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Regional differences analysis of land use efficiency and obstacle degree in Xianning-Yueyang-Jiujiang area

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ABSTRACT: This paper established an evaluation index system for the land use efficiency from social, economic, ecological and environmental aspects, and adopted the variation coefficient TOPSIS method and obstacle degree model to analyze the regional differences of land use efficiency and obstacle degree in Xianning, Yueyang and Jiujiang. The results showed that: (1) During 2000-2010, the land use efficiency in these regions had an increasing tendency and the regional differences were small. In Yueyang and Jiujiang, there were four stages, that is low, moderate, good and excellent; while in Xianning, there were only three stages, that is low, moderate and good; (2) The economic level was the greatest obstacle factor affecting the land use efficiency in these regions, followed by the environmental quality, ecological status, social development, and the regional differences in these aspects were not so obvious; (3) Per area financial revenue, the output of comprehensive utilization of "three wastes" and per capita GDP were the top three obstacle factors and the regional differences in these aspects were not so obvious.

Keywords: land use efficiency; obstacle degree; variance coefficient-TOPSIS method; Xianning-Yueyang-Jiujiang area

1 INTRODUCTION

Land use efficiency refers to the material product or the effective results of land investment and consumption in social, economic, ecological and other aspects of a region [1]. The land use efficiency is to evaluate the macro structure and pattern of land use and their influences on the external environment and internal factors, and it is a kind of evaluation for land use pattern and function [2]. The rapid economic development has made tremendous social and economic benefits, accompanied by the deterioration of ecological environment quality and obvious contradiction between people, the land and other issues [3]. Therefore, how to better coordinate the relationship between the limited land resources and socio-economy and ecological environment, thus improving the land use efficiency, has become the key point to achieve the coordinated development of "industrialization, informatization, urbanization and agricultural modernization" and the construction of "resource- economical and environment-friendly society". The land use efficiency evaluation is one of the hot topics in recent years [4]. The previous studies by domestic scholars mainly focus on a single city with microscopic scale as they always take eastern and western big cities as the main objects. However, the comparison of differences of land use efficiency in a region and the identification of their obstacle degree from local scale with one region are rarely set as the research subject, which still needs to be deepened.

Xianning, Yueyang, Jiujiang are located in the south coast and the middle reaches of the Yangtze River. Leaning against the Mufu Mountains, this region is a "Golden Triangle" where Hunan, Hubei and Jiangxi provinces are connected and intersected. In 2010, the total land area of this region is 44,000 square kilometers; the GDP is 309.175 billion yuan and the population is 13,544,900. The strategic cooperation of these three cities could realize dislocation development, resource sharing and complementary industries, thus speeding up the mutual development of Yangtze River midstream urban agglomerations, working together to build the fourth grade of China's

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Table 1. Land use efficiency evaluation index system and weights

Target layer	Criterion layer	Weight	Index level	Property of index	Weight
Land use efficiency	Social development	0.1625	C_1: Population density (person/km^2)	-	0.0040
			C_2: Per capita urban road area (m^2)	+	0.0504
			C_3: The number of college students in ten thousand people (person)	+	0.0494
			C_4: The number of buses per ten thousand people (unit)	+	0.0380
			C_5: The number of hospital beds owned by every ten thousand people (piece)	+	0.0207
	Economic level	0.3794	C_6: Per capita deposits of urban and rural residents (ten thousand yuan/person)	+	0.0622
			C_7: Per area GDP (ten thousand yuan/hm^2)	+	0.0680
			C_8: Per area financial revenue (ten thousand yuan/hm^2)	+	0.1118
			C_9: Per capita GDP (yuan/person)	+	0.0691
			C_{10}: Per capita retail sales of social consumer goods (yuan/person)	+	0.0683
	Ecological status	0.1964	C_{11}: The afforestation area (hm^2)	+	0.0640
			C_{12}: The forest coverage (%)	+	0.0055
			C_{13}: The green area of the built-up area (hm^2)	+	0.0508
			C_{14}: The green area of the built-up area per capita（m^2/person)	+	0.0512
			C_{15}: The green coverage of the built-up area per capita (%)	+	0.0249
	Environmental quality	0.2617	C_{16}: The wastewater emissions per unit area (ten thousand t/km^2)	-	0.0168
			C_{17}: The industrial soot emissions per unit area (ten thousand t/km^2)	-	0.0261
			C_{18}: The comprehensive utilization of industrial solid wastes (%)	+	0.0132
			C_{19}: The urban sewage treatment rate (%)	+	0.0960
			C_{20}: The output of comprehensive utilization of "three wastes" (ten thousand yuan)	+	0.1095

economic growth, and promoting the implementation of "rise of Central China" strategy. In this study, this region (Xianning, Yueyang, Jiujiang) is regarded as the research object to diagnose the obstacle factors affecting the land use efficiency based on the scientific evaluation. And then it will identify the regional differences in the land use efficiency and obstacle degree. The scientific analysis of the land use in this region is conducive to playing the bridgehead role of this region and providing decision-making basis for the coordinated land development pattern.

2 RESEARCH METHODS

2.1 *Construction of the index system and data sources*

A scientific index system is the key element to conduct comprehensive evaluation of land use efficiency. The evaluation index system should fully reflect the overall situation of land use efficiency, as well as the versatility of regional land use, such as the social, economic, ecological and environmental benefits. The indexes should be scientific, systematic, independent and operational. Based on the socio-economic development level and ecological environment in this region, this paper establishes an evaluation index system (Table 1). The data is from the *Xianning Statistical Yearbook, Yueyang Statistical Yearbook, Jiujiang Statistical Yearbook, and China City Statistical Yearbook of 2002-2011*, coupled with the National Economic and Social Development Statistics Bulletin in each year of these three cities.

2.2 *Variation coefficient TOPSIS*

Variation coefficient TOPSIS method is a combination of variation coefficient method [5] and TOPSIS method [6]. Its main computing steps are shown as follows:

2.2.1 *Standardization evaluation*

The extremum method is used to calculate the dimensionless quantity of indexes as follows [7]:
Standardization of forward index:

$$X_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j};$$

Standardization of reverse index:

$$X_{ij} = \frac{\max x_j - x_{ij}}{\max x_j - \min x_j};$$

Where, X_{ij} is the standardized value for the index, x_{ij} is the original value of the index; max x_j and *min* x_j respectively represents the maximum and minimum value of the index in the evaluation period. After being standardized, the decision matrix B can be established accordingly.

2.2.2 *Establishment of index weight*

First it needs to use the variation coefficient method to determine the preliminary weight of different cities, and then take the average to unify the evaluation system weights. The way of determining the index weight W by variation coefficient method is shown as follows:

(1) Calculate the mean value $\bar{x}_j$ and standard deviation S_j of each index:

$$\bar{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij},\ j = 1,2,3,\cdots,m$$

$$S_j = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_{ij} - \bar{x}_j\right)^2},\ j = 1,2,3,\cdots,m$$

(2) Calculate the variation coefficient of each index V_j and normalize the variation coefficient to give the weight W_j of each index:

$$V_j = \frac{S_j}{\bar{x}_j},\ j = 1,2,3,\cdots,m$$

$$W_j = V_j \Big/ \sum_{j=1}^{m} V_j,\ j = 1,2,3,\cdots,m$$

2.2.3 *Establish weighted and normalized matrix V*

W={W1,W2,…,Wj}

$$V = B \times W, V = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1j} \\ v_{21} & v_{22} & \cdots & v_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ v_{i1} & v_{i2} & \cdots & v_{ij} \end{bmatrix}$$

2.2.4 *Determine the positive and negative ideal solution*

The positive ideal solution:

$$V^+ = \left\{ \max V_{ij} \mid i = 1, 2, \cdots, n \right\} = \left\{ V_1^+, V_2^+, \cdots, V_n^+ \right\}$$

The negative ideal solution:

$$V^- = \left\{ \min V_{ij} \mid i = 1, 2, \cdots, n \right\} = \left\{ V_1^-, V_2^-, \cdots, V_n^- \right\}$$

2.2.5 Calculate the distance

Respectively calculate the distance D^+ between the evaluation vector of different evaluation objects and the positive ideal solution and the distance D^- between the evaluation vector and the negative ideal solution:

$$D^+ = \sqrt{\sum_{j=1}^{m}\left(V_{ij} - V_j^+\right)^2} \quad (i = 1, 2, \cdots, n)$$

$$D^- = \sqrt{\sum_{j=1}^{m}\left(V_{ij} - V_j^-\right)^2} \quad (i = 1, 2, \cdots, n)$$

2.2.6 *Calculate the evaluated value of land use efficiency C_i*

$$C_i = D_i^- / \left(D_i^+ + D_i^-\right) \quad (i = 1, 2, \cdots, n)$$

$C_i \in [0, 1]$, the greater C_i indices are, the better land use efficiency of the evaluation object would be, and vice versa.

2.3 *Obstacle model*

The method is to introduce the factor of contribution degree U_j, the indicator deviation degree V_j and the obstacle degree (M_j, B_j) [8]. The specific calculation formula is: $U_j = R_j \times W_j$, $V_j = 1 - X_j$. In the formula, R_j is the index weight in the j criterion level; W_j is the weight of single index i in the j criterion level; X_j is the normalized value of single index which is obtained from the standardization of extreme value.

The obstacle degree of j index for intensive utilization efficiencys of land is: $M_j = V_j \times U_j \Big/ \sum_{j=1}^{20}\left(V_j \times U_j\right) \times 100\%$. Based on the restriction degree of single evaluation factor, it is required to further study the obstacle degree of each criterion level factor on the land utilization efficiency. The formula is: $B_i = \sum M_{ij}$. In the formula, M_{ij} is the obstacle degree of each single index.

3 ANALYSIS

3.1 *Land use efficiency*

According to the aforementioned research methods, the land use efficiency results of the research regions in 2001-2010 can be calculated (as shown in Figure 1). Overall, the land use efficiency in this region had increasing a tendency and the regional differences were small. The land-use evolution curves indicate that during these ten years, the land use efficiency always showed an increasing trend except that Xianning and Jiujiang had temporary drop in 2002. In Yueyang City, due to the sound infrastructure and relatively abundant financial resources, the land use efficiency increased from 0.1455 in 2001 to 0.8351 in 2010 with an average annual increase of 21.43% which was the highest in this region; the average annual growth rate of land use efficiency in Xianning reached 17.86%, which is in the intermedia level; the increase of land use efficiency is the smallest in Jiujiang, growing from 0.2251 to 0.8246 with an average annual increase of 15.52%. In Yueyang and Jiujiang, there were four stages, low, moderate, good and excellent; while in Xianning, there were only three stages, low, moderate and good. In 2007, the evolution trajectory of the land use efficiency in this region had an inflection point. The land use efficiency

increased slowly before it reached the turning point and then it had rapid growth. The land use efficiency of Xianning, Yueyang, Jiujiang respectively increased by 0.2084, 0.2550, and 0.2209 during 2001-2007, and while during 2007-2010, it increased by 0.3340, 0.4346 and 0.3786. Since 2007, thanks to the rapid socio-economic development with strong support of national macroeconomic policy, coupled with the influence of the improved ecological environment and rapid development of regional national economy, the land use efficiency of this region achieved sustainable growth.

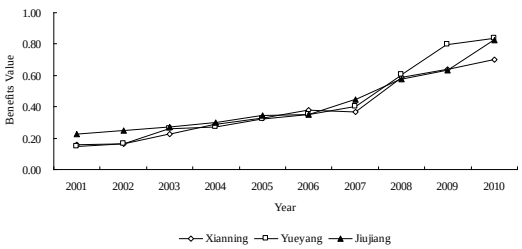

Figure 1. Evolving curves of land use efficiency in Xianning-Yueyang-Jiujiang area from 2001 to 2010

During 2001-2010, the mean value of the land use efficiency index was respectively 0.3842, 0.4148 and 0.4224 in Xianning, Jiujiang and Yueyang, indicating that Yueyang had the best land use efficiency, followed by Jiujiang and Xian Ning. However, the differences among them were small, and Jiujiang and Xianning were almost at the same level of development. With the improvement of standardization, individualization and optimization, the land use efficiency in this region has gained tremendous development, but there were differences in the development pace. In March 1999, Xianning was removed to build the city, with gradually switching from extensive agriculture to urbanization. The land use standards continued to be improved and the economic and social competitiveness were increasingly enhanced, but the irrational economic structure and the lack of independent innovation capability resulted in the decline of the development pace in 2007. Then with the implementation of "two-oriented society" in Wuhan city circle, it adhered to two main lines of development and ecology, and the land use got the best comprehensive efficiency, so the overall level rose sharply in the late period. In the new century, based on the great opening principle, Jiujiang pushed for the "3+1" strategy which means the large-scale industrial development, large-scale tourism, large-scale logistics and large-scale construction of the city. The land use efficiency each year has been improved in varying degrees. The devastating earthquake occurred in 2005 caused great damage to the ecosystems and natural landscapes of Jiujiang, and a series of ecological restoration works were carried out subsequently, coupled with the seven special rectification actions of green ecological construction in Jiangxi province, which has greatly enhanced the ecological environment carrying capacity and promoted the rapid increase of land use efficiency. The large population base led to a lower starting point in Yueyang, so the land use efficiency here had small increase during 2001-2006. With gradual expansion of the city size, the growth of land use efficiency accelerated. In 2007, the economy entered a new stage of "full-scale acceleration" and the land use efficiency achieved high-speed growth.

3.2 *Obstacle degree of land use efficiency*

Based on the evaluation of land use efficiency, it first need to diagnose the obstacle factors that affect the land use efficiency and then the main factors can be identified in accordance with the indexes of the criterion layer and index layer. The results are as shown in Table 2, 3, 4, 5.

3.2.1 *Obstacle factors of the criterion layer*

During 2001-2010, the economic level had the maximum obstacle degree of the land use efficiency in these regions, followed by the environmental quality, ecological situation and social development and the regional differences were not significant. The horizontal comparison of the obstacle degree of the criterion layer indicates that the average index number of the economic obstacle degree in Yueyang and Jiujiang is 49.98, which means that among the factors that determine the regional land use efficiency, the restriction of the economic level of Yueyang and Jiujiang on the land use efficiency is close to 50%, while the average index number of the economic obstacle degree in Xianning is 44.94. Obviously, the restriction of the economic level factor on regional land use efficiency in Yueyang and Jiujiang is greater than that in Xianning. The influence of environmental factors ranks the second place. The average index number of environmental quality obstacle degree has the maximum difference in criteria layer, and that of Xianning, Jiujiang and Yueyang is respectively 33.93, 26.00 and 24.81. The difference between Xianning and Yueyang is 9.13. Ecological situation ranks the third place and its obstacle degree has the smallest average index number, around 15.00. The maximum average index number of the obstacle degree of social development is 9.60 in Jiujiang, followed by 9.49 in Yueyang and 6.83 in Xianning, indicating that social development has slight restriction on land use efficiency. The key point to improve the land use efficiency should be laid in the environmental quality and ecological status.

Vertically speaking, in Xianning, the obstacle degree of the economic level, social development and ecological status show a declining trend, while that of the environmental quality is on a rise (Table 2). During 2001-2010, the obstacle degree of the economic

level had the largest decline of 55.45, followed by the ecological status of 4.36 and the social development of 2.49. The obstacle degree of the environmental quality grew from 22.58 to 84.88 which is the biggest increase. This indicates that environmental quality became the biggest restraining factor of land use efficiency, followed by the ecological situation and social development, and the economic level has the least impact on land use efficiency. Therefore, in order to enhance land use efficiency, it is necessary to strengthen the environmental management, improve the ecological quality and raise the level of social development. The obstacle degree of the social development and ecological status in Yueyang shows a rising trend, and that of the economic level and environmental quality shows a declining trend (Table 3). The obstacle degree of social development rose from 8.93 to 31.30, with the increase of 2.50 times, while that of the ecological status increased by 2.38 times, that of the economic level decreased by 4.41 times and that of the environmental quality decreased by 0.25 times. Obviously, the ecological situation has become a primary factor affecting the land use efficiency, followed by social development, environmental quality and economic level. In Jiujiang, the obstacle degree of social development, ecological situation and environmental quality continued to rise, while that of the economic level showed continuous declination (Table 4). The obstacle degree of the ecological situation has the greatest increase, up to 30.51, while that of the social development is 17.81, and the environmental quality has the smallest increase, only 11.28. The obstacle degree of economic level has the greatest decrease of 59.60. Therefore, to improve the land use efficiency in Jiujiang, we should start with the ecological status, environmental quality and social development.

3.2.2 *Obstacle factor of index layer*

This paper listed the top three factors of the obstacle degree (Table 5). The results indicate that per area financial revenue, the output of comprehensive utilization of "three wastes" and per capita GDP are the top three obstacle factors in Xianning, Yueyang and Jiujiang, which mainly reflect the economic level and environmental quality. The regional differences are not so significant.

The comparison of the obstacle degree order of the land use efficiency in different cities indicates that the obstacle degree has the obvious regularity in Jiujiang and the factor with the greatest obstacle degree in most years is the per area financial revenue, followed by the output of comprehensive utilization of "three wastes" and per capita GDP. In Yueyang, the factors with top two obstacle degree are per area financial revenue and the output of comprehensive utilization of "three wastes", while the index ranking the third place is instable, including per area GDP, per capita GDP, the urban sewage treatment rate and per capita retail sales of social consumer goods, the wastewater emissions per unit area which belong to the category of economic level and environmental quality. In Xianning, the first factor with frequent obstacle degree is the output of comprehensive utilization of "three wastes", followed by per area financial revenue. The third one is relatively stable, per capita GDP. Throughout the index layer obstacle degree of the regional land use efficiency, the low land productivity levels and the lack of new technology to utilize waste and develop the recycling economy are the main reasons of the low land use efficiency.

Table 2. Obstacle degree of rule hierarchy of land use efficiency in Xianning from 2001 to 2010 (%)

Year	Social development	Economic level	Ecological status	Environmental quality
2001	7.23	55.45	14.73	22.58
2002	7.46	56.09	13.94	22.50
2003	7.22	54.12	14.45	24.21
2004	5.94	54.25	13.60	26.21
2005	7.05	50.32	13.68	28.95
2006	7.18	46.73	13.39	32.71
2007	5.32	47.29	15.01	32.38
2008	7.34	48.93	14.84	28.89
2009	8.83	36.19	18.95	36.03
2010	4.74	0	10.37	84.88

Table 3. Obstacle degree of rule hierarchy of land use efficiency in Yueyang from 2001 to 2010 (%)

Year	Social development	Economic level	Ecological status	Environmental quality
2001	8.93	56.99	12.00	22.08
2002	8.84	57.10	11.22	22.83
2003	8.92	58.42	7.50	25.17
2004	8.36	56.53	10.02	25.09
2005	8.18	58.64	12.78	20.41
2006	8.39	56.22	13.61	21.78
2007	3.35	55.29	14.05	27.30
2008	2.07	45.04	20.94	31.95
2009	6.58	45.06	14.49	33.87
2010	31.30	10.53	40.58	17.60

Table 4. Obstacle degree of rule hierarchy of land use efficiency in Jiujiang from 2001 to 2010 (%)

Year	Social development	Economic level	Ecological status	Environmental quality
2001	7.19	59.60	10.22	22.99
2002	6.91	60.79	7.79	24.51
2003	7.76	59.44	6.59	26.21
2004	6.93	58.30	7.10	27.66
2005	6.56	56.97	8.84	27.62
2006	6.12	52.69	18.98	22.21
2007	7.20	54.17	14.53	24.10
2008	9.42	55.91	11.06	23.61
2009	12.90	41.93	18.39	26.78
2010	25.00	0	40.72	34.27

4 CONCLUSION

(1) During 2000-2010, the land use efficiency in these three regions had an increasing tendency and the regional differences were small. The land-use evolution curves indicate that during these ten years, the land use efficiency always showed an increasing trend

Table 5. Obstacle degree of main index hierarchy of land use efficiency in Xianning-Yueyang-Jiujiang area from 2001 to 2010 (%)

Year	Project	Xianning			Yueyang			Jiujiang		
		Index sorting			Index sorting			Index sorting		
		1	2	3	1	2	3	1	2	3
2001	Obstacle factors	C_8	C_{20}	C_9	C_8	C_{20}	C_9	C_8	C_{20}	C_9
	Obstacle degree	16.57	11.19	10.24	16.80	10.39	10.38	17.56	11.86	10.85
2002	Obstacle factors	C_8	C_{20}	C_9	C_8	C_9	C_{19}	C_8	C_{20}	C_9
	Obstacle degree	17.25	11.07	10.40	17.26	10.30	10.27	18.29	12.38	10.93
2003	Obstacle factors	C_8	C_{20}	C_9	C_8	C_{20}	C_9	C_8	C_{20}	C_9
	Obstacle degree	13.50	12.20	11.07	17.03	12.26	10.61	19.06	12.72	10.79
2004	Obstacle factors	C_{20}	C_{10}	C_8	C_8	C_{19}	C_{10}	C_8	C_{20}	C_{10}
	Obstacle degree	13.14	12.46	12.40	17.51	13.07	9.96	18.72	12.60	10.59
2005	Obstacle factors	C_{20}	C_{19}	C_9	C_8	C_{20}	C_7	C_8	C_{20}	C_9
	Obstacle degree	12.75	12.03	11.48	19.02	11.08	10.35	18.90	11.54	10.22
2006	Obstacle factors	C_{20}	C_{19}	C_9	C_8	C_{20}	C_7	C_8	C_{19}	C_9
	Obstacle degree	13.70	12.88	11.43	19.62	12.09	9.76	18.03	9.32	9.23
2007	Obstacle factors	C_{20}	C_8	C_{19}	C_8	C_{20}	C_{19}	C_8	C_{19}	C_9
	Obstacle degree	13.95	13.81	13.10	21.83	12.27	10.57	18.69	11.23	9.25
2008	Obstacle factors	C_{19}	C_8	C_9	C_{20}	C_8	C_{10}	C_8	C_9	C_7
	Obstacle degree	19.37	15.69	9.75	19.29	10.81	9.97	20.87	9.42	9.06
2009	Obstacle factors	C_{20}	C_8	C_{19}	C_8	C_{19}	C_7	C_8	C_{19}	C_9
	Obstacle degree	16.79	11.37	11.27	12.90	12.55	12.33	16.30	14.68	7.33
2010	Obstacle factors	C_{20}	C_{11}	C_{17}	C_{14}	C_{11}	C_{16}	C_{17}	C_4	C_{14}
	Obstacle degree	73.35	10.37	9.89	21.98	18.59	17.60	18.70	16.59	16.39

except that in Xianning and Jiujiang had temporary drop in 2002. In Yueyang and Jiujiang, there were four stages, low, moderate, good and excellent; while in Xianning, there were only three phases, low, moderate and good.

(2) The obstacle degree of the criterion layer index indicates that the economic level has the maximum obstacle degree of the land use efficiency in these regions, followed by the environmental quality, ecological situation and social development. The key point to improve the land use efficiency should be laid in the environmental quality and ecological status.

(3) The obstacle degree of index layer factor indicates that the average financial revenue, output of comprehensive utilization of "three wastes" and gross domestic product per capita are the top three obstacle factors in Xianning, Yueyang and Jiujiang, which mainly reflect the economic level and environmental quality. The regional differences are not so significant. The low land productivity levels and the lack of new technology to utilize waste and develop the recycling economy are the main reasons of the low land use efficiency.

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