Comprehensive Water Resource Management Strategies in Arid Oasis Regions: Taking Minqin County as an Example

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Abstract. Minqin County is the last line to block the closure of the Tengger Desert and Badanjilin Desert. For more than half a century, due to the influence of natural factors and human activities, the ecological environment of Minqin County has seriously deteriorated. The sustainable development of Minqin County has been restricted because of the unreasonable development and utilization of water resources. This paper analyses the problems and causes of the ecological environment, and reviews the main measures of water resources protection in Minqin County, including the implementation of wells closing and fields burying policy, the promotion of agricultural water-saving technology, the adjustment of planting and industrial structure, ecological migration, as well as the promotion of water rights and water price reform, the optimization of water structure, and discusses the achievements achieved. This paper summarizes the measures and effects of comprehensive control and provides a reference for the ecological restoration of the follow-up study area.

1. Study site description

1.1. Geographical location and climatic characteristics
Minqin is located in the lower reaches of the Shiyang River basin, which under the jurisdiction of Wuwei City with an area of 15,900 km². It is surrounded by Badanjilin desert and Tengger Desert on its west and north sides and has a distinctive continental desert climate[1]. The average annual precipitation was 113.2mm, while the annual evaporation was as high as 2644mm, and the drought index was 15~25. Minqin County has dry air and a large temperature difference between day and night, which is suitable for crop growth. The basic landforms are desert, plain and low mountains and hills[2]. It is one of the most arid areas in China because of its abundant wind and sand and less rainfall.

1.2. Water conservancy project
Hongyashan Reservoir is the largest artificial desert reservoir in Asia, 30 km away from Minqin County. The reservoir control basin covers an area of 13,400 km2, providing irrigation for more than 40000 ha of cultivated land and living use for 273,700 people in Minqin County. Sun et al. (2018) found that from 1962 to 2010 the incoming runoff decreased by 306 million m³, showing an overall downward trend, and the inflow water of the Shiyang River was fully consumed and utilized[3].
2. Existing problems and comprehensive management objectives

2.1. Major issues

2.1.1. Drops of groundwater level.
The surface water of Minqin has been limited with the increasing population and demand for water resources in the upper and middle reaches. To ensure normal production and daily life, the water shortage can be remedied by exploiting groundwater. From the 1970s to 2017, the underground water level had dropped from 1.9m to 12.25m. Due to the rapid decline in the water table, some plants cannot absorb groundwater to maintain life, and a large number of plants are in a dry, dead, or semi-dead state, such as Nitraria, Tamarisk, and other vegetation[4].

2.1.2. Serious desertification.
The Qingtu Lake was the largest lake according to historical records in Minqin, which has dried up completely in 1960 due to the much death of vegetation, weakened sand fixation ability, and intensified desertification[5]. The vegetation coverage rate had dropped below 15 percent in 1991. By 1994, 889.20 km2 of land have desertified and the desertification area increased to 15,000 km2[6].

2.1.3. Water Shortage.
The water resources of the Hongyashan Reservoir mainly come from the flood in the upstream and the backwater in the middle reaches. Due to the deforestation and excessive mining in the upper reaches with an increased irrigation water demand in the middle reaches, which leads to the obvious decrease of the water into the lower reaches[7]. The water resources have decreased from 552.7 million m³ in the 1950s to 115 million m³ in the 1990s, and 83 million m³ in 2005[8].

2.1.4. Serious water pollution and deterioration of water quality.
The groundwater level in Minqin is very shallow. Due to the long sunshine time and a large amount of groundwater for irrigation, repeated evaporation, and concentration, the soil began to appear salinization, the area of brackish water increased, and the salinity of groundwater increased. Liu et al. (2002) found that in 1995, groundwater salinity reached 5g/L in some areas of Minqin, resulting in drinking water difficulties for both human beings and livestock[6]. With the rapid development of industry and agriculture in the upper and middle reaches, the consumption of pesticides, chemical fertilizers, and plastics has increased. According to the environmental monitoring data of Wuwei City in 2004, the water quality in Minqin County is inferior to class V, which cannot be used for normal production and life.

2.2. Comprehensive management objectives

In 2007, the key management plan of the Shiyang River basin was formally implemented. The year 2003 as the current level year, 2010 and 2020 as the level years, and 2010 is the planning focus. The overall objectives of the plan are to adjust agricultural water use, ensuring basic living and ecological water use, meeting industrial water demand, increasing farmers’ income, implementing the requirements of Premier Wen, J. b. on governance for many times, and finally achieve the sustainable development of regional economy and society.

It is pointed out in the planning that the government target of Minqin County in 2010 is to increase the discharge volume of the Caiqi section from 98 million m³ to more than 250 million m³. Groundwater extraction went from 517 million m³ to 89 million m³. By 2020, the target is to increase the discharge from the section of Caiqi to more than 290 million m³ and reduce the groundwater exploitation from 89 million m³ to 86 million m³[9].
3. Comprehensive water resources management strategies

3.1. Implementing the policy of shut down the wells and bury the fields

Due to the shortage of water resources, Minqin County began to drill wells to extract groundwater in 1952, which lead to the water table dropped constantly and the water quality deteriorated seriously. According to the local government, 11,000 wells were drilled in the county at the peak of development in the last century. The county government has formulated relevant plans to curb the decline of groundwater level and realize the balance of groundwater exploitation and supplement[10]. At the same time, some intelligent metering control facilities have been installed for motor wells and signed a letter of responsibility with each township. The government should implement the tasks and objectives of the work, meanwhile guide and encourage farmers to transform from cultivated land to forest and grass planting and create windproof and sand-fixing forest belts around the existing cultivated land. The measure of fence to protect grass should be adopted to provide effective protection for the better ground with native vegetation. According to the data of the Minqin government from 2006 to 2010, 3,018 mechanized wells have been closed, reduced the water distribution area of 29453.3 ha, installed 4,637 water meters, and the total water consumption to 358 million m3 also reduced since the policy implemented. Remarkable results have been achieved in the treatment work[11].

3.2. Popularizing water-saving agricultural technologies and adjusting planting structure and industry structure

The development of the planting industry is limited by water quality and quantity in Minqin, therefore the efficient water-conserving agriculture and optimizing planting structure to improve the effective utilization of water resources by developing.

Specific measures include: Firstly, we will vigorously develop facility agriculture, establish solar greenhouse, and promote conventional water-saving technologies, such as small furrow irrigation, mulch, ridge and furrow irrigation, dry soil cultivation, and water-saving no-tillage technologies such as mulch reuse[12]. According to the data of the Minqin County government in 2017, the solar greenhouse reached 3186.67 ha, the average net income of the greenhouse increased from 11,400 yuan to 24,300 yuan within five years, and the water benefit increased from 14.22 yuan to 20.49 yuan. In 2019, water-saving technologies such as drip irrigation under the film, furrow irrigation with ridge film and furrow irrigation, etc., will be fully popularized, covering 167333.3 ha of land; An additional 13566.67 ha of land will be irrigated with high-efficiency water-saving, and agricultural water-saving demonstration sites such as the integration of water and fertilizer in the solar greenhouse will save 900~1500m3 of water per ha[13]. Second, optimize the structure of agricultural planting. Jin et al. (2018) showed that onion, pepper, fennel, and sunflower were the main cash crops in Minqin County, wheat and corn were the grain crops, and alfalfa was the main forage grass. Given the current situation of water resources in Minqin County, measures such as promoting excellent varieties, reducing or even fallow crops with high water consumption, and low income was adopted. According to the route of "stabilizing grain, expanding grain and increasing grass", the ratio of grain to grass was adjusted from 45:41:14 to 37:45:18[14]. Third, the implementation of "three water" joint dispatching, namely, sky water, surface water, groundwater. When the rainfall is more than 10mm, the well should be shut down and the power cut should be timely combined with the actual situation, to limit the extraction of groundwater and lengthen the interval between successive irrigation. It has been implemented and has formed an efficient and scientific operating mechanism since 2010[15].

At the same time, moderate development of light industry and tertiary industry, change the water resources distribution structure based on agricultural water.

3.3. Exerting ecological migration to relieve population pressure

In 2001, the population density of Minqin County was 18 people /km2, and the average population density of densely populated areas reached 122 people /km2, far exceeding the United Nations standard of 7 people /km2 in arid areas[16]. To guarantee people's lives and keep the population
pressure within the carrying capacity of the water environment, Minqin County implements ecological immigration policy. The main relocation targets are those close to desert fringe areas with sand storms and areas with fragile ecological environments as well as areas with low population density. The main ways are county migration and county relocation. The main measures are as follows[17].

3.3.1. Educational immigration.  
While popularizing high school education, we vigorously develop vocational education, and actively respond to the call of the government of Tianjin and Gansu provinces (cities) to help and cooperate. At the same time, the local teenagers, especially junior high school graduates from poor families, who are encouraged to go abroad for further study, and give full play to the force of the Xinjiang office to further expand the scale of sending high skilled industrial workers and modern service industry operators. In 2008, some students have been sent to the vocational and technical colleges through propaganda and launching in Xinjiang, and all registered permanent residence moved to Xinjiang. It can not only reduce the pressure of employment and family but also relieve the pressure of the ecological environment.

3.3.2. Emigrating to friends and relatives.  
The farmers are encouraged to move to areas with abundant land resources and a better environment by encouraging immigrants to buy land through their relatives and friends or by unifying the government's allocation of land resources to immigrants fairly and equitably. According to statistics, in 2007, a total of 2,011 immigrants went to live with their relatives and friends.

3.3.3. The government-funded the immigrants.  
The government will provide certain financial subsidies and substantial assistance to the relocated migrants, and give priority to the removal of farmers from areas with severe sandstorms and the relocation of whole villages in some areas voluntarily. The necessity and importance of migration are publicized at the grass-roots level, which deepens the recognition and acceptance of ecological migration by farmers, and encourages immigrants to transform the planting of economic food crops into forest and grass animal husbandry, which not only increases farmers' income but also protects the ecological environment. In 2007 the government guided 1,600 migrants.

3.3.4. Labor migration.  
Relevant departments of our province and non-local enterprises signed agreements, to Beijing, Tianjin, Nanjing, Fujian, Xinjiang, and even overseas countries to export labor enterprises. The implementation of ecological migration is a solid foundation of the road of civil logistics governance and has achieved a win-win result of poverty alleviation and environmental protection, which has far-reaching significance for the realization of harmony between people and water.

3.4. Promoting the reform of water prices  
To build a water-saving society, Minqin County formulated price management measures for industrial, agricultural, and urban water consumption in 2011 based on the actual conditions, and promoted efficient water consumption in various industries by using price lever. Among them, agricultural water implements the "basic water price + metering water price" method, the basic water price is 30.00 yuan/ha. Also, there is a reward and punishment system: in the water quota, the water-saving crops and ecological water use are rewarded. The surface water and groundwater are 30% and 50% respectively. For the crops with high water consumption and low benefit, the surface water floats 30% and the groundwater rises 50%. Industrial and agricultural water and urban water use are subject to quota management, and the system of progressive price increase over quota is implemented[18]. The price of urban water is composed of the price of water supply, the price of drainage, and the price of water resources, the industrial water shall be priced differently according to the access to the water
supply network, and shall be measured in separate meters, mainly for the same user and different types of water. The highest water price shall be implemented for the non-divided meters[19].

### 3.5. Water use system refinement

Minqin County has formulated a water use accounting report system with a monthly or quarterly calculation cycle, which takes towns as units for accounting and detailed and accurate analysis of regional water use status to make water use plans for the next month or the next quarter[20]. Units and individuals that violate the law by using water over the prescribed amount or wastewater resources shall be held accountable to individuals.

### 3.6. Clarifying the water rights and adjusting the water use structure

Minqin County following the requirements of optimizing and adjusting the water use structure, implements the real-name system of water rights management, advocates, farmers to participate in the water resource management system and improve the transparency of water rights allocation. Every month, the supervision team will assess the implementation of water rights and water price management, and establish a supervision responsibility mechanism of "taking responsibility in segments, assigning responsibility to people, and supervising door to door"[21]. After comprehensive treatment, studies by Shi et al. (2017) showed that from 2007 to 2014, the proportion of agricultural water consumption decreased from 94% to 69.598%, the proportion of ecological water consumption increased from 3.456% to 25.582%, and the proportion of industrial and domestic water consumption increased[15]. The structure of water use tends to be reasonable and the reduced agricultural water use is conducive to the restoration of Minqin's ecological environment.

### 4. Conclusions

Since the implementation of comprehensive control measures, the ecological environment has been greatly improved, and the utilization of water resources has gradually become more efficient and rational. The governance of Minqin County has achieved remarkable results. According to the data in 2018, Hongyashan reservoir has increased from medium-sized to large (II) type, the storage capacity has increased to 148 million m³, the discharge water has reached 33.58 million m³, and the ecological water supply to Qingtu lake has been guaranteed with more than 30 million m³ of ecological water, and the reservoir storage capacity has been improved; Secondly, the Minqin County has achieved or exceed the two indicators every year, the groundwater exploitation shows a downward trend and the groundwater level rises; Concurrently, the upstream water inflow increases and the cross-section water flow of Caiqi continues to increase. The economic development and the utilization efficiency of water resources have improved by governance and restored the ecological environment of Minqin County. At the same time, the governance measures are constantly improved and innovated with the actual situation.

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