

Forecasting on Total Water Demand in China in 2018

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Abstract. To forecast total water demand in advance is practically important for water supply planning. The paper first made impacting factors analysis of the total water demand in China and then established three models for the total water demand forecasting by multiple regression analysis. The research shows that the fitting precision of the forecasting models is satisfactory. Through the application of the models and experts' experiences, it is forecasted that the total water demand in China in 2018 will be 608.04 billion m³.

1. Introduction

China is severely lack in water resources. It had been pointed out that water problems which was mainly water shortage would make economic growth rate decreased by 1% to 2% in China, higher than the impact of energy prices increase and a decline in foreign investment, and the water shortage had become an important factor restricting China's economic and social development, by RAND Corporation report [1]. Therefore predicting water demand has practical significance to plan and coordinate economic development with water resources and the environment. Currently, there are many researches on water demand. Sen and Altunkaynak [2] established a fuzzy model for predicting daily drinking water requirement for a person; Firat, Turan and Yurdusev [3] found CCNN model performed better than GRNN model and FFNN model by comparing the prediction effect of daily water demand. Herrera, Torgo, Izquierdo and Perez [4] indicated SVM model had the highest prediction accuracy in water demand prediction, followed by multivariate adaptive regression spline model, projection pursuit model, random forest model and neural network model; Nasser, Moeini and Tabesh [5] established a genetic algorithm model to predict urban water demand in Tehran; Ajbar and Ali [6] built a neural network model to forecast the monthly and annual water demand. However, these models generally do not have high prediction accuracy, whose errors are usually higher than 5%, and are not conducive to analyze how the factors affect the water demand. Researches inside China mainly apply multivariate prediction model [7-8] and models considering the inherent law of water use and time trend [9]. Liu and Wang etc. [7-8] concluded that the combined forecast model performed better than the single model; its forecasting error was generally less than 3%. While the error of models which only considered the inherent law of water use and time trends was generally higher than 5%. In this paper, multivariate prediction model was chosen to predict total water demand for China.

2. Main Impacting Factors Analysis

There are complicated and diversified influence factors of the total water demand, such as demographic, grain yield, the level of economic development, industrial structure and water price and so on. The main influencing factors were analyzed in following sections.

2.1 Population

Figure 1 shows from 2000-2011, domestic water consumption increased while population increased year by year. Total domestic water consumption decreased in 2012 because from the year livestock water consumption original as a part of domestic water consumption has been classified to

agriculture water consumption.

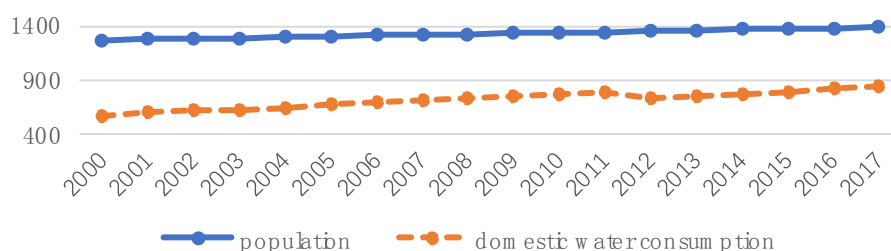


Figure 1. Trends of domestic water consumption (100million m³) and population (million) in China

2.2 National grain yield

During the past years 2000-2017, the proportion of agriculture water consumption was in the range of 61%-65%. Agriculture water consumption is directly connected with grain yield. Fig. 2 shows their trends. By calculation, the correlation coefficient between them was 0.83 in China during 1959-2017, which was a significant positive correlation.

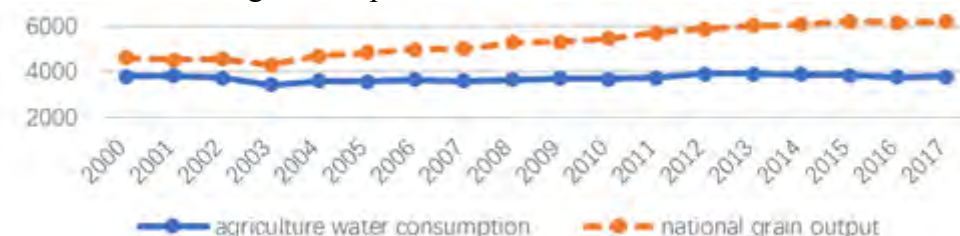


Figure 2. Trends of agriculture water consumption (100 million m³) and national grain output (10000 tons) in China

2.3 Change of industrial structure

Since 2003, with the acceleration of the industrialization process, the proportion of the value added of the secondary and tertiary industries accounted for GDP basically showed a gradual increasing trend (Fig. 3).

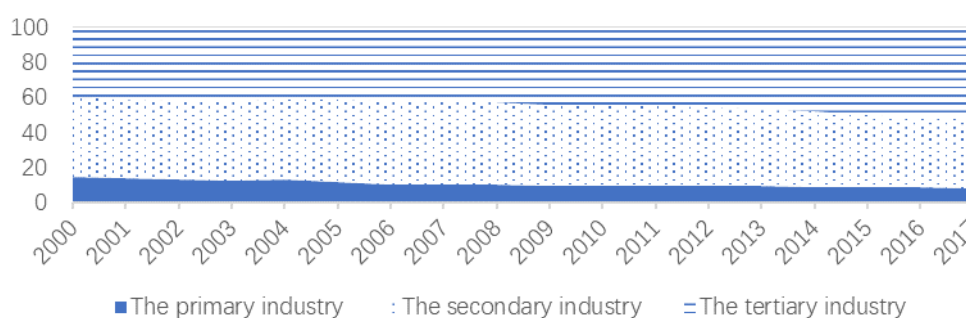


Figure 3. Trends of three industrial structure change in China

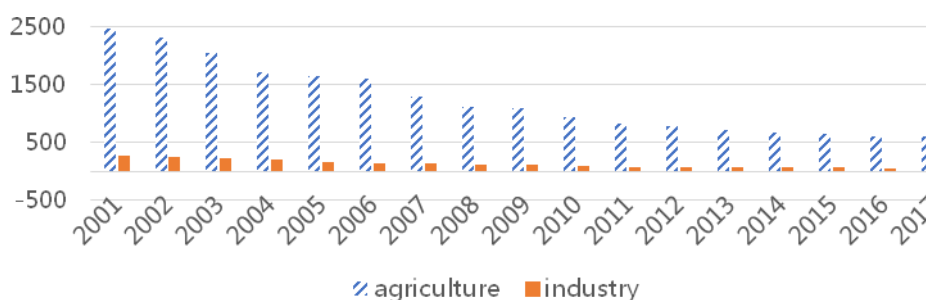


Figure 4. Water use by one hundred million Yuan of agricultural and industrial value added in China (Note: value added calculated in accordance with comparable prices in 2003)

The water use by one hundred million Yuan of industrial value added is significantly lower than those of agriculture (Fig. 4). The change of industrial structure is another major impacting factor. In addition to the three impacting factors were analyzed in sections 1.1-1.3, some other researches [6,10] have also shown that GDP, GDP per capita and so on are also closely related to the total water consumption, and here we made no longer analysis one by one.

3. Forecasting Models

Based on the analysis of impacting factors, the regression model was established by random combination of these impacting factors, finally three prediction models were chosen according to statistical test indicators and rational economic explanation of the model. The sample periods were 1980, 1990, 1993, 1995 and 1997-2017 years respectively.

$$\hat{Y} = 2995.59 + 4.10 \times 10^{-3} X_1 + 19.03 \times 10^{-3} X_2 + 87.49 \times 10^{-3} X_3 - 1.1 \times 10^{-6} X_3^2 \quad (1)$$

$$t = (3.65) \quad (0.43) \quad (3.30) \quad (2.27) \quad (0.19)$$

$$R^2 = 0.979, \text{ adjusted } R^2 = 0.974, \text{ D.W} = 1.877$$

$$\hat{Y} = -1780.82 + 43.30 \times 10^{-3} X_2 + 6160.63 X_4 - 290.25 \times 10^{-3} X_5 + 61.96 \times 10^{-3} Y(-1) \quad (2)$$

$$t = (-0.79) \quad (3.14) \quad (2.57) \quad (-0.63) \quad (0.33)$$

$$R^2 = 0.962, \text{ adjusted } R^2 = 0.949, \text{ D.W} = 1.675$$

$$\hat{Y} = -1807.60 + 42.32 \times 10^{-3} X_2 - 4.30 \times 10^{-7} X_3^2 + 5904.22 X_4 + 69.31 \times 10^{-3} Y(-1) \quad (3)$$

$$t = (-0.82) \quad (3.49) \quad (-0.66) \quad (3.00) \quad (0.36)$$

$$R^2 = 0.962, \text{ adjusted } R^2 = 0.949, \text{ D.W} = 1.687$$

Where \hat{Y} is fitted value of the total water consumption and its unit is one hundred million m^3 , $Y(-1)$ means the total water consumed last year and the unit is one hundred million m^3 ; X_1 means population, the unit is ten thousand persons; X_2 means national grain yield whose unit is ten thousand tons; X_3 stands for GDP and the unit is one hundred million Yuan, in comparable price of 1980; X_4 means the proportion of value added of secondary and tertiary industries accounted for the GDP; X_5 indicates GDP per capita and the unit is Yuan per person, in comparable price of 1980. The datum of the total water consumption in 1980 was from China Water Consumption (published in 1989), the data in 1990, 1993 and 1995 were from China's Water Supply and Demand in 21st century (published in 1999), the data of the total water consumption between 1997-2017 were from China Water Resources Bulletin (published from 1997 to 2017); other data came from China Statistical Yearbook and CEIC database. Each adjusted R-squared of models (1)-(3) is high, which indicates the overall fitting effect is well, and the value of D.W shows that the correlation of random disturbance sequence does not exist.

4. Models Application

It is assumed an increase of about 11.7 million populations in 2018 in China. It is supposed that the national grain output would be 618.4 million tons in 2018 in China. China's economic growth would be 6.7% in 2018, where the value-added growth rates of the three industries would be 3.9%, 7.1% and 8.0% respectively. The forecasting results with models (1)-(3) are shown in Table 1. As each model considered different impacting factors, the results have slight differences. For these models did not consider the impact of water conservation policies, measures and climate changes separately for data limitation, the forecasting results were adjusted with expert empirical method. The total water demand is expected to be 608.04 billion m^3 in 2018 in China.

Table 1. Forecasting results on the total water demand in 2018 (Unit: billion m^3)

Model 1	Model 2	Model 3
618.75	612.00	604.46

5. Conclusion

The total water demand in China in 2018 will increase about 4 billion m³ from 2016. After all, agriculture and livestock account for about 70% of water use. China should take more actions to improve water use efficiency in agriculture [11-12]. How to take corresponding measures in an even better way to make water security [13] will be the next research direction in the future.

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