A Macro Intervention Plan to Improve the Water Situation

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Keywords: System Dynamic Model Water Dispatch Plan Relative Cultivated Land RC

Abstract. Firstly, we define Z as the index measuring the ability of one region to meet its water demand. Next we design an intervention plan based on most influential factors in Xinjiang. The intervention plan has four aspects: Dispatch water resource, employ advanced irrigation technology, proper pricing mechanism and Recycling. We then construct the System Dynamic Model to simulate the influence of intervention plan on eco-system, local water situation and surrounding areas. We forecast the index Z in the next 15 years when the intervention plan takes effect to see its influence on the water situation in Xinjiang. As part of the plan, water is dispatched from Tibet (China) to Xinjiang. We analyze the influence of the plan on Tibet by predicting the index Z in Tibet when different proportion of water dispatched. Finally, we offer our recommendations on world water problem based on our paper.

1.Introduction

Water scarcity is now a global issue bothering the world for its wide coverage over every continent. Solving this problem is an urgent task facing any government, institution and individual.

We aim at offering recommendations on releasing the world water problem. Because of the toughness and complexity of this task, we Design a macro intervention plan to improve the water situation, targeting at one specific region. We determine the influential degree of factors in causing water scarcity. We develop our intervention plan by controlling these influential factors. Thus, we can draw recommendations for water stress from this process of analyzing water problem.

2. Intervention Plan on Four Facets

By establishing a quantitative method, We have found out the most influential factors influencing water scarcity in Xinjiang[1], They were surface water produced internally, total amount of wastewater produced by agriculture, industry and domestic, and water dispatch between regions. we focus on these 3 factors to find solutions to this tricky task. Thus, we design our intervention plan based on cultivated land, Surface water and groundwater produced internally and policy on water dispatch.

2.1 Intervention Plan on Four Facets

- **Dispatch Water Resources**

Tibet is rich in water resources and is also geographically close to Xinjiang. Chinese government initiates the Tibet-to-Xinjiang Water Diversion Project in recent years to release the water problem in this region.

We assume that the quantity of water dispatched from Tibet is the same with the quantity of water going to Xinjiang, regardless of the loss along the way.

Figure 1: Tibet-to-Xinjiang Water Diversion Project in China

- **Employ Advanced Irrigation Technology**

Since Xinjiang has a vast land of irrigated agriculture, the irrigation consumption of water is a considerable amount. As a result, to improve the irrigation methods there will help a lot in saving water.

We define Relative Cultivated Land *RC*. *RC* represents the cultivated area can be irrigated by a certain amount of water, with common irrigation technology.

Advanced irrigation technologies like sprinkling irrigation and drip irrigation reduce agricultural water use per capita cultivated land. This means the drop of *RC*.

- **Proper Pricing Mechanism**

In Xinjiang, the water prices have long been subsidized by the government. The low price of the water encourages overuse in water. Thus, eliminate the subsidy in a proper way together with smart pricing mechanism which prices water according to their consumption.

- **Recycle the Waste Water**

The sanitation infrastructure in Xinjiang is not well built, combined with few rehandling of the waste water. This causes huge amount of waste of recycling use of water.

2.2 Simulating intervention plan on System Dynamic Model

- **System Dynamic Model**

we define Z as the index measuring the ability of one region to meet its water demand. The index showing to what extent the region is capable of meeting the water demand of its population. The higher of Z is, the stronger ability of a region is. The smaller the Z is, the more likely is for a region to have water scarcity.

When we consider factors in the whole eco-system that cause water scarcity, together with the intervention plan on a macro scale, it is really a tricky task. We have to take into account the influence caused by intervention plan on the index Z in one region and surrounding areas. The relation between these intervention plan and water situation agrees with the characteristics of non-linear feedback system.

System Dynamic Model[2] is one of these systems. It excels at handling complicated, non-linear and multi-loop feedback problem with multiple factors. We thus introduce System Dynamic Model to simulate the impact of the intervention plan on the index Z.

Step 1 Set boundary for system

This model includes all the factors that affect the supply and demand of water, we set model boundary which contains all the 16 factors we have discussed above.

Step 2 Denote variables in the model

We have to decide relevant objective variables, state variables and control variables.

The goal of our model is to analyze the impacts of the 4 intervention factors on the index Z. Objective variable refers to the final goal of the model, thus the value of index Z is objective variable.

State variables are accumulative. In the system, 11 factors including Long-term average precipitation, NRI, IRWR, GDP, HDI are increased at a certain growth rate during the simulation.

These 11 factors thus serve as state variables.

Control variables are set for assuring the realization of the systematic goal. It works when it controls some values of variables. In this way, factors like internal surface water, Water consumption per capita and *RC are as* control variables.

Step 3 Depicting Flow Graph

The internal structure of the system and the interrelation between the variables needed to be explicitly demonstrated. What's more, we need to describe the feedback performance and cumulative effect. Based on the analysis on the characteristics of variables, we design the Flow Graph of the model.

The graph is as follows:

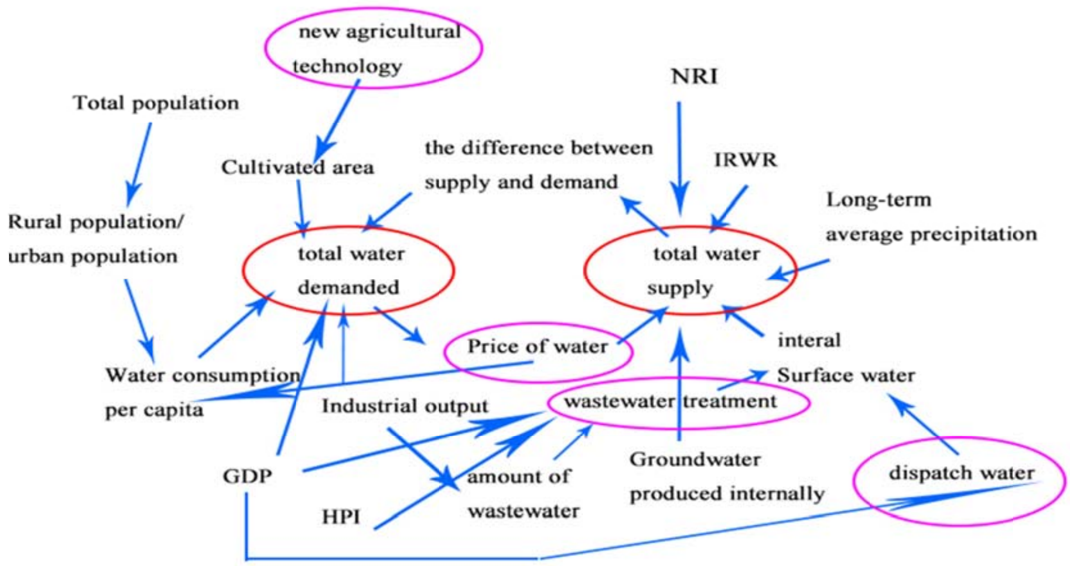

Figure 2: The Flow Graph of System Dynamic Model

The red circles are the objective variables, while the purple circles are the 4 intervention factors. The arrows refer to the contributing interrelations. There are different flow-in and flow-out for each circle, indicating the complex relations between these variables.

➢ **Result and Analysis**

In order to find out the way our intervention plan affects the index Z, we sort out the relations between these factors and find relevant information.

Dispatch water resources: During the simulation, the water dispatched from Tibet come to supplement the surface water in Xinjiang, adding to its total water supply. Thus this intervention plan enhances the index Z.

Employ Advanced Irrigation Technology: With the introduction of irrigation technology, it directly reduces the *RC,* decreases the total water demand. In this way, this intervention plan improves the index Z.

Proper Pricing Mechanism: According to basic economic theory, proper higher price will discourage water consumption per capita, decreases the demand of water in a direct way.

Recycle the Waste Water: Making the waste water into recycle expands the water supply in many aspects indirectly. The recycling water comes into supply sources for second use.

In conclusion, our intervention plan on four aspects will surely produce positive effects on water situation in a sustainable way.

2.3 Validity on intervention Plan by Prediction

➢ **How Intervention plan Affects Water Availability**

Specific attention is given to the influence of our intervention on the water availability. Since we can measure the ability of one region to supply water to its people, we determine this index is related to water availability.

So we predict the index Z from 2015-2030, using 3 different prediction methods for forecasting based on different principles, they are Grey Model[3], Cubic Exponential Smoothing Method[4], El Nino Periodicity model for Rainfall Volume[5]. We assume the intervention takes effect in late 2014, then we use System Dynamic Model to simulate the trend of Index Z after the intervention plan begins to take effect. We get the following graph.

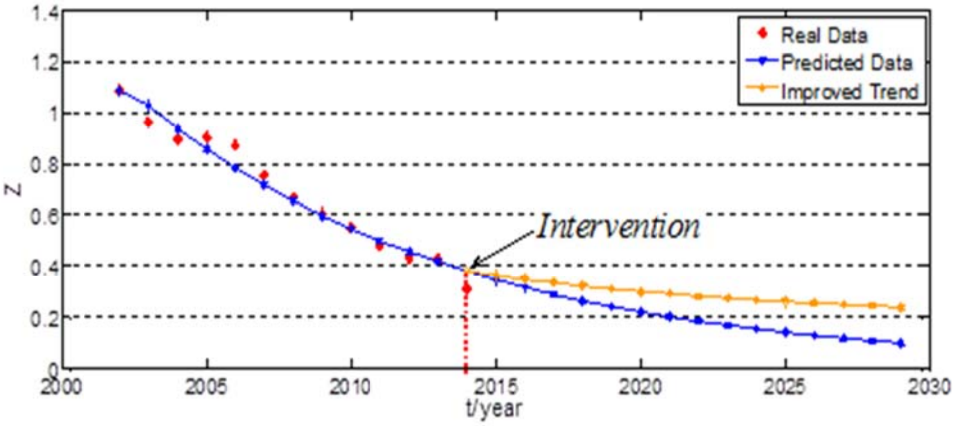

Figure 3: The impact of Intervention plan on index Z in the next 15 years

In the **Fig.3**, the red dotted means the time when intervention begins to take effect. The blue curve and yellow curve after the red dotted respectively refers to the prediction value of index Z after intervention.

We could see clearly the deviation between the prediction results, the intervention plan increases the index Z in a certain range. This picture illustrates the positive effect of our intervention plan.

Still, these trend of the two curves are in down turn, indicating the decrease of index Z with time. Specifically, the value of index Z is will be below 0.4, means the water situation will be described as worse than water shortage according to **Tab. 4**.

To conclude, chosen region become less susceptible to water scarcity because of our intervention plan. However, water will still become a critical issue in the future.

➢ **How Intervention plan Affects Surrounding Area**

Since the eco-system is related, the water situation in one region will surely influence that of its neighbor.

Although we have examined that the water dispatch plan will do good to Xinjiang, we are not sure about what happen to Tibet. We take Tibet as an example to see what impact has done by the intervention plan. Still, we make predictions about the index Z in Tibet, using data of the 16 factors before 2014.

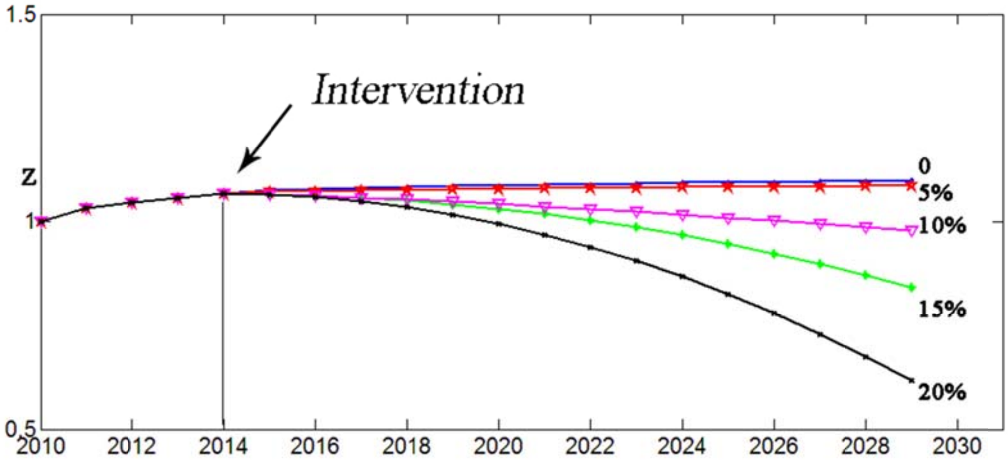

Figure 4: The impact of Intervention plan on Tibet in the next 15 years

In **Fig.4**, the different curves of different colors represents when a certain proportion of water (5%,10%,15%,20%) is dispatched to Xinjiang. We could see the greater proportion of the dispatched water is, the smaller the index will be.

To sum up, the intervention plan in Xinjiang will affect Tibet in a negative way.

3. Conclusion

All our work is done to offer recommendations for releasing water scarcity.

There are multiple factors involved in water scarcity, it is not a mono-discipline problem but an interdisciplinary one. It needs to be solved by talents that have a good grasp of different disciplines.

- **Improve management in agricultural consumption:** Since the agricultural consumption accounts for 70% of the world's water resources, it is urgent to find out controlling methods in this field by seeking scientific management.
- **Smart economic pricing mechanism:** Efforts to update price structures are needed. Prices based upon the quantity of water consumption and different water quality (recycled water, rain water)are encouraged to make the full use of water resources.
- **Advocate technology for recycling:** Advanced technology such as desalination plants or rainwater harvesting techniques needed to be invented and upgraded. For it promotes sustainability and second use of water.

References

[1] Water resources in Xinjiang. National Bureau of Statistics of China. [Online]. Available: http://www.stats.gov.cn/english/Statisticaldata/AnnualData/

[2] Qiang Wei, "The System Dynamic Pricing Model Research of Sustainable Water Resources Utilization in Changchun City". Diss., Jilin University, 2012.

[3] Zhihua jiang, Guobao Zhu. "Grey forecast model GM (1, 1) and its application in the traffic freight volume forecast." journal of Wuhan University of Technology 28.2 (2004) : 305-307.

[4] Shoukui Ci, Xijing Sun. Mathematical modeling algorithm and application[M]. National defence industry press, 2011.

[5] Daoyi Gong, Shao Wu, " ENSO's Influence on Precipitation in Global Land Dur-ing Last Centry". Chinese Science Bulletin. 44.3(1999):315-320.