Asian Agricultural Research 2013, 5(10): 143 – 145

Evaluation of Water Resource Potential in Anhui Province Based on Allocation Model

Zhenyu XU*, Yanlin ZHOU

Anhui Institute of Economic Research, Hefei 230001, China

Abstract The nature of water resources can be divided into four categories: water for life, water for agriculture, water for industry, and water for ecology. On this basis, the regional right allocation model for water resources is built, and to make the model more operable, we calculate the weight of the key factors of model (four different types of water use: life, agriculture, industry, ecology), using analytic hierarchy process (AHP). Finally, based on the amount of available water resources in Anhui Province, we evaluate the water resource potential in Anhui Province according to the principle of rational allocation.

Key words Water resources, Allocation, AHP, Evaluation

1 Introduction

China is one of the world's 13 water-poor countries, with freshwater resources accounting for only 8% of world's total amount of freshwater and per capita water resources accounting for about 25% of the world's average. From the point of view of social and economic development in China, the carrying capacity of water resources has been rapidly approaching the ceiling, and the water shortages will increasingly become constraints on China's agricultural and socio-economic development. Carrying out the evaluation of water resource potential is not only the basis for sustainable use and management of water resources, but also the premise for rational planning and normal operation of water-related projects.

2 General framework for research

This study uses the data on water resource use potential of main inflowing rivers, and total amount of available water resources in the county from the results of the second integrated assessment of water resources by Anhui Provincial Department of Water Resources (1956 – 2000) as well as the water use data in various cities from 2005 Anhui Water Resources Bulletin. The vector diagram uses 1: 50 000 administrative map of Anhui Province. We take the correlation analysis method of water resource potential from National Main Functional Area Planning as the overall technical roadmap, and the technical processes are shown in Fig. 1.

According to the existing data, we can derive the amount of available water resources, water use amount in the county and population in the county, but the water use potential of inflowing rivers is the rub.

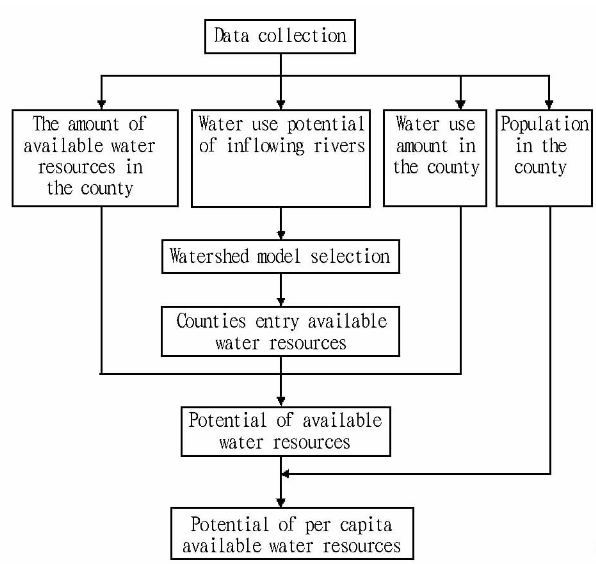

Fig. 1 The overall technical processes

3 Model estimate

3.1 Overall principle of water resource allocation

The current academic research on issues concerning water resource allocation is primarily to allocate the water rights to the provincial administrative regions (ie. initialization of water right allocation), under the principle of total amount control within the basin. The water allocation at this level, reflects the social justice as far as possible, and re-considers the problem of water use efficiency based on the premise that the fairness is ensured. Here we mainly research the allocation of water resource potential of inflowing rivers among the county-level administrative areas, namely the secondary allocation of water rights on the basis of initial allocation of water rights. From the perspective of social and economic development, the allocation of water resources at this level aims to improve water use efficiency, to meet the target of social equity as much as possible and balance efficiency and fairness. Under the potential of watershed water resources that can be tapped and utilized, the water resources allocated to the administrative areas mainly include domestic water, agricultural water and industrial water. In this scenario, the domestic water is mainly allocated ac-

Received: July 30, 2013 Accepted: September 20, 2013
* Corresponding author. E-mail: ahgisxzy@163.com

cording to population; agricultural water is mainly allocated according to the area of arable land; industrial water is primarily allocated according to the regional industrial output value.

3.2 Model establishment Based on the above analysis, we can establish the following water resource allocation model[1]:

$$Q_i = \alpha_{i1} Q_{t1} + \alpha_{i2} Q_{t2} + \alpha_{i3} Q_{t3}$$
$$= \alpha_{i1} \eta_1 Q + \alpha_{i2} \eta_2 Q + \alpha_{i3} \eta_3 Q,$$
$$= Q \sum_{j=1}^{3} \alpha_{ij} \eta_j,\ i = 1,\ \cdots,\ n$$
$$\alpha_{i1} = \frac{P_i}{\sum_{i=1}^{n} P_i} \qquad \alpha_{i2} = \frac{L_i}{\sum_{i=1}^{n} L_i} \qquad \alpha_{i3} = \frac{D_i}{\sum_{i=1}^{n} D_i}$$

where Q is potential of available water resources; Q_i is the amount of water that can be obtained by the administrative areas; Q_{t1}, Q_{t2}, Q_{t3} are total amount of domestic water, agricultural water and industrial water respectively within entire basin, $\sum_{j=1}^{3} Q_{ij} = Q$; η_1, η_2, η_3 are the share of total amount of domestic water, agricultural water and industrial water within entire basin in the potential available water resources, respectively, $\sum_{j=1}^{3} \eta_j = 1$; α_{i1}, α_{i2}, α_{i3} are the share of total amount of domestic water, agricultural water and industrial water within the administrative areas in the amount of total amount of domestic water, agricultural water and industrial water within entire basin, respectively, $\sum_{j=1}^{3} \alpha ij = 1, j = 1, 2, 3$; P_i, L_i, D_i are the population, area of arable land, and industrial output value in the administrative areas, respectively.

By analyzing the model, it can be found that except η_j, other factors can be calculated according to the statistical data, so η_j is a key factor in the model, and we use AHP for estimates.

3.3 Application of AHP The analytic hierarchy process (AHP) [2] is a structured technique for organizing and analyzing complex decisions. Users of the AHP first decompose their decision problem into a hierarchy of more easily comprehended subproblems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem-tangible or intangible, carefully measured or roughly estimated, well-or poorly-understood – anything at all that applies to the decision at hand. Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the decision makers can use concrete data about the elements, but they typically use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations. The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making techniques. In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action.

According to the previous analysis, the principles considered in the basin water allocation are efficiency and fairness, and on the basis of the two principles, the amount of domestic water, agricultural water and industrial water is determined, as is shown in Fig. 2.

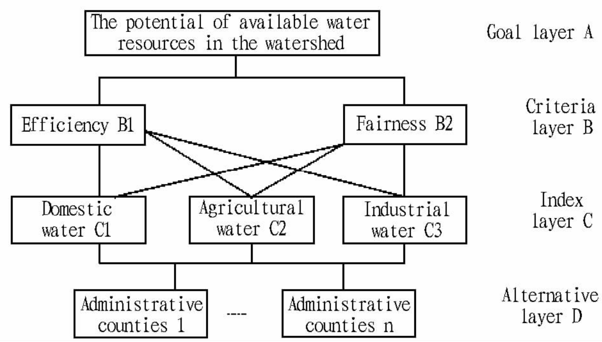

Fig. 2 Hierarchy diagram of water resource allocation

Through the establishment of a hierarchy system [3], the relationship between the upper and lower elements is determined. Pairwise comparison is carried out between the indicators at various levels, and the relative importance is determined and assigned with value. The value assignment is shown in Table 3. $f(i, j)$ signifies the degree of importance of indicator i to indicator j.

Table 1 Value assignment of relative importance between indicators through pairwise comparison

Graduation	Meaning
1	Comparison between factor i and j, there is equal importance
3	Comparison between factor i and j, the former is slightly more important than the latter
5	Comparison between factor i and j, the former is significantly more important than the latter
7	Comparison between factor i and j, the former is strongly more important than the latter
9	Comparison between factor i and j, the former is extremely more important than the latter
2,4,6,8	The middle value between the above adjacent judgements
Reciprocal	If the importance ratio of factor i to j is $f(i, j)$, then the importance ratio of factor j to i is $1/f(i, j)$.

The establishment, analysis and calculation of judgment matrix at all levels are as follows:

(i) A – B single-level judgment matrix and the hierarchical indicator weight

A – B single-level involves two indicators, efficiency (B_1) and fairness (B_2), and through pairwise comparison and value assignment, the judgment matrix U[4] is established as follows:

$$U = \begin{bmatrix} f(B_1, B_1) & f(B_1, B_2) \\ f(B_2, B_2) & f(B_2, B_1) \end{bmatrix} = \begin{bmatrix} 1 & 7 \\ 1/7 & 1 \end{bmatrix}$$

It is calculated that $\lambda_{max} = 2$, and $U = (0.875, 0.125)^T$, after the corresponding eigenvectors are normalized. The two sub –

vectors represent the relative weight of efficiency and fairness to the potential of available water resources at goal layer, respectively. The second order judgment matrix has complete consistency, without being tested.

(ii) $C-B_1$ single-level judgment matrix and the hierarchical indicator weight

According to the above principles, the judgment matrix E is established as follows:

$$C_1 = \begin{bmatrix} f(C_1, C_1) & f(C_1, C_2) & f(C_1, C_3) \\ f(C_2, C_1) & f(C_2, C_2) & f(C_2, C_3) \\ f(C_3, C_1) & f(C_3, C_2) & f(C_3, C_3) \end{bmatrix} = \begin{bmatrix} 1 & 1/3 & 1/6 \\ 3 & 1 & 1/3 \\ 6 & 3 & 1 \end{bmatrix}$$

It is calculated that $\lambda_{max} = 3.02$, and eigenvector $T_1 = (0.095, 0.250, 0.655)^T$. We carry out consistency test on the judgment matrix based on $C_R = C_I/R_I$. $C_{I1} = (\lambda \max - n)/(n-1) = 0.01$, and n is the order of the matrix. From Table 4, we know that R_{I1} is 0.58, and $C_{R1} = 0.017 < 0.1$, indicating that the judgment matrix E has satisfactory consistency, and the value of the model is credible.

Table 2 The average random consistency index

Matrix order	1	2	3	4	5	6	7	8	9	10	11
R_I value	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

(iii) $C-B_2$ single-level judgment matrix and the hierarchical indicator weight

Similarly we derive the following judgment matrix:

$$C2 = \begin{bmatrix} 1 & 4 & 6 \\ 1/4 & 1 & 3 \\ 1/6 & 1/3 & 1 \end{bmatrix}$$

It is calculated that $\lambda_{max} = 3.05$, and eigenvector $T_2 = (0.691, 0.218, 0.091)^T$. We carry out consistency test on the judgment matrix. $C_{I2} = 0.025$, $C_{R2} = 0.04 < 0.1$, indicating that the judgment matrix has satisfactory consistency.

According to previous calculation results, the total weight of the three indicators is calculated using the weight sum method:

$\eta_1 = 0.170$, $\eta_2 = 0.245$, $\eta_3 = 0.585$.

The consistency test of general ranking is as follows:

$$C_I = \sum_{i=1}^{3}(U_i C_{Ii}) = 0.875 \times 0.01 + 0.125 \times 0.025 = 0.012,$$

$$R_I = \sum_{i=1}^{3}(R_i C_{Ii}) = 0.58, \; C_R = C_I/R_I = 0.012/0.58 = 0.02 < 0.1.$$

The general ranking has satisfactory consistency, and the key factor estimated using the model is credible.

In summary, the model of amount of water resources allocated to the administrative counties is as follows:

$$Q_i = \alpha_{i1}\eta_1 Q + \alpha_{i2}\eta_2 Q + \alpha_{i3}\eta_3 Q = (0.170\alpha_{i1} + 0.245\alpha_{i2} + 0.585\alpha_{i3})Q, \; i = 1, \cdots, n.$$

4 Evaluation results

Using the model, we calculate the potential of available water resources in the counties in the Yangtze River area. Based on the amount of available water resources in local areas, the potential of available water resources of inflowing rivers, water consumption and other single factors, we use the natural grading method to evaluate the counties.

Based on the evaluation results of all single factors, we derive the potential of available water resources and the potential of per capita available water resources, as is shown in Fig. 3.

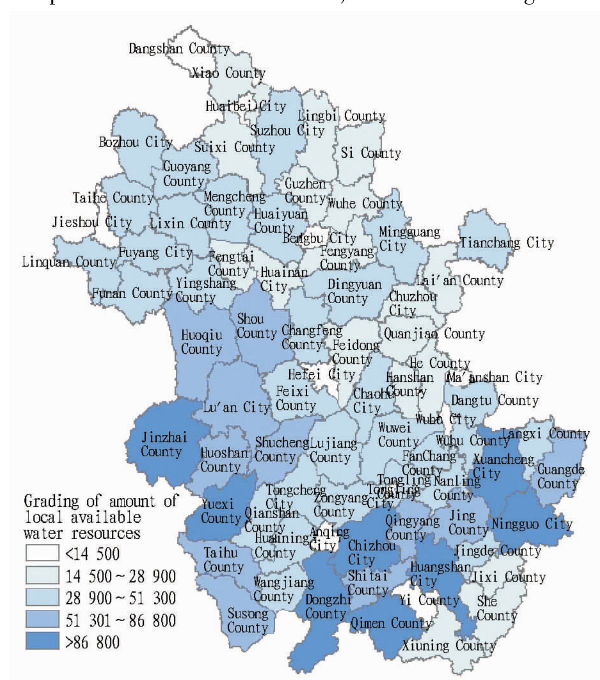

Fig. 3 Evaluation results of water resource potential in Anhui Province

References

[1] DU HW, HU W, YANG ZL, *et al*. Variance coefficient comprehensive weighting for solving water resources deployment model[J]. Yellow River, 2008, 30(8): 60–61. (in Chinese).

[2] HU MF. Study on analytic hierarchy process (AHP) and the application of MATLAB[J]. Iron & Steel Technology, 2004(2): 43–46. (in Chinese).

[3] WANG WR, TU MZ. Calculating of proportion based on analytic hierarchy process in basin water allocation[J]. Journal of Tongji University (Natural Science), 2005, 33(8): 1133–1136. (in Chinese).

[4] WANG GH, LIANG ML. A method of regulating judgment matrix according as consistent rule[J]. Systems Engineering, 2001, 19(4): 90–96. (in Chinese).