ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0005

Ecosystem Service Value Assessment Based on Clustering Analysis and ESV Algorithm

Chengwei Sun[1], Baotong Gu[2] and Jie Zhang[1]

[1]School of Statistics and Applied Mathematics, Anhui University of Finance and Economics, Anhui Bengbu 233030, China.

[2]School of Finance, Anhui University of Finance and Economics, Anhui Bengbu 233030, China.

Abstract

With the development of globalization, environmental degradation has become one of the hottest topics around the world. In order to solve the problem of establishing an ecological services valuation model and analyzing cost benefit of land use development projects, this paper adapts Cluster Analysis, ESV Algorithm, Principal Component Analysis and other theories, and establish an integrated evaluation index system and standard for cost-benefit analysis of land use projects combined with Invest Model. Besides, we use software such as MATLAB and SPSS to calculate all kinds of index data. Finally, based on Time Series Model, we provide advice for land use project planners and managers.

Keywords

Environmental degradation; Cluster Analysis; ESV; MATLAB.

1. BACKGROUND

In the past three decades, global ecological and environmental problems have become increasingly prominent, especially the deterioration of water and land resources. The United Nations has released its millennium ecosystem assessment report, which estimates that about 60 percent of the world's ecosystems are still degraded. The ecosystem services and natural resources they provide are critical to the functioning of living systems on earth [1]. Ecosystem services are the conditions and processes by which natural ecosystems and species realize human life. It not only creates necessary environmental conditions for human survival, but also provides leisure, entertainment and aesthetic enjoyment for human life. They contribute directly or indirectly to human well-being, and therefore they also represent part of the total economic value of the planet.

With the rapid development of economy, environmental degradation is becoming more and more serious. If environmental degradation is included in the cost of land use projects, the cost-benefit ratio of land use projects is analyzed, so as to make a real and comprehensive assessment of land use development projects of different scales [2]. At the same time, it can provide some help to planners and managers of land use projects.

2. DATA SOURCES AND ASSUMPTIONS

In this paper, the data are from National Bureau of Statistics of the People's Republic of China, Statistical Yearbook of Henan province, including land use and land development projects. To solve the problem clearly, the following hypothesis are put forward: (1) The ecological service value of construction land is 0; (2)Only forest, grassland, arable and wetland ecosystems can

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0005

provide the value of ecological services;(3)Principal Component Analysis and Cluster Analysis are independent.

3. ECOSYSTEM SERVICES VALUE ASSESSMENT

3.1. Assessment Preparation

(1) Choose Clustering Analysis method

After serious consideration and combining with the actual, chose correlation coefficient method and the shortest distance method of R—type clustering.

(2) Collect relevant data

Data on environmental protection and land use in Kaifeng, Henan province and China are obtained. Land use development projects from Kaifeng to Henan province to China correspond to different scales.

(3) Select appropriate indicators

In terms of ecological service assessment, the evaluation index system can be divided into subsystems, supply services, regulating services, support services, cultural services. In selecting specific indicators of each subsystem, we follow the principles of conciseness, harmony and integrity to establish a scientific, predictable and comparable indicator system. The following 23 indicators are selected, as shown in table 1:

Tab 1. Variables and their significances

Variables	Significance	Y_6	Production of industrial hazardous waste
X_1	Grass	Y_7	General industrial solid waste production
X_2	Plough	Y_8	Chemical oxygen emissions from agricultural wastewater
X_3	Forest	Y_9	Urban sewage discharge
X_4	Water area	Y_{10}	Chemical oxygen demand discharge in urban sewage
X_5	Construction land	Y_{11}	Total domestic water consumption
X_6	Unused land	Y_{12}	Urban sewage treatment plant design capacity
Y_1	Industrial effluent discharge	Y_{13}	Urban sewage treatment capacity
Y_2	Industrial wastewater directly emission	Y_{14}	Urban household garbage disposal capacity
Y_3	Industrial wastewater treatment cost	Y_{15}	Operation cost of municipal solid waste treatment plant
Y_4	Industrial waste gas emissions	Y_{16}	Operation cost of disposal plant for hazardous waste
Y_5	Industrial waste gas treatment cost	Y_{17}	Hazardous waste disposal

3.2. Cluster Analysis

Make cluster analysis on data indicators related to environmental protection and obtain 6 classes, and can get a list of 17 environmental indicators that can be measured in the city of Kaifeng. The three classification methods are shown in Fig.1.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0005

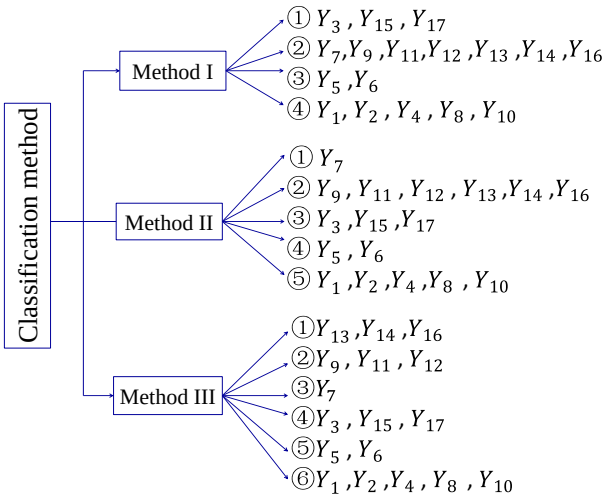

Fig 1. Classification of environmental protection index in Kaifeng city

3.3. Analysis and Disposal of Data from Land-Use Projects

Currently, the most widely recognized and internationally recognized system for ecosystem service classification is the classification method proposed by the millennium ecosystem evaluation working group, as shown in Tab.2. Combine the ecosystem structure and ecological process characteristics of Kaifeng, ecosystem services can be divided into gas exchange, climate regulation, water conservation, soil formation and protection, waste treatment, biodiversity conservation, food production, raw materials, entertainment and leisure entertainment [3].

Tab 2. Classification of ecosystem services

Type I	Type II	Definition of ecological services
Supply service	Food production	Convert solar energy into edible plant and animal products
	Raw material production	Solar energy will be transformed into biological energy to provide buildings, production and tools for human life
Regulating service	Gas adjustment	The ecosystem maintains the balance of atmospheric chemical composition and absorb SO2 nitrogen compounds and nitrogen oxides
	Climate adjustment	Adjust regional climate, such as increasing precipitation and decreasing temperature
	Hydrological adjustment	Freshwater filtration, retention and storage functions of ecosystems and the supply of fresh water
	Waste disposal	The role of vegetation and organisms in the removal and decomposition of superfluous nutrients and compounds
Support service	Maintain biodiversity	Organic matter accumulation and the role of plant root matter and organisms in soil conservation, nutrient cycling and accumulation
	Provide aesthetic	Genetic origin and evolution of wild animals, wild plants and habitats
Cultural service	Landscape	Recreational use and artistic value

3.4. Ecosystem Service Value Evaluation

According to Gaodi Xie and other researches, a standard unit of ecosystem services value equivalent factor refers to the standard farmland per year the economic value of natural food

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0005

production [4]. Considering standard equivalent and combined with the equivalent factor table of ecosystem service value, the coefficient table of ecosystem service value per unit area of each land use type and each ecosystem service function is calculated [5], which can reflect the contribution ability of each land use type and each ecosystem service function to ecosystem service value. The formula for calculating the value of ESV equivalent factor[6] is as follows:

$$VC_0 = \frac{1}{7} \times P \times \frac{1}{n} \times \sum_{i=1}^{n} Q_1$$

In the formula, the function VC_0 refers to the value of equivalent factor in ESV (Yuan/hm^2/a); the function P refers to the national average price of grain (Yuan/kg) [4] the function Q refers to average grain yield (kg/hm^2); The function n refers to years.

In the course of scholars and Gaodi Xie, it has to be improved and perfected in terms of the ecosystem services value in Kaifeng, Henan, and China. As shown in Tab.3, the equivalent factor table of Chinese terrestrial ecosystem can be obtained. At the same time, the service value coefficient of each type of ecosystem service unit area in Kaifeng can be calculated [4], as shown in Tab.4.

Tab 3. Value of ecosystem services per unit area of terrestrial ecosystems in China

Ecosystem services function	Type of land use				
	Grassland	Farmland	Forest land	Waters	Unutilized land
Gas exchange	0.80	0.50	3.50	1.80	0.00
Climate regulation	0.90	0.89	2.70	17.56	0.00
Water conservation	0.80	0.60	3.20	35.88	0.03
Soil formation and conservation	1.95	1.46	3.90	1.72	0.02
Waste disposal	1.31	1.64	1.31	36.36	0.01
Biodiversity conservation	1.09	0.71	3.26	4.99	0.34
Food production	0.30	1.00	0.10	0.40	0.01
raw material	0.05	0.10	2.60	0.08	0.00
Entertainment and leisure	1.28	0.01	1.28	9.89	0.01
Total	8.48	6.91	21.85	108.68	0.42

The calculation formula of ESV is as follows:

$$\text{ESV} = \sum_{k=1}^{n} (A_k \times VC_k)$$

$$ESV_f = \sum_{k=1}^{n} (A_k \times VC_{fk})$$

In the formula, the function A_k refers to area of land use type k (hm^2), the function VC_k refers to ecosystem value coefficient (Yuan/hm^2/a^{-1}); the function ESV_f refers to ecosystem value coefficient of f; the function VC_{fk} refers to the ecosystem value coefficient of item f of land use type k (Yuan/hm^2/a^{-1}).

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0005

Tab 4. Value coefficient of ecosystem services per unit area in Kaifeng (Yuan $\cdot$ hm^{-2} $\cdot$ a^{-1})

Ecosystem services function	Type of land use				
	Grassland	Farmland	Forest land	Waters	Unutilized land
Gas exchange	1472	920	6438	3311	0
Climate regulation	1656	16370	4966	32300.	0.
Water conservation	1472	1104	5886	65998	55
Soil formation and conservation	3587	2686	7174	3164	37
Waste disposal	2410	3017	2410	66881	18
Biodiversity conservation	2005	1306	5996	9179	625
Food production	552	1839	184	736	18
raw material	92	184	4782	147	0
Entertainment and leisure	2354	18	2354	18192	18
Total	15598	12710	40191	199906	773

As can be seen from the Tab.5: from the perspective of the composition of ESV of Kaifeng, the size of the proportion of each single function value in turn as follows: Water conservation> Keep the soil> Waste gas treatment> Climate regulation> Maintain biodiversity> Gas adjustment> Raw material production> Leisure and entertainment> Food production In terms of the contribution of individual functions, the functional value of water conservation is the most prominent, accounting for about 16% of ESV, followed by soil formation and protection, accounting for about 15.8%. The contribution of food production function is the least, accounting for only 3.4%.

Tab 5. Average level

Project	The average value of ecosystem services	Rank
Gas adjustment	46.51	6
Climate adjustment	53.18	4
Water conservation	66.69	1
Keep the soil	65.25	2
Waste gas treatment	60.69	3
Maintain biodiversity	49.32	5
Food production	14.07	9
Raw material production	29.04	7
Leisure and entertainment	23.59	8

4. PRINCIPAL COMPONENT ANALYSIS

4.1. Analysis Preparation

(1) Standardize the raw data

Suppose there are m indicator variables for principal component analysis, they are X_1,X_2,$\cdots$,X_m, there are n evaluation objects, the value of the j indicator of the i evaluation object is a_{ij}[7]. Convert each index valuea_{ij}into standardized index value $\tilde{a}_{ij}$, then

$$\tilde{a}_{ij} = \frac{a_{ij} - \mu_j}{s_j}, i = 1, 2, \cdots, n; j = 1, 2, \cdots, m$$

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0005

In the formula, $\mu_j = \frac{1}{n}\sum_{i=1}^{n} a_{ij}$ $s_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(a_{ij}-\mu_j\right)^2}, j = 1, 2, \dots, m$, so μ_j and s_j are the sample mean and sample variance of the j index[7]. Conversely,

$$\tilde{x}_j = \frac{x_j - \mu_j}{s_j}, j = 1, 2, \dots, m$$

(2) Calculate the correlation coefficient matrix R

$$\mathrm{R} = \left(r_{ij}\right)_{m\times m}$$

$$r_{ij} = \frac{\sum_{k=1}^{n}\tilde{a}_{ki}\cdot\tilde{a}_{kj}}{n-1}, i, j = 1, 2, \cdots, m$$

In the formula, $r_{ii} = 1, r_{ij} = r_{ji}$, r_{ij} is the correlation coefficient between i index and j index.

(3) Calculate eigenvalues and eigenvectors

Calculate the eigenvalues of the correlation coefficient matrix [7] R $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_m \geq 0$, and the corresponding eigenvector $u_1, u_2, \cdots, u_m$, especially, $u_j = \left[u_{1j}, u_{2j}, \cdots, u_{mj}\right]^T$, the eigenvectors make up m new index variable:

$$\begin{aligned} y_1 &= u_{11}\bar{x}_1 + u_{21}\bar{x}_2 + \cdots + u_{m1}\bar{x}_m \\ y_2 &= u_{12}\bar{x}_1 + u_{22}\bar{x}_2 + \cdots + u_{m2}\bar{x}_m \\ &\vdots \\ y_m &= u_{1m}\bar{x}_1 + u_{2m}\bar{x}_2 + \cdots + u_{mm}\bar{x}_m \end{aligned}$$

In the formula, y_1 is the first principal component; $\boldsymbol{y_2}$ is the second principal component.... ; $\boldsymbol{y_m}$ is the MTh principal component.

(4) Select p (p<=m) principal components to calculate the comprehensive evaluation value

$b_j = \lambda_j / \sum_{k=1}^{m}\lambda_k, j = 1, 2, \cdots, m, \alpha_p = \sum_{k=1}^{p}\lambda_k / \sum_{k=1}^{m}\lambda_k, \mathrm{Z} = \sum_{j=1}^{p} b_j y_j$

In the formula, b_j is the information contribution rate of the j principal component, judging by the overall score.

4.2. Model Establishing and Solving

It can be concluded that gas exchange, climate regulation and water conservation in the 9 functions are selected as the three main components, and the three main components are calculated by MATLAB as follows:

$$\begin{aligned} y_1 &= -0.3889\tilde{x}_1 + 0.0170\tilde{x}_2 - 0.1909\tilde{x}_3 + \cdots + 0.0799\tilde{x}_9 \\ \mathrm{y}_2 &= -0.3865\tilde{\mathrm{x}}_1 + 0.1813\tilde{\mathrm{x}}_2 + 0.0844\tilde{\mathrm{x}}_3 + \cdots + 0.0750\tilde{\mathrm{x}}_9 \\ \mathrm{y}_3 &= -0.3464\tilde{\mathrm{x}}_1 + 0.0348\tilde{\mathrm{x}}_2 + 0.4426\tilde{\mathrm{x}}_3 + \cdots - 0.0748\tilde{\mathrm{x}}_9 \end{aligned}$$

As can be seen from the principal component coefficient, the first principal component mainly reflects the information of gas exchange and soil formation and protection. The second principal component mainly reflects the information of gas exchange and soil formation and protection, waste treatment and biodiversity [8]. The third principal component reflects information on gas exchange, waste disposal, water conservation and biodiversity, and recreation. Three principal component values of each land use project can be obtained by substituting the standardized data of the original nine indicators of each land use project into three principal component expressions.

Each of these three main ingredients is weighted to construct the master's synthetic evaluation model,

$$\mathrm{Z} = 0.7015\mathrm{y}_1 + 0.1620\mathrm{y}_2 + 0.1365\mathrm{y}_3$$

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0005

By substituting the three principal component values of each land use project into the above formula, the comprehensive evaluation value and ranking results of the ecological service value level of each land use project can be obtained, as shown in Tab.6.

Tab 6. Comprehensive evaluation of land use projects

Land use projects	Grass	Plough	Forest	Water area
Ranking	4	3	1	2
Value	-1.5451	-0.6889	2.5568	-3.228

Cost benefit ratio: W/M and the function W refers to the region loss of ecological service value in a year. The function M refers to the region's GDP.

5. CONCLUSIONS AND RECOMMENDATIONS

In recent years, although the scale economic activity around the world is more and more comprehensive, the environmental pollution is more and more serious. As an important part of environmental pollution, land use management and planning is of great importance. In view of this problem, this paper establishes an ecological service assessment model, which can calculate the value of ecological services, and then people can manage and use the land more scientifically. With the development of social economy, the concept of sustainable development is constantly improved. At present, the development of land use in the world is restricted by ecological environment problems. Scientific and reasonable land use planning can promote the development of social economy. Therefore, land managers and planners are the key roles, land use planning should fully consider the ecological environment of the land, scientific evaluation of land environmental issues cannot be ignored.

REFERENCES

[1] Mamat Sawut, Mamattursun Eziz, Taxpolat Tiyip. The effects of land-use change on ecosystem service value of desert oasis: a case study in Ugan-Kuqa River Delta Oasis, China, Canadian Journal of Soil Science, 2013, 22.

[2] Man-Jing Li, Jia-Xu Han, Mao Zhu, Yuan-Biao Zhang.The True Valuation of Land Use Project in China Considering Ecosystem Services, Modern Applied Science, 2019,25.

[3] Xuncheng Fan, Jianbin Liu, Jianzhong Chen, Lili Zhao, Wei Hong. Changes of Land Use and Functions of Ecosystem Service: A Case Study in China, Polish Journal of Environmental Studies, 2018, 16.

[4] Yuchen Liu, Zihe Deng, Qian Lin, Lei Wang. "Assessment Model of Ecosystem Service Value Based on Environmental Kuznets Curve", IOP Conference Series: Materials Science and Engineering, 2019, 36.

[5] Xiang Huang, Yaning Chen, Jianxin Ma, Yapeng Chen. "Study on change in value of ecosystem service function of Tarim River", Acta Ecologica Sinica, 2010, 34-41.

[6] Bo Li, Te-sheng Sun, Xiao-yuan Song, Ying Hou. "Dynamic assessment of ecosystem service value in Huangfuchuan basin based on LUCC", 2010 3rd International Conference on Biomedical Engineering and Informatics, 2010

[7] Baoying Fan, Yingju Yuan. "Constructing an assessment index system for strategic risk management in coal science and technology enterprises", International Journal of Mining Science and Technology, 2016, 41-47.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202005_6(5).0005

[8] Dandan Zeng, Long Chen, Zhenhua Song. "Research on Models of Overall Land-use Planning Based on Ecological Protection Thought", IOP Conference Series: Earth and Environmental Science, 2018, 16-21.