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Land ecosystems classification and eco - economic evaluation in Wuding River Basin of Yulin Region*

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Abstract—The loess plateau, one of the most serious soil erosion region in the world, has the complex land ecosystem constituting the various natural factors, such as the highly dissected ground, gullies, the typically surface materials, and human activity. Three main units and thirty - seven sub - units of land ecosystem are divided based on the analysis of the characteristics, relation, spatial combination of the relevant factors. The structural character and ecological, economic effect of some typical and land ecosystem were discussed, usually the reactively stable land ecosystem has a good ecological and economic effect compared with the degraded and sensitive land ecosystem.

Keywords: land ecosystem; classification; eco - economic effects; evaluation.

1 Introduction

Land ecosystem is a dynamic and open system constituted of natural environmental elements and human activity. Natural environment is the basis of the system and human activity is a very active factor in the land ecosystem, which plays an important role on the exchange and flow of matter and energy, and affect the evolution and development of the land ecosystem. Some works have been done on the classification and evaluation on land type and regional landscape system (Wang, 1992; Liu, 1991; Fu, 1985). The aim of this paper is to study the differences of structure, function, land ecosystem classification and evaluation on the ecological and economic effect of different land ecological pattern.

2 The study area

The study area, located in the Wuding River basin of Yulin region in loess plateau of northern Shaanxi Province (Fig. 1), covers about 20302 km^2, including the Dingbian, Jingbian, Hengshan, Yulin, Shenmu, Mizhi, Suide, Zhizhou and Qingjian counties with more than 1.488 million population.

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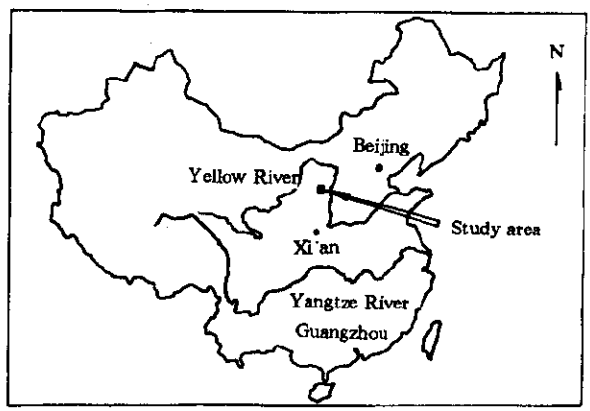

Fig. 1 Situation of the study area

3 Methods and materials

3.1 Land ecosystem classification

Land ecosystem classification is to divide land ecosystems into various sub-units according to similarity of structure, function and spatial pattern of the natural elements. Its purpose is to provide a basis for rational apportion and structural optimum on regional land ecosystem.

3.1.1 Natural factors influencing the land ecosystem

Geological structure and lithology : The study area is located at the southern part of the Eerduosi Terrace Syncline in geological structure. The loess, as the prevailing surface materials, with its loose structure, fine particle and vertical cleavage-prone provide a basic parent materials for plant growth, which is one of reasons for severe water loss and soil erosion in this region.

Elevation and landform: The landform types in the study area are mainly loess liang, loess mao, low loess hill, eroded plateau, high incision gully, shift sand dune, sand hillock, and sand hill, which lays a basic structure for the special cycle and regional distribution of matter and energy in the land ecosystem.

Soil: Soil is the core of land ecosystem, which provides the nutrient and water for plant growth. Soil in the study area are loessal soil, slope loessal soil, aquatic loessal soil, sandy loessal soil, dark loessal soil, castanozems and aeolian sandy soil. The soil is only weakly resistant to erosion.

Vegetation: Vegetation or plants, one of the principal sources of matter and energy production, determine the function and characteristics of the land ecosystem. In this area, natural vegetation have been destroyed, only a few grassland, shrub and forest patches distributed in the area. The crops, economic forest, orchard are cultivated widely.

Temperature: The average temperature in January is about -6—11°C, and above 22°C in July. The yearly change of temperature is as much as 30—35°C, there are 150—200 frost-free days. The accumulated temperature >10°C decreases gradually from southeast to northwest, changing around 3000°C, which impose a restriction on the plant growth and control the produc-

tivity potential of the land ecosystem.

Precipitation: The annual rainfall ranges from 400 to 500mm with a decrease from southeast to northwest and 60% of the rainfall falls between June and August, whereas only 2%—3% of rainfall concentrates in winter (from December to February). Usually heavy rainstorms appear very often in summer, most of which result in strong flood hazards and severe soil erosion, while drought occurs frequently in winter.

Evaporation: Evaporation (including evaporation from land and evapotranspiration from the plants), as one of the important means to exchange matter and energy with the outside of land ecosystem, is much higher than the precipitation, which determines land ecosystem with a very low productivity.

Except for the naturally element mentioned above, the atmospheric humidity, sunlight, windy and sandy days have also a noticeable effect on the circulation and distribution of matter and energy in the land ecosystem.

3.1.2 The human activity

The emergence, development and growth of human on earth has put a great pressure on the formation of land ecosystem from the original simple natural system to the complex ecosystem (CSSGOLPOCAOS, 1991a). In fact, they have changed the evolution process, structure and functions of the land ecosystem.

As a special ecological factor in the land ecosystem, human is able to suit and remould the land ecosystem. In this area, the growth of population with clearing of the natural vegetation has accclerated the loss of forest, and disrupted the original ecological balance. About 2000 years ago, the population density was only Ca. 13/km^2, most areas were covered by forest and grassland (CSSGOLPOCAOS, 1991b). However, they were converted into the farmland later with the expanding of human activity. Until 1400 years ago, the present name of Yellow River began to appear as the heavy soil erosion resulted largely from the inadequate human activity . The ecological effect of reclamation in recent decades is shown in Table 1.

Table 1 Ecological effect of reclamation in this region

(Yao, 1994)

Type of region	Period	Area reclaimed by people, km^2	Increase of soil loss, million tons
Loess Yuan,	1950—1982	343.67	196
Liang and Mao	1983—1985	32.70	56
Locss hill and	1950—1982	1172.30	1218
gully region	1983—1985	82.88	238

With increasingly understanding of the importance of ecological balance and environmental protection, the local people have begun to build level terrace field, plant tree and grass to improve the regional eco-environment. Up to now, CA 597880 ha and 105700 ha of this area have been developed as the level terrace field and check-dam land. The human activity not only influence the structural characteristics of the land ecosystem, also destroys the surrounding conditions for

the wild animal and plants.

The interrelation of factors in land ecosystem can be shown in Fig. 2.

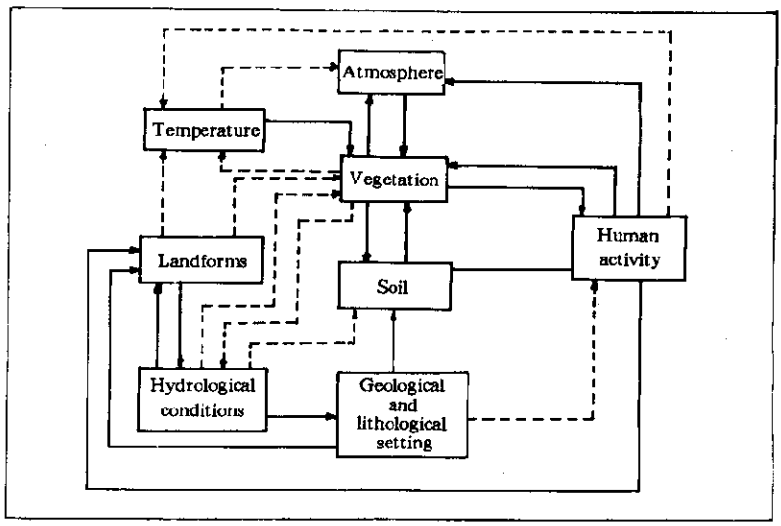

Fig. 2 The interrelation of the factors in the land ecosystem

——— direct influence – – – – – indirect influence

3.2 The principles of land ecosystem classification

The land ecosystem research can be concentrated on three - aspects: (1) the structure, evolution and formation of land ecosystem; (2)the function of the land ecosystem and (3) the optimum of ecological balance of land ecosystem (Fu, 1985). The regional difference structure of structure and function lay a foundation for land ecosystem classification. The structure is the basis of the function and the different functions represent different structure of land ecosystem (Wang, 1992). The structural difference usually results from the various combination of various natural elements, which lays a foundation for the land ecosystem classification.

The classification complies with the following four principles: (1) The land ecosystem is a holistic entity comprising various natural factors and the sub - unit is still holism. Hence, all the relevant factors, as the geology, landform, soil, vegetation, climate and human impacts should be integrated for classification. (2) The role of each element in the land ecosystem is quite different and a dominant factor often exists in the land ecosystem. Human activity, as the major influencing factor has been considered firstly. (3) Because of the close relation between human and land ecosystem, further division should be useful and practical as a guideline for the human activity to improve the land ecosystem. (4) The regional particularity, such as the loose and homogeneous loess, highly dissected ground, well - developed gullies and strong anthropogenic impacts, have been taken into account in the classification.

3.3 Materials

The maps used in this study are as follows: Topographic map of the study area; landform

type map of the study area; soil type map of the study area; landuse map of the study area; vegetation map of the study area.

4 Results and discussion

4.1 Land ecosystem classification

According to the principles mentioned above, three main units are divided based on eco-environmental quality and human impacts, and upon the spatial combination of the landform, soil, vegetation and landuse, 37 sub-units are obtained (Table 2).

Land ecosystem can be transformed from one state to another with the evolution and human remodification. When appropriate land use is adopted, the degraded land ecosystem may become a relatively stable land ecosystem, on the contrary, relatively stable land ecosystem may be changed into degraded land ecosystem.

4.2 The spatial pattern of land ecosystem

The land ecosystem demonstrates the following major regional characteristics:

(1) Noticeable multi-layer in vertical zonality: because of vertical zonality of the landform, the land ecosystem has exhibited similar features on vertical zonality from the valley bed to the hill top (Fig. 3).

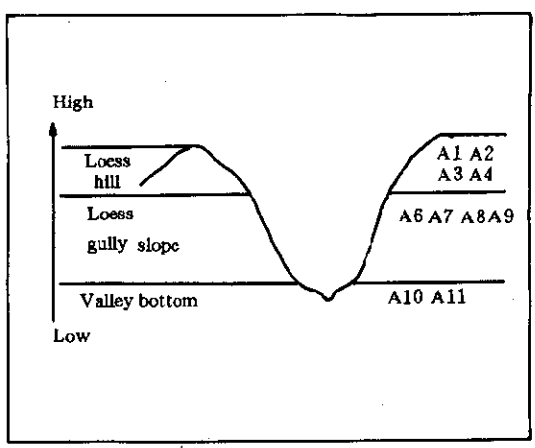

Fig. 3 The spatial relation and vertical zonality between the land ecosystem in Wuding River basin of Yulin region
A1: loessal soils - hillslope - level terrace field ecosystem; A2: loessal soils - hillslope - woodland ecosystem; A3: loessal soils - hillslope - man made grassland ecosystem; A4: loessal soils - highly dissected hill - woodland ecosystem; A6: loessal soils - gullyslope - man made - economic - woodland ecosystem; A7: loessal soils -- gullyslope - man made shrubland ecosystem; A8: loessal soils - gullyslope - man made charcoal woodland ecosystem; A9: loessall soils - gullyslope - man made grassland ecosystem; A10: aquatic loessal soils - irrigated check dam - farmland ecosystem; A11 aquatic loessal soils - chuan terrace dam - grassland ecosystem

(2) Strip and dendritic pattern: This pattern is related to the formation of ecosystem, usually, it is controlled by the landscape. The landscape in great extent is modified by the river system which appears to be a typical dendritic pattern of the loess homogeneity. Most chuan-check dam irrigatee farmland ecosystem developed along the lower plain and the other units distributed on

both sides in strip.

Table 2 The land ecosystem classification system

A. Relatively stable land ecosystem

A1 Loessal soils - hillslope - level terrace field ecosystem
A2 Loessal soils - hillslope - woodland ecosystem
A3 Loessal soils - hillslope - man made grassland ecosystem
A4 Loessal soils - highly dissected hill - woodland ecosystem
A5 Loessal soils - dissected hill - level terrace field ecosystem
A6 Loessal soils - gullyslope - man made economic woodland ecosystem
A7 Loessal soils - gullyslope - man made shrubland ecosystem
A8 Loessal soils - gullyslope - man made charcoal woodland ecosystem
A9 Loessal soils - gullyslope - man made grassland ecosystem
A10 Aquatic loessal soils - irrigated check dam - farmland ecosystem
A11 Aquatic loessal soils - man made chuan terrace dam - grassland ecosystem
A12 Sandy soils - tree protection buffle farmland ecosystem
A13 Meadow soils - lower plain - tree protectionbuffle farmland ecosystem

B. Degraded land ecosystem

B1 Loessal soils - hillslope - non irrigated farmland ecosystem
B2 Loessal soils - hillslope - scarce grass/shrubland ecosystem
B3 Loessal soil - hillslope - unreclaimed land ecosystem
B4 Loessal soils - highly dissected hill non irrigated - farmland ecosystem
B5 Loessal soils - highly dissected hill - unreclaimed landfarmland ecosystem
B6 Sheet cover loessal soils - hillslope - non irrigated farmland ecosystem
B7 Sheet cover locssal soils - hillslope - unreclaimed land ecosystem
B8 Loessal soils - gullyslope - unreclaimed land ecosystem
B9 Loessal soils - gullyslope - scarce woodland ecosystem
B10 Loessal soils - gullyslope - scare shrubland ecosystem
B11 Aquatic loessal soils - unreclaimed chuan terrace land ecosystem
B12 Aquatic loessal soils - scare chuan terrace grass/shrubland ecosystem

C. Sensitive land ecosystem

C1 Exposed shift - sand dune land ecosystem
C2 Semi - fixed sand dune scarce shrubland ecosystem
C3 Fixed sand dune shrubland ecosystem
C4 Exposed salinized humid sandland ecosystem
C5 Sand hillock - grass/shrubland ecosystem
C6 Sand hillock - scarce woodland ecosystem
C7 Gentle sandland - grass/shrubland ecosystem
C8 Gentle sandland - scarce woodland ecosystem
C9 Meadow soil lower plain - grass/shrubland ecosystem
C10 Meadow soil lower plain - woodland ecosystem
C11 Meadow soil lower plain - unreclaimed land ecosystem
C12 Meadow soils lower plain - irrigated farmland ecosystem

(3) Pattern of alternate appearance: This means that the sub - units present alternately in certain scope of this region, which is typically clear in the loess hilly region.

(4) Planar systemetry pattern: Because of the homogeneity of the loess, the river system and landform in this region takes a clear system pattern in space, which in some extent make the land ecosystem appear to be the planar systemetry pattern (Fig. 4).

(5) Strong impact of human activity: This region has been reclaimed for more than 4000 years, the natural vegetation has been destroyed. Most area have been cultivated into farmland and cause severe soil erosion.

The severe soil erosion and bad eco - environment have made the regional land ecosystem an unordered and open ecosystem. The water loss and soil erosion make up one of the most important means on substance loss and energy - exchange, this result in the land ecosystem unsuitable for the human activity. Recently, some ecological engineering as the level terrace field, economic forest, grassland and ecological forest have been set up for protection and rehailibilization of the natural ecological balance.

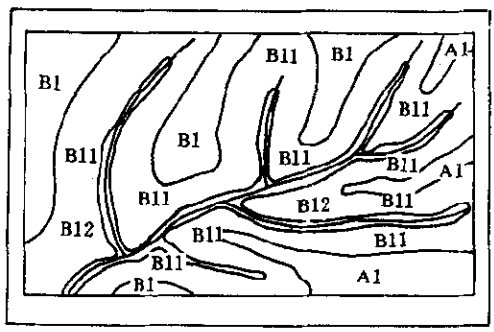

Fig. 4 The sketch map of the planar systemetry pattern of the minor land ecosystem in spatial structure
A1: loessal soils - hillslope - level terrace field ecosystem; B1: loessal soils - hillslope non irrigated farmland ecosystem; B11: aquatic loessal soils - unreclaimed chuan - terrace field ecosystem; B12: aquatic loessal soils - scare chuan terrace grass/shrubland ecosystem

4.2 Evaluation of the eco - economic effect

Evaluation of the eco - economic effect to the land ecosystem is carried out based on the difference of the structure, function and the combination of all the element for different land ecosystem. For different land ecosystem, their spatial pattern is quite different, the economic effect and ecological effect produced by the land ecosystem is varied. In this paper, several typical land ecosystem was taken as a case to analyze the ecological and economic effect.

The effects on the reduction of water loss and soil erosion is different for different ecosystem under different landuse and different combination of soil, vegetation. Table 3 gives some data of several typical land ecosystems. There is an evident difference on the reduction of water loss and soil erosion for the relatively stable and degraded land ecosystem.

For sandstorm areas, wind - prevention and sand - fixation are the main problems. For diffe rent landuse, the impacts on the reduction of wind speed and sand carrying capacity vary greatly. Table 4 shows some data about the sensitive land ecosystem with different landuse. The wind speed in the tree protection buffle farmland ecosystem is much lower than that in exposed shift - sand dune - land ecosystem. This phenomenon is closely related to the height of the trees. The wind velocity in the semi - fixed sand dune, compared with the exposed shift - sand dune, is reduced to less than one half and the sand - capacity in air decreases to less than 1/5.

Table 3 Comparison of the ecological effects of several typical land ecosystem

A. Relatively stable land ecosystem			B. Degraded land ecosystem			Percentage of difference of run-off between A & B, %	Percentage of difference of soil loss between A & B, %
Code of land ecosystem	Run-off, m^3/ha	Soil loss, t/ha	Code of land ecosystem	Run-off, m^3/ha	Soil loss, t/ha		
A1	56.1	36.15	B1	200.4	157.5	72	77
A6	100.2	89.85	B1	200.4	157.5	50	57
A7	173.7	57.6	B8	237.9	192	27	30
A8	166.5	57.6	B8	237.9	192	30	30
A9	135.6	107.55	B8	237.9	192	43	56
A10	0	0	B8	237.9	144000	100	100
A11	4.8	0	B11	96.15	64.5	95	100

Note: code is the same as that in Table 2

Table 4 Comparison of ecological effect of two typical land ecosystems in sandstorm area (CGOGOYRSP, 1987)

	Exposed shift-sand-dune-land ecosystem	Sandy soils-tree-protection-buffle-farmland ecosystem				
		5×D*	10×D*	15×D*	20×D*	25×D*
Wind speed, m/s	5.90	1.79	3.58	3.96	4.78	4.78
Yield of black soya bean, %	100	123.2%	133.1%	145.2%	120.0%	118.4%
		Semi-fixed-sand-dune-scarce-shrubland ecosystem				
Wind speed, m/s	3.71	1.49				
Sand carrying Capacity, mg/cm².s	19.83	3				

Notes: D* is the distance far from the protection-buffle comparing with the height of tree

Much difference existed on the soil structure, texture, soil moisture and organic matter for different land ecological structure. Upon the observation taken in Liushuwai Village of Jingbian County, the evaporation of water in sandy soils-tree-protection-buffle-farmland ecosystem reduced 10.7%—32.0% than those in exposed shift-sand-dune land ecosystem, soil moisture increases about 9.8% and air humidity increase about 7%. By comparing sandy soils tree protection buffle farmland ecosystem and exposed shift sand dune land ecosystem in Mangkeng Village in Yulin County, soil temperature increase 1—2°C in autumn, in otherwise similar conditions, it decreases 1—2°C, and the underground water table rises around 20—30 cm. Furthermore, organic matter changes fast with the setting up of shrub protection buffle in the farmland ecosystem (Table 5).

Evaluation of economic effect: Economic effect means the ratio between output and input of the matter and energy of land ecosystem. For the sensitive and degraded land ecosystem, some

harvest can be reaped in this region with little input of material and manpower, which seems to have a good economic benefit. However, the economic effect have contained a lot of ecological loss.

It is difficult to take an evaluation of the eco - economic effect to the whole land ecosystem. Table 6 shows some data on economic effect of several typical land ecosystem.

Table 5 Comparison of the soil organic matter of different land ecosystem (CGOGOYRSP, 1987)

Soil depth, cm	Soil organic matter, %		
	Land ecosystem in exposed shift sand dune	Land ecosystem in semi - fixed sand dune area of shrubland	
Surface	0	2.03*	7.32**
0—5	0	0.29*	2.12**
5—20	0	0.46*	1.86**
20—50	0	0.47*	1.78**

* After 3—4 years of shrub plantation; ** after 10 years of shrub plantation

Table 6 Comparison of the economic effect of several typical land ecosystem

A. Relatively stable land e. *		B. Degraded land ecosystem *		Percentage of difference between A & B, (A−B)/B, %
Land ecosystem	Grain yield, kg/ha	Land ecosystem	Grain yield, kg/ha	
A1	1950	B1	750	160
A11	3750	B8	—	—
A10	4000	B11	750	540

Note: code of land ecosystem is the same as that in Table 2

Under similar conditions, economic effect is quite different for different landuse (land ecological structure).

The eco - economic effect (E_{eco}) is the integration of ecological effect (E_1) and economic effect (E_2), which can be expressed in the following equation:

$$E_{eco} = E_1 \cdot r_1 + E_2 \cdot r_2,$$

where, r_1, r_2 represent the weights of ecological effect and economic effect.

Generally, land ecosystems, having only ecological effect without economic benefit never existed, even if it does not produce direct economic effect at present, it still has a lot of indirect economic effect. And those land ecosystem, having a good economic benefit but a bad ecological effect can not last long in nature. The economic effect will be offset with the exhibition of the ecological negative reaction. In this region, sensitive ecosystem mainly distributed in the region with bad eco - environment and lacking of necessary protection measures against the strong wind deflation with poor ecological and economic benefits. The degraded land ecosystems mostly are distributed where human activity is going on extensively and usually are carried out under less knowledge of the nature with unsound practices. They have a bad ecological effects and low economic benefits. The relatively stable land ecosystem is used with some ecological protection measures. It has a good eco - economic benefit. In summary, the eco - economic effect is as follows:

Relatively stable land ecosystem > degraded land ecosystem > sensitive land ecosystem.

5 Conclusion

The region is a complicated land ecosystem constituted of various factors and has multiple function which has been strongly remodified by the people. The human activity has plied a very important role during the formation and evolution of land ecosystems. The ecological effect of the change on land ecological structure and disruption of the ecological balance imposed by human has a profound significance for the land ecosystem and human survivor. Meanwhile people are also able to improve the land ecosystem through changing the land ecological structure.

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