Land Use, Land Cover Change and Conservation in the Dipterocarp Rain Forest Area of Southern Yunnan, China

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Abstract

Based on Landsat TM/ETM images from 1988, 2003 and field data of 2006, land uses and land cover changes were researched over 18 years in the dipterocarp rain forest area in Southern Yunnan of China. The expansion of rubber plantations has resulted in a dramatic decrease in natural forest cover, especially the tropical seasonal rain forest at lower elevation. In 1988, rubber plantations covered 765.06 ha which increased to 2,294.07 ha in 2003, with an annual rate of change at 13.32%. The pace of change increased after 2003, with a change of 213.69 ha per annum. The tropical seasonal rain forest has decreased by 111.35 ha per annum since 1988 in the study area. Arable lands increased during 1988 and 2003 but declined rapidly from 2003 to 2006 due to expansion of rubber plantations and the construction of reservoirs. There was an increase in water bodies from 2003 to 2006 as well as construction areas. Market prices, policies, increasing population, and the unregulated pursuit of commerce and trade, at times at the cost of the environment were the main driving forces of change. We suggest that local government takes strong action to regulate further expansion of rubber plantations and creates conditions for sustainable and harmonious development of economy, society and natural resources in biodiversity rich region of Southern Yunnan.

Introduction

With the increasing concern about global climate change and biodiversity conservation, study of land uses and land cover changes (LUCC) has become an extremely important and hot topic (Li, 1996). LUCC is one of the most important human alterations affecting the surface of the earth (Lambin *et al.*, 2001). It directly impacts biodiversity (Sala *et al.*, 2000), contributing to local extinction and regional climate changes (Chase *et al.*, 1999), and causing land degradation by altering ecosystem services and livelihood support systems (Vitousek *et al.*, 1997).

There have been dramatic land uses and land cover changes in some places in China in recent years. By using remote sensing (RS) and geographic information system (GIS), Chinese scholars have carried out many studies on land use and land cover change detections and their impacts on the environments (Gao *et al*., 2002; Li *et al*., 2003, 2007; Liu *et al*., 2006).

Southern Yunnan bordering Laos and Myanmar, is in a biogeographical transition zone between tropical SE Asia and temperate East Asia, and is one of the most biodiversity-rich regions in China (Zhu, 1997). The dipterocarp rain forest is the most species-rich plant community in southern Yunnan (Zhu, 2000). It is dominated by the species *Parashorea chinensis* (Dipterocarpaceae), a first grade protected plant species at national level. However, during the last few decades, forest cover has dramatically decreased from 60% to 27% (Zhang and Cao, 1995; Liu *et al*., 2005). Currently, forests remain primarily in nature reserves and state forests, and land areas outside nature reserves, which were previously forested, have largely been converted into rubber plantations. There is an essential and urgent research need to survey the land uses and land cover changes in tropical region in China in order to collect and update scientific data and to provide suggestions on how to improve the land use policy in a way that balances economic needs with biodiversity conservation. Our work here focuses on a dipterocarp rain forest area in Southern Yunnan and presents findings for a discussion on the land uses and land cover changes. It also shows the underlying driving forces in the local tropical rain forest and, thereby, provides a scientific basis for biodiversity conservation and management of the forest *in situ*.

The Study Area

The study area is located in the administrative region of Xishuangbanna, which includes three counties (Menghai, Jinghong and Mengla), and borders on Laos to the South and Myanmar to the Southwest (Fig. 1). The topography of Xishuangbanna consists of alternating hills and valleys, with elevations ranging from 2,430 m above sea level (asl) in the North and 480 m asl in the South. About 95% of the region is mountainous and hilly. The Mekong River cuts through Xishuangbanna, and the region contributes more than 20 important tributaries, resulting in many river valleys and small basins (Cao and Zhang, 1997). This region has basically a tropical monsoon climate. In the lower hills and valleys, the annual mean temperature is about 20º C, and frost has never been recorded. The annual precipitation is about 1,500 mm, of which more than 80% falls during the rainy season, which starts in May and lasts until the end of October. The dry season from November to April is characterized by little rain, but there is always heavy fog and dew, which can compensate for lack of rain. Thus the tropical rain forest in the region occurs only at lower elevations. It was also revealed that the occurrence of the tropical rain forest in southern Yunnan is more influenced by local habitats and microclimates than the regional climate (Zhu, 2004, 2008)

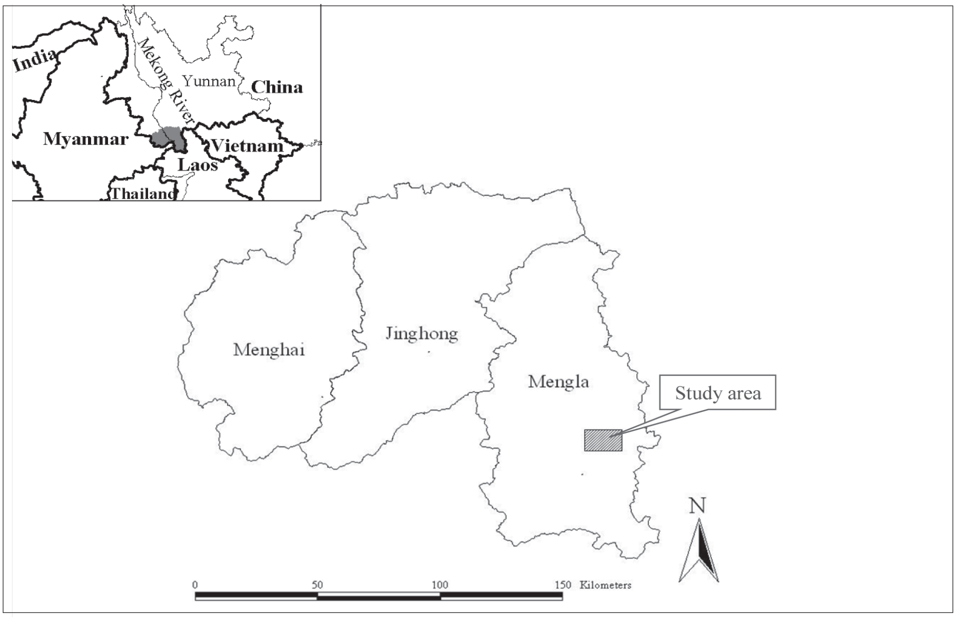

Figure 1. Xishuangbanna region and the location of study site.

The dipterocarp rain forest in Xishuangbanna is located mainly in the South of Mengla County (Zhu, 2000). Our study site (21°33'~21°38' N, 101°32'~101°41'E) covers the whole distribution of dipterocarp rain forests encompassing an area of 125 km^2. The altitude varies from 650 m to 1,600 m asl. The dipterocarp rain forest occurs in the area mainly below at 900 m asl, and other vegetation types such as tropical montane evergreen broad-leaf forest occurs in the mountains (Zhu *et al.*, 2005).

Materials and Methods

Data Sources

We obtained a Landsat Thematic Mapper (TM) image (2 February 1988-#130/45) and a Landsat Enhanced Thematic Mapper (ETM) image (7 March 2003-#130/45) of the study area. Both images were acquired during the dry season. Four land use maps (scale = 1:25000) developed by the Xishuangbanna Department of Land and Resource Management (Xishuangbanna Land Use Status Map, 1991) were used as references for the classification of the TM image. Four topographic maps (scale = 1:25,000) published by the China State Bureau of Surveying and Mapping were used to correct the images of 1988 and 2003 and to draw the land use map of 2006.

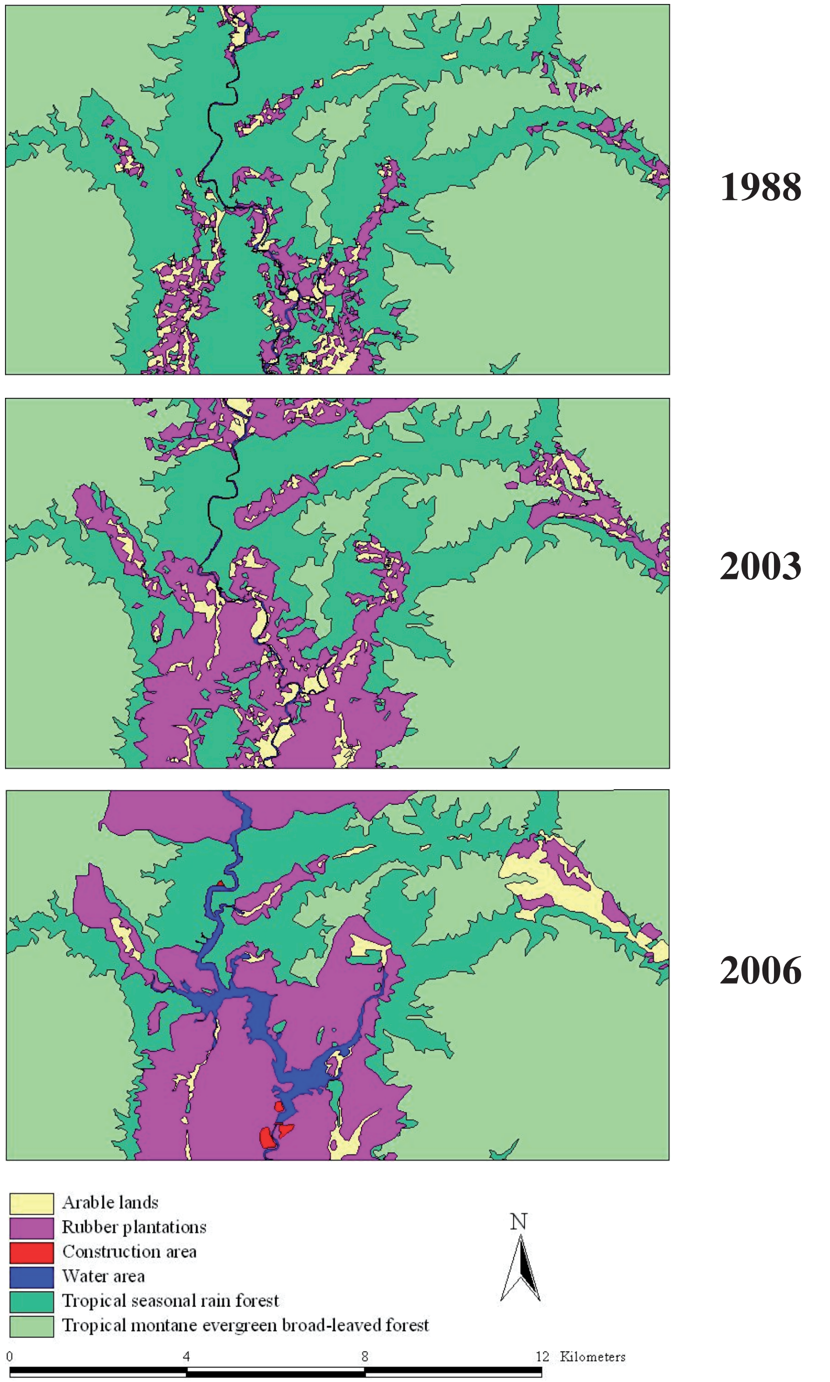

Figure 2. Land use in the distribution area of dipterocarp rain forest in Xishuangbanna, SW China in 1988, 2003 and 2006.

Data processing

Based on the land use classes developed by the National Agricultural Zoning Committee (1984), as well as characteristics of the images of study area, land uses were categorized into 5 classes (Table 1): arable lands, rubber plantations, forests, developed/constructed areas and water bodies. Due to low resolution of images, it was difficult to classify the land use types in detail; hence, the forest was simply divided into tropical seasonal rain forest and tropical montane evergreen broad-leaf forest based on elevation. Shrublands were incorporated into forests, grasslands and sugar cane fields were incorporated into arable lands.

The TM and ETM images had already undergone radiant correction, so we only had to do the geometric correction. Both images were rectified to the topographic maps and the rectification errors were <0.5 pixels.

After the correction, the images were classified using the supervised maximum likelihood classification method. For each land use type, at least 10 training areas were used to reflect the variation within a land use due to topography and slope effects.

The classified images were then transformed by using clump, elimination and filter options in Erdas Imagine (Version 8.7, Leica Geosystems). Then with the ArcView GIS (Version 3.3, Environmental Systems Research Institute, Redlands, USA) and ArcGIS (Version 8.3, Environmental Systems Research Institute, Redlands, USA), the transformed images were converted to land use maps for analysis.

The paper topographic map was firstly magnified and used in the field to draw the outline of the land use map of 2006 by using contour, topography and other information from the topographic map. The current land use cover was determined at the field site and the locations were determined by using a global positioning system (GPS). The GPS points were also used to prepare the land use map of 2006 and to assess the accuracy of the land use maps of 1988 and 2003. The field works lasted two weeks and covered the whole study area. The working map was scanned and digitized, and finally was made into a land use map of 2006 using ArcGIS.

The accuracy of the classification of both images of 1988 and 2003 was verified by the points obtained in the field in 2006. All land use maps (1988, 2003, 2006) were rectified to Albers Conical Equal Area projection system, with Beijing 54 datum and Krosovsky ellipsoid. By using ArcView GIS, the database of the land uses and land cover changes of 1988, 2003 and 2006 was determined, which was used to analyze land use and land cover changes during the research period.

Table 1. Land use classes used in our image classification.

Land use class	General description
Arable lands (AL)	Shifting cultivation or permanent agriculture (e.g. paddy rice, dry lands, fallow lands, slash and burn)
Rubber plantations (RP)	Forested areas with rubber trees clearly planted in rows and deciduous during the dry season, having a homogeneous canopy
Tropical seasonal rain forest (TSRF)	Forested areas with a canopy cover more than 30% and below 900 m above sea level.
Tropical montane evergreen broad-leaf forest (TMEBF)	Forested areas with a canopy cover more than 30% and above 900 m above sea level.
Construction areas (CA)	Land covered by constructions, including urban areas, residential areas, factory and traffic areas
Water areas (WA)	Natural terrestrial water, including river, pool, lake and reservoir

Notes: The construction areas in the study site are dispersed and too small to be distinguished from the images, so we just made a simple estimate of the increased area from 2003 to 2006. There are many rivers in the study area, but most of them are also too small to be distinguished from the images, so we only considered the charge of Nanla River, the biggest river in the study area.

Data analysis

The annual change rate index was used to reflect the rate of land use and land cover change (Wang *et al.*, 1999), and it may be expressed by the following equation:

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

In this expression, K was the annual rate of change of one land use class, U_a and U_b were the initial and the final area values of the research period respectively, and T was the time (year) of the period.

The contribution rate of LUCC was used to reflect the source of existing land use class, and it could be expressed as follows:

$$B_{dij} = \frac{U_{bij}}{U_{bj}} \times 100\%$$

In this expression, B_{dij} was the contribution rate of land use type i to j from the initial time a to the ending time b of the research period, U_{bij} was the area that land use type i turned to j, and U_{bj} was the area of land use type j in time b.

In order to analyze the change of the major land use type (Zhu *et al.*, 2003), there is another index—the intensity index of LUCC.

$$K = \frac{U_{bj} - U_{aj}}{U} \times \frac{1}{T} \times 1000‰$$

In this expression, K is the change intensity index of the land use class j, U is the area of the whole study site, U_{aj}, U_{bj} is the initial and the final area of j of the research period respectively, and T is the duration time (year) of the period.

Results

Area changes in land cover

Changes in land cover in the study area from 1988 to 2006 are shown in Fig. 2 and summarized in Table 2. The most obvious change was the decrease in forest cover and an increase in rubber plantations. In 1988, the area of rubber plantations was 765.06 ha, which increased to 2,294.07 ha in 2003, with an annual rate of change at 13.32%. However, the expansion of rubber plantation has further accelerated since 2003, increasing 213.69 ha per annum. The forested area declined rapidly from 1988 to 2006, especially the tropical seasonal rain forest at lower elevation, at a decreasing rate of 111.35 ha per annum. The forest at higher elevation also declined rapidly during 2003 and 2006. The arable lands increased during 1988 and 2003 but declined rapidly from 2003 to 2006. Water body in the study site did not change before 2003, but abruptly increased after 2003 due to the building of a big reservoir-Dashaba Reservior on Nanla River. The open-up area for settlement also increased with the building of the reservoir.

Transitions in land cover

Table 3 and Table 4 are contribution matrixes showing resources of existing

Table 2. Area changes of land use classes of the study area in different time period.

	AL	RP	TSRF	TMEBF	WA
Area (ha)					
1988	389.51	765.05	4653.50	6709.90	40.16
2003	509.59	2294.07	3202.47	6511.83	40.16
2006	403.68	2935.13	2649.23	6236.41	333.67
% of area coverage					
1988	3.10	6.09	37.06	53.43	0.32
2003	4.06	18.27	25.50	51.85	0.32
2006	3.21	23.37	21.10	49.66	2.66
Change area (ha)					
1988—2003	120.08	1529.02	-1451.03	-198.07	0.00
2003—2006	-105.91	641.06	-553.24	-275.42	293.51
Annual change area (ha)					
1988-2003	8.01	101.93	-96.74	-13.20	0.00
2003-2006	-35.30	213.69	-184.41	-91.81	-
Annual change rate (%)					
1988-2003	2.06	13.32	-2.08	-0.20	0.00
2003-2006	-6.93	9.31	-5.76	-1.41	-

Notes: The increase of water area is due to the construction of the reservoir and it is a once-off activity, so we don't calculate its annual change area and annual change rate. [AL: arable lands; RP: rubber plantations; TSRF: tropical seasonal rain forest; TMEBF: tropical montane evergreen broad-leaf forest; WA: water area.]

Table 3. Contribution matrix of land-cover categories in the study area between 1988 and 2003（%).

1988	2003				
	Arable lands	Rubber plantations	Water area	TSRF	TMEBF
Arable lands	28.49	9.66	0.00	0.71	0.00
Rubber plantations	31.23	24.78	0.00	1.10	0.08
Water area	0.00	0.00	100.00	0.00	0.00
TSRF	35.17	58.00	0.00	98.19	0.01
TMEBF	5.11	7.56	0.00	0.00	99.91

Table 4. Contribution matrix of land-cover categories of study area between 2003 and 2006 (%).

2003	2006					
	Arable lands	Rubber plantations	Water area	CA	TSRF	TMEBF
Arable lands	24.23	8.71	34.19	71.13	0.71	0.08
Rubber plantations	47.23	60.75	39.40	24.23	5.88	0.66
Water area	0.00	0.01	12.22	0.52	0.00	0.00
TSRF	11.52	21.78	14.19	4.12	93.41	0.00
TMEBF	17.02	8.75	0.00	0.00	0.00	99.26

land cover classes of 2003 and 2006. Except for the water area, all other land use categories contributed to increasing rubber plantations. Increase in rubber plantations took place in the tropical seasonal rain forest. The water body area increased between 2003 and 2006 at the expense of arable lands as well as rubber plantations. The cleared settlement area also increased with the completion of the reservoir, mainly at the expense of arable lands and rubber plantations. A large part of tropical mountain evergreen broad-leaf forest converted to agricultural use between 2003 and 2006 was the result of sugar cane planting.

Change intensity in land cover

Fig. 3 shows the change intensity index of land use categories from 1988 to 2006. The intensity of change between 2003 and 2006 is much higher than that between 1988 and 2003. Analyzing the change intensity of these two periods respectively, we found that rubber plantation was the major land cover category of LUCC between 1988 and 2003, with a change intensity index of 8.12‰, followed by the tropical seasonal rain forest, with a change intensity index of -7.70‰. Rubber plantation was still the major land-cover category of LUCC after 2003, with a change intensity index of 17.02‰, followed by tropical seasonal rain forest, water bodies, tropical montane evergreen broad-leaf forest, and arable lands.

Discussion

This study investigated the changes in land use and land cover of dipterocarp rain forest area in Xishuangbanna from 1988 to 2006. The results showed a dramatic change in land use and land cover in the study area. The most obvious change was a decrease in forest cover and an increase in rubber plantations. From 1988 to 2003, rubber plantations increased at a rate of

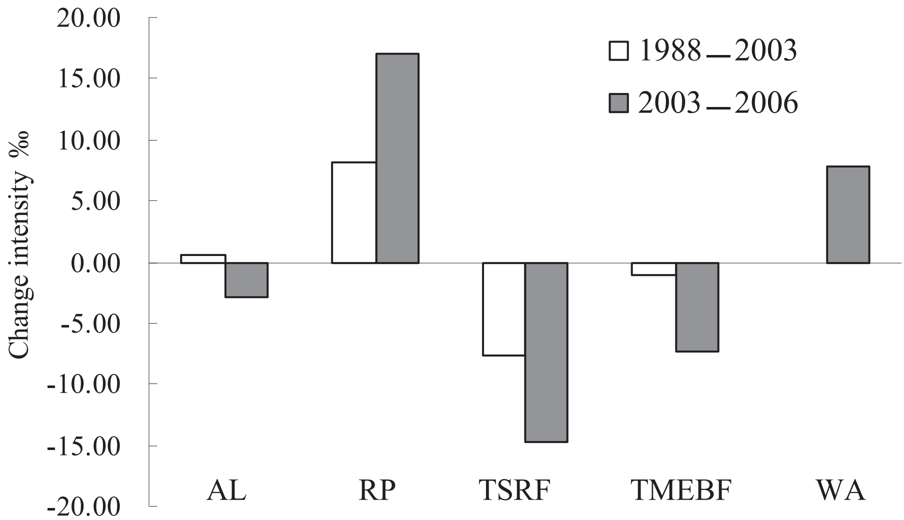

Figure 3. Comparison of land use intensity (using the permillage to describe) of study area from 1988 to 2006. [*AL*: arable lands; *RP*: rubber plantations; *TSRF*: tropical seasonal rain forest; *TMEBF*: tropical montane evergreen broad-leaf forest; *WA*: water area.]

101.93 ha per annum, between 2003 and 2006 this rate increased to 213.69 ha per annum. In contrary, the area of tropical seasonal rain forest and tropical mountain evergreen broad-leaf forest declined continually over time, especially the tropical seasonal rain forest at a rate of 111.35 ha per annum. In recent years, tropical mountain evergreen broad-leaf forest has declined faster as a result of rubber plantations expanding also to higher elevations in the region. Arable lands also decreased rapidly between 2003 and 2006 from the expansion of rubber plantations and the building of Dashaba Reservoir on Nanla River. The normal water level of the reservoir was about 680 m asl. After the construction of reservoir, some arable lands were submerged and others were replaced by buildings of hydropower station, house, hotel, parking sites, recreation ground, etc., which resulted in an increase of constructed area from 2003 to 2006.

The research also showed that almost all land use categories, in particular the tropical seasonal rain forest at low elevation, contributed to the increase of the rubber plantations. The change intensity of LUCC also became larger than before and the remaining forests, including the dipterocarp rain forest, are threatened by the expanding rubber plantations.

Increasing population is the basic driving force at LUCC, with the increasing demand for food, housing and public facilities, which resulted in the expansion of rubber plantations, arable lands and construction areas.

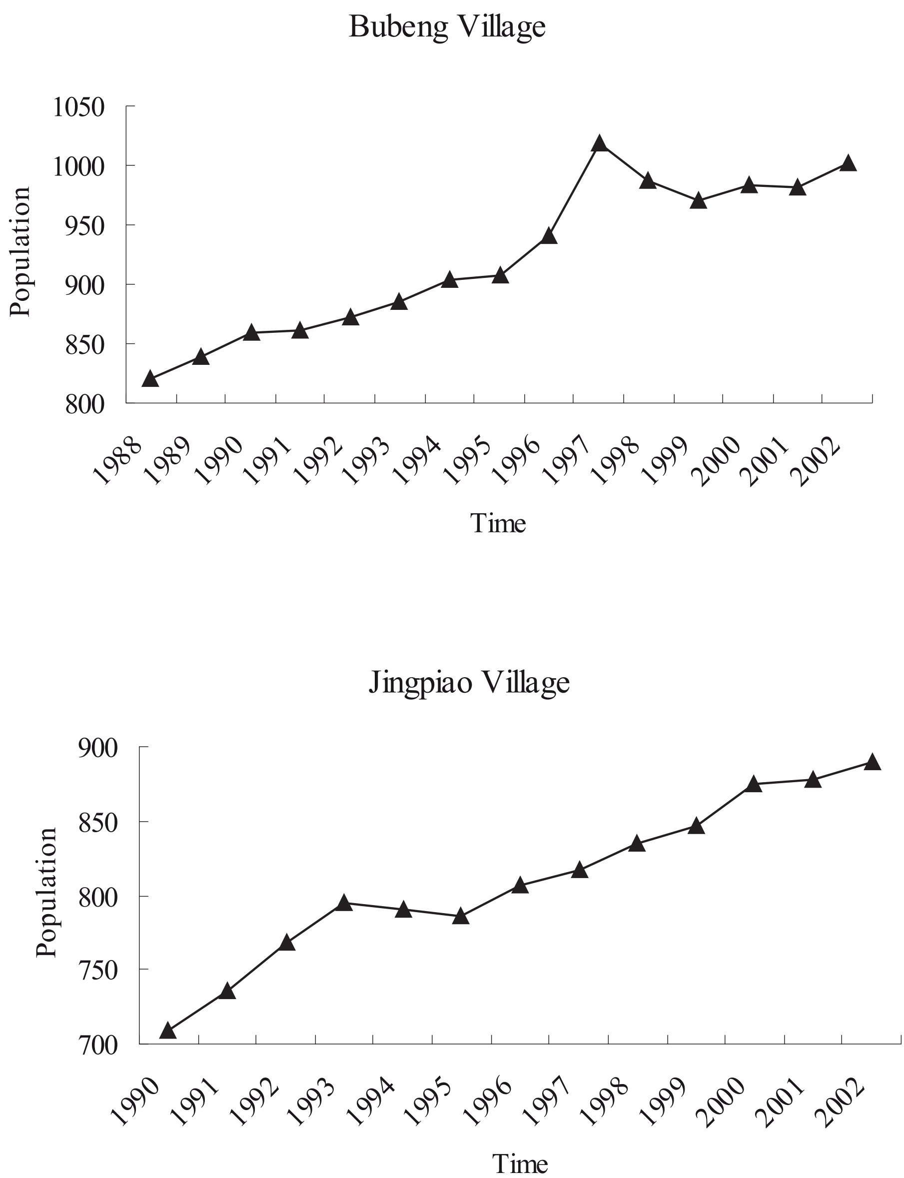

Figure 4. The changes of population of Bubeng and Jingpiao Village in recent years.

The population of the study area increased rapidly during the past 18 years. Figure 4 shows the populations of Bubeng and Jingpiao Village of the study area from 1988 to 2002.

The Household Responsibility Policy provided land to individual households and the local people have the rights to manage their own lands. With the development of the market economy in China, the increasing market price has a profound effect on land use. The price of natural rubber is constantly rising, which increases people's enthusiasm for rubber planting. As a result, rubber plantations became the major income source for local people in the study region.

The dipterocarp rain forest is the most species-rich community in southern Yunnan and is dominated by the species *Parashorea chinensis* (Dipterocarpaceae), a first grade protected plant species at national level. Similar tropical rain forests occur also at ca 27º 31' N in northeastern India (Proctor *et al*., 1998) and Burma (Kingdon-Ward, 1945), but these places still have basically tropical wet climates due to their geographical location and lower elevations.

The tropical rain forest in southern Yunnan occurs really at the northern climatic limits of tropical rain forest and is unique in biogeography and biodiversity conservation. The forest is at present strongly protected by the government policy. However, over the past 18 years, there has been a dramatic land uses and land cover changes in its area of distribution. In our research, we found that almost all forests and shrubs outside the nature reserves were converted to rubber plantations. In some places, even the nature reserves were nibbled away by rubber plantations. The dipterocarp rain forests have become quite fragmented and exposed to other external impacting factors. These include changes in the micro-climate of the habitat and the physicochemical property of the soil, which would consequently change the characteristics of the plant communities and their inherent biodiversity (Liu *et al*., 2001, Sophia *et al*., 2000, Zhu *et al*., 2004).

We suggest that local government takes strong action to control further expansion of rubber plantation and creates a sustainable and harmonious development of the local economy, the society and natural resources in the region of biodiversity rich dipterocarp forest area in southern Yunnan.

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