are the unchanged areas

Drawing a picture of a cake to feed the stomach

Although the implementation of the three fixes policy broke up state ownership, this decentralisation has so far failed to give local communities adequate control over their forest resources, especially in areas like Yunnan, where the ethnic minority population heavily depend on these resources for their livelihoods (Xu and Ribot 2004). The increase in forest cover has mostly happened at the expense of high elevation former buckwheat fields. One farmer said that planting trees is like "drawing a picture of a cake to feed the stomach" due to the restrictions on timber harvesting. The illegal cutting of trees has been made a criminal offence.

The impacts of afforestation on local livestock are shown in Figure 18.6. Farmers in the area no longer keep goats or sheep. The handover of responsibilities from state to collectives, and then from the collectives to individual contracts has led to the complete cessation of goat and sheep grazing in the forests. These animals used to provide a main source of income. Local farmers now depend more and more on cash income from tea crops although the market price for tea has not been good. Tea gardens are also encroaching on farmland. The locally produced grains – maize in the summer, and wheat or barley in the winter – mostly go for livestock feed. Rice is the main staple food and is brought in from the lowlands. The increasing number of mules (Figure 18.2) are used by farmers to transport pine needles from the forest for use as bedding and fuel and for carrying manure and crops.

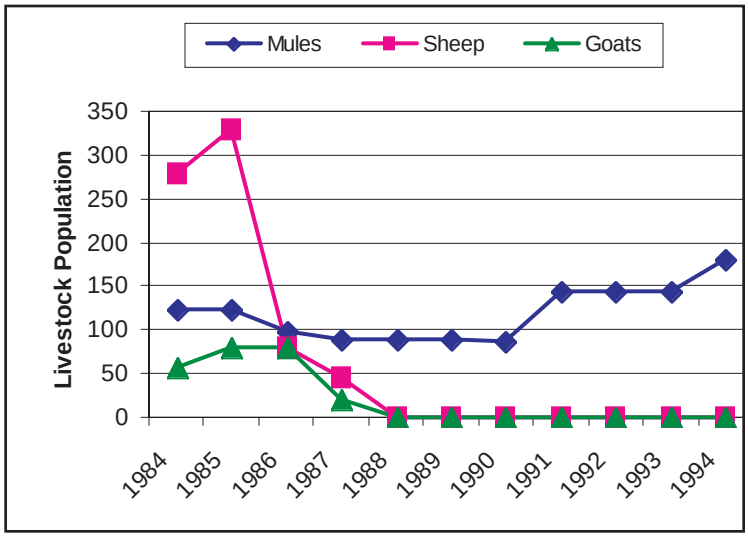

Figure 18.6: **Change in livestock population after reforestation in Lijiashi Village**

The forestlands are unevenly distributed amongst households due to their original uneven distribution and changes in household sizes since forestland allocation. This is a major challenge for forest management in this watershed. To try and maintain equity the forestlands have been divided into very small plots at different locations. For example, one Damaidi farmer has 1.06 hectare of forestlands divided into 11 plots and 0.35 hectares of tea garden over 8 separate plots. Poor accessibility and such fragmented land holdings leads to poor management.

Figure 18.7 shows that in recent times the total area of upland fields peaked in 1986 and then decreased at township level. The remote sensing data shows that upland fields decreased from covering 29% of the total area in 1987 to 16% in 2002. Over the whole watershed there was a more than 30,000 ha decrease in farmland. Many of the shifting cultivation fields at high elevations have been converted into *Pinus armandii* forest or tea gardens. The *Pinus armandii*

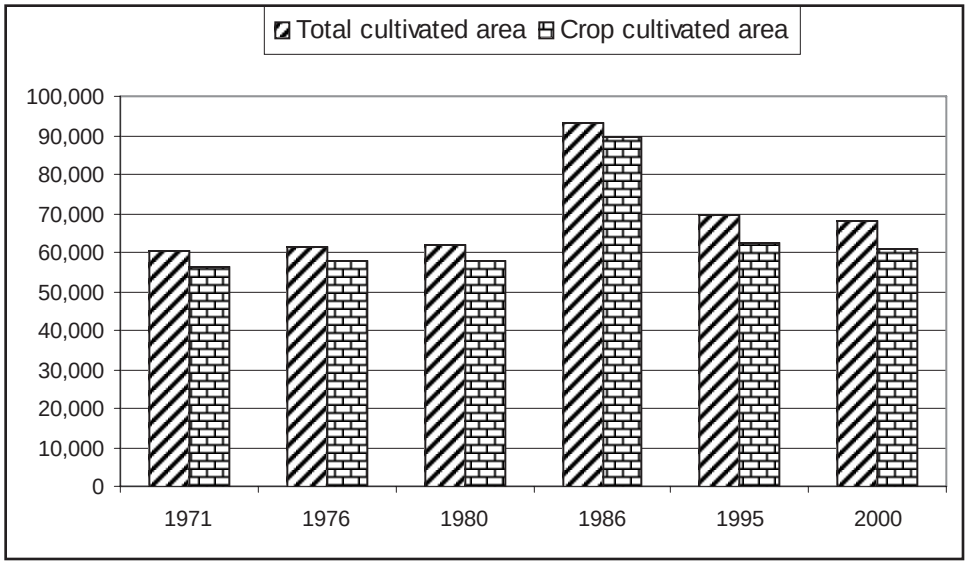

Figure 18.7: **Change in cultivated land 1971-2000, Banqiao Township**
Source: Banqiao township statistics, 2002

forests are the main source of non-timber forest products providing pine nuts, pine needles and wild mushrooms to sell in the market.

The field survey in Damaidi village recorded 22 adults, including two women from 18 households, who spend an average of 6.2 months per year on off-farm work. In 2002 they earned an average of US$74 per month from this work. The survey found that male labourers often spend more than half of the year off-farm, mainly on construction work in nearby lowland areas.

Impact of afforestation on local livelihoods

Dense forest cover increased from 44% in 1987 to 54% in 2002 due to the re-establishment of forest cover by aerial seeding and by local farmers planting pine seedlings. The establishment of pine plantations has increased soil acidity (Sha et al. 2003). The monoculture plantation has also reduced the diversity of non-timber forest products found in the area.

China took tentative steps towards decentralising forest management after the 1981 Forestry Three Fixes. However, even after this the forestry agency and local government were still involved in decision-making that affected people's livelihoods such as the establishment of forest plantations and conservation initiatives. This went ahead without any local participation. Local government authorities often fail to account for local livelihood needs in conservation-related decision making. Although local farmers maintained title over the afforested lands they did not have any decision-making power nor permission to harvest timber.

The new wave of top-down measures for protecting China's degraded environment has challenged upland farmers' livelihoods. Local village leaders say that SLCP aims to convert more than one thirds of existing farmland into forest. They see this as having a very detrimental effect on local livelihoods. As a result off-farm work has become a more important livelihood activity.

Conclusions

This land use change analysis shows the success of state driven reforestation and conservation programmes in reforesting upland areas of the Xizhuang Watershed. Forest land has significantly increased mainly at the cost of agriculture land. Land use changed at the rate of over 2% per year between 1987 and 2002. Upland farmers in the watershed have tried to compensate for their loss of cropping land by intensifying the use of their remaining cropland by introducing high yield varieties and the heavier use of chemical fertiliser and pesticides, by turning to off-farm work, and by spending more time harvesting non-timber forest products. The impact of monoculture pine forests on the local environment remains to be assessed.

The overall conclusion of this paper is that state policies have changed land use in the area without involving local people in decision-making. This will not encourage the sustainable management of the area's forests.

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