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Energy Procedia 5 (2011) 1109–1115

Energy Procedia

IACEED2010

Changes in land use and ecosystem service values in Jinan, China

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Abstract

Changes in land use and ecosystem service values in the main urban area of Jinan between 1988 and 2002 were investigated in this paper using dataset deriving from LANDSAT TM images. In the study period, the most notable changes of land use are the decrease of cropland and the increase of construction land. With the urbanization, more and more lands were occupied for the construction purpose. Woodland and cropland are the dominant land use categories providing about 80% of the total ecosystem service value. Ecosystem service valuation results showed that the total ecosystem service value decreased by 42.86 million Yuan between 1988 and 2002, with an average annual decline of 3.06 million Yuan. Emphasis should be paid on the conservation of woodland and cropland in the future.

Keywords: land use; ecosystem service; valuation; changes; Jinan

1. Introduction

Ecosystem services can be defined as the conditions, processes, and components of the natural environment that provide both tangible and intangible benefits for sustaining and fulfilling human life [1], or the goods and services that human populations derive, directly or indirectly, from ecosystem functions [2]. Ecosystem service valuation has been a hot topic in ecological economic research [3, 4]. Ecosystem service valuation can reveal information on both the structure and functioning of ecosystems and the varied and complex roles of ecosystems in supporting human welfare [5]. It can help to incorporate the value of ecosystem services into decision-making [6]. Therefore, it is very useful to ecosystem management and sustainable development especially in settings where institutional arrangements (such as

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1876–6102 © 2011 Published by Elsevier Ltd.
doi:10.1016/j.egypro.2011.03.195

markets and common property regimes) are not functioning well to reflect the social costs of environmental degradation [5, 7].

Many studies have been done to estimate the values of various ecosystem services. To our knowledge, however, there was only one researcher who valuated the ecosystem services in the southern mountain region of Jinan [8]. No investigation on the ecosystem service values in the main urban area has been done. Land-use changes leading from urbanization often have a significant negative impact on the affected ecosystems and the goods and services that they provide [9]. The objective of this paper is to estimate the land use change and the subsequent variation in ecosystem service values in the main urban area of Jinan, China, from 1988 to 2002.

2. Methods

2.1. Study area

Jinan (36° 40′ N, 116° 57′E) is the capital of Shandong Province. It is located in the north-western part of Shandong province. In the relief of the region, the city occupies a transition zone between the northern foothills of the Taishan Massif to the south of the city and the valley of the Yellow River to the north. Karst aquifers in limestone formations sloping down from the south to the north give rise to many artesian springs in the city area. Jinan has a warm-temperate semi-humid continental monsoon climate. The average annual temperature is 14.6 °C. Jinan has direct jurisdiction over 6 districts (Shizhong District, Lixia District, Tianqiao District, Huaiyin District, Licheng District and Changqing District), 1 county-level city (Zhangqiu City), and 3 counties (Pingyin Country, Jiyang Country and Shanghe Country). This study only deal with the main urban area of Jinan, as Changqing District was set up in 2001, the study area only includes Shizhong District, Lixia District, Tianqiao District, Huaiyin District and Licheng District (Fig.1).

Fig. 1. The study area

2.2. Data collection and land use classification

The land use datasets of Jinan City in 1988, 1995 and 2002 were obtained from the Resources and Environment Scientific Data Center, Chinese Academy of Sciences. The datasets were derived from the LANDSAT TM images and saved in coverage format. The land use was classified into 6 categories: cropland, woodland, grassland, water body, construction land and unused land. ArcView GIS 3.2 was used to process the data and to create the land use thematic maps.

2.3. Assignment of ecosystem service value

In order to estimate the global ecosystem services values, Costanza et al. [2] classified the global land use into 16 primary categories and grouped ecosystem services into 17 types. Based on Costanza et al.'s parameters, Xie et al. [10] extracted the equivalent weight factor of ecosystem services per hectare of terrestrial ecosystems in China and modified the value coefficient according to the nature of Chinese ecosystem (Table 1). The equivalent weight factor listed in Table 1 was obtained by surveying 200 Chinese ecologists and can be applied to different regions across china by localizing the average natural grain production. Equivalent weight factors are the potentials of ecosystems to provide ecosystem

services. The economic value of one factor can be defined as 1/7 of that of the average grain production of cropland per hectare per year [3,10]. With Jinan, the average grain production of cropland was 4984.67 kg/ha from 1988 to 2002 and the average price for grain was 1.37 Yuan/kg in 2002. The ecosystem service value of one equivalent weight factor for Jinan is therefore 975.57 Yuan.

To obtain the ecosystem services value of one unit area for each land use category in Jinan, each category was compared with that of Xie et al. [10]. The nearest equivalent ecosystems were used as the proxies for that of this study (Table 2). For example, woodland equates to forest, and unused land equates to barren land. The service value for construction land is zero.

The total ecosystem services of each land use category can be obtained through multiplying the area of each land category by the value coefficient:

$$ESV = \sum (A_i \times VC_i) \quad (1)$$

Where ESV is the estimated ecosystem services value (Yuan·a^{-1}), A_i is the area (ha) and VC_i is the value coefficient (Yuan·ha^{-1}·a^{-1}) for land use category *"i"*.

Table 1. Equivalent weight factor of ecosystem services per hectare of terrestrial ecosystems in China

	Cropland	Forest	Grassland	Water body	Barren land
Gas regulation	0.5	3.5	0.8	0	0
Climate regulation	0.89	2.7	0.9	0.46	0
Water supply	0.6	3.2	0.8	20.38	0.03
Soil formation and retention	1.46	3.9	1.95	0.01	0.02
Waste treatment	1.64	1.31	1.31	18.18	0.01
Biodiversity protection	0.71	3.26	1.09	2.49	0.34
Food production	1	0.1	0.3	0.1	0.01
Raw material	0.1	2.6	0.05	0.01	0
Recreation and culture	0.01	1.28	0.04	4.34	0.01
Total	6.91	21.85	7.24	45.97	0.42

Table 2. Ecosystem service value of unit area of different land use categories in Jinan (Yuan·ha^{-1}·a^{-1})

	Cropland	Woodland	Grassland	Water body	Barren land
Gas regulation	487.79	3414.5	780.46	0	0
Climate regulation	868.26	2634.04	878.01	448.76	0
Water supply	585.34	3121.83	780.46	19882.13	29.27
Soil formation and retention	1424.33	3804.72	1902.4	9.76	19.51
Waste treatment	1599.94	1278	1278	17735.87	9.76
Biodiversity protection	692.66	3180.36	1063.4	2429.17	331.69
Food production	975.57	97.56	292.67	97.56	9.76
Raw material	97.56	2536.48	48.78	9.76	0
Recreation and culture	9.76	1248.73	39.02	4233.98	9.76
Total	6741.19	21316.21	7063.1	44846.97	409.74

3. Results and discussion

3.1. Land use change

Fig. 2 presents the percentage contribution of each land use category to the total area. According to this figure, cropland is the dominant land use category in the study area. The area of each land use category follows the order of cropland>woodland>construction land>grassland>water body>unused land. Fig. 3 shows the land use thematic map of Jinan in 1988, 1995 and 2002. From Fig. 2 and Fig. 3, it can be seen that cropland mainly located in the north part of Jinan, accounting for more than 50% of the total area. Woodland and grassland mainly located in the south part of Jinan, accounting for 19% and 13–17% of the total area, respectively. Water body accounted for about 3% of the total area, and unused land accounted for 0.2% of the total area. During the study period, the cropland and construction land changed significantly. The cropland decreased continually, while the construction land tended to increase.

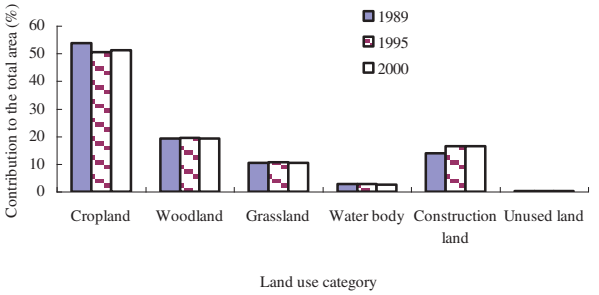
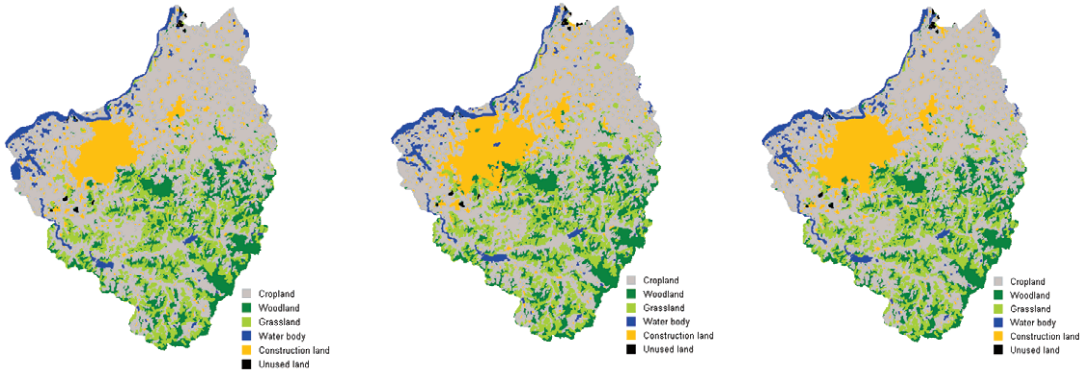


Fig. 2. Percentage contribution of each land use category to the total area



(a) 1988 (b) 1995 (c) 2002

Fig. 3. Land use thematic map of Jinan

Table 3 and table 4 are the land use transition matrices during the period of 1988–1995 and 1995–2002. The most notable change of land use is the transformation of cropland to construction land.

During 1988 to 1995, significant quantities of croplands were transited to other type of land use. Cropland experienced a net loss of 6314.08 ha, while construction lands increased 5185.70 ha, other types of land use increased more or less. Natural causes such as soil erosion, the drought climate and degradation in soil quality will led to the loss of cropland, but these only account for a small fraction. Only 16.01 ha cropland were transited to unused land (Table 3). The transition of cropland to construction land explained most of the cropland loss. From table 3, it can be seen that 6282.06 ha cropland were transited to construction land, accounting for 99.5% of all the cropland loss. This is the result of

urbanization. From Fig. 3, it can be seen that the urban sprawl from the main city to the east, the west and the south direction is very significant, and lots of croplands and vegetations were occupied.

Table 3. Land use transition matrix during 1988–1995 (ha)

1988	1995						
	Cropland	Woodland	Grassland	Water body	Construction land	Unused land	Loss
Cropland	94383.02	376.12	424.14	480.16	6282.06	16.01	7578.49
Woodland	8.00	36259.92	16.01	0.00	40.01	0.00	64.02
Grassland	32.01	24.01	19566.43	0.00	112.04	8.00	176.06
Water body	392.13	0.00	0.00	4785.57	8.00	0.00	400.13
Construction land	832.27	240.08	120.04	64.02	24984.21	0.00	1256.41
Unused land	0.00	0.00	0.00	0.00	0.00	296.10	0.00
Gain	1264.42	640.21	560.18	544.18	6442.12	24.01	
Net change	-6314.08	576.19	384.13	144.05	5185.70	24.01	

During 1995 to 2002, besides cropland, more lands were occupied for construction purpose. The inter-category transition of land use became more frequent. Lots of croplands were transited to construction land, woodland and grassland. Also, there were lots of construction land, woodland and grassland transiting to cropland. In general, the area of cropland and construction land increased, and the area of other types of land uses tended to decrease. This implies that the protection of cropland achieved significant performance, while more and more vegetation and water body were destroyed.

Table 4. Land use transition matrix during 1995–2002 (ha)

1995	2002						
	Cropland	Woodland	Grassland	Water body	Construction land	Unused land	Loss
Cropland	85548.11	2664.88	2416.79	656.22	4185.38	16.01	9939.27
Woodland	2736.90	31194.25	2096.69	32.01	648.21	0.00	5513.81
Grassland	2432.80	2096.69	15180.99	0.00	368.12	8.00	4905.61
Water body	856.28	64.02	16.01	4161.37	144.05	0.00	1080.36
Construction land	4649.53	256.08	176.06	64.02	26272.63	8.00	5153.69
Unused land	32.01	16.01	8.00	8.00	16.01	216.07	80.03
Gain	10707.52	5097.68	4713.55	760.25	5361.76	32.01	
Net change	768.25	-416.14	-192.06	-320.11	208.07	-48.02	

3.2. Changes of ecosystem service values

Table 5 presented the estimation results of ecosystem services values. Although the total ecosystem service values showed a tendency of decrease during 1988 to 2002, the ecosystem service values of different land use categories showed some fluctuations. From 1988 to 1995, the cropland ecosystem

service value decreased by 6% while that of other categories tended to increase. The decrease of cropland was the only reason for ecosystem service value loss. From 1995 to 2002, on the contrary, the cropland ecosystem service value increased a little while that of other categories tended to decrease. The decline of ecosystem service values was mainly led by the decrease of woodland, grassland and water body. Overall, the total ecosystem service value decreased by 42.86 million Yuan between 1988 and 2002, with an average annual decline of 3.06 million Yuan. This result is relatively small to that of other researches on some other areas in China [3, 11]. This is because the study area was limited to the main urban area of Jinan city which is surrounded by mountains in the east, west and south directions and by the Yellow River in the north direction, there were little space for the development of the main urban area. So, the effect of urbanization on the ecosystem service values is not so distinct.

Table 5. Total ecosystem service values estimated for each land use category in Jinan (10^4 Yuan)

	Cropland	Woodland	Grassland	Water body	Unused land	total
1988	68782.83	77456.58	13903.19	23205.39	10.85	183358.84
1995	64578.81	78822.55	14192.88	23750.36	12.20	181356.80
2002	65645.35	77456.57	13879.28	22080.58	10.85	179072.63

Fig. 4 presents the contribution of each land use category to the total ecosystem service values. Woodland and cropland are the dominant land use categories that provide most of the ecosystem service values. They together provided about 80% of the total ecosystem service value. Although the area of woodland is much smaller than that of the cropland (Fig. 2), the contribution of woodland to the total ecosystem service values exceeds that of cropland. This is because woodland is ecologically more valuable (Table 2). While in recent years, with the development of the real estate, the woodland in the southern mountain area was destroyed to some extent. Emphasis should be paid on the conservation of woodland in the future. Grassland and water body contributed 8% and 12–13% of the total ecosystem service value, respectively. The contribution of unused land to the total ecosystem service value is too small to be shown in the figure.

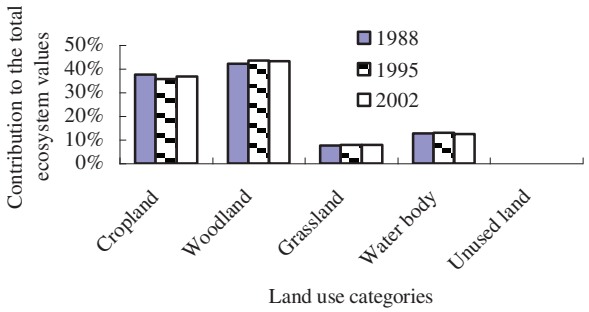


Fig. 4. Contribution of each land use category to the total ecosystem service values

3.3. Discussion

Ecosystem service values were estimated using data extracted from LANDSAT TM images. Limited by spatial resolution, some roads and water bodies were not embodied in the datasets. So this is only a rough estimation of ecosystem service values in Jinan. High resolution remote sensing images are required to improve the estimation precision.

4. Conclusions

Cropland is the dominant land use category in the study area. The area of each land use category follows the order of cropland>woodland>construction land>grassland>water body>unused land. In the study period, the most notable changes of land use are the decrease of cropland and the increase of construction land. With the urbanization, more and more lands were occupied for the construction purpose.

Woodland and cropland are the dominant land use categories providing about 80% of the total ecosystem service value. Ecosystem service valuation results showed that the total ecosystem service value decreased by 42.86 million Yuan between 1988 and 2002. Although the change of ecosystem service value is relatively small to that of some other areas in China, occupying of cropland and the expanding of Construction land to the southern mountain areas do bring about the loss of ecosystem service values.

Acknowledgements

Financial supports are from the Science and Technology Fund by University of Jinan under the grant No. Y0621 and No. XKY 0931. We gratefully thank the Resources and Environment Scientific Data Center, Chinese Academy of Sciences for providing the land use datasets of Jinan.

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