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# Exploration on Regional Water Supply Capacity

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**Abstract.** In the 20th century, the world's population has doubled, while human water consumption has increased five times. Many countries in the world are facing a water crisis. To measure the water supply capacity of a region, we define the water supply capacity index. Then we select 11 important factors according to systematic investigations and assume that the water supply capacity of the 12 chosen regions is only affected by the 11 chosen factors. We use Principal Component Analysis to calculate the principal components of collected data and their contribution rate, then linearly combine the value of them to get the water supply capacity index of the 12 chosen regions. The results reveal that South Asia has the best water supply capacity, Australia and New Zealand, Southern America, Eastern Europe and Russian Federation have a poor water supply capacity.

## 1. Introduction

According to the United Nations, 1.2 billion people are short of water, 3 billion people lack of water sanitation, 3-4 million people die each year from water-related diseases. The World Water Resources Comprehensive Assessment Report predicted that that by 2025, the world's population will rise to 8.3 billion, while population living in water shortage will rise to 3 billion.

Review the previous research, we find that in the field of water resources research, integrated water resources management draw the world's attention most. Low use ratio and waste of water and other four problems have become the main five problems. In order to deal with these problems, countries established coordination mechanisms or institutions, invested a lot of money and manpower in using membrane technology for water treatment, wastewater treatment and many other aspects [1]. From the international point of view, due to different national conditions and problem understanding, the implementation phase of water management in different countries are different. But before all those works, we need to find ways to measure the water supply capacity of an area.

## 2. Water Supply Capacity Index

In order to measure the water supply capacity of an area, we select the following 12 areas as a sample, consider the following 11 factors of two aspects of natural factors and social factors and use the Principal Component Analysis (PCA) [2]to analyze and compare the differences in their water supply capacity.

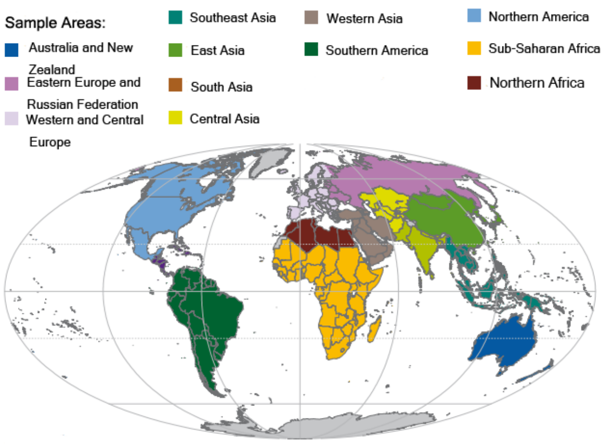


Figure 1: 12 sample areas for study.[3]

Table 1: The cumulative contribution rate of the characteristic root

| | |
|---|---|
| environmental factors | Precipitation((mm/10 thousand km3)) |
| | Renewable water resources(km3/10 thousand km3) |
| | Total freshwater withdrawal (km3/(yr*10 thousand km3)) |
| social factors | Population(100million/10 thousand km3) |
| | Groundwater irrigation (million ha/10 thousand km3) |
| | Irrigation water withdrawal (%) |
| | Equipped area(2006)(million ha/10 thousand km3) |
| | Green Land (%) |
| | Inland water bodies (%) |
| | Sparsely vegetated and barren land (%) |
| | Cultivated land (%) |

### 2.1 Data Standardization

We assume that there are *m* principal component analysis index variables: $X_1, X_2 \ldots\ldots X_m$, and *n* evaluation objects. $X_{ij}$ is the value of the index *j* of the evaluation object *i*. We convert each index into standardized indicators $\overline{X_{ij}}$ :

$$\overline{X_{ij}} = \frac{X_{ij} - \overline{X_j}}{S_j}, (i,j=1,2,...,m) \quad (1)$$

Where: $\overline{X_j} = \frac{1}{n}\sum_{i=1}^{n} X_{ij}$, $S_j = \frac{1}{n-1}\sum_{i=1}^{n}(X_{ij} - \overline{X_j})^2$, (i,j=1,2,...,m)

### 2.2 Calculating the Correlation Coefficient Matrix.

The correlation coefficient matrix:

$$R = (r_{ij})_{m*m} \quad (2)$$

According to the existing definition of PCA:

$$r_{ij} = \frac{\sum_{k=1}^{n} \overline{X_{ki}} * \overline{X_{kj}}}{n-1}, (i,j=1,2,...,m)$$

Where: $r_{ii} = 1$, $r_{ij} = r_{ji}$, $r_{ij}$ is the correlation coefficient of the index *i* and index *j*.

**2.3 Calculating the Eigenvalue And Eigenvector**

Firstly,we calculated the eigenvalue $\lambda_1 \geq \lambda_2 \geq ... \geq \lambda_m \geq 0$ of *R* and its eigenvector $u_1, u_2, ..., u_m$. Where:

$$u_j = (u_{1j}, u_{2j}, ..., u_{nj},)^T$$

Then we get *m* new index variables which is composed of eigenvector:

$$y_i = u_{1i}\overline{X_1} + u_{2i}\overline{X_2} + ... + u_{ni}\overline{X_{ni}}, (i=1,2,...,m) \quad (3)$$

Where: $y_i$ is the principal component *i*.

**2.4 Select the Principal Component P (P ≤ M) And Calculate the comprehensive evaluation value.**

We calculated the contribution rate and cumulative contribution rate of the eigenvalue $\lambda_j$, (j = 1, 2, m).We call

$$b_j = \frac{\lambda_j}{\sum_{k=1}^{m} \lambda_k}, (j = 1, 2... m) \quad (4)$$

The contribution rate of principal component,

$$\alpha_p = \frac{\sum_{k=1}^{p} \lambda_k}{\sum_{k=1}^{m} \lambda_k} \quad (5)$$

The cumulative contribution rate of $y_1, y_2, ..., y_p$.We selected the first p $y_1, y_2, ..., y_p$ as *p* principal component when the $\alpha_p$ is close to 1 and use them to take the place of the *m* original index variables. Then we can analyze the principal components comprehensively.

When we were going to measure the success of the chosen cities,we defined *Z* as the Water Supply Capacity Index which shows the comprehensive evaluation value of a region :

$$Z = \sum_{j=1}^{p} b_j y_j \quad (6)$$

## 3. Data Processing and Calculation

We got the raw data of these 12 regions from [3], using MATLAB to calculate. The contribution rate and the cumulative contribution rate of characteristic root are given in Figure 2 and Table 2.

Table 2: The cumulative contribution rate of the characteristic root

| serial number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| cumulative contribution rate | 0.572 | 0.822 | 0.923 | 0.979 | 0.989 | 0.995 | 0.998 | 0.999 |

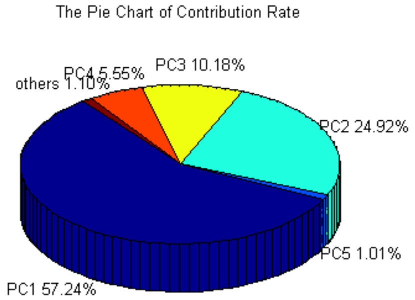


Figure 2: The contribution rate of the characteristic root.

According to the data above, we can see that the cumulative contribution rate of the first four characteristic roots reach 97%.The Principal Component Analysis performs well. Next we select five principal components (cumulative contribution rate reaches 98.9%) to carry out a comprehensive evaluation.

Calculate the first five eigenvectors of the characteristic root and we get five principal components: $y_1, y_2, ..., y_5$ expressed as:

$$\begin{aligned} y1 &= 0.3879\ X1 + 0.2822\ X2 + 0.1385\ X3 \ldots\ldots + 0.3864\ X11 \\ y2 &= 0.0327\ X1 - 0.2710\ X2 - 0.4460\ X3 \ldots\ldots + 0.1026\ X11 \\ y3 &= -0.0052\ X1 - 0.4530\ X2 - 0.4700\ X3 \ldots\ldots - 0.0285\ X11 \\ y4 &= -0.1244\ X1 + 0.2603\ X2 + 0.3226\ X3 \ldots\ldots + 0.0336\ X11 \\ y5 &= 0.2443\ X1 + 0.1517\ X2 - 0.1368\ X3 \ldots\ldots - 0.4456\ X11 \end{aligned} \tag{7}$$

Plugging the index standardized value $\overline{X}_{ij}$ of each object into (7) and regard the contribution rate of the five principal components as weight, our Principal Component Analyze Model is constructed:

$$Z = \sum_{j=1}^{p} b_j y_j \tag{6}$$

Substitute the five principal components of the sample into (6), we can obtain their water supply capacity evaluation results. In order to understand the water supply capacity more intuitively, we standardize the data:

$$Z_i' = \frac{Z_i - \overline{Z}}{S_Z}$$

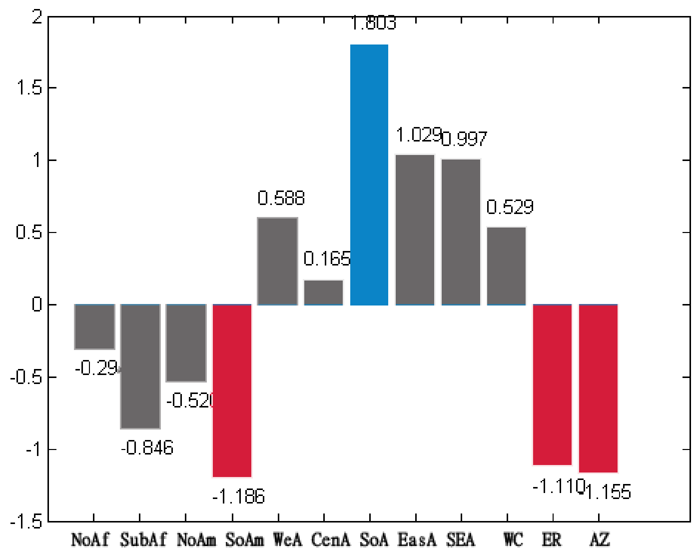


Figure 3: The comparison of Water supply capacity index in sample areas.

(NoAf: North Africa; SubAf:S ub-Saharan Africa; NoAm:Northern America; SoAm: Southern America; WeA: Western Asia; CenA: Central Asia; SoA: South Asia; EasA: East Asia; SEA: Southeast Asia; WC: Western and Central Europe; ER: Eastern Europe and Russian Federation; AZ: Australia and New Zealand )

At this point, the mean of $Z$ is 0, which means the average level of water supply capacity in the sample area. When Z is bigger than 0, the water supply capacity is higher than the average, when smaller, it is below average. And the final result is presented in Figure 3.

## 4. Conclusion

The data in Figure 3 shows South Asia has the best water supply capacity while Australia and New Zealand, Southern America, Eastern Europe and Russian Federation’s water supply capacity is poor. After checking some references, we conducted the following analysis: although the water load in South Asian is heavy, its better intervention policy of water planning, development, allocation, scheduling and protection improve the utilization of water and its water supply capacity stronger;

in contrast, the South American Andes region is of severe water shortage because of higher terrain and water resources are mostly concentrated in the plain area; As the world's smallest population density area, even if there is enough water in the Amazon plain they will not be fully utilized. While where the population is relatively dense, the water load is larger. So the water supply capacity is weak there.

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