A Cost-Benefit Analysis Model Based on NPV Methods and Full Life Cycle of Land Use Projects

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Abstract. If you realize that your sweet house will damage the ecosystem, you must be amazed. In fact, most land use projects around us affect ecosystem services directly and even result in environmental degradation. The environmental cost has caused a reduction in economic benefits presumably, nonetheless, which has never attracted enough academic attention. To show the real economic cost of land use projects, we establish an ecological services valuation model based on the governance cost method. When assessing the environmental costs caused by pollution, we evaluate the paid economic costs for the pollution control and the virtual cost that should have been paid for pollution abatement. When assessing the costs caused by non-pollution factors, we compute the economic value of regional ecosystem service value according to Costanza indicator system and the value of localized carbon storage and carbon sequestration based on the INVEST model.

1. Introduction

With acceleration of global urbanization and industrialization, people have paid excessive attention to economic benefits, so some of them exploit land resources immoderately and even alter the ecosystem by building various land use projects such as houses, factories and waterways across the country. Irrational human activities result in desertification, water pollution and even environmental degradation, which damage sustainable utilization of the natural resources severely. Unfortunately, these environmental costs are often overlooked and excluded from economic costs of land use projects by most project planners. We should regard the improvement of ecological environment as a crucial indicator for evaluating land use projects and complete a perfect evaluation system of land utilization. We should develop an ecological services valuation model to analyse the actual economic costs and benefits of land use projects.

2. The Ecological Service Evaluation Model

To describe the real economic cost of land use projects, we consider the impact of ecosystem services and establish an ecological service evaluation model composed of 3 kinds of cost, separately caused by environmental pollution, other non-pollution factors and construction cost.

2.1. Local Assumption

- All contaminants can be completely removed.
2. The virtual unit governance cost is consistent with the actual unit governance cost.
2. When calculating virtual governance costs, we only consider influence of pollutant emissions and do not consider the influence of substandard emissions.
2. Construction work will result in the destruction of all carbon storage on the land area where the project proceeds.
2. This model explores the terrestrial ecosystem.

2.2. Basic Model

To evaluate the economic cost of land use project roundly, we build the main model composed of 3 elements, involving 3 kind of possible costs in actual land use project:

\[
\text{Cost} = C_1 + C_2 + C_{\text{eng}}
\]  

(1)

Where cost is the total economical cost of land use project, \(C_1\) is the cost caused only by environmental pollution, \(C_2\) is the cost caused by other environmental factors except pollution, and \(C_{\text{eng}}\) is the construction cost (material costs, labor costs, design costs, construction costs) of the specific project, which is a specific digit corresponding the specific project, which is easy to judge so we do not mention it repeatedly. We will present the details of derivation procedures of \(C_1\) and \(C_2\).

2.2.1. The Calculation of Environmental Pollution Loss Cost. We focus on the costs of pollution harness to estimate the total cost and assume that the environmental pollution loss cost has two parts including realistic pollution control cost and virtual pollution control cost.

The realistic pollution control cost means that the actual expenditure incurred in pollution control process in all regions. Government environmental protection departments publish the data every year. The virtual pollution control cost means that a part of pollutants are not treated timely or given substandard treatment only, which causes environmental degradation. In order to help the environment recover to its prior level, people should pay the virtual pollution control cost but they do not actually. After calculating the unit cost of pollutant treatment, we multiply it by the amount of pollutants and get the virtual pollution control cost.

The total environmental pollution loss cost composed of realistic pollution control cost and virtual pollution control cost, so we separately calculate realistic pollution control cost and virtual pollution control cost, then add them up to attain the total cost.

We multiply the unit cost of pollutant treatment by the amount of pollutants and get the virtual pollution control cost:

\[
C = \sum_{i=1}^{n} \tilde{C}_i Q_i
\]  

(2)

Where \(C\) is the virtual pollution control cost. \(\tilde{C}_i\) is the unit cost of pollutant treatment, \(Q_i\) is the amount of pollutants. In reality, total emissions are often difficult to measure accurately so the amount of untreated pollutant emissions are hard to measure, so we assume that \(Q_i\) is the amount of all untreated pollutants emissions.

In pollution control, there is always a treatment method able to control several kinds of pollution caused by various pollutants. For example, the development of new energy can not only control the air pollution, but also curtail the solid waste pollution. Therefore, we subtract the repetitive treatment cost from the original equation:

\[
C_1 = k_{\text{real}} + \sum_{i=1}^{n} \tilde{C}_i Q_i - \sum_{1 \leq a < b \leq n} \lambda_b \tilde{C}_a \bar{C}_b Q_a
\]  

(3)

Where \(C_1\) is the environmental pollution loss cost, \(k_{\text{real}}\) is the realistic pollution control cost, \(\tilde{C}_i\) is the unit cost of each pollutant, \(Q_i\) is the emission of each pollutant (\(i\) is the category of each pollutant).
λ_b is the ratio of repetitive treatment cost to the total environmental pollution loss cost. \( C_a, C_b \) is the unit treatment cost of two kinds of pollutants respectively.

(1) The Unit Cost of Each Pollutant

Now we build a model to measure the unit cost of each pollutant:

\[
\tilde{C}_i = \frac{C_i}{(I_i - E_i) + M}
\]  

Where \( \tilde{C}_i \) is the unit cost of each pollutant, \( M \) is the total residue of pollutants, and \((I_i - E_i) * M\) is the removal amount of the pollutant \( i \).

To investigate the model more easily, we convert it to a simple form:

\[
\hat{C}_i = \frac{C * I_i}{S_i * M * \sum_{i=1}^{n} \left( \frac{I_i - E_i}{I_i} \right)}
\]  

2.2.2. The Calculation of Non-Pollution Loss Cost. We build a model to estimate external economic costs caused by Non-Pollution factors poisoning the environment, which involves two variables:

\[
C_2 = value_{seq} + \Delta costanza_E
\]  

Where:
- \( C_2 \) is the total cost caused by non-pollution factors poisoning the environment
- \( value_{seq} \) is the value of carbon storage and sequestration in the construction region
- \( \Delta costanza_E \) is the ecosystem services value of the specific area

(1) A Model Based on Costanza Index System

Constructing land use projects on a particular piece of land will change its current land type. Different kinds of land have different ecosystem service values. The transformation of land type will result in the change of ecosystem services in the area. To measure this change, we choose the Costanza index system, which can quantify and simplify ecosystem service values by producing Ecological Value Coefficients and estimate different kinds of land types’ value in all kinds of ecological functions.

We calculate the land’s ecosystem service value and achieve difference, then we quantify the ecological value’s degree of damage in the land into economic data and compare the condition before the land use project constructed and the condition after that.

The formulation of the model based on Costanza index system is:

\[
\Delta costanza_E = \sum_{a=1}^{n} kP_a S_a - \sum_{a=1}^{n} kP_b S_a
\]  

Where:
- \( \Delta costanza_E \) is the total variation of regional ecosystem service value
- \( k \) is the ratio of Regional Correction coefficient to Biomass Factors of Cropland Ecosystem.
- Because the size of ecosystem service functions is closely related with biomass of the ecosystem, different regions have different unit prices of ecosystem service value. So we multiply the value coefficient by regional Correction coefficient, then we will get a regional corrected number of value coefficient.
- \( S_a \) is the acreage of land use type A
- \( P_a \) is the land use type A’s Ecosystem service Value Coefficients of per unit area
- \( P_b \) is the land use type B’s Ecosystem service Value Coefficients of per unit area

(2) A Model Based on the Value of Carbon Storage and Sequestration

The carbon cycle means that the flow of carbon elements around the biosphere, the lithosphere, the soil circles and the atmosphere, describing the circulation and reuse of the carbon element on the earth.
Terrestrial ecosystems, which store more carbon than atmospheric, have a crucial impact on climate change driven by carbon dioxide. We can see that not only large-scale national projects but also small residential projects, have destructive influence on carbon storage environments of local original landscapes. The social value of tons of isolated carbon equals social damage caused by avoiding releasing large amounts of carbon into the atmosphere.

Based on the assumption that construction work will result in the destruction of all carbon storage on the land area where the project proceeds, we involve the carbon storage and carbon sequestered value of the original land into the total cost.

Based on the INVEST Model, we use carbon storage in land and four carbon pools (overground biomass, underground biomass, soil and dead organic substance), mainly to estimate current carbon storage in landscape or increased carbon volume over time. Then we refer to market data, social value, currency discount rate and annual rate of carbon change to estimate the carbon storage value and carbon sequestered value in a certain area:

\[
\text{value}_{\text{seq}} = V \times \text{sequest}_x
\]

Where:
- \( V \) is the currency price of carbon per metric ton (not \( CO_2 \)), which is 130 dollars currently. We estimate \( V \) base on an equation, where we subtract the carbon social cost from the carbon damage cost additionally.
- \( \text{sequest}_x \) is the carbon sequestration in certain area:

\[
\text{sequest}_x = \sum (C_{\text{above}} + C_{\text{below}} + C_{\text{soil}} + C_{\text{dead}})
\]

- \( C_{\text{above}} \) is the carbon density of overground biomass
- \( C_{\text{below}} \) is the carbon density of underground biomass
- \( C_{\text{soil}} \) is the carbon density in soil
- \( C_{\text{dead}} \) is the carbon density in dead organic substance

(The unit of above-mentioned four equations is mega-grams/hectare)

3. Discussion and Conclusion

We establish a comprehensive ecological services valuation model to show the real economic cost of land use projects.

What’s more, our model has strong flexibility. All of the parameters are relatively independent of one another. Thus it is easy to change metrics without making major changes to our model.

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