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Analysis of LUCC in loess plateau based on PSR model-A case study in shanghuang study area in Guyuan city

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ABSTRACT

The Pressure-State-Response model (PSR) proposed by the OECD and UNEP in 1994 was used to evaluate ecosystem health, In this paper, the PSR concept model was cited to reflect the pressures upon land resource in different time exerted by human activities, the responses of society to these pressures, and the state changes of land resources in different phase. A workable indicators system of PSR model is designed according to the characters of land resource in Loess hilly region. According to these indicators, we analyzed the land use and land cover change of the study area form 1982 to 2005 year. The results show that different responses measures to the pressures present different results during the process of land use. Before 1982 year, the inappropriate land use patterns in response to the pressures of population growth and socio-economic development leaded to the results of eco-environmental degradation and poverty, while from the "Sixth Five-year Plan" period to the "Tenth Five-year Plan" period, the rational measures of responses promoted the regional sustainable development, the net annual income per farmer increased from 47.7 Yuan(RMB) to 2093.2 Yuan(RMB), while the soil loss intensive decreased form 6000 $t \cdot km^{-2} \cdot yr^{-1}$ to 1000 $t \cdot km^{-2} \cdot yr^{-1}$.

KEYWORDS

PSR model;
Semiarid hilly area of Loess Plateau;
Land use.

INTRODUCTION

Severe soil erosion in Loess Plateau has been regarded as a major environmental problem, which exerts pressures on the environment and changes its quality and quantity of natural resources. This problem is related to both natural factors and human activities. The natural factors include intensive rainstorms,0looses soil, unique topography, while the excessive reclamation on the sloping land for long time was the human factor[1,2]. Hazards such as land degradation and ecological deterioration caused by soil erosion had threatened the

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pepole life and the ecology environment of the whole Yellow River basin. As a result, it is important to study the problems of soil erosion and understanding the natural and social factors which cause the land degradation and ecological deterioration in this region. From the beginning of the period of0the "Seventh Five-year Plan" period, Chinese government set up a number of experimental area base on small watershed for long-term research. There are many successful examples of sustainable land-use patterns in Loess plateau through nearly 30 years of scientific research[3,4].

The pressures on the environment caused by human activities, such as soil erosion and ecological deterioration, eventually exerted on land resource, the only way to alleviate these stresses is change the patterns of land use with the helps of funds, techniques and policies, however, the most important aspects is how to respond to the pressures. Different responses lead to different results, In particular to the ecological fragile areas, which is particularly important. This paper, taking Shanghuang demonstrated area as a case, analyzes the measures of response in various phases, which helps to explore the cause-effect-relationships of ecological environment changes in this region.

MATERIAL AND METHOD

Study area

The Shanghuang study area (35°592 -36°022 N, 106°262 -106°302 E), with an area of 7.61 km^2, is located in Loess hilly and gully region of south Ningxia(Figure 1), China., This region has a temperate semi-arid climate. The annual average temperature arranges between 5 ºC and 7 ºC, while the annual cumulative sunlight reaches up to 2200-2700 hours. The average precipitation is between 260 mm and 820 mm. The elevation varies from 1534.3 m to 1822.0 m. In 2005 year, its population was 519, and the net annual income per farmer was 2093.2 Yuan(RMB), the soil loss intension is 1000 $t \cdot km^{-2} \cdot yr^{-1}$.

Data source and land use classification system

Shanghuang experimental area was selected as a study area by Chinese Academy of Science and Ministry of Water resources to carry out long-term research in 1982. Since that time, investigation of the effects of eco-environmental change on agricultural economics was carried out continuously. The land use and land cover change is an important field for scientific research, the researches protracted land use maps in 1982 year according to the investigations and the relief map with scale of 1:10000 which was mapped by NingXia Bureau of Surveying and Mapping in 1982 year. The researches investigated the land use change in different period from 1982 to 2005 year, and the researches compiled the digital Orthophotoquad map based on the technical of 3S(GPS, GIS, RS) and with the information sources of color infrared aerial photography photograph of the study area with scale of 1:5000 in 2004 year.

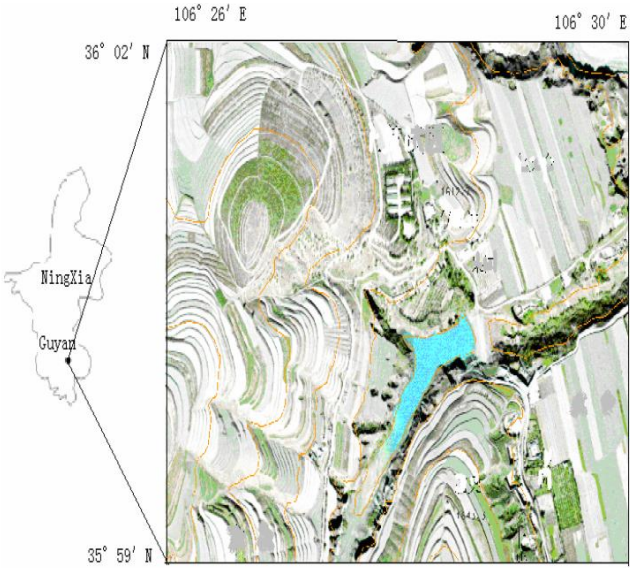

Figure 1 : Location of the study area

According to the land classification system, in this paper, cropland refers to the land for cereals which include terrace, sloping cropland and flat or basic cropland; forest land includes timber forest, ecological forest and nursery; grassland means natural of artificial grass for pasturing; and other types of land are non-agriculture land, including residential area, infrastructure, water body and unused land.

PSR model framework

The pressure-state-response model was proposed by the OECD and UNEP in 1994, subsequently, many researchers applied this model to evaluate the healthy conditions of different terrestrial ecosystems related to agriculture ecosystem[5], soil ecosystem[6], grassland

ecosystem[7], forest ecosystem[8] and wetland ecosystem[9], lake ecosystem[10-13], coastal ecosystem[14], river/stream ecosystem[15-19], coral ecosystem[20], etc. All the papers mentioned above provided a theoretical basis and some methods for the assessment of ecosystem health. This paper, with PSR model and the characters of land resource in Loess Plateau, proposes the pressure-state-response indicators system of land resource for Loess Hilly region (Figure 2).

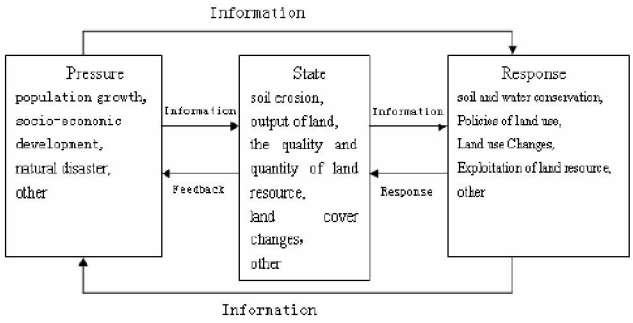

Figure 2 : The PSR structure of land resource

Based on this model we can analyze the pressures to land resource which came form population growth and socio-economic development in different phases, the measures of responses including funds, techniques and policies, and the states of quality and quantity of land resource in different phases.

MATERIAL AND METHOD

The Pressure-State-Response of land resource before 1982 year

The soil erosion in Loess Plateau, such as Shanghuang study area, is most severe due to the destroying of natural vegetation and cultivation on slope land over extensive areas[21,22], and the economic development is very slow (TABLE 1). In 1982 year, its population was 363, and the net annual income per farmer was only 47.2 Yuan(RMB), the ratio of poverty reached 60 percent with the same percent illiteracy, The annual food occupy per farmer was 230 kg, and the food production was only 510 kg/hm^2, so it was difficult to provide sufficient food for the population. At the same time, the ratio capital between input and output was only 1:3.6. Consequently, the poverty was the most pressure at that time, in order to Maintain a basic livelihood and get rid of poverty, because of the lack of fund, technique, and knowledge, the responses of the local people could only do were to destroy natural vegetation and cultivate on slope land over extensive areas, therefore, this region suffered severe soil and water losses. For many years, the populations in this region have been living in abject poverty. The ecological deterioration, backward economy and intrinsic poverty were interconnected and restricted the regions economic development.

TABLE 1 : Changes of pressure-state to land resource of ShangHuang experimental area in various phase

	Indictor system	Before 1982	1982-1985	1986-1990	1991-1995	1996-2000	2001-2005
Pressure indictor	Population density (persons/km^2)	47.7	56.6	60.1	64.0	67.3	68.2
	Net per farmer income (Yuan•yr^{-1})	47.2	418.9	572.7	1127.8	1846	2093.2
	Per farmer food occupy(kg•yr^{-1})	230	366	410	500	550	684.6
	Food production (kg/hm^2)	510	922.5	1330.5	1627.5	2250	2250
	Ratio of invest and income (%)	1∶3.6	1∶6.9	1∶5.4	1∶8.7	1∶10.5	1∶15.6
	Ratio of poverty (%)	60	40	30	15	5	2
	Ratio of illiteracy (%)	60	46	25	10	5	2
State indictor	Vegetation coverage (%)	1.87	24.5	18.4	22.9	32.0	55.7
	Soil loss intensive (t•km^{-2}•yr^{-1})	6000	5000	3000	2500	2000	1000
	Ratio of sloping cropland (%)	85.5	76.9	70.5	72.5	71.2	16.8

The Pressure-State-Response of land resource after 1982

1) he "Sixth Five-year Plan" period

Form 1982 to 1985 year. In this phase, the pressures were various including the insufficiency of provisions, poverty and eco-environmental problem. First of all, the most important was to meet the needs of food and at the same time improve the ecological environment as much as possible. Planting artificial grass on sloping cropland for decreasing soil and water losses was one of the important measures, while the aim of developing ani-

mal husbandry is to improve the economic conditions. And then, the researchers guided the local people to fertilize cropland in deep for improving the production. These measures were useful (TABLE 1), the net annual income per farmer reached 418.9 Yuan(RMB) although the population density reached 56.6 persons/km^2, the ratio of poverty reduced to 30%, the annual food occupy per farmer increase to 366 kg,and the food production reached 922.5 kg/hm^2. At the same time, the ratio capital between input and output reached 1:6.9, the soil loss intensive decreased to 5000 t•km^{-2}•yr^{-1}, while the vegetation coverage ratio was 24.5%.

2) The "Seventh Five-year Plan" period

In this phase, from 1985 to1990 year, the annual average precipitation was only 351 mm, the area of artificial grassland decreased which made it difficult to develop animal husbandry. Facing these pressures, some gentle sloping croplands were transformed to terrace so that decrease soil and water losses and improve food production. Meanwhile, the other measures were introduced such as drought-resistant and high-yielding varieties of wheat, mulches the cropland with plastic for the reason of maintaining soil moisture. Under these measures, the annual net annual income per farmer reached 572.7 Yuan(RMB) although the population density reached to 60.1 persons/km^2, the ratio of poverty reduced to 30%, meanwhile the annual food occupy per farmer increase to 410 kg, and the food production reached 1330.5 kg/hm^2, the ratio capital between input and output reached 1:5.4, the soil loss intensive decreased 3000 t•km^{-2}•yr^{-1}, while the vegetation coverage rise up to 18.4%.

3) The "Eighth Five-year Plan" period

From 1991 to1995 year, during this period, the main problem in this area still was the shortage of water resource, the researchers guided the local people to high-efficient utilize technology of water resources, including biological water saving, cellar storing water and replenishing water and adjusting water by using manure. Those methods proved to be very efficient, the net annual income per farmer reached 1127.8 Yuan(RMB) although the population density reached 64.0 persons/km^2, the ratio of poverty reduced to 15%, the annual food occupy per farmer increase to 500 kg, and the food production reached 1627.5 kg/hm^2, simultaneously, the ratio capital between input and output reached 1:8.7, the soil loss intensive decreased 2500 t•km^{-2}•yr^{-1}, while the vegetation coverage reach to 22.9%.

4) The "Ninth Five-year Plan" period

From 1996 to 2000 year, the main measures, in this phase, were to improve the comprehensive ecologic environment and the basic condition for economic development, the researcher designed a economic model of courtyard economy for local farmers, which included developing vegetable, fruit and nurture seedlings in courtyard, the income per capita of courtyard economic was over 10 times that of cropland. It proved to be very effective, the net annual income per farmer reached 1846.0 Yuan(RMB) although the population density reached 67.3 persons/km^2, the ratio of poverty reduced to 5%, while the annual food occupy per farmer increase to 550 kg, and the food production reached 2250 kg/hm^2, At the same time, the ratio capital between input and output reached 1:10.5, the Soil loss intensive decreased 2000 t•km^{-2}•yr^{-1}, while the vegetation coverage is 32.0 %.

5) The "Tenth Five-year Plan" period

From 2001to 2005 year, the main measures, in this phase, were to enforce the policy of conversion of cropland to forest and grassland. Most of sloping cropland was converted into other types of land, which results in some of basic farmland were converted into orchard for economic benefit. Increasing the intensive level of farmland and improving the income per capita can relief the pressures on farmland. The increase of funds and technical input is to improve land productivity, which can be helpful for land transformation. The net annual income per farmer reached 2093.2 Yuan (RMB) although the population density reached 68.2 persons/km^2, the ratio of poverty reduced to 2%, the annual food occupy per farmer increase to 684.6 kg, and the food production reached 2250 kg/hm^2, meanwhile the ratio capital between input and output reached 1:15.6, the Soil loss intensive decreased 1000 t•km^{-2}•yr^{-1}, while the Vegetation coverage is 55.7%.

Land use and land cover change PSR model framework

TABLE 2 shows that the land use and land cover

of Shanghuang experimental area changed greatly within 24 years. Cropland decreased from 279.7 ha in 1982 to 79.4 ha in 2005 year while forest land increased form 9.4 ha in 1982 year to 238.3 ha in 2005 year. Of the lost cropland, 62.9% was converted to forestland, 30.9% was converted to grassland, and 5.3% was converted to orchard. The unused land decreased by 33.6% during the total period, the orchard and the artificial grassland increased separately form 0.4 ha and 5.0 ha in 1982 year to 11.1 ha and 107.1 ha in 2005 year while the natural grassland decreased form 369.6ha in 1982 to 219.3 ha in 2005 year. The reason that the sloping cropland converted to terrace or artificial grassland is to increase ecological benefit while that the basic cropland converted to orchard is to increase economic benefit. From 2000 to 2005 year, the main driving force of land use was the factor of policy, 91.5% of the sloping cropland was converted into grassland and forestland, which accelerated the improvement of ecological environment.

TABLE 2 : The land use change from 1982~2005 year in Shanghuang experimental area

Land use type		Area (ha)			Land use change (ha)
		1982	2000	2005	
Cropland	subtotal	279.7	228.4	79.4	-200.3
	Sloping land	239.0	155.6	13.3	-225.7
	terrace	0.0	39.0	39.0	39.0
	basic land	40.7	33.8	27.1	-13.6
Orchard		0.4	4.8	11.1	10.7
Forestland		9.4	158.3	238.3	228.9
Grassland	subtotal	374.6	275.3	326.4	-48.2
	natural grassland	369.6	229.0	219.3	-150.3
	Artificial grassland	5.0	46.3	107.1	102.1
Non-agriculture land		96.9	94.2	105.8	8.9

CONCLUSIONS

This paper quantitatively analyzed the land use changes in Shanghuang experimental area based on PSR model. Before 1982, the study area was an ecologically fragile region due to the long-term pressures of population growth and extensive cultivation, the ecological environment was a great challenge for economic development.

From 1982 to 2000, the researchers conducted a large-scale governance activity according to the existence problem in different phases which including aspects of ecology and economic. It proved to be very efficient, the net annual income per farmer increase from 47.2 Yuan(RMB) in 1982 year to 1846 Yuan(RMB) in 2000 year, although the population density increase form 47.7

persons/km^2 in 1982 year to 67.3 persons/km^2 in 2000 year, the ratio of poverty decreased 5 percent, the annual food occupy per farmer increase from 230 kg in 1982 year to 550 kg in 2000 year. The food production reached 2250 kg/hm^2, At the same time, the ratio capital between input and output reached 1:10.5 while the soil loss intensive decreased 2000 t•km^{-2}•yr^{-1}, the vegetation coverage reached 32.0%.

Form 2001 to 2005 year, the study enforced the policy of Large-scale conversion of cropland to forest and grassland which did not brought many pressures to this area due to the improvement of economic conditions, and the sloping cropland converted to grassland and forestland Have less impact on the economy development while have most important influence to the ecological environment. The soil erosion decreased form 2000 t•kg/hm^2 in 2000 year to 1000 t•kg/hm^2 in 2005 year, while the net annual income per farmer increase from 1846 Yuan (RMB) in 2000 year to 2093.2 Yuan(RMB) in 2005 year.

Therefore, the important issue for this region is to increase funds and technical input to improve land productivity aimed to improve farmer's income, which is the key for the ecological restoration of the Loess Plateau. In addition, the population growth control is also important which could relief pressures on land resource. Also, developing characteristic agriculture according to its advantage of natural resource in this region is very important, such as pear, almond, apple, which could bring enormous economic benefits and help local farmers free themselves from the traditionally, and at the same time, which make agricultural production less dependent on grain crops. Finally, it is essential to devise some regional policy schemes that are tailored to meet the circumstances of particular land areas in Loess Plateau.

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