CHINESE GEOGRAPHICAL SCIENCE
Volume 10, Number 4, pp. 289 – 295, 2000
Science Press, Beijing, China

HUMAN DRIVING MECHANISM OF REGIONAL LAND USE CHANGE: A CASE STUDY OF KARST MOUNTAIN AREAS OF SOUTHWESTERN CHINA

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ABSTRACT: Based on analysis of the change of land use and related social-economic factors in karst mountain areas of southwestern China, the index system characterizing land use change and its human driving forces in county scale is put forward. Then the relationship of land use change and the driving forces is studied by statistic analysis to identify quantitatively the contribution of human forces and their differences in driving land use change. Moreover, taking the Luodian County as the case, a model simulating the annual change of cultivated land area under the driving of human forces is built. Result of the study will supply reference for the management of the relationship of man and land in karst mountain areas of southern-western China, and accumulate research experience for further study on land use/cover change.

KEY WORDS: land use/cover change; human driving forces; karst mountain areas

CLC number: F301. 24 Document code: A Article ID: 1002-0063(2000)04-0289-07

1 INTRODUCTION

As the advancing of the study on human dimension of global environmental change, the change of land use is becoming one of the research focuses (IGBP/HDP, 1993; IGBP/HDP, 1995). Land use change, combining with land cover change, reflects the interdependence of human and nature. While the study on land use/cover change touches upon a lot of question, the driving force and its driving mechanism are two of the key issues (IGBP/HDP, 1995). In the meantime, they are the necessary basis of discussing and forecasting quantitatively land use/cover change by means of dynamic models. At the present time, a lot of study of land use/cover change and its driving forces have been done, and great progresses have been made too (FISCHER, 1996; MEYER *et al.*, 1994; LUCC, 1997; GCTE-LUCC, 1998). Based upon these studies and combining with our research, we can conclude that in the study of land use/cover change, there are two centre questions. One is to disclose the human driving forces and their mechanism, the other is to simulate dynamically and forecast the land use/cover change. In accordance with these two questions, the paper will study the land use/cover change and its human driving mechanism in karst mountain areas of southwestern

Received date: 2000-06-26
Foudation item: Under the auspices of the National Natural Science Foundation of China (No. 49871037, 59890200).
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China in county scale.

2 BACKGROUND

Since it lies in the typical karst mountain area of China with more mounts and less smooth areas, covered by carbonate of rock, and effected by the humid and warm climate in the subtropical zone, Guizhou has fragile karst ecological environment. So many factors are limiting the use of the land resource of Guizhou Province. The ratio of low and middle classes of land is higher, the ratio of sloping land is higher, the soil is thinner and non-continuous, etc., and so, there is few and scattered of arable land to be developed (ZHANG, 1990; ZHAO, 1995).

In addition, Guizhou is one of the poor areas in China, and the rate of economic development of Guozhou is slow too because of its increasing population and backward agricultural production (CAI, 1994; FANG, 1995). The two factors, the fragile environment and undeveloped economy, make the relationship between people and land tense in Guizhou Province and the arable land degenerated seriously. For example, the area of soil loss in Guizhou Province was 35 000km^2 in 1964, and over 50 000km^2 in the middle of the 1980s (FANG, 1995).

3 DATA AND METHOD

3. 1 Data

Because a county is the basic unit of the study in county scale, the yearbook of national economy and other related statistic data of counties will be the ideal data source. For the confinement of data, we selected the economic & statistical yearbooks from 1985 to 1996 of 4 counties, which were Zhijin, Puding, Luodian and Dushan counties respectively in Guizhou Province as the basic data source. During this period, the economy of China and the study region are all developed very quickly, the human activity made more pressure on the land, the contradiction between human and environment is more serious too. So the study based on these data would be representative. The data from 1949 to 1993 of Luodian County is also gotten to do analysis of the process of land use change.

Considering the character of land resource of karst mountain areas of Guizhou Province (CAI, 1994), we take the area of cultivated land and upland to characterize the land use structure and its change. And the index of total population, agricultural population, total yield of grain crop, total output value of agriculture, per capita income, etc., are used to indicate the state and change of socio-economy.

3. 2 Method

To identify the human driving mechanism of land use/cover change, the questions about how to change and why the change happened should be answered. To answer the first question, the character of change of land use structure and its human driving forces should be studied. By means of utilizing some basic indexes to characterize these two data sequence of change, the phases of change, abrupt points, and the tendency of the change will be studied.

For the second question, the human driving mechanism of land use change should be the main content to be studied. We will make use of some quantitative method, such as the multivariate analysis, correlation analysis, and time series analysis, etc., and combining qualitative analysis, to form a proceeding model of land use change represented by cultivated land area.

Because the data sequences of all of the four counties are short, the data of every county has been standardized in the first to avoid the influence of the mean and variance of themselves and ensure the result meeting the statistic test rightly. Then the new data sequences are utilized to do statistics. This is feasible in theory and has been applied successfully in many practical studies (HUANG, 1990). Because of the similarity in the way of land use and its driving forces among the four counties, the conclusion gotten from this kind of multivariate analysis or correlation analysis, etc., can be applied to anyone of the 4 counties. The temporal change model is gotten from the annual data of cultivated land area of Luodian County just based on this premise.

4 CHARACTER OF LAND USE CHANGE AND THE HUMAN DRIVING FORCES

4.1 The Change of Land Use

The main types of land use in study areas are cultivated land (include upland field and irrigated field), woodland, shrub field, grassland, cities and towns, and non-utilized field, etc. (EBCNRC, 1995). For the planting of grain crops is the major human activity in study areas, and the data relating with cultivated land is richer than that of other types of land use, the change of cultivated land area was selected as the main object of this study.

The data from 1985 to 1996 of study areas indicate that during this period the changes of land use in the studied counties present mainly two characters. First, refer to Fig. 1 except for Dushan County whose cultivated land area changed little until the middle 1990s, the others not only decreased annually, but also dropped abruptly in some years. The area of cultivated land of Puding County experiences one stage of rapid decrease from the early to the middle 1990s, and then comes to a stable stage in recent years. The area of cultivated land of Dushan County began increase significantly after the middle 1990s, in the meantime, both of those of the Zhijin and Luodian county still decrease. Second, in the same phase, the proportion of upland in cultivated land in all of the study areas increased obscurely. At present, the ratio of upland to cultivated land is about 50 percent in Zhijin, Luodian and Puding while less than 20 percent in Dushan County

4.2 The Change of Human Driving Forces

The total population and agricultural population are important forces driving land use change in karst mountain areas (CAI, 1996). In past ten years, the population of four counties increased continuously, the most fast is Zhijin County whose rate of increase was 10 000 person per year. The most slowly is Luodian, but its rate of increase was still up to 3 000 person per year. In addition, every year of the past ten years, the ratio of agricultural population to total population of the four counties was all over 90%, although there was up-and-down between years.

The grain crop production and its stability are another key force of driving land use change. The total yield of grain crop in study areas keeps increasing in the past ten years even if there is up-and-down during the period. The relative visible fluctuation is at the early stage of the 1990s, when the total yield of grain crop decreases obviously. However in the middle 1990s, it returns and increases again. The variability of total yield of grain crop of Zhijin and Puding counties are more remarkable comparing with that of Dushan as well as Luodian County.

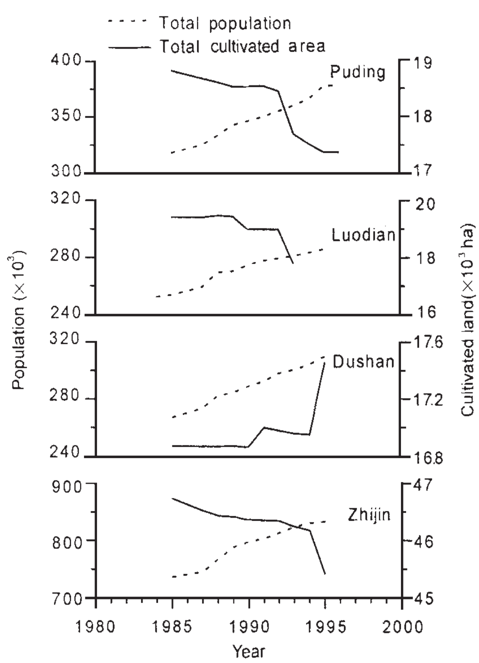

Fig. 1 Change of cultivated land area and total population

Income per capita represents the wealth hold by people and the capability of people to utilize land resource. Data from the yearbooks show that the income per capita of native people in the four counties, which are all located in poor mountain areas, is very low. For example, the income per capita in the 1980s is only about 200 yuan (RMB). The state has been improved in recent years, but the general level is still low. For instance, in the 1990s the income per capita in these four counties is less than 1000 yuan(RMB). Especially it is less than 500 yuan in Puding County.

5 CORRELATION ANALYSIS OF LAND USE CHANGE AND ITS HUMAN DRIVING FORCES

5.1 Index

The change of area and location of various land use types are influenced by a lot of factors. In some studies the human factors influencing environment change are generalized as the population, affluent degree and technology (EHRLICH *et al.*, 1990). It is in some degree a good summary of the major driving forces of human acting on nature. Correspondingly the human driving forces of land use change should include: 1) the number and quality of population; 2) the occupancy of resource and wealth by people, such as grain amount and income, etc.; 3) input to land, which can be indicated indirectly by the quantity and quality of land product. Based on the above analysis, and the availability and reliability of data, we use the indexes listed as follows to characterize the human driving forces of land use change:

(1) Basic indexes: They are selected from the indexes utilized by the yearbooks to indicate social and economic condition, including total population, agricultural population, total yield of grain crop, and total output value of agriculture.

(2) Combined index: They come from the combining of basic indexes. They include yield of grain crop per capita (total yield of grain crop/total population), agricultural output value per capita (total output value of agriculture/total population), population density (total population/land area), ratio of agricultural population (agricultural population/ total population).

5.2 Correlation Analysis of Land Use Change and the Human Driving Forces

Firstly, the linear correlation coefficients of the area change of cultivated land and the human driving forces are calculated (Table 1). When the reliability is 90%, the standard correlation coefficient is 0.36 according to the number of data sample. So the majority of the correlation coefficients in Table 1 passed the statistical test.

From Table 1 we can conclude that the change of cultivated land correlates significantly with the yield of grain crop per capita and population density. However its correlation with agricultural output value per capita and total output value of agriculture is smallest, which indicates a complex relationship between the cultivated land change and output value of agriculture.

Table 1 Correlation coefficients between index of cultivated land change and driving forces

	Total population	Per capita output of grain crop	Ratio of agricultural population	Per capita output value	Total output value	Total output of grain crop	Population density	Agricultural population
Area of cultivated land	−0.28	−0.64	0.37	−0.18	−0.20	−0.40	−0.64	−0.45

In addition, the abrupt index (WEI, 1995) of the time series of cultivated land change and the driving forces change are calculated respectively. The result indicates that in the years when the abrupt index of cultivated land is greater, which also means that the area of cultivated land changes obviously, the driving forces change apparently, too.

5.3 The Influencing Weight of Driving Forces

By the way of factorial analysis, the weights of the 8 indexes characterizing driving forces in the common factors are calculated to evaluate their relative consequence in driving cultivated land change. The interpretative variance of the former 4 common factors reaches 91% of total variance, and moreover, the subsequence of the weights of the 8 indexes keeps the same when pick out or put in randomly one or several indexes. So the weights of driving forces coming from the former 4 common factors can be thought to indicate thoroughly their relative consequence.

Fig. 2 indicates the difference of the absolute value of loading coefficients of the first common factors and the sum of that of the former 4 common factors.

The weights coming from the former 4 common factors show the relative consequence of the 8 human driving forces.

The serial of consequence in descending order is yield of grain crop per capita, ratio of agricultural population, total population, total agricultural output value, total yield of grain crop, agricultural population, population density, and agricultural output value per capita. But the difference among them is not obvious. The weight in the first common factor overhang further the influence of yield of grain crop per capita, whose weight is greater dramatically than other's. So, in study areas, the population and yield of grain crop are major forces driving the area of cultivated land.

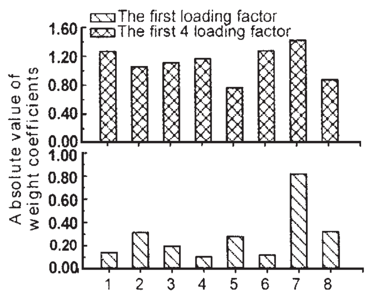

Fig. 2 Weight of driving forces expressed by load of principal factors

1—total population; 2—agricultural population; 3—total yield of grain crop; 4—total agricultural output value; 5—agricultural output value per capita; 6—ratio of agricultural population; 7—yield of grain crop per capita; 8—population density

5.4 Interpret Ratio of Driving Forces

Taking the 8 driving forces as independent variables to do multivariate regression analysis with the area of cultivated land, the following regression equation could be gotten:

$$y = -0.17x_1 + 0.77x_2 + 0.30x_3 - 0.30x_4 + 0.19x_5 - 0.13x_6 - 0.40x_7 - 0.67x_8 - 0.57 \quad (1)$$

It indicates that the change of cultivated land is associated directly with agricultural population, total yield of grain crop, agricultural output value per capita, and the ratio of agricultural population, but has inversely-proportional relationship with total population, total agricultural output value, yield of grain crop per capita, and population density. In the meantime, the absolute value of regression coefficients indicate the sensitivity of land use index to driving forces, which means that the change of cultivated land is more sensible to the change of agricultural population, population density, and yield of grain crop per capita.

The adjusted correlation coefficient of the regression equation could been used to evaluate the interpretative variance of these variables against dependent variable, which is the influence degree of the driving forces to cultivated land change. In formula (1) the interpretative level of the driving forces to cultivated land area change is 72%.

6 PROCESS SIMULATING OF THE LAND USE CHANGE

Because of the mountainous natural environment and huge pressure from poverty and population in karst mountain areas of southwestern China, the change of cultivated land is the key of land use change. The human driving forces coming from population, yield of grain crop, agricultural output value, etc., are contributing notable influence on cultivated land change. Among them the two indexes having more influence are yield of grain crop per capita and the ratio of agricultural population. But this is not enough for the study of driving mechanism of land use change, which need to identify dynamically and quantitatively the driving process of land use change to manage more effectively the social-economic environment and human activity. So the areas of cultivated land of Luodian County during 1949 to 1993 are used to set up the annual sequence data of land use change. The synchronous series of yield of grain crop per capita, ratio of agricultural population, total population, total yield of grain crop, agricultural population, population density are taken as the driving forces to simulate the annual changing process of land use.

The change of cultivated land area is the result of allocating of various land use types in terms of a given total land area. It is similar to the process of Marlkov

(CHOWDHURY, 1998), which means that after a given period, the change is no longer related with the initial state, but is only determined by the former one or several states. By means of analyzing the lagging auto-correlation coefficient of cultivated land area of Luodian County, this regularity can be confirmed further (Fig. 3).

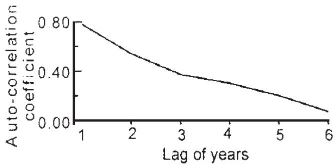

Fig. 3 Auto-correlation coefficient lagging 1 – 6 years of cultivated land of Luodian

Then the change of cultivated land area could be decomposed into two parts, the self-acting change based on the prior states and the change driven by social-economic factors. From Fig. 3 the cultivated land area of a given year could be gotten from the area of one and two years before, and the changed area driven by the human driving forces. It can be expressed as the following formula:

$$y_{(t)} \propto y_{(t-1)} + y_{(t-2)} + y'_{(t)} \quad (2)$$

where the $y_{(t)}$ is the cultivated area at the end of t year, $y_{(t-1)}$, $y_{(t-2)}$ is the area determined by the state of one and two years before t year respectively, $y'_{(t)}$ means the changed area driven by human driving forces at the end of t year. Formula (2) can be described as follow:

$$y_{(t)} = b_0 + b_1 \cdot y_{(t-1)} + b_2 \cdot y_{(t-2)} + C \cdot X_t \quad (3)$$

where the C represents the vector of regression coefficients of driving forces, $C = (c_1, c_2, c_3, c_4, c_5, c_6)$; X_t is the vector composed of the value of driving forces index in t year, $X_t = (x_{1t}, x_{2t}, x_{3t}, x_{4t}, x_{5t}, x_{6t})$, x_{1t}, x_{2t}, x_{3t}, x_{4t}, x_{5t}, x_{6t} represent successively total population, total yield of grain crop, proportion of agricultural population, yield of grain crop per capita, and population density.

The coefficients of the formula (3) are calculated by means of multivariate regression. To eliminate the impact of nonlinear relation between driving forces, the 6 driving forces are firstly disposed with the factorial analysis. Then the new common factors are used to take part in the calculation of coefficients of the regression model, and then, the regression coefficients in formula formula (3) $c_1 \cdots c_6$ can be calculated from the weights of driving forces in common factor.

The result of factorial analysis indicates that the former three common factors can carry-over 95% of the original driving forces information. So we take the former three common factors and the cultivated area of one and two years before as the independent variable, the cultivated area as dependent variable, to do multivariate regression operation. Moreover, the weights of driving forces coming from the common factors indicate too that the yield of grain crop per capita and ratio of agricultural population are the most important contributors of driving cultivated land change, which is consist with the result of the former study.

The multiple correlation coefficient of the simulating equation is 0.86, meeting the checking of F distribution.

The cultivated land area of Luodian County at the end of t year can be expressed as:

$$\begin{aligned} y_t = {} & 133\,879 + 1.1086 \cdot y_{(t-1)} - 0.5839 \cdot y_{(t-2)} \\ & - 1.5579 \cdot x_{1t} + 59.2210 \cdot x_{2t} - 6.1023 \cdot x_{3t} \\ & + 39.9365 \cdot x_{4t} - 25.2939 \cdot x_{5t} \\ & + 36.359 \cdot x_{6t} \end{aligned} \quad (4)$$

Based on equation (4), the contribution of driving forces to cultivated land change can be identified quantitatively. Especially, when future change of any of the driving forces is predicable, the possible corresponding change of cultivated land could been pre-estimated by means of equation (4).

7 CONCLUSION AND DISCUSSION

This study indicates that the land use change characterized by cultivated land change in the karst mountain areas of southwestern China is related intimately with the change of social-economic environment. The human factor is the major force driving land use change. The yearbook is a kind of suitable data source to get the representative index of land use and social-economic condition to discuss the character of land use change and it's correlation with human driving forces, and to disclose the human driving mechanism of land use change. Factorial analysis of the driving forces of land use change shows that the contribution of yield of grain crop per capita is the largest, the next one is ratio of agricultural population. Multivariate regression coefficients of land use change and driving forces indicate that the cultivated land is more sensitive to the change of agricultural population, population density and yield of grain crop per capita. Moreover, the adjusted correlation coefficient of regression equation shows that the contribution of human driving forces to land use change is over 70%. Simulation of the annual change of cultivated land area of Luodian County under the driving of human factors is not only an advanced outcome based on the former study, but also a evidence of the former conclusion. Goal of the study is to accumulate data and experience for the study of land use/cover change in karst mountain areas. In the mean time, it is also a preparation for further simulating and pre-estimating of land use change.

Because the factors influencing land use change are varied, which involve not only human dimension but also natural factors, identifying the intrinsic mechanism and constructing index system to characterize their change are important but difficult. The method of multivariate analysis used here to study the driving forces and simulate the land use change is only a trial based on the present data and cognition. With the development of the theory of land use/cover and the accumulation of the data there would be more perfect conclusion to be gotten.

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