

Application of multi level fuzzy comprehensive evaluation method in water resources assessment

Qiming Chen

Department of Automation, North China Electric Power University, Baoding 071000, China.

1132181030@qq.com

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Abstract. Water resources issue is a big problem faced by the mankind. It is of great significance to make a correct evaluation and prediction of water resources carrying capacity in a country or region. However, lots of problems exist in the evaluation of water resources carrying capacity, such as too many evaluation indicators, difficulty in quantifying and the impact of subjective factors, etc. This paper proposes a hierarchical fuzzy comprehensive evaluation method based on analytic hierarchy process to measure the water resources carrying capacity of a region. In this paper, this model is applied to the evaluation of water resources carrying capacity of Beijing and Hubei province. Theoretical analysis and practical application show that the model is effective.

1. Introduction

Water resources issue is a big problem faced by the mankind. Aiming to measure the water resources condition, we establish an evaluation system and apply it to evaluate the water resources of Beijing and Hubei in China.[1] In this paper, we establish a fuzzy synthetic evaluation model based on analytic hierarchy process.

Analytic hierarchy process is a structured technique for organizing and analyzing complex decision, based on mathematics and psychology.[2] It has particular application in group decision. Fuzzy comprehensive evaluation (FCE) means using fuzzy mathematics to make an overall evaluation of the object which is restricted by many factors[3][4]. It can well solve the problems which are fuzzy and hard to quantify.

In this paper, we take the weights of every indicator obtained from analytic hierarchy process into Fuzzy comprehensive evaluation, combining with their strength, to establish our FAHP model.

2. Model Framework

2.1 How to select index?

- Substitute the index like growth rate and percentage for the index that is an absolute magnitude, which is more representative[5].
- Notice the respective characteristics of different regions. Choosing a good index that is suitable for different regions is of importance. For example, as there is a vast territory with a sparse population in some areas, the natural population growth rate is better than population density.
- Consider whether the index is accessible to get.

2.2 The framework of our model

According to Figure 1, we make Water resource, Ecological environment, Social economy as our criterion layer, taking 12 indexes into account to analyze.[6][7]

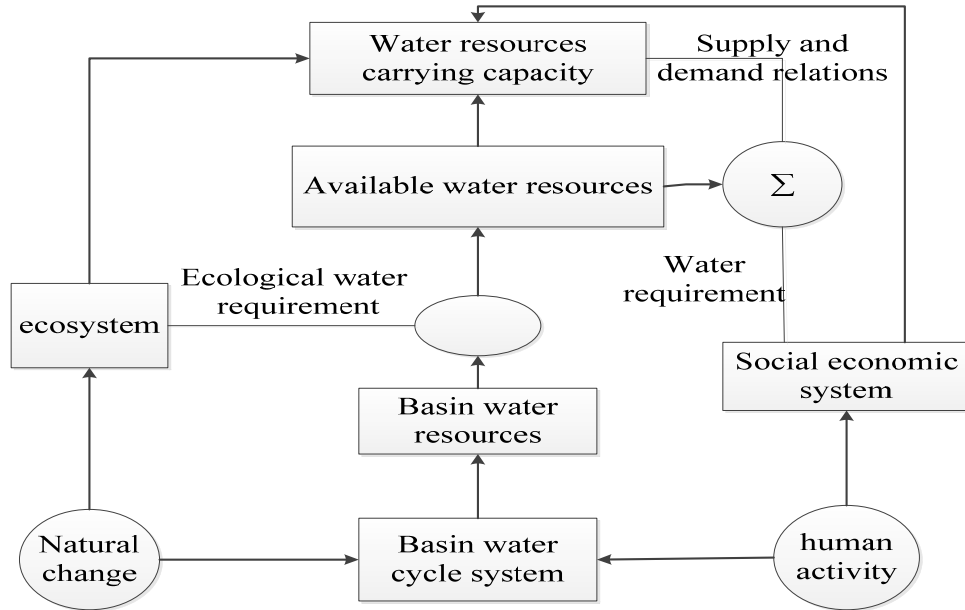


Figure 1 Relationship of water resources carrying capacity system

The determination of the critical value and the ideal standard of the water resources carrying capacity directly affects the accuracy, objectivity and practicability of the evaluation results. Through expert consultation and reference to the relevant indicators of sustainable development of the international and domestic authorities to determine the various water resources carrying capacity of the individual standard index values.

These 12 indicators are Average water resource amount capita (C1), Rate of resource utilization (C2), Per capita water consumption (C3), Vegetation coverage (C4), COD concentration (C5), Ecological water requirement ratio (C6), the natural population growth rate (C7), The level of urbanization (C8), Per capita GDP (C9), The proportion of tertiary industry in GDP (C10), The per capita share of grain (C11), Water Efficiency (C12).

The model of analytic hierarchy process is shown in Figure 2.

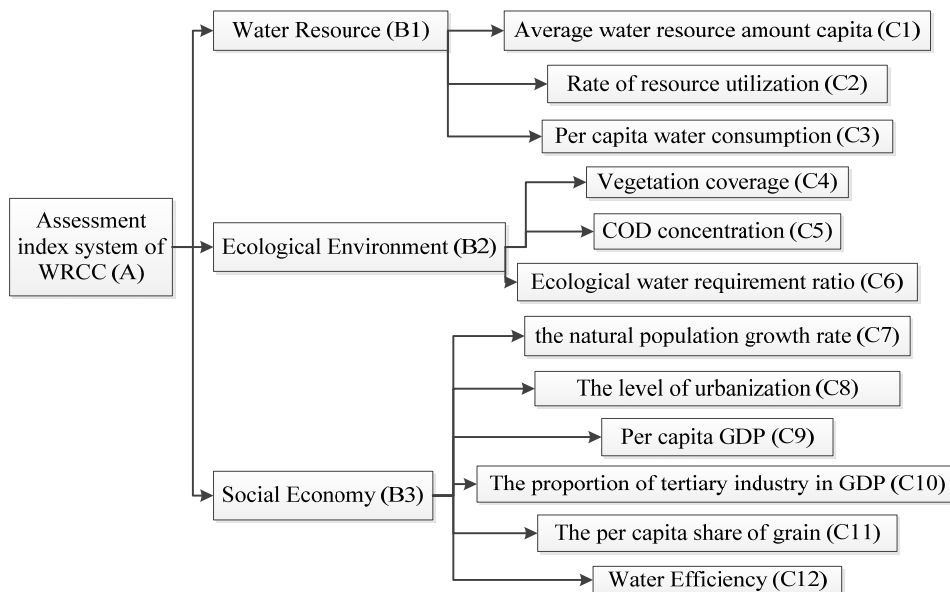


Figure 2 The Framework of Evaluation Model

Step 1: Confirm Judgment Matrix

Some authoritative figures of the sustainable development and some other related indexes, we can determine each single index of the water resources carrying capacity. Take matrix A as an example, judgement matrix of A is shown in the Table 1.

Table 1 Judgement Matrix

Matrix A	B1	B2	B3
B1	1	2/3	5/9
B2	3/2	1	5/6
B3	9/5	6/5	1

We can get the residual judgment matrix by the same method.

Step 2: Consistency check and acquire the relevant weights

Use MATLAB to calculate the value of CR by the equations.

$$CI = \frac{\lambda - n}{n - 1}, CR = \frac{CI}{RI} \tag{1}$$

From the result in Table 2, we can know the coherence of those matrix is qualified.

Table 2 CR of every matrix

	Matrix A	Matrix B1	Matrix B2	Matrix B3
CR	7.66×10^{-16}	0	0.081	0.0011

Step 3: Combinational Consistency Test

$$CR = \frac{CI}{RI} = 0.0198 < 0.1 \tag{2}$$

So, the combinational coherence of those matrix is qualified and we can get weights of every index which are show in Table 3.

Table 3 Assessment index system of water resources carrying capacity

Target layer	Criterion layer	weight	Index layer	Weight	Weight to target layer	V1	V2
A	B1	0.2326	C1	0.6522	0.1517	1700	4000
			C2	0.2174	0.0506	30	20
			C3	0.1034	0.0303	800	400
	B2	0.3488	C4	0.4387	0.153	15	60
			C5	0.2381	0.0831	30	15
			C6	0.3232	0.1127	25	50
	B3	0.4196	C7	0.1951	0.0817	9.5	2.1
			C8	0.048	0.0201	20	70
			C9	0.2753	0.1152	3280	32800
			C10	0.146	0.0611	30	60
			C11	0.03	0.0126	300	590
			C12	0.3056	0.1279	3.07	408.6

Step 4: Measurement of water resources carrying membership

$$\mu_i = \begin{cases} 1, (x_i < V_{i1}) \\ \frac{v_{i1} - x_i}{v_{i1} - v_{i2}}, (V_{i1} \leq x_i \leq V_{i2}) \\ 0, (x_i > V_{i1}) \end{cases}, \mu_i = \begin{cases} 1, (x_i > V_{i1}) \\ \frac{-v_{i1} + x_i}{-v_{i1} + v_{i2}}, (V_{i1} \leq x_i \leq V_{i2}) \\ 0, (x_i < V_{i1}) \end{cases} \tag{3}$$

The former is suitable for the situation that the water resources carrying capacity is getting smaller when the index gets larger. The latter is contrary with the former.

We use the classification criteria in the Table 4.

Table 4 Classification criteria

	0	0~0.2	0.2~0.8	0.8~1	1
Type	Unable to carry	Possible to carry	Able to carry	Easy to carry	Optimal to carry

3. APPLICATION

In this part, we put related data of Beijing and Hubei Province into our model. The result is as shown in Table 5.

Table 5 Classification of Beijing and Hubei

Place	Beijing	Hubei
Value	0	0.2618
Type	Unable to carry	Able to carry

Results of Classification of Beijing and Hubei show that the model is very satisfactory and conform to reality.

4. Summary

In this paper, we establish we establish a fuzzy synthetic evaluation model based on analytic hierarchy process and this model is applied to the evaluation of water resources carrying capacity of Beijing and Hubei province. Theoretical analysis and practical application show that the model is effective.

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