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# Forecast on Total Water Demand in China

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***Abstract*—The total water consumption in China increased year by year since 2003.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. Then established three models for the total water demand forecasting by multiple regression analysis. The fitting precision of the forecasting models is satisfactory. Applied the models and expert experiences, made the total water demand forecast in China 2015. The results show that the total water demand would be 621.42 billion $m^3$ in 2015 in China.**

***Keywords-water demand; forecast; multiple regression analysis; combined forecasting model; China***

## I. INTRODUCTION

China is severely lack in water resources. Its water resources was only 2.8 trillion $m^3$ in 2013, accounting for about 6% of the world's total water resources, and average per capita water resources was less than 30% of the world average. However, in China total water demand had been in a uptrend since 2003, China's total water demand was 554.8 billion $m^3$ in 2004 which grew to 618.34 billion $m^3$ in 2013, with an average annual growth of 6.35 billion $m^3$. With China's economic development, on the one hand total water demand will continue to increase in the short term, on the other hand the negative effects of water shortages on economic development will also grow. 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, 2002). 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 *et al* (2009) established a fuzzy model for predicting daily drinking water requirement for a person; Firat *et al* (2010) found CCNN model performed better than GRNN model and FFNN model by comparing the prediction effect of daily water demand in Izmir, Turkey. Herrera *et al* (2010) made water demand prediction of a city in southeastern Spain, the results indicated SVM model had the highest prediction accuracy, followed by multivariate adaptive regression spline model, projection pursuit model, random forest model and neural network model; Nasseri *et al* (2011) established a genetic algorithm model to predict urban water demand in Tehran; Ajbar *et al* (2013) built a neural network model to forecast the monthly and annual water demand for Mecca city, Saudi Arabia. These forecasting methods mainly are neural network model (ANNs), fuzzy systems theory model, projection pursuit model and genetic algorithms, or improved model and combined model. 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 and models considering the inherent law of water use and time trend. Liu *et al* (2012) applied gray linear combination forecast model to predict residential domestic water consumption in Baotou city. Wang *et al* (2012) combined stepwise regression and partial least squares to predict water demand, and the results showed the combined forecast model performed better. Zai *et al* (2009) established a least squares support vector machine prediction model; Multivariate prediction model not only better interprets how water consumption changes but also has higher prediction accuracy and its forecasting error generally less than 3%, which is smaller than the error of models which only consider the inherent law of water use and time trends. In this paper, multivariate prediction model was chosen to predict total water demand for China. Three water demand forecast models were established to predict 2015 total water demand in China.

## II. MAIN IMPACTING FACTORS ANALYSIS

### A. Population

The total water consumption especially domestic water consumption is directly connected with population. On the one hand, if the per capita domestic water consumption unchanged, domestic water consumption linearly will grow as the population grows. On the other hand, with the improvement of living standards, per capita domestic water consumption is growing and domestic water consumption growth will be larger than the population growth. From 1997-2011, domestic water consumption increased while population increased year by year (Figure 1). Total domestic water consumption decreased in 2012 because from the year livestock water consumption original as a part of domestic water consumption is classified to agriculture water consumption.

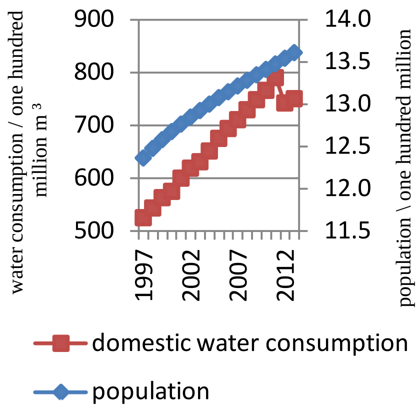


Figure 1. Trends of domestic water consumption and population in China during 1997-2013

## B. National Grain Yield

In China, agriculture water consumption accounts for a high proportion of the total water consumption. In 2013, agriculture water consumption was 392.15 billion $m^3$, accounted for 63.4% of the total water consumption. During the past ten years (2004-2013), the proportion was in the range 61%-65%. Agriculture water consumption is directly connected with grain yield. Figure 2 shows their trends. By calculation, the correlation coefficient was 0.83 in China during 1959-2011, which was a significant positive correlation.

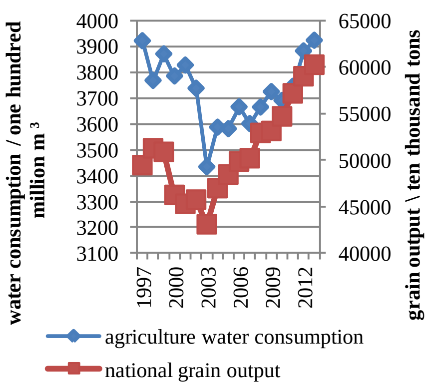


Figure 2. Trends of agriculture water consumption and grain output in China

## C. 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 the gross domestic product basically showed a gradual increasing trend. From the perspective of the industrial water use efficiency, the water use by million Yuan of industrial value added of secondary or tertiary industries is significantly lower (Figure 3). The change of industrial structure is another major impacting factor.

Except the mentioned factors, some other researches (Zuo, 2008; Ajbar *et al*, 2013) also showed that GDP, GDP per capita and so on are also closely related to the total water consumption.

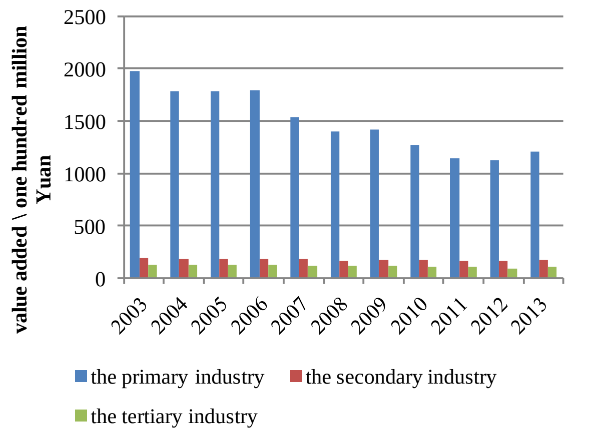


Figure 3. Water use by million Yuan of industrial value added of three industries in China (Note: value added calculated in accordance with comparable prices in 2003)

# III. FORECASTING MODELS

Based on the analysis of impacting factors, the initially selected factors of total water consumption were population, grain yield, the proportion of secondary industry and tertiary industry accounted for GDP, GDP per capita and GDP. The sample periods are 1980, 1990, 1993, 1995 and 1997-2013 years. Establishing the regression model 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.

$$\hat{Y} = 2995.59 + 4.10\times10^{-3}X_1 + 19.03\times10^{-3}X_2 + 87.49\times10^{-3}X_3 - 1.1\times10^{-6}X_3^{\,2} \quad (1)$$

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

$R^2 = 0.979$, adjusted $R^2 = 0.974$, $D.W = 1.877$

$$\hat{Y} = -1780.82 + 43.30\times10^{-3}X_2 + 6160.63X_4 - 290.25\times10^{-3}X_5 + 61.96\times10^{-3}Y(-1) \quad (2)$$

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

$R^2 = 0.962$, adjusted $R^2 = 0.949$, $D.W = 1.675$

$$\hat{Y} = -1807.60 + 42.32\times10^{-3}X_2 - 4.30\times10^{-7}X_3{}^2 + 5904.22X_4 + 69.31\times10^{-3}Y(-1) \tag{3}$$
$$t = (-0.82) \quad (3.49) \quad (-0.66) \quad (3.00) \quad (0.36)$$

$R^2 = 0.962$, adjusted $R^2 = 0.949$, $D.W = 1.687$

Where, $\hat{Y}$ is fitted value of the total water consumption and its unit is one hundred million m;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 data of the total water consumption in 1980 is from China Water Consumption (published in 1989), the data in 1990, 1993 and 1995 is from China's Water Supply and Demand in 21st century (published in 1999), the data of the total water consumption between 1997-2013 is from China Water Resources Bulletin( published in 1997-2013); other data come from China Statistical Yearbook and CEIC database. As we can see from models (1)-(3), every adjusted R-squared is high, which indicates the overall fitting effect is well, and the value of D.W indicates the correlation of random disturbance sequence does not exist.

## IV. Models Application

The total water demand in 2015 is forecasted by applying models (1)-(3). The forecasting results are shown in Table I.

Table I. Forecasting Results on the Total Water Demand in 2015 (Unit: billion $m^3$)

| Model 1 | Model 2 | Model 3 |
|---|---|---|
| 629.75 | 620.00 | 622.46 |

As we can see from Table I, the result of model 2 is close to the result of model 3, and result of model 1 is slightly high. 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 621.42 billion $m^3$ in 2015 in China.

## V. Conclusion

This paper made impacting factors analysis of the total water demand in China and established multi-factor prediction models for total water demand in China. With models (1)-(3) and expert experiences, the total water demand in China in 2015 is forecasted to be 621.42 billion $m^3$.

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