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Exploring the spatial and temporal dynamics of land use in Xizhuang watershed of Yunnan, southwest China

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Abstract

Over the last two decades, China has introduced a series of agricultural and forestland use reforms, aiming to feed the largest population in the world and maintain ecological services locally and nationally. This paper studies the impacts of local government-driven reforestation on land use and land cover change, as well as its further impacts on livelihoods of upland farmers in Xizhuang watershed. An analysis of aerial photographs and ASTER satellite imagery from 1987 to 2002, respectively, showed that the forest has significantly increased at the expense of decreasing farmland. However, the monoculture reforestation of pine has caused both biophysical and socio-economic consequences. This case study also shows forestry decentralization in China remains incomplete. Land use and land cover change is also a political economic issue. Some of the reforms designed to protect forest resources have had a negative impact on rural livelihoods.

Keywords: Land use; Forest recovery; Livelihoods; Xizhuang watershed

1. Introduction

Land use and land cover changes have been extensively researched (Lambin et al., 2001) due to its key role in environmental goods and services. The large-scale results show that, due to increasing deforestation, forests are rapidly decreasing even as farmlands extend. For example, deforestation has caused the loss of 1.16 billion ha of forest while farmland thereafter increased by 1.24 billion ha in only 300 years (Lambin et al., 2000). However, if the research is measured by a different scale in different regions, results may be significantly different. Many countries and regions experience forest transitions when economic development stimulates a decline in forest cover and later, through feedback processes, sparks some recovery in forest cover (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, as well as the environmental consequences. As a result of afforestation, agricultural intensification is also a concern (Tomich et al., 2004). Lambin et al. (2000) state that long-term population growth and economic development usually do not take place without intensification and agricultural growth.

China is a country with vast population and scarce land per capita. Food security and loss of farmland is great concern for Chinese decision-makers (Verburg, 2000; Yang and Li, 2000). However, the Chinese government has paid increasing attention to other ecosystem functions and services besides food produc-

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tion. Land use is at the center of these trade-offs. Both the public and the policy-makers have paid more attention to forest cover because the forest ecosystems provide environmental goods and services not only for the local farmers but, more importantly, for off-site and downstream people. This case study explores the spatial and temporal dynamics of the land use in the Xizhuang watershed from 1987 to 2002 and places emphasis on forestland and farmland. It addresses the following questions: (1) where does forest recovery happen and at what rate does land use change progress? (2) What drives local afforestation? (3) What are the social consequences of forest recovery to local communities? (4) What are the local people's coping strategies for such forest transition? This study presents the underlying dynamics of land use change at the micro-watershed level, which can further contribute to policy development in conservation and development at the macro-scale.

2. Study area

The Xizhuang watershed is located 20 km at northwest of Baoshan city in the western part of Yunnan province (Fig. 1), ranging from 99°06′E–99°13′E to 25°13′N–25°17′N. It covers 3437 ha, and is a subcatchment of the Nujiang (Salween River). Its elevation ranges from 1750 to 3100 m above sea level. Geographically it is located in the southern section of the Hengduan Mountains. Influenced by regional geological history and active tectonic movement from a collision of the Indian subcontinent with the Eurasian continent, the landform is quite fragile, complex and diverse. The climate in the foothills is subtropical, and temperate in the mountain areas. The annual average temperature is 12.5 °C. The average annual precipitation is 1013.2 mm with clearly defined dry and wet seasons. The main soil type is red soil (Li and Sha, 2002). The natural vegetation of semi-moist broadleaf forest that disappeared many decades ago has been replaced by conifer forest with a mix of alder (*Alnus nepalensis*). Most farmers plant two crops per year, corn in the summer and wheat or barley in the winter. Tea is the traditional cash crop.

Xizhuang watershed covers the whole administrative villages of Lijiashi and Qingshui and part of another village. The total population of the watershed is 4273 with a population density of 124 km^{-2} in 2002. Population growth and urbanization in nearby Baoshan valley 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 the water from this watershed. An irrigation canal provides crucial irrigation for Banqiao township. Baimiao reservoir also has a water intake from the Xizhuang watershed.

3. Materials and methods

The authors integrated socio-economic and spatial information collected from household interviews, participatory social mapping, land use mapping and policy review.

3.1. Spatial data

Table 1 shows the land use types classified in the Xizhuang watershed according to the Chinese Land Resources Ministry standard adopted in 2002.

The detailed features of a 1:10,000 topographic map including water systems, settlement area, administrative boundary, road and contours were digitized and entered into a geographic information system (GIS) database. A spatial database was also developed using aerial photographs taken in February 1987 at the scale of 1:40,000 from the Yunnan Land Survey Bureau. These were digitally scanned and geo-referenced, and data were segmented in eCognition software 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

Table 1
Classification system of Xizhuang watershed

I. Agriculture land
11. Paddy (rice)
12. Upland field (dryland crop—wheat and corn)
13. Garden (tea garden)
14. Forestland (dense): conifer forest with crown density more than 20%
15. Forestland (sparse): crown density is 10–20%
16. Grassland
II. Construction land
23. Rural settlement
24. Industry use land (in Xizhuang quarry)
27. Road
III. Unused land
31. Shrubland or young plantation
35. Barren land
36. River

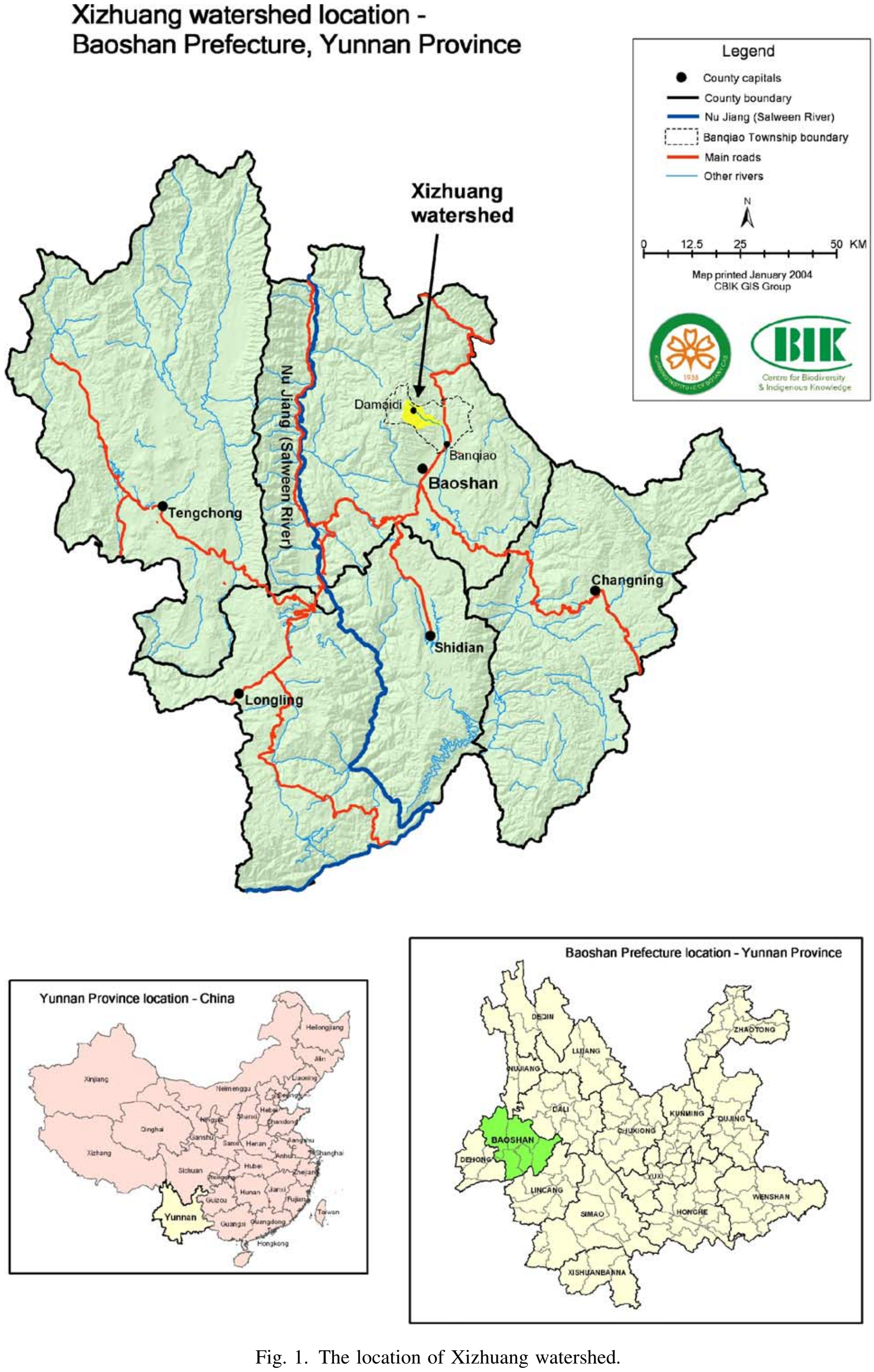

Fig. 1. The location of Xizhuang watershed.

projected into Transverse Mercator projection (Krasovsky datum).

A December 2002 ASTER image was rectified using the 1:10,000 digital topographic data. Twenty ground control points were collected and RMS control was within one pixel. Supervised classification of the image was completed also using eCognition software by selecting training sites from a priori field knowledge. Bands 1–3 were used to initially segment the Aster image into ‘‘image objects’’, then a nearest neighbor classification approach was used to derive the desired classes.

Analysis of the land use and land cover changes was carried out by performing overlay analysis using ARCGIS software using the classification results from the 1987 aerial photographs and the 2002 ASTER satellite image.

3.2. Accuracy assessment

This study is part of on-going project on People and Resource Dynamics in Mountain.

Watersheds of Hindu–Kush–Himalayan Region (PARDYP). The project team has made many trips during the classification process from 2000 to 2003. The land use classification was further evaluated during GPS soil sampling of 114 field points. 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 and experience in the study area. From this evaluation, the classifications were deemed a reasonably accurate representation of the actual land use and cover classes found in the study region during the study period. A further reference used was a 10 km × 10 km Quickbird satellite image obtained in 2003 which overlays a portion of the Xizhuang watershed. This image is extremely high resolution (63 cm pixel size) and land use type is very easy to visually discern. Unfortunately, we were unable to obtain independent reference data to assist in assessing the 1987 classification, however here again, local knowledge proved invaluable.

We acknowledge that the data resolution differences between the aerial photographs and the ASTER satellite image may account for a portion of the calculated land use and cover change. However, we believe this is minimal compared to the actual change we believe has been captured by our analysis.

3.3. Socio-economic survey

A socio-economic survey was carried out in through: (a) collecting secondary data from government agencies on population, the area of cultivated fields and food production. (b) Interviewing key informants including government officials about state land use strategies, policy planning and implementation related to land resources, land use planning and development interventions; local people about historical events and land use change trends. The relations between the government and local people under different land tenure systems were analyzed to show how tenure affected villagers' access to forest resources. (c) Participatory mapping where the survey team worked with local people to produce time lines, land use sketch maps and land use transects and land tenure maps. Topographic and land use maps were used in the field to facilitate these discussion with farmers and officials on past land use practices, present land use conflicts and plans for the future.

3.4. Index of change in land use

A formula from Wang (2000) was used to quantify the degree of land use change. The degree of individual land use dynamics is calculated through the numerical change in particular land use dynamics multiplied by the length of time of the study. The formula is:

$$\mathrm{LC} = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\%$$

In the formula, LC represents the degree of land use change, U_a the amount of the particular land use at beginning of year 'a', U_b the amount at the end of year 'b' and T represents the length of time. When the unit of T is set as a year, LC indicates the degree of annual individual land use dynamics. The degree of integrated land use dynamics is defined by the integrated numeric changing of all the categories of land use during the length of time of the study in the area. Its formula is as follows:

$$\mathrm{LC} = \frac{\sum_{i=1}^{n} \Delta \mathrm{LU}_{i-j}}{2\sum_{i=1}^{n} \mathrm{LU}_i} \times \frac{1}{T} \times 100\%$$

where LU_i represents the area of category i at the beginning year of the study, $\Delta\mathrm{LU}_{i-j}$ the amount of category i converted to other categories 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 dynamics.

4. Results and analysis

4.1. History of the watershed

The Baoshan area has a long and detailed 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. The field survey and interviews recorded the four major causes of deforestation in recent times as: (a) shifting cultivation, the intensive planting of opium and buckwheat, and overgrazing in the early part of the 20th century; (b) cutting trees for Chinese army for fuel, housing and road construction during the World War II; (c) logging for firewood to refine iron and steel during the ''Great Lead Forward'' in 1958; (d) an unexpected over-harvesting of forest resources after granting of individual household rights in early 1980s.

Box 1 Historical events in Xizhuang watershed:

- 1942–1944: Fights with Japanese army during the World War II, provision of millions of cubic meters of woods for fuel wood, housing and construction of road and bridges from nearby forests.
- Pre-1953: Practicing shifting cultivation (buckwheat 80%, potato 20%) with 3–5 years fallow cycle, raising goats in the pastureland.
- 1957–1958: Cutting large areas of forest during ''Great Leap Forward''.
- 1958: ''Great Leap Forward'' and constructing Baimiao Reservoir in downstream.
- 1962: First trial of aerial seeding of pine for large-scale afforestation in the winter.
- 1965: Establishment of 'People's Commune', collectivization and terracing construction.
- 1966: Pit-planting 1000 kg pine seeds (*Pinus armandii*).
- 1967: Pit-planting another 1000 kg pine seeds.
- 1968: Micro-hydro-power station established.
- 1974: Forest survey in the watershed.
- 1982: Introduction of household responsibility system, more forest loss.
- 1984: Big floods in Qingshui village.
- 1985: Large-scale mud-flows and the carrying out aerial seeding (*Pinus yunnanensis*).
- 1988: Building road (old) for access to outside.
- 1991: The supplementary aerial seeding.
- 1994: ''Wasteland auction''.
- 1996: Construction of new road.
- 1998: Renewal of household responsibility system (30 years).

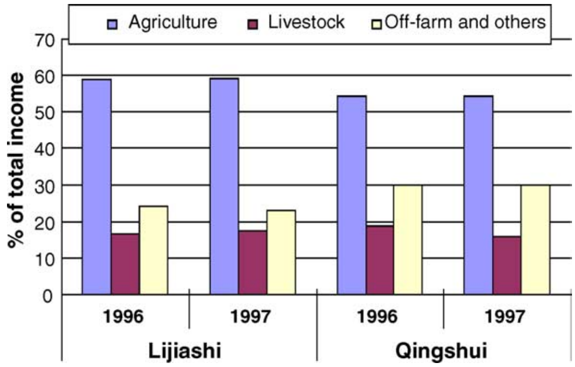

Fig. 2. Income from different livelihood activities.

The population in Xizhuang watershed has doubled in the past four decades, increasing from 3417 in 1987 to 4273 in 2002. Government official say that population growth has been greater in the upland because of less enforcement of the one child policy there. Table 2 shows that there is 0.04 ha of arable land per person in Lijiashi in upper watershed, 0.03 ha per person in Qingshui in the middle watershed and 0.02 ha per person in Xizhuang in the lower watershed.

Most families depend on agriculture for between 50 and 60% of their livelihoods (Fig. 2). Many local women spend about 15% of their working time collecting firewood, pine needle leaf litter and non-timber forest products. Leaf litter is used for fuel and fertilizer. It is put into the pigsty for bedding and after mixing with pig manure is composted for fertilizer. Some families sell fuel wood, 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 yield crop varieties and chemical fertilizers and pesticides. Income from off-farm work becomes more and more important.

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 re-vegetate degraded areas of the watershed. Logging operations have been greatly reduced since the early 1980s in state forests in the upper catchment areas of the watershed. Currently, only 500 m^3 of fuel wood 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, the villagers in low catchment areas have planted trees. The local village administration, particularly in Lijiashi, are regulating the collection of timber, fuel

Table 2
Population and farmland resources in Xizhuang watershed

	Lijiashi administrative village (upper)	Qingshui administrative village (mid)	Xizhuang administrative village (lower)[a]	Total
Population	1533	2493	1818	5844
Labor	767	1262	904	2934
Arable land (ha)	66.5	81.5	39	187
Arable land per capita (ha per person)	0.043	0.033	0.021	0.034 (average)
Tea garden (ha)	4.987	5.207	0.973	11.167
Subtotal grain production (tonnes per year)	1860	3393	671	5924

Source: 1998 government census.
[a] *Note*: Only one-third of Xizhuang Administrative village located within the watershed.

wood 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 the villagers and local forest stations. This link includes local people requesting their local forest office to provide them with seedlings for planting. The guard's salary is paid by villages from forest tax revenues.

4.2. Land use dynamics between 1987 and 2002

Fig. 3 shows the pattern of land use in the Xizhuang watershed in 1987 and in 2002. Changes over the 15-year period shows that the land use has become more fragmented. Forestland remains the principle cover in the watershed increasing from 44% of the total area in 1987 to 54% in 2002. The second most cover is upland field, 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. The change index ranges from only 1.0 for rural settlement to 36.6 for barren land. Other significant changes include a 13% decrease in dryland cropping land and a 10% increase in dense forest (Table 3).

Table 4 and Fig. 3 show that 519 ha of upland fields have been converted into forest while also the reverse has happened (forestland to upland field) over 160 ha. Rice paddies have decreased to only one plot by the outlet of the watershed and have mostly converted into upland field, forest and tea gardens. Housing also occupies former upland field and tea gardens. Large areas of tea gardens, mainly established in the 1950s, regarded as too non-productive, has been converted into upland fields for food crops or fruit trees in late 1980s. On the other hand, tea is still reliable income source for local farmers. Farmers are planting more tea in their upland fields.

4.3. Causes of forest recovery

4.3.1. State forestry policies

Forest management in Yunnan has a long history of political struggles and shifting power between the state

Table 3
Land use change between 1987 and 2002 in the Xizhuang watershed

Land use	Code	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		

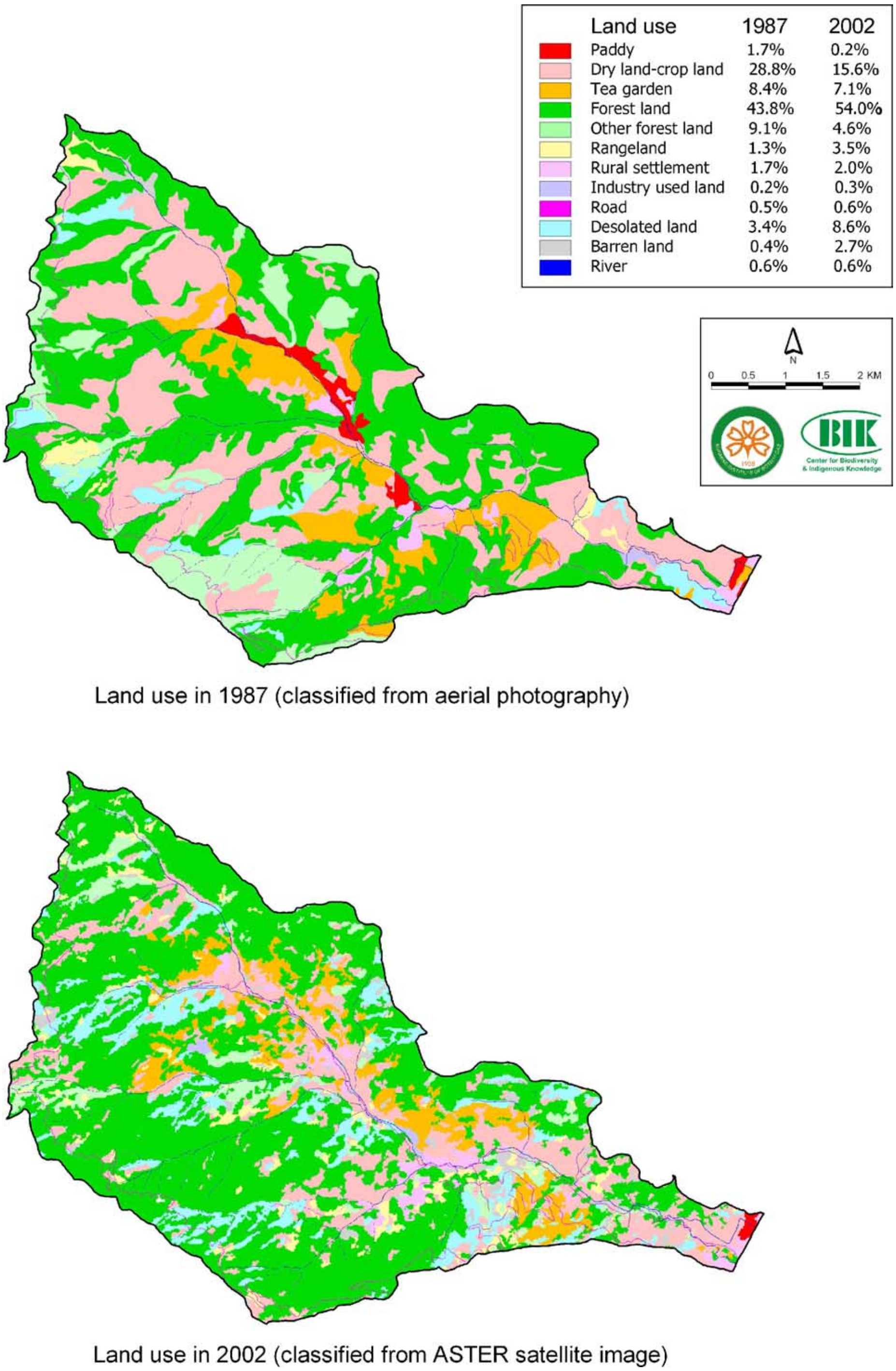

Fig. 3. Map of classification results of Xizhuang watershed in 1987 and in 2002.

and local communities (Xu and Ribot, 2004). There are three main phases: the period preceding the 1949 Revolution; the era of 'collectivization', extending from 1950 to 1978, and the post-1978 period of economic reform and decentralization. Most forestlands were either privately owned or commonly managed by customary institutions before the 1949 Revolution. The Land Reform Laws enacted in June 1950 provided the legal basis for forest resource management over the next three decades. Between 1950 and 1952, all farmlands

Table 4
Land use conversion Xizhuang watershed between 1987 and 2002 (ha)

1987	2002 Category											
	Paddy	Upland field	Tea garden	Forest (dense)	Forest (sparse)	Grassland	Settlement	Industry land	Road	Shrub or new plantation	Barren land	River
Category												
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 land	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 young plantation	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

and forestlands were nationalized. The ‘collectivization’ process was initiated between 1952 and 1956. Most farmlands and forestlands were collectivized. This was followed in 1958 by the establishment of the ‘People’s Commune’, which had a profound impact on forest ownership and customary institutions. State and collective ownership replaced private ownership and customary public ownership, particularly in mountainous peripheral areas. The collectivization policies, particularly those enacted during the ‘Great Leap Forward’ launched in 1958, resulted in large-scale deforestation. The economic liberalization 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, there were conflicts between government agencies and local collectives or individuals. In order to stake their claim to contested forestlands, the latter sometimes resorted to clearing the land for agricultural purposes, thereby causing further loss of forest cover.

The reforms in the forestry sector 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’. The stated objective of this reform was to shift forest management from the state 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. The Yunnan provincial government decided to lease degraded forestlands – known as ‘wastelands’ (‘‘*huangdi*’’) – to private (individuals or institutions) for reforestation. The land was leased for periods of between 30 and 70 years at competitive prices. This process was implemented through the ‘wasteland auctions’ policy in 1994.

These attempts to decentralize 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 was not enough to regenerate the forests, and environmental degradation, soil erosion and flooding continued. On 1 October 1998, after the most extensive flooding ever in the Yangtze basin, the Yunnan provincial government implemented the state logging ban policy, officially called the ‘Natural Forest Protection Program’ (NFPP). The ban on logging was immediately followed by the ‘Sloping Land Conversion Program’ (SLCP) policy in 1999. This program was designed to address the problem of cultivation on hill slopes, another factor contributing to soil erosion and flooding. According to this policy, any farmland with a gradient of more than 25° must be converted to forest or grassland. To facilitate the conversions, farmers receive seedlings and government subsidies for grain, education and healthcare fees. Combined with the effects of the logging ban, this policy has put indigenous communities in a dire situation.

Following the ‘Forestry Three Fixes’ policy, the local forestry bureau in 1985 carried out large-scale aerial seeding of pine trees over the most degraded forestlands. 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 fuel wood and grazing in the forestlands is highly regulated. Villagers have to apply for a quota to cut timber. Fuel wood collection is only allowed in certain forests for a period of 2 weeks during the winter. Villagers have to pay these forest products at the rate of US\$ 14 m^{-3} for timber for domestic use, US\$ 42 m^{-3} for timber for commercial use, and \$1.2 per back load of fuel wood. The township forestry station has been responsible for issuing these quotas since the system began in 1983.

4.3.2. Drawing a picture of a cake to feed the stomach

Although the forest reform through the implementation of the ‘‘Forestry Three Fixing’’ broke up state ownership of China’s forests, this decentralization 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 depends on these resources for its livelihood (Xu and Ribot, 2004). The increase in forest cover has mostly happened at the expense of high elevation former buckwheat fields. One Xizhuang farmer said that planting trees is like ‘‘drawing a picture of a cake to feed the stomach’’ due to a restrictions on timber harvesting. Illegal cutting of trees is a criminal offence punishable by a fine or a jail sentence.

Since afforestation programs have commenced local livestock populations have decreased (from local government statistics). Farmers in the area no longer keep any goats or sheep. The handover of responsibilities over forestlands from state to collective, and then from the collective to individual contracts has led to the complete cessation of goat and sheep grazing in the forests. Those animals used to provide one of the main sources of cash income for local farmers. 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, corn in the summer and wheat or barley in the winter, feed their livestock. Rice is the main staple food and is bought from the lowlands. Mule populations have increased, as mules are used by farmers to transport pine needles from the forest for use as bedding and fuel and for carrying manure and crops.

The forestlands are not evenly distributed due to the original uneven distribution and change of household sizes since forestland allocation. This is a major challenge for forest management in the watershed. To try and maintain equity the forestlands have been divided into very small plots at different locations. One farmer at Damaidi village has 1.06 ha forestlands, divided into 11 plots and 0.35 ha of tea garden over 8 separate plots. Poor accessibility and fragmented land holdings often lead to poor management.

The remote sensing data show that upland field decreased from covering 29% of the total area in 1987 to 16% in 2002. Over the whole watershed, cultivated farmland lost nearly half. The field survey shows that many swidden-fallow fields at high elevation have been converted into *P. armandii* forest or tea garden. The *P. armandii* forests are the main source of non-timber forest products providing pine nuts, pine needles and wild mushrooms that are sold in 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 off-farm work. In 2002, they earned an average of US\$ 74 per month from this work. The survey found that the male laborer often spends more than half of the year at off-farm mainly construction work in the nearby lowland areas. Feminization and agricultural intensification by applying high yield varieties, chemicals and use of plastic film are the overall trends in upland farming systems in the watershed.

4.3.3. Impact of afforestation on local livelihood

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

China took tentative steps towards decentralizing 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 affect people’s livelihoods such as the establishment of forest plantation and conservation initiatives. This went ahead without any local participation. Local government authorities commonly failed to account for local livelihood needs in conservation-related decision-making. Although local farmers maintained title over the afforested lands they have neither any decision-making power nor permission to harvest timber.

The new wave of drastic top-down measures for protecting Chinese degraded environments by implementing the logging ban and land conversion policies have challenged the upland farmers' livelihoods. Local village leaders state that the Sloping Land Conversion Program was targeting more than one-third of existing farmland to convert into forestry. They saw this as having a very detrimental effect on local livelihoods. As a result off-farm work has become a more important livelihood activity in the watershed.

5. Discussion

5.1. Land use transition and payment for environmental services

The forest is often defined as a public or state domain. The state has constantly imposed different policies for protection of and access to forest resources. Since the foundation of the People's Republic of China in 1949, the State has implemented numerous and sometimes conflicting policies affecting both agricultural and forestland ownership (Xu and Ribot, 2004). The delicate trade off among food security, economic development and environmental services of forestry ecosystem is a top governmental agenda at the local and national level. The rapid economic growth and urbanization in China have not only increased demands on forest resources but also provided opportunity to remove rural farmers from land for non-farm jobs more rapidly than it did during the earlier period (Rudel et al., 2005). The growing economic power enables government to pay or subsidize the farmers for tree planting programs even on sloped farmland. Forest cover in Yunnan has increased from 25.66% in 1978 to 33.64% in 1997 even before historical floods in Yangtze River. However, hydrological impact of forests needs to be reviewed, as the effects on forest expansion on stream flows and water provision varies with the size, geophysical features of watershed and tree species planted on land (Andreassian, 2004). The large-scale state direct-subsidized payment for environmental services through implementing 'Sloping Land Conversion Program' policy since 1999 has become a heavy burden for the Chinese government. Reducing scale of implementation and review of policy itself are already on the way since 2004. Rather than the state does all, the concept of payment for environmental services (PES) needs to be introduced to policy-makers and resource managers. For example, schemes by which upstream land managers are recompensed for measures aimed at improving downstream water supplies are a form of PES. A simple example is the downstream hydropower or drinking water corporations and industries paying a percentage of their profits to the upstream communities in return for conservation or protection of the resource.

5.2. Decentralization and forest management

Decentralization in China remains incomplete (Xu and Ribot, 2004). This study in Xizhuang watershed shows that there is insufficient transfer of power and land use decision-making to local institutions. The powers that local farmers are given can be easily be taken away while either state policy agenda changes or local government priority shift. The aim of forestry projects in China still appears to mobilize local people as mere labor for tree planting rather than empowering them to make land use decisions for themselves.

5.3. Accuracy and scale issues

The limitations of using remote sensing data in mountainous areas are well documented (Shrestha and Zinck, 2001). This study was also restricted by the lack of independent reference data for accuracy assessment. For the 2002 image, we used local knowledge and high quality fine spatial resolution imagery as a surrogate for detailed ground observation. Assessing land uses for older images was more difficult as no ancillary data could be obtained to independently confirm training areas or final classification results. The spatial scale and its aggregation is a major challenge for scientists to provide credible and salient information for land use decisions. On the other hand, the land use decision process is a political issue, which calls for participation of different stakeholders. Therefore, the participation of stakeholders particularly land users in the field assessment can provide the legitimacy of knowledge on land use and land cover change, which can then contribute to sustainable land use planning (Foody, 2002). Local knowledge, and interviewing local key informants together with participatory mapping of historical land use and land cover changes have enhanced the accuracy of this land use classification study.

6. Conclusions

The land use change analysis shows the success of state-driven reforestation and conservation programs in Xizhuang watershed. As a result, the forestland has significantly increased primarily at the cost of decreasing agriculture land. The land use change has been at an annual rate of 2.129%. The upland farmers in the watershed have to either intensify the remaining farmland by introducing high yield varieties with heavy use of chemical fertilizer and pesticides, leave the farmland for off-farm jobs, or spend more time in the forest harvesting non-timber forest products. The potential impacts of monoculture pine forest on environmental goods and services need to be assessed. Sustainable forest management cannot be achieved without the active participation of local people.

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References

Andreassian, V., 2004. Waters and forests: from a historical controversy to scientific debate. J. Hydrol. 291, 1–27.

Foody, G.M., 2002. Status of land cover classification accuracy assessment. Remote Sens. Environ. 80, 185–201.

Lambin, E.F., Turner II, B.L., Geist, H., Agbola, S., Angelsen, A., Bruce, J.W., Coomes, O., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Skånes, H., Steffen, W., Stone, G.D., Svedin, U., Veldkamp, T., Vogel, C., Xu, J., 2001. Our emerging understanding of the causes of land use and -cover change. Global Environ. Change 11, 261–269.

Lambin, E.F., Rounsevell, M.D.A., Geist, H.J., 2000. Are agricultural land use models able to predict changes in land use intensity? Agric. Ecosyst. Environ. 82, 321–331.

Li, M.R., Sha, L.Q., 2002. A primary study on phosphorus adsorption of forest soils in Xizhuang watershed, Baoshan, Yunnan. J. Mountain Sci. Chengdu (Chin.) 20 (3), 313–318.

Mather, A., 1990. Global Forest Resources Bellhaven, London, pp. 30–38.

McNeely, J., 2003. Conservation in areas of armed conflict. In: Price, S. (Ed.), War and Tropical Forests. Haworth, New York, pp. 9–11.

Rudel, T.K., Coomes, O., Moran, E., Achard, F., Angelesen, A., Xu, J., Lambin, E., 2005. The forestry transition: Towards a global understanding of land cover change. Global Environ. Change 15, 23–31.

Sha, L., Qiu, X., Gan, J., Xu, J., Gao, F., Ai, X., 2003. Study on land use and soil fertility in Xizhuang watershed, Baoshan, China. J. Ecol. (Chin.) 22 (2), 9–11.

Shrestha, D.P., Zinck, J.A., 2001. Land use classification in mountainous areas: integration of image processing, digital elevation data and field knowledge. Int. J. Appl. Earth Obs. Geoinform. 3 (1), 78–85.

Tomich, T.P., Cattaneo, A., Chater, S., Geist, H.J., Gockowski, J., Lambin, E.F., Lewis, J., Palm, C., Stolle, F., Valentim, J., van Noordwijk, M., Vosti, S.A., 2004. Balancing agricultural development and environmental objectives: assessing trade-offs in the humid tropics. In: Palm, C.A., Sanchez, S.A., Vosti, P.J., Ericksen, P.A., Juo, A.S.R. (Eds.), Slash and Burn: The Search for Alternatives. Columbia University Press, New York.

Verburg, P.H., 2000. Exploring the Spatial and Temporal Dynamics of Land Use with Special Reference to China. Wageningen University, ISBN 90-5808-200-8.

Wang, X.L., 2000. The analysis of population factors in land use/land cover change. J. Resour. Sci. Beijing 22 (3), 39–42.

Xu, J., Ribot, J., 2004. Decentralization and accountability in forest management: case from Yunnan, southwest China. Eur. J. Dev. Res. 16 (1), 143–161.

Yang, H., Li, X., 2000. Cultivated land and food supply in China. Land Use Policy 17, 73–88.

Zhang, P.C., Shao, G., Zhao, G., Le Master, D.C., Parker, G.R., Dunning Jr., J.B., Li, Q., 2000. China's forest policy for the 21st century. Science 288 (5474), 2135–2136.