Study on the Climatic Change Features of Hebei Plain

Jin-cui Wang, Liang Zhu, Ying Zhang, Ji-chao Sun*

Institute of Hydrogeology and Environmental Geology, Chinese Academy of Geological Sciences, Shijiazhuang 050061, China

Abstract: Precipitation and groundwater are essential to water circulation and they mutually influence. Groundwater is the main water supply source in Hebei Plain. On the other hand, atmospheric precipitation infiltration recharge is the main supply source of the groundwater in this area. Therefore, the studies on Hebei Plain climatic change features are of great significance to further analyze the influences of climatic changes on groundwater resources. This paper selected 10 ground climatological stations in Hebei Plain in terms of daily precipitation and temperature data from 1961 to 2010 and analyzed the spatial-temporal evolution features of temperature and precipitation. The results showed that the minimum temperature of Hebei Plain in recent 50 years increased significantly; the maximum temperature basically is stable; and the mean temperature presents an obviously increasing trend. In the spatial distribution, it gradually decreases from southwest to northeast on the whole and gradually tends to increase from the coastal to inland. The precipitation in recent 50 years owns obvious interannual change features and spatial distribution features, with a trend of overall periodic decrease and significant decrease of extreme precipitation. The annual mean precipitation intensity and annual mean extreme precipitation intensity gradually increased from piedmont plain to coastal plain. Hebei Plain has a warming and drying development trend on the whole. In space, piedmont plain belongs to the high-temperature and few-water area; coastal plain lies in low-temperature and much-water area; and central plain is in transitional zone. The climatic change and human activities are two influential factors of groundwater resources. Further revealing of the climatic change features of different geomorphic types and measuring and distinguishing of the influences of climatic change and human activities on groundwater remain to be further explored.

Keywords: Hebei Plain, Climate, Precipitation, Temperature, Groundwater

Introduction

For the water storage around the world, groundwater which is the major drinking water source of 1.5 billion people comes behind the glacial fresh water resource. It is of great significance to the maintenance of rivers and lakes, wetland and aquatic community and an essential part of water circulation (Zong-zhuang Zhao et al., 2003). Climatic changes transform groundwater depth by influencing runoff, soil humidity, the lake water level and other hydrologic features. On the other hand, alterations of large-scale shallow groundwater depth can change the spatial and temporal distribution of soil humidity and further vary the energy and water circulation between land and atmosphere and finally influence the climate.

Hebei Plain is one of the main water-deficient areas in China, with 261 m^3 per capita water resources, only accounting 9.3% of the national average level. As of 2000, 80-85% water demands lied in groundwater support and 68.26% of comprehensive groundwater recharge came from atmospheric precipitation infiltration recharge. Hebei Plain is also an important grain production base in China and groundwater is an important water supply of agricultural production in this area. Agricultural water consumption accounted about 80% of groundwater withdrawal. Yong-hai Guo et

*Corresponding author. E-mail: gwwsun@263.net.cn

al. analyzed the groundwater dynamic environment evolution in typical areas in Hebei Plain, Shijiazhuang, Hengshui and Cangzhou. Results showed that the change of meteorological phenomena is a governing factor for the hydrodynamic environment evolution of aquifer system I (Yong-hai Guo et al., 1995). Water resources shortage has severely limited the economic and social development of Hehei Plain, leading to the deterioration of ecosystem and natural environment. Under the background of global climatic changes, precipitation of Hebei Plain tends to decrease. Therefore, the study on the climatic change features in Hebei Plain area is of great significance to the further study on the influence of climatic changes on groundwater resources and the policy formulation of groundwater resource management adaptable to climatic changes.

Materials and Methods

General Situation in the Study Area

Hebei Plain is against Yan Mountain in the north, Taihang Mountain in the west, Bohai Sea in the east and surrounded by Beijing and Tianjin, including Shijiazhuang, Tangshan, Qinhuangdao, Handan, Xingtai, Baoding, Cangzhou, Langfang, Hengshui and their 119 counties (cities), with a total area of 73,129 km^2 (Zong-zhuang Zhao et al., 2003). By the end of 2010, the total population of Hebei Plain is 55,030,200 (Office for the Population Census of Hebei Province, 2010). Hebei Plain is located in the east coast of Euro-Asia Continent, with warm temperate zone semi-arid monsoon climate. In winter, it is cold and has little snow; in spring, it is dry and windy; in summer, it is hot and rainy; in autumn, it is cool. Hebei Plain is located in the river basins of the Haihe River and the Luanhe River.

Hebei Plain owns slopes towards Bohai Bay in the north, west and south, constructing one complete hydrogeologic section from mountain front to the coast. From west to east, it is divided into three parts, piedmont alluvial-proluvial inclined plain (piedmont plain for short), middle alluvial-lacustrine plain (median plain for short) and coastal alluvial-marine plain (coastal plain for short). Quaternary system of piedmont plain is constituted of Hutuo River proluvium and forms reciprocally-overlying alluvial-proluvial fan groups. The sediments carried by Hutuo River are mainly coarse particles. The central plain is mainly constituted of the sediments and lacustrine sediment of ancient Yellow River and Fuyang River, presenting a northeast strip. The sediments in this area are mainly in fine grain. The sediments of the east and coastal plain areas are major in ancient Yellow River alleviation, estuarine delta accumulation, lacustrine and marine deposition, with finer grain and in strip and schistose.

Data and Method

This paper selected 10 ground climatological stations in Hebei Plain in terms of day-by-day precipitation and temperature data from 1961 to 2010 in Shijiazhuang, Baoding, Cangzhou and other cities. Through strict quality control and data correction, there are 710,000 pieces of valid data, provided by the data sharing service network of China Meteorological Sciences.

The threshold value of extreme precipitation time is determined by the percentile method recommended by the World Meteorological Organization Committee. Namely, arrange all the daily precipitation samples of each meteorological station in ascending order. 95^{th} quantile of sub-sample with ≥0.1 mm daily precipitation is determined as extreme precipitation threshold and the standard extreme precipitation time. Only when the continuous precipitations for n days are more than the threshold value is it regarded as one extreme precipitation event of n days and the first day of the precipitation is taken as the time of continuous extreme precipitations. The longest continuous-day is 5 d (August 4-8, 1963 in Shijiazhuang Station and August 3-7, 1963 in Xingtai Station) and the events with more than 3 d are relatively less. Therefore, the extreme precipitation events are divided into 3 classes for discussion, namely 1 d, 2 d and 3 d and more. The times and total precipitation quantity of the extreme precipitation events in each station respectively are called the extreme precipitation frequency and the extreme precipitation quantity. Extreme precipitation intensity can be got by dividing extreme precipitation days by extreme precipitation quantity (Zhi-fu Wang et al., 2009).

The unary linear regression is used to analyze the temperature and precipitation change trend and Mann-Kendall test method is adopted for precipitation mutation test. In time sequence trend analysis, it is recommended by the World Meteorological Organization and is a widely-used non-parametric test method. There is no need to follow the given distribution and it is free from the disturbance of few abnormal values. It is suitable for hydrology, meteorology and other non-normal distribution data and can be calculated with ease (Feng-ying Wei, 2007; Jie-ping Cao et al., 2008).

Results and Discussion

Temperature Change Features of Hebei Plain

This paper selected the mean value of daily mean temperature, maximum of daily maximum temperature and minimum of daily minimum temperature in one year as the mean temperature, maximum temperature and minimum temperature of each year in the station. The mean values of 10 meteorological stations each year are taken as the annual temperature of Hebei Plain and results are shown in Fig.1 and Fig.2. In recent 50 years, the mean temperature of Hebei Plain was 12.6 ℃, with a speed of 0.3 ℃/10a and showing a significant increase (significance level of a=0.001). The annual maximum temperature of Hebei Plain remained stable basically, mainly between 35-41 ℃. The average annual minimum temperature in recent 50 years was -15.2 ℃, with a speed of 1.1 ℃/10a and showing a significant increase (significance level of a=0.0001). This indicated that the main manifestation of Hebei Plain climate warming showed the significant increase of the minimum temperature. The conclusion is consistent with the research results of Chen Yonghong et al., (Yong-hong Chen et al., 2009). It was reported that the rise speed of Hebei temperature is slightly higher than the national changing rate, with highly increasing rate in the north and decreasing rate in the south. The extreme low temperature event significantly decreases and warm winter prevails and the seasonal difference gradually weakens (Xia Gao et al., 2007).

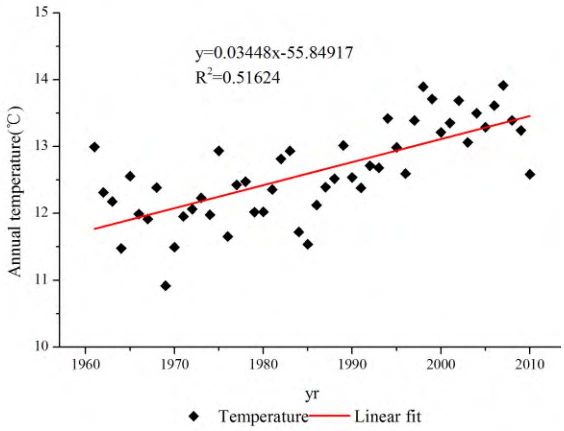

Fig.1 Dynamic Change of Annual Average Temperature

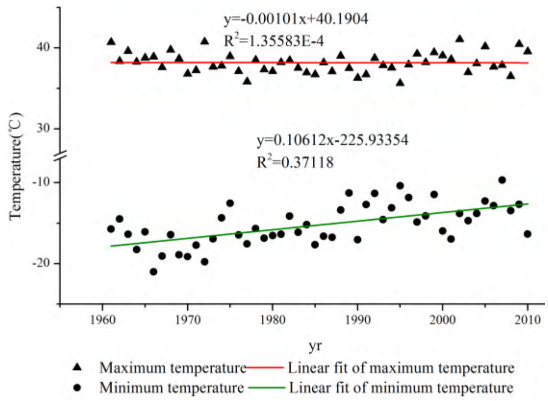

Fig.2 Variation Trend of Annual Maximum and Minimum Temperature

The spatial distribution features are as follows. The annual mean temperature gradually decreased from southwest to northeast and increased from the coastal to the inland. The distribution features of annual maximum temperature conform to the mean temperature. The high-temperature regions mainly include Shijiazhuang, Xingtai and Handan. Qinhuangdao had the lowest annual minimum temperature, followed by the border area of Hengshui, Baoding, Langfang, and Cangzhou as well as the coastal area of Tangshan and Huanghua. The minimum temperature of mountain front plain-coastal plain-coastal plain tended to firstly decrease and then increase in northeast. The high temperature areas mainly include Shijiazhuang, Xingtai and Handan (Fig.3).

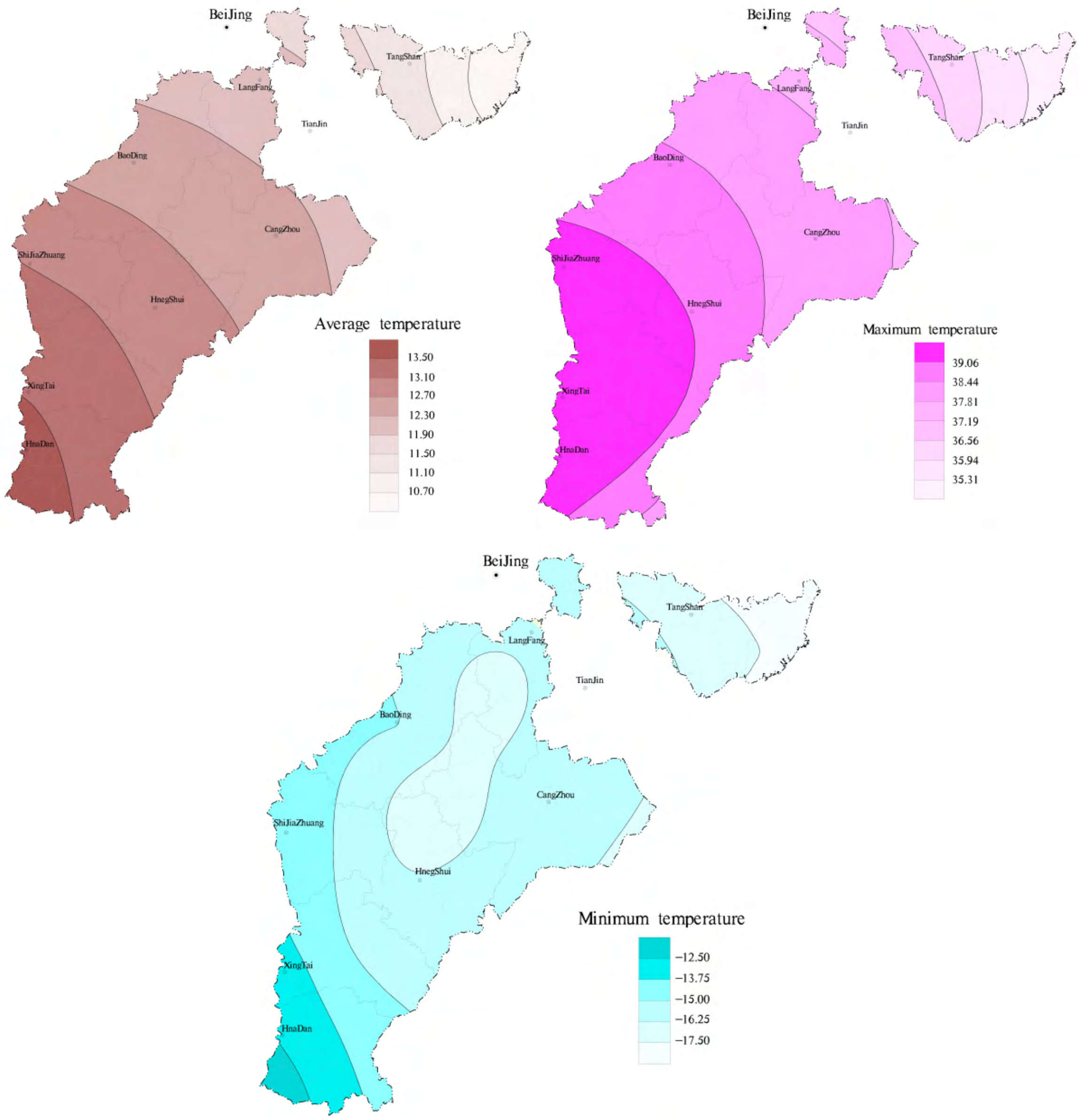

Fig.3 Spatial Distribution of 50-year Means of Average, Maximum and Minimum Temperature

Precipitation Change Features of Hebei Plain

The precipitation amount of Hebei Plain in recent 50 years fell between 330-940 mm, with annual mean of 536.2 mm. At the significance level of a=0.10, the change trend of the precipitation amount of Hebei Plain is not significant, presenting certain periodic change. 1960s belongs to wet season and its mean precipitation amount is 6.7% more than the annual mean precipitation; while the mean precipitation amount in 1990s is 3.9% less than the annual mean precipitation (Fig.4). Fig.5 shows Mann-Kendall mutation test results and the horizontal line in it represents the threshold of the significance level (a=0.05). During 1963~1980, the annual precipitation amount of Hebei Plain kept a steady increase; during 1981~1994, the annual precipitation amount was relatively steady and the trend change was not significant; during 1995~1998, it tended to increase; after 1999, it showed a decreasing trend. It had a sudden change in precipitation amount in 1996 and Hebei Plain turned from the wet season in 1960s to the less-rain season in 1990s. It was pointed out that the change rate of the annual precipitation amount of Hebei Plain was relatively large and its period was about 10 years (Zhi-qi Guo et al., 2012). The annual mean precipitation intensity gradually strengthens from the mountain front to coast; Qinhuangdao and Cangzhou are high precipitation intensity areas while Shijiazhuang and Xingtai mountain front are low precipitation intensity areas (Fig.6).

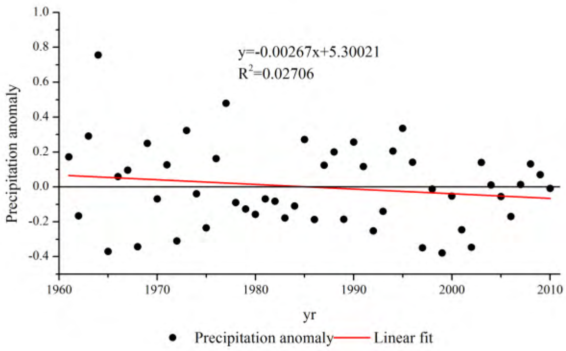

Fig.4 Variation of Annual Precipitation

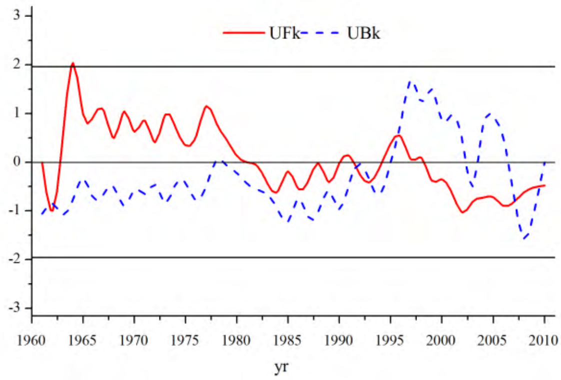

Fig.5 Mann-Kendall Abrupt Change Test of Precipitation

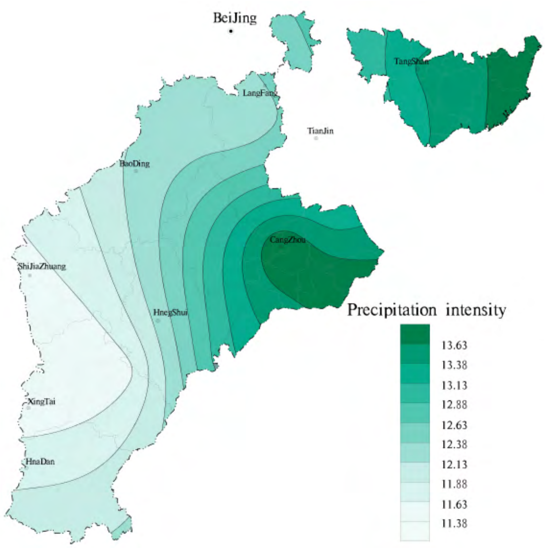

Fig.6 Spatial Distribution of 50-year Average Precipitation Intensity

The lowest precipitation occurred in 1965 and the low precipitation periods mainly focused on the middle and later 1960s and early 1970s, later 1990s and early 21st century, resulting in serious drought disasters. 1965 is a year with the least rainfall in flood season since 1949 in Hebei. A very severe drought happened in 1968; 1972 suffered great drought; and from 1997 to 2000 it suffered four-year drought. According to statistics, during 580 years from AD 1368-1948, there were 407 drought years, with a mean of 1.4 years/time. In the 51 years from 1949 to 2000, the drought years are 18 in total, with a mean of 2.8 years/time (Wen Kegang et al., 2008).

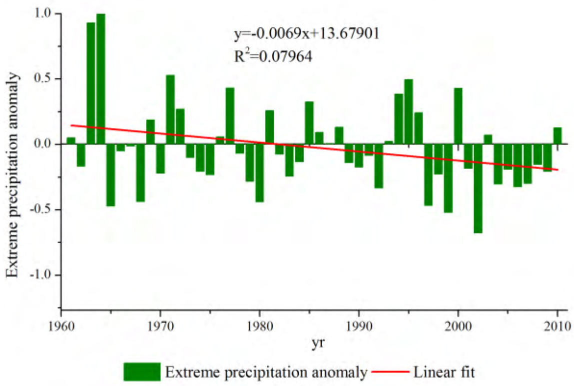

Fig.7 Change of Annual Extreme Precipitation

Fig.7 shows the annual extreme precipitation change of Hebei Plain over 95% threshold and on the whole it presents a significant decreasing trend. (a=0.10), especially after 2000, which is basically below the mean. In 1964 there was a maximum extreme precipitation amount and the periods with higher frequency are the early 1960s, middle 1970s and middle 1990s. During these periods, there are severe flood disasters, for example, the extremely heavy flood disasters in 1963 and extraordinary rainstorm in 1964, which resulted in the flood disaster, the second hardest-hit waterlogging disaster in 1977 and the extremely heavy flood disaster in 1996 in recent 50 years (Zong-zhuang Zhao et al., 2003; Ke-gang Wen et al., 2008; Ting-min Gu, 1991). The annual mean extreme precipitation intensity of Hebei Plain gradually strengthens from the piedmont plain to coastal plain, which conforms to the distribution features of annual mean precipitation intensity, with the maximum intensity of Cangzhou and Tangshan and the minimum intensity of Shijiazhuang and Baoding (Fig.8).

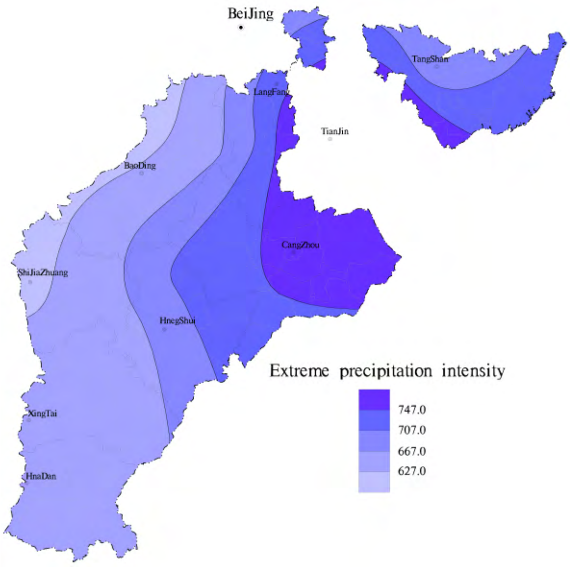

Fig.8 Space Distribution of 50-year Average Extreme Precipitation Intensity

During 1961-2010, there are 998 occurrences of extreme precipitation events in Hebei Plain. An extreme precipitation event usually lasts 1d and its frequency of occurrence is more than 90% (Table 1). It can be seen that Tangshan, Laoting and Raoyang were all over 96% and the interannual change presented a slight decreasing trend, which is not significant at the significance level of a=0.10. The occurrence of the extreme precipitation events lasting 2 d decreases rapidly and it is mainly distributed in Huanghua area. Extreme precipitation events lasting more than 3 d seldom occurred, mainly in Shijiazhuang, Baoding, Xingtai and Raoyang. The relative frequency with 2 d or more has no significant changing trend while owns distinct interdecadal difference. 1960s, middle 1970s and middle 1990s belong to relatively high frequent periods, which conforms to the extreme precipitation distribution. Though the highly-persistent extreme precipitation events have a low frequency, its contribution to the flood disaster cannot be overestimated.

Table1 Frequency of Extreme Precipitation

Station / Continuous days	Shijiazh-uang	Tangshan	Xingtai	Bazhou	Baoding	Cangzhou	Huanghua	Laoting	Nangong	Raoyang
1 d	97	104	88	89	89	94	92	102	90	94
2 d	6	4	6	6	4	5	8	4	6	3
3 d and above	1	0	3	0	2	0	0	0	0	1

Conclusion and Prospect

The minimum temperature of Hebei Plain in recent 50 years significantly increased; the maximum temperature basically is stable; and the mean temperature presents an obvious increasing trend. In the spatial distribution, the annual mean temperature gradually decreased from southwest to northeast and increased from the coastal to the inland. The high-temperature regions mainly include Shijiazhuang, Xingtai and Handan, while the lowest annual minimum temperature area is located in Qinhuangdao. The precipitation in recent 50 years own obvious interannual change features and spatial distribution features, with a trend of overall periodic decrease and significant decrease of extreme precipitation. The annual mean precipitation intensity gradually strengthens from the mountain front to coast and the annual mean precipitation intensity is consistent to this distribution rule. Shijiazhuang and Xingtai mountain front are low precipitation intensity areas while Qinhuangdao and Cangzhou are high precipitation intensity areas.

Hebei Plain climate develops towards warming and drying trend on the whole. Two drying mutations occurred in middle 1960s and later 1970s. In space, piedmont plain belongs to high-temperature and few-water area; coastal plain lies in low-temperature and much-water area; and central plain is in transitional zone.

The climatic change and human activities are two influential factors of groundwater resources. Both factors mutually influences and jointly change the influential degrees on groundwater resources. The dynamic laws of annual precipitation, groundwater recharge and agricultural extraction of Hebei Plain to the south of Beijing and Tianjin was studied (Guang-hui Zhang et al., 2006) and it was pointed out that along with the changes of the annual precipitation, the groundwater recharge and agricultural extraction in the corresponding period present reciprocal change rules. Namely, with the decrease of precipitation, the groundwater recharge decreases while the agricultural extraction increases, and vice versa. During the climate drying process, the influence of precipitation changes is greater than that of climate-increased precipitation. Therefore, further revealing of the climatic change features of different geomorphic types and measuring and distinguishing of the influences of climatic change and human activities on groundwater remain to be further explored.

Acknowledgments

This work was supported by Foundation project, "National Basic Research Program of China" (No.2010CB428806).

References

Zong-zhuang Zhao, Feng-chuan Liu, Li-jun Liu, et al. Report on Investigation and Assessment of Groundwater Resources in North China Plain (Hebei) [R]. Geological Survey of Hebei Province, Hebei (2003).

Yong-hai Guo, Zhuo-chen Zhang, Zhao-li Shen,et al. Correlativity Analysis of Affect Factors in Evolution Hydrodynamic Environment in Heibei Plain [J]. Journal of Engineering Geology, 3(3): 62-66 (1995).

Office for the Population Census of Hebei Province. Tabulation on the 2010 population Census of Hebei Province [M]. China Statistics Press (2010).

Zhi-fu Wang, Yong-fu Qian. Frequency and Intensity of Extreme Precipitation Events in China [J]. Advances in Water Science, 20(1): 1-9 (2009)

Feng-ying Wei. Modern Climatic Statistical Diagnosis and Prediction Technology (2rd edition) [M]. China Meteorological Press (2007).

Jie-ping Cao, Dao-cai Chi, Li-qiang Wu, et al. Mann-Kendall Examination and Application in the Analysis of Precipitation Trend [J]. Agricultural Science & Technology and Equipment, 5: 35-40 (2008).

Yong-hong Chen, Ai-ying Zhang, Xiao-jun Guo, et al. Characteristic Analysis of Temperature Change Nearly 45 Years in Hebei Province [J]. Journal of Shandong Meteorology, 29(2): 23-26 (2009).

Gao Xia. Temporal and Spatial Variation on Climate and Extreme Events in Heibei Province for the Recent 45 Years [D]. Lanzhou University (2007).

Zhi-qi Guo, Xiu-ru Wang. Variations of Precipitation in Recent 50 years in Hebei Province [J]. South-to-North Water Diversion and Water Science & Technology, 10(3): 67-43 (2012).

Ke-gang Wen, Jian-sheng Zang. China Meteorological Disaster Authority (Hebei Volume) [M]. China Meteorological Press (2008).

Ting-min Gu. Climate of North China Plain [M]. China Meteorological Press (1991).

Guang-hui Zhang, Yu-hong Fei, Li-zhi Yang, et al. Responses of Groundwater Recharge and Pumpage to Change in Precipitation in Hebei Plain [J]. Earth Science - Journal of China University of Geosciences, 31(6): 879-884 (2006).