地理学报(英文版) 2003年第13卷第2期

Mechanism and regulation of land degradation in Yulin district

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Yulin district is located in the transitional zone between Mu Us Desert and Loess Plateau of northern Shaanxi Provinc e, thus it is particularly vulnerable to degradation due to its fragile ecosystem and intense human activities ther e. The purpose of this study is to explore the mechanism, process and driving force of land degradation in area with vulnerable eco-environment within the context of increasing population and intensifying human economic activities, an d then find out the patterns and countermeasures of how to control them using the economic and technological ways. I n detail, this study includes three main sections: the first section analyzes the mechanism, causes and characteristi cs of land degradation, which can be achieved by the typical field investigations and systematical analysis within th e regional natural, social and economic context. Based on the technologies of remote sensing and GIS, and combined wi th the modeling methods, the second section reveals the change characteristics of land use and its driving force fro m 1990 to 2000; As to the third section, feasible countermeasures of how to prevent the degradation and rehabilitate the regional ecology are proposed, which are studied from the perspective of harmony between nature and economy, and the conception of regional sustainable development.

Mechanism and regulation of land degradation in Yulin district LIU Yansui1,2, ZHANG Xiaoping 1, LI Xianwen2, Jay Gao 3 (1. Inst. of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China; 2. Open Lab of Land Us e, China Land Surveying and Planning Inst., MLR, Beijing 100029, China; 3. Dept. of Geography, University of Aucklan d, Auckland Private Bag 92019, New Zealand) 1 Introduction Land degradation is one of the most serious ecological pro blems in the world (Scott and Sara, 1999; Al Dousari, 2000). The most typical and serious form of land degradation i n China is desertification, It has resulted in a direct economic loss estimated at between 0.2 and 0.25 billion US do llars. Indirect loss is two to three times higher. Desertified areas are currently expanding at a rate of 2,460 km2 a nnually, or 1.58 and 1.17 times the rate in the 1960s and the 1970s, respectively (UNDP, 1999; Zhou, 2000). Especiall y, desertification and soil and water losses caused by natural factors and human activities have become key ecologica l problems in the northwestern China, resulting in shrinkage of arable land, frequent natural disasters and growing p overty for the local people. The Loess Plateau, as one of the most serious soil erosion regions in the world, receive s a lot of attention from the Chinese government and international society (Cai, 2001; Fu and Chen, 2000). The land d egradation, especially serious soil erosion causes land to be less fertile and thus, more areas need to be reclaimed to sustain the population growth. Therefore, it is very important and essential to study land degradation (Zha and Ga o, 1997). This paper identifies the ecotone of intermediate zone that the agriculture and livestock farming interloc k in northern Shaanxi Province as the typical case study area. This region lies in the southeast of Mu Us Desert, whi ch is the interim region of the blown-sand area and the loess hilly zone. The representations of this region are as f ollows: (1) This region is a vulnerably ecological transitional region: it shows strong sensitivity to external chang es of key environmental factors, and the pressures of population and its negative effects on the environmental degrad ation have shown obviously in recent decade; (2) the region is a laggard region of agriculture and livestock farmin g: in it, the agricultural activities, which are greatly influenced by climates, always result in excessive cultivati on and grazing, thus make the environmental destruction more severely; and (3) it contains important mineral bases o f coal, oil and gas in China: Shenfu coalfield, the biggest coalfield in China, lies in the region, and the planned g as-feed base of "transferring natural gas from west to east" project, programmed in the "10th Five-Year Plan", lies i n the region (Jingbian County) as well. Since the set up of Shenfu coalfield in 1985, it has always been short of eff

ective administration, so the exploitations are in disorder. For instance, in Shenmu County, the number of all kinds of local collieries has increased from 18 to more than 280 within recent 10 years, and the total coal output increased from 0.32 million t to 200 million t. In addition, there are more than 1,000 small out of date oil refineries causing serious pollutions. The irrational mineral exploitation inevitably leads to many new environmental problems, which are aggravating the process of land desertification. The objective of this study is to explore the mechanism, process and laws of land degradation in area with vulnerable environment within the context of increasing population and intensifying human economic activities, and then find out the patterns and countermeasures of how to control them in the economic and technological ways. 2 Study area Yulin district, the study area, is located in the transitional zone between the Mu Us Desert and the Loess Plateau of northern Shaanxi Province in China, lying 36o57´-39o34´N and 107o28´-115o15´E geographically and covering an area of approximately 43,417 km2 (Figure 1). It encompasses 262 towns/townships distributed in 12 counties, i.e., Yuyang, Shenmu, Fugu, Hengshan, Jingbian, and Dingbian in the northern part of the study area, and Suide, Mizhi, Jiaxian, Wubu, Qingjian, Zizhou in the southern part of the study area, with a total population of 3.31 million at the end of 2000. At present the population density is 76.2 persons/km2. Over the last 10 years population in the area has been growing at an annual rate of 39,850 people (SBSP, 2001). This area is a typical agro-pastoral region and an important energy and mineral base in China. Geographically, the study area is located in the transitional zone between the Mu Us Desert and the Loess Plateau of northern Shaanxi Province. Geomorphologically, it has multiple hierarchical ecozones dominated by aeolian landforms. Its transitional climate varies from arid and semi-arid to subhumid, with a dry and windy spring, a hot but short summer, an autumn of heavy but short duration rain events, and a long, dry and cold winter. It receives an annual precipitation of 320.8-496.9 mm. Most of the rainfall events are highly concentrated in the summer months. There are relatively rich groundwater resources in the area. Vegetation in the area is characterized by the transitional type from desert and desert steppe to forest steppe. At present severe land degradation occurs mainly in the form of desertification. Overall, 88.5% of the land has been desertified to varying degrees. As an important coal base, the region will inevitably be exploited more intensively for its resources in the future, leading to more severe land degradation. Systematic study of such representative land degradation is practically and economically significant not only for demonstrating the feasibility of effectively rehabilitating degraded land into productive use, but also for improving the living standard of local inhabitants. 3 Mechanism of land degradation 3.1 The mechanism and model of land degradation The process of land degradation includes wind erosion and water erosion caused by natural effects and by the manners of human activities and inhabitation, and it also includes soil deterioration in physical, chemical, biological and economic characteristics, and the long-range loss of natural vegetation, etc. (UNEP, 1992). Its main manifestations include decrease in land productivity, decline of land output potential, loss of land resources, and the emergence of surface conditions not favourable for production (Zhu, 1994). The degradation process may be everlasting, gradual, continual, and localized (Liu, 1997). The mechanism of land degradation was determined through analysis of the natural settings in the study area and their evolution, as well as through field investigation. The objective of the fieldwork was to identify and evaluate the present characteristics and processes of desertification. The fieldwork was carried out along three routes that covered nearly the entire study area. The first route along the Great Wall aimed at investigating the distribution and status of desertification to the south and north of the Great Wall. The second route was along the upstream of the Wuding River and in the northern piedmont of the Baiyu Mountain. The main purpose was to determine the impact of land use types (farming versus grazing) and intensity on desertification. The third route between the capital of Shenmu County and Daliuta was intended to investigate how the construction of mining facilities and mining activities affected desertification. According to our field investigation and analysis, we find that land desertification, the principal form of land degradation in the study area, stems from a tipped balance between the inherently fragile environment and economic development, in which human activities, among many other factors, play an important role. In other words, land desertification in this ecologically vulnerable region is the outcome of irrational land use and land mismanagement. Inappropriate land use practices in conjunction with weak land management have transformed nature´s potential vulnerability to visible destruction (Liu et al., 1997; Liu and Deng, 2001). The model of land degradation is summarized in Figure 2. It indicates that both natural and anthropogenic factors play a critical role in the initiation and exacerbation of desertification. 3.2 The factors and process of land degradation As early as the Qin and Han dynasties (221 BC-220 AD), the study area was known as ´fertile land of million hectares´ with advanced farming and pasturing. This favourable setting still remained in the Ming Dynasty (1368-1644 AD) during the construction of the Great Wall. By the mid-Qing Dynasty (1644-1911), the policy of ´providing for people with other lands´ led to the conversion of naturally vegetated land to cultivated land. Massive stripping of natural vegetation initiated desertification. By th

e time the People´s Republic of China was founded in 1949, only 40,000 ha of natural forest remained in the six north ern counties of Yulin district, covering 2% of the land area. Later large-scale preventive efforts of afforestation a nd grass planting considerably enlarged vegetative coverage and reversed the trend of desertification within certain localities. Nevertheless, the overall trend of land degradation continues as a consequence of inappropriate human act ivities, particularly the destruction of vegetation that exposes soil. Soil erosion initiated by strong wind average s 3,800 t/km2. Wind erosion has thinned the soil layer, degraded land quality, reduced land productivity, and acceler ated desertification (Liu, 1999). In recent 10 years, with the development of regional industry (include mining) and the rapid growth of population, the intensity and negative effects of human activities are accelerating, further dete riorating the already fragile ecosystem and resulting directly in the degenerative succession of many environmental f actors (Table 1). 4 Changes of land use and land degradation 4.1 The database of changes of land use The primary info rmation for the land use change of the study area in 1990, 1996 and 2000, was gathered from the Landsat TM image reco rded. Auxiliary information sources included 1:50,000 scale of colour infrared aerial photographs taken in 1990 and 1 996, and the detailed land inventory data of 1996 and updated data in 2000 from MLR (Ministry of Land and Resources) were used in the modeling and analysis of land use types. The database and spatial distribution of land use change i n the study area are shown in Table 2 and Figure 3. 4.2 The changes of land use and its driving forces (1) Over the l ast 10 years, arable land, which decreased at an annual rate of 111.02 km2, was the predominant land use type, and th e forestland, grassland, orchard and town-industry-traffic land quickly increased because of the agricultural restruc turing and industrial park construction in this area. They have increased at an annual rate of 72.45 km2, 46.78 km2, 29.06 km2, 12.32 km2, respectively. There are obvious differences in structural change of land-use types such as Yuya ng district, Dingbian, Hengshan and Shenmu counties in the two periods of 1990-1995 and 1996-2000 (Figure 3). (2) Ara ble land and unused land were mainly transformed to forestland, grassland, and orchard in the process of "converting cultivated land back into forestry and pasture" and the construction of The "Three-Norths" Shelterbelts Project. Mean while, partial land desertification to the north of the Great Wall and severe soil and water erosion to the south of it has also been suffered by inappropriate human activities such as excessive cultivation and over-grazing. (3) Afte r the second land use contract (new land-use reform unchanged in 30 years) was finished in 1996, most of the forestla nd (trees) and unutilized land were re-assigned to farmers and a new policy "who plants, who owns" was adopted, the n, to plant trees and pasturage in the steep sloping farmland, wild sparse grassland and sandy land are encouraged, a nd much of the cultivated land and unutilized land were diverted to forestland in 1996-2000. (4) The planting and sto ckbreeding usually play key roles for the local socio-economic development. With the industrial development includin g coal and oil mining and the rapid growth of non-agricultural population, the town-industry land and traffic land ar e rapidly increasing at an annual rate of 9.39 km2 and 2.93 km2, respectively. Caused by the unreasonable mining acti vities, desertification has been seriously developed in areas surrounding coalfields since the 1990s. It has been est imated that the construction of the Shenfu-Dongsheng coalmine alone will cause an increase of desertified area by 12 9.6 km2 (Wu, 1996). 4.3 The trends of land degradation (1) It has been revealed that not all counties are equally des ertified (Liu and Gao, 2002). On the one hand, all of them except Dingbian have over half of their areas desertified at the severe level while Hengshan and Yuyang have three quarters of their territory desertified severely. On the oth er, many of the counties have a large proportion of land with latent potential. Therefore, the pattern of desertifica tion severity appears to be polarised. (2) A comparison of the recent satellite images with historical aerial photogr aphs reveals that the extent of degraded land in the study area has expanded while the overall severity of land degra dation has worsened. Confirmed by the field investigation, the desert front in the vicinity of Xincheng, Jingbian Cou nty has advanced forward by over 10 km. The sand-topped loess topography incised by gullies has encroached southward s by 10 to 30 km. In the worst affected region between Yuyang and Hengshan, the encroachment is as further as over 4 0 km. Because of the expansion of the Mu Us Desert and the impact of sandstorms, the Great Wall is no longer the divi de between sandy land and loess. (3) In addition, desertified land is not equally distributed spatially across the st udy area and temporarily constant. Land desertification is very severe in northeastern Shenmu, the upstream tributari es of the Wuding River, and in the northern piedmont of the Baiyu Mountain in Dingbian and Jingbian counties. Deserti fied areas have advanced towards the southeast linearly. Therefore, the speed of land desertification has accelerate d in the last 10 years. Furthermore, the speed of desertification has been growing in severely desertified counties d espite rehabilitation efforts, the counties not considered so vulnerable to desertification have fared less well by c omparison. (4) The patterns of land degradation have a trend of diversification in this study area. Except land deser tification, patterns like soil erosion, grassland degradation, and soil and water loss take place jointly, and their harm goes worse. Thus, they should receive more attention in the future in order to maintain the overall risk of lan

d degradation. 5 Countermeasures to land degradation 5.1 Optimize rural economic structure, mitigate population stres s on the land The substantial reason of land desertification caused by over population in the study area lies in the deep contradiction between low carrying capacity of land and excessive growth of human activities using poor agricult ure and husbandry techniques. To a certain extent, it is an inevitable result of fragile eco-environmental region wit h behindhand economy and technology. Therefore, the keystone of land desertification management is to break through t he bottleneck of technology, combine the knowledge of economy, ecology and eremology, integrate the land desertificat ion management with rural economic development, especially the development of agriculture and husbandry. On the one h and, via the application of technology in point and the preferential policies, improve economic conditions, raise th e productivity and the farmers´ income; on the other hand, the policy of "substituting woods and grass for grain, rec overing eco-environment" should be carried out, let more farmers make their living without traditional agriculture an d husbandry, thus eliminating the root of desertification, making the overall reverse of land desertification. 5.2 Ch ange the idea, build preventive vegetation system marching ecological economy The fundamental approach to desertifica tion control is to build and improve preventive vegetation systems, and increase vegetation coverage (Liu and Ci, 200 0; Kjeld et al., 2001). According to the principle of ´adjusting measures to local conditions, from easy to difficult ´, the approach includes: allocate arbor-shrub-grass fittingly, distribute belt-network-patch rationally, so as to fo rm the converging attacking to desertification. In interdunal area and sandy ground, develop timber forest network an d farm shelter network dominated by arbors like poplar, willow, elm, and pine. In the steep slope of degraded waste m ountainous area, build soil and water conservation forest by the conversion of cultivated land back into forestry. I n wet sandy ground with relative good hydrothermal conditions, develop patches of economic forest dominated with appl e, grape, sallow thorn, etc. The purpose is to gradually build up ecological economic patterns of preventive vegetati on systems divided by forest belts, crisscrossed by farm shelter network, and scattered with patches of forest and gr assland. 5.3 With a view to the future, realize sustainable land use The key to the management of land degradation i s to enhance the construction of basic farmland, fulfilling the dual targets of less farmland with more harvest and m ore vegetation with higher benefit. So it is very important to improve the land use manner and to increase the low in come of farmers, which is an important premise to mitigate the pressure and hazard of human activities on land. Agric ultural activities should make efforts to enhance the diversity, heterogeneity and stability of agricultural ecologic al system, promote its benign circulation: (1) Develop farmland, forest and grassland simultaneously. Take forest as framework, set grass belt between forest belt and farmland. The Loess Plateau is fit for planting purple medic, a kin d of high-quality pasture grass for stockbreeding. Statistics show that one hectare of purple medic will produce 60,0 00 kg of grass which costs nearly 7,000 yuan, doubling the profit of grain (SBSP, 2001). (2) Preserve nutrient and gr anule materials in cultivated horizon through overlay cultivation, improve soil structure by grain-grass rotation an d intercropping, so as to enhance the anti-erosion capacity of soils. In the degraded areas, measures of spreading so il upon sand and mixing sand into mud can be used to amend the physical properties of soil, to the effect of preventi ng the spreading of degradation. (3) This region possesses a huge potential for further exploitation of natural resou rces and economic development. However, protection of the fragile ecosystem should be reinforced to maintain a balanc e between development and land utilization. Thus it is necessary to enforce existing laws for governing the exploitat ion and management of natural resources, and to establish a mechanism to compensate for farmers whose income has drop ped as a consequence of diminished land productivity caused by mining-induced degradation in the vicinity.

关键词： land degradation; land desertification; changes of land use; Yulin district

