Scenario Analyses of the Landscape Change in the Loess Plateau: a Case Study of Qingyang Prefecture, China

Jinyan Zhan¹, Xiangzheng Deng¹,², Rui Chen³

1. Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, No. Jia 11, Datun Road, Anwai, Beijing, China, 100101
2. Center for Chinese Agricultural Policy, Chinese Academy of Sciences, No. Jia 11, Datun Road, Anwai, Beijing, China, 100101
3. Institute of Policy and Management, Chinese Academy of Sciences, No. 55, Zhongguancun East Road, Haidian District, Beijing, China, 100080

Abstract—Using the remotely sensed data from the interpretation of Landsat TM/ETM digital images, this paper analyzes the landscape changes of Qingyang prefecture since the mid-1980s by means of spatial analysis technologies, and further analyzes and identified different types of driving factors affecting the evolution of ecosystem. Based on the area percentage data of ecological types in 2000, the spatiotemporal pattern of landscape change in Qingyang prefecture in 2005, 2010 and 2015 was analyzed based on the simulation. The conclusion of this study is of significance on the decision making on the environmental protection and land use planning, rational exploitation of water and soil resources and implementation of sustainable development strategies in the watershed of the Loess Plateau.

I. INTRODUCTION

China’s Loess Plateau has the planet’s most extensive soil erosion, which results from the fragile geophysical environment and human activities [1]. The soil erosion has kept a more and more severe trends due to the increasing intensity of human disturbances. Deforestation, wasteland reclamation, illegal logging and over-grazing have accelerated the soil erosion trends [2, 3]. Soil erosion threatens the security of flood control over the Yellow River, leads to severe impact on the efficient utilization of relatively deficient water resources, causes fertility reduction of the cultivated land, restricts the development of local community and economy, and further results in the rural poverty [4]. More severely, Soil erosion leads to environmental degradation, severely damages its service functions and exacerbates the drought of land and local climate and the occurrence of other natural disasters [5, 6].

Qingyang prefecture locates in the Eastern Gansu province, with a geographical range between 106°45′~108°45′E and 35°10′~37°20′N. From a more macro landform unit, Qingyang prefecture belongs to the Loess Plateau in the middle Yellow River, covering most of the Loess Plateau of the eastern Gansu province. The major part of land area of the whole city is in the drainage basin of Jing River. It is one of the regions where loess landform is typically formed [7]. The area of water loss and soil erosion of the whole city is more than 20,000 km², covering 87.2% of the total area of the city. The gross volume of sediment discharge is 214 million Ton annually, in which sediment yield is 168 million Ton, exceeding 10% of the total volume of sediment discharge in the region of the Loess Plateau. The average number of eroded modules is 6,188 T/km² and the highest is as much as 10,000 T/km². Severe soil erosion has become the most important factor that restrains the development of local economy.

Use the remotely sensed data, this paper analyzes and quantifies different types of driving forces that affect the mechanism of the change of ecological system by means of GIS spatial analytical technologies, simulates the spatiotemporal pattern of the change of ecosystem in the case study area in 2005, 2010 and 2015 separately, and put forwards the corresponding policy recommendations on the control and prevention of the local environmental degradation.

II. DATA AND METHODOLOGY

A. Data

The data of this study are mainly derived from the digital images of Landsat TM/ETM in the middle of 1980s (hereinafter, 1985) and 1990s (hereinafter, 1995) and late 1990s (hereinafter, 2000). For the
comparison, we just select and use the digital images between the last ten days of May and the middle ten days of June or between the last ten days of August and the middle ten days of September, the right time when the digital images are more sensitive to land cover change[8-13]. In the Image Analysis of MGE, landscape classification system specific for Qingyang prefecture is established in accordance with the image features under the reference of serious growth truth. Via a visual interpretation, we got the landscape areas for the three years of 9 classes in Qingyang prefecture.

**B. Methodology**

The simulation process of landscape changes in Qingyang prefecture mainly includes the following steps: driving mechanism analysis of the change of ecosystem, the quantification of the relationship between the change of ecosystem and driving forces and the allocation of the areas of each landscape in spatial sphere. The driving mechanism analysis of the change of ecosystem mainly aims at exploring the interaction between different landscape and the driving forces including geophysical factors as well as social and economic factor; the relationship among the landscape changes and driving forces is mainly identified by the calculation of a coefficient matrix between driving forces and the landscape changes. The spatial allocation of landscape is mainly a process of locating the changing areas of each landscape based on the coefficient matrix identifying the relationship.

**III. LANDSCAPE CHANGE**

The monitoring from Landsat TM/ETM remotely sensed data indicates that the area of different landscapes in Qingyang prefecture during 1985-2000 has been substantially changed. Unused land is reduced by 1.29%, dry land in hilly areas is increased by 4,000 ha, covering 0.28% of the data in 1985; dry land in the plain is also increased by 11.17%, and water area is reduced by 1,650 ha, covering 0.68% of the data in 1985; paddy land is increased by 100 ha, while the grassland and the slope land is reduced by 75 ha respectively. The area of woodland and built-up areas almost keep unchanged.

From the conversion between landscape categories, we can see that the change of unused land into dry land in hilly area is more remarkable, with the area as much as 4,350 ha, partly because the increase of regional demand for grains caused by the population growth stimulates the reclamation of cultivated land at these areas. In the meantime, the area of water area converted into dry land in the plain exceeds 1,350 ha; on the other side, this figure suggests that the ecological projects including silt-dam construction as well as the comprehensive treatment of small watershed of this region has achieved positive results.

In terms of net change of different landscape types, the area change mainly concentrates on the unused land, dry land in hilly area, water area and dry land in the plain. It seems that there is no obvious change in such landscape as built-up areas, woodland and grassland.

**IV. DRIVING MECHANISM**

The mechanism of landscape change can be measured through the spatial regression analysis between the spatial distribution of ecological types and driving forces in Qingyang prefecture in 1985, and the regression coefficient of the spatial regression analysis directly reflects the direction of effects and the intensity of different factors. This paper classified the driving forces of the changes of ecologic types into geophysical controlling factor and socially economic factor. Geophysical controlling factor is subclassified into the time-invariant and the time-variant factors. Time-variant factors mainly includes elevation above sea level, slope degree, soil texture and soil fertility etc. In a shorter time, the impact of geophysical factors on regional landscape changes are minor, while socially economic factors are often the predominant factors that can control the direction of landscape evolvement.

**V. SCENARIO ANALYSIS**

Referring to the current conditions of Qingyang prefecture and the requirement for the case study, this paper has designed three kinds of scenarios on the landscape changes: baseline, economic and ecological scenarios.

A. Baseline Scenario

Design of the baseline scenario is on the basis of the field trip in Qingyang prefecture. It reflects the current conditions of the landscape this time. The design of different parameters is mainly based on the current conditions at the location, so in some extend, they can be a reference of the other two scenarios.

B. Economic Scenario
Considering the fact that the economic development of Qingyang prefecture is relatively lagging behind, this paper designs the economic model for its landscape changes. Some underlying points are considered: (1) establishing a complete trading market of agricultural products, reducing the transaction costs arising from the interregional adjust of agricultural products, increasing the self-sufficiency rate of local food and livestock, and taking initiative in expanding the market outside the region; (2) readjusting industrial structure, increasing the demand rate for rural surplus labors, increasing the investment in agricultural infrastructure, upgrading the mechanization level in agriculture, increasing the employment rate of industrial by-business in the rural area, extending the production chains of farm and livestock products, adding the value-added content of the products. At the same time, the local government has taken positive measures accordingly to instruct the farmers to readjust industrial structure, such as preparing applicable policies, guiding the development of vegetable plantation and unique cultivation and etc, and to improve the local economic development. However, although the economy will be rapidly developed, under the economic program, the risk of the occurrence of natural disasters at the location will get higher since the strength of regional resource will be increased while correspondent environmental protection does not keep pace with it.

C. Ecological Scenario

Given the more and more severe soil erosion in Qingyang prefecture, this paper designs the ecological scenarios for the landscape change. The following points are highlighted: implementing actively the policies of Grain for Green Program, controlling the population growth strictly and putting stress on the protection of ecological environment. Under the ecological scenarios, human input of modern materials on the farmland is reduced accordingly, agricultural pollution is mitigated and the occurrence frequency of natural disasters is reduced.

D. Landscape Succession during 2005-2015

With the support of GIS technology, this paper simulates the distribution of landscape types of Qingyang prefecture in 2005, 2010 and 2015 respectively on the basis of the interpretation of remotely sensed data and the scenarios analyses. It is discovered that the landscape have taken substantial change in the decade from 2005 to 2015, in which dry land in the plain experiences the greatest change with its area increased by 92,000 ha, while unused land and water area are reduced a great deal (by 32,250 ha and 53,500 ha respectively) due to double pressure of increasing growth of population and demand for grain. In the meantime, with the long-term effect of such projects as the silt-dam construction and ramp treatment, the grassland will be increased by 43,500 ha, dry land in hilly area will be reduced by 80,500 ha and woodland will be increased by 1,000 ha. Similarly, the conversion between landscape types indicates that the ecological system intends to be stable in Qingyang prefecture with the joint function of treatment and destruction.

This paper calculates the conversion matrix of each landscape under the baseline scenario. With regard to the conversion area, the types ranking the first two are paddy field and grassland, reaching 118,675 ha and 83,475 ha respectively. It indicates that, in the microscopic context of implementing substantially such ecological projects as comprehensive treatment of small watershed in some places, while dry land in hilly area is converted into grassland, part of the grassland is reclaimed and becomes dry land in hilly area under the pressure of population. The mutual conversion between unused land and dry land in hilly area ranks the third and fourth, reaching 24,150 ha and 37,050 ha respectively. It suggests that while the implementation of such ecological projects as silt-dam construction transforms a large amount of unused land, some silt land is changed into alkaline land due to the shallow underground water level, resulting in discontinued farming of a great deal of dam land. In addition, about 18,425 ha grassland is converted into unused land, and the continuous worsening of ecological environment causes the degeneration of grassland. From Table 4 we can find that the mutual conversions between dry land in hilly area and grassland will cover the majority of conversion area of landscape in Qingyang prefecture.

VI. CONCLUSION

Using the interpreted remotely sensed data and based on the spatial analysis of GIS, this paper analyzed the three scenarios of regional landscape changes via the research on the active mechanism of the driving forces. The practice proves that it is the method applicable to the regional landscape changes, and the research conclusions will provide necessary decision-making information for preparing regional environmental protection and land use planning.

It is discovered in the study that the area of different ecological types in Qingyang prefecture...
between 1985 and 2000 is mainly represented by the reclamation of a great deal of unused land. From the landscape conversion matrix we can find that the increase of food demand facilitates the development of farmland. In the meantime, the converted area from water area into dry land in the plain is more than 1,350 ha. This figure implies that positive results have been achieved in the implementation of ecological restoration project.

The scenario analysis suggests that some local comprehensive treatment of ecological environment has important effect on the landscape evolvement. What should be mentioned is that the mutual conversion between dry land in hilly regions and grassland will cover the majority of the converted area of ecological types in Qingyang prefecture. It further indicates that the local treatment of ecological environment will take the environmental effect of ecological function into consideration, attaching importance to the substantial results of ecological restoration.

REFERENCES


