Estimation Model of Ecosystem Service Value in Jining City Based on Remote Sensing

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Abstract. By using the spectral band characteristics of TM/ETM remote-sensing images in Jining City, we classify the remote-sensing images of 2000 and 2010 and divide the land of Jining City into five types, including farmland, woodland, water area, unused land and urban construction land. Then, we use the remote-sensing dynamic monitoring method to extract part of the area of the remote sensing-image data according to the legend and make statistics on the area of various land types. Finally, the area of different land types can be got. We establish an equivalent ecosystem service value estimation model by referring to the improved Constanza model of Xie Gao et al. The service value of different land types in the total ecosystem is calculated by the ecological value coefficient table. After calculation, the land development cost of Jining City from 2000 to 2010 is 1.6299 billion yuan. We establish an ecological compensation model to make ecological compensation according to a certain ecological compensation standard and the priority of compensation which is convenient for land developers to make decisions.

1. Introduction

1.1. Background Knowledge
Nowadays, Human activities have had a huge negative impact on biodiversity, and many organisms are gradually disappearing; the balance of interaction between living things and their physical environment ecosystems has been disrupted; reduced ecosystem service capacity results in fewer and fewer benefits and assets that humans can derive from the natural environment and fully functioning ecosystems. We need to put a value on the environmental cost of land use development projects and calculate the economic cost of mitigating the negative consequences of land use change, for example, polluted rivers, poor air quality, hazardous waste sites, poorly treated waste water, climate changes, etc. The environmental degradation should be accounted for in these project costs. Once ecosystem services are accounted for in the cost-benefit ratio of a project, then the true and comprehensive valuation of the project can be determined and assessed. On the basis of the above, an ecological service assessment model should be created to understand the real economic costs of land use projects when considering ecosystem services. In addition, the effectiveness of the established model should be evaluated and the impact of the analysis and the model given on land use project planners and managers should be indicated. Finally, considering the situation of the model over time.
2. Basic assumption
The value of ecosystem unit area ecological service in Jining city is approximately equal to that in China.

Jining belongs to the plain, so assume that the desert area of Jining is 0.

The total land area of Jining City will remain unchanged for 10 years.

The growth of construction land types in Jining City in 2010 was all transferred from other land types.

The Wetland area of Jining City is 0.

The unused land analyzed by remote sensing image is mainly grassland, so it is assumed that the ecological value coefficient of unused land area is the same as that of grassland in the table of ecological value coefficient.

Assume that all construction land is converted from one type of land, which means any site of construction land is all converted from farmland, woodland, waters, or grasslands.

3. Models

3.1. Calculation of land project development costs

3.1.1. Data collection and processing

Data collection:
The Statistical Yearbook of Jining City from 2000 to 2010, Landsat TM/ETM remote Sensing Image data of Jining City in 2000 and 2010.

Data preprocessing:
With the help of ENVI software, remote sensing dynamic monitoring was carried out on the remote sensing image data of Jining City in 2000 and 2010. The purpose of dynamic monitoring is to preprocess the remote sensing data images of Jining city, and find out the information of remote sensing data changes in 2000 and 2010 through quantitative analysis, so as to provide accurate data for the construction of Constanza model in the later period. Dynamic remote sensing monitoring can be divided into the following two steps according to the process: first, direct image comparison method; second, post-classification comparison method.

The image comparison method can calculate and change the meta-values in remote sensing images of Jining city in 2000 and 2010. In this study, we use image interpolation method, principal component analysis method, vegetation index comparison method and spectral signature variation method to process spectral data. The ratio of remote sensing images in 2000 and 2010 is calculated, and the land types in Jining city are divided into woodland, cultivated land, unused land, water area and construction land according to the ratio results.

Extract the area of the changed area according to the legend, the conclusions are as follows:

Land use situation in 2000: The total land area of Jining is: 1068490 hm².

Table 1. Land use type area table of jining in 2000

| Land use type    | Land area/ hm². |
|------------------|-----------------|
| forest           | 39286.24        |
| grass            | 157911.07       |
| farmland         | 774256.70       |
| Rivers/lakes     | 73803.81        |

Land use situation in 2010: The total land area of Jining is: 1068490 hm².
Table 2. Land use type area table of Jining in 2010

| Land use type | Land area/ hm2. |
|---------------|-----------------|
| forest        | 61529.58        |
| grass         | 179227.19       |
| farmland      | 695254.56       |
| Rivers/lakes  | 109546.01       |

3.1.2. Construction of Jining Ecological Service Model based on Constanza Model. We use the land projects of Jining city in 2000 and 2010 to establish the evaluation model of ecological services. The scope of land development projects refers to all land development projects from 2000 to 2010. In the process of data preprocessing, we obtained the changes of construction land in 2000 and 2010 by extracting remote sensing image data. Based on Xie Gaodi’s improved model of Constanza, we constructed an equivalent evaluation model of ecosystem services in Jining City. According to the ecological value coefficient table studied by Xie Gaodi and others, the service value of the total ecosystem can be calculated.

According to the ecological value coefficient table studied by Xie Gao et al., and combined with the actual situation of Jining City, the value of ecosystem service in Jining City is calculated. The criteria for calculation are as follows:

The ecosystem services model is as follows:

\[ ESV^i = \sum_{i=1}^{k} (A_k^i \times VC_k^i) \]

ESV: Total value of the ecosystem service system \( A_k \): Land use type area \( VC_k \): Value coefficient of ecosystem Services for K Land

The value assessment of ecosystem services in Jining City in 2000 can be obtained by matlab programming as follows:

Table 3. Value Assessment of ecosystem Services in Jining City in 2000

| land type        | Valuation of ecosystem services |
|------------------|---------------------------------|
| forest           | 424503537.696                   |
| meadow           | 88198648.152                    |
| farmland         | 2089004799                      |
| Rivers / lakes   | 614342914.44                    |
Table 4. Value Assessment of ecosystem Services in Jining City in 2010

| land type    | Valuation of ecosystem services |
|--------------|---------------------------------|
| forest       | 664851723.732                   |
| meadow       | 8707650.824                     |
| farmland     | 695915.06                       |
| Rivers / lakes | 911860987.24             |

The land project development cost model is as follows:

\[
C = ESV^{2000} - ESV^{2010}
\]  

(2)

After matlab programming, we get the answer:

\[
C = 16299000000
\]  

(3)

Building small projects to demonstrate the generality of the model:

The above is the construction of ecological service assessment model for the whole area of Jining, including all land use development projects from 2000 to 2010, which belong to a large land use project. For small projects, the model is the same. For small projects, a small land use project belongs directly to a land type, that is, a type of construction land formerly belonging to woodlands, farmland, grasslands, and waters. Taking the construction of a residential project as an example, we analyzes small land use projects to demonstrate the generality of the ecological service assessment model that we have built. To demonstrate the validity of the model, we will expound it in sensitivity analysis. For residential projects, assume that the previous land type of the residential project was farmland land. We need to analyze how much land is used for food production before the housing project, and then calculate the area where the farmland is used for raw material production, gas regulation, hydrological regulation, and soil retention. According to the value coefficient table of ecosystem service in Jining City, the development cost of residential project can be calculated.

3.2. Ecological compensation model

Land use project planners and managers can compensate for ecology according to the environmental costs caused by land development. Using the method of ecological compensation can not only protect the ecological environment but also develop land projects. It can also promoting the sustainable use of ecosystems. In this study, we refer to Wang Xiaoli's study on ecological compensation of Dongjiang River Basin. According to the value evaluation model of Jining city ecosystem, we establish the ecological compensation model of Jining city. First, we determine the amount of ecological compensation in Jining City, and establish the ecological compensation standard of Jining City. Then, calculate the priority of ecological compensation in Jining City in order to help the land use project planners and managers to propose Ecological compensation schemes. According to the evaluation model of ecosystem service value in Jining city and the research on Wang Xiaoli's Ecological compensation for Dongjiang River Basin, We establish the ecological compensation model. It increases the intensity coefficient of regional ecological compensation on the basis of ecological value coefficient to reflect the ecological compensation standard of Jining city. The ratio of GDP per unit area of Jining city and non-market value of ecosystem per unit area of Jining city is used to express the demand intensity coefficient of ecological compensation in Jining city.

The assessment methods of ecological compensation criteria are as follows:

\[
R_i = V_i \times k \times p_i
\]  

(4)
k refers to the conversion factor of ecological value

\[ p_i = \frac{2 \arctan(ECPS)}{\Pi} \]  \hspace{1cm} (5)

The calculation of priority of Ecological compensation:
The priority of ecological compensation indicates the urgency of obtaining ecological compensation in different areas (different counties and towns) in Jining City. The expression is as follows:

\[ ECPS = \frac{VAL_i}{GDP_n} \]  \hspace{1cm} (6)

In this model, \( R_i \) is the Total amount of Ecological compensation in Jining City; \( V_i \) is the value of ecosystem Service function in compensation range in Jining City; \( p_i \) is demand intensity coefficient of Ecological compensation in Jining City; \( ECPS \) is the ecological compensation priority; \( VAL_n \) is the non-market value of Jining to avoid ecosystem; \( GDP_n \) is unit area GDP of Jining City.

\( ECPS \) represents the influence of ecological compensation on regional economy. The larger the \( ECPS \), the greater the impact of ecological compensation on regional economic development. It should be compensated first, which means the priority of ecological compensation is high.

Based on the ecological value coefficient table and the GDP of Jining City, the ecological compensation priorities of different land types are calculated as follows:

Farmland > water land > woodland > grassland

The planners and managers of land use project may develop land projects according to the priority of ecological compensation according to the actual situation.

3.3. Land use change amplitude analysis model
Using the Constanza model, we establish the land use dynamic analysis model and the land use change amplitude analysis model to analyse the trend of Constanza Model changing with time from 2000 to 2010 in Jining City.

The dynamic analysis model of land use is as follows:

The dynamic analysis model of land use can use the dynamic attitude of land use to analyze the change process of land use type, at the same time, it can quantitatively analyze the change speed and range of land use. And forecast the trend of land use change in the future.

The models of land use dynamics are as follows:

\[ K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times \text{100\%} \]  \hspace{1cm} (7)

\( K \) is the land use type of ecosystem service value assessment model; \( T \) is the time period of change. \( U_a \) is area of land type other than construction land at the beginning of the study. \( U_b \) is area of land type other than construction land at the end of the study. The dynamic map of land use in Jining city from 2000 to 2010 is as follows:
As can be seen from the land use dynamics map: From 2000 to 2010, the farmland and grassland decreased, and the area of woodland, water area and construction land increased in Jining City. Construction land is growing at an annual rate of 1.7%. The value model of ecological services is also growing at a rate of 1.7% per year.

4. Error analysis and sensitivity analysis

The model we built above can be applied to both large projects such as land development in Jining and small land development projects such as housing. The generality of the model is demonstrated. The effectiveness of building a sensitivity index analysis model is presented below:

In this study, the sensitivity index analysis model of Jining City was constructed by referring to the sensitivity index analysis model of Lin Yajing and others. The use of ecosystem service value coefficient can greatly affect ecosystem service value. The sensitivity index (CS) of ecosystem services can be calculated by adjusting the value factor of ecosystem services up and down by 50%. If CS > 1, it shows that ecosystem service value is more sensitive to ecosystem service value coefficient; if CS < 1, ecosystem service value is not sensitive to ecosystem service value coefficient. In addition, the larger the sensitivity index is, the more accurate the value coefficient of ecosystem services is. The sensitivity index analysis model constructed is as follows:

\[
CS = \frac{\left( ESV_j - ESV_j \right) / ESV_j}{\left( VC_{jk} - VC_{ik} \right) / VC_{ik}}
\]

We take the value coefficient sensitivity index calculation of Jining ecosystem in 2010 as an example to evaluate whether the evaluation model of Jining ecosystem service system is reasonable or not. The assessment criteria are as follows:

If the sensitivity index of forest land, farmland land, water land and grassland are all less than 1, it is proved that the ecosystem service model constructed by us is reasonable and feasible and our calculation of the cost of land development projects is more accurate.

The sensitivity index table is as follows:
Table 5. Sensitivity index table

| Ecosystem-type              | ESV/yuan     | CS   |
|----------------------------|--------------|------|
| VC+50% in woodland         | 997277585.6  | 0.223|
| VC-50% in woodland         | 332425861.9  | 0.223|
| VC+50% in meadow           | 13061476.24  | 0.098|
| VC-50% in meadow           | 4353825.412  | 0.098|
| VC+50% in farmland         | 2038416844   | 0.006|
| VC-50% in farmland         | 679472281.5  | 0.006|
| VC+50% in water land       | 1367791481   | 0.009|
| VC-50% in water land       | 455930493.6  | 0.009|

By calculation, the CS of all ecosystem types is less than 1, that is, the model is within the normal error range.

5. Evaluation and Promotion of Model

5.1. Promotion

Increasing the extraction of multiple sets of remote sensing image data, calculating the average value of variation area and reducing the error in the process of remote sensing data extraction.

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