IMPACTS OF CLIMATE CHANGE ON GROUNDWATER

IMPACTS DU CHANGEMENT CLIMATIQUE SUR LES EAUX SOUTERRAINES

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ABSTRACT

Groundwater is the important water source for both domestic water supply and irrigation in north and northwest China. Due to over development of groundwater for decades, groundwater table has been continually declining in some areas, consequently surface subsidence and sea water intrusion were induced, and irrigation and drinking water supply in rural was affected. With climate change in the last decades this situation aggravated. Climate change induced the extreme draught and flood events more frequently, which presents a daunting challenge to groundwater management. With the aim to seek solution for safe water supply and sustainable groundwater management under climate change condition, a research project has been carried out in the pilot area of Cangzhou city, Hebei province. Based on the results of the project this paper analyzes the impact of climate change on groundwater by using statistical method based on the long-term historical data and generates future sceneries by developing and applying groundwater models.

Key words: *Climate Change, Groundwater management, Groundwater modeling.*

RESUME

L'eau souterraine est la source d'eau importante de l'approvisionnement en eau domestique et de l'irrigation au nord et au nord-ouest de la Chine. En raison de surexploitation des eaux souterraines depuis des décennies, dans certaines régions la nappe phréatique réduit continuellement. Tous ces facteurs donnent lieu à l'affaissement de surface et à l'intrusion d'eau de la mer, et affectent l'irrigation et l'approvisionnement en eau potable des régions rurales. Le changement climatique a aggravé cette situation dans les dernières décennies. Les changements climatiques donnent lieu aux événements extrêmes plus fréquents tels que les sécheresses et les inondations, ce qui pose un grand défi à la gestion des eaux souterraines.

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Un projet de recherche a été effectuée dans la zone pilote de la ville de Cangzhou de la province de Hebei pour rechercher une solution à l'approvisionnement en eau potable et à la gestion durable des eaux souterraines dans la condition du changement climatique. Compte tenu des résultats du projet, ce rapport analyse l'impact du changement climatique sur les eaux souterraines en utilisant la méthode statistique basée sur les données historiques à long terme et établit des scénarios futurs en développant et en appliquant les modèles d'eau souterraine.

Mots clés : *Changement climatique, gestion des eaux souterraines, modélisation des eaux souterraines.*

1. INTRODUCTION

With the rapid economic and social development, water shortage problem is getting more and more serious in many parts of China, particularly in north and northwest China. Groundwater is the important water source for both drinking and irrigation in most part of China. The total groundwater resources in China is 760 billion m^3, accounting for 26.8% of the total water resources in China. In 2008, the total pumping volume of groundwater was 60.9 billion m^3, accounting for 16.5% of the total irrigation water. Out of 700 million rural population, 460 million people use groundwater as drinking water sources, accounting for 65% of the total rural population (MWR, 2008). However, because of over development groundwater tables has dropped continuously in north and northwest China. Furthermore, with the effect of climate change the distribution of precipitation is getting more uneven in both time and space with recurring extreme draught and flood events, which reduced recharge to groundwater. The increased scale of possible impacts of climate change and over development of groundwater creates water vulnerabilities and risks to both irrigation and drinking water supply (UNESCO, 2006).

Significant research efforts have already devoted to the evaluation of climate change impact on surface water resources (Westmacott and Burn, 1997; Gellens and Roulin, 1998; Menzel and Burger, 2002; Beeton, 2002. However, as mentioned in IPCC report (Bates et al, 2008), very little research has focused on the potential effects of climate change on groundwater resources. To maintain sustainable development of groundwater under climate change condition, it is essential to monitor groundwater tables and analyze its trend by using the existing data and modeling technology (Serge et al, 2004. This paper analyzes the impact of climate change by using statistical method based on the long-term historical data and generates future sceneries by developing and applying groundwater models in a pilot area with the aim to seek solution for safe water supply and sustainable groundwater utilization.

2. DESCRIPTION OF PILOT AREA

Cangzhou city in Hebei province, one of the high alert areas in arid and semi-arid regions of Northern China is selected as pilot area, where serious groundwater depletion and deterioration already exist. The city has been suffering from severe water shortage problems for decades. Following the decrease of river flows, groundwater has become the major source of water supply for the area. Problems of groundwater depletion and pollution thus appeared due to over-exploitation together with industrial & domestic waste water contamination. Figure1 shows the location of the pilot area of Cangzhou city, Hebei province.

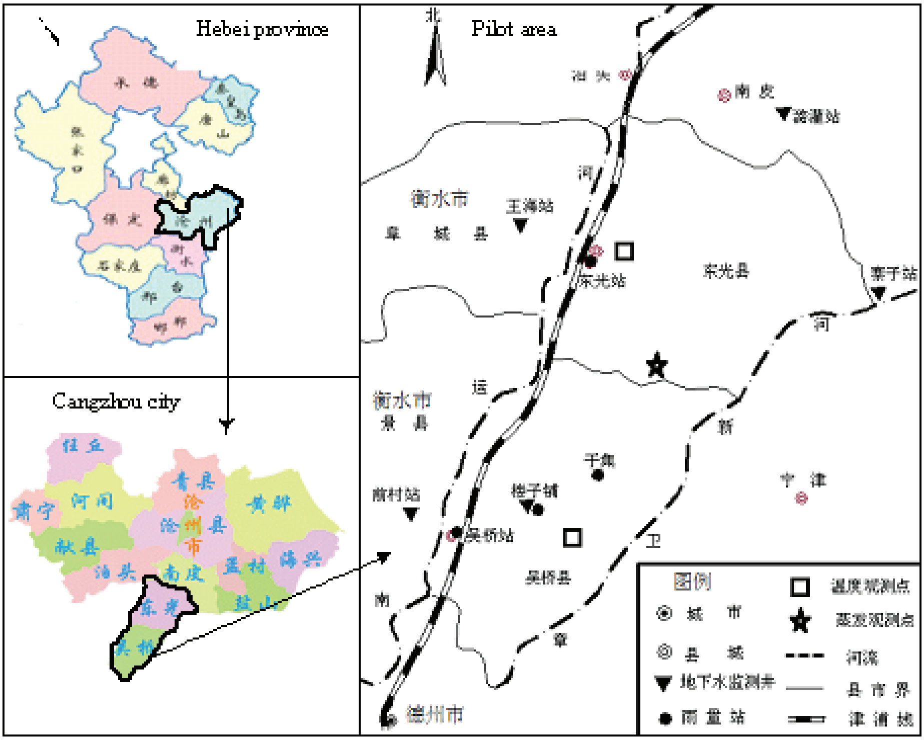

Fig. 1 Location of the pilot area of Cangzhou city, Hebei Province

3. METHODOLOGY FOR ASSESSMENT OF THE IMPACT OF CLIMATE CHANGE ON GROUNDWATER

Two methods were used to assess the climate change effect on groundwater and livelihood vulnerability. The first method is based on statistic method using long term historical data. The second method is based on developing and applying groundwater model to predict the impact of climate change on groundwater in the future. The chart 1 shows the relationship between the two methods.

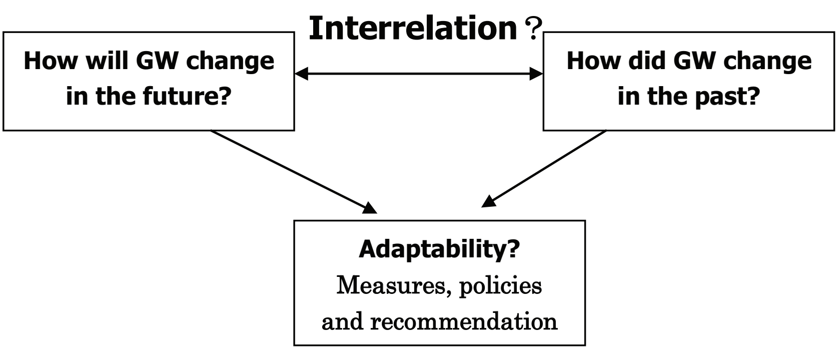

Chart 1 The relationship between statistic analysis and model

3.1 Analysis of the impact of climate change on groundwater by using statistical method

Based on the long term historical data, the statistical methods were used to analyze the change trends of groundwater tables and quality by considering both climatic factors and human activities in the last 30-40 years. The attempt also made to identify the major factors and their weight affecting the changes of groundwater table and quality. Among the considered factors are precipitation, temperature and evaporation, irrigation, drinking water supply.

3.2 Future sceneries analysis by developing and applying groundwater model

With this method, the response of groundwater table to the climate change and human activities from 2010 to 2050 is analyzed. Numerical groundwater model for the pilot area was developed. The observation data from 2004 to 2007 were used to calibrate the model, and the observation data for 2007 to 2009 were used to validate the model. Future scenarios analysis was made by considering future climate scenarios and increase of water use in irrigation, industry and domestic sector, improvement of water management, application of unconventional water, etc. The **sceneries analysis** period is 40 years, from year 2010 to 2050. The 3 scenarios are as follow:

Baseline Scenario: Under this scenario it was assumed that the climate and human activities didn't change further. For the input data of the related factors the average values in the period from 1990 to 2008 were used.

Climate Change Scenarios: Under these scenarios the future climate changes were projected by GCMs under emissions of A1B/A2/B1. Human activities just changed in passivity induced by the climate change.

Comprehensive scenario: Under these scenario, the future climate changes were projected by GCMs under emissions of A1B/A2/B1, and apart from passivity response of human activities, active human activities were also considered, such as water saving measures, application of unconventional water resources, increase in industry and domestic water use, water transfer from other watersheds, etc.

4. RESULTS AND CONCLUSIONS

4.1 Statistical analysis results

Based on the statistic analysis on the long term historical data the following major findings have been achieved:

a. In pilot area the temperature increases at a rate of 0.045^{0}C per year, as shown in Figure 2 and the precipitation has gradually decreased since 1950's. Human activities are affected by precipitation.

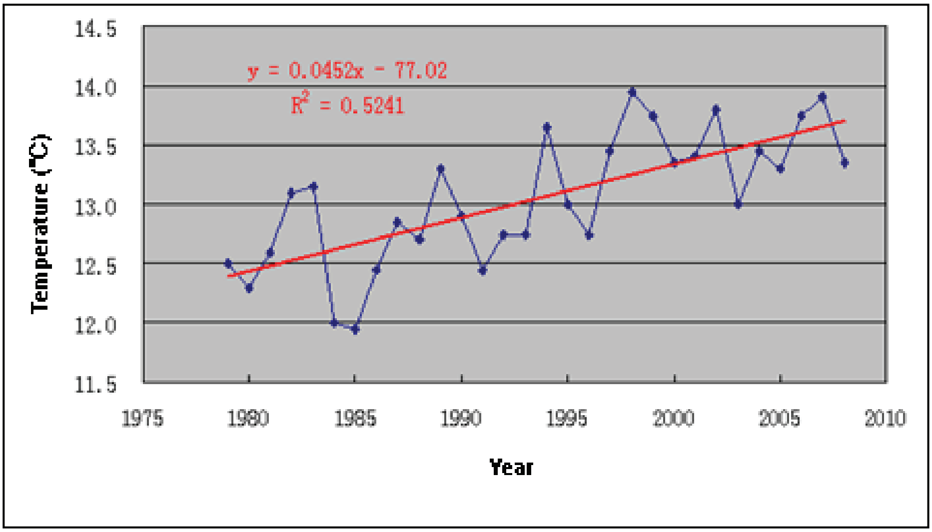

Fig. 2. The trend of temperature change in pilot area

b. During the past 30 to 40 years groundwater tables have been mainly controlled by precipitation and human activities.

c. Both evaporation and temperature have slight impact on groundwater tables directly, but they affect water use significantly and have significant indirect impact on the groundwater tables.

d. In the pilot areas the groundwater table has declined continuously (Figure 3), climate change reduced the groundwater recharge and human activities amplified the effect of climate change (Figure 4).

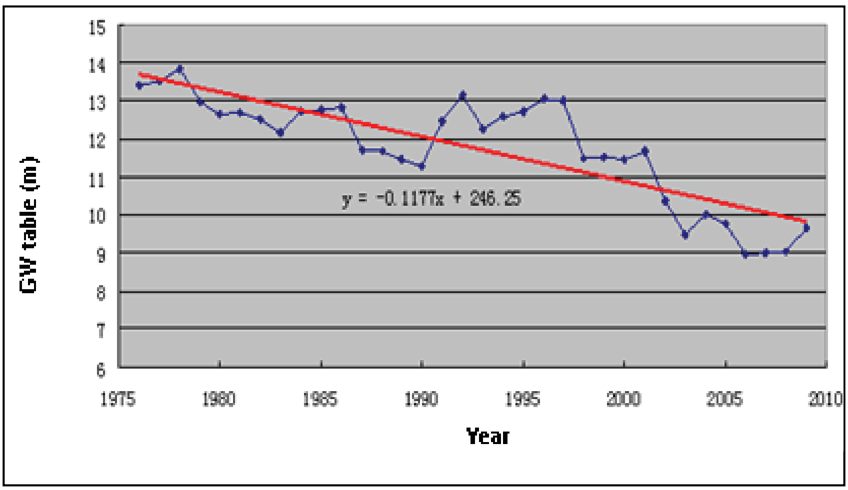

Fig. 3. The trend of GW table in pilot area

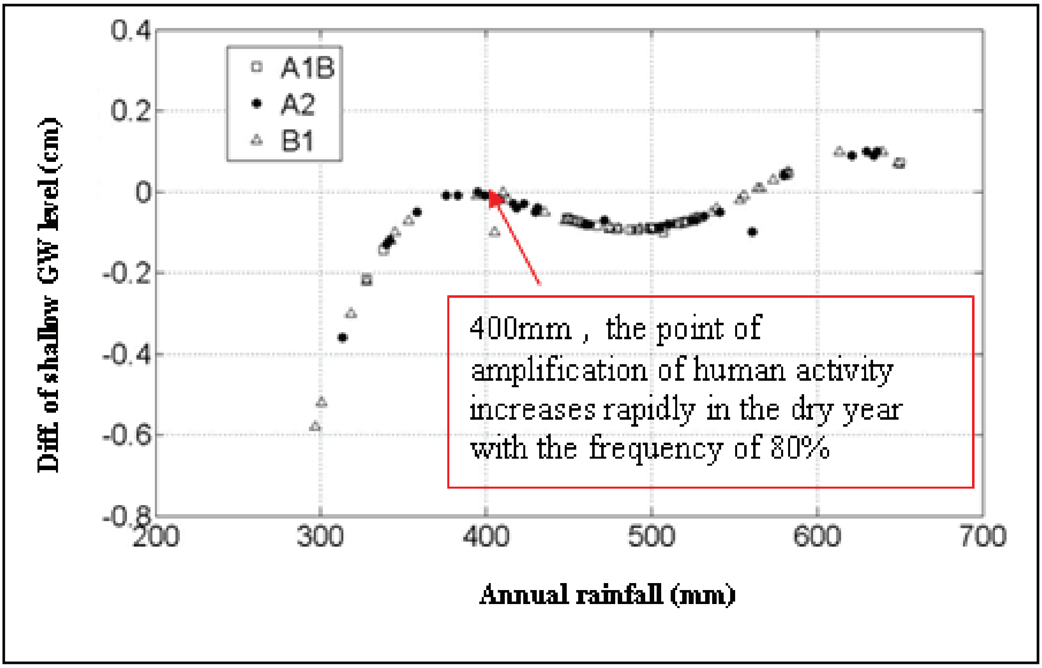

Fig. 4. Amplification of human activity in dry year

e. Both climate change and human activities have significant impact on groundwater tables. For Cangzhou, groundwater tables are influenced by precipitation (weight: 10 to 30 per cent), and by human activities (weight: 70 to 90 per cent).

4.2 Modeling results

4.2.1 Model calibration and validation

Figure 5 shows the comparison between measured and computed groundwater tables at the selected observation wells for both validation and calibration period. Figure 6 shows a scatter plot diagram of observed groundwater tables versus computed groundwater tables. Generally speaking, the results from modeling are reasonable with error less than 10%.

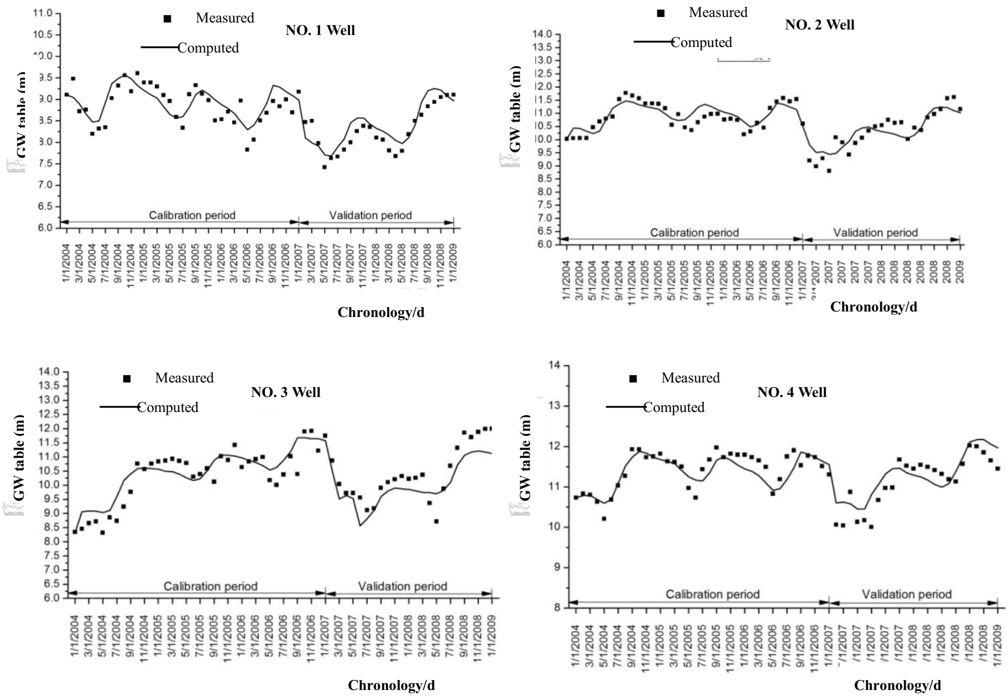

Fig. 5. Comparison between measured and computed groundwater tables (The dots represent measured groundwater level; the continuous lines represent the computed evolution of groundwater levels at the well)

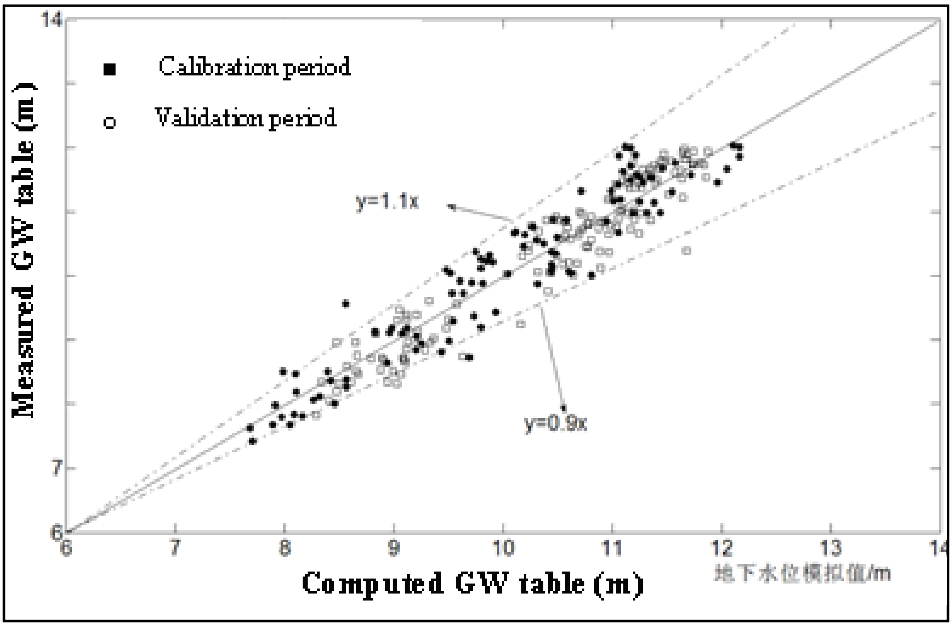

Fig. 6. Scatter plot diagram of computed and measured groundwater tables

4.2.2 Impact of climate change on groundwater under different scenarios

Baseline Scenario: as mentioned in 3.2, for this scenario the climate and human activities didn't change further. For the input data of the related factors the average values in the period from 1990 to 2008 were used. Figure 7 shows the evaluation of groundwater tables from 1990 to 2008. For this scenario the groundwater table would further decline by 19.34 m in 2050.

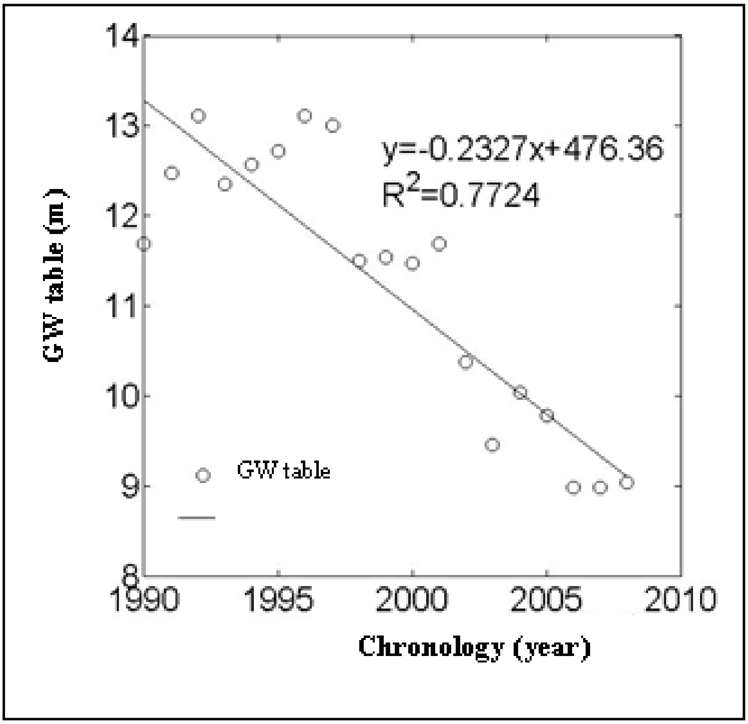

Fig. 7. Projection of groundwater table (Baseline Scenario)

Climate Change Scenarios: Under these scenerios the future climate changes were projected by GCMs under emissions of A1B/A2/B1. Human activities just changed in passivity induced by the climate change. For this scenario, precipitation might be increased. The groundwater table was predicated to drop by 5.4 m in 2050 without considering the change of human activities induced by climate change; otherwise the groundwater table would drop by 7.29m.

Comprehensive Sceneries: Under these scenerios, the future Climate changes were projected by GCMs under emissions of A1B/A2/B1, and apart from passivity response of human activities, active human activities were also considered, such as water saving measures, application of unconventional water resources, increase in industry and domestic water use, water transfer from other watersheds, etc. The projections of groundwater tables are presented in Figure 8. Based on the simulation, the following major findings have been achieved.

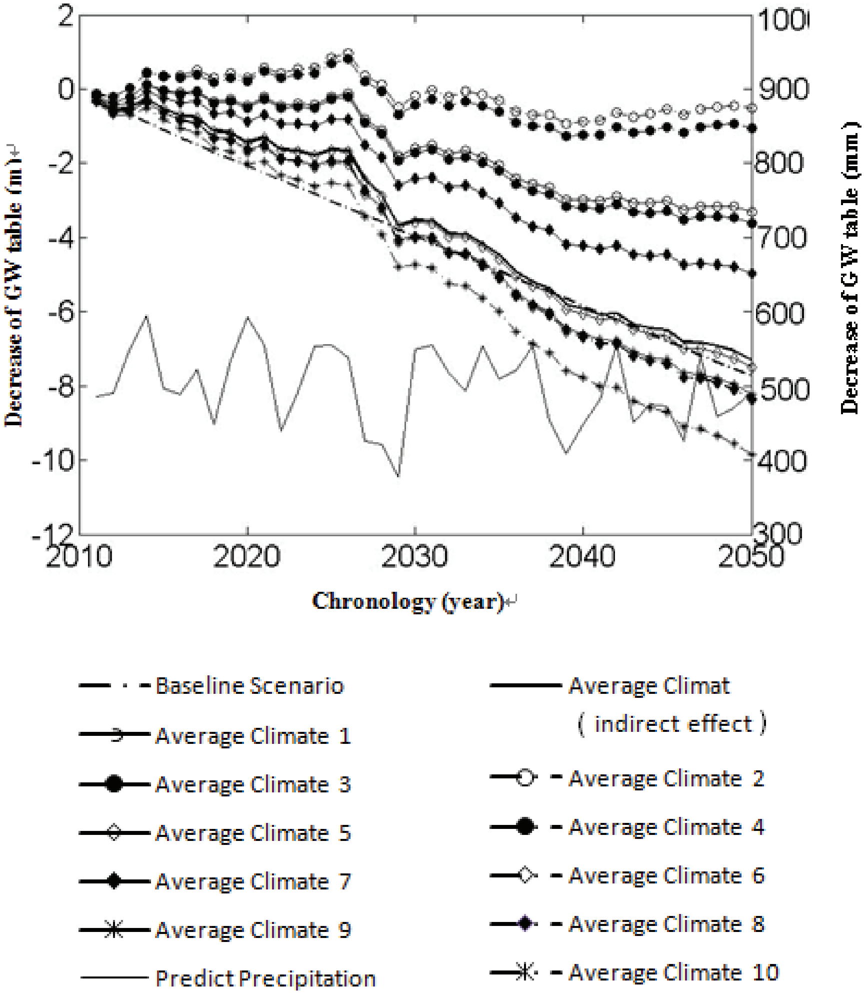

Fig. 8. Projections of groundwater tables under comprehensive sceneries

a. Groundwater table could drop by 7.29 m in 2050 if human activities were not considered.

b. The groundwater table decline could be reversed by improving water saving practices with 10% of water savings.

c. The application of unconventional water could reduce the groundwater extraction and effectively reduce groundwater table decline. The water table drop was only 1.06m by 2050 if groundwater exploitation could be reduced by 10%.

d. The groundwater level would rise by 2.23 m in 2050 if surface water supply could be increased by 10%.

5. RECOMMENDATIONS

Groundwater is the strategic resources to cope with extreme draught. Therefore, it should be utilized and managed properly. As presented by this paper, climate change has a dramatic impact on groundwater resources due to combined direct and indirect effects. Variations in temperature and precipitation during the year have slight direct impact on groundwater tables and quality, but they can trigger the response of human activities and can induce the increased application of groundwater. Human activities such as changes in land use, irrigation area and water saving practices have significant direct impact on groundwater. Therefore there are many challenges to assess the impact of climate change on groundwater. In order to realize the sustainable development of groundwater for coping with climate change, it is essential to take comprehensive measures in both policy and technology to monitor, protect and use groundwater. Groundwater modeling is a powerful tool to analyze the impact of climate change on groundwater.

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