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Study on Evaluation of Rational Land-Use Based on EES Model of Supply and Demand Equilibrium

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Abstract: *The function value of land ecological services is underestimated, which leads to over-exploitation. There is an urgent need to establish a comprehensive evaluation model that can reflect the real cost of land-use projects. In this paper, we establish an EES model based on the equilibrium of supply and demand under the fixed supply of natural resources. In this model, the target value is mainly composed of ecological value* EC_1 *and economic value* EC_2 *of land ecosystem services. Subjective value is affected by different social preferences, the relationship between human development index and social value* SC *is established through the Pearl Growth Model, and the share of subjective value in total land value under different levels of social development is calculated. Finally, according to the utility value theory, the land scarcity index* SI *is introduced to reflect the relationship between land demand and land stock of land-use projects in the region and shows that the land price per unit area of different scales is different.*

Keywords: *Supply-Demand Equilibrium; EES model; Pearl Growth Model*

1. Introduction

Ecosystem services are the conditions and processes through which natural ecosystems and the species make up, sustain, and fulfill human life [1]. However, along with industrialization and urbanization, more and more land-use projects are developed through the traditional decision-making process, which seldom accounts for the impact on the ecosystem services leading to over-exploitation of the natural resources and environment [2]. So, putting a value on the environmental cost of land-use development projects and constructing an evaluation model assessing the true and comprehensive valuation of the project is challenging but worthy of effort.

2. EES Model

To study the true cost of the land use, we first build a supply-demand equilibrium model with fixed natural resource supply, where consumer surplus corresponds to the subjective value of the land, and net land rent corresponds to the objective value of the land. Among them, the objective value mainly consists of the land's ecological and economic value, and the subjective value is influenced by people's preference factors, which some social factors can express.

2.1. Supply-Demand Equilibrium

The total land value consists of a subjective value corresponding to consumer surplus and an objective value corresponding to land rent shown in Figure 1.

We express the objective value of land in terms of ecological value (EC_1) and economic value (EC_2), and the subjective value of land in terms of social value (SC), with the following Eq.1.

$$\begin{aligned} C &= Subjective\ value + Objective\ value \\ &= EC_1 + EC_2 + SC \end{aligned} \tag{1}$$

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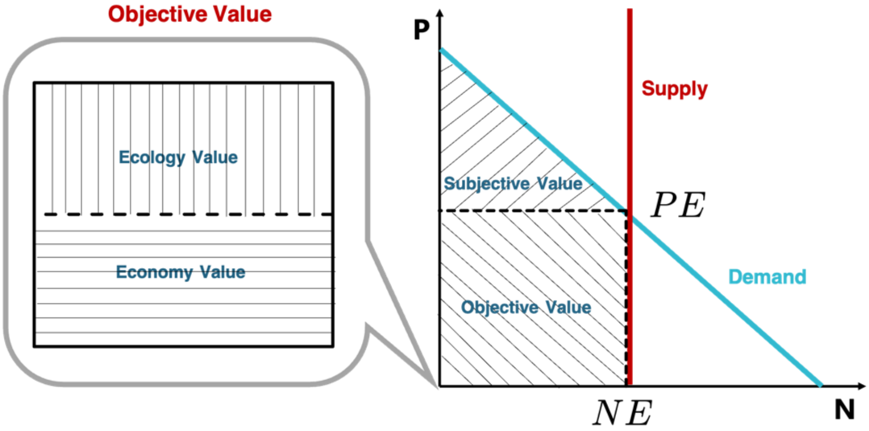

Figure 1: General Equilibrium

2.2. Ecology Model (EC_1)

The first E of the EES model [4] considers evaluating the ecological costs of land-use projects. We consider it from the following perspectives:

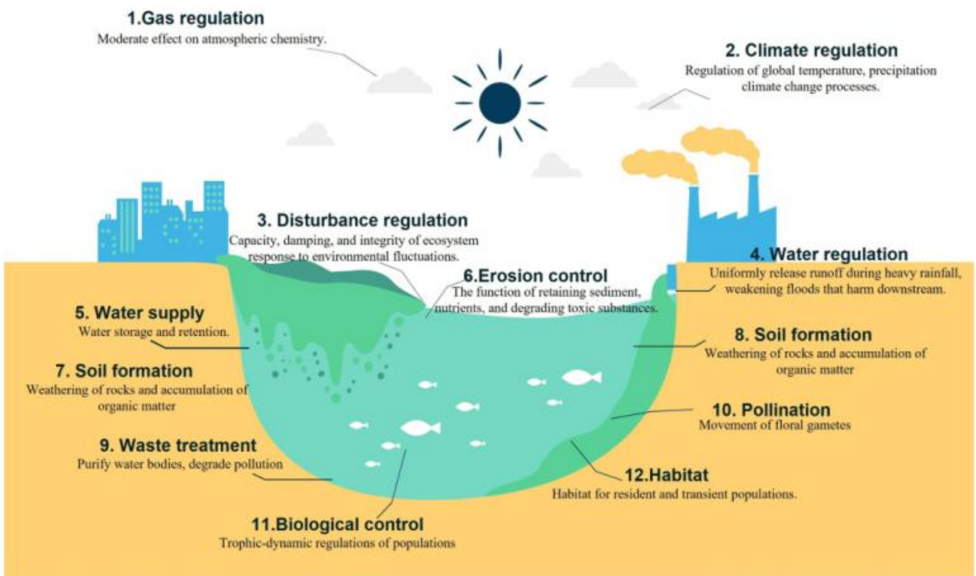

Figure 2: Ecological service perspectives

Costanza et al. [5] studied the ecological value of global land services corresponding to the values in the following Tab.1; combined with the relevant studies, we calculate the ecological value of the corresponding land services:

$$EC_1 = \sum_{j=1}^{k} \left(A_j \times VC_j \right) \tag{2}$$

Where EC_1 denotes the ecological value of the land, A_j denotes the area of the land type j. VC_j denotes the ecological service value of the land type j.

2.3. Economy Model (EC_2)

The second E of the EES model considers the evaluation of the economic costs. The economic value [6-8] of ecological products refers to the value provided by the edible, medical, and medicinal substances and energy produced by the ecosystem. In this paper, we have counted 26 three-level indicators of product economic value [10].

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$$EC_2 = \sum_{j=1}^{n} (Y_j \times P_j) \tag{3}$$

Where EC_2 denotes the economic value of the land, Y_j denotes the output of each product, P_j denotes the average unit value of each product.

Table 1: Ecological service value per unit area of different land ecosystems of 1994

Service	Farmland	Forest	Grass	Wetlands	Water area
Gas regulation	0	0	7	133	0
Climate regulation	0	141	0	0	0
Disturbance regulation	0	2	0	4539	0
Water regulation	0	2	3	15	5445
Water supply	0	3	0	3800	2117
Erosion control	0	96	29	0	0
Soil formation	0	10	1	0	0
Nutrient cycling	0	361	0	0	0
Waste treatment	0	87	87	4177	665
Pollination	14	25	25	0	0
Biological control	24	23	23	0	0
Habitat	0	0	0	304	0
Total price	38	175	175	12968	8227

Table 2: Metrics of ecosystem economic value accounting

Category	Index
Agricultural products	cereal, beans, tuber crop, vegetable, fruit, tea, cotton, carbohydrate, fungus
Forest products	wood, forset by-product
Animal products	meat, dairy, eggs, animal fur, other (honey, catch and hunt)
Aquatic products	marine products, freshwater products
Water resource	rural water, domestic water, industrial consumprtion, ecological water utilization
Energy	hydroenergy, marsh gas, straw

Agriculture products: We refers to the calculation method of Xie Gaodi et al, and takes the net profit of the grain production per unit area of farmland ecosystem as the standard equivalent.

Forest products: According to literature, the value of forest resources is the discounted value of mature forest price minus the cost of forest growth period [11].

Energy: Energy is the raw commodity of ecosystem services. By calculating metal minerals, non-metal minerals, and biomass energy, we can assess the value of the energy consumption component of the ecosystem after land development.

3. Society Model (SC)

The S of the EES model considers the evaluation of the social costs. The social value of ecological products refers to the aesthetic value, entertainment value, and emotional value provided by nature.

We use the following formula to calculate the social value of the land-use:

$$SC = \left(EC_1 + EC_2 + SC\right) \times PI \Rightarrow SC = \frac{PI\left(EC_1 + EC_2\right)}{1 - PI} \tag{4}$$

Where SC denotes the social value of the land. PI denotes the Regional Preference Index. This means that the share of social value in the total value of land varies in societies with different levels of development, and the social value of land can be calculated by its objective value combined with social development factors.

Human Development Index is a good indicator of the level of social development, it has comprehensive content and statistical data availability, which can be used as a parameter to measure the regional preference index. The relationship between PI and the degree of human social development can be described using the Pearl Growth Model.

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$$PI = \frac{1}{1 + ae^{-b\times HDI}} \tag{5}$$

Based on the HDI levels and land-use practice in each country, we assume that when the HDI is 0.5, the subjective value is 10% of the total value; when the HDI is 0.9, the subjective value is 50% of the total value. By writing a program to solve for this we can get the specific expression of the Regional Preference Index:

$$PI = \frac{1}{1 + 81\sqrt{3}e^{-10\ln\sqrt{3}HDI}} \tag{6}$$

HDI is the human development index of the region, it is an index that measures key dimensions of human development [3]. The three key dimensions and their relationships with the value of land-use are shown as follows.

A long and healthy life is measured by life expectancy which will influence the discount rate. The longer people's life expectancy is, the lower the discount rate for making decisions about future wealth, which means that the natural resources to be exploited will have greater value.

$$\text{Life Expectancy Index}=\frac{LE - 20}{85 - 20} \tag{7}$$

Access to education is measured by expected years of schooling of children at school-entry age and mean years of schooling of the adult population. The higher the level of education of people, the richer the value of the land they recognize.

$$\text{Education Index} = \left(\frac{MYS}{15} + \frac{EYS}{18}\right)/2 \tag{8}$$

MYS is the mean years of schooling; EYS is expected years of schooling.

A decent standard of living is measured by Gross National Income per capita adjusted for the price level of the country. There is a positive correlation between income and people's environmental requirements; the higher people's income, the more they need a clean and healthy living environment.

$$\text{Income Index} = \frac{\ln GNIpc - \ln 100}{\ln 75000 - \ln 100} \tag{9}$$

GNIpc is Gross National Income per capita.

4. Scarcity Index

On the basis of the above evaluation methods, the scarcity impact of the loss of ecology system services due to the development of land-use projects of different scales is considered. The utility-value theory suggests that the price of a commodity arises from its value and scarcity.[2] The scarcity which is determined by the market demand and supply is an important factor affecting the price.

So, the actual price of the land can be expressed as:

$$P = C \times \left(1 + \frac{Q_d \cdot E_d}{Q_s \cdot E_s}\right) = \left(EC_1 + EC_2 + SC\right) \times \left(1 + \frac{Q_d \cdot E_d}{Q_s \cdot E_s}\right) \tag{10}$$

Where Q_d denotes the demand quantity and the E_d denotes the demand elasticity of the market. So is the supply.

When applying the benefit-cost analysis on project k, we can use the $Area_{i,j,k}$ to substitute the market demand quantity Q_d. And because natural resources are not renewable in the short term, we can assume that $Q_s \cdot E_s$ is constant during the study period and can be expressed as the total stock volume $stock_{i,j}$. So, we get the specific expression of the land-use price of project k.

$$P_{i,j,k} = C_{i,j,k} \times \left(1 + \frac{\text{Area}_{i,j,k} \cdot E_d}{\text{Stock}_{i,j}}\right) = C_{i,j,k} \times \left(1 + s_{i,j,k}\right) \quad (11)$$

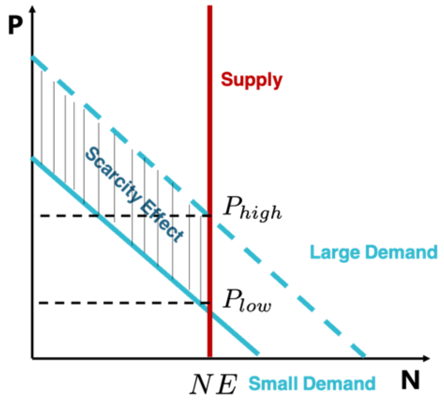

Figure 3: Scarcity effect on the market price

Where $s_{i,j,k}$ is the Scarcity Index. i denotes the region where the land-use project k is located. j denotes the type of ecosystem occupied by the land-use project.

$$s = \frac{Area \times E_d}{Stock} \quad (12)$$

This means that when a land-use project occupies a larger land area, the demand for land is high while the supply level remains the same, and therefore the market price of land rises as a result. It should be noted that the actual transaction price of land is influenced by the function of land, the level of social development, and the market supply and demand situation.

5. Conclusion

This paper aims at the proper land ecological service function planning and constructs a comprehensive evaluation model to reflect the land-use project. First of all, an EES model of supply and demand balance under fixed supply of natural resources is established to explore the ecological value EC_1 and economic value EC_2 of land ecosystem services and to calculate the share of subjective value SC in the total land value under different levels of social development. Finally, to investigate the cost differences of land-use projects of different sizes, we introduce the land scarcity index SI according to the utility value theory to reflect the relationship between land demand and land stock of land-use projects in this area and show that the land price per unit area of different scale is different.

References

[1] Daily, G.C., 1997. Introduction: what are ecosystem services. In: Daily, G.C. (Ed.), Natures Services: Societal Dependence on Natural Ecosystems. Island Press, Washington DC, pp. 110.

[2] Straton A.,2006. A Complex Systems Approach to the Value of Ecological Resources. Ecological Economics 56: 402 - 411.

[3] UNDP. 2010. Human Development Report 2010: The Real Wealth of Nations Pathways to Human Development. New York. http://hdr.undp.org/en/content/ human-development-report-2010.

[4] Barbier, E.B., Baumgärtner, S., Chopra, K., Costello, C., Duraiappah, A., et al., 2009. The valuation of ecosystem services. In: Naeem, S., Bunker, D., Hector, A., Loreau, M., Perrings, C. (Eds.), Biodiversity, Ecosystem Functioning, & Human Wellbeing: An Ecological and Economic Perspective. Oxford University Press, Oxford, pp. 248262.

[5] Costanza, R., dArge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., ONeill, R.V, Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253 260.

[6] Gómez-Baggethuna, E., de Groot, R., Lomas, P., Montesa, C., 1 April 2010. The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. Ecological Economics 69 (6), 1209-1218.

ISSN 2616-5872 Vol.4, Issue 2: 42-47, DOI: 10.25236/AJEE.2022.040209

[7] Norgaard, R., 1 April 2010. Ecosystem services: From eye-opening metaphor to complexity blinder. Ecological Economics 69 (6), 1219-1227.

[8] Richmond, A., Kaufmann R., Myneni, R., 2007, Valuing ecosystem services: A shadow price for net primary production. Ecological Economics 64, 454-462.

[9] Yang, Q., Liu, G., Casazza, M., Campbell, E., Giannetti, B., Brown, M., December 2018. Development of a new framework for non-monetary accounting on ecosystem services valuation. Ecosystem Services 34A, 37-54.

[10] Ma Guoxia, YU Fang, W ANG Jinnan, ZHOU Xiafei, YUAN Jing, Mou Xuejie... & Peng, F. 2017. China's total terrestrial ecosystem Production in 2015. China Environmental Science (04), 1474-1482.

[11] Guzmťlť cn G I, Molina M G D, Alonso A M. The land cost of agricultural sustainability. An assessment [J]. Land Use Policy, 2011, 28(4), 825-835.