

Study on Ecosystem Service Value in Pingshuo Mining Area Based on Land Use Change

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Abstract: This study used satellite photos of 1985, 1990, 1994, 1999 and 2005 in Pingshuo mining area, for the purpose of researching on the change of Ecosystem Service Value (ESV) in the past 20 years. It calculated the change amplitude, change velocity and relative change rate of ESV and compared the Sensitivity Index (SI) of ESV coefficient. The result is that, the total ESV of Pingshuo mining area descended from 31270.98×10⁴ Yuan in 1985 to 30348.14×10⁴ Yuan in 1990. When the destroyed land had been reclaimed from 1990, ESV had been raised to 31109.05×10⁴ Yuan in 2005. The change amplitude, change velocity and relative change rate of destroyed and reclamation land were the first and second highest among the types of land use in mining area. SI of dry land is the highest, while the destroyed land's is the lowest. It could conclude that the ESV coefficient of mining area is inelastic. Reclamation should be strengthening in mining area in order to recover ecosystem efficiently.

Keywords: Ecosystem service value, land use, pingshuo mining area, reclamation

INTRODUCTION

Land use is the most closely link between human and nature and the land use/cover change will inevitably affect the structure and function of ecosystem. It is important to study on the change of Ecosystem Service Values (ESV) of zone based on the land use/cover change (Semwal *et al.*, 2004; Bang-Cheng *et al.*, 2006; Zong-Ming *et al.*, 2005). Ecosystem service includes necessary ecological products and the quality of human life which provided by ecological system (Zong-Ming *et al.*, 2004; Luo *et al.*, 2004; Guang-Shi, 2007). In 1997, the research on the principle and method of value assessment about ecosystem service by had been defined, which was the most influential scientific research on ecological circles in that year (Costanza *et al.*, 1997). At present the research on ecosystem service value has been more extensive, but mining area as a particular object of research is still scarce (Gao-di *et al.*, 2003). This study takes Pingshuo mining area as the research object based on the data of land use in 1985, 1990, 1995, 1999 and 2005 and then evaluates the ESV by quantitative way. It compares the change amplitude, change speed and relative rate of change among 1985, 1995 and 2005. In the end it calculates the influence rate and Sensitivity Index (SI) by the adjusted ESV coefficient among 1995, 1999 and 2005.

GENERAL SITUATION OF STUDY AREA

Pingshuo mining area is located in the eastern area of loess plateau and the northern of Shanxi Province, E

112°10' 58"-113°37'20", N 39°23'-39°37' and the whole area is 375.12 km². The landscape of mining area is gentle slope hills and the climate belongs to typical temperate semi-arid continental monsoon climate, with an average annual rainfall is 428.2-449.0 mm, temperature of 4.8-7.8°C, ≥10°C annual accumulated temperature is 2200-2500°C, frost-free period is about 115-130. The zonal soil is chestnut soil and chestnut brown soil and zonal vegetation type is steppe (Jin-Chuan and Zhong-Ke, 2000).

Data sources: The ecosystem of Pingshuo mining area is divided into two parts, which are before and after mining and reclamation based on topographic map, satellite photos from 1985-2005, field measured data and so on. According to the land use mode characteristics and actual situation of mining area, it contains 7 land use types:

- Dry land
- Forest land
- Construction land
- Water area
- Unused land
- Destroyed land
- Reclaimed land

Among which, destroyed land and reclaimed land are the particular land type in mining area (Geng-Jie *et al.*, 2008, 2009).

Table 1: Area of land use types in pingshuo mining area (hm²)

Land use types	1985	1990	1995	1999	2005
Dry land	21101.66	20169.77	19985.47	19440.43	18591.22
Forest land	5541.85	5534.15	5339.03	5077.67	4487.06
Construction land	1115.32	1299.80	1443.58	1702.32	2032.32
Unused land	9753.47	9279.32	9406.43	9238.24	8805.79
Water area	0	0	0	0	0
Detroyed land	0	1229.26	1160.36	1588.29	2669.48
Reclamation dry land	0	0	1.12	1.12	14.8500
Reclamation forest land	0	0	170.01	486.37	821.540
Reclamation grass land	0	0	6.30	6.30	88.5100
Reclamation water area	0	0	0	1.56	1.5600

For convenience of study, it combined the characteristics of land use in mining area with the representative time point, namely 1985 before mining and 1990, 1995, 1994 and 2005 after mining and reclamation. In view of the reclamation since 1990, there are new reclamation land each year and the quality of it is also rising. It is divided into three periods according to the reclamation time, namely early reclamation (1-3 years), middle reclamation (4-6 years), later reclamation (>6 years). The reclamation time is corrected, for instance, from 1990 to 1995, taking the average value as the reclamation year, namely 2.5 years, which is the early reclamation; from 1990-1999, taking 4.5 years as the reclamation year, which is the middle reclamation year. The land use types and area statistics is in Table 1, From Table 1, the area of early reclamation land is 177.43 hm² in 1995; the area of early reclamation land is 317.92 hm², while it of middle reclamation land is 177.43 hm² in 1999; the area of early reclamation land is 431.11 hm², it of middle reclamation land is 317.92 hm² and that of later reclamation land is 177.43 hm².

METHODOLOGY

This study takes Costanza's research as the basic principle, combined with collecting data, documentation and the specific characteristic of mining area. It chooses s productivity, air conditioning, water conservation, soil conservation and so on as the factors and then evaluates them. For the destroyed land, it only focuses on the soil conservation. Because the research on unused land and construction land about ecosystem service is little and in the research of Costanza the value of them contributes to zero. For the water area, the results of Costanza *et al.* (1997) and Gao-di *et al.* (2003) have been referenced. The calculate equation of ESV is:

$$ESV = \sum A_k \times VC_k \quad (1)$$

A_k = The area of the k kind of land use

VC_k = Value coefficient of ecosystem service

When analyzing the differences of ecosystem service value, change amplitude (P), change velocity (S) and relative change rate (R) have been collected as the main three indicators. Relative change rate mode is

a fine method of reflecting the change differences. While the change rate of some kind of ecosystem service value, namely R>1, it means that the change amplitude of it is larger than that of the whole mining area; conversely it is less than the whole mining area. The equations are:

$$P = K_b - K_a / K_a \quad (2)$$

$$S = K_b - K_a / K_a \times n \quad (3)$$

$$R = |K_b - K_a| \times C_a / |K_a \times C_b - C_a| \quad (4)$$

K_a = The initial ESV of some kind of ecosystem

K_b = The final ESV of some kind of ecosystem

C_a = The initial ESV of the whole mining area

C_b = The final ESV of the whole mining area

In order to validate the accuracy of representative of various land types and the ESV coefficient, the concept of elastic coefficient in economics is used to calculate the SI of ESV coefficient. It also determines the value coefficient of dependent degree on the changes over time of ecosystem service value. It contains two parts: one is that the alteration of ecosystem's structure and function after it has been disturbed; the other one is the time of keeping original state after it has been disturbed. High SI means that small disturbance could cause a large change of ecosystem's structure and function; while long duration time means that the SI is low. In this study, the value coefficient of all ecosystems is adjusted 50% for the purpose of testing the total change of the whole ESV. If the SI>1, it means that the change of 1% independent variable dependent could cause more than 1% change of dependent variable. The equation of SI is:

$$SI = (ESV_j - ESV_i) / ESV_i / (VC_{jk} - VC_{ik}) / VC_{ik} \quad (5)$$

VC = The ecological value coefficient

i = The initial state

j = The adjusted state

k = Each ecosystem

If SI>1, it means that ecosystem service value is elastic for ecological value coefficient, while if SI<1, it is considered inelastic. SI is larger, the accuracy of ecological value coefficient is more important.

Table 2: ESV of pingshuo mining area (10⁴ Yuan)

	1985	1990	1995	1999	2005
Dry land	17871.7	17082.47	16926.38	16464.2	15745.52
Forest land	13052.33	13034.24	12574.67	11959.17	10562.09
Forest land	0	0	775.13	2390.5	4671.9
Destroyed land	0	-63.1	-53.940	-97	-158.63
Unused land	346.95	294.53	298.56	293.22	279.5
Water area	0	0	0	8.67	8.67
Total value	31270.98	30348.14	30520.8	31018.76	31109.05

Table 3: Change of ecosystem service value in pingshuo mining area (1985, 1995 and 2000)

Types	Value/10 ⁴ Yuan			Value/10 ⁴ Yuan		1985-1995			1995-2005		
	1985	1995	2005	1985-1995	1995-2005	P	S	R	P	S	R
Dry land	18269.33	17304.5	16097.27	-964.83	-1207.23	-5.28	-0.528	2.17	-6.98	-0.698	4.01
Forest land	13417.17	12926.16	10857.48	-491.01	-2068.68	-3.66	-0.366	1.5	-16	-1.6	9.2
Reclamation land	0	778.66	4713.04	778.66	3934.38	0	0	0	505.28	50.528	290.62
Destroyed land	0	-53.940	-158.63	-53.94	-104.69	0	0	0	194.09	19.409	111.63
Unused land	346.95	298.56	279.5	-48.39	-19.06	-13.95	-1.395	7.22	-6.38	-0.638	3.61
Water area	0	0	8.67	0	8.67	0	0	0	0	0	0

RESULTS AND DISCUSSION

The ESV of mining area is evaluated by market value method, opportunity cost method, shadow engineering method and production cost and so on, which is in Table 2.

From Table 2, it can be seen that the total value is in down state. During the process of mining, the original dry land and forest land has been destroyed and a lot of unused land has been occupied. From 1985 to 1990, there was no reclamation, as a result, the total value reduced drastically. After 1990, it began to reclamation while mining still continued, so the total value started to pick up. The total value in 2005 was almost the same as that in 1985. It is obvious that reclamation has played a significant role in recovering ESV, which compensates the loss value caused by destroyed land.

Because there was reclamation after 1990, the data of 1985, 1995 and 2005 has been chosen as the typical example. According to Eq. (2), (3) and (4), change of ESV can be seen in Table 3.

From Table 3, the reduced amplitude and velocity of ESV of destroyed land is the largest, 194.095 and -19.409%, respectively and the relative change rate of it is 111.63, which is 111.63 times of total value of mining area. The increased amplitude and velocity of ESV of reclamation land is the largest, 505.28 and 50.528%, respectively and the relative change rate of it is 290.62. It could conclude that mining area is the most serious area inference by human being. The change of total ESV is not too large, which means that reclamation has played an important role and the ecosystem of mining area is not collapsed by mining.

According to Table 1 and 2, it can get ESV coefficient of Pingshuo mining area.

From Table 4, it can be viewed that only the ESV coefficient of destroyed land and reclamation land are

Table 4: ESV coefficient of pingshuo mining area (10⁴ Yuan/hm²)

Dry land	Forest land	Unused land	Water area	Destroyed land	Reclamation land
0.866	2.42	0.037	5.603	-0.051	
				-0.046	4.386
				-0.059	4.867
				-0.061	5.096

not stable, because there are newly destroyed land and reclamation land each year and the area of destroyed land and quality of reclamation land changes all the time. Because the state of destroyed land is more complicated, the ESV coefficient of it could be replaced by the average value temporarily. It is assumed that all reclamation land is in the later stage and the ESV coefficient could be calculated again according to the productivity, soil bulk density, the thickness of tillage layer and so on. Consequently, the ESV coefficient of reclamation land is adapted to 6.12×10⁴ Yuan/hm², which is much higher than that of dry land and forest land. It is concluded that the ESV of reclamation could compensate the loss of total ESV of mining area caused by the loss of dry land and forest land.

Because the ESV coefficient of unused land and water area is referenced from Costanza *et al.* (1997) and Gao-di *et al.* (2003) directly and there were some ripe research results, neither of them are considered here. In view of reclamation land appeared in 1995 in this study, so the influential rate of total ESV and SI in 1995, 1999 and 2005 are calculated by the adjusted ESV coefficient.

The change tendency of SI is the same as the change of ecosystem area, which means that with the increase or decrease of different ecosystem' area, the SI will become strong or weak. From Table 5 and Fig. 1, all the SI is smaller than 1 in the different time, which means that it is reasonable for the adjusted ESV coefficient. The highest SI belongs to dry land, which is 0.49-0.55. The lowest SI belongs to destroyed land,

Table 5: SI of total ESV after adjustments

Ecosystem	ESV(10 ⁴ Yuan)			1995		1999		2005	
	1995	1999	2005	(%)	SI	(%)	SI	(%)	SI
Dry land VC+50%	40204.68	40779.58	40807.80	27.42	0.55	26	0.52	24.57	0.49
Dry land VC-50%	22900.18	23947.56	24710.53	-27.42		-26		-24.57	
Forest land VC+50%	38015.51	38510.29	38187.90	20.48	0.41	18.99	0.38	16.57	0.33
Forest land VC-50%	25089.35	26216.85	27330.42	-20.48		-18.99		-16.57	
Reclamation land VC+50%	32095.37	33874.57	35589.36	1.720	0.03	4.670	0.09	8.640	0.17
Reclamation land VC-50%	31009.50	30852.58	29928.97	-1.720		-4.670		-8.640	
Destroyed land VC+50%	31521.10	32320.69	32687.09	-0.010	0.0002	-0.130	0.003	-0.20	0.004
Destroyed land VC-50%				0.010		0.130		0.20	

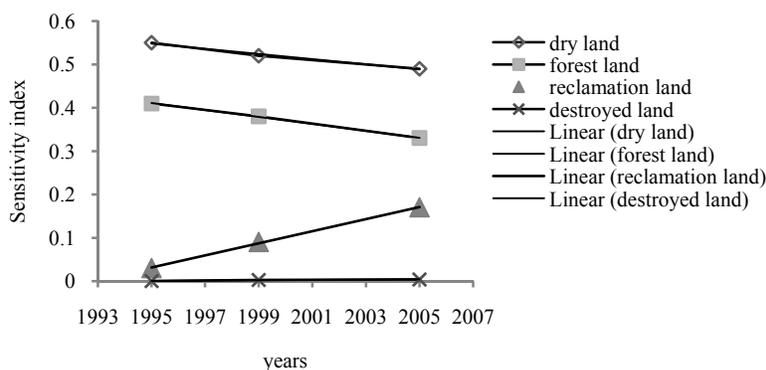


Fig. 1: Change of the main ESV coefficient's sensitivity index

which is 0.0002-0.004. It is concluded that the total ESV of Pingshuo mining area is inelastic.

CONCLUSION

Total ESV of Pingshuo mining area reduced at the beginning and then increased later from in nearly 20 years. The main reason is that there was only mining action before 1990. After that, destroyed land had been reclaimed every year. With the increase of reclamation land and time, the total ESV in 2005 has recovered to almost the same as that in 1985.

In view of the data in 1985, 1995 and 2005, the change amplitude, change velocity and relative change rate of destroyed and reclamation land are much larger than other kinds of land. It proves that mining area is the area of the most frequent human activities. Because of reclamation, the ecosystem of mining area could be keeping a relatively stable condition.

From the data of 1995, 1999 and 2005, ESV coefficient of mining area is inelastic. SI of dry land and forest land becomes less, while that of destroyed land and reclamation land becomes more. The highest SI is dry land, while the lowest SI is destroyed land.

Reclamation has played an indispensable role in keeping the balance of ecosystem in mining area, which could help the destroyed land recover to the original state, or even pass it.

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REFERENCES

- Bang-Cheng, C., L. Gen-Fa and S. Li-Juan, 2006. Variation of ecosystem services' value of Kunshan based on the land use change. *Acta Ecol. Sinica*, 9: 3005-3010.
- Costanza, R., R. D'Arge, R. Groot, F. Stephen, H. Bruce, *et al.*, 1997. The value of the world's ecosystem's services and natural capital. *Nature*, 386: 253-260.
- Gao-Di, X., L. Chun-Xia, L. Yun-Fa, Z. Du and L. Shuang-Cheng *et al.*, 2003. Ecological assesss valuation of the Tibetan plateau. *J. Nat. Resour.*, 2: 189-196.
- Geng-Jie, Z., B. Zhong-Ke, Q. Li and L. Xiao-Cui, 2008. Ecological system service value changes in Pingshuo mining area. *Resour. Industr.*, 6: 1-5.
- Geng-Jie, Z., B. Zhong-Ke, Q. Li and L. Xiao-Cui, 2009. Simulation of ecosystem service function in Pingshuo mining area. *Resour. Industr.*, 1: 10-14.
- Guang-Shi, S., 2007. Nature resources value and evaluation methods. *Acad. Forum*, 4: 77-80.

- Jin-Chuan, L. and B. Zhong-Ke, 2000. Opencast Coal Mine Land Reclamation and Ecological Reconstruction. Science Publication, Beijing, China.
- Luo, J., W. Ke-Lin and C. Hong-Song, 2004. Economic response of ecosystem service functions to landuse changes in Karst region. *Bull. Soil Water Conserv.*, 3: 19-24.
- Semwal, R.L., S. Nautiyal and K.K. Sen, 2004. Patterns and ecological implication of agricultural land use changes: A case study from central Himalaya. *Agric. Ecosys. Envir.*, 102: 81-92.
- Zong-Ming, W., B. Zhang and Z. Shu-Qing, 2004. Study on the effects of land use change on ecosystem service values of Jilin Province. *J. Nat. Resour.*, 1: 55-61.
- Zong-Ming, W., B. Zhang and Z. Shu-Qing, 2005. Estimates of loss in ecosystem service values of Songnen plain from 1980-2000. *J. Geograph. Sci.*, 15: 80-86.