Estimating the Environmental Cost of Land Use Project

Jie Xue¹*, Wenfei Mu¹ and Qiong Wu¹

¹ Business School, Shandong Normal University, Jinan, Shandong, 250358, China
*Corresponding author’s e-mail: 18340088217@163.com

Abstract: Environmental degradation is becoming a worldwide problem. However, traditional economic theory often disregards the value of environment in decision making, and the development of land use project usually ignore their damage on the land. As a result, a model needs to be proposed to calculate the cost of environment. We construct an environmental cost evaluation index system for land development projects, in order to calculate the cost of land resources loss. The land resources loss is caused by the destruction of the original land, we analyse it from the value that the land has, including land products value and ecological value. The project pollution cost is resulted from the various pollution that the projects produce after construction, we calculate the pollution treatment cost to estimate the pollution. Moreover, our model can be adjusted to the change of time easily, as we use many constants, such as prices of products and unit grain yield.

1. Introduction
Economic theory often disregards the impact of its decisions on the biosphere or assumes unlimited resources or capacity for its needs. There is a flaw in this viewpoint, and the environment is now facing the consequences. The biosphere provides many natural processes to maintain a healthy and sustainable environment for human life, which are known as ecosystem services[1]. Examples include turning waste into food, water filtration, growing food, pollinating plants, and converting carbon dioxide into oxygen. However, whenever humans alter the ecosystem, we potentially limit or remove ecosystem services. The impact of local small-scale changes in land use, such as building a few roads, sewers, bridges, houses, or factories may seem negligible. Add to these small projects, large-scale projects such as building or relocating a large corporate headquarters, building a pipeline across the country, or expanding or altering waterways for extended commercial use.

These environmental externalities can increase the economic budget of land use projects, but when the environmental costs can be evaluated more accurately, they can be internalized by improving the technological level, for example, by developing green buildings[2]. Therefore, assessing environmental costs is important both for better planning of economic activities and for implementing more effective land development strategies to mitigate environmental degradation.

2. Measurement of environment cost
In valuing the environment cost, we consider two part: cost of land resource loss[3] and project pollution[4]. Land use projects destroy the original ecosystem on the land and its value will lose, so we regard the value that the ecosystem originally has as one part of projects cost; projects also generate some pollution after construction, and we represent this pollution cost with pollution treatment fees.

We use several ways to calculate the various values of different ecosystems. Three main methods are market value method[5], shadow engineering method[6] and carbon tax rate method[7]. We calculate
the value of ecosystem one by one, and they make up to the land resource loss cost. Then we calculate the cost of treating each type of project pollution, they make up to the total pollution cost. Cost of land resource loss and project pollution make up to the total environment cost.

2.1. Calculation of products value based on market value

Ecosystem produces some products, such as woods, fruits, and fish. They can be sold on the market and they all have market prices, so we can get their value through equation \(2.1\).

\[
V_{1i} = (1 + R) \times \left( V_{11}^{(a)} + V_{11}^{(a)} \right)
\]

\[
V_{1i}^{(a)} = \sum (P_{j}^{(a)} \times S_{j}^{(a)} \times E_{j}^{(a)}), i = 1, 4; j = 1, 2, \ldots n
\]

\(a\) is the total value of the products, \(R\) is the adjustment coefficient, \(V_{1i}^{(a)}\) is the value of the products produced by the No.i type of land. \(P_{j}^{(a)}\) is the market price of No.i type of products, \(S_{j}^{(a)}\) is the area of the type of land square, and \(E_{j}^{(a)}\) is the average yield.

For \(R\), it changes as the type of land changes. For example, the planting forest, then \(x\) is 10\%, because the percentage of the products that can be utilized by human directly is 10\%. Then \(R = (1 - x) / x = (1 - 10\%) / 10\% = 9\%\).

2.2. Calculation of ecological function

- Water storage value

In general, it is difficult to calculate the value of an ecosystem’s functions, while it is easy to calculate the cost of constructing a project with similar functions. Thus, we estimate an ecosystem’s value by calculating the cost of its replacement project. This is called shadow engineering method. Here, we use it to calculate the true value of the following formula:

\[
V_{21} = V_{21}^{(a)} + V_{21}^{(a)} + V_{21}^{(a)}
\]

\[
V_{21}^{(a)} = \left( H_{1}^{(a)} \times S_{1}^{(a)} \right) \times C_{21}, i = 2, 3, 4
\]

\(V_{21}\) is the total value of the water conserved by lands, \(V_{21}^{(a)}\), \(V_{21}^{(a)}\) and \(V_{21}^{(a)}\) is the water storage value of No. \(a_{1}\), No. \(a_{2}\), No. \(a_{3}\) type of land; \(H_{1}^{(a)}\) is the average volume of water conserved by this type of ecosystem, \(S_{1}^{(a)}\) is the area of the land, \(C_{21}\) is the cost of building a reservoir with the same volume of storage.

- Soil conservation value

Soil conservation value comprises of three parts: soil value, fertility holding value and silt preventing value. Therefore, the soil conservation value calculated by:

\[
V_{22} = \sum \left( V_{22}^{(a)} + V_{22}^{(a)} + V_{22}^{(a)} \right), i = 2, 3
\]

\(V_{22}^{(a)}\) is the value of soil conserved by No. \(a_{i}\) type of land; \(V_{22}^{(a)}\) is the value of fertility conserved by the type of the land; \(V_{22}^{(a)}\) is the value of silt prevention.

- Soil value:

\[
Q_{1}^{(a)} = S_{1}^{(a)} W_{1}^{(a)}
\]

\[
V_{22}^{(a)} = Q_{1}^{(a)} / h_{1}^{(a)} \times C_{1}^{(a)}
\]
$Q_{a_i}^{(3)}$ is the soil volume conserved by the No. $a_i$ type of land; $S_{a_i}^{(0)}$ is the area of land; $W_{a_i}^{(0)}$ is the depth of soil conserved; $h_{a_i}^{(0)}$ is the depth of the earthwork; $C_{a_i}^{(0)}$ is the cost of the earthwork for unit area.

- **Fertility conserved value:**
  
  \[
  V_{22}^{a_i} = (M_1 + M_2 + M_3 + M_4) \times S_{a_i}^{(0)} \\
  M_1 = C_1 \times E_1 \times D \times Q_1 \times S_1 \\
  M_2 = C_2 \times E_2 \times D \times Q_2 \times S_2 \\
  M_3 = C_3 \times E_3 \times D \times Q_3 \times S_3 \\
  M_4 = C_4 \times E_4 \times D \times S_4
  \]  
  \[\text{(2-5)}\]

  $M_1, M_2, M_3$ and $M_4$ is the value of retaining nitrogen, phosphorus, potassium and organic matters, $S_{a_i}^{(2)}$ is the total area of the No. $a_i$ type of land, $C_1 = C_2 = C_3 = 1 \times 10^{-6}, C_4 = 1 \times 10^{-3}$; $E_1, E_2, E_3$ and $E_4$ refers to the market price of Ammonium sulfate, superphosphate, potassium chloride and organic matter; $D$ is the amount of soil conserved; $Q_1$ is the coefficient of conversion of Alkali reduction of ammonia into ammonium sulfate. $Q_2$ refers to the coefficient of quick-acting phosphorus converted into superphosphate, $Q_3$ is the coefficient of quick-acting potassium converted into potassium perchlorate; $S_1, S_2, S_3$ and $S_4$ are the average contents of alkali-soluble nitrogen, available phosphorus, and available organic matter in soil, respectively.

- **Siltation prevention value**

  According to the regular pattern of silt movement, in China's major river basins, about 24% of the sediment lost by soil erosion is deposited in reservoirs, rivers or lakes. The value of desilting in reservoirs (rivers or lakes), as shown in formula (2-6).

  \[
  V_{22}^{a_i} = 24\% \times P_{a_i}^{(0)} \times C_{a_i}^{(0)}
  \]  
  \[\text{(2-6)}\]

  $V_{22}^{a_i}$ is the value of Siltation prevention of the No. $a_i$ type of land; $P_{a_i}^{(0)}$ is the amount conserved by No. $a_i$ type of land; $C_{a_i}^{(0)}$ is the dredging cost.

2.3. **Water storage and flood control value**

By using formula (2-7), we calculate the cost of building a reservoir with the same volume regulated by the wetland.

\[
V_{23}^{l} = H_{23}^{1} \times S_{23}^{l} \times C_{23}^{l}
\]  

\[\text{(2-7)}\]

$V_{23}^{l}$ is the value of the water storage and flood control of wetland; $H_{23}^{1}$ is the average water storage depth; $S_{23}^{l}$ is the total area of local reservoir; $C_{23}^{l}$ is the construction cost of reservoir per unit storage;

2.4. **Pollution purification value**

The pollution purification value consists of sulfur dioxide absorption value and dust purification value.

- **Sulfur dioxide absorption value**

  Ecosystems are able to absorb sulfur dioxide and industrial dust, we calculate the volume of sulfur dioxide absorbed and get the industrial cost of treating the same volume of sulfur dioxide.
\[ V_{24}^{(i)} = \sum (Q_{24}^{(i)} \times S_{24}^{(i)}) \times C_{24}^{(i)}, i = 2, 3 \]
\[ V_{24}^{1} = V_{24}^{a(1)} + V_{24}^{b(1)} \]

\( V_{24}^{1} \) and \( V_{24}^{2} \) are the absorbing sulfur dioxide value of forestry and grassland. \( Q_{24}^{b(1)} \) is the absorptive capacity of land to sulfur dioxide; \( S_{24}^{(i)} \) is the area of land; \( C_{24}^{(i)} \) is the cost of industrial process for reducing per unit of sulfur dioxide.

- **Dust purification value**

\[ V_{24}^{a(2)} = \sum (Q_{24}^{a(2)} \times S_{24}^{a(2)}) \times C_{24}^{a(2)}, i = 2, 3 \]
\[ V_{24}^{2} = V_{24}^{a(1)} + V_{24}^{a(2)} \]

\( V_{24}^{a(2)} \) is the value of absorbing dust, \( Q_{24}^{a(2)} \) is the absorptive capacity of these types of ecosystems to sulfur dioxide, and \( S_{24} \) is the area of ecosystems, \( C_{24} \) is the cost of industrial process for reducing per unit of sulfur dioxide ($1100 / t$)

And the total purification value of forest and grass is
\[ V_{24} = V_{24}^{1} + V_{24}^{2} \] (2.10)

2.5. Calculation of Ecological function value based on carbon tax Law

- **Carbon absorption and oxygen release value**

  (1) Carbon absorption value

\[ V_{25}^{a(1)} = P_{25}^{a(1)} \times S_{25}^{a(1)} \times n_{25} \times C_{25}^{1} \times 0.273, i = 1, 2, 3 \]
\[ V_{25}^{a(2)} = P_{25}^{a(2)} \times S_{25}^{a(2)} \times C_{25}^{2} \times i = 4 \]
\[ V_{25}^{1} = V_{25}^{a(1)} + V_{25}^{a(2)} + V_{25}^{a(3)} + V_{25}^{a(4)} \] (2.11)

\( V_{25}^{a(1)} \) is the carbon absorption value, \( P_{25}^{a(1)} \) is the annual fixed amount of carbon dioxide per unit area of land; \( S_{25}^{a(1)} \) is the land area; \( C_{25}^{1} \) is the Swedish carbon tax rate; \( n_{25} \) is the exchange rate of the dollar to the renminbi (1: 6.745); 0.273 is the molecular weight ratio of carbon and carbon dioxide; \( C_{25}^{2} \) is the cost of planting forest.

- **Oxygen release value.**

  We use Industrial oxygen production

\[ V_{25}^{a(2)} = P_{25}^{a(2)} \times S_{25}^{a(2)} \times C_{25}^{3}, i = 1, 2, 3, 4 \]
\[ V_{25}^{2} = V_{25}^{a(3)} + V_{25}^{a(4)} + V_{25}^{a(3)} + V_{25}^{a(2)} \] (2.12)

\( V_{25}^{a(2)} \) is the oxygen release value of land, \( P_{25}^{a(2)} \) is the annual oxygen output of forestry per unit area, \( S_{25}^{a(2)} \) is the area of woodland, and \( C_{25}^{3} \) is the cost of industrial oxygen production. The total value of carbon and oxygen excretion in forest or grassland systems is

2.6. Recreational value

The travel cost method is a method for evaluating non-price goods. The change of cost of travel is used to estimate the economic loss or benefit caused by environment change. The rate of areas’ visit (the number of recreation/the total population) need to be investigated, then the cost of recreation is calculated, including the cost of transportation, accommodation, food, tickets, photograph and purchase of souvenirs.
\[ V_{26}^{n_i} = n_{26}^{n_i} \times T_{26}^{n_i} \times P_{26}^{n_i}, \ i = 1, 2, 3, 4 \]

\[ V_{26} = V_{26}^{n_1} + V_{26}^{n_2} + V_{26}^{n_3} + V_{26}^{n_4} \]

\[ i \] is the annual recreational value of an ecosystem, \( n_{26}^{n_i} \) is the total population of the region, \( T_{26}^{n_i} \) is the recreational rate, \( P_{26}^{n_i} \) is the total cost of recreation, and \( C \) is other recreational costs.

2.7. Pollution cost of Development Project

Projects produce some pollution during and after the construction, we estimate the cost of this pollution by calculating the treatment fee, through Restoration cost method. It is a method to evaluate the economic loss caused by environmental pollution by calculating the cost needed to restore the polluted environment.

- Water pollution treatment cost
  The calculation formula for the value of water pollution loss is as follows:
  \[ V_{31} = \sum (Q_{31}^{n} \times C_{31}^{n}), \ n = 1, 2, 3 \]  
  \[ m \] is the sewage type, \( Q_{31}^{n} \) the total amount of the \( n \) type of sewage, \( C_{31}^{n} \) is the cost of sewage treatment.

- Air pollution treatment cost
  \[ V_{32} = \sum (Q_{32}^{m} \times C_{32}^{m}), \ m = 1, 2, 3 \]  
  \( m \) is the type of air pollutants; \( Q_{32}^{m} \) is the amount of the air pollutants produced, \( C_{32}^{m} \) is the unit cost of treatment for this air pollutant.

- Solid waste pollution treatment cost
  \[ V_{33} = \sum (Q_{33} \times C_{33}) \]  
  \( Q_{33} \) is the amount of solid waste, \( C_{33} \) the unit cost of treatment for this solid waste.

- Noise pollution treatment cost
  Noise pollution is different from air pollution and water pollution, and its losses are mainly manifested in human health. The economic loss caused by noise pollution in land development projects can be calculated by the survey evaluation method. The average maximum willingness to pay (WTP) of the affected people can be obtained through questionnaires or on the spot, and the noise can be obtained according to formula (2-17). The value of pollution loss \( V_{34} \), \( N \) the number of people affected by noise pollution.
  \[ V_{34} = N \times WTP \]  

3. Conclusion

We construct an environmental cost evaluation index system for land development projects, calculating the cost of land resources loss, and project pollution cost. The land resources loss is caused by the destruction of the original land, we further analyze it from the value that the land has, including land products value and ecological value. The project pollution cost is resulted from the various pollution that the projects produce after construction, we calculate the pollution treatment cost to estimate the pollution. Market value method, shadow engineering method, carbon tax rate method are used. To sum up, Our model can be adjusted to the change of time easily, as we use many constants, such as prices of products and unit grain yield. As long as we change the value of the constants, based on real-time information.

References

[1] Costanza R, D’Arge R, Groot R D, et al. The value of the world's ecosystem services and natural capital[J]. World Environment, 1997, 25(1):3-15.
[2] Jin Z, Sun J, Liu C, et al. Economic Incentive Mechanism Design for Green Buildings based on Analysis of Externalities[C]// Criocm International Symposium on Advancement of Construction Management & Real Estate. 2009.

[3] Shi Y, Xuan X. Research on the Opportunity Cost of Urbanization: Based on the Loss of Cultivated Land Resource Value[J]. Modern Urban Research, 2013.

[4] Thoms J R. The cost-benefit analysis of pollution prevention projects—environmental cost analysis methodology (ECAM)[J]. Federal Facilities Environmental Journal, 1999, 10(1):43-49.

[5] Allenby G M, Brazell J D, Howell J R, et al. Economic valuation of product features[J]. Quantitative Marketing and Economics, 2014, 12(4):421-456.

[6] Tang X, Gao R. Quantitative Evaluation on Wetland Ecosystem Service Function in Chao Lake[J]. Agricultural Science and Technology, 2016.

[7] Wang J L, Huang X J, Ru-Cheng L U, et al. Assessment on the Vulnerability of Ecosystem Services to Land Use Change——A Case Study of Carbon Stock of Taihu Lake District in Jiangsu Province[J]. Journal of Natural Resources, 2010, 25(4):556-563.