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

\[ ESV_k = \sum_j A_k \times VC_{kj} \]  
\[ ESV_f = \sum_k A_k \times VC_{kf} \]  
\[ ESV = \sum_k \sum_f A_k \times VC_{kf} \]

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):

\[ CS = \frac{(ESV_f' - ESV_f)/ESV}{(VC_{kf} - VC_{kf}'')/VC_{kf}} \]  

RESULTS AND ANALYSIS

Land use change: Through overlay analysis of two land use vector and attribute data calculation within ArcGIS 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 53156.10 ha in 1996 to 341612.74 ha in 2010. 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
Moreover, with the greatest rising land use categories, accounted for about 60% (Table 4) and land use area, the value of ecosystem services extent of 1848.76 million Yuan, ecosystem services in Fuxin City. The other and the last 19077.59 million Yuan in 2010, with an increase of was about 17674.75 million Yuan in 1996 and 5. The total ecosystem services value of Fuxin City was gras sland, with an increase of 34.79 million ascending ecosystem services value produced by land.

Changes in the contribution of each ecosystem function and the area in unused land reduced CS for all the other land uses. Besides waste treatment, all other ecosystem service values of land uses showed a 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

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

| Land use categories | 1996 ESV | (%)  | 2010 ESV | (%)  | 1996-2010 ESV | (%)  | Rank |
|---------------------|---------|------|----------|------|--------------|------|------|
| Cropland            | 3739.830| 21.16| 3703.420 | 19.41| -34.420      | -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| 34.790       | 3.260 | 4    |
| Water body          | 1888.890| 10.69| 1605.370 | 8.410| -283.520     | -15.01| 3    |
| Orchard             | 439.380  | 2.490| 371.600  | 1.950| -67.790      | -15.43| 5    |
| Unused land         | 299.090  | 1.690| 206.090  | 1.080| -92.990      | -31.09| 6    |
| In total            | 17674.75 | 100  | 19077.59 | 100  |             |       |      |

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

| Ecosystem service function | 1996 ESV | (%)  | 2010 ESV | (%)  | 1996-2010 ESV | (%)  | Rank |
|----------------------------|---------|------|----------|------|--------------|------|------|
| 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             | 2416.88 | 12.15| 2415.36  | 12.66| 1.54         | 0.046| 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| -5.480        | -0.260| 6    |
| Soil conservation          | 2485.25 | 14.62| 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  | 6.870| 90.510        | 7.660| 8    |
| In total                   | 17674.75| 100  | 19077.59 | 100  |             |      |      |

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

| Land use categories | 1996 | 2010 | Change in value coefficient | CS |
|---------------------|------|------|----------------------------|----|
|                     | (%)  | (%)  | VC±50%                      | CS |
| Cropland            | ±10.58| 0.212| ±9.710                      | 0.194|
| Woodland            | ±28.97| 0.759| ±31.69                      | 0.634|
| Grassland           | ±3.020| 0.060| ±2.890                      | 0.058|
| Water body          | ±5.340| 0.107| ±4.210                      | 0.084|
| Orchard             | ±1.240| 0.025| ±0.970                      | 0.019|
| Unused land         | ±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.
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.

ACKNOWLEDGMENT

This research was supported by funds from National water pollution control and management technology major projects (Grant No. 2012 ZX07505-003).

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