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Research Article

Evaluation on Ecosystem Services Value Based on Food Production in Nanfen District of Benxi City, Northeast China

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Abstract: Ecosystem service values based on food production were estimated in Nanfen District of Benxi City, Liaoning Province, Northeast China. Two remote sensing images (1995, 2006) were applied to obtain land use change information and the most recently published value equivalent were used to valuate ecosystem services. The total value of ecosystem services in Nanfen District was 1294.1 million Yuan in 1995 and 1293.49 million Yuan in 2006, with a decrease of 568.3 thousand Yuan mainly due to the declining areas of cropland, water body and wetland. We concluded that future local land use plan should give priority to the conservation of these ecosystems, in order to promote and maintain the balance of local ecosystem.

Keywords: Ecosystem services, food production, land use, Nanfen district, value assessment

INTRODUCTION

The ecological problems caused by human activities have gradually attracted worldwide attention in recent years (Hao *et al*., 2012). Consequently, ecosystem service valuation has also become a prominent topic in the field of ecological economic research. Land use change is the main driving force of regional ecosystem change and has a major impact on environmental balance (Bian and Lu, 2013). Ecosystem services are becoming increasingly threatened in Nanfen District of Benxi City, where resources exploration and environment pollution are deteriorating. This deterioration is partially due to a lack of valuation because resources that are not valued are often ignored in management decisions (Costanza *et al*., 1997; Liu and Costanza, 2010). The challenge then is to acknowledge the multiple contributions of ecosystem services to human well being and manage them as public goods (Costanza, 2008).

Since Costanza *et al*. (1997) reported his research in nature about ecosystem service value, the valuation method on ecosystem service value has made some progress (Zhang *et al*., 2010; Kreuter *et al*., 2001; Li *et al*., 2010a). In China, Xie *et al*. (2008) modified twice (in 2002 and in 2007) the value equivalent or coefficients of Chinese ecosystem based on Costanza's parameters (Li *et al*., 2010b). In his study, Xie *et al*. (2008) considered the second value equivalent are more accurate than the first or Costanza's with time history. However, only some researchers have been conducted based on Xie's first value equivalent, but the research based on the second value equivalent has been reported rarely.

Nanfen is one of the four districts of Benxi City, where variation of ecosystem services value in response to land use change have taken place owing to human activity. The objectives of this study were:

- To assign specific value coefficients for Nanfen District and determine whether they can be used to evaluate changes in ecosystem services in the local area
- To estimate variations in ecosystem services value in response to land use changes during the study period
- To make some preliminary policy recommendations to promote and maintain local ecosystem balance

METHODOLOGY

Study area: The study was carried out in Nanfen District, Benxi City, Northeast China (123°38′-123°59′ E; 40°02′-41°14′ N). In 2006, Nanfen District covered 619 km^2, including 2 towns (Sishanling town and Xiamatang town) and an urban region (Fig. 1). Mining industry has been developed for several decades in Nanfen District of Benxi City, an old industrial base, northeast China, where Benxi Opencut Iron Mine, the biggest Opencut Iron Mine in Asia is located. Geologically, Nanfen is a part of Changbai Mountain chain, Qianshan Mountain eastern-extended section and possessing abundant forest reserves. The main rivers across Nanfen Distrci include Xihe River, Dashihe River, Changshanhe River and Sandaohe River, all belonging to Liaohe Watershed. The area has a temperate monsoon climate, with distinct seasonal variations and a rather large temperature difference between winter and summer. At the end of 2004, total

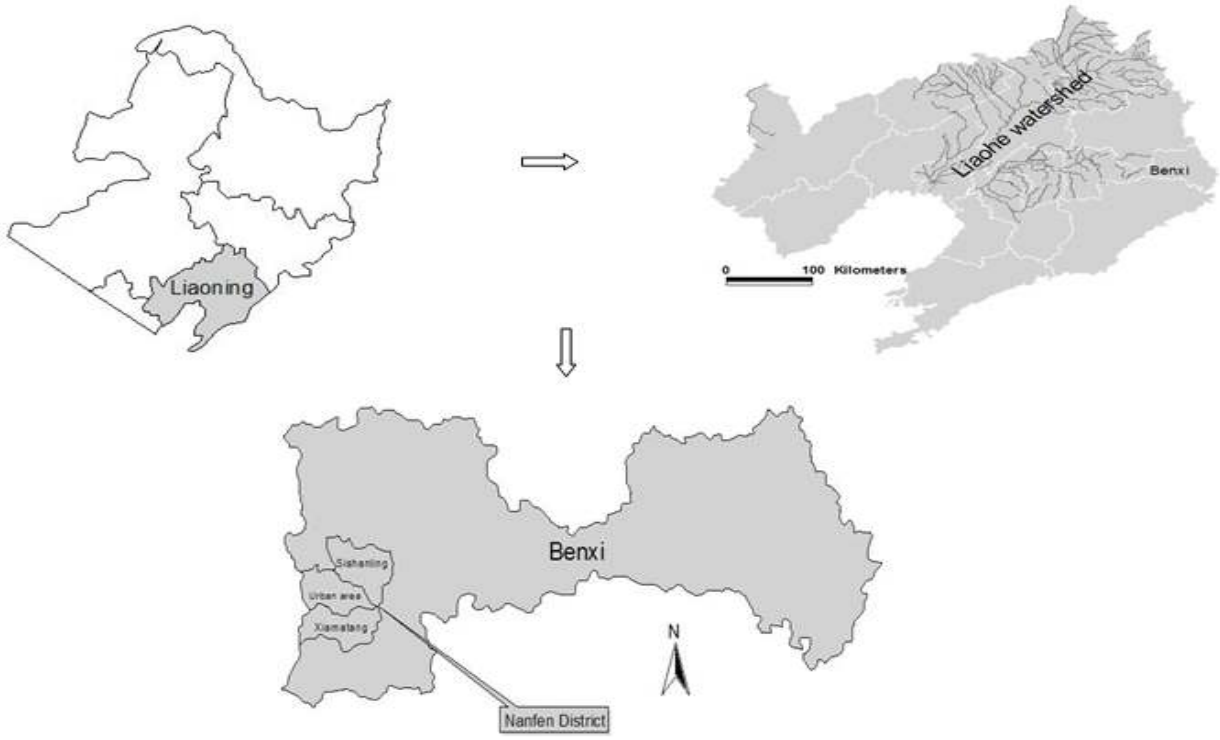

Fig. 1: The location of study area

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

Ecosystem services function	Cropland	Woodland	Grassland	Water body	Wetland	Unused land
Food production	1	0.33	0.43	0.53	0.36	0.02
Raw material	0.39	2.98	0.36	0.35	0.24	0.04
Gas regulation	0.72	4.32	1.50	0.51	2.41	0.06
Climate regulation	0.97	4.07	1.56	2.06	13.55	0.13
Hydrology regulation	0.77	4.09	1.52	18.77	13.44	0.07
Waste treatment	1.39	1.72	1.32	14.85	14.40	0.26
Soil conservation	1.47	4.02	2.24	0.41	1.99	0.17
Biodiversity conservation	1.02	4.51	1.87	3.43	3.69	0.40
Aesthetic landscape	0.17	2.08	0.87	4.44	4.69	0.24
In total	7.90	28.12	11.67	45.35	54.77	1.39

economic production was Yuan 630 million, of which industrial production was Yuan 328 million, accounting for 52.1% of total production.

Land use classification: Two cloud-free Landsat-5 TM images (collected in September, 1995 and October, 2006, respectively) were used to acquire land use change information. Topographic map, geomorphologic map, vegetation map and related socio-economic statistics of study area were used as auxiliary data for image calibration and interpretation. Based on man-machine interactive interpretation, combining spectral features shown in TM image (4-3-2 bands false color composition) with geomorphologic, vegetation map and local crop grow feature, three period vector data were acquired.

The original land use categories include two levels of national standard types (Kreuter *et al*., 2001). Referring to land use classification system and field investigation in Nanfen District, the data sets were reclassified into seven categories, including cropland, woodland, grassland, water body, wetland, 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 interpretation amounts to 85% and hence we can utilize these land use change 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. One factor is equal to

Table 2: Value coefficients of ecosystem service function in Nanfen district (VC, Yuan/ha/a)

Ecosystem services function	Cropland	Woodland	Grassland	Water body	Wetland	Unused land
Food production	885.70	292.28	380.85	469.42	318.85	17.71
Raw material	345.42	2639.39	318.85	310	212.57	35.43
Gas regulation	637.70	3826.22	1328.55	451.71	2134.54	53.14
Climate regulation	859.13	3604.80	1381.69	1824.54	12001.24	115.14
Hydrology regulation	681.99	3622.51	1346.26	16624.59	11903.81	62
Waste treatment	1231.12	1523.40	1169.12	13152.65	12754.08	230.28
Soil conservation	1301.98	3560.51	1983.97	363.14	1762.54	150.57
Biodiversity conservation	903.41	3994.51	1656.26	3037.95	3268.23	354.28
Aesthetic landscape	150.57	1842.26	770.56	3932.51	4153.93	212.57
In total	6997.03	24905.88	10336.12	40166.50	48509.79	1231.12

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 Nanfen District, the average actual food production of cropland was 3875 kg/ha from 1995 to 2006 and the average price for grain was 1.6 Yuan/kg in 2006. The ecosystem service value of one equivalent weight factor for Nanfen District is therefore 885.7 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 each land use category, each service function and total ecosystem services are given in the following Eq. (1), (2) and (3):

$$ESV_k = \sum_f A_k \times VC_{kf} \quad (1)$$

$$ESV_f = \sum_k A_k \times VC_{kf} \quad (2)$$

$$ESV = \sum_k \sum_f A_k \times VC_{kf} \quad (3)$$

ESV_k, ESV_f and ESV refer to the ecosystem service value of land use category "k", value of ecosystem service function type "f" and the total ecosystem service value respectively. A_k is the area (ha) for land use category "k" and 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, wetland and unused land categories were each adjusted by 50%. In each analysis, the Coefficient of Sensitivity (CS) was calculated using the following Eq. (4):

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

RESULTS AND DISCUSSION

Land use change: Through overlay analysis of two land use images 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 Nanfen District during the study period. The areas of woodland, grassland and build up land increased from 1992 to 2006. On the contrary, the areas of cropland, water body, wetland and unused land decreased.

As a typical mountain town, woodland comprises the largest portion (over 70%) of the total area. Moreover, the area of woodland showed a rising tendency, increasing from 47169.7 ha in 1995 to 47224.29 ha in 2006. The greatest area change was cropland, followed by build up land. The difference was that crop land decreased with 126.9 ha, with a declining rate of 2.51%. However, the build up land increased with 84.56 ha, with an increasing rate of 1.94%. Although the area of unused land was the least, the largest change in percentage was also unused land, with a decrease ratio 16.4% in total and 1.49%/year. The probable reason for the change of cropland, build up land and unused land was as a result of industrialization and urbanization. The areas of water body and wetland were very close to each other and their variation trend were the same, with a decrease from 405.43 to 387.84 ha and from 462.56 to 448.29 ha, respectively. With decline of water body and wetland, the area of grassland increased 36.75 ha, from 4361.61 ha in 1995 to 4398.36 ha in 2006. The possible causes for the decrease of water body and wetland were climate warming and environment disruption.

Change of ecosystem services value: By utilizing the value coefficients and areas of land use categories (Table 2 and 3, respectively), the ecosystem service value of land use category "k", value of ecosystem service function type "f" and the total ecosystem services value of Nanfen in 1995 and 2006 were obtained according to the formulas (1)-(3). These results are shown in Table 4 and 5. The total ecosystem services value of Nanfen District was about 1294.1 million Yuan in 1995 and 1293.49 million Yuan in 2004, with a reduction of 568.3 thousand Yuan (Jinbo and Kaijun, 2014).

Table 3: Area changes of land use in Nanfen district of Benxi city, Liaohe watershed

	1995		2006		1995-2006		
Land use categories	ha	(%)	ha	(%)	ha	(%)	%/year
Cropland	5048.59	8.16	4921.69	7.95	-126.90	-2.510	-0.23
Woodland	47169.70	76.20	47224.29	76.29	54.59	0.12	0.01
Grassland	4361.61	7.05	4398.36	7.11	36.75	0.84	0.08
Water body	405.43	0.65	387.84	0.63	-17.58	4.34	0.39
Wetland	462.56	0.75	448.29	0.72	-14.27	3.09	0.28
Build up	4347.94	7.02	4432.50	7.16	84.56	1.94	0.18
Unused land	104.52	0.17	87.38	0.14	-17.14	-16.40	1.49
In total	61900.35	100	61900.35	100	0	0	0

Table 4: Values of ecosystem service for land use category in 1995 and 2006 (ESV_k in 10^4 Yuan/year)

	1995		2006		1995-2006		
Land use categories	ESV_k	(%)	ESV_k	(%)	ESV_k	(%)	Rank
Cropland	3532.51	2.73	3443.72	2.66	-88.79	-2.51	3
Woodland	117480.29	90.79	117616.25	90.93	135.96	0.12	1
Grassland	4508.21	3.48	4546.20	3.52	37.99	0.84	2
Water body	1628.47	1.26	1557.82	1.20	-70.65	-4.34	5
Wetland	2243.87	1.73	2174.64	1.68	-69.23	-3.09	4
Unused land	12.86	0.01	10.75	0.01	-2.11	-16.39	6
In total	129406.21	100	129349.38	100	-56.83	-0.04	-

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

	1995		2006		1995-2006		
Ecosystem service functions	ESV_f	(%)	ESV_f	(%)	ESV_f	(%)	Rank
Food production	2025.91	1.57	2016.35	1.56	-9.56	-0.47	9
Raw material	12786.15	9.88	12796.44	9.89	10.29	0.08	6
Gas regulation	19067.18	14.73	19080.93	14.75	13.75	0.07	3
Climate regulation	18670.42	14.43	18663.74	14.43	-6.68	-0.04	4
Hydrology regulation	19244.05	14.87	19213.78	14.85	-30.27	-0.16	2
Waste treatment	9442.91	7.30	9398.17	7.27	-44.74	-0.47	8
Soil conservation	18415.29	14.23	18422.08	14.24	6.79	0.04	5
Biodiversity conservation	20298.52	15.68	20304.33	15.70	5.81	0.03	1
Aesthetic landscape	9455.79	7.31	9453.56	7.31	-2.23	-0.02	7
In total	129406.21	100	129349.38	100	-56.83	-0.04	-

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

	1995		2006	
Change in value coefficient	(%)	CS	(%)	CS
Cropland VC±50%	±1.36	0.027	±1.33	0.027
Woodland VC±50%	±45.39	0.908	±45.46	0.909
Grassland VC±50%	±1.74	0.035	±1.76	0.035
Water body VC±50%	±0.63	0.016	±0.60	0.012
Wetland VC±50%	±0.87	0.017	±0.84	0.017
Unused land VC±50%	0	0	0	0

Because of the high value coefficient and the largest area, the value of ecosystem services produced by woodland was the highest among the six land use categories, accounted for about 90% (Table 4) of the total value, far more than 72.6% (Table 3) of its proportion in land use. Rank 2nd and 3rd in values of ecosystem service for land use were grassland and cropland (Table 4), for the value coefficients of grassland was far better than cropland although the area of cropland was greater than grassland. Wetland and water body generated fewer service values owing to their small area, though they have the relatively higher value coefficients. Comparatively speaking, both the area and value coefficient of wetland were greater than that of water body, so the values of ecosystem service for wetland were more than that of water body. Unused land has the smallest area and the lowest value coefficient and hence the value of ecosystem services was the least.

The Ecosystem Service Values (ESV_f) provided by individual ecosystem functions were shown in Table 5. In general, the changes in the contribution of each ecosystem function to the total ESV were small, with all the change rates lower than 0.5%. Specifically, values of ecosystem service functions for gas regulation, raw material, soil conservation and biodiversity increased slowly and the other five service functions showed a reduction trend from 1995 to 2006. 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, biodiversity conservation, hydrology regulation, gas regulation, climate regulation, soil conservation, raw material, aesthetic landscape, waste treatment and food production. The cause for the rank order likely resulted from the high ability of woodland to protect biodiversity and the high capacity of grassland, water body and wetland to regulate hydrology, gas and 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, were 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, about 0.9, because of the large area and high service value coefficient. However, The CS for the other land-use was near zero. CS for water body decreased from 0.016 in 1995 to 0.012 in 2006 while that for other land-use relatively remained constant. 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 based on land use in Nanfen District from 1995 to 2006, we came to the conclusions as follows:

- The total ecosystem services value of Nanfen District was about 1294.1 million Yuan in 1995 and 1293.49 million Yuan in 2006. The net decline in ecosystem service value was about 568.3 thousand Yuan from 1995 to 2006, which was mainly caused by the decreasing areas of cropland, water body and wetland. Some measures should be taken to protect their land use so as to maintain the balance of ecosystems.
- Owing to the high ability of woodland to protect biodiversity and the high capacity of grassland, water body and wetland to regulate hydrology, gas and climate, the relatively higher values for each ecosystem function were biodiversity conservation, hydrology regulation, gas regulation, climate regulation.
- 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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