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Environmental and Socioeconomic Impacts of Increasing Rubber Plantations in Menglun Township, Southwest China



Significant changes in land use and land cover have occurred in Menglun Township, Xishuangbanna Autonomous Prefecture, southwest China. This is a region of high agro-ecological diversity representative of the general biophysical and socioeconomic conditions of Xishuangbanna. An analysis of satellite images showed that from 1988 to 2003, rubber plantations increased by 324%; this expansion generally occurred at the expense of forests and shifting agriculture. Most rubber expansion was in the lowland areas, where suitable microclimates and proximity to roads favored the development of the rubber industry. Economically, all the villages showed an improved living standard; from 1988 to 2003, the total net income of the township increased from CNY 4 million (US$ 0.49 million) to CNY 44 million (US$ 5.49 million). The increasing population and rising living standard of the area will put greater pressure on the environment and available land resources. Although the government considers rubber and other plantations such as tea and sugar to be 'green industries,' the loss of tropical rainforest and agricultural lands (including diverse shifting agriculture) suggests that the potential impacts of policies to promote green industries should be considered carefully. Communities such as those in northern Laos, where the rubber industry is now expanding rapidly, are likely to experience a similar scenario.

Keywords: *Land use/cover change; tropical forest; cash crop; Green Industry; rubber; China.*

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Introduction

Globally, some of the most intensive land use and land cover changes have occurred in tropical areas (Alves 2002; Arroyo-Mora et al 2005). This change is characterized by very rapid deforestation and a shift towards human-dominated landscapes (Laurance 1999; Houghton 2002). Consequently, a number of associated problems such as forest conversion, biodiversity loss, and local environmental change have aroused widespread attention. Similar processes are occurring in Xishuangbanna in southwest China, a mountainous area with tropical ecosystems that lies near the northern limit of the tropics. This region has undergone rapid land use change in recent decades and has been internationally recognized as a hotspot for biodiversity conservation (Davis and Heywood 1995; Xu et al 2005a).

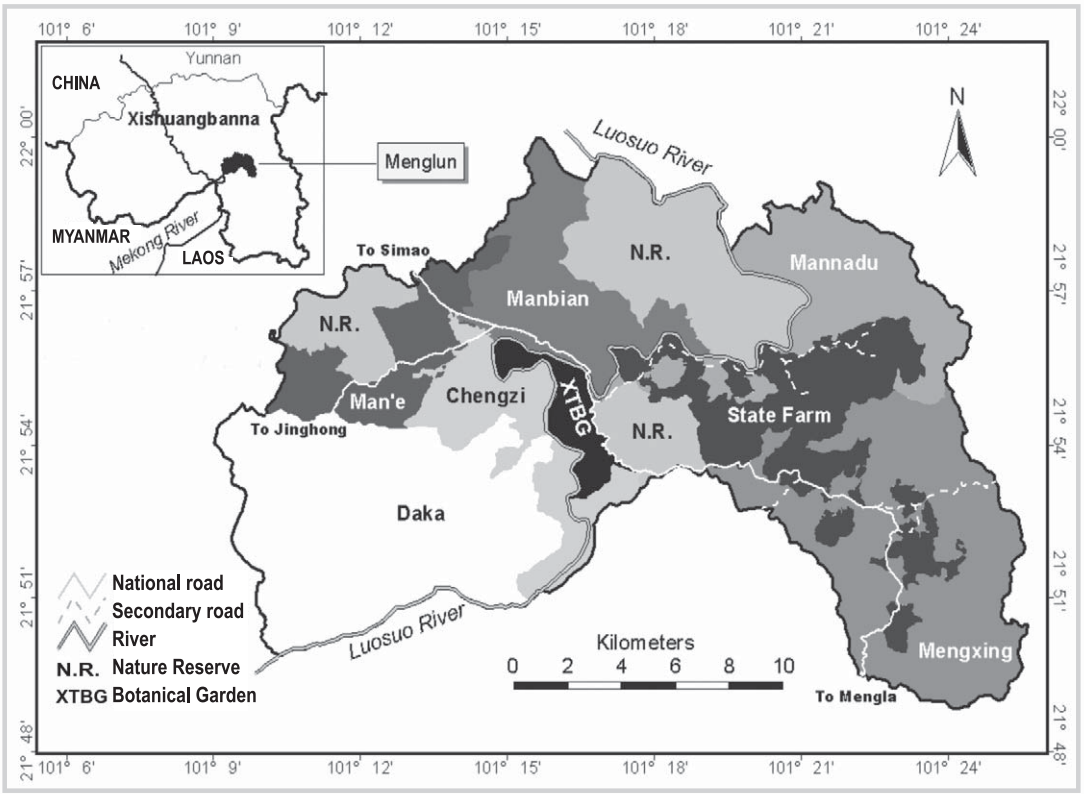
The subject of the present study, Menglun Township in Xishuangbanna Prefecture, is typical of the diverse tropical and subtropical regions in southwest China. The landscape ranges from lowland river valleys, through tropical and subtropical forest, to cooler mountainous highlands. The local economy used to depend largely on traditional agriculture, including paddy in the lowlands and swidden in higher areas, but also on an interaction of mixed systems in which forests were maintained by upland communities to supply good quality water, timber, and non-timber forest products, as well as hunting and fishing (Xu et al 2005b). This township is also culturally diverse, being home to more than 10 ethnic minorities. There is a relatively high population of Han, who were largely resettled here in the 1950s and 1960s as part of the large-scale post-revolutionary government attempts to modernize this region.

In recent decades, obvious changes in land use and land cover have occurred in this township, mainly due to the establishment of rubber plantations that have replaced large areas of forest and farmland, including traditionally managed fallow land (Liu et al 2005). The expansion of rubber plantations began in the early 1950s as post-revolutionary governments aimed to modernize and industrialize the agricultural systems in minority dominated rural regions of southern China. During the collective period (1950–1978), most rubber and other cash crop plantations (eg sugar, tea, orchards) were managed by State and people's communes as State farms and enterprises. More recently, the implementation of the Household Responsibility System after 1979 allowed farmers to decide for themselves where, what, and how much to plant (Xu et al 1999). This policy gave individual households greater incentives to produce cash crops (Long et al 1999). Additionally, as private rubber growers are more competitive in the cost of production than State farms, private rubber plantations have expanded rapidly, to the extent that most newly established rubber plantations are now private (Xu et al 2005b). In the current climate of greater privatization, infrastructure and market development, plantations and other cash crops, as opposed to traditional agriculture, dominate.

At the end of the 1990s, the Chinese government introduced the Green Industry policy, which was implemented in combination with the Sloping Land Conversion Program. These policies discouraged swidden, which was regarded as environmentally damaging and primitive (in fact the Sloping Land Conversion Program specifically aims to eliminate

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FIGURE 1 Location and administrative boundary of the six villages and Nature Reserve (N.R.), Botanical Garden (XTBG) and State Farm in Menglun Township, southwest China. (Map by Wenjun Liu and Huabin Hu)



swidden on sloped sites and increase forest coverage), and further promoted a transition from traditional shifting agriculture to cash crop plantations. In Xishuangbanna, rubber was favored because it is deemed to meet both aims: increasing tree cover and providing cash income for private landholders. In the meantime, Menglun Basin was selected by local government to be one of the economic centers for food crops, fruits and rubber production in Mengla County owing to its favored climate and land resources. All of these factors have led to the rapid development of agriculture at the cost of most fallow land and large areas of forest.

The present article presents information that illustrates the dramatic land use changes in Menglun Township, with special emphasis on rubber expansion. In addition, we link these changes with socioeconomic data and the physical conditions of the township to trace how the landscapes and economies of the villages changed accordingly. The expansion of plantations and cash crops may have increased income in the region, but at the cost of a loss of agrobiodiversity and cultural identity within local communities.

Study area

Menglun is an administrative township (101.15°E – 101.43°E, 21.81°N – 22.00°N) of Mengla County in the Xishuangbanna Dai Autonomous Prefecture of Yunnan Province, China (Figure 1). The township covers about 335 km^2. The region is mountainous, with elevations ranging from 540 m to 1400 m, and is traversed by Luosuo River, a tributary of the Mekong, which winds from the north to the southwest. The township contains 6 administrative villages—in China an administrative village is a governance region which can include a number of individual villages, so-called natural villages. Four administrative villages (Daka, Chengzi, Man'e, and Manbian) are located to the west of Luosuo River, and Mannadu and Mengxing are located to the east of the river. Besides these villages, the township incorporates a tropical botanical garden, a State farm, and part of the Xishuangbanna National Nature Reserve (Figure 1).

The township is accessible by national road from Mengla County to the southeast, from Jinghong City to the west, and from Simao to the northwest. National roads pass through the lowland areas of Manbian, Man'e, Mengxing and Chengzi, while secondary roads service Mannadu and Daka. The Botanical Garden, State Farm, and Nature Reserve are within easy access of the main road.

There are more than 11 ethnic groups in Menglun Township, including Dai, Hani, Han, Yi, Ji'nuo, Lahu, Wa, Bai, Yao, Hui, and Bulang. Of these ethnic groups, the Dai and Hani are dominant, accounting for 56.3% and 22.4% of the total population, respectively. Han Chinese comprise 14.3% of the population. The total

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population of Menglun (including people in the State Farm) has been growing at an average rate of 2% per year since 1980. As of 2000, the total population was 18,860 (including a State Farm population of 4407). The population density is about 55 persons/km^2 (SDMTG 1988–2003). Most of the villages are predominantly Dai, except Daka village, which is located in a more mountainous region and is chiefly Hani. Traditionally, Dai people live in the lowland river areas, where paddy cultivation is their major agricultural activity, whereas the Hani live in mountainous areas, employing swidden cultivation augmented by hunting and fishing.

Methods

Image processing

The spatial database was developed from 3 sources: 1) the land use and land cover maps derived from independent supervised classifications of a February 1988 Landsat TM image and a March 2003 Landsat ETM image (both with 30-m spatial resolution); 2) records from field surveys; and 3) a digital elevation model (DEM) derived from digitized topographic maps (scale 1:25000). Geometric rectifications used a pre-rectified image to confirm all the images in the same coordinating system (with root mean square [RMS] error less than 1 pixel).

To enable post-classification analysis of the images, land use and land cover maps of the two periods used the same classification system (including 13 classes of land use and land cover type). The classification accuracies exceed 80% according to several sources of reference: our analyses of ground-truthed GPS points; a 2002 Ikonos image covering the northwestern part of the study area; and the land use and land cover map of the 1990s.

Five main land use and land cover types based on area weight were chosen to study the processes of change and characterize the major agricultural economic activities in this area: 1) fallow field ('slash-and-burn land' or shifting cultivation land, including cultivated land and land fallowed within 1 or 2 years); 2) paddy field; 3) rubber plantation; 4) forested area (covered with dense forest, including bamboo); 5) shrubland (>20% shrub cover and <20% tree cover).

Data collection

Secondary data, including statistics on population, agricultural production, and income and expenditure between 1988 and 2003, were collected from local government offices. Local officials were interviewed for land use history and details about implementation of relevant policies. We sorted the State statistics to the finest scale possible (administrative village), so that we could compare these data with the land use and land cover data at the same level.

Data analysis

Geographic Information System spatial analysis functions (overlay, buffer, and area tabulation) were used to analyze the process and character of land use and land cover change during the study period.

Land use and land cover change in the sub-areas (including each administrative village and the national gardens, reserves, and State farms) were compared. Because of differences in total area, relative rather than absolute changes to land use and land cover change were measured using the index R, which was calculated as follows:

$$R = (U_b - U_a) / (U_a + U_b)$$

where U_a, U_b are the areas of certain land use and land cover type in 1988 and 2003, respectively. R is the index of relative change over time that ranges from –1 to 1. The proximity to –1 or 1 shows the extent to which a particular land use and land cover type decreased or increased over the 15 years. When there was no change in land use ($U_b = U_a$), R is 0.

The proximity to roads in the individual administrative areas is a calculation of the percentage of the total village area within 1.5 km of a road. This buffer distance was selected because the effects of roads on land use and land cover change are most significant within this distance (Liu 2004).

Results

The expansion of rubber plantations

Rubber plantations expanded rapidly between 1988 and 2003 (Figure 2). Over this period the total area under rubber grew from 4042 ha to 13,104 ha: an increase of 324%. The change matrix shows that the majority of these new rubber plantations were derived from forested areas (4150 ha, 42%) and fallow fields (3001 ha, 23%).

Changes within sub-areas in relation to accessibility

Rubber plantations

During the period 1988–2003, all areas within the boundary of Menglun Township showed considerable increases in rubber plantations. As shown in Table 1, the greatest relative increases were in the villages of Chengzi and Daka. Both have an index of relative change (R) of 1, indicating that there were no rubber plantations in 1988; the area of rubber plantations increased from 0 to 1276 ha in Chengzi and 1788 ha in Daka. These increases in rubber plantations were concentrated in the lower and more accessible areas. This is well illustrated

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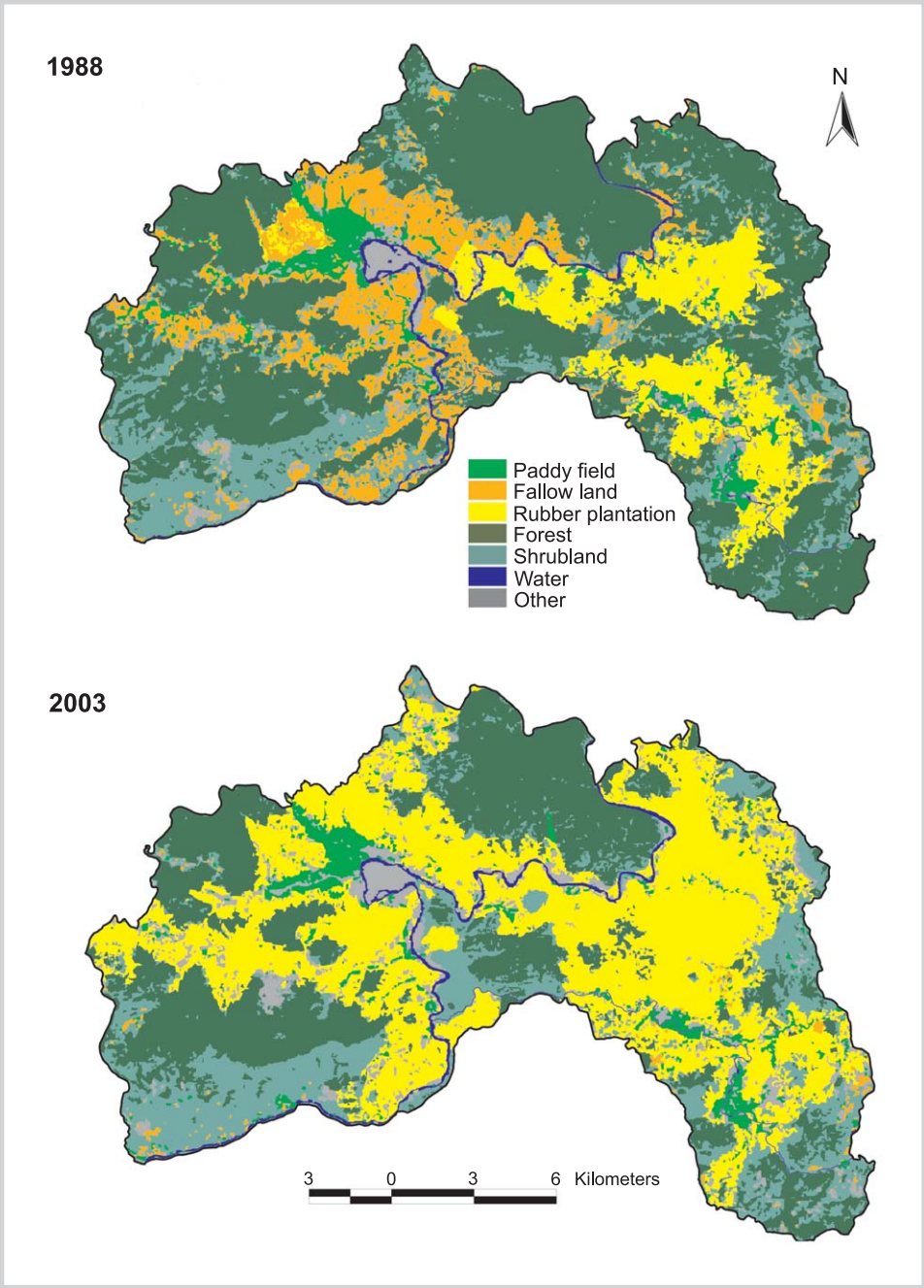


FIGURE 2 Land use and land cover map of Menglun Township showing how rubber plantations have expanded from 1988 to 2003. (Note: The category 'others' includes built-up, orchard, sand, garden, nursery, vanilla plantation, and cleared land.) (Map by Wenjun Liu and Huabin Hu)

by Daka Village, which is the least accessible sub-area in Menglun because it is the highest and most mountainous. Only 10% of Daka is within 1.5 km of a road and 48% of the area lies above 1100 m. However, over 90% of its rubber plantations are below 900 m, and over 60% of the area within 1.5 km had rubber planted.

The villages of Manbian and Man'e also showed significant increases in rubber plantations (R = 0.85 and 0.79, respectively); both these areas have good road access and are at relatively low elevations. In Manbian and Man'e, over 50% and 80% of the area is within the 1.5 km road buffer respectively, and over 90% of the total area lies below 900 m. Mannadu, which is adjacent to the State Farm, has also experienced a large expansion of rubber (R = 0.76). The State Farm maintains a large area of rubber plantation (over 2500 ha), but as most of it was planted before 1988, the relative change is small (R = 0.10).

Forested area

The forested area decreased markedly in all areas (Table 1). Most villages have lost more than 50% of their forest cover within 15 years; however, forest cover has been retained in the Nature Reserve, in which the R value for forest transition was –0.06. Mannadu had the lowest R value for forest, indicating that large areas of forest have been lost over the last 15 years, while Daka has the lowest relative forest loss.

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TABLE 1 Changes in major land use and land cover types in Menglun from 1988 to 2003. Figures given show area (ha) per type and year, and relative change index (R). The bolded R values are equal or close to 1 or –1, indicating a **very significant change** (increase or decrease) in area.

Area (see Figure 1)	Year	Land use type and relative change index for 1988–2003				
		Paddy	Fallow	Rubber	Forest	Shrubland
Nature Reserve	1988	27	131	66	4668	265
	2003	34	10	268	4146	643
	R	0.11	**–0.86**	0.6	–0.06	0.42
State Farm	1988	112	70	2561	703	296
	2003	168	17	3106	186	145
	R	0.2	–0.6	0.1	–0.58	–0.34
Botanical Garden	1988	10	257	53	141	88
	2003	3	0	115	57	363
	R	–0.58	**–1**	0.37	–0.42	0.61
Chengzi	1988	320	871	0	613	283
	2003	254	0	1276	320	112
	R	–0.11	**–1**	**1**	–0.31	–0.43
Man'e	1988	245	525	111	514	74
	2003	231	0	957	178	5
	R	–0.03	**–1**	**0.79**	–0.48	**–0.88**
Manbian	1988	183	1026	130	909	372
	2003	165	19	1628	322	267
	R	–0.05	**–0.96**	**0.85**	–0.48	–0.16
Mannadu	1988	37	126	252	2153	451
	2003	53	0	1834	416	565
	R	0.19	**–1**	**0.76**	**–0.68**	0.11
Daka	1988	169	1181	0	3208	2529
	2003	126	77	1788	2580	2293
	R	–0.15	**–0.88**	**1**	–0.11	–0.05
Mengxing	1988	308	196	849	3028	1321
	2003	364	124	2024	1321	1716
	R	0.08	–0.22	0.41	–0.39	0.13
TOTAL	1988	1426	4408	4042	16,331	5730
		4.3%	*13.2%*	*12.1%*	*48.7%*	*17.1%*
	2003	1407	249	13,104	9859	6139
		4.2%	*0.7%*	*39.1%*	*29.4%*	*18.3%*
	R	–0.01	**–0.89**	0.53	–0.25	0.03

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TABLE 2 Change of economic structure in Menglun from 1988 to 2003, based on RESSMT (1988–2003).

Industrial sectors	1988		2003		Change
	Gross income (10^4 yuan)	(%)	Gross income (10^4 yuan)	(%)	(%)
Agriculture	246.2	55%	2981.7	67%	11.39%
Forestry	51.2	11%	306.6	7%	–5%
Livestock raising	110.5	25%	258.6	6%	–19%
Fishery	12.1	3%	71.5	2%	–1%
Industry	10.2	2%	478.9	11%	8%
Construction	N/A	N/A	155.0	3%	—
Transportation	11.5	3%	72.6	2%	–1%
Services	N/A	N/A	79.4	2%	—
Others	4.0	1%	69.9	2%	1%
Total	**445.7**	**100%**	**4474.0**	**100%**	**—**

Paddy field
There were only minor changes in the area of paddy field except in the Botanical Garden, where the R value reached –0.58 (Table 1). The changes show that paddy fields in lowland villages decreased slightly because of more urbanization and cash crop development (eg Manbian Village), but increased in areas of higher elevation such as Mannadu, and even on the edge of the Nature Reserve.

Fallow land
Fallow land decreased markedly, with R values close to –1 in virtually all areas. The only exception was Mengxing Village, where the degree of loss was less drastic (Table 1).

Shrubland
Changes in shrubland varied among administrative areas. Shrubland increased in the Nature Reserve, Botanical Garden, and Manadu and Mengxing villages, but decreased in the State Farm and other villages; therefore, the total area of shrubland in the township showed little change (R = 0.03).

Socioeconomic changes

Several trends have been apparent in Menglun since 1988 (Table 2). The most obvious change in the economic structure of Menglun (based on gross income) over the last 15 years is the expansion of agriculture (an increase of over 11%); this includes rubber plantations, paddy fields, fallow land, and fruit trees. Although State statistics do not distinguish rubber from other agriculture, this expansion is largely a result of increased rubber plantations in accordance with the overwhelming dominance of rubber in the total land area. Moreover, the increase in industry (more than 8%) is almost entirely due to rubber processing. The effects of this rubber and agricultural expansion can be seen in the other sectors that have declined, most notably livestock raising (down 19%). Some tertiary industries (services) gradually emerged owing to tourism development.

The decrease in livestock is due to the reduction of buffaloes, the number of which dropped from an estimated 5260 head in 1988 to fewer than 700 in 2003. Fewer of these animals are kept because they tend to destroy rubber seedlings. This drop was most pronounced after 1995. By contrast, the number of pigs increased from 5052 to 8371 during 1988–1995, then decreased to 5648 in 2003 (SDMTG 1988–2003).

During the period 1988–2003, all villages in Menglun experienced rapid economic growth, with a three-fold increase in per capita net income and a four- to eight-fold increase in per capita expenditure on durable consumer goods (Table 3). Income and expenditure among villages vary with local conditions, such as physical settings, per capita rubber holdings, market access, and consumption patterns.

Discussion

Rubber expansion in Menglun

The expansion of rubber in Menglun (>9000 ha) has been dramatic over the last few decades. Rubber plantations have replaced former land use in all administrative areas. The greatest expansion of rubber (95%) occurred in the lowland areas (<900 m) (Liu et al 2005). There are 2 closely related explanations for this pattern. First, the microclimate of lowland areas is better for rubber trees (Qu and Gao 2003). However, new varieties are being introduced that will permit the expansion of rubber plantations at higher elevations

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TABLE 3 Changes in income and expenditure (in yuan) in the villages of Menglun, based on RESSMT (1988–2003) and SDMTG (1988–2003).

	Per capita net income			Per capita expenditure on durable consumer goods		
Village	1988	2003	Increase (%)	1988	2003	Increase (%)
Chengzi	459.3	1557.7	339%	159.6	1025.9	643%
Man'e	434.4	1388.6	320%	227.2	1090.6	480%
Manbian	452.3	1701.7	376%	155.4	615.0	396%
Mannadu	456.2	1394.9	306%	187.5	1054.9	563%
Mengxing	510.4	1683.0	330%	208.5	1108.0	531%
Daka	478.7	1478.0	309%	39.5	316.9	802%

(Lin 2004). Secondly, road access in lowland areas is better (by virtue of the flatter terrain and natural corridors provided by river valleys), facilitating the development and transport of raw rubber for processing. For example, Daka, which is the largest, highest, and least accessible administrative village (2300 ha, of which 48% is above 1100 m), had no rubber prior to 1988. Since this time 1788 ha have been planted; 90% of the rubber occurs below 900 m.

The drivers of rubber expansion

The expansion of rubber in southern China results from the interaction of several factors. Before the market economy developed in China, rubber was part of an ideological drive to modernize post-revolutionary China and make the country self-sufficient (Xu et al 2005b). In recent decades, continued expansion has been driven in part by an expanding rubber market, powered largely by the modernization and massive increase of vehicles in China, because rubber is a very important material for car production. In addition, free market and the lure of cash products have encouraged numerous private landholders to consolidate and turn to rubber over the last few decades.

Our data in Menglun showed that rubber expansion in recent years was mainly in the private sector, ie the index of relative change for rubber increase in the State Farm since 1988 was very small ($R = 0.10$). This increase in private rubber is likely due to several factors. The first, as mentioned earlier, is that following the end of the commune system (which designated land use), the introduction of the Household Responsibility System in 1979 granted farmers greater autonomy and long-term land security, and many were more confident about planting rubber. Secondly, while State farms and facilities still process rubber, privatization has made rubber farms less competitive and responsible for increasing additional costs (eg education, health care of workers), so their ability to survive, let alone expand, is limited.

Many studies of land use history have shown that the conversion of forest to cash crops or other commercially important simplified forest types is widespread in developing countries (eg Rao and Pant 2001). This loss of forest can also be explained by the fact that efficient economic use of land generally dictates a greater preference for agricultural production than for forest activities (Kammerbauer and Ardon 1999). This is the case in Menglun, where traditional forest use (eg hunting, non-timber forest products, and some grazing) is low compared with rubber plantations, which have driven the loss of tropical rainforest. The economic benefits of this cash crop economy are clearly evident in the large rises in per capita income and spending seen across all villages. These economic benefits are likely to continue driving the expansion of rubber.

Unlike other parts of Asia, where rubber may be grown as part of mixed agro-ecosystems, rubber in Xishuangbanna is mainly grown in monoculture plantations. Therefore, it is important to carefully address all the potential effects of this, both positive and negative (eg changes in rural incomes, loss of agrobiodiversity, water catchment implications), and consider a coordinated strategy to balance land use and environmental values.

Green industries: benefits and problems

Over the last 15 years, the massive expansion of rubber plantations in Menglun was promoted by a series of policies—Developing Green Industry—which promoted the development of plantations of rubber, tea, and fruit, together with tourism. The term 'green' is used because these industries, which are not supposed to produce negative environmental effects, bring socioeconomic benefits such as access to health and education services and growth in net income (Xu et al 2005a). In addition, recent introduction of the national Sloping Land Conversion Program further supported additional conversion from traditional agriculture (ie swidden) to cash crop plantations.

However, there has been a price to pay for this progress, namely the loss of forest for agriculture, increased urbanization, and timber extraction. Such deforestation has been widely recognized as being a threat to local environments and cultures in other parts

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of the world (eg Alves 2002), and certainly the same threats exist in Xishuangbanna, where the rich ethnic culture is rooted in the originally diverse environment. The increasingly homogenous landscape in Xishuangbanna will affect the diverse cultures of the ethnic minority groups who live here (Zhang et al 2001). Traditionally, local minority people lived self-sufficiently.

Currently, in modern China, market demand for consumable goods is growing rapidly (evidenced locally by the rapid rise in consumption of goods in all villages). The rapid urbanization taking place across China is also apparent in Menglun. This urbanization puts more pressure on local resources (ie power, transport, and water), which in turn can spur further expansion of rubber plantations and other cash-generating industries, perpetuating a vicious cycle of development and ecological simplification.

In addition to the loss of natural forestlands, the expansion of monocultures such as rubber plantations, which dominate the lowland spaces in place of mixed forest and agricultural systems, will significantly reduce agrobiodiversity and livelihood flexibility. The loss of fallow and mixed farming can be directly attributed to their replacement by rubber plantations; moreover, this trend is continuing. Although rubber is the largest culprit in this loss of agrobiodiversity, increased production of paddy rice and fruit plantations was also observed in Menglun; these too have replaced mixed swidden systems.

Similarly, the loss of livestock seems to be related to rubber because the decrease is due entirely to a reduction in buffaloes rather than pigs. Pigs are usually kept in sties and fed with fodder and animal feed, and are a significant source of cash income for rural households. By contrast, buffaloes, which were regarded as an indicator of family wealth by ethnic minorities in this area, are grazed in the wild (eg swidden land, forests). Consequently, these animals often cause damage to rubber trees, and grazing areas are also limited due to the expansion of rubber plantations.

By concentrating on rubber production, these communities have experienced rapid economic growth. But the benefits must also be viewed carefully over the long term. A collapse of the rubber market could have disastrous consequences for these communities, particularly now, since the market is privatized and lacks the government protection it enjoyed in the past.

The long-term balance between the environment and development in Menglun is a cause for concern. In order to promote sustainable development, the local people and government should be attentive to the possible effects of the so-called 'Green Industry.' Slowing down the expansion of rubber plantations and protecting local forests would seem to be a prudent step, but in the light of the increased income generated, some re-evaluation of natural resources is needed.

Limitations of the present study

Although this study shows some very clear land use trends, it is important that the limitations of the current data be acknowledged. As noted in the section on methods, the constraints of available imageries (time sequences and quality), in concert with the usual topographic challenges of working in this type of mixed terrain, made some of the smaller dissected areas difficult to distinguish (eg sections of fallow, shrubland, and mixed forest). Moreover, there are many restrictions in attempting to link land use and socioeconomic data. For one thing, the easy availability of State data is relatively recent and its continuity and reliability are often less than ideal. Furthermore, we are limited by the State definition of rubber as part of the general agricultural statistics, so it is hard to tell accurately how much rubber contributed to the local economy. But the overwhelming dominance of rubber plantations within the agricultural land category suggests that most economic increases in Menglun result from rubber expansion. Finally, land use study data are often based on topography, such as watersheds, while socioeconomic data are based on political boundaries—making comparative studies far more difficult. Nevertheless, we feel confident that trends outlined for Menglun are very significant, and this study helps establish a baseline from which better data collection and monitoring can be continued.

Conclusions

What we have observed in Menglun seems to be indicative of land use trends in Xishuangbanna generally. These results are also likely to have greater regional relevance, particularly as rubber plantations expand into neighboring countries (a large-scale expansion of rubber is planned by Chinese interests in northern Laos). The rapid development of cash crops at the expense of traditional agriculture suggests that the economy of this area has jumped from the 'first phase,' dominated by agriculture, to the 'second phase,' characterized by the loss of traditional agricultural land and increases in urbanization and economic crops (Kong et al 2005). These changes may well lead to better socioeconomic conditions for local communities, but there is a risk in depending too heavily on 1 or 2 crops, particularly now, in a largely unprotected free market environment. The loss of traditionally flexible farming systems is something that must be carefully monitored. Similarly, the loss of biodiversity is also of great concern.

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