The Sustainability Analysis of Land Use and Social Economy in Mountain Areas, Western Hunan Province, China

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Abstract: Western Hunan is the core and key area of ecological restoration and protection in the mountain areas of southern China and the middle and upper reaches of the Yangtze River. How to make a good trade-off in land-using between ecological conservation and economic development is the primary issue for the regional sustainable development. We analyzed the spatial-temporal changes of land use and socio-economic development in this area. The results showed that: 1) The change of cropland, woodland and urban construction land from 1980 to 2018 was significant, and cropland was evolving towards the hollowing pattern, while the urban construction was expanding from the center to the periphery; 2) With the high speed of socio-economic development in recent years, rural population and the proportion of rural population and the production industry decreased, while urban population, the proportion of the manufacturing industry and the service industry proportion were increasing; 3) There was a strong correlation between the area proportion of cropland, woodland and the proportion of rural population and the production industry, and the correlation decreased first and then increased with the annual economic development, while the urban construction land had a certain correlation with urban population and the manufacturing industry and the service industry, especially with the service industries. On the basis of further analysis, it was concluded that the social and economic development were the important driving factors to land use change, the capacity of ecosystem services reduced in recent years. The results could be used as the basis for the local government to make decision on the effective land protection. It was also a reference information for researchers to carry out in-depth optimization and integrated management on land resources, so as to achieve the good synergistic effect for both socio-economic development and land protection and promote the sustainable development of human society and economy.

1. Introduction

Land use, closely related to socio-economic, is the result of the interaction of human activities and natural factors [1]. Land use change and ecological environment impact are of great significance to regional sustainable development[2]. Increasing land use value will bring sustainable economic benefits, and have a certain synergistic effect on economic growth and ecosystem restoration and protection[3]. Social-economy mainly includes social population and economic value. The temporal-
spatial study of social population requires a large-scale [4-5] and high-resolution [6] population simulation. However, the area of most studies was often small, which was insufficient to ensure the research demand. On the other hand, in terms of economic value, Samuelson, a world famous economist, thought that GDP was the greatest invention of the 20th century[7]. Since Hill and Clark[8] clearly divided the three industries, the three industry classification method has been widely used in the world. Regional socio-economic analysis was a statistical and comparative analysis on regional macroeconomic laws and operation conditions based on national economic accounting [9]. In recent years, there have been many studies on the correlation between land use and social-economic data. For example, Gao [10] used the land use data of the spatial correlation between the value of ecosystem services and urbanization rate, per capita GDP, population density in Guizhou Province in 2000 and 2010; Chen [11] used the land use data of Chongqing Metropolitan Area in 2003 and 2013 to study relationship between the ecosystem service value and social-economic development level. Land use types include cropland [12], woodland [13], wetland[14], water area [15], and urban green space [16]. Experts and scholars in the field of land use have made some progress in land uses and assessing ecosystem service. Nepal, in a non-Western environment, placed ecosystem services in the scope of national priorities and issues [17]. Mankind's compliance with ecosystem management and policies and correct perception, access and use of ecosystem services can promote the development of ecosystem benefits in a sustainable direction [18]. Overall, ecosystem services are related to natural conservation, social development and human livelihoods and well-being.

However, few studies have focused on whether socio-economic characteristics (such as GDP, per capita income, industry value) [18] related to land use change, how to assess the role of land use change in urban construction and ecosystem protection in the issue of economic-social development. This can lead to prominent problem in typical ecological fragile zones including the lack of effective solutions to livelihood development of local rural communities [19]. Fragile environments contain low ecosystem service capacity which may bring more negative effects on society. How to derive the data of land use and socio-economic indicators, how to analyze the relationship between land use and social-economy, and what are the pattern of their distribution and change, are one of the core issues in nation’s environmental policies. To solve this issue, it needs to clarify the spatial-temporal effect of land uses on economic development and prosperity and the national economy and people's livelihood. The ultimate purpose of land uses effect assessment in this study is to provide decision-making basis for the coordinated management of regional ecosystems and protect the ecological resources.

2. Study area and method

2.1. Study area

Western Hunan is the core and key area of ecological restoration and protection in the hilly areas of southern China and the middle and upper reaches of the Yangtze River, with abundant natural resources with typical karst geomorphological characteristics[20]. The ecosystem of land use is dominated by terraces and mountain forests. The dominant industries in Western Hunan are agriculture, and the energy input of agricultural ecosystem accounts for 40% of the total energy input of Hunan Province. The forest coverage rate reached 70.24% in study area in 2018. It has Nanhua Mountain National Forest Park, Buermen National Forest Park, Donghe National Wetland Park, Luxi Wushui National Wetland Park, and other 32 nature reserves. But Western Hunan is remote, the ecological environment is fragile, the foundation of agricultural economy is weak, and the development of rural society is backward.

2.2. Data Source and Preprocessing Method

The data are derived from the Landsat-TM/ETM remote sensing image of land use status and socio-economic spatial distribution kilometer grid data sets of the ecological environment cloud platform of CAS. Using geographic information system (GIS) platform to select the geographical scope of Western Hunan from various types of land use for five years (1980,1990,2000,2010, 2018) from 1980 to 2018, as well as GDP and population from 1995 to 2015. Through consulting the Statistical Yearbook of Western
Hunan, Hunan Volume of China Meteorological Disaster Code, Statistical Yearbook of China's County Town Construction and Socio-economic Statistics Yearbook of China's Sub-counties and Districts, we collected data of natural disasters, investment in ecological environment protection and social economic development, GDP and per capita income from 1980 to 2018.

2.3. Study Method

Land use / land cover change is one of the most significant manifestations of human activities affecting the natural environment and affecting the natural resources and environment [20]. Land use change, especially spatial change research, is closely related to the spatial analysis method of GIS [[21]]. Land use transfer matrix comes from the quantitative description of system state and state transfer in system analysis. It can comprehensively and concretely analyze the quantitative structural characteristics and transformation direction of regional land use change [22]. It is the phase between different land use types in the early 1980’s and the late 2018’s. According to Markov theory, the important models of mutual transformation are as follows:

\[
S_{ij} = \begin{bmatrix}
S_{11} & S_{12} & \cdots & S_{1n} \\
S_{21} & S_{22} & \cdots & S_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
S_{n1} & S_{n2} & \cdots & S_{nn}
\end{bmatrix}
\]

In the formula: S is the land area, n is the number of land use types. \(S_{ij}\) indicates that the land use of type \(i\) in the early stage of the study is transformed into the land use area of type \(j\) in the late stage of the study; \(S_{ii}\) indicates that the land use of type \(i\) has not changed during the study period.

For any two-stage \((k, k+1)\) land use type maps \(\left( S_{kj}^k, S_{kj}^{k+1} \right)\), the spatial overlay is carried out by using GIS tools according to map algebra method. Based on the analysis, the transfer matrix of land use types in each time period was obtained.

\[
C_{ij} = S_{ij}^k \times 100 + \frac{S_{ij}^{k+1}}{\sum_j S_{ij}^k} (1)
\]

Among them, \(C_{ij}\) is from Period \(k\) Land Use Change Map to Period \(k+1\). \(A_{ij}\) denotes the change of land use types from \(i\) to \(j\) in \(k+1\) period Area of type.

The dynamic degree of regional land use can describe the speed of land use change, in which the single dynamic degree of land use can be used to analyze the change rate and quantity of land use types in a certain period of time in the study area, compare the difference of regional land use change and predict and analyze the future change trend [[24]-[25]]. The calculation formula (2) is as follows:

\[
K_i = \frac{S_{ij}^T - S_i}{S_i} \times \frac{1}{T} \times 100\%
\]

where \(K_i\) is the dynamic degree of a certain land use type in \(i\)-\(j\) time period, \(S_i\) is the number of a certain land use type before the research time period, \(S_j\) is the number of a certain land use type after the research time period, \(T\) is the length of \(T\) research time period.

There are many research methods about the relationship between land use change and social economic impact, including chart analysis, correlation analysis, regression analysis, principal component analysis, etc. Because R language has powerful ability of data processing and visualization of graphics[[26]], scatter plot shows the relationship between indicators and data, judges the correlation between two variables, and is ideal for the distribution of processing values and clustering of data points. Western Hunan Response analysis of three industry, correlation analysis method to study whether there is a dependence relationship between indicators and whether there is related direction and degree[[27]]. Then t-value test and significance analysis were carried out using cor (), test () and spss correlation functions, and then the effects of socio-economic and land use change in natural conservation and utilization were analyzed in five years.

3. Results and analysis

3.1 Land use change
By comparing the land use status of Western Hunan in five years from 1980 to 2018, we got the change of different land use types in four periods (Table 1). It reflected the area of cropland, woodland, water area, grassland gradually decreased, and unused land and urban construction land area gradually increased in the four periods. Compared with the other land types, the dynamic rate of cropland was only higher than that of water area, while the construction land paddy field ranked first in 2010-2018, indicating that the change rate was not particularly obvious in this period. The results of land use change in Western Hunan from 1980 to 2018 showed that the area of cropland and woodland was significantly reduced, while the area of urban construction was significantly increased.

Table 1. the change of land-use types and their dynamic change of Western Hunan from 1980 to 2018

| Land Types   | Area Changes / km² | The Dynamic Rate /% |
|--------------|--------------------|---------------------|
|              | 1980-1990         | 1990-2000          | 2000-2010          | 2010-2018          | 1980-1990 | 1990-2000 | 2000-2010 | 2010-2018 |
| Cropland     | -13                | -1                | -51               | -0.0424           | 0.0033    | -0.0524   | -0.1679   |
| Woodland     | -4                 | 7                 | 5                 | -0.0037           | 0.0064    | 0.0046    | -0.0147   |
| Grassland    | -1                 | -5                | -8                | -0.0078           | -0.0389   | -0.062    | -0.0079   |
| Water area   | 16                 | 0                 | 3                 | -23               | 1.4815    | 0         | 0.2419    | -1.8110   |
| Construction | 2                  | 5                 | 15                | 90                | 0.1869    | 0.4587    | 1.3158    | 6.9767    |
| Unused land  | 0                  | 0                 | 0                 | 0                 | -        | -        | -        | -        |
| Total        | 0                  | 8                 | -1                | 2                 | 0         | 0.0052    | -0.0006   | 0.0013    |

3.2. Change of socio-economic values

The total population of western Hunan increased the most from 1980 to 1990, with an average annual growth rate of 101.69%; the urban population increased the most from 2010 to 2018, with an average annual growth rate of 103.37%; the rural population decreased the most from 2000 to 2010, with an average annual reduction rate of 98.02%. The growth rate of GDP in western Hunan was the highest in 1990-2010, with an average annual growth rate of 110.413%, of which the growth rate of service industry is 113.22%; the growth rate of production industry in western Hunan was the highest in 1990-2000, with an annual growth rate of 104.28%, and the growth rate of manufacture industry was the highest in 1980-1990, with an annual growth rate of 112.68%. Among them, GDP represented gross domestic product, production represented production industry which take Agricultural production as the principal thing, manufacture industry represented construction, mining and excavation sect, and service represented business and services sect. After comparable price conversion, the socio-economic indicators of three industry values increased (Table 2).

Table 2. the change of social-economy of Western Hunan from 1980 to 2018

| indexs           | Changes / (10^4 each, 10^4 yuan) | The year rate /% |
|------------------|----------------------------------|------------------|
|                  | 1980-1990 | 1990-2000 | 2000-2010 | 2010-2018 | 1980-1990 | 1990-2000 | 2000-2010 | 2010-2018 |
| Rural population | 18.7587   | 3.9458    | -36.9052  | -24.7900  | 1.0099    | 1.0019    | 0.9802    | 0.9840    |
| Urban population | 16.87352  | 26.2085   | 31.0403   | 34.7800   | 1.0807    | 1.0628    | 1.0441    | 1.0337    |
| Total population | 35.6322   | 30.1543   | 24.1894   | 12.2243   | 1.0169    | 1.0124    | 1.0089    | 1.0042    |
| production       | 141.980558| 152.118101| 136.905766| 142.1706185| 1.0357    | 1.0428    | 1.0319    | 1.0358    |
| manufacture      | 329.9839024| 260.5191537| 313.5127677| 144.0871203| 1.1268    | 1.1005    | 1.1211    | 1.0372    |
| service          | 213.8671412| 252.3600865| 346.0481779| 221.7729531| 1.0790    | 1.0970    | 1.1322    | 1.0829    |
| GDP              | 196.6165414| 211.042065 | 269.2789732| 178.787697 | 1.0699    | 1.0776    | 1.1047    | 1.0598    |

3.3. The relationship between land use and social-economic development

Using SPSS principal component analysis of relationship between land use and social-economic, the score function of principal component was obtained as follows:
F1 = 0.864x1 + 0.873x2 + 0.784x3 + 0.439x4 − 0.643x5 + 0.839x6 − 0.321x7 + 0.751x8 − 0.341x9 − 0.390x10
F2 = 0.406x1 + 0.383x2 + 0.324x3 + 0.604x4 + 0.270x5 + 0.766x6 + 0.222x7 + 0.532x8 + 0.808x9
F3 = 0.105x1 + 0.190x2 + 0.354x3 + 0.582x4 − 0.027x5 − 0.425x6 + 0.419x7 − 0.521x8 − 0.391x9 + 0.147x10

The comprehensive score function is:
F = (43.705%*F1 + 24.872%*F2 + 13.130%*F3)*100%

Among them, x1−x10 represented the proportion of cropland, woodland, grassland, water area, construction land, rural population, urban population, production industry, manufacture industry and service industry respectively. F1 was mainly interpreted as the correlation of the proportion of cropland, woodland, grassland, rural population and the production industry, while F2 was mainly explain the relevance of the proportion of urban construction land, urban population, manufacture and third industry, etc. With the spatial and temporal changeed, the overall trend was less and less land for agriculture and forestry, the proportion of production decreased, urban construction land increased, and the proportion of manufacture production and production increased.

4. Discussion

With the socio-economic development dominated by total population and GDP, the proportion of the rural population and production industry ratio were declining, and the proportion of urban population, the manufacture and service industries ratio were rising. Because rural population and the production industry were significantly related to the cropland and woodland, while urban population, the manufacture industry and the service industry were related to urban construction, the social-economic development of population and GDP had become one of the driving factors of land use change. The negative effects of rapid urbanization on ecosystem services were also consistent with other regional research results [28].

The coupling of cropland and social-economy was multifunctional. There were many factors affecting the change of cropland, including population, social economy, agricultural system, natural disasters and ecological construction [29][29] . Land use, as a special ecosystem, had an important impact on ecosystem services. Assessment of changes in ecosystem services caused by LULC changes on different time and space scales would help to determine ecosystem services value and maintain ecological balance management practices [[30][0]-[31]]]. The change of land use or land cover objectively reflected the change of regional ecosystem services. In this study, land use change data were extracted from remote sensing images and GIS, and the total value of ecosystem services in Western Hunan was processed by Wang [[32]2], which was calculated in different types of ecosystem services (ESVs) in different regions of China, and also according to Xie [33]. The ESVs increased in 1980-1990 and 2000-2010, and decreased year by year after 1990-2000 and 2010-2018. This showed that the capacity of ecosystem service had declined in recent years while socio-economic increased all the way.

Spatial modelling of land uses was a key component of an integrated assessment of policies and management practices aimed at achieving environmental sustainability. The spatial effect of ecosystem services had a great promoting effect on the production industry, mainly agriculture. The proportion of land uses, especially cropland area, were closely related to the socio-economic development. Therefore, the capacity of land uses directly and indirectly promoted the development of agriculture and regional GDP. But in recent years, the area of cropland and woodland had been decreasing. As of 2017, the protection of basic farmland in Western Hunan was 155,300 hectares, while the area of nature reserves was only 237,000 hectares. The continuous growth of socio-economy had affected the improvement of ecosystem service capacity. The driving force of policy-oriented urban construction land had led to the reduction of the area of cropland and woodland. It had become one of the main reasons for the decline of ecosystem service capacity.

5. Conclusion

(1) The cropland was evolving towards the hollowing pattern in Jishou City and other counties of Western Hunan, the woodland was evolving towards the marginalization pattern of remote villages, and the industrial urban construction was expanding from the center to the periphery. (2) With the
development of the years, rural population and the production industry ratio of each county were decreasing, while urban population, the manufacture industry ratio and the service industry ratio were increasing. (3). The production industry ratio was significantly related to the cropland and woodland of spatial-temporal variation, while the manufacture industry ratio and the service industry ratio were related to urban construction. Of the temporal variation, the proportion of cropland and rural population, the production industry were correlation, while the proportion of urban construction land and urban population, the service industry were more consistent also. the social and economic development of GDP had become one of the driving factors of land use change. We would achieve the synergistic promotion effect between ecosystem service capability and rural community development, and better realize the sustainable development of human society and socio-economy.

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