Are We Heading Toward a Thirsty Planet?

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Abstract. Currently, one quarter of the world's population is experiencing water scarcity. In order to alleviate this situation, the *Comprehensive Evaluation Model based on Entropy Method* (CEE) is used to evaluate the ability of a region to provide clean water to meet the needs of its population. The CEE has selected 7 representative index, such as GDP water consumption, per capital water resources, the waste-water emissions and so on. These index reflect the relationships between water resources and economy, society, ecology. Entropy method is applied to calculate the weight of each indicator, and then we compute the final score of the comprehensive indicator. The higher the final score is, the better the supply situation is.

1. Introduction

The evaluation of water supply and demand we usually say have two meanings, narrow sense and broad sense. In the narrow sense, we used to think that our assessment of water resource supply and demand is the problem that supply can meet the present demand of water resources or not. But in the broad sense, the focus of evaluation lies in the future.

Water safety is the essence of water supply can meet the demand for rational water resources, but the core problem is the water resources of a country or region can meet the long-term development of society, the requirements of sustainable development or not. If a regional water supply can meet their reasonable demands for long-term social-economic development, water resources in the region is safe, otherwise it is not safe [1].

So in this paper, an effective model is constructed to evaluate the ability of a region to provide clean water to meet the needs of its population.

2. Comprehensive Evaluation Model based on Entropy Method

2.1 Define Factors and Reviews Set.

Firstly, considering the dynamic nature of the factors that affect both supply and demand, We chose the factors listed in table 1 as our index. These index constitute the factors set.

Table 1 Factors Symbols Setting

Factors	Symbol
Per Capital Water Supply and Demand Ratio	u_1
Per Capital Water Resources	u_2
GDP Water Consumption	u_3
Population with Access to Improved Drinking Water	u_4
Population with Access to Sanitation in % of the Total Population	u_5
Waste-water Emissions	u_6
Annual Precipitation	u_7

The index are represented by the corresponding symbol in the table 1. The factors set are defined as the symbol ‘U’. So we get the set

U= {u 1, u 2, u 3, u 4, u 5, u 6, u 7}.

Then we determine the reviews set. The evaluation is divided into four levels, slightly exploited, moderately exploited, heavily exploited and over exploited. The reviews set are consisted of these four degrees of evaluation (Table 2).

Table 2 Degrees of Evaluation Symbol Setting

Degree of Evaluation	Symbol
Slightly Exploited	v_1
Moderately Exploited	v_2
Heavily Exploited	v_3
Over exploited	v_4

2.2 Weight Calculation.

Through the UN water scarcity map, we can know that the capital of China, Beijing is a heavily exploited region [2]. So we select Beijing as an example. And then we can calculate the weight of each factor according to Beijing's data (Table 3).

Table 3 index Data (2004--2014)

Year	u_1 (m^3 / p)	u_2 (m^3)	u_3 (m^3)	u_4	u_5	u_6 (10^4*t)	u_7 (mm)
2004	1.618	142.99	57.266	85	70	98063	539
2005	1.488	151.21	49.501	87	75	101009	468
2006	1.554	141.52	42.253	88	77	104922	318
2007	1.462	148.16	35.352	90	78	107816.69	483.9
2008	1.026	205.53	31.561	95	78	113259	480.6
2009	1.625	126.61	29.211	97	80	140812.88	480.6
2010	1.525	124.2	24.941	97	80	136415	533.8
2011	1.341	134.71	22.127	97	83	145468.95	721.1
2012	0.908	193.24	20.068	98	85	140273.72	530
2013	1.466	118.59	18.373	98	87	144579.93	480
2014	1.847	95.15	17.545	98	87	150713.57	439

Table 3 has given the data of index in the past decade[3], we can calculate the weight of the index above by using the Entropy method.

Firstly, we have to positive managed the index. The true digit of these index are defined as the symbol 'X_{ji}', and the symbol 'ρ_{ji}' means the digit of index after positive management. Then we can get the formula

$$\rho_{ji} = \frac{X_{ji}}{\sum_{i=1}^{n} X_{ji}} \tag{1}$$

Where: $1 \le j \le 11,\ \ i \le i \le 7$

Table 4 is the data of index after normalizing.

Secondly, we are expected to calculate entropy. The symbol 'φ_i' means the entropy.

The formula is

$$\varphi_i = -\sum_{i=1}^{n} \rho_{ji} \left(\ln \rho_{ji} \right). \tag{2}$$

Table 4 index Data after Normalizing (2004--2014)

Year	u_1 (m^3 / p)	u_2 (m^3)	u_3 (m^3)	u_4 (%)	u_5 (%)	u_6 (10^4*T)	u_7 (mm)
2004	0.309	0.071	0.175	0.850	0.700	0.218	0.587
2005	0.336	0.076	0.202	0.870	0.750	0.230	0.543
2006	0.322	0.071	0.237	0.880	0.770	0.216	0.449
2007	0.342	0.074	0.283	0.900	0.780	0.230	0.552
2008	0.487	0.103	0.317	0.950	0.780	0.321	0.550
2009	0.308	0.063	0.342	0.970	0.800	0.167	0.550
2010	0.328	0.062	0.401	0.970	0.800	0.179	0.584
2011	0.373	0.067	0.452	0.970	0.830	0.187	0.701
2012	0.550	0.097	0.498	0.980	0.850	0.285	0.581
2013	0.341	0.059	0.544	0.980	0.870	0.173	0.550
2014	0.271	0.048	0.569	0.980	0.870	0.136	0.524

Thirdly, reverse the entropy. The symbol 'ω_i' means the entropy after reversing. We can gain the results by the formula

$$\omega_i = \frac{\max \varphi_i}{\varphi_i} \quad . \tag{3}$$

Where: $w \geq 1, i \in [1, n]$

Finally, we can gain the weight which is defined as the symbol 'ϕ_i' by the formula

$$\phi_i = \frac{\omega_i}{\sum_{i=1}^{n} \omega_i} \quad . \tag{4}$$

After solving the formulas, we can get the weight matrix

Φ= [0.1429, 0.1429, 0.1456, 0.1417, 0.1417, 0.1433, 0.1419] T.

It is not difficult to find that the weight of each indicator is almost the same, there aren't a large proportion differences among them.

3. Model Solving

Traditional fuzzy comprehensive evaluation methods can't meet the needs of our model, so we made improvements to it. We use normalized index' values and their respective weights multiplied, to get the final score. We define this final score as the symbol 'P i', so the set is

Pi = {0.4141, 0.4280, 0.4193, 0.4502, 0.4998, 0.4559, 0.4738, 0.5105, 0.5478, 0.5018, 0.4849}.

According to the situation of China, we considered the degrees of evaluation as table 5 shows.

Table 5 Evaluation Grade Classification

Final Score	Degree of Evaluation
0—0.3	Over exploited
0.3—0.6	Heavily Exploited
0.6—0.8	Moderately Exploited
0.8—1.0	Slightly Exploited

Through the table 5 we can judge that from 2004 to 2014, Beijing is in the second degree of the table. There are enough reasons for us to believe that Beijing is a heavily exploited region.

4. Discussion of Results

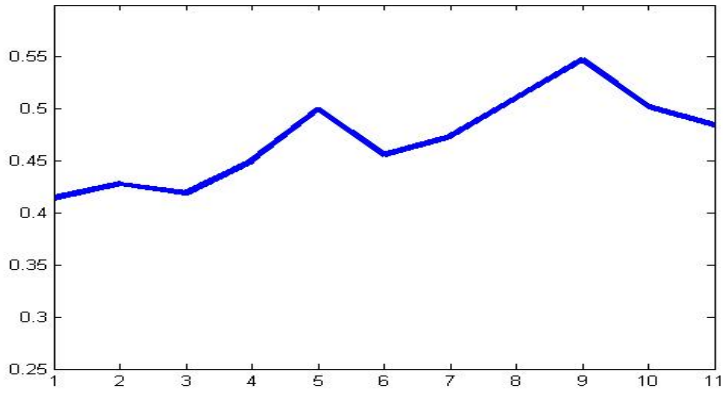

Fig.1 the Final Scores of Evaluation (2004--2014)

Through analyzing the plot (Fig. 1), we can draw the conclusions as follow:

1. It is obvious that 2008 is special. There is an apparent peak in 2008. After considering it twice, we think that it's the Olympic Games that lead to the difference. So ignore the indicator's scores in 2008, the curve showed a trend of first increasing and then decreasing.

2. For the geographical position, Beijing is an inland city. So it has the physical scarcity firstly.

3. For another, with the development of the global economy, GDP water consumption is decreasing, utilization rate of water resources increased. And the index are also increased such as the population with access to improved drinking water, the population with access to sanitation in % of the total population. All the reasons above lead to the rise in total index.

4. But at the same time of economic development, our environment is influenced, too. According to the index of our model, both the waste-water emissions and per capital water supply and demand ratio are increased, which lead to the trend of decreasing in the curve.

5. Through the above analysis, we believe that if no action is taken, the situation must be even more severe.

6. Beijing needs to take measures to solve the current problems of the south to North Water Transfer.

5. Summary

The CEE selects the representative index, which simplifies the complexity of evaluation, and t-he weight of each index is determined by the entropy weight method, which avoids the influence of subjective factors on the accuracy of the results.

However, each indicator will have a corresponding change with the development of society.Therefore, in order to further improve the accuracy of the model results, we have to use additional index and data.

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