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Dynamic Evaluation of Rationality of Land Use Structure in the Changsha-Zhuzhou-Xiangtan Area

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Abstract The rationality of land use structure was evaluated with dynamic TOPSIS method based on changing data of land use from 2008 to 2011 in the Changsha-Zhuzhou-Xiangtan area. The results showed that during 2008 - 2011, the rationality of land use structure was totally high, the dynamic value hi of Changsha, Zhuzhou, Xiangtan and the Changsha-Zhuzhou-Xiangtan area was 0.7954, 0.7821, 0.8245 and 0.8186, respectively; the value $C_i(t_k)$ reflecting the rationality of land use structure at different time points was rapidly increased, and the gap between regions was not big and shrinking. According to the grey relational analysis, the change of different land use types had different effects on the rationality of land use structure: transportation land, the land for cities, towns and villages and the land for mining and industry are most highly correlated with the rationality of land use structure, while arable land, woodland, water area and water conservancy facility land have also an important impact on the rationality of land use structure; controlling the excessive growth of transportation land, the land for cities, towns and villages and the land for mining and industry, protecting arable land, forest land, water area and water conservancy facility land, and moderately increasing the garden plot, plays a decisive role in optimizing the land use structure in the Changsha-Zhuzhou-Xiangtan area.

Key words Dynamic TOPSIS method, Land use structure, Rationality evaluation, Changsha-Zhuzhou-Xiangtan

1 Introduction

Land use structure determines the functionality and efficiency of land use, and the adjustment and optimization of land use structure is the fundamental way to solve the sustainable use problem of land resources, and also the core of overall planning of land use[1]. Limited land resources and spatial differences in land use as well as the contradiction between limited land resources and unlimited growth of socio-economic development needs, have required that the review of land use structure should be long and dynamic[2]. From the optimal allocation model of land use[3-8], land use structure and dynamic land use[9-11], experts and scholars have conducted a large number of studies. The evaluation of land use structure rationality is the basis of land use structure adjustment and optimization, and there are some experts and scholars having made useful discussion on the evaluation of land use structure rationality from a static point of view[12-15]. From a dynamic perspective, this paper uses dynamic TOPSPS method[16] to carry out fuzzy evaluation of rationality level of land use structure in the Changsha-Zhuzhou-Xiangtan area, to provide a reference for the optimization and adjustment of land use structure in the Changsha-Zhuzhou-Xiangtan area, establishment and revising of overall land use plan, and sustainable use of land resources.

2 Overview of the study area and data sources

The Changsha-Zhuzhou-Xiangtan area (111° 53′E — 114 ° 15′E, 26° 03′N — 28°5′N) refers to the area administered by Changsha City, Zhuzhou City and Xiangtan City, and it is the core growth pole of economic development in Hunan Province, with complex land use structure. It has a total area of 2.8240 km^2, and features a typical subtropical humid continental climate with distinct four seasons. It has changeable warm springs, and clear summers and falls in most of time. The severe winter is short while the hot summer is long. The average annual temperature is 17.5 ℃ and the frost-free period is over 286 d. The rainfall is abundant, and the light and heat are adequate. The average annual rainfall is about 1378 mm, and the annual average number of hours of light is 1665 h. Changsha-Zhuzhou-Xiangtan's terrain is mostly mountainous and hilly, with an average elevation of 400 m or more. In the study area, red soil and paddy soil are dominant, accounting for 70% and 25% of total area of soil, respectively. There is 1342097.7 ha of woodland, the forest coverage rate reaches 54.7%. The main tree species include pine, fir and bamboo, etc. Land use data are from the land use change survey data in Hunan Province, and the land use type uses the new land use classification standard proposed in August 2007. In order to avoid overly simplified or complicated classification of types, commercial use land, mining warehouse land, residential land, public administration and public service land and special land are merged into land for cities, towns and villages and land for mining and industry. A total of eight first-level types are selected for calculation and analysis.

3 Rationality evaluation of land use structure in the Changsha-Zhuzhou-Xiangtan area

The Technique for Order of Preference by Similarity to Ideal Solu-

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tion (TOPSIS) is a multi-criteria decision analysis method, which was originally developed by Hwang and Yoon in 1981 with further developments by Yoon in 1987, and Hwang, Lai and Liu in 1993. TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. It is first used for studying multi-attribute decision making problems[17]. At present, it has been widely used in social, economic, and military areas to solve the multi-objective mixed decision-making problems[18-19]. Compared with the static TOPSIS method, the dynamic TOPSIS method not only has index weight vector, but also has time weight vector. It can also give the final dynamic evaluation results, and the evaluation results at each time point[16]. This study takes the annual land use structure as evaluation object, and land use type as evaluation indicator. The original index data are used to measure the proportional structure of each land use type, and establish the matrix after the normalization of various time points. According to the characteristics of land use structure change, combined with the actual situation of the Changsha-Zhuzhou-Xiangtan area, the time dimension value takes 0.1, and takes 0.5. The calculation results of dynamic degree of land use structure rationality in the Changsha-Zhuzhou-Xiangtan area during 2008 – 2010 can be shown in Table 1.

Table 1 The dynamic evaluation results of land use structure rationality in the Changsha-Zhuzhou-Xiangtan area during 2008 – 2011

Area	2008 $C_i(t_k)$	2009 $C_i(t_k)$	2010 $C_i(t_k)$	2011 $C_i(t_k)$	Dynamic value h_i	Order
Changsha	0.467533851	0.470367	0.473178	0.654719	0.795411703	3
Zhuzhou	0.488215639	0.488742	0.488513	0.622937	0.782107458	4
Xiangtan	0.529388847	0.529308	0.528847	0.645231	0.824518402	1
Changsha-Zhuzhou-Xiangtan	0.484963017	0.486588	0.487320	0.672196	0.818561145	2

4 Result analysis

4.1 Analysis of land use structure rationality in the Changsha-Zhuzhou-Xiangtan area The larger the value of $C_i(t_k)$, the better the cross-section evaluation object. As can be seen from Fig. 1, the land use structure rationality has been gradually increased in the Changsha-Zhuzhou-Xiangtan area in recent years, $C_i(t_k)$ value increased from 0.4850 in 2008 to 0.6722 in 2011, and especially from 2010 to 2011, $C_i(t_k)$ value increased significantly. The trend of land use structure rationality in various regions of Changsha-Zhuzhou-Xiangtan tends to be the same as the overall trend of land use structure rationality in the Changsha-Zhuzhou-Xiangtan area, the gap between the regions is small, and this gap continues to narrow. In terms of $C_i(t_k)$ value, the difference between Xiangtan with the greatest $C_i(t_k)$ value and Zhuzhou with the smallest $C_i(t_k)$ value was 0.062 in 2008, while the difference between Changsha-Zhuzhou-Xiangtan with the greatest $C_i(t_k)$ value and Zhuzhou with the smallest $C_i(t_k)$ value was reduced to 0.049. In terms of the final dynamic value hi, it is found that the current overall land use structure rationality is high in the Changsha-Zhuzhou-Xiangtan area, and rationality reaches 0.8186; the region with the highest rationality (0.8245) is Xiangtan; the region with the lowest rationality (0.7821) is Zhuzhou; the difference between the highest hi value and the lowest hi value is only 0.0424, indicating that there is a small difference in the land use structure rationality between regions in Changsha-Zhuzhou-Xiangtan.

4.2 Dynamic degree of land use The change in land use type is directly related to the change in land use structure rationality, and this paper calculates the dynamic degree of use of 8 main land types in the Changsha-Zhuzhou-Xiangtan area during 2008 – 2011. The dynamic degree of land use is calculated as follows:

$$D = \frac{S_2 - S_1}{T \cdot S_1} \times 100\% \qquad (1)$$

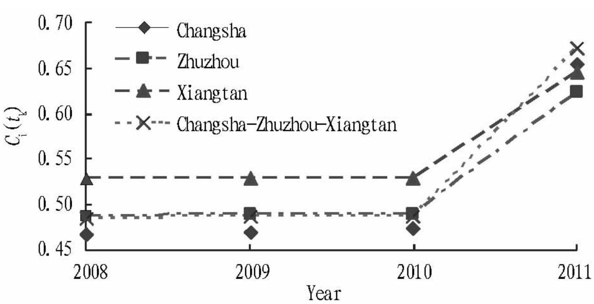

Fig. 1 $C_i(t_k)$ value change of land use structure

where D is the dynamic degree of one land use type in the study period; S_1 and S_2 are the amount of one land use type at the early and late stages of study, respectively; T is the length of study period.

By putting the land data during 2008 – 2011 into the above formula, we get Table 2. Through the analysis on dynamic degree of land use in this region, it is found that within the study period, in the Changsha-Zhuzhou-Xiangtan area, there is a decline in the area of arable land, garden plot, woodland, grassland, water area, water conservancy facility land, and other land, and the woodland is reduced most, reaching 15928.68 ha; there is an increase in the area of land for cities, towns and villages, land for mining and industry and transportation land, and land for cities, towns and villages and land for mining and industry increase most, reaching 15690.60 ha; except the increase of water area and water conservancy facility land in Zhuzhou, the trends in various regions are basically the same as the overall trends in the Changsha-Zhuzhou-Xiangtan area. In terms of the rate of change of single land type, it is highest for transportation land, an average increase of 5.57% annually, and it is highest for Changsha, followed by Zhuzhou and Xiangtan; the second is land for cities, towns and villages and land for mining and industry, an average increase of

1.84% annually, and it is also highest for Changsha, followed by Zhuzhou and Xiangtan; it is slowest for water area and water conservancy facility land, with an average annual reduction of 0.094%; it is slowest for arable land in various regions, with an average annual decrease of 0.40%, 0.013% and 0.13% in Changsha, Zhuzhou and Xiangtan, respectively. The regional land use change rate is proportionate to regional economic development rate, and Changsha > Xiangtan > Zhuzhou.

Table 2 Dynamic degree of land use

Land types	Arable land	Garden plot	Woodland	Grassland	Land for cities, towns and villages and land for mining and industry	Transportation land	Water area and water conservancy facility land	Other land
Changsha	−0.396862	−1.576885	−0.481841	−1.51264	2.4516476	7.442834	−0.5408760	−1.77515
Zhuzhou	−0.012567	−1.424488	−0.282141	−0.77410	1.4410691	5.217089	0.6446946	−0.69215
Xiangtan	−0.134656	−1.231012	−0.194044	−0.73909	0.9891604	2.308540	−0.2607900	−0.48980
Changsha-Zhuzhou-Xiangtan	−0.210910	−1.467943	−0.351230	−0.88396	1.8364361	5.572504	−0.0937980	−1.06100

4.3 Grey relational analysis of $C_i(t_k)$ value change of land use structure and land use type The land use structure rationality and its change are determined by land use type and its change. Table 3 shows the grey relational analysis results of $C_i(t_k)$ value and land use type. As can be seen from Table 3, the degree of correlation between $C_i(t_k)$ value and land use type is as follows: Changsha ($X_6 > X_5 > X_3 > X_1 > X_7 > X_2 > X_4 > X_8$); Zhuzhou ($X_6 > X_5 > X_7 > X_1 > X_3 > X_8 > X_4 > X_2$); Xiangtan ($X_6 > X_5 > X_1 > X_3 > X_7 > X_8 > X_4 > X_2$); Changsha-Zhuzhou-Xiangtan ($X_6 > X_5 > X_1 > X_7 > X_3 > X_4 > X_8 > X_2$). The Changsha-Zhuzhou-Xiangtan area is the pilot area of "two-oriented society" and economic growth pole of Hunan. Through rapid economic development in recent years, the transportation land and construction land are rapidly expanded, with the greatest dynamic change, so transportation land, the land for cities, towns and villages and the land for mining and industry are correlated with land use structure rationality to the highest degree. The dynamic change of arable land is minimal, but arable land is the most valuable resource, and the arable land protection is fundamental to stability of the state, so arable land has also an important impact on land use structure rationality. The dynamic change of woodland, water area and water conservancy facility land is also large, having an important impact on the land use structure rationality. Therefore, reasonably controlling excessive growth of transportation land, the land for cities, towns and villages and the land for mining and industry, protecting arable land, woodland, water area and water conservancy facility land, and moderately increasing garden plot, is a feasible measure to constantly improve the land use structure rationality in the Changsha-Zhuzhou-Xiangtan area.

Table 3 Grey relational analysis of $C_i(t_k)$ value change of land use structure and land use type

Land type	Arable land (X_1)	Garden plot (X_2)	Woodland (X_3)	Grassland (X_4)	Land for cities, towns and villages and land for mining and industry (X_5)	Transportation land (X_6)	Water area and water conservancy facility land (X_7)	Other land (X_8)
Changsha	0.2111	0.2081	0.2114	0.2032	0.2447	0.3352	0.2100	0.1993
Zhuzhou	0.2140	0.1979	0.2115	0.2070	0.2421	0.2883	0.2200	0.2084
Xiangtan	0.2131	0.1986	0.2118	0.2046	0.2377	0.2799	0.2104	0.2059
Changsha-Zhuzhou-Xiangtan	0.2061	0.1985	0.2056	0.2016	0.2311	0.3644	0.2058	0.1987

5 Conclusions and discussions

Using dynamic TOPSIS method, this paper constructs a model concerning land use structure rationality for comprehensive evaluation of the land use structure rationality in the Changsha-Zhuzhou-Xiangtan area. $C_i(t_k)$ can quantitatively analyze the use structure rationality of different land types in the study area from different time sections, and the dynamic value hi can conduct overall evaluation of land use rationality in the study area from a dynamic perspective. According to the grey relational analysis of land use types and $C_i(t_k)$ value of land use structure, combined with the dynamic degree of land use, we can analyze the influence of land use type change on land use structure rationality, and put forward corresponding policies. Therefore, the evaluation results of existing land use structure rationality using dynamic TOPSIS method are of theoretical and practical significance to land use structure adjustment. From the evaluation results of land use structure rationality in the Changsha-Zhuzhou-Xiangtan area, it is found that there are significant fluctuations in land use structure rationality during the evaluation period. In the future, it is necessary to fully consider the land suitability in various regions affected by topography, climate, hydrology, soil and other natural factors, as well as positioning of regional development and industrial structure adjustment; rationally developing land use plan, and timely adjusting land use structure; focus on the protection of good quality arable land, and protect and restore forest land; increase intensive level of construction land, and reasonably control transportation land size; promote the relocation and consolidation of rural settlements, and actively accelerate the urbanization process.

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loss of developers and government officials. In addition, it is recommended to improve quality of public policy, build up good faith culture and ethical awareness, and expand participation channels of functional departments, the public, and news media, to effectively stop black box transaction and gray negotiation of public right and private interests.

(iv) Strengthening management and supervision of land market. Market mechanism of land market in China is inadequate. It is mainly manifested in information asymmetry and non-free flow of land elements. Besides, there are series of problems such as unfair land use, low efficiency of land allocation, and unstable expected income. As a result, developers are face with intense industrial competition and market pressure. This accelerates combination of economic benefits and political power and promotes developers to take bribery as their wise choice. Therefore, it is urgent to strengthen management and supervision of land market, establish perfect bidding, auction, and listing system for operational land, and create fair competition and equal access market environment. Furthermore, it is recommended to consolidate hidden market, regulate normal circulation and reasonable use of land, and implement land transaction license system and land transaction declaration system, to get overall control of market operation situation in time. Finally, it is recommended to publically issue land supply information and land price information, and improve land supervision and management system, to realize real-time supervision of law-breaking and discipline-breaking activities.

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