Analysis of Grey Correlation between Agricultural Output Structure and Agricultural Water Consumption in Beijing

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Abstract. The shortage of water resources is the key factor that restricts the sustainable development of agriculture in Beijing. This paper introduced the changes of agricultural water consumption and agricultural output value structure in recent ten years, and the correlation between them was quantitatively analyzed by the grey correlation method. The results showed that the proportion of animal industry output in the total agricultural output is greatest relevant to the change of agricultural water consumption from 2008 to 2017, followed by fishery and farming, while forestry showed the minimum correlation.

1. Introduction
Agriculture is the major water user, and water has become a primary constraining factor in regional economic development. Under the increasingly serious situation of global water resources, water-saving agriculture is imperative for the sustainable development.

In China, agricultural water-saving research mainly focuses on the changes of agricultural water use in various regions [1,2,3], the impact of agricultural water use efficiency [4,5], and the impact factors of agricultural water use [6,7]. However, the actual situation of regional water resources and water use structure in China are quite different, and the characteristics and influencing factors in different regions also are obviously discrepancy [8]. As a big city with severe water scarcity, Beijing’s agricultural water saving is urgent to act. There are many factors that affect agricultural water consumption in Beijing, and agricultural structure is one of the important factors. This paper intends to analyze the changes of agricultural water use in Beijing in recent ten years, and study the relationship between agricultural output value structure and agricultural water consumption, in order to provide scientific basis for rational allocation and effective utilization of agricultural water resources in Beijing.

2. Overview of the research area
Beijing is located at the Northwest of the North China Plain, with a total area of 16 thousand square kilometers, of which mountainous area accounts for 62%. It is a continental monsoon climate in the north temperate zone, with distinct seasons and an average annual temperature of 8-12 °C. The annual average rainfall is 650 mm, mainly distributed in summer, and the frost-free period is about 180-200 days. The average annual water resources supply is 3.74 billion m³. In the past ten years (2008-2017), the annual amount of water resources is 2.82 billion m³, which is less than 1/4 of the national value. The water resources per capita is 140 m³, which is less than 1/16 of the average value of China and
showing Beijing is a serious water shortage city. The increasingly serious shortage of water resources has become an important bottleneck hindering the sustainable development of agriculture in Beijing.

3. Research methods and data sources

3.1. Research methods
Grey correlation analysis is a method to study the degree of correlation between different factors in one system. By comparing the correlation degree, the influence degree of different factors on the object could be judged. In this study, agricultural water consumption is considered as the reference sequence, while the time series of the proportion of output value of farming, animal industry, forestry and fishery are the compared sequences. For comparative purposes, data need to be dimensionless. The formula is as follows.

$$x'_i(k) = x_i(k) / \overline{x_i}$$  \hspace{1cm} (1)

Then the following formula is used to calculate the correlation coefficient $\xi(X_i)$ of the compared sequences and the reference sequence at any time.

$$\xi_i(k) = \frac{\min\min_{k} \Delta i(k) + \rho \max_{k} \max_{k} \Delta i(k)}{\Delta i(k) + \rho \max_{k} \max_{k} \Delta i(k)}$$  \hspace{1cm} (2)

Among them, the resolution coefficient $\rho$ is usually between 0~1, commonly is set as 0.5. The absolute difference sequence is as bellows.

$$\Delta i(k) = |x'_0(k) - x'_i(k)|$$  \hspace{1cm} (3)

The grey correlation degree of reference sequence and compared sequence is expressed by the average of correlation coefficient of each period with the following formula.

$$r_i = \frac{1}{N} \sum_{k=1}^{N} \xi_i(k)$$  \hspace{1cm} (4)

$ri$ is the grey correlation degree of compared sequence $xi$ for reference sequence $x_0$. The closer the $ri$ value is to 1, the greater the correlation degree is. In this study, the larger the $ri$, the greater the impact of the factor on agricultural water consumption is.

3.2. Data sources
The data of agricultural output value is from Beijing Statistical Yearbook, and the data of agricultural water consumption is from Beijing Water Resources Bulletin.

4. Changes of agricultural water consumption and output structure in Beijing

4.1. Agricultural water consumption
In recent ten years, the total amount of water used in Beijing was between 3.51 to 3.95 billion m$^3$. Agriculture has always been a big water user with huge potential for water saving. Therefore, agricultural water saving is the key to build a water-saving city for Beijing.

In 2008, Beijing's agricultural water consumption was 1.2 billion m$^3$, accounting for 34.2% of the city's total water consumption. In recent years, as the reduction of agricultural scale and the vigorous development of water-saving agriculture, the water consumption of agriculture, whether the absolute volume or proportion, has been declining due to the implementation of engineering water-saving, agronomic water-saving and management water-saving. Domestic water use and environmental water use exceeded agricultural water use in 2005 and 2015, respectively. Agricultural water use ranked the third. In 2017, Beijing's agricultural water consumption decreased by 0.69 billion m$^3$ (57.5%) compared with 2008, while the proportion of water consumption decreased from 34.2% to 12.9% (Figure 1).
4.2. Changes of agricultural output structure

In the past ten years, the structure of agricultural output value in Beijing still showed the trend of farming keeping up with animal industry. Although there are fluctuations between them, the individual proportion was above 35%. In recent years, Beijing has vigorously implemented the measures to prohibit and restrict livestock breeding. The scale of animal industry dropped dramatically, and the proportion of output also dropped to 33.0%. Another notable change was the proportion of forestry output. Since 2011, Beijing has carried out a large afforestation project of 66.6 thousand hectares, and the forestry output value has increased rapidly. The proportion of forestry in the total agricultural output has also increased from 5.2% in 2011 to 21.6% in 2014. After that, although there has been a slight decline, it was still at a high level of 19.1% in 2017 (Figure 2).
5. The influence of agricultural output value structure on water consumption in Beijing

5.1. Calculation results
The results of correlation analysis between the agricultural output value structure and the change of agricultural water consumption is shown in Table 1. The order of correlation degree between agricultural water use and agricultural output value structure in Beijing from 2008 to 2017 is: animal industry > fishery > farming > forestry.

| Year | Farming | Forestry | Animal industry | Fishery | Year | Farming | Forestry | Animal industry | Fishery |
|------|---------|----------|-----------------|---------|------|---------|----------|-----------------|---------|
| 2008 | 0.6024  | 0.3857   | 0.7750          | 0.6208  | 2014 | 0.9464  | 0.3811   | 1.0000          | 0.8876  |
| 2009 | 0.6853  | 0.3588   | 0.6919          | 0.6468  | 2015 | 0.6551  | 0.4888   | 0.7017          | 0.6308  |
| 2010 | 0.7721  | 0.3681   | 0.7457          | 0.7803  | 2016 | 0.6064  | 0.4779   | 0.6786          | 0.7453  |
| 2011 | 0.7817  | 0.3863   | 0.8962          | 0.7332  | 2017 | 0.5446  | 0.3427   | 0.6543          | 0.5478  |
| 2012 | 0.9413  | 0.9007   | 0.9477          | 0.9938  | 2013 | 0.9180  | 0.5434   | 0.8892          | 0.9232  |

5.2. Results analysis
Animal industry: pig accounts for a larger proportion in the animal industry in Beijing. There were 2.42 millions of live pigs put on the market in 2017, while only 80 thousands of cattle and 640 thousands of sheep in the same period. In addition, the water consumption for swine flushing is relatively large. Therefore, the output proportion of animal industry is the most relevant to the change of agricultural water consumption.

Fishery: pond aquaculture is the common model of fishery in Beijing, except for a small number of cold-water fish, which requires a large amount of water. Therefore, the correlation degree between the proportion of fishery output value and the change of agricultural water consumption ranked the second.

Farming: crop farming is a traditional water consuming industry, which scale was vigorously reduced recently in Beijing. In recent years, the sown area of grain and vegetable in Beijing has been declined from 226 thousands hectares and 68 thousands hectares in 2008 to 67 thousands hectares and 42 thousands hectares in 2017. The correlation between farming output and agricultural water consumption was decreasing, and ranked the third.

Forestry: forests have a strong function of water conversation. Except the water supply for afforestation and tending of young plants, forestry basically does not need the additional irrigation. So the correlation between forestry output and agricultural water consumption is the minimum.

6. Conclusion
Based on the analysis of the changes of agricultural water consumption and agricultural output value structure in Beijing from 2008 to 2017, and the grey correlation analysis of the both, it is concluded that: (1) the agricultural water consumption and proportion in Beijing have been declining in the past ten years; (2) the agricultural output value structure still shows the trend that the farming has been keeping pace with the animal industry, and the proportion of forestry output value has increased rapidly in recent years. (3) In the structure of agricultural output value from 2008 to 2017, the proportion of animal industry output value has the greatest correlation with the changes of agricultural water use, followed by fishery, farming and forestry.
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