

# Evaluation of Ecological Service Value in Project Decision

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**Abstract.** In this paper, ecosystem service value (ESV) valuation models is presented to serve the need of a comprehensive cost-benefit analysis. Environmental cost is subdivided into environmental degradation cost, and environmental mitigating cost. To quantify environmental degradation cost, Equivalent Factor Method (EFM) is employed to generate monetized ecosystem value. As for environmental mitigation cost, Life Cycle Cost Analysis is adopted to quantify negative environmental influence. Two models are applied on Ankang Airport Project to evaluate the projects' true value. The presented model contains more comprehensive factors, hence better decisions can be made.

**Keywords:** ecosystem service value (ESV); Equivalent Factor Method (EFM); Environmental cost.

## 1. Introduction

With extreme weather hitting our communities frequently recent years, more attention is drawn to climate change, which is seen as responsible for inducing more extreme weather events. (Huber, 2011) Among numerous ecological research interests, ecosystem service evaluation (ESE) focuses on quantifying how much benefit, which we often take for granted, ecosystem provides us with every day (Daily, 1997). This quantified value of an ecosystem is also known as ecosystem service value (ESV). A diverse portfolio of ESE models exists to address different types of evaluations. (Pandeya et al., 2016). Each specific model has its own focus, attempting to emphasize a particular aspect of ESV. There are primarily four categories of ecosystem services service (Millennium Ecosystem Assessment, 2005), Richmond a et al. (2007) built a regression model, whose interest is in provisional service, to assess GDP's reliance on ecosystem. Other than this, there are many different models that assess ESV. To the best of our knowledge, little attention is drawn to assess regulating service, cultural service value, and supporting value, due to their intangibility and measurement difficulty. Besides evaluating ESV itself, Ponser et al (2016) denoted that policy makers in California can obtain more awareness about the ecosystem given ESV, hence they make better decisions.

In contrast to previous effort to acquire ESV, we attempted to include regulating service, cultural service, and supporting service, into our model. All services are lost after alternation of the land made by human, and those services' value can be translated into currency. Considering that different categories of lands have different types and amounts of ecosystem services, and land ecosystems are categorized into 6 types: forest, grassland, farmland, wetland, waters, and desert (Current land use classification, 2017). We characterize each type of land's ESV by identifying an equivalent factor, proposed by Xie et al (2015). But Xie's model is general and non-specific if applied to a certain area, thus we modified the model to accommodate for a region. The model is tested on one case, Ankang Fuqiang Airport Construction Plan, Ankang City, China, to conduct cost-benefit analysis of each project and test models' performance.

## 2. Methodologies

To capture ESV and incorporate it into total cost, we firstly decompose total income into gain and cost. Secondly cost is divided into construction cost, maintenance cost and environmental cost, which is comprised of environmental protection expense, and environmental degradation cost. Divide the impact of the ecosystem on the project into the Environmental degradation cost brought

by the land change and the Environmental mitigation cost brought by the project construction and implementation.

## 2.1 Equivalent Factor Method

Among many methods, Equivalent Factor Method has the most popularity, and thus is employed in this model and modified to satisfy our needs. Equivalent Factor Method generates a factor for each kind of land to indicate the equivalent value of a unit area of land. Multiplying that factor with land area, whose land type corresponds to the factor, yields the equivalent value of the land ecosystem. Because equivalent factors are customized by local environment, so it's unavoidable to personalize the factors for a specific region.

### 2.1.1 Hierarchy Structure

Every type of land ecosystem serves humanity in a unique manner. But generally speaking, their services can all be translated into monetary value. Analytical Hierarchy Process is then employed to quantify the value of ecosystem service, referring to Millennium Ecosystem Assessment (2005). This ESE contains a target layer, a criterion layer, and index layer. Land ecosystem service value lies in target layer; 4 aspects, provisional, regulating, supporting, and cultural service, of ecosystem are in criterion layer; and in index layer are 11 indicators that represent ecosystem the most (Xie et al, 2015). Table 1 shows the detail of our hierarchy structure.

Table 1. Analytical Hierarchy of ESE

Target Layer	Criterion Layer	Index Layer
Land Ecosystem Service Value	Provisional Service	Food Supply
		Raw Material
		Water Supply
	Regulating Service	Gas Control
		Weather Control
		Purification
	Supporting Service	Water Control
		Soil Regulation
		Nutrient Cycling
		Bio-diversity
	Cultural Service	Esthetical Value

Target layer's ecosystem total value is the sum of each aspect of ecosystem service, aka each indicator's equivalent value for ecosystem. The next step to acquire ecosystem service is to obtain local equivalent factor.

### 2.1.2 Degradation Cost and Equivalent Factor

A unit land (area) of ecosystem's equivalent value is defined as Equivalent Factor. Xie (2015) considered that ESV equals to the value of equivalent area of agricultural product. The following equation is employed to compute equivalent factors:

$$D = S_r \times P_r + S_w \times P_w + S_c \times P_c$$

Where subscript *r*, *w* and *c* stand for rice, wheat and corn respectively; *S* and *P* denote crop's sown area percentage in total farmland, and profit of the crop; *D* is the equivalent factor.

Table 1 shows the average of China's ecosystem equivalent factors, however in a local scale the table needs to be transformed to accommodate the region. The transformation process is as follow:

- (1) Compute the percentage of each subtype of land area in its superset.
- (2) Multiply the percentage with the factor given above, substitute the original factor.
- (3) Iterate the previous steps until the factors are all transformed.

After obtaining a customized table, the total ESV can be derived from multiplying land area to the corresponding equivalent factor and adding all outcomes, as follow:

$$ESV = \sum_{i=1}^m ESV_i = \sum_{i=1}^m \sum_{k=1}^n (V_{ik} * A_i) = \sum_{i=1}^m \sum_{k=1}^n (D_{ik} * Q * A_i)$$

Where  $m$  and  $n$  are number land type and type of ecosystem service;  $Q$  is the equivalent factor modifier, which is used to calculate local equivalent modifier by multiplying  $Q$  with  $D$ ;  $A$  is the area of a type of land;  $V$  is the ecosystem service value of  $i$ th type of land.

By adding ESV into environmental cost, combining other subset of total cost, the impact of ecosystem brought by human alternation is incorporated into monetary cost of a plan. Planners can thus use this total value to conduct cost-benefit analysis regarding environmental degradation.

## 2.2 Environmental Mitigation Cost (Model 2)

The alternation of ecosystem results in service lost, meanwhile the created artificial facility results in pollution during and after its construction. Construction period and operation period are considered here, and the possible environmental influence is shown in table 2:

Table 2. Possible influence regarding project life cycle period

Period of Life Cycle	Environmental Influence (Pollution)
Construction	Water, Air and Solid Pollution, Bio-destruction
Operation	Water, Air, Solid Pollution

In order to monetize influence abovementioned, environmental mitigation cost is defined as:

$$M_p = \sum_{i=1}^n M_{ci}$$

Where  $M_p$  is the general environmental mitigation cost;  $M_{ci}$  is the  $i$ th type of mitigation cost; when  $i$  equals to 1, 2, 3, and 4, it represents water pollution, air pollution, solid pollution, and bio-destruction respectively. The next discusses each.

### 2.2.1 Water and Air Pollution (i=1,2).

Water pollution is comprised by household water pollution and industrial water pollution, and industrial water pollution is the most influential. Household waste water is less pollutive so that it requires little purification, whereas industrial waste water is heavily polluted and must be processed before discharging. Air pollution is mainly caused by chemicals, such as, and other toxic gases. When an ecosystem mitigates a quantity of waste water as a sewage treatment plant, its value of this process is equivalent to the construction and operation expense on this plant. Hence mitigation can be further defined as:

$$M_{ci} = \begin{cases} M_{ci} + M_{ci0} + t \times M_{cit} \\ \sum k(E \times R) \end{cases}$$

Where  $M_{ci}$  the cost of facility construction;  $M_{ci0}$  is the cost spent on waste disposal of material process phase and construction phase;  $M_{cit}$  is the cost of facility operation in each year;  $k$  is the convert factor;  $t$  is the year of running;  $E$  is the amount of waste disposal;  $R$  is the unit waste disposal.

The discount factor  $k$  can be calculated through:

$$k = \begin{cases} 1, construction \\ \frac{1}{(1+r)^t}, operation \end{cases}$$

Where  $r$  the discount rate ( $r=4.35\%$ ). Through the above model, cost of environmental mitigation can be computed and monetized. This enables comprehensive analysis of a plan's true cost.

### 2.2.2 Solid Waste Pollution (i=3).

Solid waste includes household waste, construction waste, industrial waste and other unwanted solid disposals. The cost of mitigating such waste's influence is convertible into money referring to the cost of a facility neutralizing such waste. The cost of mitigating solid waste thus is represented as:

$$M_{c3} = \sum BE$$

Where  $B$  is the convert factor;  $E$  is the amount of waste disposal. Combining all costs of solid disposal can generate total solid waste pollution.

### 2.2.3 Bio-destruction (i=4).

During the construction process biosystem receives damage. The cost of mitigating bio - destruction contains reviving plantation, soil maintenance and avian dismissal. Thus bio-destruction cost is converted as:

$$M_{c4} = M_s + M_z + \sum AP_c$$

Where  $M_s$  is the cost of maintaining soil;  $M_z$  is the cost of avian dismissal;  $A$  is the land area;  $P_c$  is the cost reviving a unit land area. Combining all types of mitigation cost discussed above yields general environmental mitigation cost of a project.

## 2.3 Cost-benefit Analysis.

Considering Environmental Cost above, if the Project's Environmental Cost is Denoted as:

$$E_c = \frac{ESV_{before} - ESV_{after}}{r} + M_p$$

Where  $E_c$  is the total environmental cost;  $M_p$  is the total environment maintenance cost.

The profit of a project is simply denoted in the plan, as estimated income. The Net Project Value (NPV) can be computed as:

$$NPV \square Income - E_c - EI - EO$$

Where  $EI$  is initial investment cost,  $EO$  is other costs per year. If  $NPV$  is positive, the project is profitable; otherwise it is counter-productive.

## 3. Solutions

Models are applied on Ankang Fuqiang Airport to evaluate the cost containing ESV. Statistics about Ankang are retrieved from Statistical Yearbook of Ankang (2016), and the data about Ankang Fuqiang Airport are gathered from (Wang et al, 2016).

### 3.1 Environmental Degradation Cost of Ankang Airport (Model 1)

Using model 1 proposed in section 2, Forest occupied by Ankang Airport can be considered as farmland to simplify computation (Huang et al, 2019). The ESV of occupied land before construction and the ESV of occupied land after construction thus are gathered:

$$ESV_{before} = \sum_{i=1}^m \sum_{k=1}^n (D_{ik} * Q * S_i) = 1092722.40$$

$$ESV_{after} = \sum_{i=1}^m \sum_{k=1}^n (D_{ik} * Q * S_i) = 226750.10$$

The environmental degradation cost is the subtraction between  $ESV_{before}$  and  $ESV_{after}$  :

$$ESV_{cost} = ESV_{before} - ESV_{after} = 865972.3$$

### 3.2 Environmental Mitigation Cost of Ankang Airport (Model 2)

This part considers environmental mitigation cost of Ankang Airport.

#### 3.2.1 Water Pollution (i=1).

The airport requires a water treatment plant, which cost 1.2 million Yuan for construction and 30 thousand Yuan each year for maintenance (Ankang Airport Construction Project Plan, 2016). Thus, the water pollution mitigation cost of Ankang Airport is derived as:

$$M_{c1} = 120 + \frac{3}{4.35\%} = 18667000$$

The water pollution caused by Ankang Airport needs 1866700 yuan for disposal in 3 year's period.

#### 3.2.2 Air Pollution (i=2).

Air pollution mainly covers vehicle exhaust, smell of water treatment, and other relevant undesired gas bodies. The construction project acclaims the project's construction period and operation phase will produce such amount of pollutants. Thus, considering data given from above tables, the air pollution mitigation expense is computed as:

$$M_{c2} = 13.53 + \frac{5.21}{4.35\%} = 1333000$$

#### 3.2.3 Solid Waste Pollution (i=3).

Solid waste in the airport is handled artificially. The plan explains that it invests 150 thousand Yuan on construction waste and 24.4 thousand more on each year. The solid waste mitigation cost can be retrieved as:

$$M_{c3} = 15 + \frac{2.44}{4.35\%} = 711300$$

This is the cost of treating solid waste pollution originated from the airport.

#### 3.2.4 Environmental Protection (i=4).

Considering 3.1.1 and 3.1.2, environmental cost considering ESV is obtained. To analyze the project's true profit, stated profit in the plan needs to be subtracted from general environmental cost. The calculation is as follow:

$$E_c = \frac{(ESV_{before} - ESV_{after})}{r} + M_c = 29357300$$

Here, total environmental cost is acquired, and that enables cost-benefit analysis regarding environmental cost.

### 3.3 Cost and Benefit of Ankang Airport

Assume that the airport runs forever after its completion. The total economical cost is comprised of Airport Profit (AP), Ecosystem Service Value (ESV), and Initial Investment (II). Hence, the total economical cost can be characterized as:

$$E_c = pAP - M_p - ESV_{cost} - II$$

Where p is a discount factor. In this case, the variables' values are (Ankang Airport Construction Plan, 2016) : II=1591790000; AP = 0.25II = 397947500;  $p = \frac{AP}{r} = 9148218400$ .

Eventually, there is:

$$E_c = 6094399500 > 0$$

This denotes that the project is profitable, when considering the environmental cost.

#### 4. Conclusion

With the results given in above, cost-benefit analysis regarding ecosystem service is viable. This subsection conducts cost-benefit analysis of example cases. Through cost-benefit analysis, it's proofed that Anakng Airport is productive and bring benefit to humanity, thus it's worth-investing.

The presented model contains more comprehensive factors. The model include regulating service, cultural service, and supporting service. The project designer can obtain more awareness about the ecosystem given ESV, hence they can make better decisions.

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