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Assessment of the Value of Ecosystem Services

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Abstract. To some extent, land use project implementation influences ecosystem. Although these projects may seem inconsequential to the total ability of the biosphere's functioning potential, cumulatively they are causing environmental degradation, thus imposing some environmental costs on land use projects. In order to take into account the impact of environmental degradation in land use project costs, our ecosystem service evaluation model is established to assess environmental costs and obtain the true economic costs of land use projects. The ecosystem of the land use project region is divided into 7 types. Furthermore, the ecosystem services are classified into 6 parts. We evaluate ecosystem services of various land use types and obtain the total value by adding these ecosystem services. The environmental costs of land use projects can be calculated as the absolute value that ecosystem services before and after the land use project implementation minus each other. The true economic costs is the sum of environmental costs and build costs.Last, we studied the effect of time on the model. Take the Three Gorges Reservoir Area (Chongqing Section) as an example. We find that the value of ecological services will decrease over time in a certain period of time, and will also increase the real economic cost of land use projects.

Keywords: Ecosystem Services Evaluation Model; Environmental Degradation; Benefit-cost; Linear weighting.

1. Introduction

Typically, economic theory ignores the effect of its decision making on the biosphere, and even the neglected the unrestricted resources and capability that the biosphere can provide for its demands. An originally developed biosphere has the ability to provide ecosystem services such as transforming carbon dioxide into oxygen and purifying water.[1] However, these ecosystem services may possibly be restricted or even eliminated whenever human beings change the ecosystem. For instance, a few small-scale variations in land use even after incorporated with small projects and large ones including constructing bridges or building a pipeline across the country, may influent ecosystem services a little in terms of a region, country and the world within a short time. But over time, these variations have a direct impact on biodiversity and contributing to environmental degradation.

There are few studies on the cost of land development projects at home and abroad, and most of them do not consider environmental costs. For the study of ecosystem service value assessment, it has been international for more than 40 years. Energy-based analysis, such as Constanza, examines the value of ecosystem services.[2] In recent years, research in this area has become a hot spot in environmental economics and ecological economics, and of course, has achieved remarkable results. Domestic Xie G [3]and others have improved the research results of Constanza, but it emphasizes and evaluates the value of utilization, and reveals the value of ecosystem services is not comprehensive enough.[4] There is no research on ecosystem services and natural costs, whether domestic or foreign. There are few studies on the relationship between ecosystem service value and land use.

We divide the project area ecosystem of the land use project into seven ecosystems. In the division of ecosystem functions, we divide the ecosystem service functions into six parts.[5] The ecological service value of different land use types is comprehensively considered, and the total ecological service value is obtained. Then, we factor the ecosystem services into the cost-effectiveness of land-use projects and integrate the environmental costs and construction costs to get the real economic costs of land development and utilization. The applicability and accuracy of our model were verified by evaluating the ecological service value of land projects of different scales. Finally, we also studied the relationship between time and the value of ecosystem services.

2. Ecosystem Services Evaluation Model

In Land Economics theory, land use planning projects contain multiple land use types. We divide the ecosystem in the land use project region into 7 types, including forestland, farmland, transportation land, water area, grassland, city and industrial land and other land.

Based on the research of Costanza and Xie G [3] et al. in the aspect of the ecosystem service evaluation, ecosystem services in land use projects are classified into 6 parts, including air regulation, climate regulation, water conservation regulation, disturbance regulation, support services and cultural services.

We improve the research findings of Costanza and Xie G et al. and establish our ecosystem service evaluation model. The ecosystem service evaluation formula is illustrated as follows.

$$ESV_j = \sum_{j=1}^{m} P_j A_j \tag{1}$$

$$ESV_l = \sum_{j=1}^{m} \left(P_j \times A_{lj} \right) \tag{2}$$

Where j denotes data type in land use project region. P_j denotes area of land use type and its unit is hm^2. A_j denotes ecosystem services value per unit area, while A_{ij} denotes single ecosystem services value per unit area, and their units are USD/hm^2. ESV_j denotes total value of the ecosystem service in land use project region, while ESV_i denotes single value of the ecosystem service in land use project region and their units are *USD*.

The ecosystem services are restricted or even eliminated after the implementation from the land use project region. The land use project region yet cause environmental degradation, further generating negative costs.[6] This is due to the impact of land use project on the ecosphere of the land use project region.

Thus, the environmental cost produced in land use project region is calculated as follows.

$$EC = ESV_{l(later)} - ESV_{l(before)} \tag{3}$$

Where *EC* denotes the environmental cost produced in land use project region and its unit is *USD*.

Based on the cost calculation relation of land use projects in the book named *Land Economics*, we also take environmental cost into account. Therefore, the true economic cost of land use project is calculated as follows.

$$TC = BC + EC \tag{4}$$

Where *TC* denotes the true economic cost of land use project and *BC* denotes the build cost of land use project.

3. The Effectiveness of Our Model

In order to verify the effectiveness of our model, we randomly select a small community-based project, the Nanhu administrative region land use planning project in Xuancheng city, and a large national one, the Three Gorges reservoir land use planning project in the independent municipality of Chongqing.

3.1 Nanhu Administrative Region Land Use Planning Project

We search the relevant land planning data of Nanhu administrative region in Xuancheng city from the *Thematic Database for Human-earth System*.[7] We apply the data in the formula (1) and (2). Then the single ecosystem services value of various land use types can be obtained, as is shown in Table 1.

Table 1. Ecosystem services value of Nanhu administrative region (*USD*)

Land use type	Before the land use project implementation		After the land use project implementation	
	$ESV_{l(before)}$	Proportion	$ESV_{l(after)}$	Proportion
Forestland	2231893.035	24.28%	2302673.827	25.05%
Farmland	2685073.951	29.21%	2813766.301	30.61%
Transportation land	1054358.036	11.47%	1139846.525	12.4%
Water area	909119.527	9.89%	776750.253	8.45%
Grassland	8466.814	9.21%	734465.624	7.99%
City and industrial land	1403665.842	15.27%	1405504.304	15.29%
Other land	61588.48	0.67%	19303.85	0.21%
Total	9192310.686	100%	9156994.590	100%

From the Table 1, total values of ecosystem service before and after the land use project implementation of Nanhu administrative region are obtained as follows. $ESV_{l(before)}$ = 9192310.686 *USD* and $ESV_{l(after)}$ = 9156994.5906 *USD*. The economic cost is attained as follows from the formula (3). *EC* = 35316.0954 *USD*.

Based on the framework for economic impact analysis and cost benefit analysis released by *Marsden Jacobs Institue*, we analyze environmental benefit and cost of Nanhu administrative region, and find that its environmental benefits far outweigh its environmental costs. However, environmental degradation is caused after the Nanhu administrative region land use project implementation, which in a way increases economic costs of land use. Hence, our ecosystem service evaluation model proves to be effective for small community-based projects.

3.2 The Three Gorges Reservoir Area Land Use Planning Project

From the *Thematic Database for Human-earth System*,[7] we obtain relevant data about the Three Gorges reservoir area land use planning project in from 2000 to 2010. We apply the data in the formula (1) and (2). Then the single ecosystem services value of various land use types can be obtained, as is shown in Table 2.

Table 2. Ecosystem services value of the Three Gorges reservoir area (*USD*)

Land use type	Before the land use project implementation		After the land use project implementation	
	$ESV_{l(before)}$	Proportion	$ESV_{l(after)}$	Proportion
Forestland	5.62×10^9	61.38%	5.81×10^9	63.52%
Farmland	2.02×10^9	22.08%	1.94×10^9	21.28%
Transportation land	1.8×10^8	0.02%	1.831×10^8	0.02%
Water area	3.601×10^8	4.04%	4.972×10^8	5.43%
Grassland	2.02×10^8	9.95%	1.13×10^8	7.79%
City and industrial land	1.728×10^9	1.86%	1.602×10^9	1.75%
Other land	7.31×10^8	0.67%	6.921×10^8	0.21%
Total	1.3981×10^{10}	100%	1.3923×10^{10}	100%

From the Table 2, total values of ecosystem service before and after the land use project implementation of the Three Gorges reservoir area are obtained as follows. $ESV_{l(before)} = 1.3981\times10^{10}$ *USD* and $ESV_{l(after)} = 1.3923\times10^{10}$ *USD*. The economic cost is attained as follows from the formula (3). $EC = 5.8\times10^7$ *USD*.

Based on the framework for economic impact analysis and cost benefit analysis released by *Marsden Jacobs Institue*, [8] we analyze environmental benefit and cost of the Three Gorges reservoir area, and find that its environmental benefits far outweigh its environmental costs. However, environmental degradation is caused after the Nanhu administrative region land use project implementation, which in a way increases economic costs of land use. Hence, our ecosystem service evaluation model proves to be effective for small community-based projects.

As disscussed above, we draw a conclusion that our model is effective and applicable to land use projects of varying size.

4. The Relational Expression about Time and Ecological Services

Considering the impact of time on our ecological services model, we first establish the relational expression about time and ecological services as follows.

$$ESV = ESV_{l(begain)} + EC \times \frac{\lambda}{1-e^{-t}} \tag{5}$$

Where ESV denotes ecosystem services value considering the time factor. $ESV_{l(begin)}$ denotes the initial ecosystem services value. λ denotes the time coefficient. t denotes the time during land use project implementation.

λ varies as land use project differs. [9]Still take the Three Gorges reservoir area as an example, we utilize Matlab software to obtain the change curve of single ecosystem services value and total ecosystem serves value over time. The change trend of ecosystem services evalution value model, based on the example of the Three Gorges reservoir area, can be obtained and illustrated in Fig.1 and Fig.2.

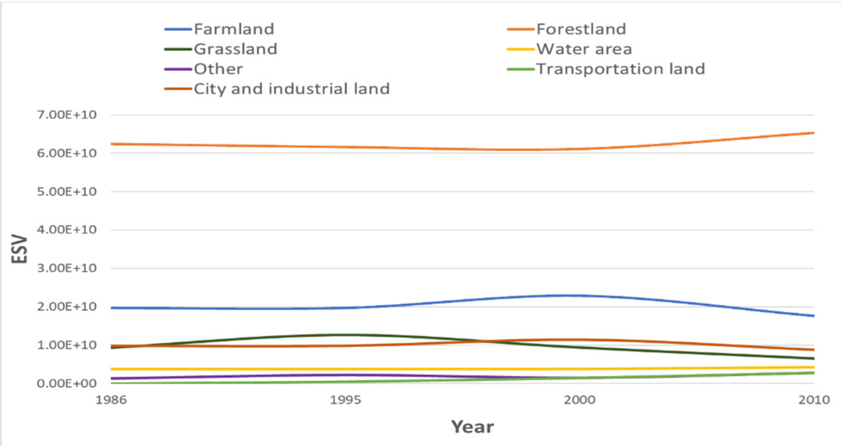

Fig.1 The change curve of single ecosystem services value over time.

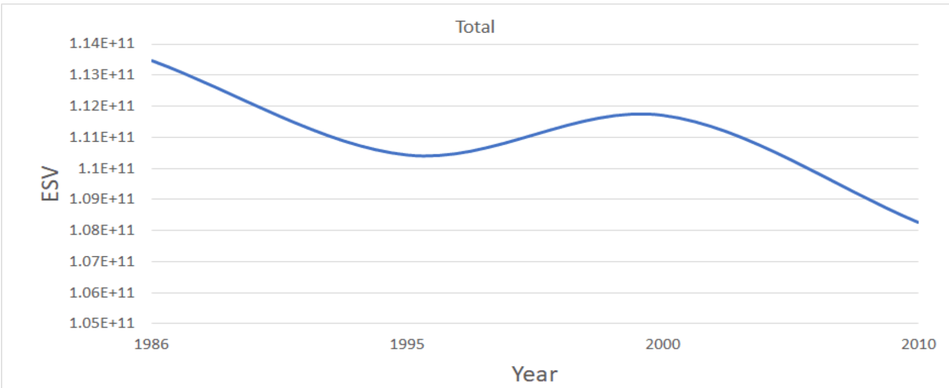

Fig.2 The change curve of total ecosystem services value over time.

As Fig.1 and Fig.2 show, ecological services decrease while ecosystem services value of diverse land use types varies over time. Some details are illustrated as follows. Farmland ecosystem services value increases with time at the beginning. Then, its value gradually decreases due to soil loss. Forestland and grassland services value rise over time but in the later period decelerate. Value of transportation land, water area, city and industrial land and other land are going down but also in the latter stage slow down.

As discussed above, we draw a conclusion that ecosystem services values decrease over time and their spatial distributions are also transferring.

5. Conclusion

Since a land use planning project contains multiple land use types, we will classify the ecosystem based on various ways of land use in this article. We improve the evaluation model of ecosystem services proposed by Costanza in 1997 based on social stage development coefficient, and establish a novel one.[10] Then, we calculate the total value of ecosystem services before and after the implementation from the land use project region. The absolute value they minus each other refers to the environmental cost required for the land use project. The environmental cost plus the construction cost equals the true economic costs of the land use projects. Lastly, we use Matlab software to attain the relationship between the change varying from each single ecosystem services value and the change varying from the total value, and determine the change curve graphs. We can analyze the time-dependent effectiveness of the relational expression and the time-varying change trend of our model based on the change curves of ecological service evaluation value over time for land use projects of varying sizes.

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