Dynamic evaluation of ecosystem service value in southern mountainous areas of Jinan based on 3 “S” technology

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Abstract. In this paper, change of land cover and use type was first studied through interpretation of the two images (2007 and 2018), and then, dynamic evaluation of ecological service value in Southern Mountainous Areas of Jinan was made with evaluation system and equivalent factors built by Xie GD based on Costanza's system. The results revealed that the area of bare land and grass land decreased by 4875.48 hm² and 55141.56 hm² respectively, on the contrary, cultivated land, forestland and building land has increased by 26915.671 hm², 32261.31 hm² and 1442.16 hm² respectively. The ecological service value showed the increasing trend generally, among of which water conservation, air regulation, land protection, recreation have increased distinctly, which can be explained that the control develop strategies had taken action actively.

Introduction

The southern mountainous area of Jinan belonging to Mount Tai, is the ecotone of mountain and plain between Mount Tai and the Yellow River with southern high and northern low-lying. This area is the main recharge area of spring water, water conservation area and one of the important ecological defences of Jinan city. The environment of the southern mountainous area of Jinan has improved a lot since 2003 when the strategy of “Southern controlled and Northern crossing” was first performed. It's the time to evaluate the effect of the development strategy in order to make future development plan accurately.

The study area in this paper is mainly based on the "Protection and Development Planning for Southern Mountain Areas of Jinan City" posted by Jinan municipal government, which delimits the boundary north to south of central city of Jinan, south to Tai'an, west to Licheng, and east to Zhangqiu, covering an area of 226806.12hm², with a total population of about 6.1×10^5 . The study area belongs to warm temperate monsoon climate with cinnamon soil and deciduous broad-leaved forest.

1. Data source and study method

1.1 Data source and processing

The TM image in Apr. 3rd 2007 and OLI image in May 3rd 2018 were taken as main data resources. After pre-processing of image data, water, cultivated land, forest land, grass land (including barren grassland), building land, bare land were distinguished according to the classification standard. Modified Normalized Difference Moisture Index (MNDMI) was first used to make a

distinction between land and water, and then Normalized Difference Vegetation Index (NDVI) was used to differentiate the five land types.

Finally, building land and bare land were distinguished through temperature retrieving combining with slop. The land use types in 2007 and 2018 are shown as Fig.1.

1.2 Land-use change index

Land-use change index was used to reveal the change extent of land use during the study term [1]. The formula as follow:

$$K = [(U_b - U_a) / U_a] \times (1/t) \times 100\% \quad (1)$$

Here, K is the Land-use change index, U_a and U_b are the area of any land use type in start year and final year respectively, T is the length of study time.

1.3 Evaluation system of ecosystem service value and equivalence factor

The evaluation system of ecosystem service value and main equivalence factors performed by Xie GD [2, 3, 4] based on Costanza's evaluation system were selected to evaluate ecosystem service of the southern mountainous area of Jinan in this paper. The equivalence factor of building land came from Duan RJ [5] (Tab.1).

Then, the formula of ecosystem service as follows:

$$ESV = \sum P_i \times L_i \quad (2)$$

$$ESV_f = \sum P_{if} \times L \quad (3)$$

Here, ESV is the total ecosystem value (yuan), P_i is the ecosystem service value of i land use type (yuan/hm².a), L_i is the area of i land use type (ha), ESV_f

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is the sum of service value of f service type in i land use type. (yuan/hm².a)

Fig.1. The land use types of the southern mountainous area of Jinan in 2007 and 2018
(The left figure is in 2007 and the right one is in 2018)

Tab.1. Evaluation system of ecosystem service value and equivalence factors (yuan/hm²)

ecosystem service	cultivated land	forest land	water	grass land	bare land	building land
Air regulation	442.4	3079	0	707.9	0	-6678
Climate adjustment	787.5	2389.1	407	796.4	0	0
Water conservation	530.9	2831.5	18033.2	707.9	26.5	0
Soil protection	1291.9	3450.9	8.8	1725.5	17.7	0
Waste disposal	1451.2	1159.2	16086.6	1159.2	8.8	0
Biodiversity protection	628.2	2884.6	2203.3	964.5	300.8	-2174.1
Food product	884.9	88.5	88.5	265.5	8.8	0
Raw material production	88.5	2300.6	8.8	44.2	0	0
Recreation	8.8	1132.6	3840.2	35.4	8.8	0

From Xie GD and Duan RJ [2, 3]

Tab.2. Land use type transition matrix (hm²)

Land use type		2007						Total area in 2018
		Water	Grass land	Building land	Bare land	Cultivated land	Forest land	
2018	Water	821.34	23.31	38.16	49.32	24.66	0.18	956.97
	Grass land	87.57	50686.56	0	467.46	7509.15	950.13	59700.87
	Building land	66.96	0	19655.19	61.38	7865.64	0	27649.17
	Bare land	114.21	3588.57	270.45	1206.27	1428.48	490.59	7098.57
	Cultivated land	93.06	35330.94	6614.55	1705.05	35127.54	0	78871.14
	Forest land	4.59	25213.05	0	8484.57	0	18827.19	52529.40
	Total area in 2007	1187.73	114842.43	26578.35	11974.05	51955.47	20268.09	226806.12
	Change	-230.76	-55141.56	1070.82	-4875.48	26915.67	32261.31	0
$K(\%)$		-1.77	-4.36	0.37	-3.70	4.71	14.47	0

2. Result and Analysis

2.1 Land use change from 2007 to 2018

It can be found that the land use type had changed a lot from 2007 to 2018 (fig.1 and Tab.2).

The area of cultivated land, forest land and building land has increased distinctly from 2007 to 2018 by 26915.67 hm², 32261.31 hm² and 1442.16 hm² respectively, while the area of bare land and grass land has decreased by 4875.48 hm² and 55141.56 hm² respectively (Fig.1. and Tab.2). Reduced area of grass land (including barren grassland) and bare land was mainly converted to cultivated land, forest and building land. Although a series of control strategies have already implemented, building land has still increased 0.37%, and that most of the added area coming from cultivated land, which should pay close attention to.

The Land-use change index (*K*) revealed that the largest increase extent came from forest land, which led to environment improvement (Tab.3). The shrinking of bare land also can improve the environment quality. Because the ecosystem services value of water, forest land and grass land are the most top three types (Tab.1), the high extent of reduction of grass land and water area might lead to negative effect on the whole ecosystem service.

2.2 Evaluation of ecosystem service value

Fig.2. Ecosystem service value in 2007 and 2018

The total ecosystem service value of the southern mountainous area of Jinan has grown from 126275.81 ten thousands yuan/hm² to 167712.74 ten thousands yuan/hm² by 32.81% from 2007 to 2018 (Tab.3 and Fig.2). The value of forest land and cultivated land contributed a larger share of the total added value. The reason might lie in two aspects: the first reason is that the forest land and cultivated land have strong ecological service capacity; another one lies in the increasing of the two land use type area. Ecological service value of grass land and water dropped a lot, because of decrease in area.

All ecological service type values have improved distinctly (Fig.3). Among all the service types, water conservation service value was found the largest increase, and followed by recreation, raw material product, air regulation, climate adjustment, biodiversity protection, soil protection. The increase of water conservation service value is very impelling. Because the southern mountainous area is not only with high ecological value itself but very important to Jinan city, which is famous for rich underground water and spring. The southern mountainous area is just the source of the spring. From all the above, the strategies to control the expending of building and protect environment have already taken action positively.

Fig.3.Composition of ecosystem service value in 2007 and 2018

Tab.3. Change of various ecosystem service values (ten thousands Yuan/hm²)

Year	Cultivated land	Forest land	Grass land	Water	Building land	Bare land	Total value
2007	31767.13	39186.33	73573.80	4831.26	-23527.42	444.72	126275.81
2018	48224.35	101560.34	38247.36	3892.61	-24475.56	263.64	167712.74
Change (%)	51.81	159.17	-48.01	-19.43	4.03	-40.72	32.81

3. Conclusion and Discussion

(1) The area of land use type has changed obviously. The area of bare land and grass land have decreased substantially, on the contrary, cultivated land, forestland and building land has increased a lot.

Cultivated land increased by 51.81%, while grass land decreased by 48.01%, which should pay more attention to.

Because cultivated land expending and grass land shrinking might lead to the serious potential soil erosion.

(2) The total ecological service value in southern mountainous area of Jinan showed the increasing trend. The value of forest land and cultivated land contributed a larger share of the total added value. The value of water conservation, creation, air regulation, land formation and protection also increased distinctly.

(3) The strategies to control the building expending and protect environment by Jinan municipal government have already taken positive effects on the environment of the southern mountainous area of Jinan. But building land still expended. In the future, more strict control strategies and supervision might be carried out in order to protect the southern ecological defences of Jinan.

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References

1. H.J. Shen, R.Z. Guo, Y. M. Jiang. Effects of Land Use Change on Ecosystem Services Value Based on RS and GIS Technology. *Journal of Anhui Agri. Sci.* **36**, 4781-4785 (2008)
2. G.D. Xie, C.X. Zhang, L.M. Zhang. Improvement of the evaluation method for ecosystem service value based on per unit area. *J. Nat. Resour.* **30**, 1243-1254 (2015)
3. R. Costanza, R. D'arge, R.D. Groot. The value of the world's ecosystem services and natural capital. *Nature.* **387**, 3-15 (1999)
4. J.Z. Zhao, H. Xiao, G. Wu. Comparison analysis on physical and value assessment methods for ecosystems services. *Chin. J. Appl. Ecol.* **11**, 290-297 (2000)
5. R.J. Duan, J.M. Hao, J. Wang. Study on the change of land use structure and ecosystem service function value: a case Study of datong city, Shanxi Province. *Ecol. Econ.* **20**, 59-64 (2005)