Changes in water use structure in Shandong Province in the past 20 years

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Abstract. This paper analyzes the changes of water use structure in Shandong Province from 2000 to 2017 in Shandong Province, reveals the driving factors that lead to changes in water use structure. The results show that in the past 20 years, the total water use has firstly increased and then slowly decreased; the agricultural water use has decreased continually; the industrial water has firstly fluctuated and then kepted stable; while the domestic water use and environmental water use has continually increased. The driving factors of water use are agricultural water saving, industrial water saving, population and water consumption per capita growing and landscaping area enlarging.

1. Introduction

Shandong Province is an important large province in population and economy in China. In 2017, there are 100 million people in Shandong Province, which ranked the second in all provinces of the country and occupied 7.2% of the national population. The population density of Shandong Province was 636 people per square kilometres, which was 4.4 times of the national average population density. The regional gross domestic product (GDP) was 726.34 billion yuan, which ranked the third in all provinces in the country and occupied 8.8% of the national GDP. However, Shandong Province lacks of water resources, and water is an important constraint to the economic and social development of the province. The average annual precipitation in Shandong Province is 676.5mm, and the precipitation distributes among seasons very unevenly. 60-70% of annual precipitation concentrates in the period from July August. The water resources per capita of Shandong Province is 334 cubic metre, which is less than one sixth of that of the national average and is 1/25 of that of the world average. There is a large gap in water use efficiency among various industries in Shandong Province, so understanding the optimal water use structure is an important way to improve the integrated water use efficiency, reach equilibrium between water supply and demand, and achieve coordinated development among water resources, economy and society.

2. Changes of water use in Shandong Province

The water use of Shandong Province is composed of agricultural, industrial, domestic and ecological water use. The changing characteristics of water use structure from 2000 to 2017 in Shandong Province have the following aspects as Figure 1 (Water Conservancy Department of Shandong Province, 2000-2017).
Figure 1. The water use from 2000 to 2017 in Shandong Province.

(1) The total water use firstly increased and then slowly decreased. In 2001 and 2002, the total water use in Shandong Province reached the maximum of 25.3 billion cubic metre, and then gradually decreased to 20.8 billion cubic metre in 2005. The total water use was relatively stable from 2006 to 2012, maintaining around 22 billion cubic metre. The total water use has gradually decreased from 2012 to 2017, and the total water use in 2017 has dropped to 20.8 billion cubic metre.

(2) The agricultural water use in Shandong Province and the proportion of that in the total water use has continually decreased. Shandong Province is a large agricultural province. Agriculture is the main water use sector, and the proportion of agricultural water use in total water use is more than 60%. During the study period, the agricultural water consumption decreased from 18 billion cubic metre to 13.4 billion cubic metre with the decrement of 5.6 billion cubic metre. The proportion of agricultural water use between 2000 and 2012 was higher, which is basically above 70% in every year. The changing trend of the proportion was fluctuated. In 2002 and 2006, the proportion of agricultural water use is more higher, which is close to 80%. The proportion of agricultural water use between 2013 and 2017 gradually decreased, and fell to 64% in 2017.

(3) The total amount of industrial water use firstly fluctuated, and then remained stable. From 2000 to 2005, the industrial water use in Shandong Province decreased from 4.2 billion cubic metre to 2.2 billion cubic metre, which was reduced by nearly 50%. After that, it gradually increased and remained stable. The industrial water use remained within 3 billion cubic metre in the past 10 years. The proportion of industrial water use is similar to that of industrial water use. It reduced and then maintained a steady trend which was 18% in 2000 and fell to 14% in 2017.

(4) The domestic water use has increased year by year, and the proportion has also increased accordingly. During the study period, the domestic water use in Shandong Province grew from 2.1 to 3.5 billion cubic metre between 2000 and 2017 continually except in 2002, with average annual growth of 82 million cubic metre per capita, and the growing rate is faster. From 2000 to 2017, the proportion of domestic water use in the total water use of Shandong increased from 8% to 17%. In 2005, this proportion was 12%, which began to exceed the proportion of industrial water use, and became the second water use sector in Shandong Province.

(5) The ecological and environment water use data has been included in water resources statistics since 2005 in Shandong Province. From 2005 to 2017, the ecological and environment water use increased by years, which changed from the initial 168 million cubic metre to 1.202 billion cubic metre in 2017 closing to half of the industrial water use. And the ecological and environment water use grew faster with an average annual rate of 0.80 cubic metre.
3. Changing reason of water use in Shandong Province

3.1. Changing reason of agricultural water use

The agricultural water use in Shandong Province is mainly composed of farmland irrigation water use and forestry, fishery and livestock water use, of which farmland irrigation water use is the main part, accounting for more than 85% of agricultural water use (Bai et al., 2018, Yan et al., 2018, Liu et al., 2003). The change of agricultural water use in Shandong Province is mainly determined by the farmland irrigation water use. From 2000 to 2017, the irrigation water use of farmland decreased by years, from 16.7 billion cubic metre to 11.5 billion cubic metre as Figure 2.

The water use of forestry, fishery and livestock is basically two billion cubic metre with little change. The irrigation water use for farmland is determined by the planting area of crops, planting structure and irrigation efficiency. From 2000 to 2017, the planting area and structure of crops in Shandong Province have varied little, and the planting area of crops and grain crops in Shandong Province were about 11 million hectares and 7.3 million hectares respectively. Food crops have always been the main crops in Shandong Province, with a planting area accounting for around 65% of crops planting area. So, the main reason for the continuous reduction of agricultural water use is the role of agricultural water saving. Shandong Province has been vigorously promoting agricultural water conservation. The effective irrigation area of the province increased from 4,760.79 thousand hectares to 5,122.67 thousand hectares between 2000 and 2015, and increased by 362 thousand hectares in 15 years. Among them, the area of water-saving irrigation projects reached 2,918 thousand hectares. It accounts for 61.3% of the effective irrigated area. In 2015, the effective utilization coefficient of farmland irrigation water in Shandong Province reached 0.63, which is at the forefront in the country (Wang et al., 2010).

![Figure 2. The planting area of crops and grain crops in Shandong Province](image)

3.2. Changing reason of industrial water use

The industrial scale of Shandong Province expanded significantly, which increased from 290.4 billion yuan in 2000 to 3,485.9 billion yuan with growth of 11 times. Therefore, the reduction of industrial water use in Shandong Province mainly depends on the improvement of industrial water saving and industrial water use efficiency heightening. The industrial water saving measures included strictly controlling industrial projects with high water consumption, implementing national standards of intaking water quotas for enterprise with high water consumption, promoting water saving technologies and equipment, and improving industrial water use efficiency. Water consumption for every 10 thousand yuan worth of industrial value added was 117 cubic metre in 2000, and now it is 11.4 cubic meters dropping by 90.3%. The industrial water efficiency is at the domestic advanced level (Yang, 2015, Chen et al., 2019).
3.3. Changing reason of domestic water use
Domestic water includes urban domestic water and rural domestic water. And urban domestic water includes residential water and public water. The increase of domestic water use in Shandong Province is closely related to the rapid growth of population and changes in domestic water use patterns. With the fast development of urbanization, the permanent resident population in Shandong Province has soared from 89.75 million in 2000 to 100.50 million in 2017. Of the permanent resident, the urban population increased from 24.09 million to 50.24 million, but the rural population decreased from 65.66 million to 49.84 million. The increase of urban population is the main reason for the increase in domestic water use in Shandong Province. In addition, as living level improving, people demanded more water in daily life. But at the same time, water price adjustment and utilizing water-saving life used implement restrained the growth of water demand. Therefore, the annual per capita water use in Shandong Province increased slowly over the 17 years from 23 cubic metre in 2000 to 35 cubic metre in 2017. However, in 2002, water use per capita was anomaly low, and mainly due to there was a severe drought in the year, and which urban and rural water supply was restricted.

3.4. Changing reason of ecological water use
There is ecological and environment water use in statistics from 2003. The amount of ecological and environment in Shandong Province has increased rapidly since then, mainly due to landscaping area increasing. The landscaping area of Shandong Province has increased by years since 2000. The area was 56,301 hectares in 2000, 80,385 hectares in 2003, and 235,690 hectares in 2017 with an increase of 1.9 times over 2003.

4. Discussion

4.1. Water Resources in Shandong Province
The water resources in Shandong Province is insufficient and distributes unevenly in regions. There exists drastically interannual and interdecadal variation in the province. And there usually are continuous rainy years, continuous dry years and drought and flood turning suddenly, which affects the development and utilization of water resources. In recent years, with the impact of climate change, the extreme value of precipitation occurs frequently shown as Figure 3, and water resources changes more intensely, which has brought great difficulties to the development and utilization of water resources. For example, there is a drought spreading the whole province in 1999-2002. In 2006, the precipitation of the province was lower than 36% of the annual average. In 2014, the precipitation was lower than 20% of the annual average, and the water resources were lower than 50% of the annual average.
4.2. Water use structure trends

According to the national economic and social development plan of Shandong Province by 2030, the total population of the province will reach to 109.4 million, the urbanization rate will reach to 75%, and the urban population will reach to 82 million (Water Conservancy Department of Shandong Province, 2017). The total amount of GDP will add to 17.78 trillion yuan, and the proportion of the three industries will adjust to 5: 35: 60. The effective irrigated area will increase to 84.53 million mu. With the irrigation area increasing, more water will be demanded in agriculture. According to the overall plan of water security in Shandong Province, the increase of agricultural water demand will be solved by water saving. And the agricultural water use will be stable with a slight decline until 2030. And although there will be potential in industrial, domestic and environmental water use, but the water-saving amount will be much less than the increase of water demand (Jin et al., 2015, Wang et al., 2012). So all the water use amount will certainly grow in a very long time, and the contradiction between water demand and supply will be more tense.

5. Conclusion

This paper analyzes the changes of water use structure in Shandong Province in the past 20 years, reveals the main reasons affecting the evolution of water use structure, and discusses the development trend of water use structure in Shandong Province in the future. The main research conclusions are as follows:

(1) In the recent almost 20 years, the total amount of water use has increased first and then slowly decreased. Agricultural water use continued to decrease, and the proportion of total water use decreased persistently, but it was still the main water use sector in Shandong Province. The industrial water use fluctuated first and then remained stable; the domestic water use increased year by year, and the environmental water use increased rapidly.

(2) With the stable planting area of food crops, the main reason for the continuous reduction of agricultural water use is the role of agricultural water saving. The reduction of industrial water use mainly depends on the improvement of industrial water saving and industrial water efficiency. The increase in domestic water use is closely related to the rapid growth of population and changes in water use patterns of residents. The ecological and environment water use has increased rapidly, mainly due to expanding landscaping area.
(3) In the future, agricultural water supply will be stable with a slight decline; the water demand for industry, life and ecological and environment will continue to increase, and the amount of water saving will be much less than the new water demand. The total amount of water use will always grow in a long period. The controdic between supply and demand of water resources will continue to be intensified.

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