

Research Article

Changes in Ecosystem Service Values in Fuxin City, Liaoning Province

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Abstract: Variation in ecosystem services value across land-use scenarios in Fuxin City of Liaoning Province were explored in the study. Two-period land use survey data (1996 and 2010) were used to estimate changes in the size of seven land use categories and the most recently published value equivalent was used to estimate changes in the values of ecosystem services. The total value of ecosystem services in Fuxin City was 17674.75 million Yuan in 1996 and 19077.59 million Yuan in 2010, with an increase of 1402.84 million Yuan mainly due to the inclining areas of forestland and grass land, which indicated the eco-environment in Fuxin City has been becoming better and better. However, agricultural land including farmland and orchard showed the tendency of decrease, which indicated food security has been facing with challenge in Fuxin City.

Keywords: Ecosystem services value, Fuxin city, GIS, land-use scenarios, value coefficients

INTRODUCTION

Valuation on ecosystem services has gathered extensive attention in the field of eco-environment home and abroad. Since Costanza reported his research in nature about ecosystem service value in 1997, the valuation method on ecosystem service value has made some progress (Costanza *et al.*, 1997; Costanza, 2008; Liu and Costanza, 2010). In China, Xie *et al.* (2008) modified twice (in 2002 and 2007) the value equivalent or coefficients of Chinese ecosystem based on Costanza's parameters. In his study, Xie considered the second value equivalent are more accurate than the first or Costanza's with time history. However, only some researches have been conducted based on Xie's first value equivalent, but the research based on the second value equivalent has been reported rarely.

As the important coal industrial base, Fuxin City has ever made much contribution to economic development of our country by exporting energy. With the depletion of coal resources and deterioration of eco-environment, Fuxin City was approved to be the first pilot city of economic transition for resources-exhausted cities in 2001. The variation of land use and eco-environment has taken place in different development stages in Fuxin City. The objectives of this study were:

- To assign specific value coefficients for Fuxin City and determine whether they can be used to evaluate changes in ecosystem services in the local area

- To estimate variations in ecosystem services value across land-use scenarios during the study period
- To make some preliminary policy recommendations for the change of land use and ecosystem service values

METHODOLOGY

Study area: The study was carried out in Fuxin City of Liaoning Province, Northeast China (121°01'-122°56' E; 41°41'-42°56' N). In 2010, Fuxin City covered 10323 km², including urban district and 2 counties (Fuxin Mongolia Autonomous County and Zhangwu County) (Fig. 1). Coal-mining industry has been developed for over one hundred years in Fuxin City, an old industrial base, northeast China, where Haizhou Opencut Coal Mine, the biggest Opencut Coal Mine in Asia is located. Geologically, Fuxin City is located in the northwest of Liaoning Province and in the low hills region of the middle and upper reaches of Liaohe and Daling River. The area has a semiarid continental monsoon climate of northern temperate region with 7.6°C average temperature and 481 mm rainfall precipitation per year. Hills and mountains occupy the widest distribution in Fuxin City, 58% of the total area and the rest are 19% sand and 23% plains. At the end of 2011, total economic production was Yuan 47.04 billion, the structure ratio of three industries was 23.4:44.0:32.6.

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Fig. 1: The location of study area

Table 1: Equivalent value per unit area of ecosystem services in China

Ecosystem services function	Cropland	Woodland	Grassland	Water body	Orchard	Unused land
Food production	1	0.33	0.43	0.53	0.67	0.02
Raw material	0.39	2.98	0.36	0.35	1.69	0.04
Gas regulation	0.72	4.32	1.50	0.51	2.52	0.06
Climate regulation	0.97	4.07	1.56	2.06	2.52	0.13
Hydrology regulation	0.77	4.09	1.52	18.77	2.43	0.07
Waste treatment	1.39	1.72	1.32	14.85	1.56	0.26
Soil conservation	1.47	4.02	2.24	0.41	2.75	0.17
Biodiversity conservation	1.02	4.51	1.87	3.43	2.77	0.40
Aesthetic landscape	0.17	2.08	0.87	4.44	1.13	0.24
In total	7.90	28.12	11.67	45.35	18.01	1.39

Land use classification: Two-period land use raster data (1996, 2010) were acquired from local management division of land resources in Fuxin City. Referring to land use classification system and field investigation in Fuxin City, the data sets in the process of vectorization were reclassified into seven categories, including cropland, woodland, grassland, water body, orchard, built up and unused land. The land use map and their corresponding attribute data were showed and analyzed in Arc GIS software for subsequent calculation of ecosystem service value. By on-the-spot sampling checkup, precision of vectorization amounts to 94% and hence we can utilize these land-uses information.

Assignment of ecosystem service value: Based on Costanza's parameters, Xie *et al.* (2008) extracted the equivalent weight factor of ecosystem services per hectare of terrestrial ecosystems in China and modified

the value coefficient of Chinese ecosystem. The equivalent weight factor listed in Table 1 was obtained by surveying 213 Chinese ecologists and can be applied to different regions across China by localizing the average natural food production. In the study, the equivalent weight of orchard was assigned to be the average of the sum of that for cropland and woodland. One factor is equal to the economic value of average natural food production of cropland per hectare per year. Generally, the natural food production is proposed to be 1/7 of the actual food production. With Fuxin City, the average actual food production of cropland was 3670.8 kg/ha from 1996 to 2010 and the average price for grain was 2.4 Yuan/kg in 2010. The ecosystem service value of one equivalent weight factor for Fuxin City is therefore 1258.6 Yuan (Table 2).

Calculation of ecosystem service values: Once the ecosystem service value of one unit area for each land use category has been extracted, the service value for

Table 2: Value coefficients of ecosystem service function in Fuxin city (VC, Yuan.ha/a)

Ecosystem services function	Cropland	Woodland	Grassland	Water body	Orchard	Unused land
Food production	1258.60	415.340	541.200	667.0600	836.970	25.170
Raw material	490.850	3750.63	453.100	440.5100	2120.74	50.340
Gas regulation	906.190	5437.15	1887.90	641.8900	3171.67	75.520
Climate regulation	1220.84	5122.50	1963.42	2592.720	3171.67	163.62
Hydrology regulation	969.120	5147.67	1913.07	23623.92	3058.40	88.100
Waste treatment	1749.45	2164.79	1661.35	18690.21	1957.12	327.24
Soil conservation	1850.14	5059.57	2819.26	516.0300	3454.86	213.96
Biodiversity conservation	1283.77	5676.29	2353.58	4317	3480.03	503.44
Aesthetic landscape	213.960	2617.89	1094.98	5588.180	1415.93	302.06
In total	9942.94	35391.83	14687.86	57077.51	22667.39	1749.45

Table 3: Area changes of land use in Fuxin city, Liaoning province

Land use categories	1996		2010		1996~2010		
	ha	(%)	ha	(%)	ha	(%)	%/year
Cropland	376129.69	36.44	372467.20	36.08	-3662.490	-0.970	-0.07
Woodland	289375.86	28.03	341612.74	33.09	52236.88	18.05	1.29
Grassland	72578.040	7.030	74946.820	7.260	2368.780	3.260	0.23
Water body	33093.400	3.210	28126.150	2.720	-4967.250	-15.01	-1.07
Orchard	19383.990	1.880	16393.520	1.590	-2990.470	-15.43	-1.10
Build up	70794.080	6.860	80964.730	7.840	10170.65	14.37	1.03
Unused land	170959.51	16.56	117803.41	11.41	-53156.10	-31.09	-2.22
In total	1032314.57	100	1032314.57	100	0	0	0

each land use category, each service function and total ecosystem services are given in the following Eq. (1), (2) and (3):

$$ESV_k = \sum_f A_k \times VC_{kf} \tag{1}$$

$$ESV_f = \sum_k A_k \times VC_{kf} \tag{2}$$

$$ESV = \sum_k \sum_f A_k \times VC_{kf} \tag{3}$$

where,

ESV_k : The ecosystem service value of land use category “k”

ESV_f : Value of ecosystem service function type “f”

ESV : The total ecosystem service value respectively

A_k : The area (ha) for land use category “k”

VC_{kf} : The value coefficient (Yuan·ha/a) for land use category “k”, ecosystem service function type “f”

Since uncertainties exit in the value coefficients, sensitivity analyses were conducted to determine the dependence of temporal changes in ecosystem service values on the applied value coefficients. The ecosystem value coefficients for cropland, woodland, grassland, water body, orchard and unused land categories were each adjusted by 50%. In each analysis, the coefficient of sensitivity (CS) was calculated using the following Eq. (4):

$$CS = \frac{(ESV_j - ESV_i) / ESV_i}{(VC_{jk} - VC_{ik}) / VC_{ik}} \tag{4}$$

RESULTS AND ANALYSIS

Land use change: Through overlay analysis of two land use vector and attribute data calculation within Arc GIS soft, the area of land use change was obtained (Table 3). There was an obvious land use change in Fuxin City during the study period. The areas of woodland, grassland and build up land increased from 1996 to 2010. On the contrary, the areas of cropland, water body, orchard and unused land decreased.

In general, area ratio of land use in Fuxin City from high to low was cropland, woodland, unused land, grassland, build up, water body and orchard. As a traditional agricultural region, cropland comprises the largest portion (about 36%) of the total area. However, the area of cropland showed declining tendency from 1996 to 2010, with a decrease ratio 0.97% in total and 0.07% per year. Besides unused land, the greatest area change was woodland, moreover, the area of woodland showed a rising tendency, increasing from 289375.86 ha in 1996 to 341612.74 ha in 2010. In contrast, the area of unused land decreased with 53156.1, with the greatest declining rate of 31.09% in total and 2.22% per year. The other two land uses which showed increasing trend were grassland and build up and their areas were very close to each other, with an increase from 72578.04 to 74946.82 ha and from 70794.08 to 80964.73 ha, respectively. The least two land uses were water body and orchard, furthermore, their areas continued to reduce during the study period, with a declining ratio 1.07 and 1.1 %/year, respectively.

Change of ecosystem services value: By utilizing the value coefficients (Table 2) and areas of land use categories (Table 3), the ecosystem service value of

Table 4: Values of ecosystem service for land use category in 1996 and 2010 (ESV_k in 10^6 Yuan/year)

Land use categories	1996		2010		1996-2010		Rank
	ESV_k	(%)	ESV_k	(%)	ESV_k	(%)	
Cropland	3739.830	21.16	3703.420	19.41	-36.4200	-0.970	2
Woodland	10241.54	57.94	12090.30	63.37	1848.76	18.05	1
Grassland	1066.020	6.030	1100.810	5.770	34.7900	3.260	4
Water body	1888.890	10.69	1605.370	8.410	-283.520	-15.01	3
Orchard	439.3800	2.490	371.6000	1.950	-67.7900	-15.43	5
Unused land	299.0900	1.690	206.0900	1.080	-92.9900	-31.09	6
In total	17674.75	100	19077.59	100	1402.84	7.940	-

Table 5: Values of ecosystem service functions in 1995 and 2006 (ESV_f in 10^4 Yuan/year)

Ecosystem service function	1996		2010		1996-2010		Rank
	ESV_f	(%)	ESV_f	(%)	ESV_f	(%)	
Food production	675.470	3.820	686.680	3.600	11.210	1.660	9
Raw material	1367.14	7.740	1551.13	8.130	183.99	13.46	7
Gas regulation	2146.88	12.15	2415.36	12.66	268.49	12.51	5
Climate regulation	2259.28	12.78	2495.98	13.08	236.70	10.48	4
Hydrology regulation	2849.12	16.12	2987.82	15.66	138.71	4.870	1
Waste treatment	2117.44	11.98	2111.97	11.07	-5.4800	-0.260	6
Soil conservation	2485.25	14.06	2725.18	14.28	239.93	9.650	3
Biodiversity conservation	2592.65	14.67	2831.43	14.84	238.77	9.210	2
Aesthetic landscape	1181.52	6.680	1272.03	6.670	90.510	7.660	8
In total	17674.75	100	19077.59	100	1402.84	7.940	-

Table 6: Percentage change in estimated total ecosystem service value and Coefficient of Sensitivity (CS) resulting from adjustment of ecosystem Valuation Coefficients (VC)

Change in value coefficient	1996		2010	
	(%)	CS	(%)	CS
Cropland VC±50%	±10.58	0.212	±9.710	0.194
Woodland VC±50%	±28.97	0.579	±31.69	0.634
Grassland VC±50%	±3.020	0.060	±2.890	0.058
Water body VC±50%	±5.340	0.107	±4.210	0.084
Orchard VC±50%	±1.240	0.025	±0.970	0.019
Unused land VC±50%	±0.850	0.017	±0.540	0.011

land use category “*k*”, value of ecosystem service function type “*f*” and the total ecosystem services value of Nanfen in 1996 and 2010 were obtained according to the formulas (1-3). These results are shown in Table 4 and 5. The total ecosystem services value of Fuxin City was about 17674.75 million Yuan in 1996 and 19077.59 million Yuan in 2010, with an increase of 1402.84 million Yuan.

Because of the relatively higher value coefficient and land use area, the value of ecosystem services produced by woodland was the highest among the six land use categories, accounted for about 60% (Table 4) of the total value. Moreover, with the greatest rising extent of 1848.76 million Yuan, ecosystem services value in woodland led the change direction of ecosystem services in Fuxin City. The other and the last ascending ecosystem services value produced by land use was grassland, with an increase of 34.79 million Yuan. Rank 2nd and 3rd in values of ecosystem service for land use were cropland and waterbody (Table 4), for the area of cropland was far greater than waterbody although the value coefficients of waterbody was better than cropland. Orchard and unused land generated fewer service values owing to small areas in orchard

and low value coefficient in unused land, although the value coefficient in orchard and the area in unused land were relatively high.

The Ecosystem Service Values (ESV_f) provided by individual ecosystem functions were shown in Table 5. Changes in the contribution of each ecosystem function to the total ESV were even, with most change rates swing around 10%. Besides waste treatment, all other ecosystem service values of land uses showed an increasing trend from 1996 to 2010. The overall rank order for each ecosystem function based on their contributions to the overall value of ecosystem services was as follows, from high to low, hydrology regulation, biodiversity conservation, soil conservation, climate regulation, gas regulation, waste treatment, raw material, aesthetic landscape and food production. The cause for the rank order likely resulted from the high ability of woodland to regulate hydrology, protect biodiversity and the high capacity of cropland and water body to preserve soil and regulate climate.

Ecosystem services sensitivity analysis: As shown in Table 6 the percentage change in estimated total ecosystem service value and the coefficient of sensitivity resulting from a 50% adjustment in the value of the coefficient, was calculated using formula (4). In all cases, CS was far less than unity and often near zero, indicating that the total ecosystem services value estimated in this study area was relatively inelastic with respect to the value coefficients. CS for woodland was the highest and showed increasing tendency, from 0.579 in 1996 to 0.634 in 2010, because of the large area and high service value coefficient. Besides woodland, the CS for all the other land uses reduced slightly. The sensitivity analysis indicated that the

estimation in this study area was robust in spite of uncertainties on the value coefficients.

CONCLUSION

By analyzing and discussing the changes of ecosystem service value across land use scenarios in Fuxin City from 1996 to 2010, we came to the conclusions as follows:

- The areas of woodland, grassland and build up land increased from 1996 to 2010. On the contrary, agricultural land including cropland and orchard showed the tendency of decrease, which indicated food security, has been facing with challenge in Fuxin City.
- The total ecosystem services value of Fuxin City was 17674.75 million Yuan in 1996 and 19077.59 million Yuan in 2010. The net increase in ecosystem service value was about 1402.84 million Yuan from 1996 to 2010, which indicated the eco-environment in Fuxin City has been becoming better and better.
- Changes in the contribution of each ecosystem function to the total ESV were even, with most change rates swing around 10%. Besides waste treatment, all other ecosystem service values of land uses showed an increasing trend from 1996 to 2010.

- The newest value equivalents were utilized in the study and the results of our sensitivity analysis suggest that the value coefficients we used can produce meaningful results.

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