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Forecasting Water Demand and Supply of China for 2025

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Abstract

Water resource is the most critical resource; it is the basic condition of human survival, production and maintaining a good ecological environment. Water is a kind of renewable resources, but China is faced with a serious shortage of freshwater because of its huge population. In this paper, two models are built to make a forecast of water demand and supply of China in 2025. These two forecasting models for water demand and supply based on the algorithm of Double Exponential Smoothing. Based on the results of these models, the water amount of the nation and every province is obvious and two advices are proposed for China government makes any *water strategy to meet the water demand of China in 2025, such as building desalination plants in the coastal provinces which are lack of water, and meanwhile, more water diversion projects should be constructed between different provinces in the middle of China.*

Key words: Double Exponential Smoothing, Demand forecast, Math models, Water Strategy

Introduction

Water resource is the most critical resource; it is the basic condition of human survival, production and maintaining a good ecological environment. China is faced with a serious shortage of freshwater. In total, its annual average freshwater resources are about 2.8 trillion cubic meters, accounting for 6% of the world's freshwater resources, ranking sixth in the world. But per capita water resources are 2200 cubic meters, only 1/4 of the world average, 1/5 of the United States. China's water resources have several characteristics: First, the distribution of rainfall is extremely uneven in space and time, the water resources in the south are abundant and the north is opposite. Second, the amount of sewage discharge is large, and processing rate is low. In addition, a large number of water is seriously polluted. With those reasons, the lack of water is more and more serious. Third, the lack of scientific water quota and management, production needs much water and the waste of water is quite common. So, the water problem in China is very serious and some strategies should be carried out now to improve the state of living. The first step to make a water strategy is to make the forecast of water demand and supply.

Relevant Research

To carry out the water supply and demand forecasts and balance analysis medium and long-term in China, water demand prediction is very important basic work in the process. Conducting water demand forecasting including the commonly used method: development index and water quota method, general trend analysis, mechanism of forecasting methods, the per capita water demand; and water demand forecasting based on statistical methods: structural analysis method, system analysis method and time series method (Li-yuan, 2007). According to the forecasting of the water of whole China, here it’s not wise to use the structural analysis method, system analysis method, because of the complexity of computation and real affecting factors. See Jain et al. (2001), Almutaz et al. (2013), Caiado (2007). Then, after the comparison, the Exponential Smoothing method is chosen to make the prediction.

Problem Definitions

Fresh water is the limiting constraint for development in China. In order to realize the sustainable development, build a mathematical model for determining an effective, feasible, and cost-efficient water strategy for 2013 to meet the projected water needs of in 2025. In this paper, a non-technical position paper to governmental leadership outlining our result is provided.

In order to build a mathematical model to meet the projected water needs of China in 2025. First, the amount of the water needs and the available water should be estimate based on the data about water demand in the past 15 years (1997~2011). With a data analyzing approach, a simple model is raised for forecasting the total water demand and the water demand of every province in 2025. Based on these data of the amount of available water in the past 18 years (1994~2011), a model that is used to estimate the total available water and available water of every province in 2025 is built. Next, comparing the available water of every province with the water needs of every province, those provinces which are shortage of water are obvious.

Models and Results

Model of Forecasting the Water Needs of China in 2025

Assumptions

1. We will not experience the mass human activity that can impact the model.
2. The storage water includes groundwater and face water.

Model

This model is given to forecast the water demand. By analyzing the data we get from the National Bureau of Statistics of China (2013), we can get the data of water needs in 2025 from the result. At first, the model is built based on the data of water demand of the nation from 2003 to 2011. The estimated data provided by this model is the basic of the next model.

The original data of total water of china is shown as figure 1:

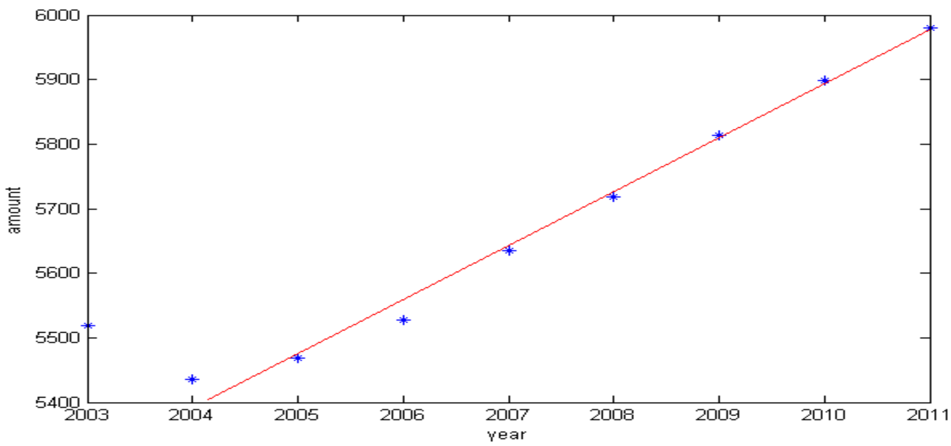

Figure 1.National Water Consumed

The amount of original data is large enough to use Exponential Smoothing. The Exponential Smoothing algorithm is used to forecast. It includes Single Exponential Smoothing and Double Exponential Smoothing (Caiado, 2007). The weighted coefficient α and initial value $S_0^{(1)}$ should be determined at first. The weighted coefficient α is more precise as long as the forecasting error is smaller. But the initial value is determined by the number of data. When the number of sample data is more than 15, the initial value will use the first data. If the number of sample data is about 9, the initial value will use average value of the first three data. When the trend of change of time series is linear, Single Exponential Smoothing will have obvious error. Therefore we will use Double Exponential Smoothing in this model.

The model of linear trend is this:

$$\hat{y}_{t+T} = a_t + b_t T$$

$$\begin{cases} a_t = 2S_t^{(1)} - S_t^{(2)} \\ b_t = \dfrac{\alpha}{1-\alpha}\left(S_t^{(1)} - S_t^{(2)}\right) \end{cases}$$

$S_t^{(1)}$ = the smoothing value of single exponential smoothing;

$S_t^{(2)}$ = the smoothing value of secondary exponential smoothing;

α_t = weighted coefficient;

By analyzing the sample data of every province, it can be proved that the model is correct, shown as figure2 and figure 3:

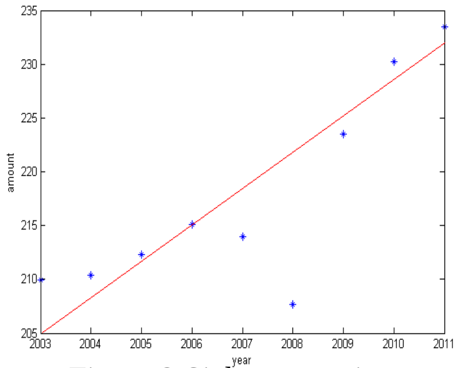

Figure 2.Sichuan province

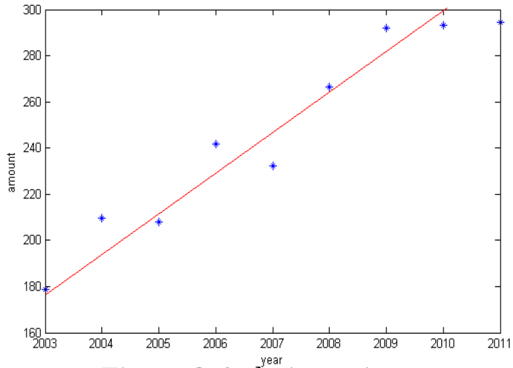

Figure 3.Anhui province

Solution and Result

We use the calculation formula of Double Exponential Smoothing to calculate the model (Caiado, 2007). The calculation formulas are flowing behind:

$$S_t^{(1)} = ay_t + (1-\alpha)\,S_{(t-1)}^{(1)}$$

$$S_t^{(2)} = aS_t^{(1)} + (1-\alpha)\,S_{(t-1)}^{(2)}$$

Table 1: The solution of identifying the weighted coefficient α

year	amount	a=0.2	a=0.5	a=0.8
2003	5320.4	5492.549	5420.66	5358.131
2004	5547.8	5503.599	5484.23	5509.866
2005	5633	5529.479	5558.615	5608.373
2006	5794.97	5582.578	5676.793	5757.651
2007	5818.7	5629.802	5747.746	5806.49
2008	5909.95	5685.832	5828.848	5889.258
2009	5965.15	5741.695	5896.999	5949.972
2010	6021.99	5797.754	5959.495	6007.586
2011	6107.18	5859.639	6033.337	6087.261

With the different weighted coefficient, we can get the forecasting error.

Table 2: Forecasting error

a	0.2	0.5	0.8
S	152.9992	66.91754	23.19948

The result identifies that α =0.8 is the best.

We can get the value of water needs in 2025. The result is shown as table 3:

Table 3: The water needs in 2025

(10^8 m^3)

Nation	Beijing	Tianjin	Hebei
7146.3	42.2267	26.12	212.62
Shandong	Henan	Hubei	Hunan
246.997	247.045	413.371	346.473
Anhui	Fujian	Jiangxi	Shanxi
350.177	274.155	473.144	123.11
Neimenggu	Liaoning	Jilin	Heilongjiang
216.916	155.624	271.925	651.195
Guangxi	Hainan	Chongqing	Sichuan
289.851	42.7082	99.2507	301.908
Qinghai	Ningxia	Shanxi	Xizang
36.6025	83.5091	192.84	1.99139
Guangdong	Yunnan	Shanghai	Jiangsu
443.672	122.784	118.326	593.819
Gansu	Xinjiang	Guizhou	Zhejiang
134.964	441.691	49.9565	158.771

Analysis of the Result

The result is gotten by improving the Single Exponential Smoothing. The trend of data approaches a line. Besides, initial value uses average value of the first three data. We can reduce the error to some extent. Through the test of residual error, the forecast of result is reliable.

Model of Forecasting the Available Water of China in 2025

Assumptions

1. The distribution of rainfall in the same province is uniform.
2. The utilization rate of the water is invariable.

Model

In this model, our purpose is to estimate the available water. First, we get the data of rainfall (1994-2011) from the National Bureau of Statistics of China. In a long period of time, rainfall is equal with runoff and evaporation in amount. We regard the value of rainfall deducting evaporation as available water. To get the data of the available water in 2025, the following model is built.

The data is analyzed at the first time. We process these data with the Moving Average Method [2]. The time series data is the basic of Moving Average method. The method is used to calculate the average number of the time series that contains a certain number of items. The method reflects the long-term trend.

Set:

The time series: $y_1, \ldots y_T$

N : The number of items (N<T)

So, the formula of moving average is:

$$M_t^1 = \frac{1}{N}(y_t + y_{t-1} + \ldots + y_{t-N+1})$$

This method is repeated, because these data are volatile, and then a new time series is provided.

Based on the new time series, a forecasting model is built by Exponential Smoothing. The method is similar to Model 1. So we can get figure 4 and table 4:

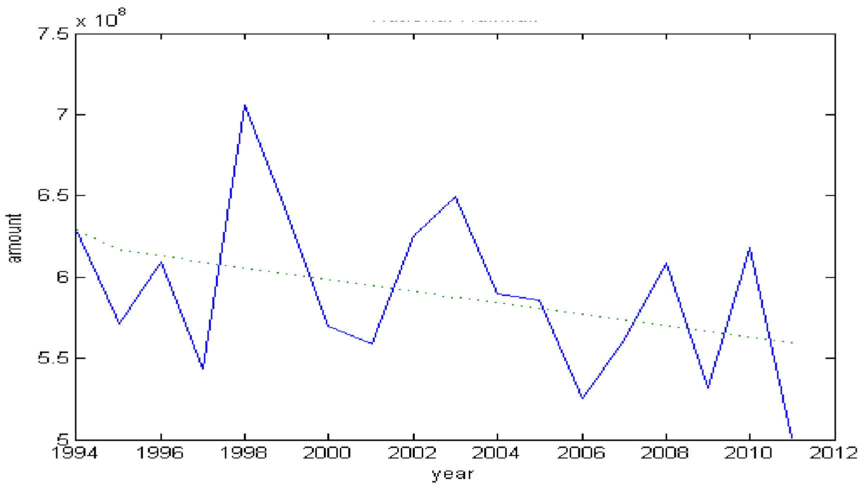

Figure 4.National rainfall

To describe the tendency of rainfall in past 18 years (1994~2011), the line according to the data of historical rainfall is colored blue. Then, the green line fits to the new time series.

Table 4: The rainfall in 2025 (Unit: 10^6 m^3)

Xizang	Xinjiang	Neimenggu	Qinghai	Sichuan	Heilongjiang
2828914.18	3610000.76	5405501.33	2267006.07	1230463.14	2326110.58
Gansu	Yunnan	Guangxi	Hunan	Shanxi	Hebei
149247.23	775746.50	4528638.87	2623291.73	1499361.69	2036570.45
Hubei	Jilin	Guangdong	Guizhou	Henan	Jiangxi
1841749.63	1590775.67	4302360.32	1728978.99	797583.07	2222990.19
Shanxi	Shandong	Liaoning	Anhui	Fujian	Zhejiang
1057165.75	336550.97	1253707.81	1425068.60	1922144.48	1312077.64
Jiangsu	Chongqing	Ningxia	Hainan	Beijing	Tianjing
1475072.45	1230463.14	194847.54	1862513.70	163949.18	49750.95
Shanghai	Nation				
83874.02	54132476.64				

But just 15% of the rainfall is available to human use. The value of available freshwater as following table:

Table 5: The available freshwater in 2025 (Unit: 10^6 m^3)

Xizang	Xinjiang	Neimenggu	Qinghai	Sichuan	Heilongjiang
565782.84	722000.15	1081100.27	453401.21	246092.63	465222.12
Gansu	Yunnan	Guangxi	Hunan	Shanxi	Hebei
29849.45	155149.30	905727.77	524658.35	299872.34	407314.09
Hubei	Jilin	Guangdong	Guizhou	Henan	Jiangxi
368349.93	318155.13	860472.06	345795.80	159516.61	444598.04
Shanxi	Shandong	Liaoning	Anhui	Fujian	Zhejiang
211433.15	67310.19	250741.56	285013.72	384428.90	262415.53
Jiangsu	Chongqing	Ningxia	Hainan	Beijing	Tianjing
295014.49	246092.63	38969.51	372502.74	32789.84	9950.19
Shanghai	Nation				
16774.80	10826495.33				

Analysis of the Result

In order to examine the accuracy of the fitted line, a small model that can gain the residua is built.

Fitted time series:

$$\hat{X}^{(0)} = (\hat{X}^{(0)}(1), \ldots \hat{X}^{(0)}(n))$$

Original time series:

$$X^{(0)} = (X^{(0)}(1), \ldots X^{(0)}(n))$$

Residual:

$$e(k) = \left| X^{(0)}(k) - \hat{X}^{(0)}(k) \right|$$

So, residual series:

$$e = (e(1), \ldots e(n))$$

Thus, relative error:

$$rel(k) = \frac{e(k)}{x^{(0)}(k)}$$

Average error:

$$\sigma = \frac{1}{n} \sum_{k=1}^{n} rel(k)$$

With these formulas, we can get results as table 6:

Table 6: Residual Test

Original series	Fitted series	Residual series	Relative error	Average error
543791120.6	613119843.4	69328722.8	0.127491458	0.064803562
705597293.9	618355411	-87241882.92	0.123642599	Average accuracy
640280458.3	613651595	-26628863.29	0.041589374	93.52%
569445504.8	604090408.4	34644903.58	0.060839717	
558640537.2	602583845.9	43943308.61	0.078661153	
625039015.4	602156296.1	-22882719.32	0.036610066	
649454811	599150377.6	-50304433.4	0.077456403	
589292054.6	586535179.2	-2756875.347	0.004678284	
586091415.6	575968511.8	-10122903.87	0.017271886	
525163725.2	558451754.2	33288028.97	0.063386002	
561691237.4	562215901.4	524663.9658	0.000934079	
608866930.1	565922618.9	-42944311.22	0.070531522	
531840552.5	564030476.4	32189923.89	0.060525516	
617696211.1	562138333.9	-55557877.22	0.089943691	
500894377.2	560246191.4	59351814.16	0.118491676	

Table 6 shows the average accuracy is 93.52%, and it's obvious that the result of estimating is credible.

Implementation and Evaluation

According to the data of model 1 and model 2, we can get the value of water shortage in 2025. By analyzing the result, it is easy to know whether the province is short of water. Then the national value of water shortage is available. The all conditions is shown as table 7:

Table 7: Water deficit (Unit: 10^6 m^3)

Nation	9.73570	Liaoning	0.32433
Anhui	-1.36416	Neimeng	5.93909
Beijing	-0.17634	Ningxia	-0.54282
Fujian	0.14167	Qinghai	3.03448
Gansu	-1.12577	Shandong	-1.96515
Guangdong	2.01683	Shanxi	-0.34265
Guangxi	3.89444	Shangxi	1.76763
Guizhou	2.09390	Shanghai	-1.05745
Hainan	2.36669	Sichuan	-1.17338
Hebei	0.92866	Tianjin	-0.18657
Henan	-1.27408	Xizang	4.22346
Heilongjiang	-3.02279	Xinjiang	0.99809
Hubei	-1.37109	Yunnan	-0.06422
Hunan	0.47021	Zhejiang	0.38041
Jilin	-0.33308	Chongqing	0.85319
Jiangsu	-3.72558	Jiangxi	-1.39696

According to these models, they forecast the water demand and supply in 2025. Moreover, we have gotten some useful conclusions about the forecast model. In addition, the model is fit for a lot of problems with high accuracy. But the models just apply to the problem with numerous data. When the model applies to reality, it must be improved, more factors should be considered, such as the influence of economy, politics and environment.

The ultimate goal of establishing the forecast model is to solve practical problems, for China to make water strategy. As shown on the previous research (Wang, 2009), the prediction of the water demand is usually lager than the real water demand. So, according to the water demand, a 5%-15% discount is acceptable.

Conclusion

By analyzing the result, on the view of the nation, we find that China is not short of water. But in the view of every province, we find the different conclusion. Many provinces are lack of water while few are not. Because a lot of factors impact the result, these factors must be considered to analyze the situation of water shortage. In order to be a feasible advice, the whole China can be divided into two parts, one contains the all provinces of surplus water and the other part includes the all provinces of water shortage, whether it's coastal or inland. So, here is the advice: building desalination plants in the coastal provinces which are lack of water. Meanwhile, more water diversion projects should be constructed between different provinces in the middle of China.

References

Almutaz, I., Ali, E., Khalid, Y., & Ajbar, A. H. (2013). A long-term forecast of water demand for a desalinated dependent city: case of Riyadh city in Saudi Arabia. *Desalination and Water Treatment, 51*, 31, 5934-5941.

Caiado, J. (2007). *Forecasting water consumption in Spain using univariate time series models*. MPRA Paper.

Jain, A., Varshney, A. K., & Joshi, U. C. (2001). Short-term water demand forecast modelling at IIT Kanpur using artificial neural networks. *Water Resources Management, 15*, 5, 299-321.

Li-yuan, H., Jun, X., & Li-ping, Z. (2007). Present research and development trend on water resources demand forecast. *Journal of Yangtze River Scientific Research Institute.*

National Bureau of Statistics of China. (2013).Chinese Statistics Database. Retrieved from http://219.235.129.58/welcome.do

Wang, H.H., He, J., Pang, J.P., Zhang, W., (2009). Method of forecasting the water demand and its problem. *Water Resource Development Research, 9*, 3.