Prediction of water demand in Gui'an city of Guizhou province in China

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Abstract. As one of 18 national key developing area in China, the traditional water demand prediction methods don't apply to Gui'an city because of its uncertainties. The paper uses the mathematical model and quota method of water user classification, based on 2012, to discuss the water quota of Gui'an, and the social and economic development is predicted, providing the basis for the reasonable allocation of water resources and a new idea for new city water demand prediction.

Introduction

Water is important resource [1], while it's in trouble with the development of the social, so, a rational allocation of water resources is needed urgently, the foundation of which is water demand prediction.

The common methods of water demand prediction is according to the growth trend of water or a fixed trends to make predictions about the future, such as analysis of index, trend analysis method, time series method and mathematical model [2]. However, it does not fit for new city. New city means new area, new industrial structure, new construction and development planning. Everything is in the changing, which means great uncertainty.

Gui'an city is one of 18 national key developing areas in western China [3], being in great demand to development, so, prediction of water demand is significant. The classification quota method and mathematical model (such as gray model, linear or nonlinear method and logarithmic equation etc.) are used to predict future water demand under changing condition and the validity of quota and water demand are compared and analyzed. All the methods in the paper is given a supplement and perfect, aimed to provide a basis for the practical and feasible measures for the relevant departments.

Forecast of water requirement

Forecast methods. The analogy method, gray model, logistic and quota method are applied to water resource prediction.

(1) Analogy method. The administrative region of Gui'an is 1895 km^2, including Qingzhen, Huaxi, Xixiu and Pingba [4]. Lack of statistical Gui'an annual GDP, hydrologic analogy method is

referred [5]; analogize the economic product in primary, secondary, tertiary industry in 2004~2012 in the original area to new administrative area, then correct the predicted data based on the statistical data in 2012 in Gui'an (refer with: Table 1, Table 2).

$$W = W_i \times \frac{F_i}{F} \times g \tag{1}$$

Where W_i is economic product in original administrative area; W is economic product in new administrative area; Fi is new administrative area; F is original administrative area; γ is correction items.

Table 1. Comparison of the original and the new administrative area of Gui'an

Administrative division	The original area	The new area	Ratio
	km²	km²	
Huaxi	901	244	0.27
Qingzhen	1383	216	0.16
Pingba	999	907	0.91
Xixiu	1546	528	0.34

Table 2. The economic product by industry in Gui'an/ $\times 10^4$ RMB

Year	Comparative value			Correct value		
	Primary industry	Secondary industry	Tertiary industry	Primary industry	Secondary industry	Tertiary industry
2004	71390.69	224301.46	168031.95	67992.49	213624.71	160033.63
2005	79012.68	226518.15	195262.46	75251.68	215735.89	185967.97
2006	89209.12	265628.18	231384.98	84962.77	252984.28	220371.05
2007	96867.95	314434.55	271474.33	92257.04	299467.47	258552.15
2008	103828.00	386200.85	316048.05	98885.79	367817.69	301004.16
2009	118397.02	402884.40	372329.34	112761.32	383707.10	354606.46
2010	125230.38	484828.55	439821.45	119269.41	461750.71	418885.95
2011	137880.59	622257.06	559546.31	131317.47	592637.62	532911.91
2012	162823.77	755534.49	696462.73	155073.36	719571.05	663311.10

(2) Gray model. Gray system theory is that all random values are within certain range, certain amount of time on the ranges in gray and gray process, the amount of ash after the data through a certain way to become more regular time series data, and then build models. GM(1,1) is used to predict the future Gross Domestic Product (short of GDP) in primary, secondary, tertiary industry based on the statistical data in 2004~2012 through building the bound between GDP and time series [6,7]). The primary industry belongs to agriculture and the secondary and tertiary industries belong to non-agriculture in the paper (refer with: Table 3).

The forecast model of GDP in primary, secondary, tertiary industry shows below (refer with: Eq. 2 to Eq. 4).

$$x^{(1)}(k) = (67992.4932 + 650266.451)e^{0.099(k-1)} - 650266.451 \tag{2}$$

$$x^{(1)}(k) = (213624.711 + 855307.491)e^{0.1746(k-1)} - 855307.491 \tag{3}$$

$$x^{(1)}(k) = (160033.629 + 669424.487)e^{0.18747(k-1)} - 669424.487 \tag{4}$$

Table3. The prediction of economic production of Gui'an city[10^4 RMB]

Year	2012	2020	2030
Agriculture	155073.4	349774.2	941324.4
Non-agricultural	1382882.2	5312091.0	32567835.6

From 2012 to 2020, the economic value of agricultural production with an average annual growth rate of 10.70%, to non-agriculture economic output value the rate is 18.32%; from 2020 to 2030, the economic value of agricultural production, with an average annual growth rate of 10.41%, to non-agriculture economic output value the rate is 19.88%, which is growing rapidly.

(3) Logistic prediction. Under the conditions of limited resources in the limited space of organized distribution of population is the accelerate growth period in the past half of the maximum value, after this point, the growth rate gradually decrease and will reach zero sooner or later, this is the slow growth period [8].

$$\frac{dN}{dt} = rN(1-\frac{N}{k}) \tag{5}$$

$$N = \frac{k}{1+e^{a-rt}} \tag{6}$$

Where N is population size; k is maximum environmental capacity; t is time series; r is constant.

According to water resources bulletin and social survey in China, it is showed 3 models, uniform growth, rapid growth and speeding growth, by logistic theory considering government's main macro-control and population shift etc. started from 2012 to 2030. Once more than 2 million, the population is 2 million.

$$N = \frac{400}{1+e^{1.488-0.85t}} \tag{7}$$

$$N = \frac{200}{1+e^{0.597-0.408t}} \tag{8}$$

$$N = \frac{200}{1+e^{0.597-0.736t}} \tag{9}$$

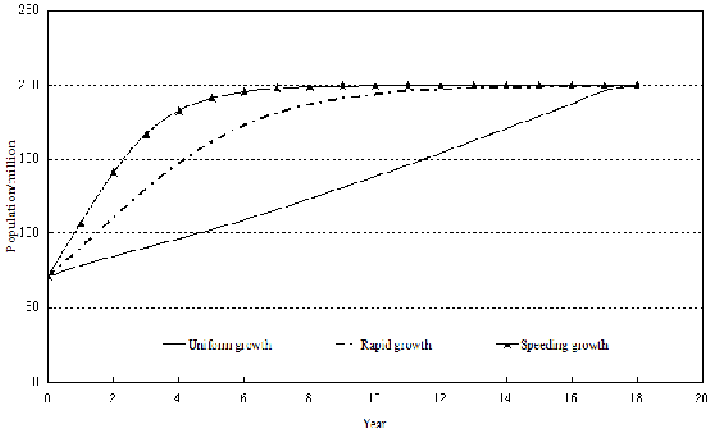

Figure 1. Forecast of population in Gui'an [10^4 people]

Uniform growth (refer with: Eq.7), considering everything is in the construction, the population rises 0.56 million, annual growth rate is 7.5%; rapid growth (refer with: Eq.8), considering greatly investigating to the construction, the population rises 1.16 million, annual growth rate is 12.9%; speeding growth (refer with: Eq.9), considering completing the construction ahead of schedule, the population rises 128 million, annual growth rate is 13.8%. Besides, aiming at excessive increase in population or uncontrollable factors in 2030, it is set 3 scenes follow as 2, 2.5 and 3 million people.

(4) Quota method. Domestic water, production water, and ecological water refer with the Eq.10 to Eq. 12.

$$W_t = P_t \times D_t \tag{10}$$

Where W_t is article t domestic water in the urban or rural; P_t is article t the number of population; D_t is article t quota in the urban or rural.

$$W_{i,t} = g_{i,t} \times D_{i,t} \tag{11}$$

Where $W_{i,t}$ is article t production water of the i industry; $g_{i,t}$ is article t economic value water of the i industry; $D_{i,t}$ is article t quota of the i industry.

According to Code For Design Of Outdoor Water Supply Engineering(GB50213-2006 in China), street flushing water is watering area multiplied by 2.0～3.0L/(m^2.d); green water is watering area multiplied by 1.0～3.0L/(m^2.d). It is 2 L/(m^2.d) in the paper.

$$W_{e,t} = P_t \times q_{s,t} \times F \tag{12}$$

Where $W_{e,t}$ is article t ecological water; P_t is article t the number of population; $q_{i,t}$ is article t ecological quota; F is the green space for everyone, it's 11.5 m^2 according to Gui'an city plans (2013-2030).

The quota analysis. According to Guizhou Statistic Yearbook (2000~2012), Guiyang Water Resource (2004~2012), Anshun Water Resource (2004~2012), it is Guiyang city that is used as representative through analyzing the trends of water use in agriculture, non- agriculture and per capita use in cities and rural areas in every reference city. Then mathematical models like linear or nonlinear, analysis of index, logarithm and gray model are used based on fitting algorithm, compare each coefficient of correlation, choose the maximum to analyze and make a prediction, the predictions will be taken for reference (refer with: Fig 2, 3).

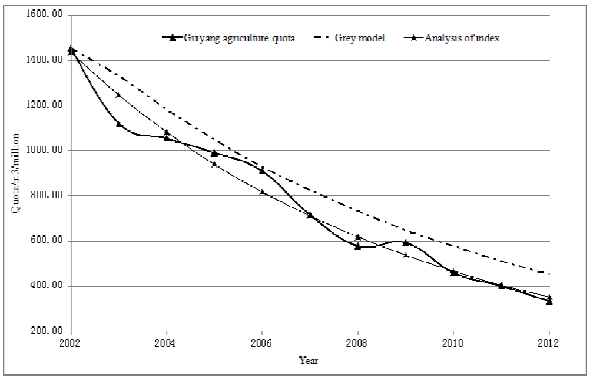

Figure 2.Comparison of simulations and actual value about Guiyang agricultural quota

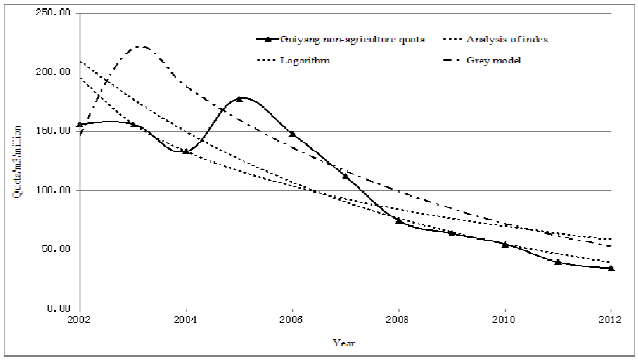

Figure 3.Comparison of simulations and actual value about Guiyang non-agricultural quota

The agricultural quota is 173.12×10^4 m^3 in 2020, 52.14×10^4 m^3/ in 2030; the non-agricultural quota is $12.55\times10^4 m^3$ in 2020, 2.475×10^4 m^3 in 2030;The per capital living water quota of urban and rural residents is 132.65 L/d in 2020, 135.80 L/d in 2030.

The scheme of Water demand forecasting. Schemes 3 in 2020 are below: (1)considering everything is in the construction, the water use is $19937.1\times10^4 m^3$. (2)considering greatly investigating to the construction, the water use is $23345.9\times10^4 m^3$. (3)considering completing the construction ahead of schedule, the water use is $24027.6\times10^4 m^3$.

Schemes 3 in 2030 are as follow. (1)the water use is $24561.0\times10^4 m^3$ based on 200 million people. (2)the water use is 27459.1×10^4 m^3 based on 250 million people. (3)he water use is 30357.2×10^4 m^3 based on 300 million people(refer with: Table 4).

Table 4. Prediction of water demand in Gui'an

Year	Schemes	Population	Living	Agriculture	Non-agriculture	Economic	Total
		$\times10^4$ people	$\times10^4$ m^3	$\times10^4$ m^3	$\times10^4$ m^3	$\times10^4$ m^3	$\times10^4$ m^3
2020	1	127	6149.0	6055.3	6666.7	1066.2	19937.1
	2	187	9054.0	6055.3	6666.7	1569.9	23345.9
	3	199	9635.0	6055.3	6666.7	1670.6	24027.6
2030	1	200	9913.4	4908.1	8060.5	1679.0	24561.0
	2	250	12391.8	4908.1	8060.5	2098.8	27459.1
	3	300	14870.1	4908.1	8060.5	2518.5	30357.2

Rational analysis

According to Standard Of Integrated Quota For Urban Water Use (The Ministry of Water Resources of the People's Republic of China 2006),the scale of Gui'an belongs to Grade VI, close to a big city scale, and the per capita comprehensive water consumption index is 110~155 m^3/d, then, Gui'an prediction of water use (schemes 1~3) is 156.99 m^3/d , 124.84 m^3/d , 120.74 m^3/d in 2020, 122.81 m^3/d , 109.84 m^3/d , 101.19 m^3/d in 2030, which reaches the basic line. The standard is published in 2006, whose quota is on behalf of the actual.

In the 1990s GDP water consumption in developed countries is generally below 50 m^3, France 29 m^3, Japan 21 m^3, British 13 m^3, middle income countries in general about 150 m^3 [9].

In the results of Gui'an, the water consumption of 10,000 RMB GDP is (schemes 1~3) 35.21 m^3, 41.44 m^3, 42.44 m^3 in 2020; 7.33 m^3, 8.19 m^3, 9.06 m^3. As we all know, Gui'an is to build as one of the new national economic zone in the western China, so Gui'an structure of water consumption is reasonable. (refer with: Table 5)

In summary, Gui'an water demand prediction results are reasonable.

Table 5. Gui'an structure of water/%

Year	schemes	Living	agriculture	Non-agriculture	economic
2020	1	30.84	30.37	33.44	5.35
	2	38.78	25.94	28.56	6.72
	3	40.10	25.20	27.75	6.95
2030	1	40.36	19.98	32.82	6.84
	2	45.13	17.87	29.35	7.64
	3	48.98	16.17	26.55	8.30

Conclusions

It is engineering shortage of water in Gui'an, and the antinomy of water resources and demand is outstanding, so, it's rather important to rationally explore, of which prediction of water demand is the foundation. The paper uses the mathematical model and quota method of water user classification, and have a discuss of the water quota of Gui'an, and the social and economic development is predicted, providing the basis for the reasonable allocation of water resources and a new idea and method for new city water demand prediction. In the paper, Gui'an water demand is 19937.1×10^4 m^3, 23345.9×10^4 m^3, 24027.6×10^4 m^3 in 2020; 24561.0×10^4 m^3, 27459.1×10^4 m^3, 30357.2×10^4 m^3 in 2030. The social and economic indicators are in line with relevant requirements, of reasonable water supply structure, the water demand prediction results can be taken for reference.

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