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Evaluation Method of Land Resources Carrying Capacity Based on Gray Target Model: a Case of Zhangzhou City in Fujian Province

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Abstract:

With the rapid development of ecological civilization construction in China, the bottleneck of resources and environment, especially land resources, to social and economic development has become increasingly prominent. The government and scholars are increasingly concerned about the regional resources and environment carrying capacity, especially the comprehensive carrying capacity of land resources. This paper takes Zhangzhou City as the research area, constructing the evaluation index system of comprehensive land carrying capacity of Zhangzhou from the perspective of ecology, production and living, evaluation of land comprehensive carrying capacity in Zhangzhou City from 2004 to 2016 by Using Grey Target Model. The results show that: (1) From 2004 to 2016, the comprehensive carrying capacity of land is affected by three subsystems due to the ecological, production and living capacity of the land, and the carrying capacity level is converted from a lower level to a higher level. (2) The relationship between the three subsystems changed from ecological bearing capacity > production bearing capacity > living bearing capacity in 2004 to living bearing capacity > production bearing capacity > ecological bearing capacity in 2016, indicating that Zhangzhou's ecological bearing capacity is facing certain challenges.

Keywords*: Comprehensive carrying capacity of land resources, Gray target model, Zhangzhou city.*

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I. OVERVIEW OF THE STUDY AREA AND DATA SOURCES

1.1 Overview of the Study Area

Zhangzhou is located in the southeast of Fujian Province, with geographical coordinates between 116 53 '-118 09' east longitude and 23 32 '-25 13' north latitude. It faces Taiwan Province across the sea in the east, borders Quanzhou and Xiamen in the northeast, and is known as the "Hokkien Golden Triangle of China" [1,2]. It borders Longyan and Shantou in Guangdong in the northwest and southwest respectively. The land area of Zhangzhou is 12,900 square kilometers and the sea area is 18,600 square kilometers. Zhangzhou's urban development positioning is to build a "rural city, ecological city", it has a permanent population of 5.1 million and now has jurisdiction over 2 municipal districts, 1 county-level city and 8 counties [3-6]. There are mountains, hills and plains in Zhangzhou, which are high in the northwest and low in the southeast. The forest coverage rate is 64.58%. The annual climate is warm, is a natural "greenhouse", the temperature is suitable, adequate light, rainfall, suitable for the growth of various crops, "a land of milk and honey", "Ukraine in Fujian" and other laudatory name [7-9].

1.2 Data Sources

The data of land use change in Zhangzhou adopted in this study mainly include three periods (2004, 2010 and 2016). The 2010 and 2016 are from Zhangzhou database of land use change, land use data of 2004 are from Geospatial Data Cloud platform (http://www.gscloud.cn/) and the website of U.S. Geological Survey (http://earthexplorer.usgs.gov/). The social and economic data involved in this study are mainly from Statistics Yearbook of [10-13].

Zhangzhou from 2004 to 2016, including fixed asset investment, natural population growth rate and mechanization degree, etc. Data on water resources come from Fujian Province Water Resources Bulletin.

II. EVALUATION OF COMPREHENSIVE LAND RESOURCES CARRYING CAPACITY IN ZHANGZHOU CITY

2.1 Index System Construction

Based on a large number of literatures, this article draws on Wang Shuhua [14], Fang Chuanglin [15] and others on the study of comprehensive carrying capacity of land resources in

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the eastern coastal area and the content of the evaluation index system of comprehensive carrying capacity of land ecology, production and life, based on the actual situation in Zhangzhou and the principle of data availability, with the comprehensive carrying capacity of land resources as the target layer, and the ecological, production and living carrying capacity as the criterion layer, to construct a 23 indicators composed of per capita water resources, per capita GDP, and natural population growth rate. The evaluation index system is constructed Comprehensive Carrying Capacity of Land Resources in Zhangzhou city (Table I)

TABLE I. Evaluation index system of land comprehensive carrying capacity in Zhangzhou

Target level	**Criterion level**	**Index level**	**Unit**	**Nature**
Comprehensive land resources carrying capacity	Ecological bearing capacity	X1：Water resources per capita	[m³/person]	(+)
		X2：Forest cove	[%]	(+)
		X3：Comprehensive utilization rate of industrial solid waste	[%]	(+)
		X4：Public green area per capita	[㎡]	(+)
		X5：Discharge of industrial wastewater per land	[t/ hm²]	(-)
		X6：Industrial SO2 emissions per area	[t/ hm²]	(-)
		X7：Industrial pollution control investment as a percentage of GDP	[%]	(+)
		X8：Pesticide application amount per unit of cultivated land	[kg/ hm²]	(-)
		X9：Chemical fertilizer application amount per unit of cultivated land	[kg/ hm²]	(-)
		X10：Per capita arable land area	[Mu/person]	(+)
	Production bearing capacity	X11：Investment in fixed assets per land	[10,000 yuan/ hm²]	(+)
		X12：GDP per land	[10,000	(+)

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			yuan / hm²]	
		X13：The proportion of tertiary industry	[%]	(+)
		X14：Grain supply and demand ratio	/	(+)
		X15：Per capita gross output value of agriculture, forestry, animal husbandry and fishery	[yuan/person]	(+)
		X16：Degree of mechanization	[kw/ hm²]	(+)
		X17：Total import and export	[One hundred million dollars]	(+)
	Living bearing capacity	X18：Transport length	[km]	(+)
		X19：Natural population growth rate	[‰]	(-)
		X20：Population density	[person/ hm²]	(-)
		X21：Number of hospital beds per thousand people	[piece/One thousand people]	(+)
		X22：Per capita housing area	[㎡ /person]	(+)
		X23：Investment in science and technology education as a proportion of GDP	[%]	(+)

2.2 Data Standardization

The evaluation index cannot be calculated directly because of the different units of measurement. Therefore, the influence of different units on the calculation results is eliminated through data standardization processing before calculation. Depending on the different properties of indicators, they can be divided into positive indicators and negative indicators. The calculation of its formula is as follows:

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Positive index:

$$X_{ij}^{'} = \frac{X_{ij} - minX_{ij}}{maxX_{ij} - minX_{ij}} \quad (1)$$

Negative index:

$$X_{ij}^{'} = \frac{maxX_{ij} - X_{ij}}{maxX_{ij} - minX_{ij}} \quad (2)$$

In these two formula, $X_{ij}^{'}$ is the initial data X_{ij}'s standardized value, $maxX_{ij}$ is the maximum of X_{ij}; $minX_{ij}$ is the minimum of X_{ij}. The standardized values are all between [0, 1]. Positive optimal value index is 1, and the worst value is 0. Negative indicators are the opposite. In this study, standardized values of 23 indicators were obtained through the above formulas.

2.3 Determine the Index Weight

In this study, the combined weighting method of gray relational entropy was adopted for the index weight. Based on the gray relational degree analysis, the gray relational coefficient of each index in different years was calculated, and then the gray relational entropy value was calculated with the entropy weight method, so as to obtain the weight of each index. The combined weighting method of grey relational entropy avoids the artificial interference of subjective weighting and can reflect the order degree and stability of the index system [16].

2.3.1 Gray correlation coefficient calculation

Gray relational degree analysis is applicable to multi-factor statistical analysis, aiming at seeking the key relationship between the system and various factors, figuring out the key factors affecting the system, so as to promote the rapid and orderly development of the system [17]. Gray relational degree analysis has been widely used in many fields such as science and technology, management and economy because of its small requirements for data processing, simple calculation and strong operability.

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1) Determine reference sequence and comparison sequence

The reference sequence was determined on the basis of the initial data standardization, and the optimal values of the standard values in the evaluation indexes were selected to form the reference sequence X0= $\{x_0(m)|m=1,2......23\}$,compare sequence Xi= $\{x_i(m,n)|m=1,2......24; n=1,2......13\}$.

2) Calculation of correlation coefficient

Compare equence X_i, the correlation coefficient of the mth index in the nth year relative to the reference series X0, the calculation formula is:

$$\delta(m,n)=\frac{\min_u\min_v|x_0(t)-x_s(t)|+\rho\max_u\max_v|x_0(t)-x_s(t)|}{|x_0(t)-x_i(m,n)|+\rho\max_u\max_v|x_0(t)-x_s(t)|} \quad (3)$$

In this formula： $\min_u\min_v|x_0(t)-x_s(t)|$ indicates the smallest difference between the two levels, $\max_u\max_v|x_0(t)-x_s(t)|$ indicates the biggest difference between the two levels. $\rho\in[0,1]$ is the resolution coefficient. The higher the ρ value is, the higher the resolution coefficient is, and the value in this study is 0.5.

2.3.2 Entropy weight method to determine the weight

The basic principle of entropy weight method is to calculate the weight according to the information content of evaluation index data [18]. If the entropy value is smaller, the weight is larger; and vice versa, the smaller the weight. The grey correlation coefficients of each index calculated by the grey correlation method are taken as grey columns and put into the formula of entropy weight method.

1) Calculate the ratio of the index values. The specific gravity of each index value is calculated according to the grey correlation coefficient. The formula for the specific gravity of the mth index value in the nth year is as follows:

$$Z_{mn}=\frac{\delta(m,n)}{\sum_{i=1}^{n}\delta(m,n)} \quad (4)$$

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2) Calculate the entropy of each indicator e_m, the formula is:

$$Y_{mn} = -Z_{mn} * \ln Z_{mn} \tag{5}$$

$$e_m = \frac{1}{\ln n}\sum_{i=1}^{13} Y_{mn} \tag{6}$$

3) Calculate indicator weight, the formula is:

$$W_m = \frac{1-e_m}{\sum_{m=1}^{23} 1-e_m} \tag{7}$$

Through the above formula, the weight value of each index in the evaluation system of comprehensive carrying capacity of land resources in Zhangzhou is obtained (Table II).

TABLE II. Land comprehensive carrying capacity evaluation index weight

Target level	**Criterion level**	**Index level**	**Weight**
Comprehensive land resources carrying capacity	Ecological carrying capacity	X1: Water resources per capita	0.0395
		X2: Forest cove	0.0547
		X3: Comprehensive utilization rate of industrial solid waste	0.0279
		X4: Public green area per capita	0.0431
		X5: Discharge of industrial wastewater per land	0.0464
		X6: Industrial SO2 emissions per area	0.0256
		X7: Industrial pollution control investment as a percentage of GDP	0.0727
		X8: Pesticide application amount per unit of cultivated land	0.0224
		X9: Chemical fertilizer application amount per unit of cultivated land	0.0066

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		X10：Per capita arable land area	0.0376
	Production carrying capacity	X11：Investment in fixed assets per land	0.0555
		X12：GDP per land	0.0480
		X13：The proportion of tertiary industry	0.0443
		X14：Grain supply and demand ratio	0.0681
		X15：Per capita gross output value of agriculture, forestry, animal husbandry and fishery	0.0451
		X16：Degree of mechanization	0.0392
		X17：Total import and export	0.0453
	Living carrying capacity	X18：Transport length	0.0348
		X19：Natural population growth rate	0.0570
		X20：Population density	0.0349
		X21：Number of hospital beds per thousand people	0.0590
		X22：Per capita housing area	0.0522
		X23：Investment in science and technology education as a proportion of GDP	0.0400

2.4 Construction of Evaluation Model

2.4.1 Calculation of comprehensive carrying capacity of land resources

This study introduces the improved gray target model into the evaluation of comprehensive carrying capacity of land resources in Zhangzhou. This model can find the optimal value under relative conditions without a standard model, so it can break through the limitation of no evaluation reference standard. Calculate the relative value of the comprehensive carrying capacity of land resources in the research period, and provide new exploration and reference for the evaluation method of comprehensive carrying capacity of land resources.

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(1) Construction of standard pattern

The comprehensive carrying capacity evaluation of land resources takes year as year independent evaluation model. The maximum value of the standard mode of positive indicators is exponentials, the standard pattern for negative exponentials is to minimize the exponentials.

The standard mode calculation formula of the positive index is as follows:

$$x_0(m) = \max\{x_1(m), x_2(m), x_3(m), \ldots, x_{23}(m)\} \quad (8)$$

The standard mode calculation formula of the negative index is as follows:

$$x_0(m) = \min\{x_1(m), x_2(m), x_3(m), \ldots, x_{23}(m)\} \quad (9)$$

The resulting standard pattern sequence is

$X_0=\{x_0(1), x_0(2), x_0(3),\ldots, x_0(23)\}=\{4325.15, 63.73,99.32,14.64,119.44, 0.01,1.39,60.88,2094.18,0.58,21.95,24.26,39.9,0.51,15170.27,11.93,113.26,13248,5.8,363,4.39,40.9,2.26\}$.

(2) Gray target conversion

Let T be the gray target conversion, center of the target $x_0=TX_0=(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1)$,

The conversion formula of the positive index gray target is:

$$y_m = \frac{(X_m - \min X_m)}{(\max X_m - \min X_m)} \quad (10)$$

The conversion formula of the negative index gray target is:

$$y_m = \frac{(\max X_m - X_m)}{(\max X_m - \min X_m)} \quad (11)$$

In the two formulas, represents the converted value of gray target; the actual value of the mth indicator in the nth year; indicates the maximum value of the mth index in the evaluation

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year; is the minimum value. Taking 2004 as an example, the 23 indicators in X1 mode are the evaluation value obtained after gray target conversion.

y_1=[$x_1(B_1), x_1(B_2), x_1(B_3), \ldots, x_1(B_{23})$]=(0.3615,0.9729,0.3399,0.4816,0.2797,1,1,0.8853,0.7845,0.8621,0.0579,0.1772,0.9023,1,0.3469,0.8961,0.2864,0.4989, 0.9667, 1, 0.3986, 0.5826, 0.5796).

In the same way, the y_2— y_{13} of the gray target transformation of the mode X_2—X_{13} to be evaluated can be obtained, and the matrix （ y_1, $y_2, y_3, \ldots, y_{13}$） is finally obtained.

(3) Calculate the grey relation difference information space

The grey correlation difference information space $\Delta = \{\Delta_n(B_m) | n = 1,2,3,\ldots,13; m = 1,2,3,\ldots,23\}$, among them, $\Delta_n(B_m)$ represents B_m difference information between Xn and standard X0 in the mode to be evaluated, which is $\Delta_n(B_m) = |x_0(B_m) - x_i(B_m)|$. Through formula calculation, the grey relation difference information of mode X1 to be evaluated can be written $\Delta_{01}(B_m) = [\Delta_{01}(B_1), \Delta_{01}(B_2), \ldots, \Delta_{01}(B_{23})]$ =(0.6385,0.0271,0.6601,0.5184,0.7203,0,0, 0.1147,0.2155,0.1379,0.9421,0.8228,0.0977,0,0.6531,0.1039,0.7136,0.5011, 0.0333, 0, 0.6014, 0.4174, 0.4204).

Similarly, the grey relation difference information of the mode X_2-X_{13} to be evaluated can be obtained, and the matrix can be finally obtained (Δ_{01}, $\Delta_{02}, \Delta_{03}, \ldots, \Delta_{13}$), $max\Delta_n$=0.9856, $min\Delta_n$=0.

(4) Calculate bullseye coefficient

The formula for calculating the bullseye coefficient of the evaluation mode Xn under the evaluation index m of the comprehensive carrying capacity of land resources is:

$$\gamma(x_0(B_m), x_n(B_m)) = \frac{\min_n \min_m \Delta_n(B_m) + 0.5 \max_n \max_m \Delta_n(B_m)}{\Delta_n(B_m) + 0.5 \max_n \max_m \Delta_n(B_m)} = \frac{0.49325}{\Delta_n(m) + 0.49325} \quad (12)$$

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Through formula calculation, the bull 's-eye coefficient of each index of the mode X1 to be evaluated can be: $\gamma(x_0(B_m), x_1(B_m)) = [\gamma(x_0(B_1), x_1(B_{m1})), \gamma(x_0(B_2), x_1(B_2)), \ldots \gamma(x_0(B_{23}), x_1(B_{23}))]$=(0.4358, 0.9478, 0.4277,0.4875,0.4064,1,1,0.8113,0.6959,0.7815,0.3436,0.3748,0.8346,1,0.4303, 0.8260, 0.4087, 0.4961, 0.9367, 1, 0.4506, 0.5417, 0.5399).

In the same way, the bullseye coefficient of the model X_2—X_{13} to be evaluated can be obtained, and finally, the matrix composed of the bullseye coefficient[$\gamma(x_0(B_m), x_n(B_m))$]can be obtained.

(5) Calculate the target degree

Combine the weight determined by the grey correlation entropy method with the bull's-eye coefficient and bring it into the bullseye degree calculation formula (4-8) of the improved gray target model to obtain the comprehensive bullseye degree of each mode to be evaluated, that is, the comprehensive 2004-2016 The bullseye values are: $\gamma(x_0, x_1)$=0.6658, $\gamma(x_0, x_2)$=0.6552, $\gamma(x_0, x_3)$=0.6730,…, $\gamma(x_0, x_{13})$=0.8520.

(6) Determination of evaluation criteria

As we can know from Table III, the value range of the bull's eye is mainly between 0.5 and 0.9. The evaluation grade is divided according to the principle of equality and unity. Zhangzhou land carrying capacity from 2004 to 2016 is divided into five grades [19].With high bearing capacity (I) γ> 0.9, high bearing capacity (II) 0.8 γ< 0.9, or less medium capacity (III) 0.7 γ< 0.8, or less low bearing capacity (IV) 0.6 γ< 0.7, or less low bearing capacity (V) γ< 0.6.

According to the above method of carrying capacity classification, the specific evaluation grade results of comprehensive carrying capacity of land resources in Zhangzhou from 2004 to 2016 can be obtained (Table III).

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TABLE III Evaluation results of comprehensive land bearing capacity of Zhangzhou

Year	Comprehensive carrying capacity	Grade	Year	Comprehensive carrying capacity	Grade
2004	0.6658	IV	2011	0.6744	IV
2005	0.6552	IV	2012	0.6960	IV
2006	0.6730	IV	2013	0.7496	III
2007	0.6375	IV	2014	0.7621	III
2008	0.6451	IV	2015	0.7913	III
2009	0.6433	IV	2016	0.8520	II
2010	0.6657	IV			

2.4.2 Calculation of carrying capacity of each subsystem

According to the above method, firstly, the weights of ecological, production and living carrying systems were determined by the gray relational entropy method, and the index weights of each sub-carrying system were obtained. The improved gray target model is used to evaluate the modes composed of land ecological carrying capacity, production carrying capacity and living carrying capacity respectively, and the bullseye value of each carrying capacity can be obtained. Table IV shows the evaluation results.

TABLE IV Evaluation results of bearing capacity of various subsystems in Zhangzhou

Year	Ecological carrying capacity	Grade	Production carrying capacity	Grade	Living carrying capacity	Grade
2004	0.7152	III	0.6311	IV	0.5642	V
2005	0.6756	IV	0.6456	IV	0.5686	V
2006	0.7639	III	0.5840	V	0.6120	IV
2007	0.6144	IV	0.6005	IV	0.6523	IV
2008	0.6162	IV	0.6198	IV	0.6418	IV
2009	0.6122	IV	0.6227	IV	0.6327	IV
2010	0.6158	IV	0.6354	IV	0.6744	IV
2011	0.5973	V	0.6617	IV	0.6616	IV
2012	0.6488	IV	0.6787	IV	0.6478	IV
2013	0.6844	IV	0.6988	IV	0.7954	III
2014	0.6697	IV	0.7382	III	0.7751	III
2015	0.6995	IV	0.7778	III	0.8337	II
2016	0.8128	II	0.8451	II	0.8473	II

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2.5 Analysis of Evaluation Results

2.5.1 Analysis of land carrying capacity changes

According to the evaluation results of the comprehensive carrying capacity of land resources in Zhangzhou (table), the change trend map of the ecological carrying capacity, production carrying capacity, living carrying capacity and comprehensive carrying capacity of the land after the calculation of the improved gray target model can be obtained (Fig 1).

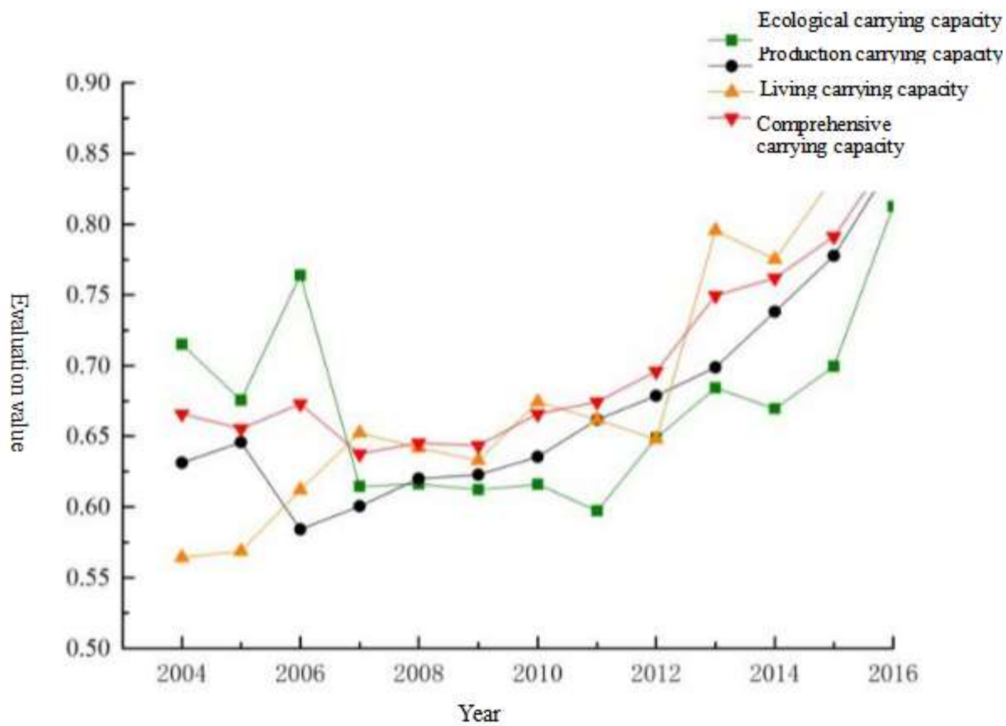

Fig 1: trend of land carrying capacity in Zhangzhou from 2004 to 2016

(1) Analysis of land ecological carrying capacity

The study used the following 9 indicators for the ecological carrying capacity of land: X1 per capita water resources (m³/person), X2 forest coverage rate (%), X3 comprehensive utilization rate of industrial solid waste (%), X4 per capita public green area (m^2), X5 average industrial waste water discharge (t/hm^2), X6 average SO2 waste water discharge (t/hm^2), X7 industrial pollution investment as a percentage of GDP (%), X8 pesticide application per unit

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area of farmland (kg/ hm^2), and X9 chemical fertilizer application per unit area of cultivated land (kg/hm^2).

It can be seen from Table 4 and Figure 1 that from 2004 to 2016, the ecological carrying capacity of land in Zhangzhou City showed an overall upward trend, from 0.7152 to 0.8128, an increase of 0.0976, and the carrying grade changed from a medium level to a higher level. However, it can be seen from the figure that in 13 years, the level of ecological carrying capacity has changed from being higher than the carrying capacity of production and living to being lower than the carrying capacity of production and living, which promoted the comprehensive carrying capacity of land resources and turned into a restrictive effect.

From 2004 to 2010, the overall ecological carrying capacity showed a downward trend. During this period, the amount of industrial waste water and SO_2 emissions increased, and the proportion of industrial pollution control investment in GDP decreased. The degree of changes in natural resources is quite drastic, and industrial wastewater and SO_2 emissions and industrial pollution control investment have an impact on the regional ecological environment. The above two factors have caused the overall ecological carrying capacity to decline during the past six years.

From 2010 to 2016, the ecological carrying capacity of land showed a fluctuating upward trend, reaching a maximum of 0.8128 in 2016. The forest coverage and per capita public green area, which have a positive impact on ecological carrying capacity, have increased year by year, reaching their peaks in 2016 (63.74% and 114.64 square meters) respectively; the per capita industrial wastewater discharge and the amount of pesticide application per unit of arable land that have a negative impact Significantly reduced, reaching valley values (119.44 tons/hm^2 and 60.88kg/hm^2) in 2016. Therefore, the ecological carrying capacity of the land reached its maximum in 2016 compared to 2004.

(2) Analysis of land production carrying capacity

The study uses the following 8 indicators for land production carrying capacity: X10 per capita arable land area (mu/person), X11 per capita investment in fixed assets (10,000 yuan/hm^2), X12 per capita GDP (10,000 yuan/hm^2), X13 third Industry proportion (%), X14 grain supply and demand ratio (m^2), X15 per capita total output value of agriculture, forestry, animal husbandry and fishery (yuan/person), X16 degree of mechanization (kw/hm^2), X17 total imports and exports (100 million US dollars).

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It can be seen from Table 4 and Figure 1 that from 2004 to 2016, the land production carrying capacity of Zhangzhou city has been greatly improved, from a low level to a higher level, and showing a good development trend. The carrying capacity score increased from 0.6311 to 0.8451, an increase of 33.90%. In the three carrying systems, the production carrying capacity changes from lower to higher than the ecological carrying capacity ability.

From 2004 to 2010, the production carrying capacity few changes, and most of the evaluation grades were at a lower carrying capacity level. The main reason for the sharp drop in production carrying capacity in 2006 was the degree of mechanization and the decline in the ratio of food supply and demand. The main influencing factors of the food supply-demand ratio are food production and the total population of the region. The low level of mechanization and the decline in food production directly affect the regional land production capacity.

From 2010 to 2016, the production carrying capacity increased well, with an average increase of 4.89%, and the carrying capacity evaluation level reached a higher level in 2016, with a maximum increase of 8.64%. At this stage, the annual growth of fixed asset investment per land, GDP per land, the proportion of tertiary industry, and the total output value of agriculture, forestry, animal husbandry and fishery per capita played a positive role in stimulating the increase in production capacity. The above four indicators were all reached a peak in 2016.

(3) Analysis of land living carrying capacity

The study uses the following six indicators for the living carring capacity of the land: X18 transportation length (km), X19 natural population growth rate (‰), X20 population density (person/km^2), X21 number of hospital beds per thousand people (pieces/ thousands of people), X22 per capita housing area (m^2/person), X23 science and technology education investment accounted for the proportion of GDP (%).

It can be seen from Table 4 and Figure 1 that from 2004 to 2016, the living capacity of land in Zhangzhou City showed an overall increasing trend, and the carrying grade gradually shifted from a low carrying grade to a higher carrying grade. The evaluation value rose from 0.5642 to 0.8473, an increase of 50.18%, is the highest value among the three sub-carrying systems, changing from the control subsystem of the comprehensive carrying capacity of land resources to the promotion subsystem.

From 2004 to 2010, from 2004 to 2010, the production carrying capacity changed little, the carrying capacity increased from 0.5642 to 0.6744, an increase of 19.54%. The main factors

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driving the growth of production capacity at this stage are the length of transportation, the number of hospital beds per thousand people, the per capita housing area, and the increase in the proportion of science and technology education investment in GDP. However, the carrying capacity declined from 2007 to 2008, mainly due to the slow increase in the length of transportation that year, only increasing by 5 kilometers; the population density and natural population growth rate have increased, and the per capita housing area has also increased from 32.7 square meters. The meter is reduced to 30.9 square meters.

From 2010 to 2016, the production carrying capacity increased rapidly, and the carrying capacity changed from a lower grade to a higher grade. The carrying capacity rose from 0.6744 to 0.8473, an increase of 25.64%, which was 1.31 times that of 2004-2010. The length of transportation, the per capita housing area, the number of hospital beds per 1,000 people, and the proportion of investment in science and technology education in GDP all play a positive role in promoting the development of living capacity. Especially in 2012-2013, the carrying capacity increased from 0.6478 to 0.7954, the largest annual increase, reaching 22.78%.

(4) Analysis of comprehensive carrying capacity of land resources

It can be seen from Table 3 that from 2004 to 2016, the comprehensive carrying capacity of land resources in Zhangzhou City has steadily increased, from 0.6658 to 0.8520, and the carrying capacity level has changed from a lower level to a higher level. The comprehensive carrying

Capacity of land resources is obtained by the interaction of the three subsystems of land ecology, production and living carrying capacity. In 2004, the relationship between the three sub-carrying systems was as follows: ecological carrying capacity> production carrying capacity> living carrying capacity; in 2016, it was: living carrying capacity> production carrying capacity> ecological carrying capacity. From 2004 to 2006, the ecological bearing system played a positive role in the comprehensive carrying capacity of land resources. After 2007, with the development of social economy and the improvement of production and living capacity, the ecological environment was affected. It gradually becomes the weakest system among the three sub-carrying systems. During this period, the main contribution to the improvement of the comprehensive carrying capacity of land resources is the production and living carrying system. In 2007-2011, the comprehensive carrying capacity was relatively stable, which is also related to the relatively stable sub-carrying system at this stage. From 2014 to 2016, the comprehensive carrying capacity increased rapidly. At this time, the ecological, production and living carrying capacity systems also showed a good upward trend, which had a positive and far-reaching impact on the overall carrying capacity improvement.

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IV. CONCLUSION

Based on the research area of Zhangzhou City, this study starts from the ecological, production and living functions of the land and constructs an evaluation index system for the comprehensive carrying capacity of land resources. The gray system theory is used throughout the whole paper, and the gray relational entropy method is used to determine the index weight, and the gray target model is constructed to evaluate the comprehensive carrying capacity of land and the bearing capacity of each subsystem. Compared with other evaluation models, it is more targeted and unified when closely combined with "production-living-ecological" spaces in territorial spatial planning, and more in line with the needs of land and resources management practice. Meanwhile, as far as the study area is concerned, the research results show that: (1) From 2004 to 2016, the comprehensive land resources carrying capacity in Zhangzhou increased from 0.6658 to 0.8520, and the bearing capacity grade changed from a lower level to a higher level. (2) The carrying capacity of the three subsystems changed from the ecological carrrying capacity > production carrying capacity >living carrying capacity in 2004 to the living carrying capacity >production carrying capacity >ecological carrying capacity in 2016. It can be seen that the pressure of the comprehensive carrying capacity of land resources in the future is mainly reflected in the pressure of the ecological carrying capacity.

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