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Authors: Ediger, Laura, and Huafang, Chen

Source: Mountain Research and Development, 26(3) : 220-226

Published By: International Mountain Society

URL: https://doi.org/10.1659/0276-4741(2006)26[220:UCIT]2.0.CO;2

Mountain Research and Development Vol 26 No 3 August 2006: 220–226

Laura Ediger and Chen Huafang

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The Impacts of Afforestation on Landscape Patterns and Livelihoods

Changes in land cover patterns can be analyzed to improve understanding of macroscopic environmental change and impacts on landscape-level processes. However, analysis at only the landscape scale neglects the linkages between land use change and local livelihoods. In this paper we describe both land cover change from 1989–2001 and the resulting household impacts in a small upland watershed in western Yunnan, using remote sensing, spatial analysis, and interviews. Afforestation has substantially reduced farmland area over the past 15 years, affecting both ecological and economic patterns. Landscape fragmentation has decreased, as small scattered patches have been consolidated into larger patches. Household access to arable land has been reduced, total grain production has decreased, and households have become more dependent on cash income. The transition of farmland to non-agricultural, forested land marks a policy-driven shift in land use.

Keywords: *Land use change; landscape ecology; afforestation; agriculture; livelihoods; Yunnan; China.*

Peer-reviewed: *January 2006* ***Accepted:*** *April 2006*

Introduction

Land use and cover change (LUCC) research is an important component in the study of global environmental change. Land use patterns and land cover changes affect the structure and function of ecosystems, altering the movement of soil, water, and nutrients. Changes at the local and regional scales ultimately contribute to global processes (Houghton 1994; Riebsame and Parton 1994; Vitousek et al 1997). LUCC is influenced by geophysical, socioeconomic, and institutional factors, with the scale and intensity of human impact dramatically increasing over the last few decades.

Currently, nearly half of the Earth's human population is still engaged in subsistence agriculture (Marsh and Grossa 1996). However, low-input agriculture is perceived as a relatively inefficient use of land, and farmers are therefore under pressure to provide either more efficient economic (through intensified crop production) or environmental services for both local and global populations. In China, arable land is a precious commodity, but it is not immune to the twin pressures of agricultural industrialization and environmental conservation.

Widespread deforestation in China in the late 1950s and 1960s was intended to support national goals of self-sufficiency in natural resources by providing timber and fuelwood, while expanding agricultural area (Shapiro 2001). Individual planting of woodlots was allowed beginning in the late 1970s, and the rate of tree-planting rapidly increased after de-collectivization of rural land in the early 1980s. State forest areas represent some of the only remaining primary growth forest, and non-state forested areas have almost all been planted within the last 25 years (Hyde et al 2003). Government-sponsored reforestation efforts have expanded over that period, beginning with the devolution of forest management in the early 1980s from collectives to households, and now with widespread subsidies in the last 5 years for conversion of farmland and 'wasteland' (*huangshan*) to forest (Figure 1).

Most recently, a nationwide project has been implemented to encourage afforestation on a large scale: the *Sloping Land Conversion Program* (SLCP), also translated as 'Grain for Green.' By providing grain and cash subsidies to farmers who plant trees in designated cropland areas, the SLCP policy aims to convert vast amounts of steeply sloping agricultural land to forest or grassland, specifically targeting areas with a slope greater than 25°. Over 220 million *mu* (around 15 million ha) are scheduled to be converted from cropland to forest or grassland by 2010. Between 1999 and 2002, the project included nearly all of China's provinces and autonomous regions, more than 100,000 villages, and over 15 million farming households, and reported a successful conversion of over 3 million ha from cropland to forest (Bennett et al 2004).

The forestry policies mentioned above have played an important role in influencing LUCC in China over the last few decades. However, it is not only government policy that is causing changes in land use. Social and economic processes also play an important role in driving and directing patterns of land use change, although these processes, particularly at the individual and household scales, are often neglected (Irwin and Geoghegan 2001). While many different drivers and constraints on land use change have been identified in various settings (eg Liverman et al 1998; Pan et al 2004), this study focuses on demographic and policy changes, 2 highly salient factors in the Chinese context. China has both one of the lowest levels of per capita arable land and a history of stringent controls on population growth and migration.

The so-called 'one child' policy has been strictly enforced since the late 1970s, with families required to pay a large fine for having additional children (while urban families are limited to one child, minority groups and rural families are usually allowed to have 2). Migration has also been heavily regulated, so that for many

FIGURE 1 Example of changing landscape patterns in the study area: terraces for seasonal crops are interspersed with patches of pine planted on former farmland. (Photo by Jacob Hamstra)

years residents with a rural housing permit (*hukou*) were unable to find employment in urban areas. Migration regulations have been relaxed over the last decade, so that short-term relocation, especially for unofficial employment, is much easier. As more rural residents were allowed and encouraged to seek off-farm employment, the number of workers in the agricultural sector dropped steadily during the 1990s (Guang and Zheng 2005). This shift in rural economic options is occurring at the same time that reforestation limits the availability of arable land, and may be encouraging the diversification of farming households' labor and resource allocation.

Methods

This study was conducted in a small watershed that feeds into the Agazhai River, within the Nu River (Salween) watershed, located in Yangliu Township, Baoshan Prefecture, Yunnan Province (25°13′01.24″N: 99°01′38.20″E) (Figure 2). The watershed covers 42.35 km^2 of mostly steeply sloping land. It contains portions of 5 administrative villages and 14 natural villages, as well as approximately 3.8 km^2 of forested area managed by the Longyang District Forestry Bureau. The elevation ranges from 1120 to 2790 m. The average annual temperature is 11–14°C, and annual precipitation is 1200–1700 mm (Yangliu Township Council and Yangliu Township Government 1996). The complex topography in the watershed provides opportunities for a variety of land management techniques. Farmers grow paddy rice in the lower areas near the river, and corn and potatoes at higher elevations.

The focus administrative village, Pingzhang, is the only one that lies entirely within the watershed. This village consists of 8 natural villages, with a total population of 1573 in 401 households, and a population density of 116 inhabitants per km^2. The per capita annual income for the village was 873 yuan (US$ 106) in 2002.

Landsat TM and Landsat ETM+ images (30-m resolution) were used to classify land use for 2 periods. Scenes from February 1989 and 2001 were selected from available imagery to minimize cloud cover. ASTER images (15-m resolution) were used to improve visual interpretation of the Landsat images. The watershed boundary was determined on the basis of elevation data from a 1:50,000 topographic map.

FIGURE 2 Location of Yangliu watershed, situated in Baoshan Prefecture, Yunnan, China. (Map by authors and Andreas Brodbeck)

TABLE 1 Definitions of land use categories used in image classification.

Land use category	Criteria
Farm	Irrigated (paddy rice) and non-irrigated cropland
Forest	Average tree height >2 m; cover >20% of area
Grass	Grassy vegetation; shrubs <20% of area
Brush	Average woody plant height <2 m, cover >20% of area
Water	Water bodies
No cover	Bare rock/soil

To detect land cover change between the two periods, the images were first geo-corrected (rms error <1), and then classified into 6 categories (Table 1). The images were classified with object-oriented image processing techniques using Ecognition 2.0 (Definiens Imaging), with a combination of supervised and unsupervised classification techniques. Accuracy assessment using groundtruth points was 76%, with most classification errors occurring in the grass and brush categories.

Spatial data processing and LUCC analysis were performed with ArcGIS 8 (ESRI). Elevation and slope information was acquired from DEM data (derived from a 1:50,000 topographic map), and used to analyze the distribution of land use type based on elevation and slope. Landscape ecology indices, including number and size of patches and a 'clumpiness index,' were calculated using Fragstats 3.3 (McGarigal et al 2002). The clumpiness index is calculated based on the adjacency matrix of the land use types, which shows the frequency of specific patch types that are spatially adjacent to other patch types. The result ranges from '–1' when a patch type is maximally disaggregated to '0' when a patch type is randomly distributed, and approaches '1' when that patch type is maximally aggregated.

The interview data come from 43 households in Pingzhang, sampling approximately 10% of the population in each natural village. A semi-structured survey instrument was used to elicit information on household and land use changes over the last 15 years. Demographic information for all the administrative villages in the watershed was provided by the Yangliu Township government.

TABLE 2 Land use change in Yangliu watershed, 1989–2001.

Land use/cover	Area in 1989 (ha)	Area in 2001 (ha)	Change in area (ha)	Change in %
Farmland	2089	1567	–522	–25
Forest	720	1360	+640	+89
Grass	903	865	–38	–4
Brush/small trees	518	439	–79	–15

Results

Land cover change

The image classification indicates that land cover in Yangliu watershed changed substantially between 1989 and 2001 (Table 2). Farmland area decreased in this period by 522 ha, or 25%. This land was converted mostly into grass and brush (Table 3), as trees planted in the late 1990s are not yet classified as forest. The forested area of the watershed increased over those 10 years by 89% as a result of transition from brush and grassland to forest, as well as some conversion from farmland (Table 3). The area of grass and brush declined, by 4 and 15% respectively; brush in particular represents transitional land use rather than a stable condition. Overall, the landscape is very dynamic, with between 14% (of forest) and 84% (of brush) of the 1989 land use categories changing over the study period (Table 3).

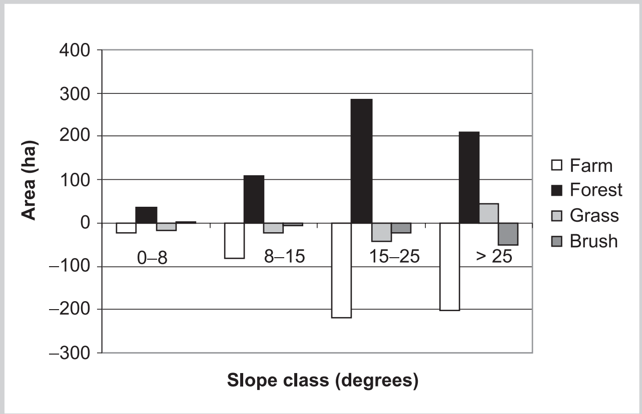
Slope is an important factor in land use, especially under recent policies. The slope categories used for our analysis were assigned based on those used for agricultural planning in Yunnan Province. Between 1989 and 2001, most of the reduction in farmland and increase in forest area occurred on less severe slopes (Figure 3). While the afforestation trends are having a major impact on the overall landscape, during the 1990s they were not aligned with national policy goals of converting slopes over 25°. In this study, 67% of the increase in forestland occurred on slopes of less than 25°. 2001 land use figures indicate that the dominant land use on steeply sloping lands was still farmland (37%), and that 40% of farmland was located on >25° slopes (Figure 4). Thus, a great deal of current farmland is located on marginal, highly erosive land, and afforestation projects during the 1990s did not explicitly target those areas. It may be that the SLCP will be more successful in converting steeply sloping land, but those results will not be visible for several more years. If the SLCP is successful in converting all slopes >25°, local farmers will lose nearly half of their current farmland.

During the 1989–2001 study period, most of the tree-planting was done by individual households, without external subsidies. All households were allotted plots of collective forest or wasteland in 1982 under the *Household Responsibility System* and—after an initial period of tree-planting in the early 1980s—they have maintained timber plantations in those areas. Respondents

TABLE 3 Land use transition matrix between 1989 and 2001. Each cell is read as a transition from the horizontal category to the vertical category. The numbers represent the proportion of a particular land use from 1989 which changed or remained stable over the study period.

2001 / 1989	Farm	Forest	Grass	Brush
Farm	0.67	0.09	0.14	0.10
Forest	0.03	0.86	0.03	0.07
Grass	0.12	0.23	0.55	0.10
Brush	0.07	0.65	0.11	0.16

FIGURE 3 Land use change by slope in Yangliu watershed, 1989–2001.



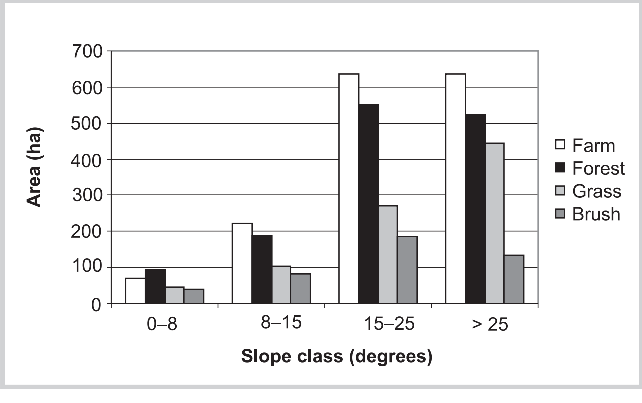


FIGURE 4 Distribution of land use by slope in Yangliu watershed, 2001.

FIGURE 5 Terraced farmland prepared for planting walnut seedlings in the study area. (Photo by Jacob Hamstra)

listed several reasons for deciding to convert their cropland to trees: the most frequently mentioned were "location too far from house," "low yield due to soil infertility or cold climate," and "landslides."

In addition to planting initiated by individual households, local government projects have encouraged farmers in this area to plant trees, especially on 'wasteland' (ie barren, unused land). During the 1989–2001 period, most of these projects were relatively small scale. For example, local governments in Yangliu Township have promoted planting of fruit and nut trees. The Pingzhang village government and the District Forestry Bureau supported a large planting of pear trees in 1998, and continue to facilitate planting and grafting of walnut trees by supplying plant material and technical assistance (Figure 5).

Landscape pattern

The distribution of land cover types also changed over the study time period. Patchiness decreased for all cover classes, resulting in fewer and larger patches (Table 4). The overall pattern of land cover has become less fragmented since 1989, as the total number of patches was reduced and patches of each type were either connected, or small patches were eliminated, creating a greater connectivity of patch types in the landscape. This is corroborated by a slight increase for all categories in the 'clumpiness index,' which demonstrates that land cover types became more spatially aggregated.

Population and per capita arable land

Based on township statistics, the 5 administrative villages which overlap the watershed of interest have had steady or slightly declining populations since 1980. The number of households has increased slightly over this time, but the number of persons per household has declined, from an average of 5.7 in 1980 to 4.1 in 2003. Meanwhile, the total agricultural land (both irrigated and dry) and the agricultural land per capita have gradually decreased. On average, the per capita arable land decreased by 10% in all villages over the study period. In Pingzhang (1989–2001), per capita paddy land and dry cropland decreased by 16% and 29%, respectively. In 1989, Pingzhang already had the least irrigated land per capita of all villages in the watershed, with 0.3 *mu* (.02 ha) per person, and this declined even further after recent afforestation. The total amount of farmland in Pingzhang declined from 1.2 *mu* to 0.9 *mu*/person (0.08 to 0.06 ha/person) between 1989 and 2001.

At the household scale, the dramatic nature of these changes becomes even more evident: 43% of interviewed households had a reduction of arable land during the study period, with an average of 40% of their productive cropland converted. The afforestation process continued after 2001, with the implementation of the SLCP. As of 2004, nearly 80% of interviewed households had reduced arable land, with an average of 49% of each household's productive cropland converted to tree plantations. Thus the process of landscape transformation identified for 1989–2001 is continuing, as even more farmland is being converted to perennial cultivation of timber and fruit trees.

Impacts on household economy

Staple crops such as corn, rice, and potatoes were slightly reduced during 1989–2001, but most converted plots during that period, especially those converted by household initiative, were on marginal land with low productivity, so planting trees there did not substantially reduce grain yield. Under the SLCP, however, the levels of grain production were much more dramatically reduced for participating households, due to the selection of plots with relatively high productivity. The SLCP was designed to provide farmers with compensation for crop losses: it allocated 150 kg of grain for each *mu* of

TABLE 4 Landscape ecology indices.

Land use/cover	Number of patches		Patch area (mean, in ha)		Clumpiness index	
	1989	2001	1998	2001	1989	2001
Farm	18	13	116.2	120.8	0.83	0.89
Forest	37	24	19.5	56.6	0.80	0.86
Grass	65	34	13.9	25.5	0.73	0.82
Brush	41	22	12.6	20.0	0.72	0.81

converted farmland. In our study area, this supplement was actually received only for the first year of the program (2002). Even when delivered, this grain supplement falls far short of the average 300 kg/*mu* that farmers in Pingzhang reported losing due to the SLCP.

The reduction of basic food crops is compounded by the loss of land available for supplemental food crops cultivated by simultaneous cropping with corn, or by planting wheat or vegetables in the secondary agricultural season. Wheat is used to make a significant portion of the homemade alcohol (*baijiu*) that is consumed in this area; other secondary crops (squash, beans, sunflowers, vegetables) are cultivated for household consumption and livestock fodder. Potatoes, which are grown at higher elevations instead of rice and corn, are often transported to nearby villages at lower elevations to barter for the household supply of rice. Many villagers at mid-elevations, who produced plenty of corn but not enough rice, bartered their corn for rice in the township. Thus, the decrease in arable land has meant a reduction in both food supply and economic options, as the farmers who relied on their own production for consumption or sale find it necessary to earn more income for the purchase of staple foods.

Farmers with reduced corn yield reported that they had less corn to feed their pigs, and some households now had to purchase corn for this purpose, or sell their pigs earlier, thus earning less money. Others had to borrow grain or money from relatives in order to meet their basic needs. Nearly 20% of interviewed households had paddy fields that were selected for conversion under the SLCP, and therefore had reduced rice production as well. These households had to sell more corn or pigs in order to buy rice for consumption, and also earned additional income doing manual labor in the village and surrounding area.

Discussion

The loss of arable land, and consequent decrease in crop production, has altered the landscape and directly affected household economies. Since field visits were conducted in 2004–2005, our results regarding household economies focus on changes over the last 5 years; over this period, the process of conversion identified for 1989–2001 has expanded, although with some differences. Earlier conversion activities were typically carried out at the household level, and targeted low-productivity farmland. Recently, most afforestation has been government-designed and implemented at the village or district levels, and has included farmland with higher productivity. Therefore, the reduction of food production and farming flexibility that accompanied the loss of agricultural land has become more pronounced in the last 5 years.

The impact of recent land use changes on the landscape ecology of this watershed can be interpreted in part from changes in land use patterns. These changes have implications for habitat availability (especially with the increase in forest patch size), and the possibility of an increase in biodiversity due to the variation in microenvironment that occurs when a patch is large enough to include both edge and core habitat (eg Chen et al 1992). The pattern of land use change also has implications in relation to altering hydrology and erosion in the watershed, the 2 issues that motivated the design of the SLCP.

The large portion of farmland on >25° slopes implies that previous afforestation did not target highly erosive areas. Under the SLCP, a slope of 25° or more is one of the primary criteria for selecting land to be converted. In this watershed, nearly half of the currently used farmland is on a slope of 25° or more, and is considered vulnerable to serious soil erosion. If this cropland is targeted for further afforestation, it will mean an even greater reduction in current levels of grain production.

The impacts of farmland conversion policies in the Yangliu sub-watershed over the last 15 years affect immediate resource availability and landscape configuration, but also influence long-term economic changes. The reduction of arable land is contributing to greater economic integration of the rural household economy with the market economy. Directly, this shift has fostered economic integration by making it more important for farming households to access cash for meeting basic needs, and may also be directing the allocation of labor from intensive farm work to off-farm employment opportunities.

The decline in rural self-sufficiency is clearly evidenced by the reduction in per capita agricultural land seen in this study. One of the most frequently cited drivers of land use change is the relationship between population and arable land (Liverman et al 1998). However, in the Yangliu watershed, strict controls on population growth have stabilized population levels. Restrictions on land tenure and migration, together with recent land conversion projects, have contributed to the per capita reduction in arable land.

The shift of labor resources away from intensive agricultural production illustrates a contradiction in terms of China's agricultural policies. On the one hand, long-term goals for social and economic development outline the transfer of significant portions of China's rural population to more profitable employment. Moreover, improved infrastructure and economic connectivity increase the convenience of seasonal migration, which has also been made easier by the relaxation of government controls on population movement. This shift of land and labor use effectively parallels national environmental and timber production goals to increase forest cover over large areas of the country. On the other hand, the national government continues to emphasize the protection of arable land and the importance of increasing agricultural production. This would require an intensification of the portion of the landscape that remains in agricultural use, and the application of unused labor to the grain and vegetable fields that still remain. Both household livelihoods and land use in China's mountainous margins are currently in transition, with the opportunities of farmers shaped and constrained by both environmental and economic policies. This process offers important lessons for the many other communities attempting to balance the pursuit of economic prosperity and conservation of natural resources.

ACKNOWLEDGMENTS

This research was conducted in collaboration with the World Agroforestry Centre (Kunming), with additional support from National Science Foundation Grant # DGE0237769. We would like to thank Dr Horst Weyerhaeuser for his invaluable advice and support; Deng Xiqing, Su Yufang, and Fredrich Kahrl for their expert assistance with data collection, processing, and analysis; and the officials and residents of Baoshan who generously shared their time and knowledge with us. This paper was improved by the helpful comments of 2 anonymous reviewers.

AUTHORS

Laura Ediger
Institute of Ecology, Ecology Building, University of Georgia, Athens GA, 30602-2202, USA.
lkediger@uga.edu

Chen Huafang
World Agroforestry Centre, c/o Kunming Institute of Botany, 3rd Floor, Library Building, Heilongtan, Kunming 650204, China.
chenhuafang@cbik.ac.cn

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