



Methods

Application of PCA integrated with CA and GIS in eco-economic regionalization of Chinese Loess Plateau

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ABSTRACT

Eco-economic regionalization (EER) is to divide an area into geographical zones. Each zone is linked to the others based on the eco-economic similarity and disparity. In this study, models of EER of the Chinese Loess Plateau were constructed. Data on 22 selected indicators were gathered for the 282 administrative counties. Then they were analyzed through an approach of PCA integrated with CA and GIS. In the generated model, the plateau was assigned to 4 belts and 18 eco-economic zones. The relationship among the subdivisions was able to represent the real situation. It demonstrates the division scheme is very comprehensive, concise and applicable. The work has established a novel methodological framework for EER of large-scale area.

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1. Introduction

The Chinese Loess Plateau is an area congested with problems of over-population, scarce resources and harsh environment in China; however it is also the major region where large energy industry and heavy chemical manufactories are located. The ecological environment is very fragile under a situation of population growth out-control and environmental protection largely neglected. Human activities in terms of reproduction and daily life do not comply with the nature; and the consequential degradation in ecological environment is very serious.

The recent economic development has not only exacerbated the deterioration process, but also made the environment more vulnerable. The complex ecological structure has been disrupted due to localized damages, and the ecosystem is slowly receding into a dysfunctional state. This situation also has made a tremendous negative impact on the overall ecological environment in China.

The deterioration of natural ecological environment causes declining of productivity and other tangible economic losses; it also affects the price of the local products in the international market and the investment environment of the area. The resultant threat on living conditions will inevitably harm the quality of human life. Such unfavorable situation has formed a vicious circle in several locations on the Chinese Loess Plateau.

In order to improve the situation, the Chinese government has implemented various measures albeit without much success on managing the Loess Plateau since the founding of the People's Republic of China. Among the many reasons, lack of a comprehensive agro-ecological economic regionalization map is the key factor.

In the past 60 years the Loess Plateau was under the control of the central government. During this time period, no strategic management plan was executed. There were only several debates over the strategies of ecological environment construction. The first debate occurred in the 1950s. The central issue was to reduce soil erosion whether through increasing natural ground coverage with forests and herbaceous plants or by adopting a civil engineering approach.

The second debate lasted from the late 1970s till the early 1980s. The focus at this time was on what should be done about the ecological environment in the Loess Plateau. A group of scientists strongly advocated a forestry-based policy; they insisted that the Loess Plateau should be developed into a state-owned forest farm. Another group of scientists upheld that animal husbandry should be the priority, and proposed to develop this area into an animal production base. The third group supported a comprehensive strategy; they argued that the developmental plan for this area should include subsistence agriculture, protective forestry, and commercial livestock production.

The third debate has been going on since the late 1990s up to date. Different from the previous ones, the current focus is more on protecting the ecological environment. Three schemes were put forward. The first one aimed at implementing the policy of "returning farmland to forestry and grassland", the second one proposed to keep sufficient acreage of basic farmland, forestry and grassland, and the third proposal recommended to build a central dam in the valley to harness all the natural resources in the area.

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Overall, the first two ideas were based on pure academic understanding of nature, and the last one was more on building a balanced relationship between the interests of investors and different local authority departments. The common drawback in the three proposals is that the effect from the regional variation in the whole plateau was not appropriately assessed. Furthermore, economic development has never been featured as a positive factor in the environmental protection plan (Jing, 2006).

The goal of this study was to promote a healthy natural environment in which agro-ecological economic development, forestry and animal husbandry coexist and develop in harmony. The Chinese Loess Plateau is a special geographical region where the original ecological environment has undergone visible regional differentiation. Thus the overall ecological environment and economic development models should be constructed to accommodate each individual resources and environmental characteristics.

Previously, several zoning maps including the comprehensive ecological or economic zoning of the Loess Plateau have been drawn based on regional differentiation. In these zoning plans, the whole Plateau was divided based on single-element variation, instead of combining ecological function with economic principles.

In the older versions of the ecological function zoning maps, the landscape plans were mainly focusing on environmental protection paying little or no attention to the economic impact. On the other hand, the economic function zoning map was constructed using administrative divisions as basic units without assessing the impact from industrial development on regional ecological systems.

This study aimed to develop a system which features coordinated developments of both ecological and economic systems as a whole in the Loess Plateau. The general regional delineation of the eco-economic status was assessed using principal component analysis (PCA) method integrated with clustering analysis (CA) and geographic information system (GIS) technologies. Results from this study will provide the foundation for guiding the ecological and economic development in this area, furthermore, they are the methodological framework for regionalization of areas on as large scale as the Chinese Loess Plateau. These findings will be used as the specialized supplemental information for optimizing theoretical concepts in regional eco-economy.

2. Background of the Study

Eco-economic regionalization emphasizes coupling of ecological and economic dimensions. It is essentially a component of a comprehensive zoning plan (Xiao and Qian, 2006a,b). China is one of the countries that have started regionalization since the very early days; those activities were described in the historical records such as the Zhu Kezhen's "Climate division of China" and Huang Bingwei's "Vegetation division of China". The division research in China has evolved from natural zoning, agricultural zoning, and ecological zoning to comprehensive zoning (Fu et al., 2001; Wang et al., 2005). There are three types of partition methods, namely the "bottom-up" clustering method, the "bottom-up" combined with "top-down" method, and the combination with GIS division method (Pan and Hu, 1997).

In the case of the Loess Plateau, multiple zoning schemes have been proposed using various spatial scales and from different aspects, including single element to multi-factorial zoning integrating natural resources, agricultural meteorology, human factors and others (LPCSE, 1990; Yan et al., 2006). These division schemes target the natural systems on large-scale (Song and Wang, 1996; Zhang et al., 2007), whereas human activity is factored in as indicators on small scopes (Hu et al., 1994). In general, these zoning plans have made significant contribution to both theoretical understanding and development of the area, but they are mostly constrained to studies in small scope area. No information is available on comprehensive eco-economic regionalization on as large-scale as the whole Loess Plateau.

Division of the Loess Plateau has been the most important spotlight in academic research. From 1950s to date, researchers in the field have conducted various regionalization practices from the large scope Loess Plateau (LPCSE, 1990), to provincial sizes (Wang et al., 2005; Ma et al., 2006), as well as at county scale level (Xiao and Qian, 2006a,b; Xiao, 2007).

Several large-scale scientific expeditions on the Loess Plateau have been undertaken by several generations of scientists, including long-term field study, site monitoring and case investigations. Zoning schemes have been designed separately based on landforms, erosion factors, erosion type, erosion intensity, soil type, soil parent material, vegetation, soil moisture, land use, rainfall conditions, landscape elements, economic development factors and other elements (LPCSE, 1990 & 1991). Results from both overall analysis and synthetic research relevant to the natural environment in this region have provided effective scientific and technological support for soil and water conservation, ecological environment protection and construction, and economic development during various time periods.

However, most of these division schemes essentially belong to natural division which mainly focuses on natural environmental features, very minimal consideration was given to the role that human activities played in the process of natural resources development and environmental protection. Those approaches are not very applicable for constructing models that require integration of ecological issues with economic development. For this reason, they should not be used to guide sustainable development of local economy.

Zoning scheme based on eco-economic interaction has been proposed to characterize human activities. The aim of this study was to provide a regionalization scheme that can be used to reliably assess the local ecological and economic situation, and it will eventually replace manual classification at large-scale level.

3. Study Area

Chinese Loess Plateau has among the world's highest soil erosion rate. Characteristic powdery dry soil and centuries of unsustainable farming practices combined with huge population pressures, have led to serious environmental deterioration. Roughly 1.6 billion t of sediment clogs the Yellow River annually, posing a serious flood risk to the downstream area. In recent years, the discontinuation of farming on steep slopes and the establishment of large-scale terracing and sediment control structures have made significant strides in staving off further erosion.

The Loess Plateau is a special region named according to its major geomorphologic features. It covers 7 jurisdiction provinces (autonomous regions) including Shanxi, Ningxia, Shaanxi, Gansu, Qinghai, Inner Mongolia, Henan, and 282 counties in total. The area spans about 1300 km from east to west and 800 km from north to south, and the elevation is c.a.500~2 000 m. The total ground area is 635,000 km², which is equal to 6.5% of the total land surface area in China. The total population is 10.59 × 10⁷ people (according to the 2005 Yearbook), and the urbanization level is 33%. The per capita GDP is 2, 383 Yuan (RMB), which is within the low income level in China.

Chinese Loess Plateau is located in the upstream regions of Yellow River and Haihe River in the north-central China with geographical attributes of N33° 41' to 41° 16' and E100° 54' to 114° 33'. It is the transition zone from humid climate of eastern China to the arid region of the north-western China. It is an important birthplace of Chinese agricultural civilizations as well as one major agricultural region in the world. The conflicts among population–resources–environment, in addition to the most poverty population, are the major problems in this area. The plateau also represents the transition zone between the economically developed regions in the southeast coast and the western poor areas of China. Most importantly this region provides a vast reservoir of potential for agricultural production in the country.

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