Swimming in Issues: A Guide to Dealing with Chinas Water Problems

Water, Water, Everywhere

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Abstract

In this paper we present models for projected water needs in China, and examine some of its major problems associated with water. Chinas water use can be broken down into three main categories: agricultural, industrial, and domestic. We model these individually by analysing recent data and extrapolating it into the near future, and by examining policies on water use. The result is a picture of how much water China will need in 2025, but more importantly how much water of varying purity is needed. This is important due to the large amounts of pollution in Chinas rivers and ground water. We use our model to analyse China's current water strategies and evaluate potential solutions.

Contents

1 Introduction

In this paper, we present a computerized mathematical model for planning water strategy that fits to current government situation. Since China is a very big country with variety of problems and different situations in each individual provinces involving water, we decides to put importance on water sanitation and supply for specific areas such as Beijing provinces and Shanghai provinces. The beginning of our paper will be description of our theoretical framework of measuring future water needs and outline of our computer implementation. The later section of our paper will present another mathematical model calculating the cost of water sanitation. Lastly, We will present specific example regions where the solution for problem is eminent and application of our model. This is rough outline of our approach:

- **Calculate projected water needs** by predicting population, agriculture, and industrial growth.
- **Calculate projected waste produced** using previously estimated water needs as water consumption to estimate the cost of sanitation.
- **Discuss specific region** such as Yangtze River region, Yellow River, and Capital city region..

1.1 Assumptions

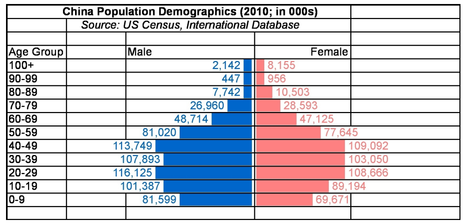
Due to the large variation of

2 Projected Water needs

The total annual water consumption of China is modelled by adding together the results of the models for domestic, agricultural, and industrial water use. We used Matlab to analyse data and produce plots.

2.1 Population Growth and Expected Water necessity

We constructed our model based upon the data involving the whole China. We presents some demographic data for the year 2010 in China: Our model has this data stored in a vector that is then multiplied by a matrix called A to produce the population demographic for the next year. This is done several times to generate the population over time. A advances the age of the population by taking 10% of the people in each age group and puts them in the next one. It also automatically kills off some of the population in a weighted matter so that older people are much more likely to die, and men are slightly more likely to die than women in their age group. The average age of first time mothers in China was 31.6 years old in 2000. Thus we assumed that the number of children born each year is equally dependent on the number of women in their 20s and 30s. A also accounts for the fact that about 1.13 boys are born for every girl in



Age Group	Male	Female
China Population Demographics (2010; in 000s)		
Source: US Census, International Database		
100+	2,142	8,155
90-99	447	956
80-89	7,742	10,503
70-79	26,960	28,593
60-69	48,714	47,125
50-59	81,020	77,645
40-49	113,749	109,092
30-39	107,893	103,050
20-29	116,125	108,666
10-19	101,387	89,194
0-9	81,599	69,671

Figure 1: China demographic 2010

China. However, not everyone uses the same amount of water. People living in urban areas use about three times as much water as people living in rural areas do. It turns out that Chinas urbanization rate was about 50% in 2010, and it is increasing by about 0.9% annually. Policy makers in China want to keep it that way, so we assume that it will. Then to calculate the total domestic water use, we use this equation

$$DWU = pop * (dwcppu * (urbrate) + dwcppr * (1 - urbrate))$$

Where DWU is annual domestic water use, pop is the population as calculated by using A, dwcppu is the water use per person in urban areas, dwcppr is the water use per person in rural areas, and urbrate is the rate of urbanization. This is the plot of DWU over time:

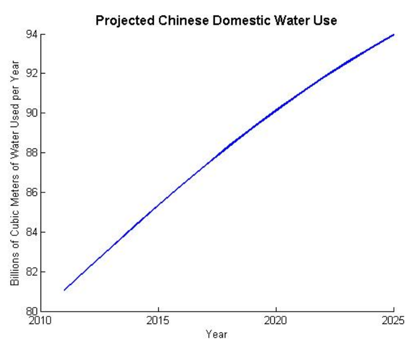


Figure 2: population water use

2.2 Agriculture Growth and Expected Water necessity

In recent years Chinas water use for agriculture has been in decline. This is caused by urban expansion, loss of farm land to natural disasters, and some improvements in irrigation techniques. The decline is small, and Chinese policy makers are unlikely to allow continued net loss of farm land in the years to come as the population is still increasing. With all these factors, and poor data on future policies, we are unable to determine with confidence if agricultural water use will increase or decrease in China over the next 12 years. Thus we assume that the water use remains constant over the next 12 years at about 360 billion cubic meters of water per year.

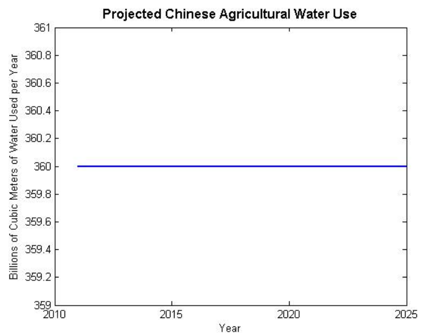


Figure 3: agricultural water use

2.3 Industrial Growth and Expected Water necessity

For the last ten years or so industrial water consumption has grown by about 3% annually. Thus we modelled it with an exponential growth model:

$$IWU = 130\ billion\ cubic\ meters\ of\ water\ per\ year * e^{0.03*t}$$

where IWU represent for the industrial water usage and t is the time in years since 2010, and 130 billion cubic meters of water per year is the amount of water used in 2010 by China for industrial purposes. Here is the resulting plot:

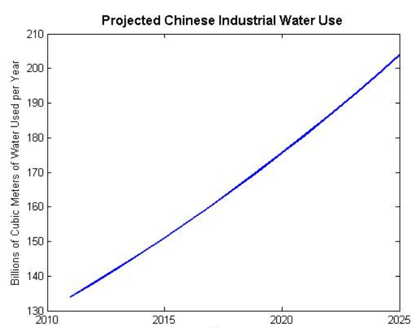


Figure 4: industrial water use

2.4 Total Water Needs

Thus we have the total water use annually in China over the next 12 years:

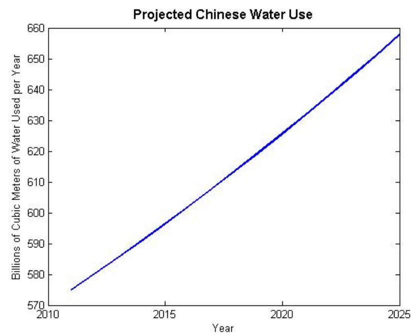


Figure 5: total water use

2.5 Current Storage Situation and Future Needs

After calculating all the projected water needs in 2025, we compare this result with current water situation.

3 Strategies

we first introduce

3.1 Water Purification and De-salinization

3.1.1 Capital Area

South-North Water Transfer Project is a multi-decade infrastructure project to better utilize water available to China. Plan to transfer 44.8 billion m^3 water from south China and intend to solve 7 million people's drinking water problem.

The project consists of three parts: east route, middle route and west route. While the east route was already finished, middle route is going to be completed in 2014, the west route is still under discussion. Though for the middle route, water would flow automatically, there's a need to pump water to a higher place to achieve the transfer. So, it rises a question: how much energy will it cost and should we consider this plan logical?

Within existing data, there's a difference of 40 meters from the canal to the Yellow River. The strategy here is to set 13 pumps with a 65 meters spread to bring the water up the step with 17 others on the branches. Together can pump $10,200$ m^3/s, power 10.1 million kilowatts. And the annual water flow of the east route is 14.8 billion m^3.

The basic efficiency formula is given by:

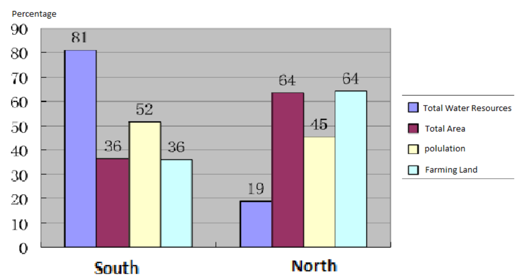


Figure 6: why move water for south to north

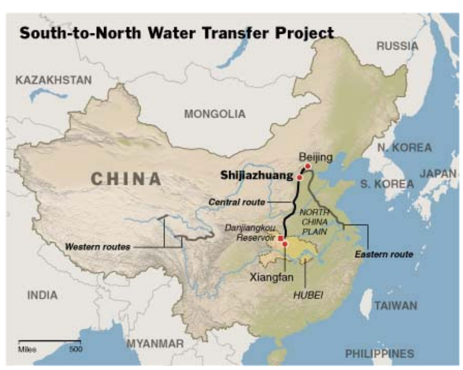


Figure 7: The South-North Water Transfer Project

$$\eta = \frac{W_{effective}}{W_{total}} = \frac{P_{pump}}{V_{flow} h_{step}}$$

where P_{pump} is the power of pumps, V_{flow} is the volume of water being pumped in a second, and h is the height difference between steps.

After that, we can get the waste of energy of the pumps annually given by:

$$W_{extra} = \frac{V_{annual}}{V_{flow}} \eta W_{total}$$

After calculation, we get result 407 $million\ kW \cdot h$.

3.1.2 Yellow River Area

There is one million tons of sand being dumped into ocean annually form Yellow River which is like create a new foot ball ground a day in the sea. However, Yellow River is not 'yellow' from the very beginning. As shown, 90 percent of the sand of Yellow River's sand comes from its middle branch, and most of it comes from erosion when the river passes Loss Plateau.

LOCATION	FLOW AREA(square kilometers)	SAND
Upper Branch	386,000	8%
Middle Branch	344,000	92%
Lower Branch	23,000	

Figure 8: Sand Percentage for Yellow River

Figure 9: Position of Loess Plateau

To prevent erosion the traditional sulotion is to plant trees to hold the soil. We mainly consider two different type of trees: Deep root trees and Shallow root trees. Since deep root trees are more likely to survive in the harsh environment of Loess Plateau, they're the main type used to hold the soil in dry areas. The deep root trees which Chinese government currently uses have servival rate of 90% and annaul height increase of 3 meters with maximum height of around 20 meters. The root that can effectively hold the soil is within the spread of a circle with diameter equal to the tree's height, the total number of trees we need on the Loess Plateau will be estimated as:

$$N_{total} = \frac{S_{erosion}}{S_{root}}$$

With the known erosion area to be 750,000 square kilometers, and a mature trees effective root spread area to be $315m^2$ approximately, the suppose number of trees to cover in this area will be around 24 million.

Since the forest coverage of the plateau is less than 5%, then we have formula for the trees we need to plant:

$$N_{need} = \frac{N_{total}(1 - R_{coverage})}{R_{survive}}$$

where $R_{coverage}$ is the percentage of forest coverage and $R_{survival}$ is the rate of survival for the trees. The result is 25.13 million.

To calculate the cost, we use the data of expense for farming use trees (Since baby trees hardly survive by themselves). According to research, the cost through the trees become mature(around 7 years) is 12,094 *yuan*(1950 US dollars) per *mu*(666.7 square meters). Further more, the density for farming trees is about 60/mu, thus we have:

$$C_{total} = \frac{C_{unitArea}}{N_{unitArea}} N_{need}$$

The result is about 5.1 billion yuan (round 0.82 billion US dollars).

0.82 billion dollars seems to be a good deal if it's possible to control the local erosion. However, this is even less than a base number, there're still countless factors like storms(frequent and strong as characters), illegal logging(quite common in the area) and we can't plant all the trees in one day... A more proper but still an underestimate model is goint to be:

$$N_n = N_{n-1} R_{survival*}(R_{storm}) - N_{logging} + N_{plant} R_{survival}$$

$$C_{total} = \sum_{1}^{n} C_n(N_n)$$

This is a recursive function on annual basis which terminates at N_n exceeds our goal number. Thus, the whole project is quite not likely to be finished in 10 years, instead, probably takes decades.

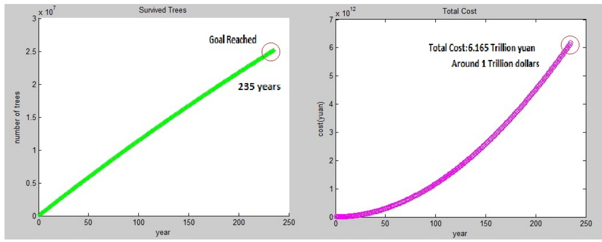


Figure 10: Sample Simulation

3.1.3 Yangtze River Area

About one third of the industrial waste water and more than 90 percent of household sewage in China is released into rivers and lakes without being properly treated. Major water supply in china, Yangtze River has become too polluted such that Shanghai and other cities near it pumps water from far upper part of the river.

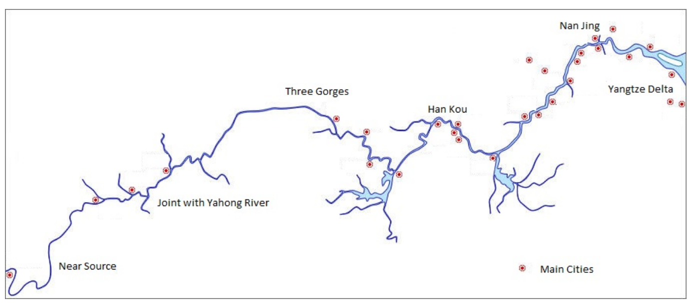


Figure 11: Flow Map

4 References

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