Analysis on regional differences of water use efficiency rigid constraints and countermeasures in Zhejiang Province

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Abstract. With the implementation of the most stringent water resources management system, rigid constraints on water resources have gradually increased, the total amount of water used has been effectively controlled. In order to quantify the strength of rigid constraints on water resources, the concept of rigid constraints on water efficiency was proposed, and the constraints on industrial and agricultural water efficiency targets and regional differences in 11 districted cities in Zhejiang Province were analyzed, and the target constraints in the industrial and agricultural water use were comprehensively considered through scenario analysis. Seven types of areas, including industrial and agricultural strong control, agricultural main control, and industrial main control are drawn, and countermeasures for optimizing water resources and water-saving management for different types of areas are put forward to further improve the level of water resources management in Zhejiang Province.

1. Introduction

General Secretary Xi proposed to take water resources as the most rigid constraint, in order to implement the spirit of the general secretary’s instructions, the 2011 Central Committee’s No. 1 document “Decision of the CPC Central Committee and the State Council on Accelerating Water Conservancy Reform and Development” requires the establishment of “three red lines” for water resources development and utilization control, water efficiency control, and water function zone pollution restrictions. Water efficiency control is the focus of water conservancy reform and development. In the “Measures for the Implementation of the Most Strict Water Resources Management System Assessment” issued by the General Office of the State Council in 2013, the water consumption of 10,000 yuan of industrial added value and the effective utilization coefficient of farmland irrigation water were taken as important assessment indicators. Zhejiang Province implements the most stringent water resources management system evaluation index system, the new era of beautiful Zhejiang construction index system, high-quality development comprehensive performance evaluation index system also include water efficiency control indicators.

Under the policy background of implementing the “water saving priority” policy, a large number of scholars have carried out research on water use efficiency and spatial differences in various fields. It focuses on the following aspects: First, water efficiency prediction, which mainly uses econometric methods such as data envelopment analysis and stochastic frontier production function models to evaluate and analyze water use efficiency at different spatial scales[1-3]. The second is the analysis of factors affecting water efficiency, using spatial clustering, regression analysis and other methods to explore the key factors driving changes in water efficiency from the perspectives of natural conditions, economic development, and industrial structure[4-6]. The third is the discussion on the relationship...
between water efficiency and economic and social development [7-9]. In view of the relatively few researches on the rigid constraints of water efficiency and their spatial differences, in order to quantify the constraints of the most stringent water resources management system objectives and assessments on local water use, this paper proposes the concept of rigid constraints on water efficiency and explores the space for the strength of rigid constraints on regional water efficiency. Analyze and calculate the target rigid constraint intensity of industrial and agricultural water use efficiency in 11 cities in Zhejiang Province, and comprehensively consider the efficiency constraints of industrial and agricultural water use through context analysis, and classify the differences between industrial and agricultural control, agricultural control, industrial control, etc. type areas and put forward countermeasures for optimizing water resources and water-saving management.

2. Data and methods

2.1. Data source
The current water consumption data for 10,000 yuan of industrial value added per year comes from the Water Resources Bulletin of Zhejiang Province. The current effective utilization coefficient of farmland irrigation water comes from the report on the effective utilization coefficient of farmland irrigation water in Zhejiang. The control targets for water consumption data for 10,000 yuan of industrial and water consumption and effective utilization coefficient of farmland irrigation water come from the evaluation work plan of the most stringent water resources management system in Zhejiang Province during the “14th Five-Year Plan” and the “14th Five-Year Plan” for water conservation in each cities.

2.2. Research method
Under the strictest water resources management system target assessment constraints, this paper proposes the concept of rigid constraint strength for water efficiency, and defines the rigid constraint strength as a quantitative indicator of the gap between the target control target and the status quo in the target assessment of the most stringent water resources management system. At the same time, in order to analyze the spatial difference of rigid restraint strength, the difference between the control targets in different regions and the status quo was standardized, and then compared with the average level of the province, the specific water efficiency rigid restraint strength value was calculated. It is believed that the greater the value of rigid constraint strength, the stronger the strictest water resources management system target assessment will restrict the actual local water use. In this area, water use control should be increased to meet the control target requirements. Water resources management indicators can usually be divided into positive and negative indicators (Table 1). Due to the different setting of the positive and negative indicators, the target constraint strength calculation formulas are defined for the two indicators respectively.

| Indicator attributes | Description | Objectives setting | Formula | Indicator example |
|---------------------|-------------|--------------------|---------|------------------|
| Positive            | The higher the value, the better the completion | The target value is generally higher than the status quo | Formula (1) | Farmland irrigation water effective utilization factor, total water consumption, industrial water reuse rate |
| Negative            | The smaller the value, the better the completion | The target value is generally lower than the current value | Formula (2) | Water consumption per 10,000 yuan of GDP, water consumption per 10,000 yuan of industrial added value, leakage rate of pipe network |

\[
C_{ij} = \left[ \left( \frac{T_{ij} - P_{ij}}{P_{ij} \times S_{ij}} \right) / \left( \frac{T_{nj} - P_{nj}}{P_{nj} \times S_{nj}} \right) \right] 
\]  \hspace{1cm} (1)
\[ C_{ij} = \left[ \frac{(P_{ij} - T_{ij})/P_{ij} \times S_{ij}}{(P_{nj} - T_{nj})/P_{nj} \times S_{nj}} \right] \]

In the formula, \( i \) is the region, \( n \) is the whole province, and \( j \) is the index. \( C_{ij} \) is the rigid constraint strength of the index \( j \) in the region \( i \); \( T_{ij} \) is the target of the index \( j \) in the region \( i \); \( P_{ij} \) is the current status of the index \( j \) in the region \( i \); \( S_{ij} \) is the index \( j \) in the region \( i \). The proportion of water consumption in the field of water consumption to the total local water consumption. According to the calculation results, the index rigid constraint strength \( C_{ij} \) is divided into three levels: strong, medium and weak (Table 2).

**Table 2. Explanation of objective rigid constraint strength (RCS) rating**

| Serial number | Rigid restraint strength | Rate   | Description                                                                 |
|---------------|-------------------------|--------|----------------------------------------------------------------------------|
| 1             | \( C_{ij} > 1.0 \)      | strong | The rigid restraint strength of index \( j \) in region \( i \) is higher than the average level of the province |
| 2             | \( 0.5 \leq C_{ij} \leq 1.0 \) | medium | The rigid constraint strength of index \( j \) in region \( i \) is lower than the average level of the province, but higher than half of the average level of the province |
| 3             | \( C_{ij} < 0.5 \)      | weak   | The rigid restraint strength of index \( j \) in region \( i \) is lower than half of the provincial average |

3. Application of rigid restraint strength and analysis of regional differences

Taking the city as the unit, the effective utilization coefficient of farmland irrigation water and the water consumption of 10,000 yuan of industrial added value were selected to analyze the industrial and agricultural water efficiency of 11 cities in Zhejiang Province. Among them, the effective utilization coefficient of farmland irrigation water is a positive index, and formula (1) is selected to calculate the rigid restraint strength; the water consumption of 10,000 yuan of industrial added value is a negative index, and formula (2) is selected to calculate the rigid restraint strength. According to the calculation result, the intensity of rigid constraints on industrial and agricultural water use efficiency is analyzed according to three levels of strong, medium, and weak. Nine scenarios are combined to analyze, and countermeasures for optimizing water resources and water-saving management are proposed according to different types of regions.

3.1. Calculation results

According to the definition and calculation formula of rigid restraint strength, the rigid restraint strength of industrial and agricultural water use efficiency in 11 cities in Zhejiang Province was calculated. The results are shown in Table 3.

**Table 3 Rigid Constraint Strength (RCS) of agricultural and industrial water-use efficiency for various city regions in Zhejiang.**

| Serial number | Region  | Rigid restraint strength of industrial water efficiency | Rigid restraint strength of agricultural water efficiency |
|---------------|---------|--------------------------------------------------------|--------------------------------------------------------|
| 1             | Hangzhou| 0.96                                                   | 0.23                                                   |
| 2             | Ningbo  | 1.50                                                   | 0.39                                                   |
| 3             | Wenzhou | 1.19                                                   | 0.59                                                   |
| 4             | Jiaxing | 1.27                                                   | 0.70                                                   |
| 5             | Huzhou  | 0.77                                                   | 0.54                                                   |
| 6             | Shaoxing| 1.35                                                   | 0.23                                                   |
| 7             | Jinhua  | 1.46                                                   | 0.57                                                   |
| 8             | Quzhou  | 1.15                                                   | 1.69                                                   |
| 9             | Zhoushan| 2.53                                                   | 0.07                                                   |
3.2. Rigid restraint strength analysis

The formulation of water efficiency control indicators needs to consider factors such as current water efficiency, local social development water demand, and water-saving technology level. This article focuses on the impact of rigid constraints on regional water use, so it only analyzes the correlation between the current water use efficiency and the intensity of rigid constraints on water efficiency. Through spatial comparison, it is found that areas with greater rigid constraints on industrial and agricultural water efficiency have obvious the spatial aggregation and distribution characteristics of, and areas with less rigid restraint strength generally have higher water efficiency in the corresponding water use field.

In terms of agricultural water use efficiency (Figure 1), there are three cities with rigid restraint strength greater than 1.0 (Quzhou, Lishui and Taizhou), mainly in the southwestern region. Among them, Quzhou has the strongest rigid restraint strength. Through analysis, it is found that the difference between the control index value and the current situation is large, reaching 0.015, and the proportion of agricultural irrigation water is also high (51.8% in 2020). Secondly, there are 4 cities with rigid restraint strength between 0.5 and 1 (Huzhou, Jinhua, Wenzhou, and Jiaxing). This is mainly due to the high proportion of agricultural water used, which contributes to a higher rigid restraint strength. In addition, the rigid constraint strength of the four cities of Ningbo, Hangzhou, Shaoxing, and Zhoushan is less than 0.5, and the agricultural water use efficiency in these areas is relatively high. The effective utilization coefficient of farmland irrigation water in 2020 is higher than the average level of Zhejiang (0.602).

| Serial number | Region   | Rigid restraint strength of industrial water efficiency | Rigid restraint strength of agricultural water efficiency |
|---------------|----------|--------------------------------------------------------|--------------------------------------------------------|
| 10            | Taizhou  | 0.94                                                   | 1.06                                                   |
| 11            | Lishui   | 0.71                                                   | 1.47                                                   |
| 12            | Zhejiang | 1.00                                                   | 1.00                                                   |

Figure 1: Spatial comparison of agricultural water-use efficiency by present condition, objective and rigid constraint strength (RCS).

In terms of industrial water efficiency (Figure 2), there are 9 cities with rigid restraint strength greater than 1.0 (Zhoushan, Ningbo, Jinhua, Shaoxing, Jiaxing, Wenzhou, and Quzhou). Among them, Zhoushan has a rigid restraint strength of 2.53. Based on local conditions, Zhoushan's industrial water efficiency target setting and the proportion of industrial water consumption are both high, so the target constraint is relatively strong. In addition, the rigid restraint strength of the four districts and cities of Hangzhou, Taizhou, Huzhou and Lishui is between 0.5-1.0. This is mainly due to the relatively high status of industrial water use efficiency, which accounts for a small proportion of total water use.
3.3. Scenario analysis and countermeasures

In order to conduct a comprehensive analysis of the rigid constraints on industrial and agricultural water use efficiency in the same area, the rigid constraints on industrial and agricultural water use efficiency were combined in three levels: strong, medium, and weak (Table 4), and nine scenarios were obtained. According to the calculation and analysis of the rigid restraint strength of industrial and agricultural water efficiency in 11 districts and cities in Zhejiang Province, the classification results of each city are shown in Figure 3.

The industrial and agricultural strong control type (Scenario 1) and dual control type (Scenario 5) have strong rigid constraints on the efficiency of industrial and agricultural water use. Compared with the current situation, the water efficiency target setting has been improved. For example, the industrial and agricultural water efficiency targets in Quzhou have increased by 16.7% and 2.8% respectively. For areas with strong industrial and agricultural control (Quzhou) and industrial-agricultural dual-control areas (Huzhou, Taizhou), both industrial and agricultural water-saving management should be strengthened at the same time, to promote water-saving transformation of large and medium-sized irrigation areas and develop high-efficiency water-saving irrigation. Promote the integration of water and fertilizer technology, increase the construction of field water-saving facilities, strictly control the development of high water-consuming industries, implement industrial water-saving transformation, eliminate outdated water use technology, promote green upgrading of industrial park recycling, and strictly manage water quotas.

Lishui belongs to the dominant agricultural control type (Scenario 2), and the efficiency of agricultural water use is stronger than that of industrial water use. Analyzing the specific water use situation, it is found that agricultural water accounts for a relatively large amount of more than 60%, and the current agricultural water efficiency is low. The effective utilization coefficient of farmland irrigation is 0.584, which is lower than the province's average level of 0.602. For areas with major agricultural control, it is recommended to improve agricultural water use efficiency through measures such as perfecting water intake measurement, adjusting planting structure, and popularizing water-saving irrigation technology, including: ① Implementing agricultural water-saving infrastructure standards and strengthening agricultural irrigation water measurement management; ② Rationally determine the scale of irrigation development based on the carrying capacity of water resources and reduce the planting area of high-water-consuming crops; ③ Develop and construct agricultural water-saving irrigation parks, supporting advanced water-saving irrigation facilities, and popularize and implement water-saving technologies such as nozzles and micro-irrigation.
Table 4: Scenarios based on objective rigid constraint strength (RCS) of agricultural and industrial water-use efficiency.

| Water efficiency rigid restraint strength | Scenario 1: Strong control type of industry and agriculture | Scenario 4: Industrial master type | Scenario 7: Industrial strong control type |
|-----------------------------------------|------------------------------------------------------------|----------------------------------|------------------------------------------|
| $C_{IA} > 1.0$                           |                                                             |                                  |                                          |
| $0.5 \leq C_{IA} \leq 1.0$               |                                                             |                                  |                                          |
| $C_{IA} < 0.5$                           |                                                             |                                  |                                          |
| $C_{II} > 1.0$                           | Scenario 2: Agricultural master control type |                                  |                                          |
| $0.5 \leq C_{II} \leq 1.0$               |                                                             |                                  |                                          |
| $C_{II} < 0.5$                           | Scenario 3: Strong agricultural control                     |                                  |                                          |

Figure 3: Regional divisions based on objective rigid constraint strength (RCS).

In Scenarios 4, 7, and 8, the industrial water efficiency is more rigidly constrained than agricultural water efficiency. The industrial and agricultural water use efficiency targets in Scenarios 4 and 8 have smaller rigid constraints, and they are divided into industrial-dominant areas; in Scenario 7 there is a large gap in the intensity of the constraints of industrial and agricultural water efficiency targets, and the control of industrial water efficiency should be mainly strengthened and divided into areas with strong industrial control. In the above scenarios, all cities except Jiaxing have set high industrial water efficiency targets, exceeding 18%. For industrially controlled areas (Hangzhou, Wenzhou, Jiaxing, Jinhua) and industrially controlled areas (Ningbo, Shaoxing), it is recommended to promote industrial water-saving and emission-reduction actions through measures such as total amount control and efficiency improvement, including: ① Strengthening Water quota management for high water consumption industries, using advanced and reasonable water quota indicators to suppress water demand; ② Using water quota has become the market access standard, strictly controlling the production and sales of products that do not meet the mandatory water-saving standards; ③ Encouraging the use of unconventional water Resources, formulate relevant preferential water use policies to reduce the total amount of industrial water use.
4. Conclusion
By defining the concept of rigid restraint intensity of water efficiency, this paper analyzes and calculates the rigid restraint intensity of industrial and agricultural water use efficiency in 11 cities in Zhejiang Province, comprehensively evaluates the types of scenarios that each region belongs to and proposes targeted water-saving measures.

The research in this paper shows that areas with higher target constraint strength have obvious spatial distribution characteristics, and areas with lower target constraint strength are mostly areas with higher water efficiency. Due to policy adjustments and other influencing factors in target formulation, the target constraint strength analysis results have certain shortcomings, and the scientific nature of rigid constraint strength needs to be further improved and perfected.

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