Water Evaluation and Prediction by Using SD model

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Abstract. In this paper, the evaluation and prediction model is presented to measure the ability of a region to provide clean water to meet the needs of its population. Considering that the dynamic nature of the factors affects both supply and demand, this model is improved by using the **SD** theory. And what the water situation will be in 15 years of Wuwei city, Gansu Province, Northwest China, is predicted.

Introduction

Water, the basis of life, is the most active factor in the climate system. The bodies, innumerable ecological systems, even the big biosphere of our entire planet can't live without the beautiful gift from our Almighty God. With the rapid development of the global economy, the demand of human for water is increasing constantly. However, water has evolved into the bottleneck, which severely restricts the development of a region, a country, even the global.

Basis Evaluation Model

The water resources carrying capacity is an important index of water resources security which can provide guidance to the sustainable development of arid and semi-arid areas [1].

The system of quantifying the water resources carrying capacity is shown in Fig.1. From this figure, we realize how significant the water resources carrying capacity is.

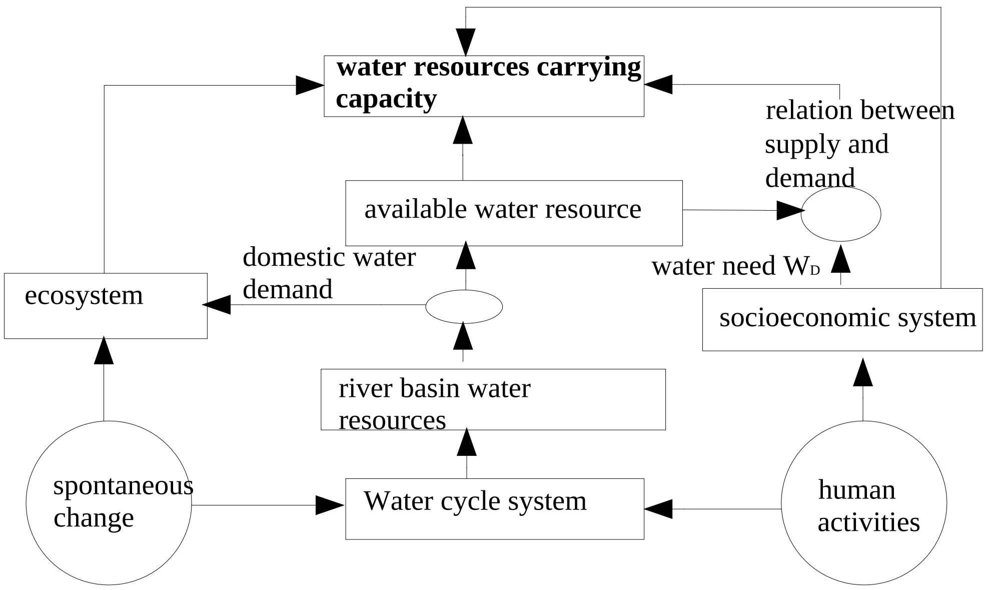

Fig.1 System related to water resources carrying capacity

Evidently, the equilibrium index *(ID)* can be calculated via

$$ID = \frac{W_S - W_D}{W_S} \tag{1}$$

where W_S and W_D stands for the available water resources and the total demand for water resources, Obviously, while $W_S < W_D$, the ID < 0, which explain that the available water resources can not bear the socioeconomic system. Otherwise, it is shown that the demand and supply of water are balanced well.

In order to investigate the each water-consuming system, we comp up with the separate-measure model.

$$\lambda_1=\frac{P}{W_S},\ \lambda_2=\frac{GDP}{W_S},\ \cdots,\ \lambda_n=\frac{H}{W_S} \tag{2}$$

where λ_1 is the least water resources bearing the current population size, λ_2 is the least water resources bearing the current agricultural scale, λ_3 represent the least water resources bearing the current commercial scale, λ_4 represent the least water resources bearing the current animal husbandry scale, and λ_5 represent the least water resources bearing the current ecosystem scale.

To look into water resources carrying capacity of each water-consuming system, we define the index of weight measures of water resource. It can be written as

$$su=\frac{\lambda_{real}-\lambda_{theory}}{\lambda_{theory}} \tag{3}$$

where *su is* the coefficient of separate-measure.

Water shortage degree can reflect the risk of water shortage to some extent, so we can assess the risk of water shortage according to Tab.1.

Tab.1 Risk assessment of water shortage

su	≤0.2	0.2-0.3	0.3-0.4	0.4-0.6	≥0.6
Risk assessment	Very low	Low	Medium	High	Extreme

Improved Model:

System dynamics (**SD**) is growing at an impressive exponential rate. In order to consider the ability providing fresh water due to the dynamic changes of the physical and economic factors, the evaluation model is improved. Then the forecast-evaluation model is built by us. On the whole, the procedures of building this model contain five steps.

Firstly, the boundary of investigated subject and forecasting time are determined.

Secondly, the system is divided into five sub-systems: population sub-system, economy sub-system, farmland sub-system, husbandry sub-system, water resource sub-system.

Then, the relationships of all kinds of variables in ecosystem are complicated.

Subsequently, the structural equations of system dynamics are built through analyzing the dynamics behavior of the system.

In the following equations, there are some explanations here. *A* and α represent the auxiliary variable and state-variable equation, respectively. β represent the rate equation. *G* and *N* are a moment of the past and now. *GN* and *ND* stand for the time quantum from past to now and the time quantum from now to future. And DT is the time step. Thus, we can arrive at the general expression of the equation of state:

$$\frac{d\alpha}{dt}=f\left(Ni,\beta i,Ai,Pi\right)=\beta \tag{4}$$

SD model equation of population sub-system

$$\begin{cases}\mathrm{N}_P.\mathrm{N}=\mathrm{N}_P.\mathrm{G}+\mathrm{DT}(\mathrm{N}_B.\mathrm{GN}\text{-}\mathrm{N}_D.\mathrm{GN}+\mathrm{N}_I.\mathrm{GN})\\ \mathrm{N}_B.\mathrm{NF}=\mathrm{N}_L.\mathrm{N}\bullet \mathrm{R}_B.\mathrm{N}\\ \mathrm{N}_D.\mathrm{NF}=\mathrm{N}_L.\mathrm{N}\bullet \mathrm{R}_D.\mathrm{N}\end{cases} \tag{5}$$

where N_P is the number of population, N_B and N_D are the population of birth and the number of death per year, N_I and N_L are the net immigration population per year and the population at the end of year, R_B and R_D stand for fertility rate and human mortality, respectively.

SD model equation of economy sub-system

$$\begin{cases}\mathrm{I}_I.\mathrm{N}=\mathrm{I}_I.\mathrm{G}+\mathrm{DT}\bullet \mathrm{R}_{GDP}.\mathrm{GN}\\ \mathrm{R}_{GDP}.\mathrm{NF}=\mathrm{T}_F.\mathrm{N}\end{cases} \tag{6}$$

where I_I represents the industrial added value, R_{GDP} is the GDP growth rate, T_F is the table function of growth rate.

SD model equation of farmland sub-system

$$\begin{cases} F_M.N=F_M.G-D_F.GN \\ D_F.NF=F_E.N \bullet R_T.N \end{cases} \tag{7}$$

where F_M and D_F stand for the agricultural acreage and the decrease of farmland, F_E and R_T are the farmland at the end of year and the rate of abandon the farmland, respectively.

SD model equation of animal husbandry sub-system

$$\begin{cases} L_N.N=L_N.G+DT \bullet (I_L.GN-D_L.GN) \\ I_L.NF=L_E.N \bullet R_{LI}.N \end{cases} \tag{8}$$

where I_L and D_L stand for the increment and the decrement of livestock per year, L_N and L_E are the number of the remaining livestock and that at the end of year, R_{LI} and R_{LD} represent the increasing rate and the decreasing rate of the livestock per year, respectively.

Finally, determine the values of parameters in the system and substitute these values into kinetic equations. And we can get these values through trend extrapolation, actual survey, and policy analysis.

Water Resources Forecast of Wuwei

We take Wuwei, the city of northwest China, as the example, and forecast the water resources in the future, according to the model built above.

For the sake of simplicity, we only forecast the water resources in 2030. Based on the various factors in the society, we simply use the past general growth rate to forecast the prospective values. Considering that there are several development situations in this region, we investigate the high, middle, low, three velocity of development, detailed in the following tables.

Tab.2 the demand water resources in 2030

	current situation	high	middle	low
domestic water 10^8m^3	0.5469	0.729178	0.694909	0.676642
water of livestock 10^8m^3	0.1932	0.293516	0.228708	0.235213
industrial water 10^8m^3	0.7382	3.696439	2.84114	1.897607
agricultural water 10^8m^3	14.9934	11.47138	12.21147	13.05364
water of ecology 10^8m^3	0.3278	1.306561	0.925479	0.650248
gross water requirement 10^8m^3	16.79	17.49707	16.90171	16.51335
total water resource available 10^8m^3	14.9105	15.3318	15.25	15.1637

According to the Tab.2, we can conclude that the available water resources in 2030 still can not meet the demand. With the different velocity of development in this region, the relationship of supply and demand varies. Therefore, it is essential to evaluate the water resources.

In accordance with the results above, the water resources shortage of Wuwei is severe, which will decrease the life quality, drag on the expansion of the economy.

Water Resources Evaluation of Wuwei

Substitute the values represented in Tab.1 into Eq. (2), and we can arrive at the *ID* of three situations, mentioned in Tab.3.

Tab.3 The evaluation of water resources capacity in 2030

	high	middle	low
total water resource available $10^8 m^3$	15.3318	15.25	15.1637
the total demand for water resources W_D $10^8 m^3$	17.49707	16.90171	16.51335
ID	-0.14123	-0.10831	-0.08901

Obviously, the values of *ID* are less than zero, which state that the water resources can not satisfy the demand of system in 2030. The higher the development extent is, the bigger the diversity of supply and demand is.

Summary

A model of evaluation and prediction is built to measure the ability of providing clean water. We dynamically predict the supply and demand of water resources of the region which is selected by us. According to Tab.3, the water situation of this region is very awful. This situation has great effects on the quality of people's life, worsen ecological environment, and hinder the development of the city. At the same time, the successful application of the evaluation and prediction model verity the validity of this model.

References

[1] Youling Wan, Bo Zhang, Chundu Wu, "Research on water environment carrying capacity of Neijiang river basin in Zhenjiang City, "*Future Information Technology and Management Engineering,2010 International Conference*, vol.3, no. ,pp.234-237, 10 Oct 2010.