Say No to the Thirsty Planet: Too Few Freshwater for the Daily Life of Human Beings

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Abstract Though more than 70 percent of the earth space is covered by ocean, only no more than 2.5 percent of the freshwater is available for the daily life of human beings. However, as the country who owns the biggest population in the world, China’s per-capita average of freshwater resources amounts to only quarter of the world’s. By analyzing the relationship between supply and demand of water resource, we build the Water Resources Carrying Capacity (WRCC) model and analyze the current situations of water resource in China.

1. Introduction
Water is a kind of irreplaceable resource for human society to survive and develop, a kind of basic condition for human society to make sustainable development. In the last century, the usage amount of water resources is increasing at twice the speed of the population. With the sustaining increase of population and the advance of social economy, water resources scarcity and water environment deterioration have become global issues.

Taking China as an example, China is a country that has both 20 percents of global population and 7 percents of water resources. With rapid increase usage of urban domestic and industrial water and the sustaining aggravation of water pollution, the demand contradiction of water resources in our country becomes more prominent. Water resources scarcity has become the bottleneck of domestic social and economic sustaining development. In addition, as a developing country, China is in duty bound to settle the increasing demand of water resources causing by economic growth and the crying needs of increasing water resources Coe cient of utilization.

2. The evaluation of Water Resources Carrying Capacity (WRCC)
“Carrying Capacity” is a word from ecology, which is originally used to measure the maximum maintainable quantity of one kind of species under a certain environmental conditions in a specific area. While for regional water resources carrying capacity, we consider it as a region's scale, where water sources can hold the harmonious development of society, economy and ecotope. The conclusion regards foreseeable technology, economic and social developmental level as our gist, regards social sustainable development and sustainable utilization of water resources as our principle, regards a condition that water resources are exploited and allocated reasonably as our premise.

From the various factors of affecting WRCC, we synthetically consider the influence of various factors. Then we make systematic assessment on Chinese WRCC and establish regional WRCC assessment system of the 4 subsystems .The 4 subsystems respectively are social subsystem, economic
subsystem, and ecological subsystem and water resources subsystem. By means of building comprehensive evaluation index system, we establish comprehensive evaluation model of regional WRCC. Then we use this model to measure the ability of providing clean water to meet the region's population demand in a region.

2.1. Evaluation System of WRCC
The comprehensive evaluation index system of WRCC is a kind of gist and standard of the harmonious developmental condition of regional water sources, society, ecology and economy, which is used to make comprehensive evaluation and research. On the basis of previous studies, we synthesize frequency statistics and theoretical analysis methods to choose our index. Then we establish the systematic comprehensive evaluation index system of regional society, economy, ecology and water resources.

| Primary Goal | Secondary Goal | Index |
|--------------|----------------|-------|
| The Index of Water Resource Carrying Capacity | The Index of Water Resource System (C1) | Total Amount of Water Resource (X1) |
| | | The Exploitation Rate of Water Resource (X2) |
| | | The Modulus of Water Supply (X3) |
| | | Mean Annual Precipitation (X4) |
| | The Index of Social System (C2) | Population Density (X5) |
| | | Natural Growth Rate of Population (X6) |
| | | Urban Population Proportion (X7) |
| | | The Quota of Domestic Water (X8) |
| | The Index of Economic System (C3) | GDP Per Capita (X9) |
| | | Growth Rate of GDP (X10) |
| | | The Quota of Industrial Water (X11) |
| | | The Quota of Agricultural Water (X12) |
| | The Index of Ecological System (C4) | Percentage of Forest Cover (X13) |
| | | Wetland Proportion (X14) |

2.2. Modeling of WRCC

2.2.1. Data Processing. Owing to the differences of the chosen index's dimension, there exists difference of magnitude. So we need standardization treatment on the chosen index data, trend acting force of all index on the evaluation project in the same way, figure out the comparability of the data, and quantify the index attribute value of it. The theory of it is:

\[
X'_{ij} = \frac{(X_{ij} - \bar{X}_j)}{\sigma_j^2} \quad (1)
\]

\[
\sigma_j^2 = \frac{1}{n} \sum_{i=1}^{n} (X_{ij} - \bar{X}_j)^2 \quad (2)
\]

\(X_{ij}\) Means the original statistic data of index, \(\bar{X}_j\) means standardized variable data.

2.2.2. Model Building. According to the comprehensive evaluation index system designed by us, the expression of regional WRCC comprehensive index CW is:
In this expression, \( CN \) means the demand index of water resources system, \( CS \) means the supply index of water resources system. As for \( CS \), we select each index of water resources system \( C_1 \) and ecological system \( C_4 \) to calculate; As for \( CN \), we select each index of social system \( C_2 \) and economic system to calculate. Thereinto:

\[
C_i = \sum_{i=1}^{n} \Phi_i X_i
\]  

(4)

In this expression, \( C_i \) stands for integrated assessment value of each index in Sheet 1, \( \Phi_i \) for the \( i \)th index's weight of factor, \( X_i \) for the \( i \)th index's evaluation value of index.

We calculate numerical value by the model, and determine the metrics of the comprehensive indexes of WRCC (CW), which is shown in following table.

| CW     | [0.00,0.50] | (0.50,0.80] | (0.80,1.00] | (1.00,1.50] | >1.50 |
|--------|-------------|-------------|-------------|-------------|-------|
| Carrying level | Surplus carrying capacity/Rich water Resources | Appropriate carrying capacity/ Harmonio water resources utilization | Be close to overload/ Strained Water resources | Mild overload/ Water resources shortage | Severe overload / Severe shortage of water resources |

2.2.3. **Determine Index's Weight by AHP.** AHP (Analytic Hierarchy Process) is a method raised by American operational research expert T. L. Saaty et al. in the middle of 1970s, which is both qualitative and quantitative and used to make multi-objective decision analysis in a systemic and hierarchical way. This method is neither pursue recondite mathematics merely, nor pay attention to behaviour, logic, inference in a one-sided way. This method bands qualitative method and quantitative method together organically and resolve complex system. Then the thinking process of human will turn into mathematicization and systematization. AHP can make the complex things more acceptable.

When applying AHP to ensure the weight of evaluation index, we base on establishing orderly hierarchical index system, and then synthetically calculate weight coefficient of the index by contrasting each index of the same level's relative importance. Using AHP to model, we averagely follow these steps:

- Construct judgment matrix.
- Calculate the index weight of the matrix.
- Judge the consistency test of the matrix.

We judge each index two by two and then get the judgment matrix of the four systems respectively:

\[
A_1 = \begin{bmatrix}
    X1 & X2 & X3 & X4 \\
    X1 & 1 & 1/3 & 1/7 & 1/5 \\
    X2 & 3 & 1 & 1/4 & 1/3 \\
    X3 & 7 & 4 & 1 & 3 \\
    X4 & 5 & 2 & 1/3 & 1
\end{bmatrix} \quad A_2 = \begin{bmatrix}
    X5 & X6 & X7 & X8 \\
    X5 & 1 & 8 & 7 & 3 \\
    X6 & 1/8 & 1 & 1 & 1/2 \\
    X7 & 1/7 & 2 & 1 & 1/4 \\
    X8 & 1/3 & 5 & 4 & 1
\end{bmatrix}
\]
Through the programming by MATLAB, we can get the weight of the four systems’ index. The results are shown in figure 1 below:

![Figure 1. AHP index weights](image)

Test the consistency of the judgment matrix:

\[ CR = \frac{CI}{RI} \tag{5} \]

When \( CR < 0.10 \), we consider that the consistency of the judgment matrix is acceptable, or we should amend the judgment matrix appropriately.

After computation, matrices of the four systems are all accorded with the consistency check. From this, we get each index’s weight of factor. However, AHP has its weakness too. AHP is a method carrying decision making way of human brain simulation. And it must have major qualitative elements and definite subjective factors, so it’s not easy to convince someone of it. To get more objective index weight, we choose some other ways to model.

### 2.2.4. Determine index’s Weight by Entropy Value Method

Using AHP to determine the index’s weight will be influenced by subjective factors, so we adopt a kind of assessment method to allocate weight objectively. This method is entropy evaluation method. According to original information capacity’s size of objective social quality condition, objective economic quality condition, objective ecologic quality condition and objective water resource quality condition, we can figure out the weight of index. When the information content becomes bigger, the no determinacy will be smaller, then the entropy will be smaller either. On the contrary, when the information content becomes smaller, the no
determinacy will be bigger, then the entropy will be bigger either. By means of analysing the connection degree of each index through degree of variation of index, we can avoid the error from subjective factors to some extent.

The steps of determining the weight of index through entropy evaluation method are shown below:

Step 1. Do positive dispose on the index, then do proportion conversion on evaluation index

\[ \rho_j = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \]  

(6)

Thereinto, j means the sample area where index value exists. For example, we choose the relevant data of Chinese 31 provinces and regions, so \( 1 \leq j \leq 31 \), \( 1 \leq i \leq 14 \);

Step 2. Do entropy calculation on evaluation index

\[ \phi_i = -\sum_{j=0}^{n} \rho_j (\ln \rho_j) \]  

(7)

Step 3. Reverse the entropy

\[ w_j = \frac{\max \phi_i}{\phi_i} \]  

(8)

Step 4. Calculate the weight of index \( \phi_i \)

\[ \phi_i = \frac{w_j}{\sum_{j=0}^{n} w_j} \]  

(9)

Entropy method is a kind of objective weight determination method which has theoretical basis. Compared with subjective weight determination, it has higher credibility and higher accuracy. The weight of index, obtained by means of this method, deeply reflects separating capacity of the index. This is consistent with the choice theory of our chosen evaluation model index.

3. Conclusion

We use WRCC to define the ability of providing clean water to meet the demand of population in that region. And we consider the evaluation index of WRCC comprehensively on water resources, society, and economy and ecology system. Using the connection between water resources supply and demand, we establish the evaluation model of WRCC. On the basis of each chosen index data, we can obtain WRCC of the region. This indicator system enriches the research on regional WRCC evaluation and plays an important reference role for the rational development and utilization of regional water resources and the sustainable development of social economy.

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