Article

Evaluation of Water Resources Carrying Capacity in Guiyang City

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Abstract: Based on the situation of Guiyang's water resources, society, economy, ecology, etc., a comprehensive evaluation index system of Guiyang's water resources carrying capacity is established by selecting appropriate indexes. Based on the analytic hierarchy process (AHP) and the entropy method, an evaluation model of Guiyang's water resources carrying capacity is constructed. The results showed that the comprehensive evaluation value of water resources carrying capacity in Guiyang City increased by nearly 53% from 2009 to 2018, and the regulation and control force of water resources carrying capacity and water resources carrying pressure showed an upward trend. Within ten years, the total comprehensive evaluation value of Guiyang is 0.4503—close to H_2 level—and the membership degree of evaluation results over the years to H_2 is greater than that of H_1 and H_3. H_1, H_2, and H_3 are the three standard grades of water resources carrying capacity index, and the degree of carrying capacity represented is decreasing in turn. This indicated that at this stage, water resources can maintain the rapid development of the social economy, and that there is still some development potential. The research results have certain reference value for Guiyang's development and utilization of water resources.

Keywords: water resources carrying capacity; analytic hierarchy process; entropy method; fuzzy analysis; Guiyang City

1. Foreword

A shortage of water resources is one of the most important natural resources problems facing humankind today. The water resource crisis will bring great threats to the economic development of various countries. For example, China is currently short of water resources due to the uneven spatial and temporal distribution of water resources and the mismatch of water and soil resources, which is a factor in the restriction of sustainable social and economic development in China [1]. Regional water resources carrying capacity has become a hot topic in water resources research. Regional water resources carrying capacity refers to the reasonable scale that measures the degree to which the regional water resources system can support sustainable social and economic development under the condition of a certain level of economic, social, and technological development. It also evaluates the premise of the coordination between the healthy development of ecology and environment and sustainable social and economic development [2]. Correct evaluation of water resources carrying capacity can guide the rational utilization of water resources, and is of great significance to promote harmonious social and economic development [3,4]. At present, the evaluation methods of water resources carrying capacity in China mainly include principal component analysis [5], system dynamics method [6], ecological footprint method [7], and fuzzy analysis [8]. For example, Hong Xinyan [5] used principal component analysis to evaluate Xinjiang's water resources carrying capacity, but in the evaluation process, it failed

to hierarchically divide the carrying capacity of water resources in order to intuitively express it. Guo Weihong et al. [6] used a system dynamics model and predicted the water resources carrying capacity of Henan Province. However, the establishment of the system dynamics model is only the result of subjective abstraction and generalization after the research and insight of some specific systems, and its applicability needs to be further verified. Zhang Qian et al. [7] used a water ecological footprint model in addition to other models in order to analyze Chongqing's water ecological footprint, water resources carrying capacity, and water resources development and utilization from 2003 to 2016. However, the ecological footprint method is a calculation method based on the current static data, and thus the conclusion is instantaneous and cannot reflect the future development trend. Sun Kang et al. [8] concluded that the water resources carrying capacity of Wuhu City showed a gradual increasing trend from 2006 to 2015 based on the fuzzy comprehensive evaluation, but only when using the analytic hierarchy process to establish the weight of each index to ensure it has certain subjectivity. However, the current evaluation index system of water resources carrying capacity is not complete, and the determination of weights—the relative importance of each indicator—is uncertain. There are differences in the utilization of water resources in various regions, and further research is still needed. Guiyang is a city with a typical karst landform. Its unique surface–underground water storage structure results in serious seepage of surface water, and leads to a high cost of water resources development and utilization. This is the prominent problem of an engineering water shortage [9]. In this study, a comprehensive evaluation index system containing 15 indicators was established, and the weights were established through the coupling of the analytic hierarchy process and the entropy weight method. While absorbing the experience of experts, the amount of objective information is comprehensively considered in order to avoid the subjectivity caused by personal preferences. The evaluation model of water resources carrying capacity based on fuzzy analysis was established to evaluate the water resources carrying capacity of Guiyang from 2009 to 2018, and to determine the membership degree and comprehensive evaluation value of the evaluation results over the years. The overall objective is to provide guidance for the future development and utilization of water resources in Guiyang City.

2. Study Method

2.1. Establishment and Grading of the Index System

The evaluation index system of water resources carrying capacity is the core of the study on the regional water resources carrying capacity [10]. To fully and truly reflect Guiyang's water resources carrying capacity, the index system in the national water resources supply and demand analysis and the existing related research [9,11–13] are taken for reference for this study. In view of the prominent contradiction between supply and demand of water resources and the severe water pollution in Guiyang City, the index selection and analysis are carried out from three aspects, including the main support force of water resources carrying, the control force of water resources carrying, and the object pressure of water resources carrying. Fifteen influencing factors are selected to construct the evaluation index system of water resources carrying capacity in Guiyang City, which are composed of the target layer, the criterion layer, and the index layer (Table 1). The selected factors in the index system are of three grades: H_1 indicates that the water resources carrying capacity of the region is in a sustainable state, and that there is great potential for development; H3 indicates that the water resources carrying capacity of the region is close to the saturation value, the water resources are utilized to the maximum extent, and the contradiction between supply and demand of water resources obviously restricts social and economic development and aggravates the vulnerability of ecological environment; and H_2 is a grade between H_1 and H_3, indicating that the water resources carrying capacity of the region is moderate but that there is still room for further development and utilization. In order to quantitatively reflect the carrying capacity, $z_1 = 0.95$, $z_2 = 0.5$ and $z_3 = 0.05$ [14] are assigned to the three grades—namely H_1, H_2, and H_3—within the range of 0–1. Therefore, the calculation formula for the comprehensive score value Z of water resources carrying

capacity is Z = 0.95 z_1 + 0.5 z_2 + 0.05 z_3. The higher the value of the comprehensive score value obtained, the stronger the water resources carrying capacity. This is shown in Table 1 for specific rating indexes and the grading standard.

Table 1. Comprehensive rating indexes and grading standard of water resources carrying capacity.

Target Layer	Criteria Layer	Index Layer	Grading Standard		
			H_1	H_2	H_3
Water resources carrying capacity	Water resources carrying support	Per capita water possession u_1/m³	>1100	1100~1000	<1000
		Per capita water supply u_2/m³	>400	400~300	<300
		Annual water production modulus u_3/(10,000 m³·km⁻²)	>70	70~60	<60
		Vegetation coverage u_4/%	>40	40~25	<25
		Development and utilization rate of water resources u_5/%	<20	20~30	>30
	Water resources carrying control	Per capita GDP u_6/(CNY·person⁻¹)	>35,000	~	<
		Proportion of five kinds of inferior water in river length u_7/%	<8	8~17	>17
		Ecological water utilization rate u_8/%	>2	2~1	<1
		Compliance rate of water functional areas u_9/%	>70	70~40	<40
		Population density u_{10}/(person·km⁻²)	<400	400~560	>560
		Urbanization rate u_{11}/%	<50	50~70	>70
	Water resources carrying pressure	Water consumption per CNY 10,000 of GDP u_{12}/m³	<50	50~100	>100
		Daily domestic water consumption per capita u_{13}/(L·person⁻¹·d⁻¹)	<70	70~180	>180
		Water consumption per CNY 10,000 of industrial added value u_{14}/m³	<30	30~100	>120
		Water consumption for agricultural irrigation per hectare u_{15}/ m³	<3700	3700~6000	>6000
	Scoring		0.95	0.5	0.05

2.2. Determination of Index Weights

To ensure the reliability of the evaluation results, subjective method (analytic hierarchy process) and objective method (entropy method) are combined to assign weights. Since there is no preference for the two methods, the arithmetic average method is used as the combined weighting method.

2.2.1. Calculation of Subjective Weight by Analytic Hierarchy Process

The analytic hierarchy process (AHP) was proposed in the early 1970s [15], and effectively determines the weight value of each index from qualitative analysis to quantitative integration. It is a typical multi-criteria decision-making method, which combines subjective judgment with objective facts, expresses the views of decision makers quantitatively, and reflects the thinking of decomposition, judgment, and synthesis in decision-making. The analytic hierarchy process can divide a complex system into an orderly hierarchical structure. The weight coefficient of the relative importance ranking of all indexes can be determined based on the subjective judgment of the importance of each index to the subjects, according to expert experience. The key problem is to calculate the maximum eigenvalue λ_{max} of the judgment matrix and its corresponding eigenvector W.

(1) On the basis of the comprehensive evaluation index system, score the relative importance between two factors at the same level, using the numbers 1–9 and their reciprocals as scales [15], and construct a judgment matrix $U' = (u_{ij})_{n \times n}$.

(2) Calculate the weight vector $W' = [W_1, W_2, \ldots, W_n]$ T of the judgment matrix by the geometric average method. See Equation (1).

$$W_i = \frac{\left(\prod_{j=1}^{n} u_{ij} \right)^{\frac{1}{n}}}{\sum_{i=1}^{n} \left(\prod_{j=1}^{n} u_{ij} \right)^{\frac{1}{n}}}, i = 1, 2, \ldots, n \tag{1}$$

In the formula, Wi is the weight of the i line; u_{ij} is the element of the i line and the j column of the judgment matrix U'.

(3) Calculate the maximum eigenvalue λ_{max}. See Equation (2).

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(U'W)_i}{nW_i} \tag{2}$$

In the formula, λ_{max} is the maximum eigenvalue of the judgment matrix, while U' is the judgment matrix.

(4) In order to judge whether the fuzzy matrix has satisfactory consistency, a consistency test is required. The negative mean value of the eigenvalues—other than the maximum eigenvalue λ_{max} of the judgment matrix—is used as a numerical index to measure whether the judgment matrix is consistent [16]; when CR $\leq$ 0.1, the consistency is satisfactory. When CR > 0.1 (CR is the calculated consistency ratio), the judgment matrix needs to be corrected.

$$CI = \frac{\lambda_{max} - n}{(n-1)RI} \tag{3}$$

In the formula, CI is the consistency index and n is the order of the judgment matrix.

2.2.2. Calculation of Objective Weights by Entropy Method

The entropy method is a mathematical method used to calculate a comprehensive index on the basis of comprehensively considering the amount of information provided by various factors. Weights are mainly determined according to the amount of information transmitted by each index to decision makers [17]. In regard to the evaluation of an object, if its value of a certain index differs greatly and the entropy value is small, it can be inferred that the index provides a large amount of effective information and the weight of the index should be large [18]; under the opposite condition, the weight of the index should be small. The steps of determining index weights by entropy method are as follows:

(1) Construct a judgment matrix $P = (p_{ij})$ $m \times n$, according to the data of m evaluation indexes in n years, and process the data to eliminate the influence of dimensions and orders of magnitude. For cost indexes (such as urbanization rate) where the lowest is the best, refer to Equation (4) for normalization. For profitability indexes (such as per capita water supply) where the highest is the best, refer to Equation (5) for normalization.

$$p'_{ij} = [\max_j \{p_{ij}\} - p_{ij}] / [\max_j \{p_{ij}\} - \min_j \{p_{ij}\}] \tag{4}$$

$$p'_{ij} = [p_{ij} - \min_j \{p_{ij}\}] / [\max_j \{p_{ij}\} - \min_j \{p_{ij}\}] \tag{5}$$

where p_{ij} is the statistical value of the i-th index in the n-th year; $\max_j \{p_{ij}\}$ and $\min_j \{p_{ij}\}$ are the maximum value and the minimum value of the i-th index in the n-th year, respectively; p_{ij}' is the normalized data.

(2) In the evaluation involving the data of m indexes in n years, the entropy value of the i-th index can be calculated according to Equation (6).

$$E_i = (-\sum_{j=1}^{n} f_{ij} ln f_{ij}) / \ln n \tag{6}$$

where: f_{ij} can be calculated according to Equation (7).

$$f_{ij} = (1 + p'_{ij}) / \sum_{j=1}^{n} (1 + p'_{ij}) \tag{7}$$

(3) According to the entropy values of the m evaluation indexes, the entropy weight can be calculated according to Equation (8).

$$w_i'' = (1 - E_i)/(m - \sum_{i=1}^{m} E_i) \tag{8}$$

According to Equation (9), the weight of the previous criteria layer can be calculated with the weights of all indexes.

$$W'' = [w_i''(1 - E_i)]/[\sum_{i=1}^{m} w_i''(1 - E_i)] \tag{9}$$

2.3. Determination of Membership Function

The indexes near the critical value may have small numerical correlation but completely different evaluation levels. In order to eliminate this jump phenomenon, such indexes should be fuzzified [19]. Set the membership degree of the interval midpoint value of H_2 to be 1, the membership degree of the two critical points to be 0.5, and the value decreases from the middle to both sides.

Set the critical values of H_1 and H_2 to be k_1, the critical values of H_2 and H_3 to be k_3, the interval midpoint value of H_2 to be k_2, and $k_2 = (k_1 + k_3)/2$. The evaluation factors are divided into positive and negative effect factors according to their effect on the objects being evaluated. As shown in Equations (10)–(12) [20], for the calculation formulas of membership functions of positive influence factors (such as u_1, u_2, u_3, u_4, u_6, u_8, and u_9) relative to each evaluation grade:

$$W_{H1} = \begin{cases} 0.5 \left(1 + \frac{u_i - k_1}{u_i - k_2}\right), & u_i > k_1 \\ 0.5 \left(1 - \frac{u_i - k_1}{k_2 - k_1}\right), & k_2 < u_i \leq k_1 \\ 0, & u_i \leq k_2 \end{cases} \tag{10}$$

$$W_{H2} = \begin{cases} 0.5 \left(1 - \frac{u_i - k_1}{u_i - k_2}\right), & u_i > k_1 \\ 0.5 \left(1 + \frac{u_i - k_1}{k_2 - k_1}\right), & k_2 < u_i \leq k_1 \\ 0.5 \left(1 + \frac{u_i - k_3}{k_2 - k_3}\right), & k_3 < u_i \leq k_2 \\ 0.5 \left(1 - \frac{u_i - k_3}{u_i - k_2}\right), & u_i \leq k_3 \end{cases} \tag{11}$$

$$W_{H3} = \begin{cases} 0, & u_i > k_2 \\ 0.5 \left(1 - \frac{u_i - k_3}{k_2 - k_3}\right), & k_3 < u_i \leq k_2 \\ 0.5 \left(1 + \frac{k_3 - u_i}{k_2 - u_i}\right), & u_i \leq k_3 \end{cases} \tag{12}$$

For membership functions of the negative effect factors, the interval notations of u_i should be changed from "<" to ">" and from "$\leq$" to "$\geq$" on the right side of the above equation.

2.4. Fuzzy Comprehensive Evaluation Model

Construct a set of the objects being evaluated: $U = \{u_1, u_2, \ldots u_m\}$, where u_i ($i = 1 \ldots m$) are the m evaluation indexes of the objects being evaluated. Construct an evaluation grade set: $V = \{v_1, v_2, \ldots v_n\}$, where v_i ($i = 1 \ldots n$) are the n evaluation grades of the objects being evaluated. Determine the degree of different evaluation grades of each object being evaluated in the evaluation grade set, that is, the membership degree expressed by r_{ij}, thus obtaining a matrix R:

$$R = \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix} \tag{13}$$

Comprehensive evaluation matrix:

$$B = W \times R \tag{14}$$

where the weight matrix $W = (W_1, W_2, \ldots, W_n)$ are the weights assigned to all evaluation factors according to their influence on the water resources carrying capacity. $B = (b_1, b_2, \ldots b_j)$, and b_j is the membership degree of the grade v_j to the fuzzy subset B obtained by the comprehensive evaluation, reflecting the result of the comprehensive evaluation. Then, calculate the comprehensive evaluation value of regional water resources carrying capacity with the scores z_1, z_2 and z_3 corresponding to the grading indexes H_1, H_2, and H_3.

3. Evaluation of Guiyang's Water Resources Carrying Capacity

The data used in this study is mainly from the Guiyang Water Resources Bulletin (2009–2018) [21] and the Statistical Bulletin of Guiyang's National Economic and Social Development (2009–2018) [22]. Table 2 indicates the actual index values of Guiyang from 2009 to 2018. According to the grading standard in Table 1, the evaluation matrix R is calculated by using the membership function calculation Formulas (10)~(12). The membership degrees of each index to grades H_1, H_2, and H_3 are calculated. Due to the immense amount of data, only the data of 2018 is taken as an example, as shown in Equation (15). The analytic hierarchy process and the entropy method are used to calculate the weight of each index to the target layer, and combination weighting is done, as shown in Table 3. The comprehensive evaluation matrix and b_1, b_2, and b_3 are obtained according to Equation (14), and the comprehensive evaluation value of Guiyang's water resources carrying capacity is obtained according to the score, as shown in Table 4. The diagram of the changes in the comprehensive evaluation value and the evaluation indexes of all subsystems is drawn, as shown in Figure 1.

$$R_{2018} = \begin{pmatrix} 0 & 0.1092 & 0.8908 \\ 0 & 0.2061 & 0.7939 \\ 0 & 0.4808 & 0.5192 \\ 0.8077 & 0.1923 & 0 \\ 0.18 & 0.82 & 0 \\ 0.9264 & 0.0736 & 0 \\ 0.6691 & 0.3309 & 0 \\ 0.7642 & 0.2358 & 0 \\ 0.735 & 0.265 & 0 \\ 0 & 0.3134 & 0.6866 \\ 0 & 0.324 & 0.676 \\ 0.7259 & 0.2741 & 0 \\ 0.0533 & 0.9467 & 0 \\ 0.3267 & 0.6733 & 0 \\ 0.2247 & 0.7753 & 0 \end{pmatrix} \tag{15}$$

Table 2. Evaluation index values of Guiyang's water resources carrying capacity from 2009 to 2018.

Index	Year									
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
u1	1076.23	769.66	616.28	1127.88	742.54	1275.15	1044.61	693.03	1096.42	820.99
u2	278.4	275.22	231.03	226.9	231.3	232.3	227.4	232.7	224.3	228.7
u3	49.17	35.7	33.7	62.5	41.8	72.3	60.1	40.5	65.5	59.8
u4	42.3	42.3	42.8	43.15	43.5	45	45.5	46.5	48.66	52.0
u5	25.6	35.6	37.5	20.1	31.2	18.2	21.8	33.6	20.5	23.2
u6	24,590	30,064	31,481	38,194	48,862	55,018	63,003	67,771	74,493	78,449
u7	23.6	15.7	16.6	16.6	16.6	7	24.3	7	6	5.7
u8	1.37	1.36	1.87	2.38	1.34	1.19	1.49	1.59	1.81	2.56
u9	33.2	36.5	39.2	42.9	47.8	58.8	58.8	64.7	76.5	83.3
u10	456.90	464.46	546.84	554.11	562.85	567.09	575.28	584.62	597.71	607.65
u11	67	68.18	69.2	70.53	72	73.2	73.25	74.16	74.8	75.43
u12	113.2	91.5	73.4	59.4	50.2	42.4	36.4	34.6	30.4	29.4
u13	124.64	124.08	140.31	112.01	105.42	111.73	114.47	115.03	115.88	119.14
u14	168.2	155.3	105.3	88.6	74.3	60.2	53.3	50.2	43.9	45.6
u15	6750.29	5750.66	5421.82	5096.62	4666.01	4756.40	4781.04	4860.45	4404.21	4333.23

Table 3. Weight of each index of Guiyang's water resources carrying capacity.

Subjective Weighting						Objective Weighting						Combination Weighting
Target Layer	Criteria Layer	Weight of the Criteria Layer	Index Layer	Weight of the Index Layer	Weight	Target Layer	Criteria Layer	Weight of the Criteria Layer	Index Layer	Weight of the Index Layer	Weight	Weight
A	B1	0.1634	u_1	0.0969	0.0158	A	B1	0.4738	u_1	0.1538	0.0729	0.0444
			u_2	0.4348	0.0710				u_2	0.3794	0.1798	0.1254
			u_3	0.1820	0.0297				u_3	0.1696	0.0804	0.0550
			u_4	0.2863	0.0468				u_4	0.2972	0.1408	0.0938
			u_5	0.0929	0.0276				u_5	0.1675	0.0483	0.0379
	B2	0.2970	u_6	0.0464	0.0138		B2	0.2881	u_6	0.1924	0.0554	0.0346
			u_7	0.4081	0.1212				u_7	0.1767	0.0509	0.0861
			u_8	0.1767	0.0525				u_8	0.2428	0.0700	0.0612
			u_9	0.2760	0.0820				u_9	0.2206	0.0636	0.0728
	B3	0.5396	u_{10}	0.2589	0.1397		B3	0.2381	u_{10}	0.2811	0.0669	0.1033
			u_{11}	0.1357	0.0732				u_{11}	0.2446	0.0582	0.0657
			u_{12}	0.2589	0.1397				u_{12}	0.1235	0.0294	0.0846
			u_{13}	0.0750	0.0405				u_{13}	0.1005	0.0239	0.0322
			u_{14}	0.1357	0.0732				u_{14}	0.1488	0.0354	0.0543
			u_{15}	0.1357	0.0732				u_{15}	0.1015	0.0242	0.0487

Table 4. Comprehensive evaluation results of Guiyang's water resources carrying capacity.

| Year	Membership Degree b1 to V1 Level	Membership Degree b2 to V2 Level	Membership Degree b3 to V3 Level	Comprehensive Evaluation Value
2009	0.0846	0.4991	0.4164	0.3507
2010	0.0741	0.5273	0.3986	0.3540
2011	0.0942	0.4983	0.4075	0.3590
2012	0.2060	0.5160	0.2780	0.4676
2013	0.1424	0.4879	0.3697	0.3977
2014	0.3222	0.4659	0.2119	0.5496
2015	0.1939	0.5058	0.3003	0.4521
2016	0.2563	0.4210	0.3228	0.4701
2017	0.3587	0.4291	0.2122	0.5659
2018	0.3643	0.3527	0.2830	0.5366
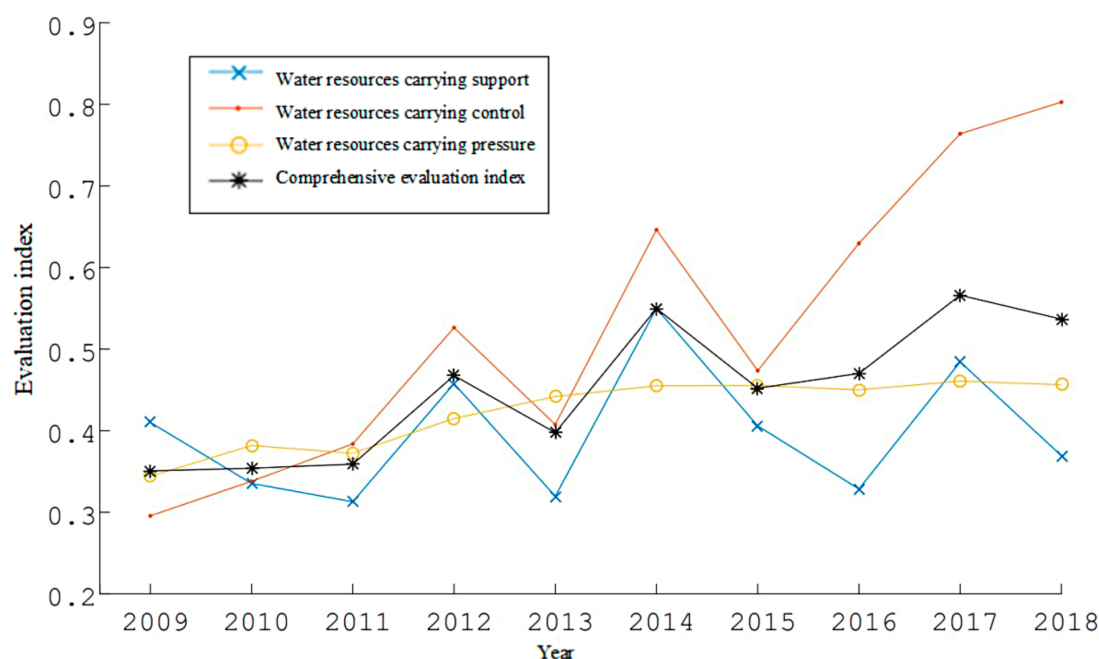
Figure 1. Evaluation result of Guiyang's water resource carrying capacity from 2009 to 2018.

4. Analysis of Results

The evaluation results of Guiyang's water resources carrying capacity from 2009 to 2018 is analyzed based on Table 4 and Figure 1.

(1) As for the comprehensive evaluation index, the comprehensive evaluation value of Guiyang's water resources carrying capacity from 2009 to 2018 is 0.4503, which is close to the value of H_2, indicating that the water resources carrying capacity is moderate. Except for 2012, 2014, and 2017, the comprehensive evaluation value of Guiyang's water resources carrying capacity showed a steady upward trend. Due to the sharp increase of precipitation in Guiyang in 2012, 2014, and 2017, the total amount of water resources exceeded 5 billion m^3, and the water resources carrying capacity improved, which is consistent with the calculated results.

(2) From the perspective of the three subsystems, the water resources carrying support system is in a fluctuating state due to the obvious influence of the total amount of water resources. The evaluation value fluctuates greatly between 0.3 and 0.6. Affected by the change of regional population, precipitation, urbanization, and other factors, the per capita water possession, per capita water supply, annual water production modulus, and vegetation coverage of Guiyang City fluctuated greatly from 2009 to 2018. The water resources carrying capacity control system is generally on the rise, which is closely related to Guiyang's vigorous promotion of ecological civilization construction. Thanks to the steady development of water environment management, the ecological water use rate and the compliance rate of water functional areas have been greatly improved. The water resources carrying capacity control system had large positive fluctuations in 2012 and 2014 due to the relative decrease in the utilization rate of water resources development caused by the large total amount of water resources. However, since 2015, the decrease in the total amount of water resources has not affected the rise of the water resources carrying capacity control curve, reflecting the particularly remarkable effect of water environment improvement in recent years. The water resources carrying pressure system showed a steady upward trend from 2009 to 2014. From 2014 to 2018, the evaluation value gradually stabilized at about 0.45, and the water consumption per CNY 10,000 of GDP and per CNY 10,000 of industrial added value were greatly reduced due to the improvement of technology and productivity. However, the acceleration of economic development,

population growth, and urbanization has brought greater pressure of water consumption, which restricts the further improvement of water resources carrying capacity. Guiyang needs to further optimize the water consumption structure to cope with the large-scale water consumption.

(3) According to the evaluation results B (b_1, b_2, and b_3) set over the years, the membership degrees to H_2 are greater than those to H_1 and H_3, indicating that Guiyang's development and utilization of water resources has reached a certain scale. There is still some development potential, and the water resources can maintain rapid social and economic development at the current stage. The membership degree b_1 has continuously increased from lower than 0.1 at the beginning to about 0.2 and 0.3 in recent years, and the membership degree b_3 has shown a gradual downward trend, indicating that the good components of Guiyang's water resources carrying capacity are increasing year by year, and the water resources carrying capacity is improving.

5. Conclusions

In this paper, with the comprehensive consideration of water resources, society, economy, ecology, etc., the evaluation system of water resources carrying capacity is divided into three subsystems: water resources carrying support, water resources carrying control, and water resources carrying pressure. The evaluation index system of Guiyang's water resources carrying capacity is constructed, the combination weight is determined by the analytic hierarchy process and the entropy method, and a model for evaluating Guiyang's water resources carrying capacity based on fuzzy analysis method is built. The model is applied to comprehensively evaluate Guiyang's water resources carrying capacity. The results show that Guiyang's water resources carrying capacity improved year by year from 2009 to 2018. At the current stage, the water resources can maintain rapid social and economic development, and there is still some development potential. In order to further improve the water resources carrying capacity, Guiyang should continue optimizing the allocation of water resources, actively promote the construction of water-saving cities, and realize the efficient development and utilization of water resources in addition to maintaining the existing achievements of water environment improvement.

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