The crises of water and population: The case of central Iran

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Abstract

This paper is about the shortage of water resources in the central part of Iran -Isfahan while the region faces rapidly growth of the population. The study utilizes the system dynamics approach. The model consists of the following three main parts: water consumption, water resources and population. We will account for the current policies and the current population growth rate in hope of preventing a catastrophic failure in less than two decades from now. So, emigration, birth control policies and major changes in consumption style are evaluated.

Keywords: *System dynamics, Iran, Population crisis, Water crisis*

1. Introduction

The issue challenging developing countries such as Iran is the ever diminishing water resources on one side and the high rate of population growth on the other side [1]. Global warming exacerbates this problem since the amount of water resources decreases drastically as the earth becomes warmer. Sixty percent of the world's population is living in Asia, but only about a third of the world's water resources are in this area [2]; almost all Middle East countries face both crises of rapid population growth and limited accessible water resources. This implies the need for planned and correct management of these resources to compensate for the water shortage. In fact, according to the final report of the 3rd world water forum, main reasons for the crisis include both the lack of water and the way its use is managed [3].

In this paper, we describe a system dynamics approach to analyze the level of underground water resources and population growth of Isfahan-Borkhar, in the central region of Iran. A permanent solution for this problem should be based on a dynamic and general approach, because by following this approach we can study feedback of human activities, changes in ecosystem and social and economic factors; so we can analyze possible solutions. In this model, the trend of water resources and consumption behavior and some other effective factors, such as the population, have been considered. This model can be used in supporting future urban planning decisions in other cities.

Isfahan, a large city in the central part of Iran, deals with socio-economic development and the lack of adequate water resource. One main reason for population growth is the higher GDP of the region compared to the neighboring cities. Located in a semi-dry region the region already had problems to supply enough water for the population; high rates of birth and immigration happened fast enough to overtake any action to provide water.

The study goes back to J. Forrester who integrated the population and available sources to study limits to the growth of a city [4]. The demand for water is associated with industries, population, agriculture, non-renewable sources and pollution [5]. An optimum allocation based on system dynamics approach is presented for San Juan catchment, Mexico [6]. Water management based on a combination of surface and underground waters have been studied in [7] for Bear River. Salavitabar et al develop a dynamic model for Tehran water resources and present solutions for managing the water in this region [8].

In this paper we take the classical steps of the SD approach for the present case. At first, we will discuss the importance of underground water resources in this region, then we develop our descriptive model to better define the problem, followed by presenting the system boundaries and sub-systems of the model. Finally we will present possible policies and their effects on the system in the course of time.

2. Underground water resources and supplying water for the region

Inspired by Forrester's model in urban dynamics, we can divide the water consumption into three main sectors: agricultural, industrial and domestic uses. With the rapid population growth, the share for domestic use becomes larger and for industrial and agricultural uses become smaller. The most common solution to supply more water is to use the underground water resources. But this solution causes a huge drop in the level of underground water resources such that the aquifer cannot recharge them as according to the local data, an annual drop of 0.5 meter has been observed for decades now.

According to the data provided by the Mourchekhort meteorological station located in the region, as presented in figure 1, an increase in evaporation and a decrease in the rainfall can be seen during 1972 to 2010 [9].

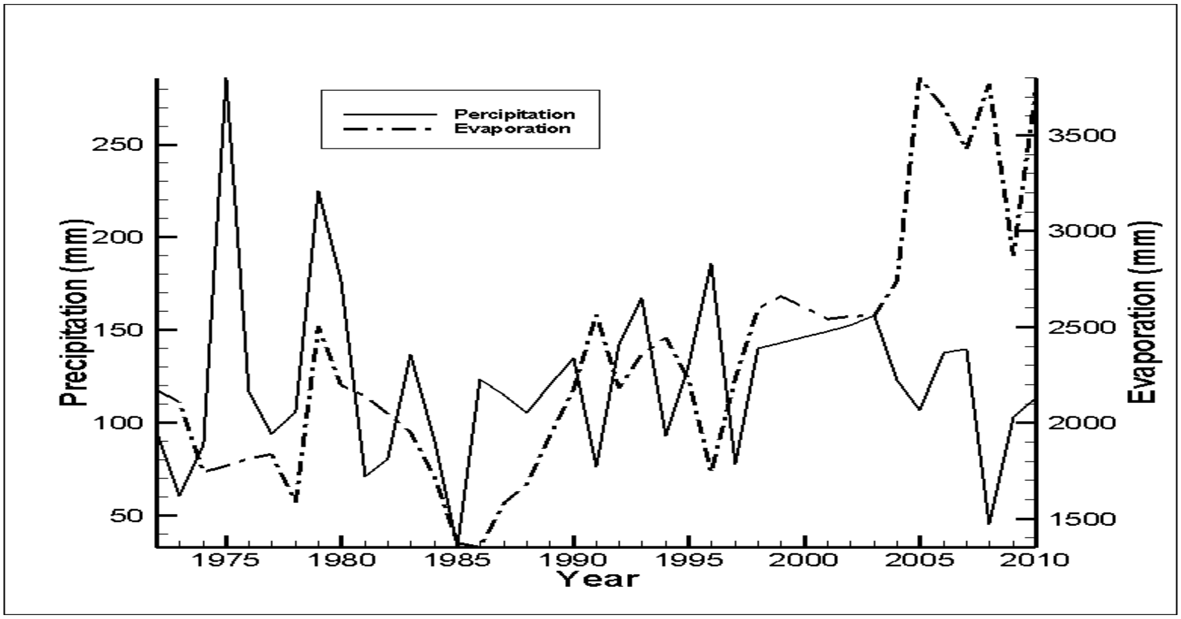

Figure 1- Precipitation and evaporation in Mourchekhort station from 1972 to 2010

According to figures 2 and 3, an almost monotonic increase in the mean, maximum, and minimum air temperature for the hottest month of the year can be seen [9].

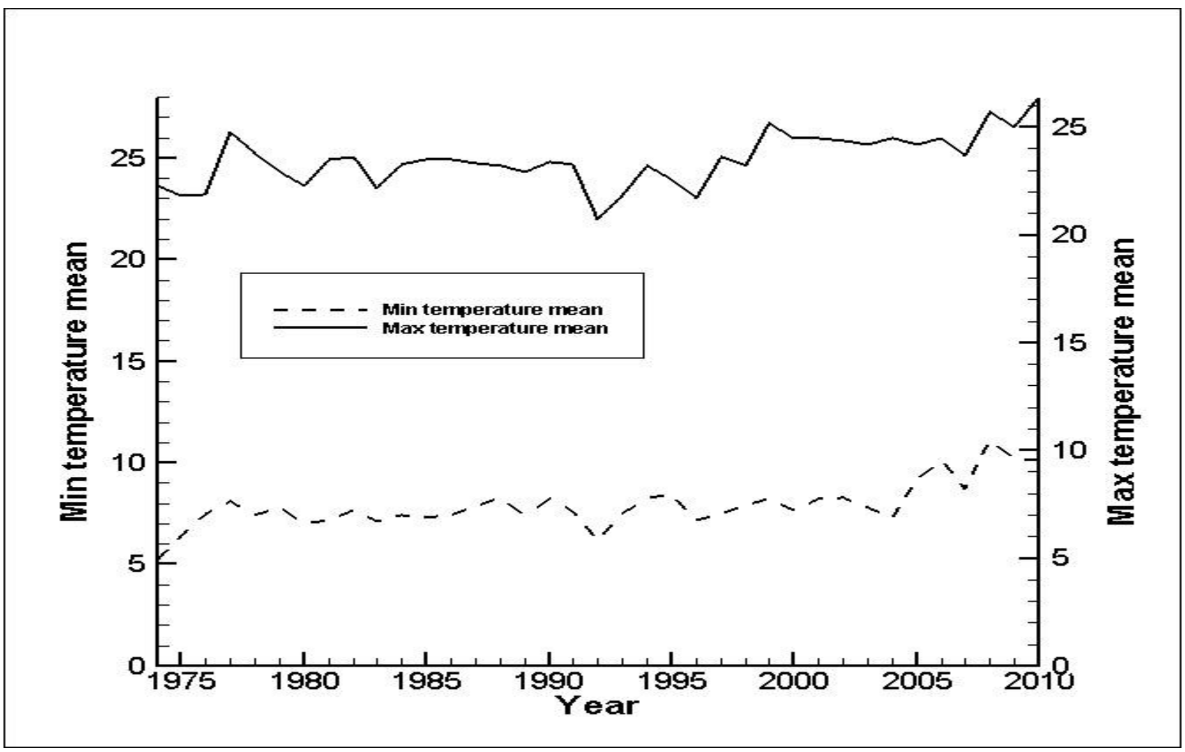

Figure 2- Average of Max & Min temperature (°C) in Mourchekhort station from 1974 to 2010

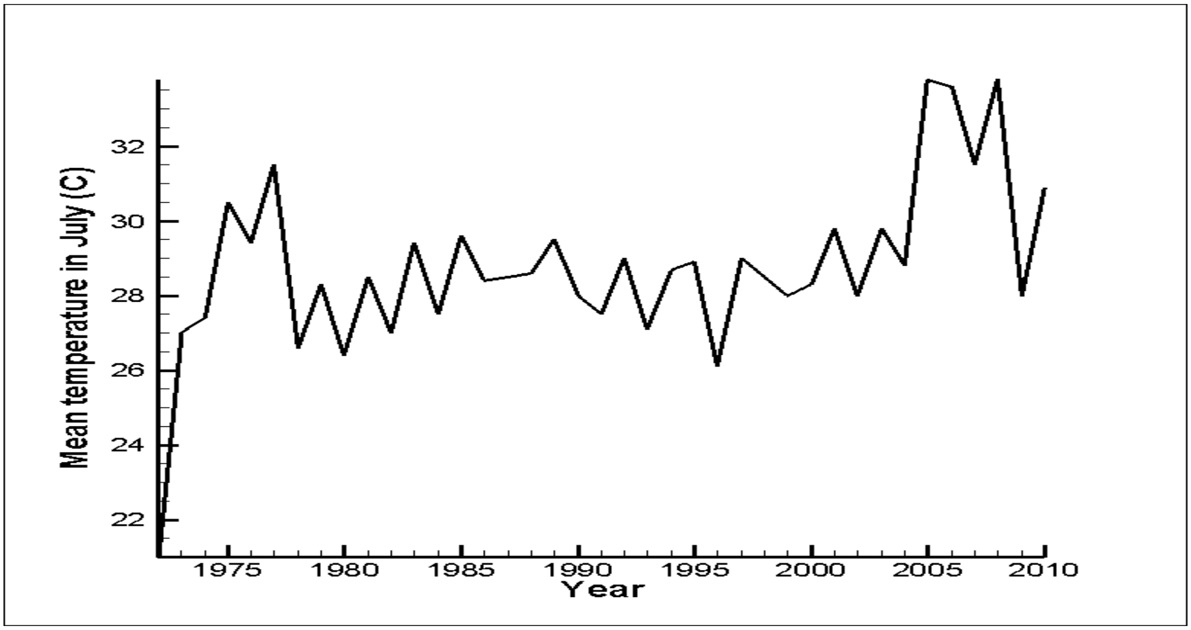

Figure 3- Mean temperature in July (°C) in Mourchekhort station from 1972 to 2010

As figure 4 shows, the humidity has been decreasing year by year [8].

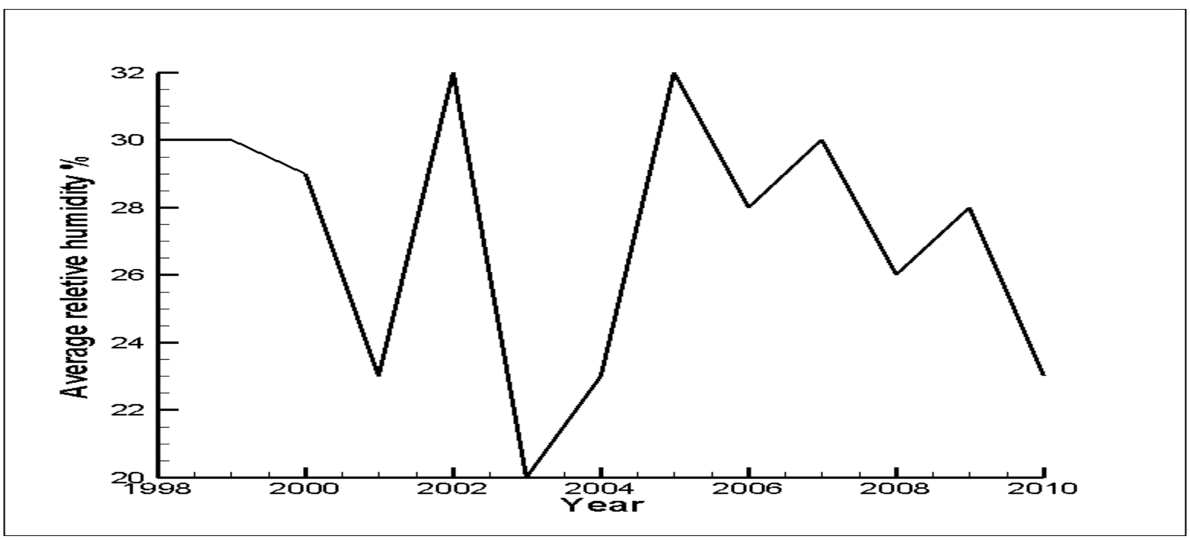

Figure 4- Average relative humidity (%) at 12:30 pm, in Mourchekhort station from 1998 to 2010

The available surface water in this region has been reduced drastically and now there is a huge consumption from underground water resources. Figure 5 shows the rate of decrease in the level of underground water resources for 40 years [10]. So, this paper aims in defining policies to reduce the population in Isfahan-Borkhar region.

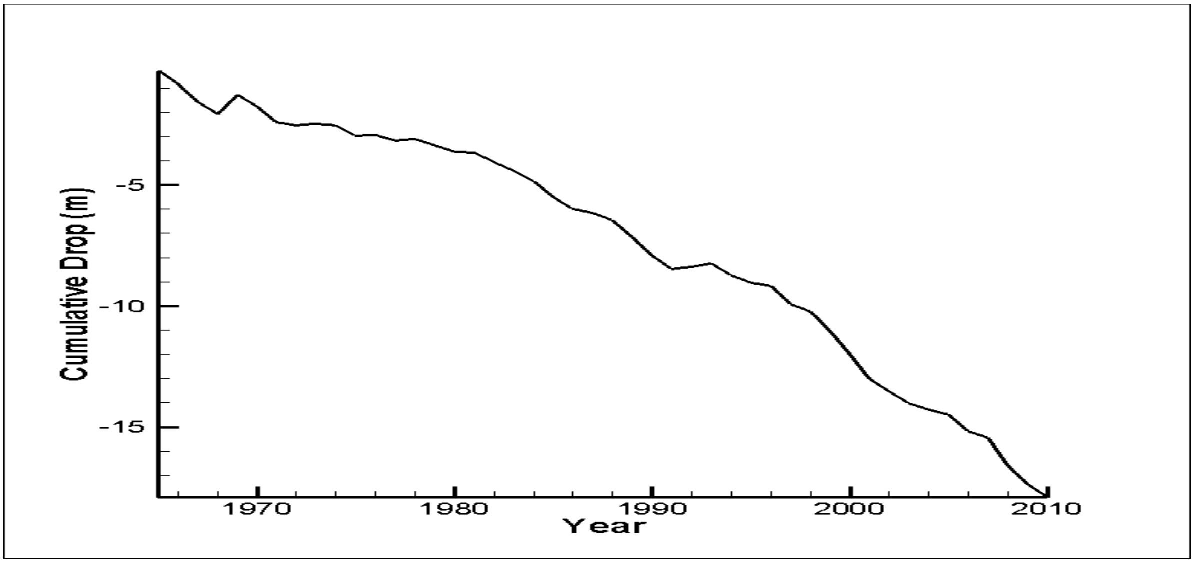

Figure 5- Drop rate of underground sources in Iran from 1965 to 2010

As all figures so far indicate, the rainfall has been decreasing almost monotonically and the temperature increasing. On the other side of the story, the population enjoyed rapid growth during the 1980s due to the high birth dare then due to the migration to big cities. Figure 6 shows the population growth in the city of Isfahan from 1956 to 2012 [11] as well as the predicted number until 2026. Currently, the population in Isfahan-Borkhar region is close 300,000 while the annual family income is only 7000 US$. The average family size is 4.2. Due to the dry nature of the region, similar to almost all the central parts of Iran, the increase in population and decrease in the rainfall mean extremely difficult conditions for the inhabitants. The neighboring regions have already the same problem and there is no surplus of water in any region to be transferred to the others. Therefore, it seems that the policy should focus on birth rate, migration trends, and the consumption behavior.

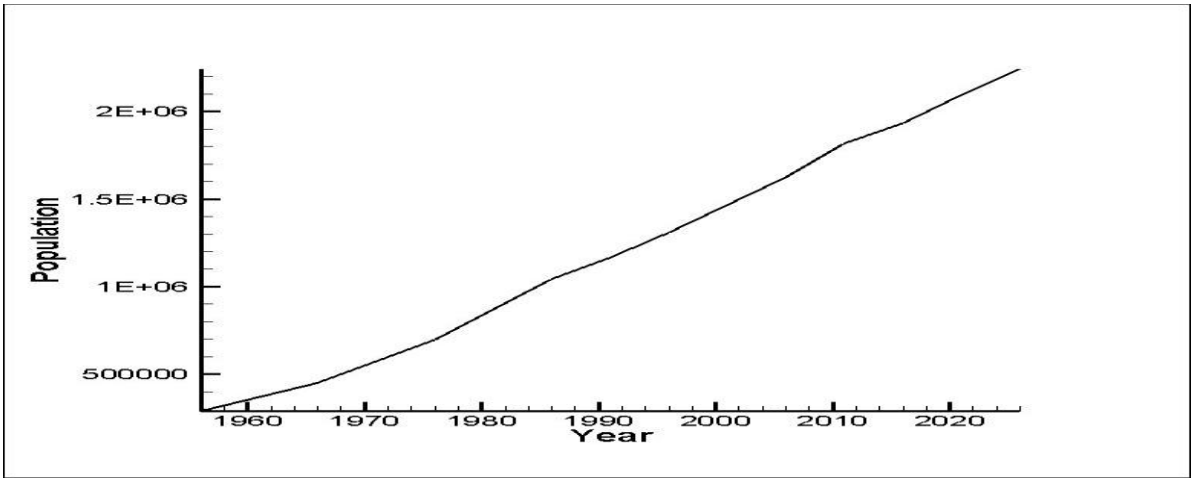

Figure 6- Population of Isfahan city from 1956 to 2026 (Anticipated)

3. System Boundaries

Isfahan-Borkhar region located in northern part of City of Isfahan, the area is about 2,459 square kilometers. 1,813 square kilometers of this area is plain and the rest is mountainous. Water is consumed for agricultural, industrial and domestic uses. The analysis considers the natural and social changes of the system up to 2026.

4. The structure of the model

4.1. Underground water system

This system covers auxiliary parameters such as rainfall minus the evaporation (RER: Reduced Evaporated Rain), and aquifer and ground percolation rates. 99.4 percent of the underground water comes from wells and the rest comes from springs and subterranean [9].

4.2. Surface water system

This system consists of auxiliary parameters that define how the water is provided from current sources by a specific pattern. These parameters are Borkhar plain area, height of the precipitation, volume of the precipitation, evaporation, the RER, seasonal rivers and ground cross rate.

4.3. Population

Population is the main reason for water demand in this region. This subsystem consists of population, birth rate, death rate and migration input and output.

4.4. Water demand

This consists of agricultural, industrial and domestic demands. Agricultural demand covers the agricultural lands and the pattern for consuming water for each hectare. Industrial demand consists of industrial units and the amount of water demand. Domestic demand is affected by the population of the area. About 95 percent of underground water resources are used in agriculture.

The model is presented in figure 7. Other variables used in the model are defined as:

GW: Ground Water
GWD: Ground Water Demand
BC: Birth Constant
DC: Death Constant
MIC: Migration Input Constant
MOC: Migration Output Constant

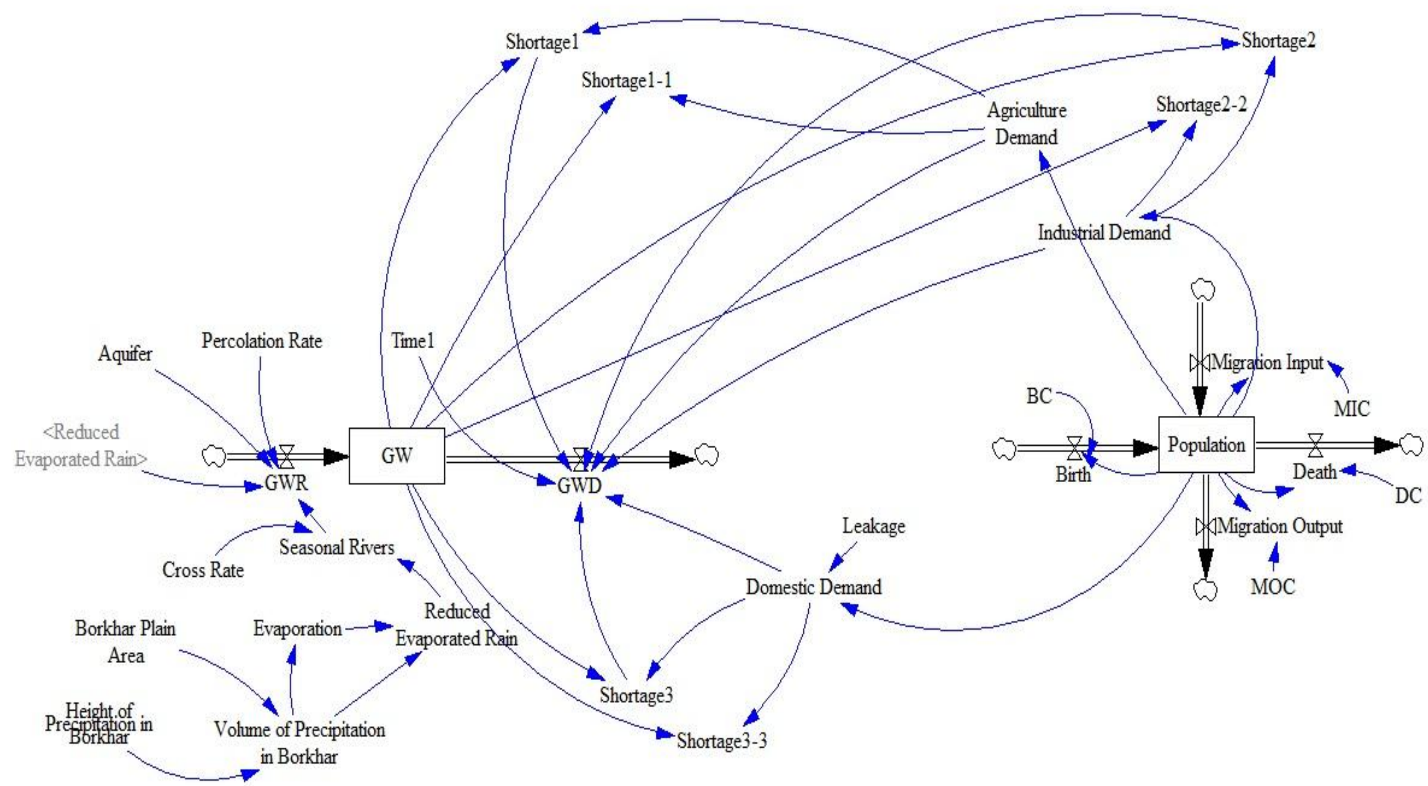

Figure 7- The model consists of two main sections: the population and the water resources.

5. **Calibration and verification of the model**

To check the validity of our model, we simply looked at the current data and checked if simulating based on the data of the past years could predict this year. The data of the last decade was used to predict the data of 2011. The agreement for the population and the water levels was acceptable (>90%) for system studies.

6. **Policies**

A rather expensive but sustainable policy is often to change the behavior of the agents involved in the system. To educate people to optimize their use of water takes time but is the most effective policy. Another policy can be through population control in this region. The measures that need to be implemented are through reduction of the birth rate by taking contraceptive methods and means. This can be implemented both by cultural changes and providing contraceptive facilities for free. Another policy is towards the consumption side, i.e., there should be no initialization of water consuming industries in the region, and the region should lose its attraction for work-seers. Figure 7 shows how rapidly the ground water levels goes down, and figure 9 shows how this can be controlled by both reducing the birth rate from 2.4% to 0.4%, and increasing the emigration rate from 0.3% to 1%. Obviously the available underground water cannot be negative and it will become zero around 2035.

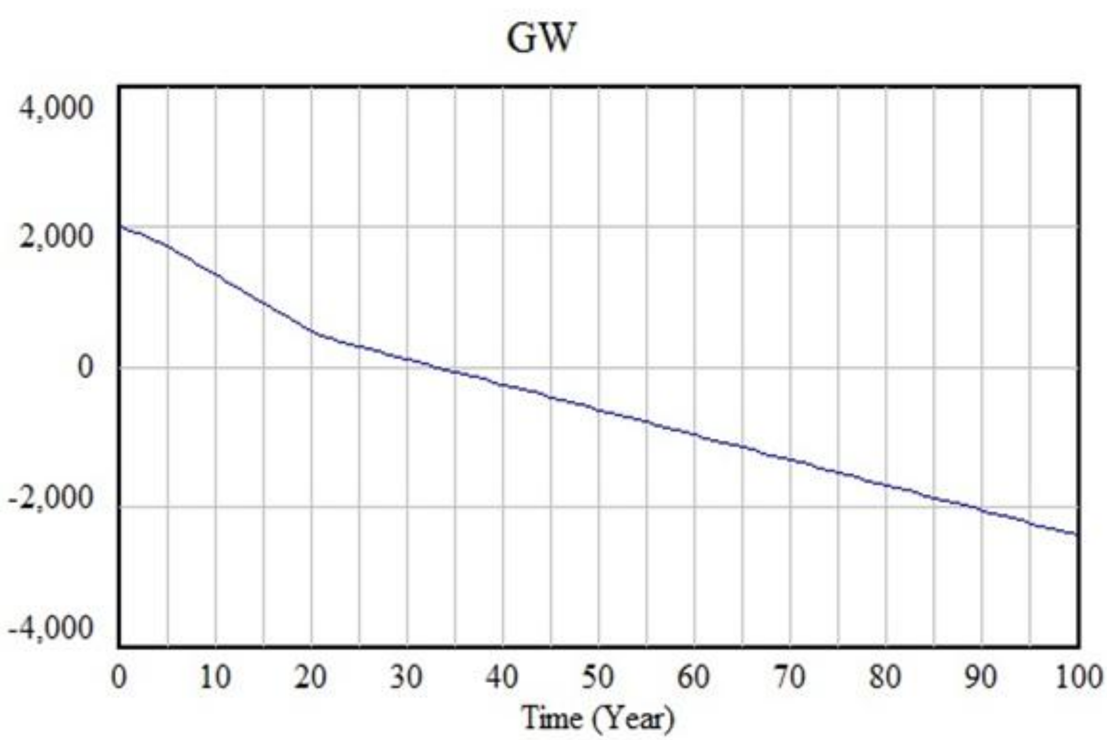

Figure 8- Available underground water resources (million cubic meters) before implementing the birth rate and emigration policies. The first year corresponds to 2002.

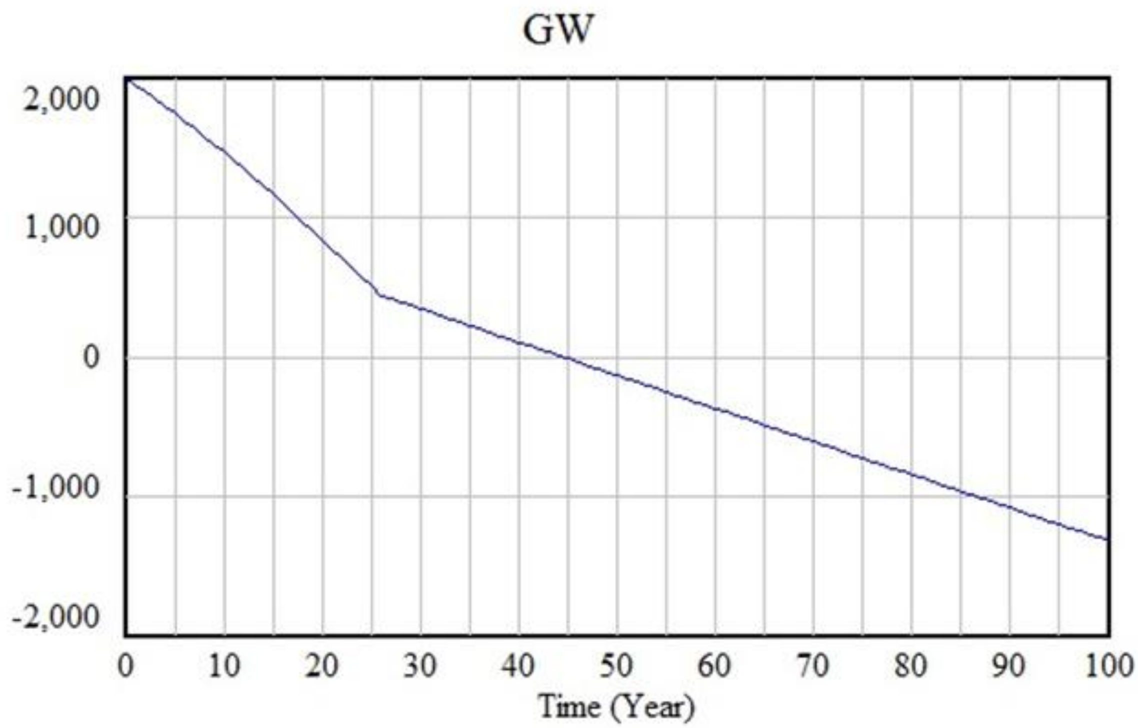

Figure 9- Available underground water resources (million cubic meters) after implementing the birth rate and emigration policies. The first year corresponds to 2002.

If the customers change their behavior in using the water in all sectors, e.g. agricultural, industrial and domestic, we can expect considerable changes in the behavior of the system too. For example let us consider the case when the domestic use is reduced by 30% which is just close to the developed countries. Figure 10 shows that even in this case the end of the line reaches thirty years later when the available water is almost zero.

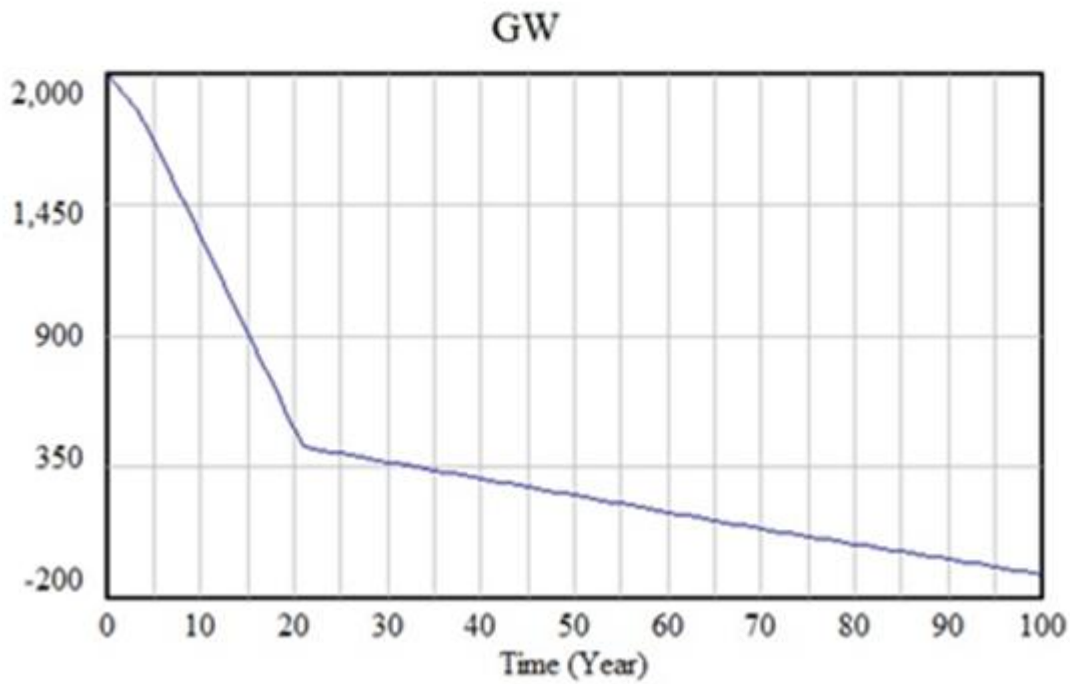

Figure 10- Available underground water resources (million cubic meters) after changing the consumption behavior. The first year corresponds to 2002.

Finally, if a combination of all policies mentioned so far is used, then the available underground water will not reach the zero limit, as shown in figure 11.

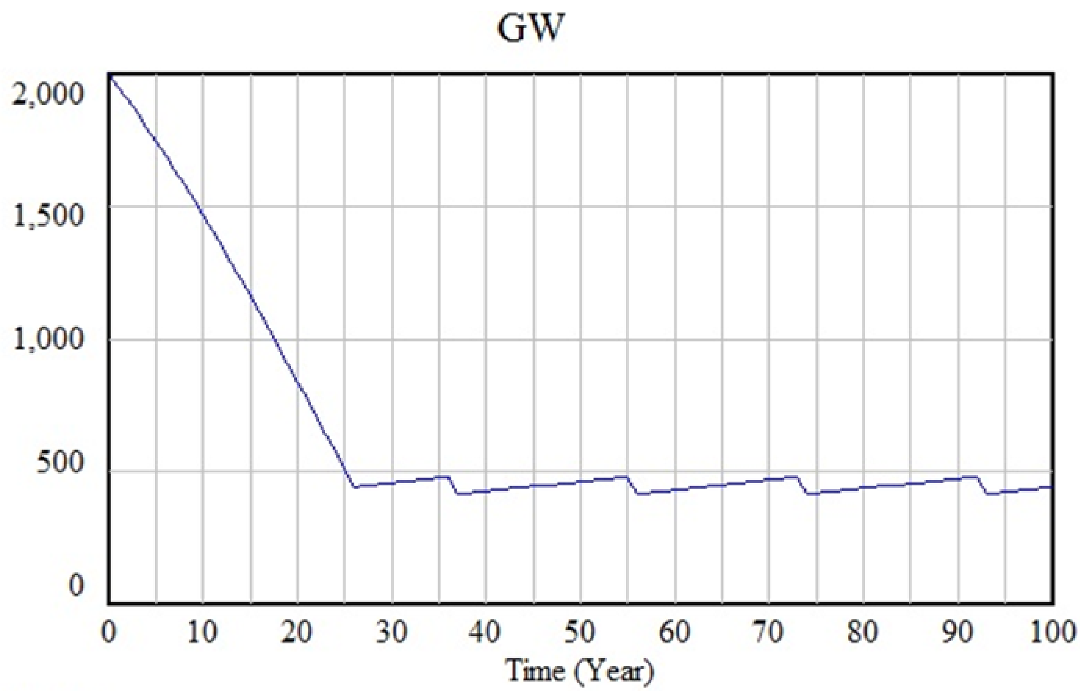

Figure 11- Level of underground water resources after implementing the second and third policies. The first year corresponds to 2002.

7. Conclusions

The region studied in this paper has a lot in common with most regions of Iran: a growing population needs more water, and the water is not available for them. Relying on the underground reserves is a short term remedy but as experiments and real life data show, the accessible underground water is diminishing rapidly and a big socio-economic disaster is expected in less than twenty years. To policy makers should react urgently by controlling the population growth and encouraging/teaching people to change their consumption behavior.

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