Evaluation and Optimization Algorithm of Regional Multi-Scale Land Spatial Coordination Degree Under Multi-Source Data Fusion

Feng Chen(✉), Yifang Li, and Yuxin Zhang

Zhejiang University Urban-Planning & Design Institute Co, Ltd., Hangzhou 310010, Zhejiang, China
zjufengc@foxmail.com

Abstract. Against the backdrop of rapid economic and social development, accelerated urbanization, and changes in land use structure, we actively respond to the national ecological protection strategy, coordinate regional and multi-scale land spatial planning, and comprehensively promote the construction of ecological civilization Therefore, we put forward the evaluation and optimization algorithm of regional multi-scale land spatial coordination under multi-source data fusion. The evaluation price index system of regional multi-scale land spatial coordination degree is constructed, the calculation model of coordination degree is established, and the evaluation and optimization algorithm of regional multi-scale land spatial coordination degree is realized by multi-source data fusion. The experimental results show that the coordination degree under the studied algorithm is getting better and better, and it shows a linear upward trend every year; The maximum value and average value of the consistency test results are lower than 0.1, and the index weight setting is reasonable and feasible.

Keywords: Multi-source data fusion · Regional multi-scale land space · Coordination evaluation · Optimization algorithm

1 Introduction

With the in-depth research and continuous promotion of ecological environment protection, it has brought more stringent requirements and challenges to the management of land space use and the overall planning and layout. Evaluating and optimizing the spatial coordination degree of regional multi-scale land is of great significance to realize the overall social economy, promote regional ecological construction, and accelerate the virtuous circle development between man and nature. With the rapid development of economy and society, the planning and management of land space has become more and more important.

However, in the process of regional development, the influence of various factors is often complex and diverse, so how to evaluate and optimize the regional land spatial

S. H. B. D. M. Zailani et al. (Eds.): ICMSEM 2023, 259, pp. 688–695, 2024.
https://doi.org/10.2991/978-94-6463-256-9_69

coordination degree becomes a challenge [1]. In addition, with the continuous development of information technology, multi-source data fusion has become an effective method to solve these problems. However, with the gradual improvement of social productive forces, the process of industrialization and urbanization has accelerated. With the large-scale agglomeration of industry and population, various urban problems have emerged, such as resource shortage, traffic congestion and housing shortage, which have aggravated the deterioration of global environmental quality; At the same time, it has greatly affected the global living environment. The living environment is facing very severe challenges [2, 3]. Therefore, the study of sustainable development has been widely favored by scholars from all walks of life. Rethinking, understanding and solving the human living environment problems through the concept of sustainable development such as scientific discovery and harmonious coexistence between man and nature, how to solve the difficulty of the lack of standard system for the coordination of land and resources spatial planning at this stage, and at the same time strengthen the research on the reform and coordination evaluation of land and resources spatial planning system have become the main problems of current research. This paper focuses on the evaluation and optimization algorithm of regional multi-scale land spatial coordination degree under multi-source data fusion. The evaluation price index system of regional multi-scale land spatial coordination degree is constructed, the calculation model of coordination degree is established, and the evaluation and optimization algorithm of regional multi-scale land spatial coordination degree is realized by multi-source data fusion. The research shows that the development of the coordination degree under the studied algorithm is getting better and better, and the maximum and average values of the consistency test results are lower than 0.1, so the index weight setting is reasonable.

2 Evaluation and Optimization Algorithm of Regional Multi-Scale Land Spatial Coordination Degree

2.1 Construction of Evaluation Index System

In the actual regional development and planning, it is often necessary to evaluate and optimize the spatial coordination degree of land, and an index system is needed for quantitative evaluation in the evaluation process [4]. In this paper, an evaluation index system of regional multi-scale land spatial coordination degree is established, which includes various indicators to analyze and evaluate the regional land spatial coordination degree from different angles. The index system aims to provide a scientific, comprehensive and accurate evaluation method to guide local governments and relevant departments to make more reasonable decisions in regional planning and land space management. The construction of regional multi-scale land spatial coordination evaluation index system must obey the principles of highlighting key points, serving the whole, appropriate levels, appropriate proportions, comprehensiveness, practicality and sustainability [5]. It is assumed that the total data sample number of related influencing factors of regional multi-scale land spatial coordination evaluation is E, including F evaluation indicators. The two forms a matrix with the size of $E \times F$, that is, the correlation coefficient matrix of evaluation index, which is expressed as:

$$A = E \times F = \begin{bmatrix} a_{11} & \cdots & a_{1i} \\ \vdots & \ddots & \vdots \\ a_{i1} & \cdots & a_{ij} \end{bmatrix} \tag{1}$$

In Formula (1), A represents the correlation coefficient matrix of regional multi-scale land spatial coordination evaluation index; a_{ij} stands for correlation coefficient. According to the calculation results of correlation coefficient matrix, the weights of each factor are calculated, and the system indicators and weights are obtained, as shown in Table 1.

On the basis of the above multi-scale evaluation index system and weight of regional land spatial coordination degree, a calculation model of coordination degree is constructed by integrating multi-source data.

Table 1. Evaluation index system and weight of regional multi-scale land spatial coordination degree

Index	Evaluating indicator	Weight
Land use structure index	Urban land use ratio	0.03
	Rural land use ratio	0.21
	Ecological land use ratio	0.01
Topographic and geomorphological index	Topographic elevation difference	0.21
	Slope	0.08
	Aspect	0.10
Traffic network index	Road density	0.01
	Railway density	0.21
	Traffic accessibility	0.08
Natural environment index	Climate	0.08
	Water resource	0.10
	Ecological environment	0.01
Socioeconomic indicators	Per capita GDP	0.01
	Industry structure	0.21
	Employment rate	0.08
Urbanization index	Urbanization rate	0.01
	Urban expansion speed	0.01
Historical and cultural heritage indicators	Quantity of cultural resources	0.10
	Conservation rate of cultural relics	0.15

2.2 Establish the Calculation Model of Coordination Degree

The degree of coordination indicates the strength of the interaction and correlation between the evaluation index systems of regional multi-scale land spatial coordination. However, in some cases, the degree of coordination is difficult to truly and concretely reflect the development differences. The coordination degree of the seven modules is consistent, but due to the different levels of construction and development of different modules, some may be in a low level of coordination, while others are very likely to be in a high level of coordination [6–8]. In order to better reflect the degree of coordination between regional development and ecological environment construction, a regional multi-scale land spatial coordination model is established, and its calculation formula can be expressed as:

$$Z = A \times C \times \frac{\alpha f(x) + \beta g(y)}{f(x) + g(y)} \tag{2}$$

In formula (2), Z represents the degree of coordination; α and β both represent index weights; C represents the comprehensive evaluation index coefficient between different evaluation indexes, $f(x)$ represents the evaluation coefficient of trade scale, and $g(y)$ represents the sustainable development coefficient of ecological construction. Economic transformation and ecological construction can be compared, so in a certain sense, $\alpha = \beta = 0.5$. Coordination degree combines the coupling coordination degree between ecological construction and economic development and its comprehensive index coefficient, so it has better stability and wider application scope, and can analyze and evaluate the development of regional multi-scale national spatial coordination degree in the same area without development stage or between different areas in the same stage.

2.3 Realize the Evaluation and Optimization Algorithm of Regional Multi-Scale Land Spatial Coordination Degree

Multi-source data fusion is to integrate and process information from different data sources to generate more accurate, detailed and comprehensive information [9]. In practical application, it is often necessary to obtain data from multiple data sources, but the data quality, characteristics and accuracy of each data source may be different in different degrees, so it is necessary to fuse these data to improve the reliability and accuracy of the data [10]. It is necessary to preprocess each data source, including data cleaning, data completion, data format conversion, etc., to eliminate differences and inconsistencies between data sources. Then, the preprocessed data can be fused by simple weighted average method or more complicated method. Finally, it is necessary to evaluate and optimize the fusion results to ensure the accuracy and reliability of the results. Multi-source data fusion is a method to determine the weight coefficient, which can divide all factors in complex problems into interrelated and orderly layers and make them more organized. Through the fuzzy judgment of objective reality, the quantitative expressions of regional multi-scale land spatial coordination degree evaluation and optimization of the relative importance of each level are given respectively, and the specific operation steps are as follows:

Step 1: Identify the problem:

Determine the main research scope of research objectives, such as the relationship between different factors, so as to promote users to fully grasp the information of research objectives.

Step 2: Build a hierarchy:

It is necessary to divide the factors contained in all the problems, and set each group as a level, and sort them according to the form of the highest level and the lowest level. Structural diagrams are usually used to represent different hierarchies, and the relationship between upper and lower elements needs to be marked in detail.

Step 3: Build a judgment matrix:

For the random elements in the upper level, it is necessary to comprehensively evaluate the relative importance of each element in the system and divide it into five different grade scales.

Step 4: Sorting hierarchical documents:

The main purpose is to determine the importance order weight value of elements that are related to this level. The task of hierarchical single sorting can be reduced to the problem of calculating the eigenvalues and eigenvectors of the judgment matrix, that is, for the judgment matrix ***B***, the calculation needs to meet the following constraints:

$$\boldsymbol{B} = \lambda_{\max} \times W \times Z \tag{3}$$

In formula (3), $\lambda_{\max}$ represents the maximum value of hierarchical sequence and W represents hierarchical association.

Step 5: Consistency check:

In order to determine the consistency of the evaluation results, similar to the ranking of hierarchical lists, consistency tests are also needed.

On the basis of the above analysis, the optimization algorithm of regional multi-scale land spatial coordination degree evaluation is realized, namely:

$$H_G = \frac{\boldsymbol{B}}{\sum_{k=1}^{P} \alpha_k} \tag{4}$$

In formula (4), α_k represents the optimization coefficient of regional multi-scale land spatial coordination degree evaluation, and P represents the optimization weight of regional multi-scale land spatial coordination degree evaluation.

3 Experimental Analysis

In order to test the feasibility and application effect of regional multi-scale land spatial coordination evaluation and optimization algorithm under multi-source data fusion, a simulation experiment was designed. The test platform of the experiment is built based on ArcEngine system. In order to ensure the stability of the platform, Python is used as the programming language of the system. The historical data of regional multi-scale land spatial planning in a certain area are stored in the database of the experimental platform as test samples for use. In order to verify the application effect of the algorithm in this article and highlight its advantages, standards for the accuracy of algorithms in generating data, their validation performance, and their ability to process large datasets in the Matlab program of the platform, the evaluation and optimization algorithm of regional multi-scale land spatial coordination under multi-source data fusion (the proposed algorithm), the graphic database algorithm (the algorithm in reference [2]) and the uncertainty propagation algorithm (the algorithm in reference [3]) are introduced as test algorithms, and the simulation experiments are carried out and the results are analyzed.

The evaluation of regional multi-scale land spatial coordination degree is a very complicated work. This paper evaluates the spatial coordination degree of A city through the constructed evaluation model. Combined with the actual development of city A, the coordination degree is calculated, and the results are shown in Fig. 1.

By analyzing the data in Fig. 1, it can be seen that during the period from 2015 to 2022, the development of coordination degree in City A is getting better and better, and it shows a linear upward trend every year.

On the basis of the above contents, the consistency of the calculation results of the evaluation index weights of the three algorithms is further tested to check whether the logic of the algorithms is correct. The test formula is as follows:

$$\zeta = \frac{\lambda - \theta}{\theta - 1} \times D \times H_G \tag{5}$$

In Formula (5), ζ represents the consistency index of the evaluation result of consistency test results; λ represents the largest characteristic root of coordination evaluation index; θ represents the dimension of coordination evaluation index; D stands for average random consistency index; Substitute the calculation parameters of the three algorithms into Formula (9) for calculation, and get the consistency test results, and extract the maximum and average values of the test results for comparative analysis. The results are shown in Table 2.

As can be seen from Table 2, the maximum and average values of the consistency test results of the proposed algorithm are all below 0.1; The maximum and average values of the consistency test results of the algorithm in reference [2] are higher than 0.1; The maximum consistency check result of the algorithm in reference [3] is higher

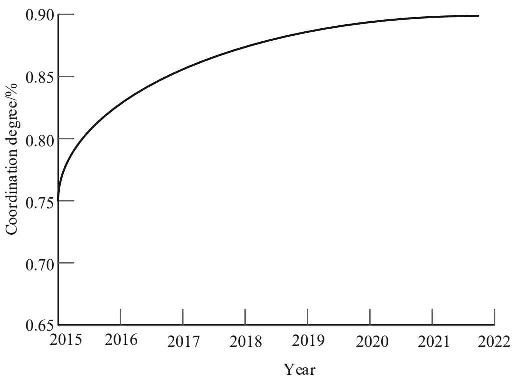

Fig. 1. A Spatial Coordination Degree of Multi-scale Land in Urban Area

Table 2. Regional Multi-scale Land Spatial Coordination Evaluation and Optimization Consistency Test Results

Different algorithms	Consistency test result	
	Maximum	Average value
The proposed algorithm	0.0016	0.0014
The algorithm in reference [2]	0.1251	0.1039
The algorithm in reference [3]	0.1059	0.0985

than 0.1, and the average value is lower than 0.1. It shows that the index weight setting of the regional multi-scale land spatial coordination degree evaluation and optimization algorithm under multi-source data fusion is reasonable and feasible. The index weights of the algorithm in reference [2] and the algorithm in reference [3] are unreasonable.

4 Conclusion

This paper puts forward the evaluation and optimization algorithm of regional multi-scale land spatial coordination degree under multi-source data fusion, and obtains through research:

(1) During the period from 2015 to 2022, the development of coordination degree of A city is getting better and better, and it shows a linear upward trend every year.
(2) The maximum value and average value of the consistency test results of regional multi-scale land spatial coordination evaluation and optimization algorithm under multi-source data fusion are all below 0.1; It shows that the index weight setting of the proposed algorithm is reasonable and feasible.

References

1. Xha B, Qga B, Yan H A 2022 Assessment of PM2.5-related health effects: A comparative study using multiple methods and multi-source data in China-ScienceDirect. Environmental Pollution, 306(1):119–125.
2. Origlia A., Rossi S., Di M S 2021 Multiple-source Data Collection and Processing into a Graph Database Supporting Cultural Heritage Applications. Journal on Computing and Cultural Heritage (JOCCH), 14(4):1–27.
3. Tian X, Liao Z, Sun S 2021 Impacts of Multiple Source Data on Forest Forecasting and Uncertainty Propagation. Chinese Journal, 57(3):51–66.
4. Daly S W, Harris A R 2022 Modeling Exposure to Fecal Contamination in Drinking Water due to Multiple Water Source Use. Environmental Science & Technology: ES&T, 56(6): 3419–3429.
5. Liu Y, Niu H, Yang S 2022 Multiple source localization using learning-based sparse estimation in deep ocean. The Journal of the Acoustical Society of America, 150(5):3773–3786.
6. Ma Y J, Kong L X 2022 Simulation of Cache Conflict Handling in Multi-Source Database Based on Dynamic Feedback. Computer Simulation, 39(1):432–436.

7. Pan X X, Chu J, Tong D, et al 2022 The Coordination Between Large Land Parcel Expropriation and Development and Territorial Space Planning. Planners, 38(4):5–11.
8. Zhao F Y, Chen B K 2021 Spatial Allocation of Land and New Development Pattern—Based on the Analysis of Quantitative Spatial Equilibrium. China Industrial Economics, (8):94–113.
9. Peng L L 2022 Design of Land Space Planning System Based on Multi-information Fusion Technology. Computing Technology and Automation, 41(2):158–163.
10. Dong J H, Tang J Y 2022 Reliability Evaluation Model of Multi-weight Data Statistical Fusion Based on Principal Feature Mapping. Statistics & Decision, 38(7):26–30.