Assessment Model of Ecosystem Service Value Based on Environmental Kuznets Curve

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Abstract. As more and more land is developed, the environment is being destroyed more and more seriously, and the country and people begin to pay more attention to environmental degradation. However, the value of ecosystem services and the cost of environmental degradation are not taken into account when land projects are developed, and the impact of decisions on the biosphere is often overlooked. The real economic cost is often negative. In order to measure the real cost-benefit, we established our own measurement cost-benefit ratio model based on the value of ecosystem services and the cost of environmental degradation. In the modeling process, we first measured and counted the economic output of the land project, and then calculated the cost of environmental degradation based on its economic output according to the Kuznets curve formula. The use of these models can ensure the timeliness and applicability of our conclusions. Finally, we calculate the ecosystem service value of the whole region through the ecosystem service value of unit area and conduct evaluation and sensitivity analysis. In addition, we use RSEI to analyze the environmental quality of each part, and finally determine whether it exceeds or falls below the critical point by comparing the total value of ecosystem services with the total value of ecosystem services not included. So we can get a specific ratio to determine whether its real cost-effectiveness is positive or negative.

1. Introduction
In recent years, as the human land-use and more and more land are developed, the environmental protection issues have become more serious, including environmental degradation. The problem is that most land projects are implemented without taking into accounts the impacts and changes in ecosystem services. As a result, it causes environmental degradation and affects biodiversity. That's why the government wants a perfect plan to continue development without damaging the environment. We built our model based on the impact of human activities on environmental change.

Therefore, we consider measuring the cost of ecosystem degradation and environmental degradation caused by land use projects through the Ecosystem Services Value Assessment Model (ESV) [1-8].

However, environmental degradation is very complex, and the considered situations are not enough just by the ESV model. Therefore, we will establish our model by the multiple existing models such as Environmental Kuznets Curve (EKC) [9-17], ESV, and Remote Sensing Ecology Index (RSEI) [18-21] and establish our second-generation model. We analyzed the ESV value is negative or positive by calculating environmental degradation cost. This is a special ratio by our model which considers multiple factor and situations: First, the economic output of land development projects is estimated. Secondly, taking ecological degradation as the pollution index and combining the characteristics of the environmental Kuznets curve, the cost of environmental degradation caused by land project
development is calculated. Then, the ESV model is used to calculate the value of ecosystem services. Finally, the real cost benefit is obtained through our model.

We use several methods and models below in our research. Firstly, the Remote Sensing Ecology Index (RSEI) is an index widely used by scholars in recent years to analyze the environmental quality of each part of a small area (such as Wuhan City Circle, Alashan Plateau). We use RSEI to analyze the ecological quality of each component and finally determine whether it exceeds or falls below the critical point by comparing the total value of ecosystem services with the total value of ecosystem services not included. We calculate the value of ecosystem services across the region through the value of ecosystem services per unit area and conduct assessments and sensitivity analyses. RSEI is divided into four indicators: Green Degree (NDVI), Humidity (Wet), Heat (LST) and Thousand (NDSI). (See the Solution section for details). Through the calculation of RSEI, we can get the quality of the ecological environment.

Also, we cite an example to evaluate the value of ecological, environmental services. For example, water resource is an indispensable part of human life. To have a more comprehensive understanding of the regional ecological status, some scientific researchers analyze the final results of water environment security evaluation based on the fuzzy comprehensive evaluation method and weight. Different from the traditional comprehensive evaluation, the weight is calculated by the method of excessive weight for pollutants [6]. The change range of the observed value of the index also represents the amount of information included, so the weight of the index can be obtained, avoid the influence of subjective factors. But it does not take into account the impact of the relationship between the indicators. As for the cost analysis of environmental degradation, this paper first analyzes the main factors affecting the water ecological security in the Beijing-Tianjin-Hebei region through the above methods to analyze the main elements of environmental degradation and further calculate the Ecosystem value.

Because of the analysis of environmental safety and pollution, we analyze the cost of ecological, ecological degradation through research on the relationship between pollution and income. This lack of universality also demonstrates the singularity of the "Environmental Kuznets curve": it simply shows that the positive correlation between pollution and income in developing countries is juxtaposed with the very different negative correlation in developed countries. Therefore, we have improved the EKC model and set it to perform under ideal conditions of pollution, income and policy interaction. Thus, the environmental quality detected by RSEI is taken as the pollution index of ecological degradation, and the environmental degradation cost caused by land project development is calculated according to the characteristics of the Environmental Kuznets curve.

Finally, the ESV model is used to calculate the value of ecosystem services. And, the real cost benefit is obtained through our model. The empirical results show that without considering the impact of policy factors, the current land projects in some developing countries are still in the state of real negative economic growth, and the sustained economic growth may lead to further deterioration of the environmental situation.

2. Related Work
In our paper, we build models based on human activities and the impact on the natural environment [2-6]. These reports analyzes the effects of environmental degradation caused by land desertification, sandstorm evolution, land anthropogenic use, and oasis degradation. These documents and examples are of great help to our research.

Previous studies on the relationship between pollution and income have tended to analyze cross-sectional or panel data from samples from developing and developed countries [22] therefore, economists have concluded that almost all low-income observations are from developing countries, while all high-income observations are from developed countries. This lack of data and facts has led to criticism of the findings. Specifically, the environmental Kuznets curve (inverted U-shape) It may simply reflect a juxtaposition of the positive relationship between pollution and income in developing countries and the fundamentally different negative relationship in developed countries, rather than a single relationship that applies to both. As a result, the experts concluded that the change in TSP concentration and per capita GDP over the past five years is inversely proportional to each other, and
thus the EKC concluded that the TSP concentration will be higher as the population density, income or purchasing power rise, and the environmental quality will become worse.

3. Method
We create our Cost-benefit ratio model as the primary method in our research. The formula is based on the ratio of the value of ecosystem services to the value of ecosystem services. We can judge the cost-effectiveness of projects of different sizes. The Cost-benefit ratio model can be calculated by using the following formula:

\[ \eta = \frac{C_e + E - E_u}{C_u} \]  

This formula is divided into three components: (1) the economic output of the land project, (2) the value of the ecological environment, and (3) the cost of environmental degradation. As shown in the above formula, the real benefit ratio of the environmental cost is obtained by dividing the real benefit (calculated environmental, real cost) of (1) + (2) - (3) by the primary benefit (1).

The formula (1) also takes into account periodic time and can observe changes in environmental quality. Moreover, it considers the impact of economic costs. Under certain circumstances \( E \). According to the calculation of the model, as output \( C \) increases, so makes the impact of the environment \( Y \). The result can adequately reflect the effects of Land using on environmental quality.

3.1. The Economic Output of Land Development
When we build a land development project, we get the revenue from the project, which deducts all the economic input costs. Unlike ordinary economic output calculation, our land development economic output calculation includes all the income and the expenditure of the establishment project and other related costs.

3.2. EKC Model Improvement
EKC model is improved to calculate the cost of environmental degradation through the model and more accurately reflect the proportion of economic growth and environmental degradation. We assume that the EKC formula is entirely consistent with the reality, and give a new definition to the formula. Meanwhile, to distinguish different geographical and policy situations, we express them by different \( \beta \) values. Therefore, the environmental degradation cost of land use projects can be expressed as:

\[ \ln E_u = \beta_y + \beta_1 \ln Y_0 + \beta_2 (\ln Y_1)^2 + \beta_3 (\ln Y_2)^3 + X_u + \mu_u \]  

The horizontal ordinate represents project input cost, and the ordinate represents environmental degradation cost. By calculation, there are five different outcomes that produce different phenomena: If \( \beta_1 > 0, \beta_2 < 0, \text{and} \beta_3 = 0 \), it is an inverted U-shaped curve. If \( \beta_1 < 0, \beta_2 > 0, \text{and} \beta_3 = 0 \), it is a positive U-shaped curve; If \( \beta_1 < 0, \beta_2 = 0, \text{and} \beta_3 = 0 \), the cost of environmental degradation will decrease linearly. If \( \beta_1 < 0, \beta_2 > 0, \text{and} \beta_3 < 0 \), the environmental degradation cost presents an inverted N-type; If \( \beta_1 > 0, \beta_2 < 0 \) and \( \beta_3 > 0 \), the environmental degradation cost presents positive N-type. Moreover, \( E_u \) changes as \( Y_0 \) changes in formula (2).

3.3. Remote Sensing Based Ecological Index (RSEI)
The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations. RSEI is a method for assessing the state of the ecological environment in a local area. It includes Greenness (NDVI), Humidity (Wet), Heat (LST) and Thousands (NDSI). We used vegetation index,
humidity component, surface temperature and bare soil index for the four indicators above. The formula is as follows:

$$RSEI = \frac{(RSEI_{0} - RSEI_{0_{-min}})}{(RSEI_{0_{-max}} - RSEI_{0_{-min}})}$$

According to formula (3), we can measure the environmental quality of a specific area over a period of time and arbitrarily adjust its scope of application. The high correlation between RSEI and various indicators can be used to reflect the environmental quality of the region comprehensively.

3.4. Data Selection
This article is available for download at the geospatial data cloud site (http://www.gscloud.cn). The Landsat8 OLI image (spatial resolution: ) of the Beijing-Tianjin-Hebei urban agglomeration in 2015 was taken as the main data source and combined with a field survey and relevant historical data. With the support of ArcGIS 10.2, the land use data of the Beijing-Tianjin-Hebei urban agglomeration in 2015 were obtained by artificial visual interpretation of the research area. The land use types interpreted include woodland, grassland, water area, cultivated land, artificial surface, and unused land. Since the following estimation of ecosystem service value of Beijing-Tianjin-Hebei urban agglomeration is based on raster data, the interpreted land use data is rasterized first, and the raster size is determined as . Besides, the grain statistics used in the estimation of ecosystem service value of the Beijing-Tianjin-Hebei urban agglomeration in 2015 were obtained from “China grain yearbook 2016”.

3.5. Determination of Equivalent Factor Table of Ecosystem Service Value Per Unit Area in Beijing-Tianjin-Hebei Urban Agglomeration
In 2015, per unit area, ecosystem service value with Chinese characteristics had been proposed. The secondary classification of the scale of the ecological system is carried out, divided into 14 types, including dry land, paddy field, coniferous forest, needle broad-leaved mixed forest, broad-leaved forest, steppe, scrub-grassland, meadow, wetland, desert, bare land, drainage, and glacier snow. According to the determined in this paper, in the ecosystem services value equivalent factor tables, the secondary ecosystem classification of 14 types should be matched with the six kinds of land use type. However, the value of artificial surface ecosystem services is not considered here. The equivalent factor table of ecosystem service value per unit area of Beijing-Tianjin-Hebei urban agglomeration (Table I) was generated. In this table, the economic value of 1 hm2 national average farmland natural grain yield per year is defined as the value of 1, and the equivalent factor of other ecosystem service values refers to the contribution of ecological services generated by this ecosystem to farmland food production services. Due to the lack of systematic research data on the function and value of marine ecosystem services, marine ecosystems have not been included in this study.
Table 1. Ecosystem service equivalent value per unit area of Beijing-Tianjin-Hebei Urban Agglomeration in 2015

| Ecosystem service                     | Ecosystem types          | Forest | Grassland | Water | Farmland | Artificial surface | Unused land |
|---------------------------------------|--------------------------|--------|-----------|-------|----------|--------------------|-------------|
| Supply service                        |                          |        |           |       |          |                    |             |
| Food Production                       |                          | 0.23   | 0.23      | 0.74  | 1        | 0.00               | 0.02        |
| Raw material production               |                          | 0.53   | 0.34      | 0.28  | 0.39     | 0.00               | 0.02        |
| Water supply                          |                          | 0.27   | 0.19      | 7.15  | -0.03    | 0.00               | 0.01        |
| Regulat-ory service                   |                          |        |           |       |          |                    |             |
| Gas conditioning                      |                          | 1.75   | 1.21      | 1.00  | 0.68     | 0.00               | 0.09        |
| Climate regulation                    |                          | 5.24   | 3.19      | 2.55  | 0.36     | 0.00               | 0.2         |
| Clean environment                     |                          | 1.56   | 1.05      | 5.16  | 0.1      | 0.00               | 0.15        |
| Hydrologic regulation                 |                          | 3.85   | 2.34      | 86.64 | 0.32     | 0.00               | 0.17        |
| Support service                       |                          |        |           |       |          |                    |             |
| Soil conservation                     |                          | 2.13   | 1.47      | 1.21  | 1.01     | 0.00               | 0.11        |
| Maintain nutrient cycle               |                          | 0.16   | 0.11      | 0.09  | 0.12     | 0.00               | 0.01        |
| Biodiversity                          |                          | 1.94   | 1.34      | 3.61  | 0.13     | 0.00               | 0.01        |
| Cultural service                      |                          | 0.85   | 0.59      | 2.46  | 0.06     | 0.00               | 0.05        |

3.6. Determination of Ecosystem Service Value of 13 Cities in Beijing-Tianjin-Hebei Area

The economic value of food production and service per unit area of farmland in the Beijing-Tianjin-Hebei urban agglomeration was determined by referring to the sown area per unit yield of grain crops in Beijing, Tianjin and Hebei province in 2015 in the "China grain yearbook 2016" and the corresponding national average price:

$$E_a^{(i)} = \frac{1}{7} \sum_{i=1}^{n} s_i p_i q_i (i = 1, \cdots, n)$$

where the economic value (yuan /hm²) of food production and service function provided by $E_a^{(i)}$ for farmland ecosystem per unit area in the time $t$, $i$ is the species of food crops in the research area. The main crops in the Beijing-Tianjin-Hebei urban agglomeration are rice, wheat, corn, and soybean. $n$ is the typical food crop species in the study area, where $n=4$; $S_i$ is the planting area (hm²) of the $i_{th}$ grain crop in the research area. $S$ is the total planting area (hm²) of $n$ food crops. $p_i$ is the national average price of grain crop $i$ (yuan/kg); $q_i$ refers to 1/7 of the yield per unit area (kg/hm²) of grain crop $i$, indicating that the economic value provided by natural ecosystem without human input is 1/7 of the economic value of food production services offered by existing farmland per unit area.

According to the economic value of farmland food production and service per unit area in the Beijing-Tianjin-Hebei urban agglomeration, the ecological service value per unit area of other ecosystems in the Beijing-Tianjin-Hebei urban agglomeration was determined, and the total value of ecosystem services in the Beijing-Tianjin-Hebei urban agglomeration was estimated based on the area of various ecosystems. The calculation formula is as follows:

$$E_{ij}^{(i)} = f_{ij}^{(i)} E_a^{(i)} (i = 1, 2, \cdots, 6; j = 1, 2, \cdots, 11; t = 2015)$$

$$ESV^{(t)} = \sum_{i=1}^{6} \sum_{j=1}^{11} f_{ij}^{(i)} E_{ij}^{(i)}$$

According to formula (5), where $E_{ij}^{(i)}$ is the service value of ecosystem type $j$ corresponding to ecosystem type $i$ in unit area(yuan/hm²) in the time $t$; $f_{ij}^{(i)}$ is the equivalent factor of ecosystem service value of ecosystem type $j$ corresponding to ecosystem type $i$ in the time $t$; $i$ is six ecosystem types; $j$ is the ecosystem service function type in Table I, including food production, raw material production, water supply, gas regulation, climate regulation, and purification. There are 11 kinds of landscape, including environment, hydrological regulation, soil conservation, nutrient cycling, biodiversity, and
aesthetics. ESV is the total value of ecosystem services in Beijing-Tianjin-Hebei urban agglomeration (yuan); $A_i$ is the area of ecosystem type $i$ (hm$^2$).

To verify whether the equivalent factors determined in this paper are suitable for the ecosystem service function of each kind of ecosystem in Beijing-Tianjin-Hebei region, the concept of elasticity coefficient in economics is used to verify the sensitivity $CS$ of ESV to six ecosystem value coefficients $E_i$. The dependence of total ecosystem service value on ecosystem service value coefficient was determined by adjusting the ecosystem service value coefficient of forest land, grassland, water area, cultivated land, artificial surface and unused land by 50%.

$$CS = \left| \frac{(ESV^{(t)} - ESV^{(l)}) / ESV^{(l)}}{(E_i^{(l)} - E_i^{(l)}) / E_i^{(l)}} \right|$$

where $CS$ is the sensitivity coefficient, $ESV^{(l)}$ and $ESV^{(t)}$ are the total value of ecosystem services before and after adjustment, $E_i^{(l)}$ and $E_i^{(l)}$ are the six ecosystem services value coefficients before and after adjustment, and $i$ is the six ecosystem types.

4. Experiment

We will substitute the existing data into the above calculation model and method, and the final result can show the service value of the specific ecological environment.

4.1. Determination of Value Coefficient of Ecosystem Services

Based on the grain statistics of Beijing, Tianjin, and Hebei in 2015, the economic value of an equivalent factor of ecosystem service value was determined by formula (3) to be 1766.10 yuan/hm$^2$. According to the formula (4), the value coefficient of each ecosystem service type per unit area can be determined (Table II). Combined with the area of different ecosystem types, the ecosystem service value in Beijing-Tianjin-and-Hebei region can be estimated.

4.2. Ecosystem Service Value Coefficients Prefecture-level Cities

Thirteen prefecture-level cities in the region were respectively analyzed in this subsection; the results are shown in Table III.

**Table 2. Ecosystem service value coefficients of Beijing-Tianjin-Hebei urban agglomeration**

| Ecosystem service | Ecosystem types | Forest | Grassland | Water | Farmland | Artificial surface | Unused land |
|-------------------|-----------------|--------|-----------|-------|----------|-------------------|-------------|
| Supply service    | Food Production | 406.20 | 406.20    | 1306.91 | 1766.10  | 0.00              | 35.32       |
|                   | Raw material production | 936.3 | 600.47    | 494.51 | 688.78   | 0.00              | 35.32       |
|                   | Water supply    | 476.85 | 335.56    | 12627.62 | -52.98   | 0.00              | 17.66       |
| Regulatory service| Gas conditioning | 3090.68 | 2136.98   | 1766.10 | 1200.95  | 0.00              | 158.95      |
|                   | Climate regulation | 9254.36 | 5633.86   | 4503.56 | 635.80   | 0.00              | 353.22      |
|                   | Clean environment | 2755.12 | 1854.41   | 9113.08 | 176.61   | 0.00              | 264.92      |
|                   | Hydrologic regulation | 67994.9 | 4132.67   | 153014.90 | 565.15   | 0.00              | 300.24      |
| Support service   | Soil conservation | 3761.79 | 2596.17   | 2136.98 | 1783.76  | 0.00              | 194.27      |
|                   | Maintain nutrient cycle | 282.58 | 194.27    | 158.95 | 211.93   | 0.00              | 17.66       |
|                   | Biodiversity    | 3426.23 | 2366.57   | 6375.62 | 229.59   | 0.00              | 88.31       |
| Cultural service  | Aesthetic landscape | 1501.19 | 1042.00   | 4344.61 | 105.97   | 0.00              | 88.31       |

For 13 prefecture-level cities of Beijing-Tianjin-Hebei urban agglomeration, the total value of ecosystem services varies greatly. Among them, Chengde City and Zhangjiakou City have higher total value of ecosystem services, accounting for 10.92 billion yuan and 65.60 billion yuan respectively,
accounting for 24.03% and 14.43% of the total value of ecosystem services in 13 cities, which is not only related to the larger area of these two cities but also the land use situation of the two cities and their surrounding areas. For Chengde City, because there are large areas of forest land in and around the city, the total value of ecosystem services provided by single ecosystem services of forest land reaches 94.35 billion yuan, which is far greater than that of other cities; for Zhangjiakou City, the large area of grassland and good land use conditions around the city also ensure the validity of ecosystem services in the region. Secondly, Beijing and Tianjin, as municipalities directly under the Central Government, share ecosystem services with the surrounding cities because of their unique geographical location, so the total value of ecosystem services they actually enjoy is also high, reaching 45.31 billion yuan and 37.87 billion yuan, respectively, while the value of ecosystem services in Beijing mainly comes from forest land. To 33.28 billion yuan, while Tianjin is close to the Bohai Bay and contains a large area of wetlands, the value of ecosystem services provided by the waters is 33.83 billion yuan. Among the other cities, Tangshan City and Baoding City, which are 41.80 billion yuan and 38.29 billion yuan respectively, are similar to the total value of ecosystem services obtained by Beijing and Tianjin City. However, the total value of ecosystem services actually obtained by other cities is relatively small, accounting for no more than 7.00% of 13 cities.

Table 3. Ecosystem service value coefficients of Beijing-Tianjin-Hebei urban agglomeration

| Prefecture Level Cities | Ecosystem types | Support service | Total |
|-------------------------|----------------|----------------|-------|
|                         | Supply service | Regulatory service | Cultural service |       |
| Beijing                 | 28.67          | 317.66          | 87.75  | 19.09 | 453.18 |
| Tianjin                 | 44.93          | 298.02          | 27.79  | 7.97  | 378.71 |
| Shijiazhuang            | 24.85          | 186.07          | 56.62  | 11.16 | 278.72 |
| Baoding                 | 41.96          | 241.46          | 85.76  | 13.77 | 382.95 |
| Cangzhou                | 37.14          | 183.04          | 31.02  | 5.24  | 256.45 |
| Chengde                 | 72.65          | 712.35          | 260.08 | 47.05 | 1092.13|
| Handan                  | 21.59          | 69.27           | 26.45  | 3.66  | 120.97 |
| Hengshui                | 16.85          | 56.94           | 29.24  | 2.20  | 105.23 |
| Langfang                | 11.58          | 43.97           | 16.63  | 1.68  | 73.86  |
| Qinhuangdao             | 14.98          | 124.94          | 35.44  | 6.81  | 182.16 |
| Tangshan                | 37.43          | 322.78          | 46.61  | 11.23 | 418.05 |
| Xingtai                 | 21.64          | 82.06           | 37.68  | 4.99  | 146.38 |
| Zhangjiakou             | 67.27          | 420.07          | 142.09 | 26.59 | 656.01 |
| Total                   | 441.54         | 3058.64         | 883.16 | 161.46| 4544.81|

5. Conclusion

Our self-built environmental cost-benefit model has been established, which can predict and analyze the real benefits of environmental costs, including environmental degradation costs, by substituting existing or simulated data. This model can also better help the government and project developers to make proper use of the environment and maintenance. Besides, our model has many advantages that existing environmental analysis models do not. Firstly, our model is based on EKC theory and ESV model to calculate the analysis results, with a high degree of rigor. Secondly, our model is time-sensitive and can be applied to different scale land projects. Thirdly, our model analysis environment is more detailed and precise through the data analysis of the RSEI model and our ecosystem service value assessment is matched with the latest data, indicating that our model is reasonable and adequate.

6. References

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