Evaluation of Land Use Multifunctionality from the Perspective of "Production-Living-Ecology"

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Abstract. Based on the entropy TOPSIS model and clustering method, this article builds a multi-functional evaluation index system for land use based on 21 indicators from the perspective of "production-life-ecology", evaluates the multifunctionality of land use, and analyzes its spatial differences in Baise, Guangxi, China. The results show that the multifunctional level of land use in Baise is still at a poor level, and the ecology function are better utilized. There are big differences in the spatial distribution of multifunctional land use among counties in Baise, and the overall spatial distribution pattern is "slightly stronger in the south than in the north". Multifunctional land use in Baise is greatly affected by production function factors. It is recommended to accelerate industrial transformation and upgrading, and give full play to the different ecology, resource, location or policy advantages of each county to improve the level of land production functions, and pay attention to green development, the common development of each function and the regional coordinated development.

1. Introduction

Land resources are the foundation of human survival and development, reasonable allocation of land resources and improvement of land use efficiency are indispensable. Although China has made great progress in its development in recent years, the utilization of land resources and sustainable development are still under tremendous pressure. The sustainable development concept of “innovation, coordination, greenness, openness and sharing” put forward by the Fifth Plenary Session of the 18th Central Committee is an important theoretical support for solving the problem of land resource supply and demand. The realization of such a development concept requires comprehensive land use and expansion of land use functions.

The concept of multifunctionality originated in the agricultural sector, and was gradually adopted and expanded to other research fields [1]. In 2001, the EU Sensor Project first proposed the concept of land use multifunctionality. Since then, the research on land use multifunctionality has become a research hotspot [2]. Since the 21st century, scholars have conducted in-depth discussions based on the multifunctional meaning and classification of land use, and have conducted research on different land types, different evaluation methods, and factors affecting the dynamic changes of temporal and spatial patterns. Foreign scholars mainly studied the multifunctional theory of land use from the perspective of sustainable land use, and constantly improved the framework and research methods of the...
multifunctional evaluation index system of land use [3][4]. Research on the multifunctionality of land use in China mainly focused on the multifunctional evaluation index system of land use [5][6], measurement models [7], evaluation methods [8][9], analysis of temporal and spatial changes [10][11], influencing factors [12][13] and so on. On the whole, the framework and methodological system of multifunctional evaluation research on land use in China has been initially formed. Although land use multifunctional evaluation models and research methods are constantly improving, the existing land use multifunctional evaluations are mostly based on time periods, large areas or a relatively single evaluation system. Few evaluations are based on the spatial perspective of the "production-living-ecology", and there are few studies on the multifunctionality of land use at the city or county level. 

Baise is a special area of “six in one” in Guangxi, China, integrating old revolutionary areas, ethnic minority areas, border areas, Dashi mountainous areas, national-level poverty-stricken areas, and reservoir immigration areas. The research on the multifunctionality of land use in Baise is typical and representative. It is of great significance for the expansion of the multifunctional of land use in border cities and space planning under the background of the new era, and it is of practical significance for the sustainable development of land use in Baise. Therefore, this article studies the multifunction of land use in Baise based on the perspective of "production-life-ecology", hoping to provide references for the scientific and rational use of land functions for Baise.

2. Methodology

2.1. Evaluation index system

Based on the research of related scholars, considering the scientific, hierarchical, representative, and operability principles of the evaluation index system, and combining with the actual situation of Baise, this article constructs a multifunctional land use evaluation index system of "production-living-ecology" dimension (Table 1). Production function is the ability of human beings to obtain products, wealth, and smooth traffic from the land, which can be characterized by indicators D1-D8. Living function refers to the ability of humans to use the land to carry out a series of human activities to meet their life needs, which can be characterized by indicators D9-D16. Ecology functions are often associated with "green water and green mountains", representing resource supply and ecological conservation, etc., which can be characterized by indicators D17-D21.

| Target layer A | Sub-target layer B | Criterion layer C | Index layer D | Calculation instructions |
|----------------|-------------------|-------------------|---------------|--------------------------|
| Total land use function (A) | Production function (B1) | Agricultural production function (C1) | Sown area of crops per capita (D1) | Sown area of crops/ population |
| | | | Land reclamation rate (D2) | Cultivated area/administrative area |
| | | | Per capita meat and water production (D3) | Total meat and water products/population |
| | Economic development function (C2) | | Per capita output value of the secondary and tertiary industry (D4) | Output value of secondary and tertiary industries/ population |
| | | | GDP per land (D5) | GDP/administrative area |
| | Traffic function (C3) | | Fixed asset investment per land (D6) | Investment in fixed assets /administrative area |
| Living function (B2) | Social Security Service Function | Personnel Density in Health Institutions (D9) | Health technical staff/administrative area |
| | | Public budget expenditure density (D10) | Public budget expenditure/administrative area |
2.2. Entropy weight TOPSIS model

The entropy weight TOPSIS model is a fusion of the entropy weight method and the TOPSIS model. The entropy method is an objective method to determine the weight, the TOPSIS (technique for order preference by similarity to ideal solution) model is a sorting method that approximates the ideal solution, also known as the distance method of superior and inferior solutions. The entropy weight TOPSIS model is an improved TOPSIS model based on entropy weight. The main steps are as follows:

1. Standardize data processing. Since this article uses positive indicators, the standardized formula is:

\[ A_{ij} = \frac{X_{ij} - X_{min}}{X_{max} - X_{min}} \]  

(1)

Where, \( X_{ij} \) and \( A_{ij} \) are the original value and standardized result of the index respectively, and \( X_{min} \) and \( X_{max} \) are the minimum and maximum values of the index respectively.

2. Entropy method to determine the index weight.

\[ p_j = A_j \left( \sum_{i=1}^{m} A_{ij} \right)^{-1} \]  

(2)

\[ e_j = \ln(m) \sum_{i=1}^{m} p_{ij} \ln p_{ij} \]  

(3)

\[ w_j = \left( 1 - e_j \right) \left( \sum_{j=1}^{n} e_j \right)^{-1} \]  

(4)

Where, \( p_{ij} \) is the proportion of the \( j \)-th evaluation index in the \( i \)-th evaluation county, \( e_j \) is the information entropy of the evaluation index, \( w_j \) is the weight, \( m \) is the number of evaluation units, and \( n \) is the number of evaluation indicators.

3. Construct a weighted standardized decision matrix \( V \) to determine the positive and negative ideal solutions. Normalized decision matrix \( V = W \times A \).

4. Distance calculation. Calculate the Euclidean distance \( D^+ \) from the positive ideal solution \( V^+ \) and the Euclidean distance \( D^- \) from the negative ideal solution \( V^- \) respectively.

\[ D^+ = \left( \sum_{j=1}^{m} (V^+_j - V^-_j)^2 \right)^{1/2} \]  

(5)

| Cultural function (C4) | GDP per capita (D11) | From the statistics department |
|------------------------|----------------------|-------------------------------|
| Teacher density in primary and secondary schools (D12) | Number of primary and secondary school teachers/administrative area |
| Per capita green area per capita (D13) | From the statistics department |
| Environmental resource supply function (C7) | Cultivated area per capita (D17) | Cultivated area/population |
| Daily domestic water consumption per capita (D18) | From the statistics department |
| Ecological conservation function (C8) | Green area rate of built-up area (D19) | From the statistics department |
| Green coverage rate of built-up area (D20) | From the statistics department |
| Forest cover rate (D21) | Forest area/administrative area |
\[ D^- = \left( \sum_{j=1}^{m} (V^-_j - V^-_j)^2 \right)^{1/2} \]  

(6)

Where, \( V^+ = \{ \max V_j | i = 1, 2, \ldots, n \} = \{ V^+_1, V^+_2, \ldots, V^+_n \} \), \( V^- = \{ \min V_j | i = 1, 2, \ldots, n \} = \{ V^-_1, V^-_2, \ldots, V^-_n \} \).

5. Calculate the closeness between the evaluation object and the optimal plan.

\[ C = D^+ \left( D^+ + D^- \right)^{-1} \]  

(7)

Where, \( C \) is the closeness, its value is between \([0, 1]\). The larger the value, the closer the index of the evaluation object is to the positive ideal solution of the index, and the multifunctional level of land use is optimal. Based on the existing related research [14]-[15], this article divides the closeness into 4 grades (Table 2) to indicate the degree of versatility of land use.

| Functionality   | Poor       | General   | Good       | Excellent  |
|-----------------|------------|-----------|------------|------------|
| Closeness       | 0.00-0.30  | 0.31-0.60 | 0.61-0.80  | 0.81-1.00  |

3. Results and Analysis

3.1. Multifunctional evaluation of land use

The total land use function value, production function value, living function value and ecology function value of all counties in Baise in 2018 are calculated according to above formulas (Table 3).

| District | Total Function | Production Function | Living Function | Ecology Function |
|---------|----------------|---------------------|-----------------|-----------------|
| Youjiang| 0.3116         | 0.2402              | 0.5147          | 0.6944          |
| Tianyang| 0.2549         | 0.2263              | 0.3723          | 0.3457          |
| Tiandong| 0.2224         | 0.1967              | 0.3076          | 0.7077          |
| Pingguo | 0.3513         | 0.2594              | 0.6148          | 0.5497          |
| Debao   | 0.1674         | 0.1287              | 0.2553          | 0.7438          |
| Jingxi  | 0.6920         | 0.8135              | 0.3621          | 0.2089          |
| Napo    | 0.3382         | 0.3773              | 0.1661          | 0.6607          |
| Lingyun | 0.0874         | 0.0603              | 0.1142          | 0.5319          |
| Leye    | 0.0953         | 0.0766              | 0.1034          | 0.5610          |
| Tianlin | 0.0794         | 0.0558              | 0.1159          | 0.4001          |
| Xilin   | 0.2279         | 0.0603              | 0.4273          | 0.7433          |
| Longlin | 0.0949         | 0.0652              | 0.1275          | 0.6009          |

Table 3 shows that:

1. The land use function level of most counties in Baise is still at a poor level. There is still much space for improvement in production and living functions, and the ecology function shows certain advantage which is inseparable from the rich natural resources in Baise.

2. The overall functional level of land use in Jingxi is relatively good, and the production functional level is excellent, ranking first in Baise. This is inseparable from its own excellent geographical location and government policies. Jingxi belongs to the Sino-Vietnamese border area and has obvious location advantages and policy advantages. The functions of agricultural production, economic development, and transportation have a good level of performance in the process of land use, and the level of land production functions should be maintained. Meanwhile, Jingxi has the lowest score for ecology function which is related to its development model.
Generally, land use is a complex process interacting with each other in the dimension of "production-living-ecology". Therefore, green and coordinated development is indispensable, and the economy cannot be developed at the expense of ecology.

3.2. Spatial difference of land use multifunctionality

According to table 2, a grading map of the multifunctional land use level are obtained by using ArcGIS (Figure 1).

Figure 1 shows that:

1) The spatial distribution of each type of function is different, but all show the characteristics of "slightly stronger in the south than in the north". The overall multifunctional level of land use in the northern region is slightly weaker than that in the southern region. This is closely related to the poor natural conditions, backward infrastructure, weak industrial foundation, and small economic aggregate in the northern part of Baise. And some areas in the south also have an unreasonable industrial structure. The production, living and ecology functions of land use restrict each other, and development is hindered.

2) The spatial distribution of production function is similar to that of total land use function, indicating that the land use production function and total function are closely related. The total functional of land use is greatly affected by production functional factors such as agricultural production, economic development, and transportation. The continuous and stable development of the production function should be maintained.

4. Conclusion

The article has studied the multifunctional land use in Baise from the perspective of "production-living-ecology". The study found that the overall level of land use function in Baise is not high which is closely related to the basic conditions of Baise, such as abundant resources, severe rocky
desertification, fragile ecology, weak material and living foundations, and irrational industrial structure.

(1) The multifunctional level of land use in most counties in Baise is still at a poor level. Production and living functions have more space for improvement, and the ecology functions are better utilized. In the process of industrial structure transformation, it is necessary to pay attention to green development, protect the ecological environment, strengthen the control of rocky desertification, and maintain good ecology functions.

(2) There are big differences in the spatial distribution of multifunctional land use in each county, but the overall spatial distribution pattern of "slightly stronger in the south than in the north" is still present. It is recommended that areas with similar levels of land use multifunctional can be consulted with similar counties when formulating relevant policies.

(3) Multifunctional land use in Baise is greatly affected by production function factors. It is recommended to accelerate industrial transformation and upgrading, give full play to the different ecology, resource, location and policy advantages of each region, improve the level of land production function, and pay attention to the joint development of each function and the coordinated development of land use regions.

Acknowledgments
This article is financially supported by the Guangxi Natural Science Foundation (2020GXNSFAA159065) and the Seventh Batch of Distinguished Experts in Guangxi.

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