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Research of water resources in China

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ABSTRACT

Fresh water is a limiting factor influencing the development of most regions in the world. Taking China's vast land and uneven water resource distribution into account, we will divide it into seven regions of North China, Northeast China, East China, Central China, Southwest China, Northwest China and South China and then construct a water resource strategic optimization model. Construct a multi-source and multi-terminal network flow model and work out the minimum cost maximum flow from the source to the sink point so as to put forward an effective, feasible, low-cost water resource strategic optimization model.

KEYWORDS

Multi-source and multi-terminal network;
Minimum cost maximum flow;
Multi-objective linear programming.

ANALYSIS OF THE PRESENT STATUS OF WATER RESOURCES

As an essential resource to sustain the survival and development of human beings, water resources serve as one of the controlling factors in ecological system, act as strategic economic resources, and meanwhile pose as an organic part in a country's comprehensive capabilities. However, many countries and areas around the world are suffering from the shortage of water resources. Therefore, formulating reasonable and feasible water resources strategies is one of the important research issues of the world.

At present, there are around 1.5 billion people in 80 countries facing a serious shortage of fresh water resources. Among them, more than 300 million people in 26 countries are living entirely in a severe state of water shortage. It is estimated that by the year of 2025, 3 billion people in the world will be confronted with water shortage. *Global Environmental Outlook*, released by United Nations Environment Programme in May 22nd, 2002, points out that, currently, half of the global river water is reduced by a large margin and is severely contaminated. The fact the 1.1 billion people around the world cannot obtain safe drinking water, and 2.4 billion people (about 40% of global population) suffer a lack of health facilities, makes it urgent to take more effective measures. If not, by the year of 2025, with a huge increase of 40% in fresh water demand, almost half of the global population will be living in water-deficient areas, one third of global population cannot get access to safe drinking water, and more than half of global population have no health facilities. Human beings and the natural environment they live on are in a more and more dangerous situation.

In China, with the development of economy and

TABLE 1 : Water Supply of North China (unit:100 million cu.m)

Year	Surface Water	Ground Water	Others
2004	32.2	62.9	0.5
2005	32.9	62.4	0.7
2006	33.9	63.1	0.9
2007	34.5	64.2	1.1
2008	34.9	63.7	1.6
2009	34.1	61.4	1.9
2010	35.7	60.6	2.1
2011	36.3	61.2	2.4
2012	36.3	61.2	2.4

society, the imbalance between supply and demand of water resources is aggravated day by day. The water resources evaluation results announced by China's Ministry of Water Resources show that for many years, the average annual river runoff is 2,711.5 billion cubic meters, and average annual groundwater resource is 828.8 billion cubic meters. With the double counting of 727.9 billion cubic meters between the two taken off, the average annual water resource is summed up as 2,812.4 billion cubic meters. This number ranks 6th in the world, only next to Brazil, Russia, Canada, America and Indonesia. For the total amount, China is rich in water resources. However, due to a vast territory with a large population, per capita and per mu availability of water resources make up little share. According to statistics, China's per capita possession of water share about 2,260 cubic meters, ranking 121st in the world, less than 25% of the global average share. According to this standard, China is approaching the edge of severe water shortages.

EFFECTIVE AND FEASIBLE WATER RESOURCE STRATEGIC MODEL CONSTRUCTION

Data processing

There are many sources of fresh water supply with the surface water and groundwater being the most basic ones. In addition, rainfall and snow melting are all available sources. According to the data in " The National Data Book of China 2012[1]", we collect the influencing factors of fresh water supply and analyze them. Take North China as an example: (See Appendix 1 for the rest areas)

Based on the analysis of above data, it can be seen that ground water in North China remains relatively stable, so we take the average value 62.3 (100 million cu.m) of the underground water supply in North China as the future groundwater supply.

To study the fresh water supply and demand relationship in seven regions, we collect the total demand of fresh water from 2004 to 2011 (See TABLE 2).

Supply and demand prediction

Taking North China as an example, we adopt the curvilinear regression to predict the regional water supply with surface water being x_1, groundwater being x_2 and other water sources being x_3, which are fitted with the time respectively. Compare the fitting degree of various curves (See TABLE 3) and take the curve with best fitting degree as the relation curve of water supply condition and time (Figure 1).

It is observed in TABLE 3 that the linear model and quadratic curve model have the best fitting degree among various regression models. Comparing the two models, we can see clearly that R Square is both 0.883 and the sig. value of quadratic curve is 0.01. Therefore, the quadratic curve model is chosen to construct the

TABLE 2 : Average water demand of seven areas (unit:100 million cu.m)

Year	2004	2005	2006	2007	2008	2009	2010	2011
North China	95.7	96.0	98.0	99.8	99.9	97.0	98.0	99.4
Northeast China	159.4	163.0	167.7	176.8	178.3	181.3	190.0	196.2
East China	214.5	237.8	237.8	247.7	253.2	259.0	261.0	262.8
Central China	250.5	255.7	259.9	271.2	264.1	274.0	279.2	279.3
South China	260.7	267.3	272.0	273.4	273.2	272.8	270.4	271.6
Northwest China	107.6	109.4	112.1	113.6	115.2	116.6	118.5	120.2
Southwest China	158.1	159.7	163.8	165.9	164.8	168.9	167.4	168.7

TABLE 3 : Model summary and parameter estimates

Dependent Variable: Surface water								
Equation	Model Summary					Parameter Estimates		
	R Square	F	df1	df2	Sig.	Constant	b1	b2
Linear	.879	43.677	1	6	.001	31.971	.520	
Logarithmic	.866	38.612	1	6	.001	31.930	1.797	
Quadratic	.883	18.884	2	5	.005	31.713	.676	-.017
Compound	.878	43.225	1	6	.001	32.022	1.015	
Power	.874	41.625	1	6	.001	31.971	.053	
Growth	.878	43.225	1	6	.001	3.466	.015	
Exponential	.878	43.225	1	6	.001	32.022	.015	
Logistic	.878	43.225	1	6	.001	.031	.985	

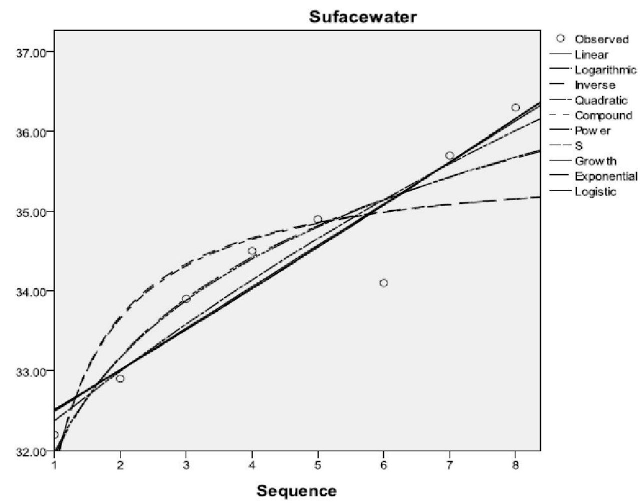

Figure 1 : Relational graph between surface water and time function

regression equation:

$$x_1 = -0.017S^2 + 0.676S + 31.713$$

$$x_2 = 62.3, x_3 = 0.007S^2 + 0.219S + 0.232$$

$$y_1 = x_1 + x_2 + x_3$$

The equation of total water supply in North China is, $y_1 = -0.01S^2 + 0.895S + 94.25$

Fitting the water supply of each region with the curvilinear regression, we can get the total water supply and demand equation of these seven regions:

$$\begin{cases} y_1 = -0.01S^2 + 0.895S + 94.25 \\ y_2 = -0.367S^2 + 3.378S + 94.25 \\ y_3 = 23.648\ln S + 246.04 \\ y_4 = -0.098S^2 + 4.045\ln S + 4.016S + 245.871 \\ y_5 = e^{\frac{1}{S}(5.566S - 0.05)} + 13.7 \\ y_6 = 1.6S + 107.35 \\ y_7 = 0.068S^2 + 0.511S + 160.346 \end{cases} \quad (1)$$

$$\begin{cases} z_1 = 98 \\ z_2 = 0.117S^2 + 4.122S + 155.048 \\ z_3 = 22.805\ln S + 216.496 \\ z_4 = -0.207S^2 + 6.077S + 244.659 \\ z_5 = e^{5.616 - \frac{0.051}{S}} \\ z_6 = -0.045S^2 + 2.179S + 105.50 \\ z_7 = 5.447\ln S + 157.442 \end{cases} \quad (2)$$

In the above equations, $y_1, y_2, y_3, y_4, y_5, y_6, y_7$ represent the total water supply of North China, Northeast, East China, Central China, South China, Northwest and Southwest, while z_1、z_2、z_3、z_4、z_5、z_6、z_7 stand for the average water use of these regions respectively.

Predict the total water supply and use of these regions in 2025 by using equation (1) and (2).

Project design

The geographical location of the administrative regions of China is shown in Figure 2.

Northwest, Southwest and Central China is located in the hinterland, far away from the ocean, so the freshwater sources can only come from the water movement from other regions apart from its surfacewater and groundwater[2]. Northeast, North, East and South China are in coastal areas with rich sea water resources. In case of shortage of fresh water resources, it can not only come from water movement, but also from seawater desalination.

It can be seen from TABLE 4 that water shortage is common in China. The fresh water supply and de-

TABLE 4 : Predicted water supply and use in 2025 (unit:100 million cu.m)

project	North China	South China	Central China	Northeast China	Southwest China	Northwest China	East China
Water Supply	98	274.15	278.165	302.36	174.28	131.66	286.99
Water Use	109.10	274.48	299.29	237.41	205.00	142.55	319.14
D-value	-11.1	-0.33	-21.125	64.95	-30.72	-10.89	-32.15

Figure 2 : Regional distribution chart

mand in South China nearly reach the balance; Northeast China is abundant in fresh water with water supply exceeding demand, which makes water storage possible; Northwest, Southwest, Central China and other inland areas are lack of water resource and can rely on water movement from other regions to meet residents' needs; East and North China are lack of water, mainly relying on seawater desalination and water movement to satisfy the needs.

AN ANALYSIS OF THE IMPACT OF WATER RESOURCES STRATEGY

According to the water resources strategy introduced above, we establish optimization planning of water resources development and utilization based on fuzzy multiple objective linear programming, to move forward to analyze the impacts of this strategy planning on economy, environment and society:

In economic terms: considering the net economic benefit brought about by internal water and external water, we try to maximize the benefits;

In environmental terms: based on the contents of important pollution factors (chemical oxygen demand and biochemical oxygen demand) in discharge intensity of water waste, we try to minimize the pollutant discharge;

In social terms: taking water resources reutilization into accountant, we make great efforts to optimize water resources utilization.

To sum up, we come up with a reasonable plan of application and allocation of water resources to achieve optimization among economy, environment and society.

EVALUATION OF WATER RESOURCES

STRATEGY PLANNING

Based on the balance of supply and demand of water resources, economical, social and environmental factors, the water resources strategy optimization planning described above is promoted. We are hoping to offer useful advice to the government officials. The prediction of supply and demand of water resources in 2025 guarantees the effects of the validity of the water resources strategy; the analysis of the present status of China's water resources ensures the feasibility of the strategy; the program of minimum-cost maximum-flow make sure the low cost of the strategy planning. Furthermore, according to the results of the planning, water for agriculture and industry plays a great role in China's total water use, therefore we suggest that it should be crucial to take effective measures to save resources, such as, adjusting industrial structure, reducing or diverting high-water-consumption agricultural planting, resorting to drip-fed farming, transferring high-energy-consumption and high-water-consumption enterprises and turning to low-energy-consumption high-technology industry.

TABLE 5 : Application and allocation of water resources (unit: 100 million cu.m)

Project	agriculture	industry	Consumption
North	49.31723	267.1678	0.569225
Northeast	19.18004	86.07674	0.231019
East	38.25577	228.3265	0.557766
Central	16.80602	100.9944	0.496359
South	22.96942	143.7488	0.663818
Northwest	2.04668	35.25347	0.901354
Southwest	19.86317	118.8924	0.546101

To sum up, the water resources strategy planning can be applied into and scheme water resources strategies in different periods. Besides, it can be put into the prediction and allocation of other resources, which provides a reference for the sustainable development of various resources.

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