

Water intervention plan

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Abstract. According to the United Nations, 1.6 billion people (one quarter of the world's population) experience water scarcity. Water use has been growing at twice the rate of population over the last century. What should we do to mitigate water scarcity? we use Multiobjective Dynamic Programming(MDP) Model to propose a intervention plan.

First, we conduct Principal Component Analysis again to filtrate major scarcity factors from a total of 9, based on which they are classified into economy, society and eco-environment. Analyzing the objective function of three part, we present our intervention as a water distribution plan. Take Hebei as a case study, we plan to provide 118.926 million cu.m water to this region in 2016 and 74% of that should be used for agriculture while the number for industry is 12%, 22.879 million cu.m.

1. Introduction

Water scarcity is obviously an enormous and knotty problem for human being. Therefore, it is very urgent to solve the problem of water scarcity. However, water use is rapidly increasing while the rate of population is only the half. That's to say, there are other reasons of scarcity. In order to solve water scarcity, we should consider several factors. There are three primary factors to solve water scarcity: economy, society and eco-environment.

We develop the Multiobjective Dynamic Programming(MDP) Model that provides generic methods to solve water scarcity. Meanwhile it also can be used for the world.

2. Models for water strategy

2.1 Multiobjective Dynamic Programming

Considering the shortage of water resources, we conclude that the Hebei is in terrible water situation. On purpose of inventing the water scarcity, we propose a Multiobjective Dynamic Programming(MDP) Model^{[1][2]} to handle it.

2.2 Symbols, Definitions & Assumptions

● Symbols & Definitions

| Symbols | Definitions |
|--------------------------------|--|
| $\alpha_1, \alpha_2, \alpha_3$ | The weight of economy, society and eco-environment |
| m_i | The province of region group |
| X_m | The total demand water of a province |
| D_m | The total water content of a province |
| k_m | Pollution factors content of wastewater |
| d_m | Sewage discharge coefficient |

● Assumptions

➤ We assume that the intervention plan only have effect on adjacent province.

- We assume that all the effect of intervention plan can be classified into economy, society and eco-environment.

2.3 Model construction

We regard Hebei itself and provinces adjacent to Hebei, namely, Beijing, Tianjin, Henan, Neimenggu, Shandong, Liaoning, Shanxi as a region group, which are marked as $m_1 \sim m_8$, respectively. m_1 denotes Hebei.

- Determine the weight based on PCA

To begin with, we divide all the drivers of water scarcity mentioned above into three aspects, namely, economy, society and eco-environment. We list them in Table 2.1. To get the weight of each aspect, Principal Component Analysis is conducted.^[4]

Table 2.1 The weight of drivers

| Drive <i>r</i> | HC | EI | WD | PW | WC | GDP | GD | CA | MA |
|-------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| <i>ranks</i> | 1 | 7 | 6 | 4 | 3 | 5 | 9 | 8 | 2 |
| <i>weight</i> | 23.78 | 5.336 | 10.11 | 15.02 | 15.28 | 13.01 | 0.000 | 0.018 | 17.41 |
| | 6 | | | 9 | 2 | 8 | 2 | 4 | 4 |

Where $HC, EI, WD, PW, WC, GDP, GD, GA, MA$ denote “hydropower construction investment”, “Effective irrigation area”, “Wastewater discharge amount”, “Other water content”, “Water consumption per capita” and “Gross Domestic Product”, “Garbage disposal rate”, “Controlled soil erosion area”, “Mean annual precipitation”, respectively.^[3]

Remove EI, CA, GD which rank 7, 8, 9, and classify, we obtain the weight of economy, society and eco-environment is 36.803%, 30.311%, 27.529%.

- Obtain the objective function

To apply multiobjective dynamic programming, objective function is necessary.

- **Economy:** to clearly measure the influence on economy, we propose the concept of production value per cubic meter water, which denotes the value produced by per cubic meter water in each province. Here the objective function is:

$$f_1(x) = \max \left[\sum_{m=2}^8 B_m X_m + \alpha_1 B_1 X_1 \right] \quad (2.1)$$

Where B_1 denotes production value per cubic meter water in Hebei, X_1 denotes the total water resource in Hebei.

- **Society:** we define the objective function here is:

➤

$$f_2(x) = \min \left[\sum_{m=2}^8 (X_m - D_m) + \alpha_2 (X_1 - D_1) \right] \quad (2.2)$$

Where D_1 denotes the total water content of Hebei, X_1 denotes the total demand water of Hebei.

- **Eco-environment:** we measure the pollution factors in wastewater with the COD index. Then we discuss the objective function in consideration of wastewater.

$$f_3(x) = \min \left[\sum_{m=2}^8 k_m d_m X_m + \alpha_3 k_1 d_1 X_1 \right] \quad (2.3)$$

- Present constraint condition

$$\begin{cases} X_m \geq 0 \\ T_{mmin} \leq X_m \leq T_{mmax} \end{cases} \quad (2.4)$$

In which, T_{mmin} denotes the minimum historical data of total demand water while T_{mmax} denotes the maximum historical data of total demand water.

2.4 Result and analysis

$$\left\{ \begin{array}{l} f_1(x) = \max \left[\sum_{m=2}^8 B_m X_m + \alpha_1 B_1 X_1 \right] \\ f_2(x) = \min \left[\sum_{m=2}^8 (X_m - D_m) + \alpha_2 (X_1 - D_1) \right] \\ f_3(x) = \min \left[\sum_{m=2}^8 k_m d_m X_m + \alpha_3 k_1 d_1 X_1 \right] \\ X_m \geq 0 \\ T_{m \min} \leq X_m \leq T_{m \max} \end{array} \right.$$

Putting these formula together, we have the amount of water should be distributed to each region of this group. Here we illustrate it with a figure. The unit is million cubic meters water.



Figure 2.1 The amount of water distribution

From the Figure 2.1, we can easily know how much water should be distributed to each region in specific group.

After that, we analyze the water application circumstance in Hebei^[5] and divide water into four parts: agriculture, industry, living and eco-environment. According to the historical data, we conclude the specific distribution as:

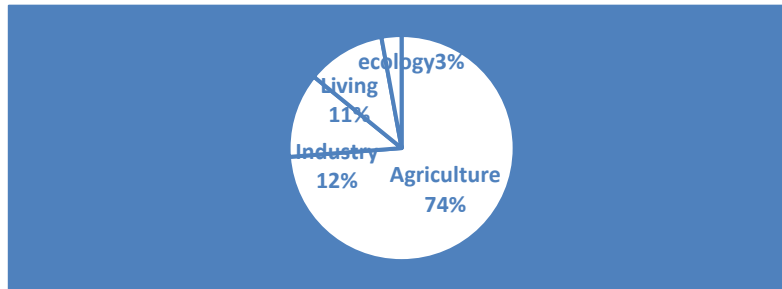


Figure 2.2 The pie chart of water applicant distribution

In other words, for agriculture, we could use 139.349 million cubic meters water. And for industry, living and eco-environment, the value should be 22.879, 21.276, 5.422, respectively.

3. Conclusions

Based on above calculation and analysis, we propose our intervention plan as follows:

- Determine the water distribution of each province in specific group. Take Hebei as an example, we plan to provide 118.926 million cubic meters water to this region to balance the water situation.
- Specifically classify the water distribution for diverse function. Take Hebei as an example, for its agriculture, we decide to provide 129.349 million cubic meters water, which is consistent with the fact that the agriculture in Hebei is developed.

Reference

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