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ORIGINAL PAPER

Demand for rubber is causing the loss of high diversity rain forest in SW China

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Abstract As the economies of developing countries grow, and the purchasing power of their inhabitants increases, the pressure on the environment and natural resources will continue to increase. In the specific case of China, impressive economic growth during the last decades exemplifies this process. Specifically, we focus on how changing economic dynamics are influencing land-use and land-cover change in Xishuangbanna, China. Xishuangbanna has the richest flora and fauna of China, but increasing demand for natural rubber and the expansion of rubber plantations is threatening this high-diversity region. We quantified land-use/land-cover change across Xishuangbanna using Landsat images from 1976, 1988, and 2003. The most obvious change was the decrease in forest cover and an increase in rubber plantations. In 1976, forests covered approximately 70% of Xishuangbanna, but by 2003 they covered less than 50%. Tropical seasonal rain forest was the forest type most affect by the expansion of rubber plantations, and a total of 139,576 ha was lost. The increase of rubber plantations below 800 m, shifted agricultural activities to higher elevations, which resulted in deforestation of mountain rain forest and subtropical evergreen broadleaf forest. Although these changes have affected the biodiversity and ecosystem services, we believe that long-term planning and monitoring can achieve a balance between economic and social needs of a growing population and

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the conservation of a highly diverse flora and fauna. Below 800 m , we recommend that no more rubber plantations be established, existing forest fragments should be protected, and riparian forests should be restored to connect fragments. Future rubber plantations should be established in the abandoned arable or shrublands at higher elevations, and tea or other crops should be planted in the understory to improve economic returns and reduce erosion.

Keywords Biodiversity conservation · Economic development · Land-use/land-cover change · Rubber plantations · Xishuangbanna

Introduction

Globally the rate of deforestation has decreased during the last decade, and in more than 50 countries reforestation has surpassed deforestation (FAO 2000). Although these are positive signs, most of the countries that are experiencing forest transition are in the northern hemisphere and are developed countries. In many tropical and developing countries, deforestation continues to exceed reforestation. Logging, mining, slash and burn agriculture, and fire wood collection contribute to deforestation and forest degradation, but by far the most important factor is the conversion of forest to agriculture and pastures. Although technological advances have helped to increase productivity and limit agricultural expansion, the increasing human population and the increase in per capita caloric intake continue to drive agricultural expansion. For example, the demand for soy products has lead to the deforestation of millions of hectares of dry forest (i.e. cerrado, chaco) in South America (Grau et al. 2005a, b), and between 1990 and 2002, an additional 10.7 million ha of tropical forest were converted to oil palm plantations, mainly in SE Asia (Casson 2003). As the economies of developing countries grow, and the purchasing power of their inhabitants increases, the pressure on the environment and natural resources will continue to increase.

The impressive economic growth of China during the last decades exemplifies this process. During the last 25 years, on average, the Gross Domestic Product (GDP) has increased at a rate of more than 8% per year (Wong and Chan 2003). China has shifted from an exporter of soybean to the largest importer (Tuan et al. 2004). It presently uses 40% of the global supply of cement and 20% of the global supply of steel (Chandler and Gwin 2004). Furthermore, hundreds of power plants and dams are in construction around the country (Sinton et al. 2005). What will be the biodiversity consequences of this economic growth?

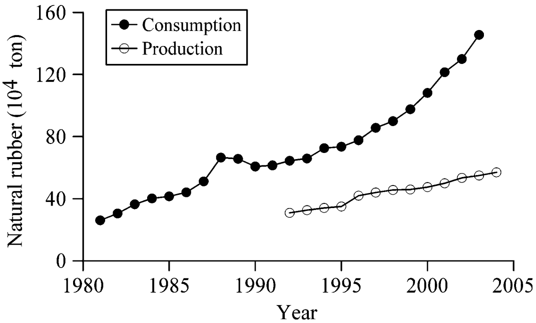
Within China, the Xishuangbanna region is the most diverse region of China, and it is included in the Indo-Burma biodiversity hotspot (Myers et al. 2000). It represents only 0.2% of the area of China, but it contains approximately 5000 species of higher plants (16% of the nation's total), 102 species of mammals (21.7%), 427 species of birds (36.2%), 98 species of amphibians and reptiles (14.6%), and 100 species of freshwater fish (2.6%) (Zhang and Cao 1995). The ecological and socioeconomic context of Xishuangbanna is representative of other tropical regions of Southeast Asia that contain high levels of biodiversity and are threatened with deforestation and environmental degradation.

An important driver of land-use/land-cover change in the Xishuangbanna region has been the transformation of tropical forest to rubber plantations. The first rubber plantations were established in 1956 to meet the needs of national defense and economic development. In 1978, the expansion of rubber plantations was accelerated by the China's Reform and Innovation policy (Edit committee of Xishuangbanna Dai Autonomous Prefecture Difangzhi 2002). Today, the expansion of rubber plantations in Xishuangbanna is continuing, driven by the increase in national consumption (Fig. 1). The increasing demand for natural rubber during the last 10 years, in large part, has been driven by the need for automobile tires due to the dramatic increase in automobile production. Although there has been an expansion of plantations in China and an increase in production (Fig. 1), China produces less than half of what it consumes, and this is promoting the conversion of forest to rubber plantations in other tropical regions.

The Chinese government has enacted different policies in response to the impacts that economic development is having on the environment. At the national scale, new forestry laws and polices were enacted. This included increasing the number and extent of conservation areas, and the implementation of the Natural Forest Protection Plan to control deforestation and increase forest cover (Yin 2001). Within Xishuangbanna, these policies had a mixed impact. On the positive side, a series of nature reserves were established in 1980 that cover 240,000 ha, 12% of Xishuangbanna (Guo et al. 2002). But, the Natural Forest Protection Plan actually lead to a reduction in natural forest cover, because in the plan the definition of forest includes rubber plantations. Furthermore, given that rubber plantations are a major component of the local economy, there continues to be local incentives for establishing new plantations. This policy assumes that rubber plantations would have positive environmental effects by increasing forest cover. However, to assess the net effect, three factors need to be considered: (1) the environmental effects of the plantations in relation to other land cover types, (2) the effects of new plantations on the dynamics of other land uses, in particular if new plantations are replacing agriculture or mature forests, and (3) the spatial distribution of the resulting land cover configuration.

A major limitation for enacting effective development and conservation activities is the lack of spatially explicit information on land-use dynamics. In the past, land-use decisions in Xishuangbanna were often based on government reports that did not even include land-use categories appropriate for the region (Guo et al. 2002). The lack of recent spatially explicit information has led officials to believe that the expansion of rubber plantations was occurring in areas of shifting cultivation, when they were actually replacing the most species diverse forest in China. If local officials

Fig. 1 Production and consumption of natural rubber in China. Data source from Li and Zhang (2004)



in Xishuangbanna or in other region experiencing rapid transformation are to balance development and conservation needs, they must have access to the best information.

The major objective of this study is to quantify land-use/land-cover changes over the past 27 years (1976–1988 and 1988–2003) in Xishuangbanna, China. Based on our results, we provide suggestions on how to improve land-use policy in a way that balances the need for economic development and biodiversity conservation.

Methods

Study area

Xishuangbanna (21°08′–22°36′ N, 99°56′–101°50′ E), in Yunnan Province, southwest China, covers 19,150 km^2, includes three counties (Jinghong, Menghai and Mengla), and borders Laos to the south and Myanmar to the southwest (Fig. 2). The region has mountain-valley topography with the Hengduan Mountains running north-south, and about 95% of the region is covered by mountains and hill. The Mekong River flows through the center of Xishuangbanna, and the region contributes more than 20 important tributaries, resulting in many river valleys and small basins (Cao and Zhang 1997). The altitude varies from 2430 to 475 m above sea level. The climate of this region is influenced by warm-wet air masses from the Indian Ocean in summer, including monsoons, and continental air masses of subtropical origin in winter, resulting in a rainy season from May to October, and a dry season from November to April (Zhang 1988). Within Xishuangbanna the annual rainfall ranges from 1100 to 2400 mm, and is lower in center region and higher in the western and eastern regions (Edit committee of Xishuangbanna Dai Autonomous Prefecture Difangzhi 2002). The combination of geography and climate in Xishuangbanna has created a transition zone between the flora and fauna of tropical South East Asia and subtropical and temperate China (Cao et al. 1996), resulting in the region with the highest biodiversity in China (Zhang and Cao 1995; Cao and Zhang 1997). The five primary forest types in Xishuangbanna are: tropical seasonal rain forest, tropical mountain rain forest, evergreen broad-leaved forest, monsoon forest over limestone, and monsoon forest on river banks (Wu et al. 1987).

Data sources

Land-use/land-cover change was determined using two Landsat Multi Spectral Scanner (MSS) images (24 February 1976–#139/45, and 25 April 1975–#140/45), a Landsat Thematic Mapper (TM) image (2 February 1988–#130/45) and a Landsat Enhanced Thematic Mapper (ETM) image (7 March 2003–#130/45). Two images were used to create the 1976 cover, with information from 1975 used to fill in areas with cloud cover in the 1976 image. All images were acquired during the dry season between February and April. Two land-use maps developed by the Xishuangbanna Department of Land and Resource (Xishuangbanna Land-use Status Map 1982, 1991) and a vegetation map developed by the Xishuangbanna Forestry Bureau (Xishuangbanna Vegetation Distribution Map 1993) were used as references for the classification of the MSS and TM images, respectively. Topographic maps (scale = 1:50,000) and digital topographic data with a contour interval of 100 m

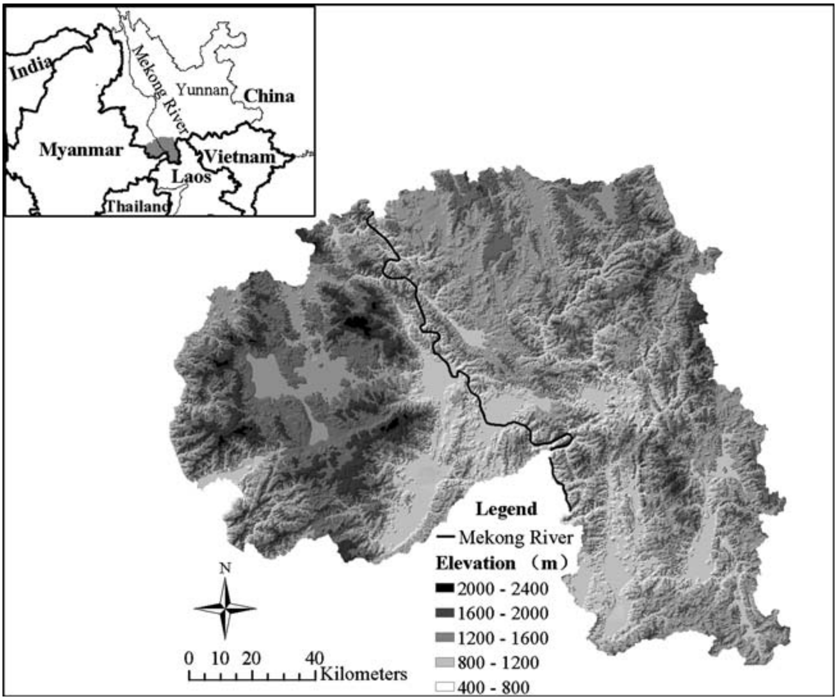


Fig. 2 The location and topography of Xishuangbanna in the southern part of Yunnan province of China

published by the State Bureau of Surveying and Mapping of China were used to build a digital elevation model (DEM).

Geometric correction and classification of satellite images

The TM satellite images were rectified to Albers Conical Equal Area projection system with a 35-m pixel size. The ETM and MSS images were registered to the TM images using an image-to-image registration technique: rectification RMS errors were <0.5 pixels and <1 pixels, respectively.

All non-thermal channels of the TM and ETM images and all channels of the MSS images were used to create class spectral signatures for classification. The images were classified using the supervised maximum likelihood classification method. Training areas for each land-cover class were identified for each image. For the ETM image, training areas were identified in the field during February–March 2003. For the TM and MSS images, training areas were generated from the Department of Land and Resource maps of 1982 and 1991, and the Forestry Bureau's vegetation map of 1993, respectively. We selected large homogeneous areas for the training areas. For each land-use type, we included at least 10 training areas to reflect the variation within a land use due to topography and slope effects.

Initially we used the same 15 land-use classes developed by the National Agricultural Zoning Committee (1984); however, to assure the greatest accuracy we combined these into eight classes (Table 1). Forests were classified into four classes.

It was difficult to distinguish the different forest types from the images so tropical seasonal rain forest, mountain rain forest and subtropical evergreen broadleaf forest were separated based on elevation (Guo et al. 1987) (Table 1). Conifers and bamboos dominated the ‘‘other forest’’ class, and they could be distinguished based on differences in texture and spectral characteristics. Rubber plantations were easy to classify because the trees are deciduous during the dry season, and most native forest species are evergreen. Shrubland is a common land-use class, but it is often a transition between abandoned agricultural land and forest or plantations. Arable lands included areas of active agriculture, recent fallow lands, grassland, tea gardens, and paddy rice. All other land-use types (e.g. urban, water) were combined into the ‘‘Other land-use’’ category if the individual land-use cover was <1% of the study area.

Post classification

The classified images were transformed using the clump, elimination, and filter options in Erdas Imagine (Version 8.6, Leica Geosystems). The ‘‘clump’’ option helps maintain spatial coherence by identifying clumps, which are contiguous groups of

Table 1 Land-use classes used in image classification and change detection

Land-use class	General description
Tropical seasonal rain forest (TSRF)	Forested areas with greater than 30% closed canopy dominated by broadleaf trees, and at an altitude less than 800 m
Mountain rain forest (MRF)	Forested areas with greater than 30% closed canopy dominated by broadleaf trees, and at an altitude between 800 and 1000 m
Subtropical evergreen broadleaf forest (SEBF)	Forested areas with greater than 30% closed canopy dominated by broadleaf trees, and at an altitude greater than 1000 m
Other forest (OF)	Forest with greater than 30% closed canopy dominated by conifer trees or bamboo
Rubber plantations (RP)	Forested areas with trees clearly planted in rows and a homogeneous canopy. Deciduous during the dry season
Arable lands (AL)	Shifting cultivation or permanent agriculture (e.g. slash and burn, tea plantation, fallow lands, grassland and paddy rice)
Shrublands (SL)	Land covered by secondary growth or highly degraded forest areas with <30% tree cover
Other land-use (OL)	Other land uses include: urban areas, water and sand. Together these areas accounted for less than 1% of the area

pixels in one thematic class. The ‘‘elimination’’ option removes small clumps (<8 pixels) by replacing them with the value of nearby larger clumps. The ‘‘3 × 3 filter’’ option was used to smooth the classified images.

The transformed images were then exported to ArcView GIS (Version 3.3, Environmental Systems Research Institute, Redlands, USA). In ArcView, the images were converted to a grid format, and then to a shape format. The new polygon themes were exported to ArcGIS (Version 8.3, Environmental Systems Research Institute, Redlands, USA) and polygons <1 ha were eliminated in ArcGIS (e.g. merging the selected polygons with neighboring polygons with the largest shared border). This final transformation was necessary to minimize any classification errors due to differences in the resolution of the three satellite images. These polygon themes were used for the analyses to derive land-use/land-cover changes and spatial distribution of each land-use/land-cover type in various elevations.

Accuracy assessment

The accuracy of our classification was verified by ground-truthing. Specifically, we compared our classification of the 2003 ETM image with field observations in December 2004. A total of 286 points were verified. In each point, we determined the current land-use cover, determined the location using a global positioning system (GPS), and took a photograph of the site. The field observations were then referenced to the classification to assess the overall accuracy and the accuracy of the different land-use categories.

The accuracy of our classification was greater than 90% for all land-use classes, with the exception of shrublands (Table 2). We correctly classified shrublands 66.7% of the time. The errors included classifying shrublands as forest, other land-use, and arable lands. The major explanation for this problem is that in Xishuangbanna shrublands are a transition land-use class between arable land and forests. In the period, between the time the image was taken and field observations a shrubland could be cleared and converted to arable land or the vegetation could have grown sufficiently to be considered forest. Rubber plantations were occasionally classified as grassland (arable lands) because they have similar spectral properties during the dry season when the rubber plantations are deciduous.

Table 2 Accuracy assessment of land-cover classification of the 2003 ETM image. A total of 286 points were verified with field observations

Field observations	Image classification				
	Forest	Rubber plantations	Arable lands	Shrublands	Other land-use
Forest	67			5	
Rubber plantations		64	1		
Arable lands	1	6	77	7	
Shrublands	1	1		24	
Other land-use			1		31
Total	69	71	79	36	31
Accuracy (%)	97.1	90.1	97.5	66.7	100.0

Results

Land-cover area and change

Land cover of Xishuangbanna changed dramatically between 1976, 1988, and 2003 (Fig. 3). The most obvious change was the decrease in forest cover and an increase in rubber plantations. In 1976, forests covered approximately 70% of Xishuangbanna, but by 2003 they covered less than 50% (Figs. 3, 4). During this period, the area of tropical seasonal rain forest was reduced by 67% (139,576 ha). This forest type occurs below 800 m, and covered 10.9% of the area in 1976, but only 3.6% by 2003. A large proportion of this change was due to the conversion of this forest type to rubber plantations. The establishment of rubber plantations began in the 1950s, but by 1976 they only occupied 1.1% of the area; by 2003 they increased to 11.3% (Figs. 3, 4).

The area of mountain rain forest, subtropical evergreen broadleaf forest and other forests also decreased between 1976 and 2003 (Figs. 3, 4). The area covered by mountain rain forest and subtropical evergreen broadleaf forest decreased by approximately 20% (205,847 ha) between 1976 and 2003. The expansion of rubber plantations was not a major cause of the loss of these forests because they occur above the elevation range most appropriate for rubber plantations (i.e. 500–800 m). The major cause of forest loss was the conversion to arable lands and shrublands.

In this region, the land-cover categories of arable lands and shrublands are very dynamic. Between 1976 and 1988, arable lands increased from 17.7% to 22.8%, but between 1988 and 2003, they decreased to 19.8%. More importantly, 60% of the area classified as arable lands in 2003 originated from another land-cover category in 1976. The increase in arable lands during the first period was mainly due to forest conversion to slash and burn agriculture, while the subsequent decrease was primarily due to the Natural Forest Protection Plan (NFPP, 1998). This plan encouraged an increase in forest cover, particularly in areas of steep slopes. The NFPP contributed to an increase in rubber plantations at higher elevation, and an increase in shrublands following the abandonment of slash-and-burn agriculture. Similar to the pattern observed in arable lands, 80% of shrublands in 2003 originated from another land-cover category in 1976. Along with a high turnover rate, shrublands increased from 11.6% to 18.4% between 1976 and 2003, and much of this increase was at the expense of subtropical evergreen broadleaf forest.

The area of “other land-use” also increased from 0.4% to 0.7% between 1976 and 2003, mainly because of increasing urban cover.

Land-cover change at different elevations

Elevation is an important factor influencing land-use change in Xishuangbanna (Fig. 5). Forest, shrublands, and arable lands occurred across a large range of elevation, but rubber plantations were primarily limited to the lower elevations. In 1976, forest was the dominant land cover category at all elevations, but by 2003 rubber plantations dominated areas below 800 m. Between 1976 and 2003, forest area decreased at all elevations, with the largest decreased below 1300 m. For the period 1976 to 1988, the expansion of rubber plantations mainly occurred between 600 and 800 m. The area of rubber plantations continued to expand between 1988 and 2003, and there was a marked increase in areas at higher elevations. For

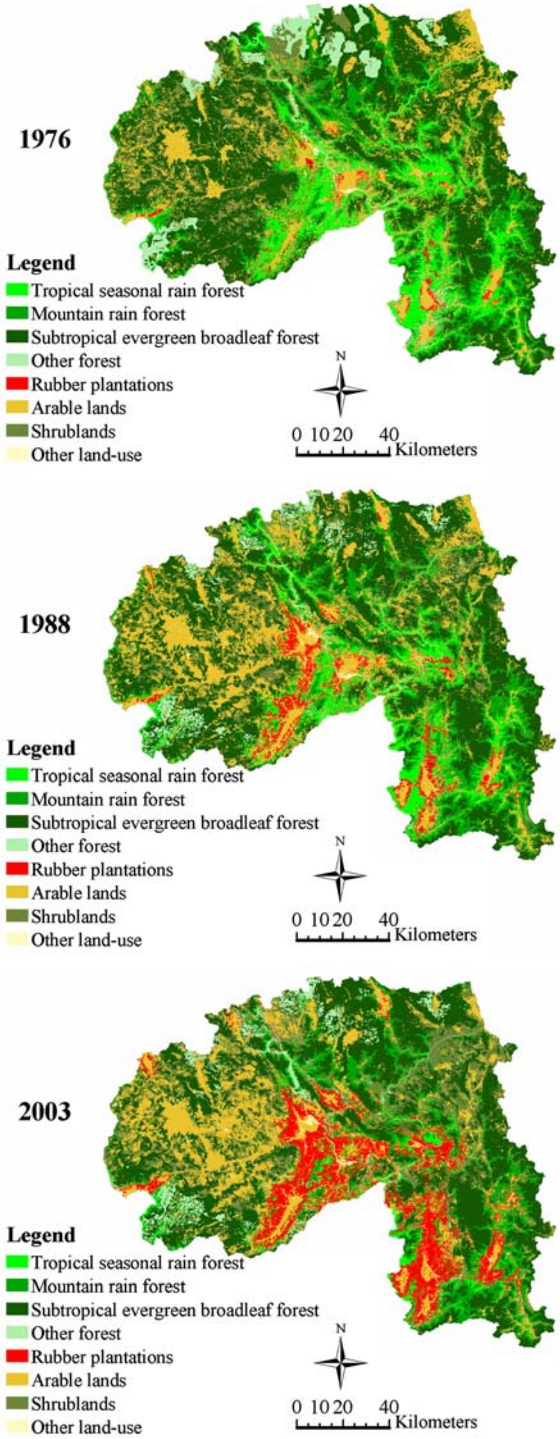


Fig. 3 Land use in Xishuangbanna in 1976, 1988 and 2003

example, in 2003 the area of rubber plantations above 1000 m was seven times greater than in 1988.

An increase in arable land and especially shrublands between 800 and 1300 m also reduced forest cover. From 1976 to 1988, arable lands area expanded at most elevation, but this trend changed between 1988 and 2003 when arable land below 800 m was converted to rubber plantations. There was little change in the elevational distribution of shrublands between 1976 and 1988, but by 2003 there was a large increase in shrubland area between 700 and 1300 m.

Land-cover change in the natural reserves

In 1980, five natural reserves were established in Xishuangbanna, and together they cover approximately 12% of total area. The major land-cover classes within the reserves were: subtropical evergreen broadleaf forest (48%), mountain rain forest (31%), and tropical seasonal rain forest (8%) (Fig. 6). Since the reserves were established there has been a decrease in the cover of mountain rain forest, tropical seasonal rain forest, and arable lands. In contrast, there has been a slight increase in subtropical evergreen broadleaf forest, shrublands and rubber plan-

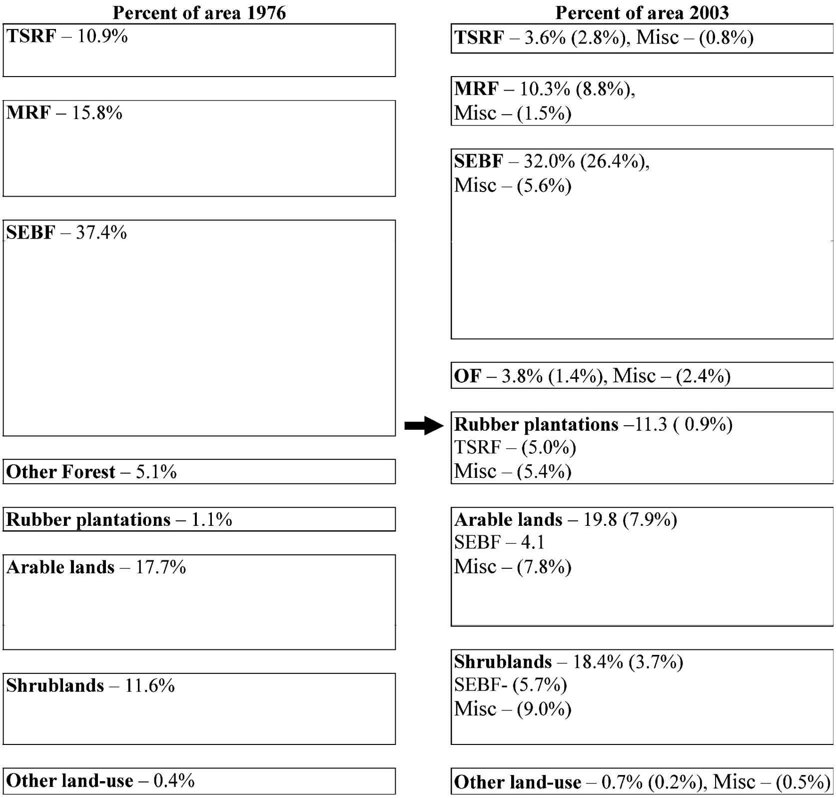


Fig. 4 Percent area of the eight major land-use categories in 1976 and 2003. The first value is the total percent of area for each land use in 1976 and 2003. The values in brackets are the source of the area in 1976. See Table 1 for abbreviations

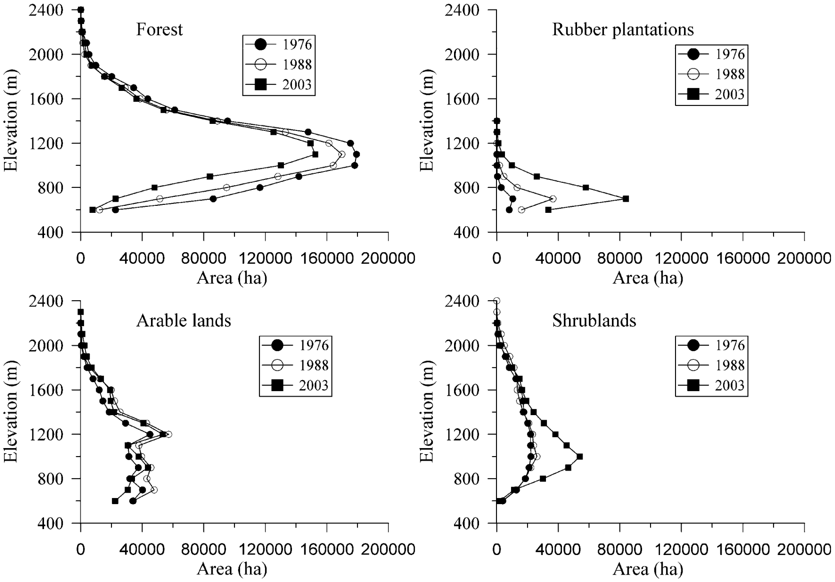


Fig. 5 The elevational distribution of forest (TSRF, MRF, SEBF and OF), rubber plantations, arable lands and shrublands in 1976, 1988, and 2003

tations. Since 1976, the area in shrublands has increased by approximately 15,000 ha, in part reflecting the decrease in arable lands. In 1976, there were no rubber plantations in these areas, but by 2003 they covered 4,310 ha within the reserves.

Discussion

Implications of land-use/land-cover change

Patterns of land-use change varied with elevation due to interactions between environmental limitations and changing economic and land-use policy. The most dramatic change in Xishuangbanna between 1976 and 2003 was the conversion of high diversity tropical seasonal rain forest (below 800 m) to monospecific rubber

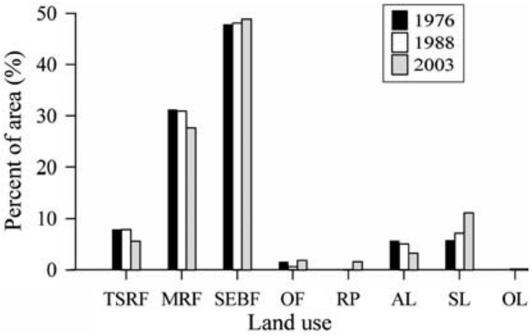


Fig. 6 Land-cover change in natural reserve in 1976, 1988, and 2003. See Table 1 for abbreviations

plantations. This transformation has greatly reduced the local plant species richness, and changed plant species composition (Zhu et al. 2004). For example, *Barringtonia macrostachya*, the dominant species in tropical seasonal rain forest, has disappeared from most fragmented forests (Zhu et al. 2004). This transformation also eliminated habitat for many animal species including the Asian elephant (*Elephas maximus*) and tiger (*Panthera tigris tigris*), whose distribution in China is limited to these forests in Xishuangbanna (Xu 2004). Bird species richness has also decreased with the conversion of the tropical rain forest into rubber plantations (Yang et al. 1985).

At higher elevations (>800 m), the area covered by forests (i.e. mountain rain forest and subtropical evergreen broadleaf forest) also was reduced by the conversion to arable lands, shrublands, and more recently to rubber plantations. A series of socioeconomic factors and national policies have lead to the complex land use pattern in these areas. First, the combination of population growth and the expansion of rubber plantations at lower elevations resulted in the expansion of agriculture into higher elevations. This increase in arable lands was most obvious during the 1976–1988 period. During this period, the Household Responsibility Policy provided land to individual households, and much more land was cleared than could actually be worked. Most crops were used for local subsistence, and included many varieties of upland rice, maize, beans, cotton, and many minor crops (Gao 1999). During the period 1988 to 2003, the Sloping Land Conversion Program enacted in 1999 redirected land-use patterns. The goal of this nation-wide program was to increase forest cover on steep slopes to reduce soil erosion and sedimentation. In Xishuangbanna, the policy mainly led to the conversion of arable lands to shrublands, but there was also a shift from local food crops to export crops, such as sugar cane, sun tea, and rubber plantations. Because rubber plantations were classified as ‘‘forests’’ large areas of arable land were converted to plantations, and this explains the increase in plantations at higher elevations.

While increasing forest cover usually implies an improvement in watershed protection, our analysis indicates that this needs further assessment. By dedicating the best agricultural lands for rubber plantations, other areas, usually at higher elevations and on steep slopes, are being deforested for local food production. These areas are often the most vulnerable to soil erosion, and, in general agricultural cover provide little protection for soil erosion. These agricultural activities on marginal lands, plus the open understory of the rubber plantations have increased levels of soil erosion in the region (Wang et al. 1982; Zhang et al. 1997).

Furthermore, the conversion of tropical rain forest into rubber plantations appears to be affecting the local climate, which could influence the long-term future of tropical seasonal rain forest in Xishuangbanna. Tropical seasonal rain forest occurs at its northern limit in Xishuangbanna, and the conditions are drier and cooler than in the rest of the distribution of this forest type. Zhu (1997) has argued that the foggy conditions are the main reason that the forest occurs in this region. Unfortunately, in Jinghong County, an area with a high density of rubber plantations, the number of foggy days has decreased from 166 per year in the 1950s to less than 60 in the 1990s (Gong and Ling 1996). This change has been attributed to the difference in water relations between rubber plantations and natural forest (Huang et al. 2000; Liu et al. 2003). If changes in fog conditions continue, this could result in the decline of many species (Burgess and Dawson 2004; Liu et al. 2004).

Although the government has set aside approximately 12% of the province in reserves, forest cover within the reserves has declined over the last 20 years, and the reserves are virtual islands in a matrix of different land-use practices. In a 5-km buffer around the reserves, most of the area has been converted to rubber plantations or arable lands (Li, unpublished data). Furthermore, because the reserves are isolated and there is little or no appropriate habitat connecting them, the system is not suitable for the migration of large animals such as elephants. In addition, the presence of villages within and around the reserves, has led to conflicts with elephants. The relatively small areas of the reserves result in elephants frequently leaving in search for food, such as bamboo and wild banana, and this often results in damage to crops and even human injury (Xu 2004).

Conservation and management recommendations

It is no surprise that current land use changes involving replacement of tropical forest with rubber plantations will negatively impact the flora, fauna, and some ecosystem services, but economic development, particularly in the developing world, is necessary to help millions of people out of extreme poverty. The challenge is to try to balance the economic and social needs of a growing population, with the habitat requirements of a highly diverse flora and fauna, and the maintenance of ecosystem services. An important first step to assist in determining appropriate strategies is to provide citizens, conservationists, and decision-makers with the best scientific information on land-use dynamics and the implications for conservation. In addition to providing the information, we believe that it is essential to provide recommendations to help decision-makers in understanding and interpreting these results.

In Xishuangbanna, rubber plantations are a critical component of the local economy, and given the increasing demand for natural rubber we can only assume that there will be a continued pressure to establish more plantations. However, we believe that there are strategies that can improve the conservation efforts of the region, without creating barriers to economic development. The area of high-diversity tropical seasonal rain forest has almost been eliminated, and the areas that remain are highly fragmented. Future expansion of rubber plantations below 800 m should be stopped, and restoration efforts that expand bamboo forest along rivers should be promoted to create corridors among the existing stands of tropical seasonal rain forest. In addition, resources should be invested in promoting plantation management strategies, which could increase rubber production. These may include technological advances in breeding, fertilizer applications, or tapping methods.

Areas that are presently dominated by shrublands between 800 and 1200 m may be the most appropriate areas for future rubber plantations expansion. To reduce the negative effects of erosion in the monospecific plantations, we would encourage the establishment of multispecies plantations. One option is to plant tea trees in the understory. Shade tea has become very profitable, it provides habitat for many bird species (Wang and Young 2003), and rubber plantations with a tea understory have been shown to be very productive (Xie 1989). A second approach would be to encourage secondary regeneration in the understory. In Brazil, rubber plantations with understory vegetation had no negative effect on rubber production and actually prolonged latex flow (Schroth et al. 2003). Furthermore, these additional species provided other forest products and reduce erosion.

The growing economies of many developing countries are presenting new challenges for conservation. If we are to balance the need for economic development and preserve the biodiversity of these regions, scientists must produce reliable information on land-use dynamics and the implications of these dynamics. But, most importantly, we must work directly with national and local decision-makers to insure that the most appropriate strategies are enacted.

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