Research on the Evaluation Model of Multi-objective Optimal Allocation of Water Resources in Guizhou Province

Huan Wang1, Zaimei Mei1
1Guizhou Normal University, Guiyang 550025, China

Abstract. Aiming at the characteristics of multiple water sources and multiple users in Guizhou's urban water system, this paper establishes a multi-objective allocation model of urban water resources. The paper uses multi-objective programming to solve the model, and analyzes the impact of different target weights on the water resources allocation results of Guizhou Province in the fuzzy multi-objective decision model. The results show that the optimization model and fuzzy decision are reasonable and feasible.

1. Introduction
Generally speaking, multi-objective optimal allocation of water resources is to scientifically optimize the realization of water resources from the perspective of present and future, in order to facilitate the sustainable development, utilization, protection and management of water resources, so that multiple objectives can be optimized as best as possible in a given area at the same time. Guizhou Province is in the east of Yunnan Guizhou Plateau. Like most cities in China, many cities in Guizhou Province are close to medium and above rivers. There are 14 rivers managed by the provincial water administrative department (or above) in Guizhou Province, including Wujiang River, Liuchong River, Sanca River, Furong River, Qingshui River, Chishui River, Qingshui River and Wuyang River in the Yangtze River Basin, Huangni River, Duliu River, Beipan River, Hongshui River, Mengjiang River and Nanpan River in the Pearl River Basin. The current water supply sources of 21 cities (counties) are mainly the nearby big rivers, small and medium rivers, reservoirs, groundwater (Springs), etc. there are 10 cities directly taking water from the main stream of the big rivers, accounting for 47.6% [1]. The main contradictions and problems of the current water sources are as follows: among the current water sources, 7 cities have groundwater or spring water the proportion is 33.3%. Almost all these cities occupy the environment water. Every time there is a drought, the downstream section of the spring almost stops flowing, seriously damaging the ecological environment. In the current water supply sources, there are 11 cities with reservoir water sources, accounting for 52.4%. Almost all these cities are occupied with irrigation water and power generation water, resulting in the original irrigation surface cannot be fully irrigated, and the power generation efficiency of hydropower station is poor [2].

2. Relationship between water resources allocation system and water resource circulation system
The water resources system is a complex large system. Before human activities did not interfere with it, it was a natural system. The functions of precipitation replenishment, runoff, confluence, runoff, and conversion of surface water and groundwater were all performed in accordance with natural laws.
The water resource circulation system currently is a natural water circulation process. However, under the influence of human activities, the original water resources circulation system (including the structure of the water resources system, the runoff process, and the mechanism of action) has been artificially changed, which makes the original water resources system more complicated. Figure 1 below is a diagram of the relationship between the water resources allocation system and the water resource circulation system. In fact, the two cross each other and complement each other. There is no strict limit. This figure is only for the purpose of illustrating the relationship between the two.

![Diagram of the relationship between water resources allocation system and water resource circulation system](image)

**Figure 1.** Relationship between water resources allocation system and water resource circulation system

The optimal allocation of water resources is to use systems engineering theory to optimize the allocation of regional or river basin water resources among various districts and water use departments. An optimization model with objective function and constraint conditions must be established.

First, it is necessary to divide the sub-regions, determine the water source route, and the water sector. Let the study area be divided into K sub-areas, k = 1, 2, ..., K; k sub-area has I(k) independent water sources and J(k) water use departments. There are M public water sources in the study area, c = 1, 2, ..., M. The amount of water allocated by the public water source c to the k sub-region is represented by $D_{k,c}$. Its water volume, like other independent water sources, needs to be distributed among water users. Therefore, for the k sub-region, it is the optimal allocation of water resources for I(k) + M water sources and J(k) water users. Second, you need to determine the model goals. The optimal allocation model of water resources for sustainable development pursues the greatest comprehensive benefits of society, economy and environment. According to the different methods of establishing objective function, it can be divided into multi-objective model and single-objective model. Finally, enumerate all constraints of the model.

3. Technical roadmap for regional water resources optimal allocation

In the study of the optimal allocation of regional water resources, it is necessary to seriously study the coordination between water resources management, socio-economic development and ecological environmental protection. In today's rapid social and economic development and the acceleration of
urbanization, there are two main ways to solve the shortage of water resources: First, we must find our own reasons. In terms of water conservancy construction and water use, we must strengthen water conservancy projects Raising the effective utilization coefficient of canal water, improving the level of farmland irrigation technology, and improving the industrial technology level are beneficial measures for "throttling"; the other is to adopt "open source" measures. The general technical roadmap of regional water resources optimal allocation research is as follows [3]:

4. Establishment of optimal allocation model of water resources in Guizhou Province
The urban water resources system is a complex large system with multiple water sources and multiple water users. Its water sources include local fresh water resources, external water transfer, seawater, rainwater resources and recycled water. Water users include urban residents' domestic water, industry and ecology. The optimal allocation model of water resources, like the general optimization model, should consist of an objective function and constraints. The general form is as follows:

\[
\max \left( \min f_1(x), f_2(x), f_3(x) \right) \\
\text{s.t. } G(x) \leq 0 \quad x \geq 0
\]

In the above formula: \( x \) is the decision variable, \( f_1(x), f_2(x), \) and \( f_3(x) \) are the economic benefits, environmental benefits, and social benefits; \( G(x) \) is the constraint set, which indicates the water resource carrying capacity and environment Capacity, land resources, other social constraints and subsystem state equations. The key to establishing the above model is to determine the objective function and constraints [4].

4.1. Objective function
Social benefits: Because social benefits are not easy to measure, they can be reflected indirectly by minimizing the total regional water shortage. Because the amount or degree of regional water shortage directly affects social development and stability, which is a side reflection of social benefits:

\[
\min f_1(x) = \sum_{k=1}^{K} \sum_{j=1}^{J} D_j^k - \sum_{k=1}^{K} \sum_{j=1}^{J} \sum_{i=1}^{I} x_{ij}^k
\]

In the above formula: \( D_j^k \) is the water demand of the user \( j \) in the \( k \) sub-zone (10,000 m\(^3\)), and \( x_{ij}^k \) is the water supply quantity of the user \( j \) in the \( k \) sub-zone \( i \) (10,000 m\(^3\)). Economic benefits: quantified by GDP maximum:
\[
\max f_2(x) = \sum_{k=1}^{K} \sum_{j=1}^{J} gdp_j^k \sum_{i=1}^{L} x_{ij}^k
\]

In the above formula: \( gdp_j^k \) is the unilateral aquatic production value coefficient of the production sector of sub-\( k \) of \( j \), which is represented by unilateral water GDP.

Environmental benefits: Environmental issues directly related to the use of water resources are quantified by the maximum guarantee rate of water supply for ecological environment users:

\[
\max f_3(x) = \sum_{k=1}^{K} \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{i=1}^{S} S_j
\]

In the above formula: \( S_j \) is the water demand of the ecological user \( j \) (10,000 m\(^3\)).

4.2. Constraints

In order to determine the most reasonable water supply for each water source, the water supply should be as close as possible to the configuration target, that is, the objective function value of the optimization model is the largest or the smallest, and the water supply of each water source must meet certain conditions, which is reflected in the set of constraints of the optimization model.

Constraints on the amount of water available from the source are as follows. Where \( W_i \) is the water supply of the \( i \) water source (10,000 m\(^3\)).

\[
\sum_{j} x_{ji} \leq W_i
\]

The project water delivery volume is as follows. In the above formula: \( Q_{ij} \) is the water delivery capacity (10,000 m\(^3\)) of water source \( i \) to user \( j \).

\[
x_{ij} \leq Q_{ij}
\]

The water sector's water demand constraints are as follows. In the above formula: \( D_{j,\text{min}}^k \), \( D_{j,\text{max}}^k \) respectively, are the lower and upper limits of the water demand change for users in \( k \) sub-zone \( j \).

\[
D_{j,\text{min}}^k \leq \sum_{i} x_{ij} \leq D_{j,\text{max}}^k
\]

Non-negative constraints on decision variables:

\[
x_{ij} \geq 0
\]

4.3. Solving the Multi-Objective Model

Because the objective functions in multi-objective optimization problems are often unfair, there is no unique solution. In contrast, there are only valid solutions, that is, there is no better solution than the effective solution within the allowed range. There are many solutions to multi-objective optimization problems. The weights and methods are introduced below. This method transforms the objective function problem into a scalar problem of the sum of all objective weights, namely:

\[
\min f(x) = \sum_{t=1}^{m} \omega_t * F_t(x)^2.
\]

Among them, there are many methods for selecting the weighting factor.
including expert scoring method, $\alpha$ method, tolerance method and weight factor decomposition method. This paper uses MATLAB programming to solve the multi-objective model [5].

5. Optimization results and analysis

Starting from the principle of coordinating economic, social and environmental benefits, priority is given to domestic water use, followed by ecological and industrial water, and finally the principle of agricultural water. Different initial values are assigned to various variables. MATLAB optimization functions are used to solve Multi-objective programming problem, can get the optimal configuration scheme with different initial values. After comparison and optimization of various parameters, the results of the configuration scheme determined by the final calculation are shown in Table 1 and Table 2.

| Water resources          | Surface water | groundwater | Sewage treatment | Outflow water diversion | Shallow brackish water | total   |
|--------------------------|---------------|-------------|------------------|-------------------------|------------------------|---------|
| Thermal power industry   | 940           | 230         | 20               | 180                     | 4410                   | 5780    |
| General industry         | 2140          | 3220        | 30               | 540                     | 8010                   | 13940   |
| Rural industry           | 4140          | 8050        | 50               | 1040                    | 15540                  | 28820   |
| Life of urban residents  | -             | 10940       | -                | 1570                    | -                      | 12510   |
| Urban utilities          | 1340          | 2890        | 20               | 310                     | 4020                   | 8580    |
| Rural farmland irrigation| 39900         | 116480      | 240              | 11790                   | -                      | 168410  |
| Rural forestry, animal husbandry and fishery | 810 | 1340 | 20 | 250 | 2090 | 4510 |
| Life of rural residents  | -             | 12820       | -                | 1110                    | -                      | 13930   |
| Rural livestock life     | -             | 2950        | -                | 710                     | -                      | 3660    |
| ecosystem                | 5340          | 13550       | 60               | 110                     | 20950                  | 40010   |
| total                    | 54610         | 172470      | 440              | 17610                   | 55020                  | 300150  |

| Water resources          | Surface water | groundwater | Sewage treatment | Outflow water diversion | Shallow brackish water | total   |
|--------------------------|---------------|-------------|------------------|-------------------------|------------------------|---------|
| Thermal power industry   | 930           | 730         | 20               | 330                     | 4520                   | 6530    |
| General industry         | 2120          | 4230        | 30               | 740                     | 9020                   | 16140   |
| Rural industry           | 4110          | 10060       | 50               | 1430                    | 15440                  | 31090   |
| Life of urban residents  | -             | 9450        | -                | 3650                    | -                      | 13100   |
| Urban utilities          | 1330          | 2690        | 20               | 370                     | 5020                   | 9430    |
| Rural farmland irrigation| 39530         | 111480      | 240              | 10680                   | -                      | 161930  |
| Rural forestry, animal husbandry and fishery | 800 | 1940 | 20 | 280 | 1010 | 4050 |
| Life of rural residents  | -             | 13840       | -                | 700                     | -                      | 14540   |
| Rural livestock life     | -             | 3550        | -                | 340                     | -                      | 3890    |
| ecosystem                | 5300          | 14550       | 60               | 1850                    | 20050                  | 41810   |
| total                    | 54120         | 172520      | 440              | 20370                   | 55060                  | 302510  |
The overall benefit function of the allocation plan for each planning year is based on first meeting the premise of domestic water use. The final allocation plan shows that in the 2010 water allocation plan, industrial water consumption is 485.4 million m$^3$, domestic water consumption is 31 million m$^3$, and public utility water consumption. 85.8 million m$^3$, urban public utilities use 85.8 million m$^3$, ecological water consumption is 40.1 million m$^3$, forest, animal husbandry and fishery water consumption is 45.1 million m$^3$, agricultural irrigation water consumption is 168410 m$^3$; industrial water consumption in the 2015 water allocation plan is 537.6 million m$^3$, domestic water consumption is 315.3 million m$^3$, public utility water consumption is 94.3 million m$^3$, ecological water consumption is 418.1 million m$^3$, forest, animal husbandry and fishery water consumption is 45.1 million m$^3$, agricultural irrigation water consumption is 16.193 million m$^3$; industrial water consumption and ecology Water consumption continues to increase. Due to water-saving measures and adjustment of planting structure, agricultural irrigation water continues to decrease [6].

6. Conclusion

The problem of multi-objective optimization of water resources allocation has been increasingly valued by water resources management and decision makers. Many scholars have also used various algorithms to solve some practical multi-objective optimization problems, but each algorithm has its own Defects of its own. Therefore, with the continuous development of various multi-objective optimization algorithms, it is necessary to further study more effective methods to solve the multi-objective optimization problem of water resources allocation.

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