The Value of a Land Use Project's Ecosystem Services

Yongxiong Liu[1], Mingzhi Li[2], Jiacheng Zhao[1]

[1]School of Information Engineering, Chang'an University, Xi'an, China

[2]School of Construction Mechinery, Chang'an University, Xi'an, China

Email address:
lyx1518234852@163.com (Yongxiong Liu), 18392117617@163.com (Mingzhi Li), joeric07@163.com (Jiacheng Zhao)

Abstract: The evaluation of ecosystem service value is a focus issue in the construction of ecological civilization in China. With the progress of human civilization, various types of land use projects are increasing day by day, which not only bring huge economic benefits, but also profoundly affect the regional land use pattern and ecological process, and have many influences on ecosystem services. In order to understand the real economic cost of land use projects, it is urgent to evaluate the ecosystem service cost of specific land use projects. In this paper, an ecological service evaluation model for comprehensive evaluation of land use project ecological service value is established. In this model, the emerging theory, virtual disposal cost method and market price method are applied to quantify the ecosystem service cost of land use project from four aspects of water, land, gas and biology. Using our model, we can estimate the ecological cost of a land use project more quickly and obtain the real economic cost of the project. Taking a thermal power plant as an example, the annual cost of the system service is calculated based on the ecosystem evaluation model and the existing model. By comparing the results of the two models, the feasibility and validity of the model are revealed.

Keywords: Ecosystem, Ecosystem Services Valuation, Land Use Project

1. Introduction

Since the 1970s, the ecosystem service function has become a scientific term and a branch of ecology and ecological economics. The connotation of ecosystem services mainly includes the generation and maintenance of biodiversity, the renewal and maintenance of soil fertility, environmental purification and many other aspects.

Since the 21st century, with the progress of human civilization, the ecological environment has been continuously destroyed and the human living environment has gradually deteriorated. It is very important to measure the damage of ecological environment accurately to improve ecological environment. The existing quantitative models of "ecosystem services" [1] can be divided into three categories. The first is to apply the aggregate analysis of multiple policy changes to explore whether these changes can have a positive impact on improving the environment. [2] The second is to analyze the ways to control pollution from the national factors such as industrial structure, international trade and so on. [3, 4] The third is to analyze environmental costs directly or indirectly from the perspective of cost quantification. However, the above models are used to assess the overall environmental costs of a country and a region from a macro perspective, and it is difficult to measure the costs of environmental degradation caused by a project from a micro perspective.

2. The Ecological Services Valuation Model

2.1. Literature Review

Based on existing Ecosystem Services Valuation, we propose a new method to measure the environmental impact of economic activities in a specific land use project. By citing multiple factors, we divide these factors into four main areas: water, land, biology and air. Emergy theory, virtual disposal cost approach, market price method are applied to quantify the ecosystem services costs of a project in four aspects (water, land, air and biology), and transformed from physical unit to monetary unit, so as to effectively measure its pollution index
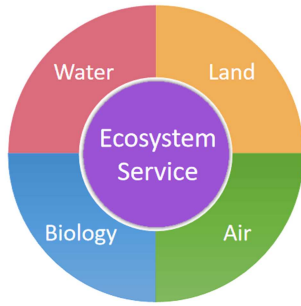
to the environment.

Figure 1. Ecosystem Services Valuation index.

2.2. Water

Water resources within the ecosystem system and all kinds

of ecosystem systems play a very important function, in the process of forming and maintaining the human survival environment. The ecosystem services value of water resources is the degree to which water satisfies the demand for the normal operation of the ecosystem. Considering the indirect water service is hard to calculate, we use the method of emergy evaluation analysis of the water ecosystem services costs.

According to the emergy theory [5], emergy refers to the amount of another kind of energy contained in the energy flowing or stored, which can be used as a benchmark to measure the energy value of various energies. The basic idea of emergy analysis is to use emergy as a benchmark to unify the energy in the ecosystem on the emergy scale to quantitatively analyze the functions of the system.
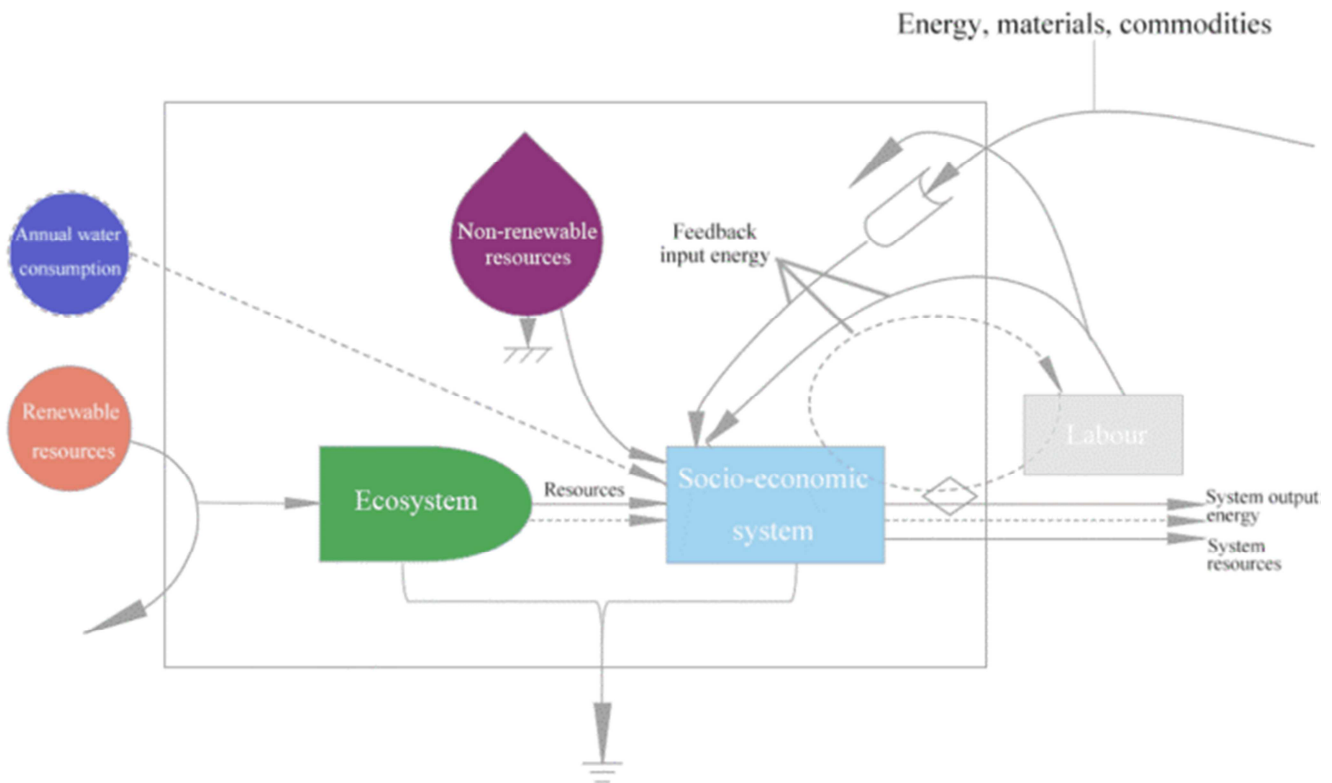

Figure 2. Water resource emergy flow.

The conversion relationship between emergy and matter is as follows:

$$E_{mW} = \tau B \tag{1}$$

Where E_{mW} is the emergy of water (sej).

B is the amount of water (m^3). It should be noted that here B indicates how much water is used. In land use project, besides using water B_1, sewage B_2 will also be removed. When calculating the ecosystem cost of sewage, we can borrow the alternative equivalent analysis method: add purified water B_2 to sewage B_3 to meet discharge standards. At this time B is as follows:

$$B = B_1 + B_3 \tag{2}$$

τ is emergy transformity, That is, the amount of solar energy per unit of matter or energy (sej/m^3). According to Buenfil's calculations [6], the conversion rates of solar energy in mineral water and purified water are $1.43 \times 10^{14} sej/m^3$ and $1.56 \times 10^{14} sej/m^3$.

We use the emergy/money ratio to convert emergy to money flow:

$$EDR = \frac{EM_\mu}{GNP} \tag{3}$$

Where:

EDR is Emergy Divide Ratio(sej/dollar)

EM_μ is the total energy value used throughout the year by the regional economic system(sej)

GNP is the corresponding region's current gross national product (dollar)

Finally, the formula for calculating the water ecosystem services by using the emergy theory is as follows:
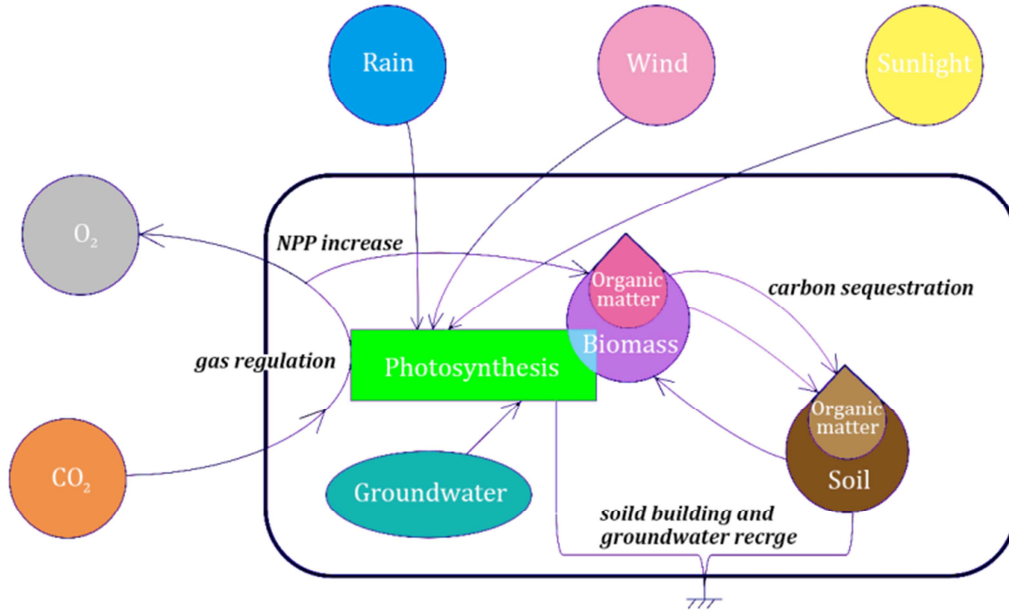
$$M_{water} = EDR \times E_{mW} \qquad (4)$$

2.3. Land

As most land use projects expands, land are occupied and plants are being cut to obtain construction materials, fuelwood for cultivation. Considering the direct and indirect services of vegetation, we divide the value of the areas of the ecosystem into four parts: net primary production, carbon sequestration, soil building and groundwater recharge, gas regulation.

Figure 3. The ecosystem services provided by land.

2.3.1. NPP Increase

Net primary production (NPP) is the difference between the fixed energy consumed by photosynthesis and the energy consumed by plant respiration.

The formula of E_{mNPP} increase is:

$$E_{mNPP} = \varepsilon \times f_1(T) \times f_2(\beta) \times PER \times FPER - R \qquad (5)$$

Where E_{mNPP} is the amount of the emergy required by NPP increase in study area, ε is maximum light utilization, $f_1(T)$ and $f_2(\beta)$ is the effects of temperature and soil moisture on ε, PER is photosynthetic effective radiation reaching the surface. $FPER$ is proportion of photosynthetic effective radiation absorbed by vegetation. R is geopotential and chemical potential energy.

2.3.2. Carbon Sequestration

Plants can convert atmospheric carbon dioxide into carbohydrates and fix it in the form of organic carbon.

The formula of carbon sequestration is:

$$E_{mCS} = \frac{1}{2} \times \Delta B \times S \times UEV_{bio} \qquad (6)$$

$$UEV_{bio} = \frac{E_{mNPP}}{S \times NPP} \qquad (7)$$

Where E_{mCS} is the emergy producted by photosynthesis of plants (sej); ΔB annual increase in biomass per unit area of local ecosystem (g/hr/year); S is the area of ecosystem occupied by projects. Considering that carbon sequestration amount in plants is about a half of the biomass, the right hand-side of the equation has to be multiplied by 0.5. UEV_{bio} is the transformity of biomass (sej/g); NPP is the NPP mass per unit area per year (g/ha/year).

2.3.3. Soil Building and Groundwater Recharge

The existence of vegetation can increase the recharge of groundwater and build the soil. The formula of soil building and groundwater recharge is:

$$E_{mGR} = L \times S \times \rho \times k \times UEV_{GR} \qquad (8)$$

Where E_{mGR} is the emergy producted by groundwater recharge(sej); L is the precipitation in the local ecosystem (mm/year); S is the area of ecosystem occupied by projects; ρ is the density of groundwater (g/m^3) ; k is the coefficient by which a plant absorbs water(%); UEV_{GR} is the specific emergy of groundwater(sej/g).

2.3.4. Gas Regulation

In assessing the role of ecosystems in immobilizing CO_2 and releasing O_2, we calculated from the reaction equations of photosynthesis and respiration that for every 1g of dry matter

formed, 1.62g of CO_2 would be required and 1.2g of O_2 would be released at the same time. Using Sweden's carbon tax rate of \$0.15/kg and virtual disposal cost approach [12], we can translate it into a tax on the absorption of CO_2. The formula of gas regulation is:

$$M_{gas} = n_{co_2} \times m_{co_2} + n_{o_2} \times m_{o_2} \qquad (9)$$

Where n_{co_2} is the amount of CO_2 absorbed by the vegetation in the area; n_{o_2} is the amount of O_2 absorbed by the vegetation in the area. m_{co_2} is the tax rate of CO_2 calculated according to the Swedish carbon tax rate, the value is $\$4.094 \times 10^5 /kg$ [13]; the unit mass value of m_{o_2} is calculated according to the industrial O_2 production price, the value is \$488/g.

2.3.5. Land Service Valuation

To quantifying the cost of land services occupied by a project, we apply the emergy evaluation method and the market price method in three parts: net primary production, carbon sequestration, the soil building and groundwater recharge. Since the value of ecosystem services created by vegetation in this area is not easy to be directly reflected, EDR is introduced to quantify its environmental costs by emergy method. When it comes to gas regulation, the value of carbon dioxide and oxygen can be reflected by market value, thus, we use market price method to evaluate its ecosystem cost.

Above all, the formula of land service valuation is:

$$M_{land} = EDR \times (E_{mNPP} + E_{mCS} + E_{mGR}) + M_{gas} \qquad (10)$$

Considering the landforms and the types of vegetation is different in different areas, the four functions that affect the environment are also different. For example, the ecosystem services valuation of forest landforms is higher than that of grasslands. Based on this, we need to consider the landform of the occupied land before calculate the cost of services valuation.

2.4. Air

In the process of construction and operation, land use projects will inevitably emit toxic and harmful gases. Air pollution refers to the environmental pollution caused by the discharge of air pollutants into the atmosphere, which mostly produced by enterprises and sudden air pollution accidents. Market price method and emergy evaluation method can not evaluate the atmospheric environmental damage very precisely. According to the above reason, we choose the virtual governance cost method [6] to evaluate it. The idea is that the cost of virtual governance is calculated by the cost method of governance, that is, the cost of governance that is used to prevent the degradation of environmental functions is equal to the assumed cost of pollution control and the harm caused by pollution emissions. the formula of air is:

$$C_{ave} = \frac{C_{so_2} \times K_{so_2} + C_{NO_X} \times K_{NO_X}}{2} \qquad (11)$$

Where C_{ave} is the average cost per unit of air pollutant reference material treatment (dollar/t). C_{so_2} and C_{NO_X} are the land use project on SO_2 and NO_X governance costs. K_{SO_2} and K_{NO_X} are the weight of overhead expenses, which is the proportion of SO_2 and NO_X dioxide pollutants in total pollutants in the land use project(%).

$$C = \frac{C_{ave}}{D_i} \times D_{ave} \qquad (12)$$

Where C is the unit treatment cost of air pollutant (dollar/t). D_i is the amount of atmospheric pollutants. D_{ave} is the amount of the reference substance.

$$M_{air} = C \times n \qquad (13)$$

Where M_{air} is the air service valuation, n is the pollution exhaust gas emitted by the project.

2.5. Biology

Ecosystem services in biology mainly include indirect services and existence services. We value biology services in the perspectives of biodiversity, tourism and recreational value by emergy theory.

2.5.1. Biodiversity

Ecosystem can maintain biodiversity and the formula of biodiversity is as follows:

$$E_{bc} = \frac{N_1 \times S \times (GEB \times T)}{N_0} \qquad (14)$$

Where E_{bc} is the emergy required by biodiversity conservation (sej); N_1 is the species density in the areas (N/ha); S is the area of ecosystem (ha); GEB is the geobiosphrere emergy baseline(sej/year); T is the average turnover time of species(year); N_0 is the number of global species.

2.5.2. Tourism and Recreational Value

Each ecosystem has a natural landscape, which can generates tourism income for local residents. Both tourism and recreational value can be measured by annual tourism value M_{tou}.

2.5.3. Biology Service Valuation

Above all, the formula of land service valuation is:

$$M_{bio} = EDR \times E_{bc} + M_{tou} \qquad (15)$$

2.6. Ecosystem Services Valuation

Based on the service valuation discussed above, the service valuation of the local areas can be calculated as follows:

$$M_{total} = M_{water} + M_{land} + M_{air} + M_{bio} \qquad (16)$$

Where M_{total} is the total ecosystem services valuation of the land use project.

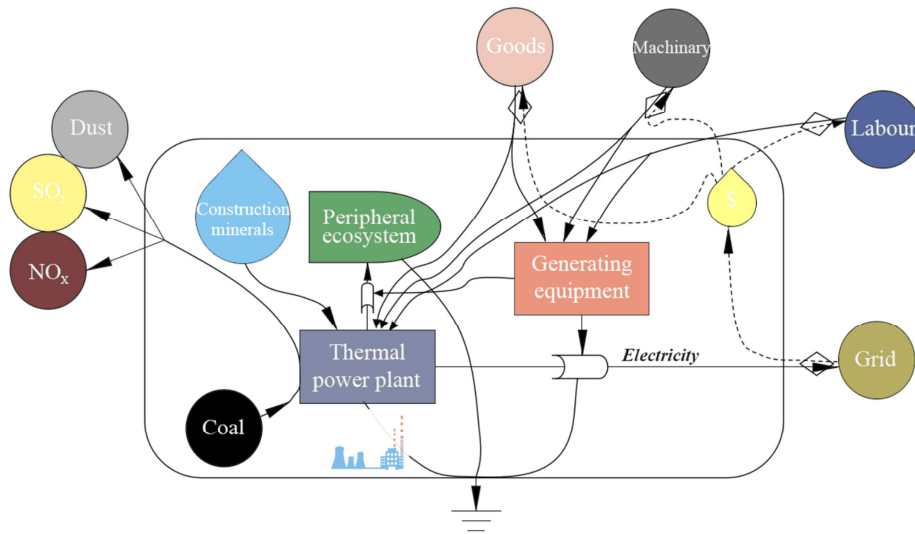# 3. Case Study and Model Effectiveness Evaluation

Figure 4. The ecosystem services related to thermal.

We selected a thermal power plant as a regional project. The quantitative method of ecosystem services is demonstrated concretely, and the effectiveness of our model is verified.

We found the power generation, air pollution [7], water resource utilization [8] and land use [9], of the thermal power plant in the network and literature.

The annual ecosystem services cost of the project was calculated by our ecosystem model and compared with that of

Robert Costanza model [10]. The difference percentager ε is calculated:

$$\varepsilon = \frac{M_2 - M_1}{M_1} \times 100\% \qquad (17)$$

The calculation results are shown as follows:

Table 1. Results contrast.

	ecosystem index	Amount	Cost M_1 (dollars)	Robert Costanza's index	Cost M_2 (dollars)	E (%)
Index	Water	1.11×10^{10} (m^3)	1.72×10^7	water regulation water supply	1.13×10^7 1.51×10^7	53.7%
	Land	$3.50 \times$ (hm)	2.65×10^5	Disturbance regulation Erosion consrol Soil formation Nutrient cycling Waste treatment	1.26×10^3 6.18×10^4 2.52×10^3 2.33×10^5 2.20×10^4	20.8%
	Air	1.20×10^6 (kg)	2.02×10^8	Gas regulation Climate regulation	4.50×10^7 2.30×10^7	-66.3
	Biology	32200 (number)	4.47×10^7	Biological control Habitat/refugia	3.86×10^7 1.15×10^7	12.1%
	Total		2.64×10^8	Total	1.45×10^8	45.1%

4. Conclusion

The existing methods of ecosystem services valuation is complex and uncertain, which makes ecological conservation and restoration difficult to be effectively put into practice. In order to make the data easier to access, easier to change over time. This paper establishes an ecological services valuation model to value the ecosystem services of a land use project comprehensively. In this model, emergy theory, virtual disposal cost approach, market price method are applied to quantify the ecosystem services costs of a land use project in four aspects (water, land, air and biology).

In conclusion, this study can overcome the limitations of

ecosystem services valuation accounting methods, and estimate the ecological cost of a land use project more quickly.

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