

Land use/land cover change and driving force analysis in Xishuangbanna Region in 1986–2008

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Abstract This article summarizes the change of land use in 1986–2008 through data analysis on land use/land cover in Xishuangbanna Region, Yunnan Province, China. The major driving forces of land use change are identified by the gray incidence analysis method. The results shows that the area ratio of forestland in Xishuangbanna Region decreased from 57.62% to 42.87% in the studied period, The ratio of plantation and shrub land increased from 4.77%, 15.10% to 13.92%, 23.87%, respectively, The ratio of crop land increased from 4.77% in 1986 to 5.85% in 1999, and then dropped to 4.99% in 2008. The driving force analysis shows that population density, the average annual temperature, grain output and economic density are among the major driving forces causing land use/land cover change (LUCC) in Xishuangbanna Region.

Keywords land use/land cover change (LUCC), driving force, grey incidence analysis, Xishuangbanna Region

1 Introduction

Land use/land cover change (LUCC) is one of the key topics in the global change research (Foley et al., 2005; Fox and Vogler, 2005; Zhang et al., 2008). Most of the research on LUCC has been focused on the dynamic mechanism of land use change, the regional and global mode of LUCC, the application of remote technology in LUCC research and the sustainable research. In China, the research on LUCC mainly has been focused on the change pattern, driving mechanism and environmental effect of the land use from a regional perspective (Wear and Bolstad, 1998; Yu and Yang, 2002; Hietel et al., 2004). The selected areas involve mainly two types. One type is the “hot spot area,” which is the area with intense human activities and

natural drivers; the other is the “fragile area” with fragile ecological environment. Study on land use in fragile areas is beneficial in increasing the awareness of fragility and revealing the formation and evolution mechanism in those areas. Xishuangbanna Region in Yunnan Province of China lies in the southernmost part of Longitudinal Range-Gorge Region. It is one of the world-class genes bank rich in biologic species, and is also a key area under biodiversity protection in China (Li et al., 2006; He et al., 2007). As a result of the increasing population and human activities in this region in recent years, the land use/land cover has changed distinctly, as shown in the rapid growth of tropical cash trees or crops (e.g. rubber, tea, cotton), and serious deforestation which has led to forest fragmentation. Such changes have huge impacts on the eco-environment and bio-diversity across the region. However, the previous research on land use/land cover in Xishuangbanna Region were mainly focused on land use change, with little involvement of study on the driving forces of changes. Therefore, the study of LUCC and driving forces in Xishuangbanna Region is of unique significance.

Based on the statistics on land use in Xishuangbanna Region, this article analyzes the LUCC and features through the gray incidence analysis and identifies the driving forces for the land use change. This study provides scientific basis for land resources management and ecological environment protection in Xishuangbanna Region.

2 Materials and methods

2.1 Profile of the studied area

Xishuangbanna (21°09′ – 22°36′N, 99°58′ – 101°50′E) is located in the southern tip of Yunnan Province with western tropical monsoon climate. The region lies in the south of Hengduan Mountains as the extension of Wulian Mountains and Nushan Mountains. Topographically, the

region is lower in the middle and higher in the surroundings. And the topography is based on mountain plateaus, which has a wide distribution of valley basins, low mountains and hilly areas. The relative height is 2000 m, with 2429 m above the sea level at the highest peak and 475 m above the sea level at the lowest point. The region covers a total area of 19150 km², including Jinghong City, Menghai County and Mengla County.

2.2 Methods

Major types of land use/land cover in Xishuangbanna are forestland, shrub land, crop land and plantation (rubber plantation and tea garden) (Li et al., 2008). The combined areas take up about 90% of the total area of the region. So the change of the above four types can reflect the LUCC in Xishuangbanna. By selecting the driving factor for the LUCC, a driving force analysis system is established. And using gray incidence analysis method to calculate the degree of incidence between each driving factor with area changes of crop land, forestland, plantation and shrub land, we will be able to identify the key driving factors for the LUCC.

2.2.1 Gray incidence analysis

Gray incidence analysis method is a multi-factor statistics and analysis method, which is used to describe the strength, size and order of relations among different factors based on the sample data for each of the factors. If the sample data column shows that the trends in changes of different factors, such as direction, size and speed, are consistent, it indicates that the degree of incidence between them is stronger. Otherwise, the degree of incidence is smaller.

2.2.2 LUCC intensity index

The LUCC intensity index was calculated using Eq. (1) as follows

$$P = \frac{U_{bj} - U_{aj}}{U} \times \frac{1}{T} \times 100\%, \quad (1)$$

where, P indicates the change intensity index of the type j of land use/land cover in the region during the research period. U_{bj} and U_{aj} refer to the area of type j of land use/land cover at the beginning period and ending period respectively. U indicates the total area of land for research. T indicates the intervals (years) between the beginning year and ending year for the research. The larger P means the greater intensity of changes of the type of land use/land cover (Wang and Bao, 1999).

2.2.3 LUCC dynamic degree index

The LUCC dynamic degree index was calculated using Eq. (2) as follows

$$K = \frac{U_{bj} - U_{aj}}{U_{aj}} \times \frac{1}{T} \times 100\%, \quad (2)$$

where, K indicates the change dynamic degree of type j of land use/land cover during the research period. U_{bj} and U_{aj} refer to the area of type j of land use/land cover at the beginning period and ending period respectively. LUCC dynamic degree index (Liu and Buheasier, 2000; Wang et al., 2001) describes the changing speed of land use quantitatively which plays a positive role in forecasting the tendency of future land use change.

3 Results

3.1 Changes in land use areas

The years of 1986, 1995, 1999, 2003 and 2008 were selected as the typical year for analysis, because the land use pattern has changed obviously in these years. As seen from Table 1 and Fig. 1, the percentage of forestland in the research area has decreased from 57.62% in 1986 to 42.87% in 2008. Forestland is the type with the greatest change. Areas for plantation have risen from 4.77% to 13.92% and areas for shrub land has increased from 15.10% to 23.87%. Areas for crop land have been fluctuating, rising from 4.77% in 1986 to 5.85% in 1999, then falling down to 4.99% in 2008.

Table 1 Changes in the area of major land use types in Xishuangbanna from 1986 to 2008

Land use type	1986		1995		1999		2003		2008	
	area/km ²	%	area/km ²	%	area/km ²	%	area/km ²	%	area/km ²	%
Crop land	953	4.98	1070	5.59	1120	5.85	1040	5.43	956.2	4.99
Forestland	11035	57.62	10445	54.54	9807	51.21	9537	49.80	8209	42.87
Shrub land	2375 ¹⁾	12.40	2819 ²⁾	14.72	3114	16.26	3523.6	18.40	4570.2	23.87
Plantation	913	4.77	1273	6.65	1877	9.80	2336	12.20	2892	15.10

Notes: 1) refers to 1988 data and 2) refers to 1992 data

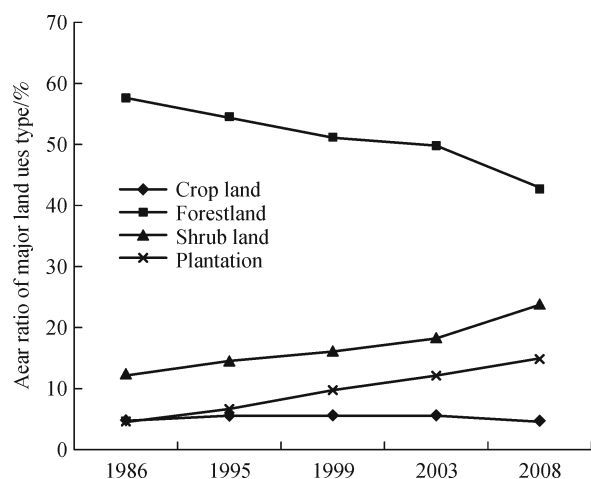


Fig. 1 Changes in area of major land use types in Xishuangbanna area from 1986 to 2008

3.2 Land use change intensity

There have been various change intensity indexes of major types of land use/land cover in Xishuangbanna at different times (Table 2). The change intensity index of forestland in various periods are obviously greater than that of other types, which indicates serious damage on the forest land. From 2003 to 2008, in particular, the area of forestland is shrinking more quickly. The plantation area experiences a great change from 1995 to 1999, indicating the area of economic plantations (rubber plantation and tea garden) have grown rapidly since 1995. The growth momentum slows down after the year of 2000. The area of shrub land changes greatly before 1995 and after 1999, especially after 2003. Considering the change trend of forestland, it can be figured out that large portion of forestland have turned into shrub land after 2003. The area of crop land changes slightly as compared with other types of land, but

has greater changes between 1999 and 2003 than in other periods.

3.3 Changes in the land use dynamic degree

As learnt from Table 3, the dynamic degree change for land use/land cover varies in different periods in Xishuangbanna. From 1986 to 1995 and from 1999 to 2003, various land use in terms of area appears in a descending order as follows: plantation > shrub land > crop land > forestland. From 1995 to 1999, the order is plantation > shrub land > forestland > crop land. From 2003 to 2008, the order is shrub land > plantation > forestland > crop land. It is clear that the speed for forestland area reduction is gaining and the growth of shrub land is accelerating. From 1986 to 2008, the dynamic degree of plantation change is great, and the area for plantation grows quickly, showing that the economic plantation in this region develops fast and will continue to develop fast in the coming years. The change tendency of land use/land cover in this region is dominated with area reduction of forestland and increase of economic plantation.

4 Driving force analysis of LUCC

4.1 Index system of the driving force

Land means a combination of nature-human factors. LUCC is constrained by both the natural driving force and the social, economic, technical and historical factors. It is both comprehensive and geographical (Turner et al., 1996; Lambin et al., 2001; Togtohyn and Dennsi, 2002). In areas with complicated natural conditions, such as plateau and mountainous areas, various natural driving forces have a great impact on the change of land use. Whereas in areas with little natural constraints, such as

Table 2 Changes in the intensity indexes of major types of land use in Xishuangbanna from 1986 to 2008

Types of land use	Intensity indexes/%			
	1986–1995	1995–1999	1999–2003	2003–2008
Crop land	– 0.066	– 0.063	0.102	0.087
Forestland	0.333	0.810	0.342	1.387
Shrub land	– 0.552	– 0.220	– 0.535	– 1.093
Plantation	– 0.203	– 0.766	– 0.583	– 0.580

Table 3 Changes in the dynamic degree of major types of land use in Xishuangbanna from 1986 to 2008

Types of land use	Dynamic degree indexes/%			
	1986–1995	1995–1999	1999–2003	2003–2008
Crop land	– 1.215	– 1.111	1.938	1.743
Forestland	0.628	1.627	0.707	3.235
Shrub land	– 1.751	– 2.3660	– 2.9090	– 4.580
Plantation	– 3.146	– 8.0347	– 4.920	– 3.842

developed areas, the land use changes are mainly controlled by the human driving force such as economic development, population growth and policies (Gobin et al., 2002; Yu and Yang, 2002). Considering the sound natural conditions in Xishuangbanna with flat terrains, and the fact that agriculture is the major pillar for economic and social development, with reference to the suggestions from experts and data available, this research has chosen the following indexes for driving force analysis: temperature and rainfall. They are the typical indexes for natural environment changes, and indexes that represent the changes of social and economic conditions, such as population density, per capita income (farmer's per capita income), crop farming areas, total grain output, number of animals and economic density. Among them, the per capita income and economic density have shown the degree of people's richness and economic growth. The crop farming areas and total grain output reflect the development of agriculture, and the number of animals reflects the development of animal husbandry.

4.2 Results of the gray incidence analysis

The data for areas of crop land, forestland, plantation and shrub land and driving force indexes for different years in Xishuangbanna from 1986 to 2008 are selected. It takes gray incidence analysis method to calculate the incidence grades between various driving force indexes and area changes of crop land, forestland, plantation and shrub land. The results are shown in Table 4.

4.3 Discussion

4.3.1 Driving force for the change in crop land

Major driving force for the change in crop land include population density, grain output and annual average temperature. Therefore, the economic and social development is the key driving force for the change of crop land. In Xishuangbanna, the population grows from 705900 in 1986 to 1.07×10^6 in 2008, with annual growth rate of 2.34%. More population demands more food, which in

turn demands more crop land. Since the minority population in Xishuangbanna still takes traditional slash-and-burn farming method, which means reclamation and cultivation in slope areas with crop rotation farming, the increasing population has resulted in a constant increase of crop land from 1986 to 2000. By the year of 2000, over-reclamation had caused severe damage to the forestland and led to a drastic reduction of forests. The local government, therefore, reduced the areas for rotation farming through policy regulation. The rising trend of crop land has been curbed. By 2008, the area of crop land was brought down to the 1986 level.

In addition, the incidence calculation degree results show that the degree of incidence between annual average temperature and changes of crop land is 0.9431. Therefore, the natural factor is also an important factor driving the change of crop land in Xishuangbanna. Xishuangbanna is a rare piece of land located in tropical and subtropical area of China. The development of agriculture in this place mainly takes use of the natural conditions of high temperature and heavy rainfall. The region develops tropical economic crops, medicines from the south and tropical fruits. The main grain is rice, which include single cropping rice and double cropping rice in different geographical regions. That said, the natural driving forces such as temperature also pose constraints to the agriculture development in Xishuangbanna, driving the changes of arable land.

4.3.2 Driving force for the change in forestland

The major driving force for the change of forestland is the annual average temperature, followed by sowing areas, population density and number of big animals. Since the degree of incidence of various forces do not vary greatly, the natural conditions and development of human society jointly drives up the changes of forestland. Most of the forests in Xishuangbanna are tropical forests, including tropical rain forest, tropical monsoon forest, and south Asia tropical evergreen broadleaved forest. The requirements for water and heat for these forests are high. Hence,

Table 4 Incidence grades between major types of land use and driving force indexes

Factors	Crop land	Forestland	Plantation	Shrub land
Annual average temperature	0.9431	0.9579	0.7428	0.8352
Annual rainfall	0.8879	0.8747	0.7347	0.7082
Population density	0.9739	0.9051	0.7949	0.8776
Sowing areas	0.9352	0.9433	0.6967	0.4319
Annual income	0.6927	0.6465	0.7510	0.6938
Economic density	0.6361	0.5814	0.7500	0.6576
Grain output	0.9626	0.8849	0.7843	0.8114
Big animal	0.8543	0.9026	0.6250	0.6489
Small animal	0.6037	0.5731	0.6905	0.5957

the distribution and changes in areas and types of these forests are closely related with temperature and rainfall. In areas with rich water and heat resources, the survival rate of forest is high. In areas with poor water and heat resources, the forest land is replaced by other types of land. Accordingly, the annual average temperature is the major driving force for the change of forestland. In addition, economic and social factors are also important in causing constant increase of rubber plantation, grassland and residential areas, which takes up a large portion of forest land. The area of forestland is decreased every year. In particular, the areas for tropical rain forest and mountainous rain forest are dramatically reduced and fragmented. Then the social development is also an important factor driving the change of forestland.

4.3.3 Driving force for the change in plantation

The major driving force for the change of areas in plantation are population density and grain output, followed by economic density and farmer's per capita income. Then the economic and social development poses the major driving force for the change of plantation area. In Xishuangbanna, due to sparse population distribution and traditional ways of agricultural production, the grain output is relatively low and the land use is less frequent. However, with the increase of the population in the region and the demand for economical development and better living, the local people take advantage of the water and heat resources by actively establishing economic plantations such as rubber plantation and tea garden. Statistics show that, from 1978 to 1990, the annual rubber output is 4.5 times the amount of the period from 1956 to 1977. The vigorous development of private rubber plantation has enlarged the area for rubber plantation. In 2008, the area of rubber plantation takes up 13% of the total area. The expansion of rubber plantations eats away large patches of tropical forests, rotation cropping land and mountainous rain forests. Especially from 1998 to 2003, the rubber plantation occupies almost all the low sea level areas suitable for rubbers, and its following expansion further invades the high level areas. As a result, the mountainous rain forest becomes the type which has shrunk most dramatically. Currently, the area for rubber plantation and tea gardens still keep increasing.

4.3.4 Driving force for the change in shrub land

The major driving force for area change of shrub land are the population density and annual average temperature, followed by grain output. The social development and natural conditions jointly drive the area change of shrub land. From 1988 to 2008, the areas for shrub land grow constantly, with incremental areas coming partly from the degraded forests resulting from destroyed tropical monsoon rain forests, and partly from the rotation cropping land. Due

to constant growth in population in the region, the destruction of forestland is rather severe. The ecological system succession cannot sustain a virtuous cycle. The shrub land keeps enlarging and the grain output keeps growing. Excessive reclamation and cultivation are widespread. The depleted soil makes it hard to recover the native vegetation. The rotation cropping lands are then deteriorated to the barren mountains, grassland or shrub land.

5 Summary

The change of land use/land cover in Xishuangbanna is mainly driven by the economic and social development. Due to the growth of population and grain output, and the increase of economic density, the structure of land use/land cover has changed dramatically. The area of tropical rain forests reduced significantly and fragmented seriously; the area of the simplex structure economic plantation such as rubber plantation and tea gardens has kept growing; and the area of shrub land has been increasing constantly. The changes in land use/land cover certainly led to a series of ecological effects. For example, the destruction of large scale forests has led to local climate change, and has affected the structure and species composition of the forest. Single economic plantation of rubber is bringing a loss of bio-diversity and an increase of water and soil losses.

That said, in the development of Xishuangbanna Region people have to consider the sustainability of both land use and eco-environment. It is suggested that people in this region should change the traditional slash-and-burn cultivation, return the crop land on the slopes in the mountain district to the forest and pasture, strengthen the construction of infrastructure facilities in the farmland, improve crop yield, stabilize the area of crop land, and curb the growth of rubber plantation, develop crop cultivation in a scientific and reasonable way wherever the natural conditions are suitable, seek other patterns for economic growth, take various means to improve people's living-condition, strengthen the recovery of the abandoned crop rotation land and damaged tropical rain forests, take more efforts to nurture young forests, and regain the virtuous cycle of ecological system gradually. At the same time, it is suggested that protective forests be built among the economic plantation to protect the bio-diversity and reduce water and soil losses.

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