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ARTICLE



Human settlement and changes in the distribution of river systems in the Minqin Basin over the past 2000 years in Northwest China

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ABSTRACT

Introduction: Arid area is an important base for human settlement, however, long and drastic human activities have altered the drainage patterns in the arid watersheds significantly, causing serious ecological consequences. This study, through a case study of the Minqin Basin, a microcosm of the artificial oases in the arid northwest China, used the multi-types of data to recover the spatial distribution of human settlement and drainage patterns during historical period and analyze the relationship between them over the past 2000 years.

Outcomes: Before the Han Dynasty (121 BC), the utilization of water resources in the Minqin Basin was in the primitive stage and the drainage pattern maintained the natural state. From the Han (121 BC- 220) to the Wei-Jin Dynasties (220- 316), the utilization of water resources intensified unprecedentedly, but the natural shape of the river systems was still maintained. In the following 1,000 years or so, the drainage pattern was in the state of "following its own course" due to the small human population. In the Ming Dynasty (1368-1644), with the alteration of the main rivers, the water resource utilization increased obviously, but the human reclamations were mainly confined to the southern part of the basin. In the Qing Dynasty (1644-1911), the reclamation of the Liulin Lake area significantly changed the drainage patterns, resulted in the drastically northward expansion of human settlement. Since the foundation of the People's Republic of China (PRC) in 1949, the artificial water system completely replaced the natural water system and intensified the ecological problems in the basin.

Discussion: The changes over the past 2000 years show the drastic impacts of human activities on the alterations of the drainage patterns and related ecological problems in the arid Northwest China.

Conclusion: Rehabilitation of such ecological impairments requires both ecological restoration projects and changes in human paradigm and behavior over multiple temporal and spatial scales.

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Minqin Basin; Chinese Dynasties; human settlement; utilization of water resources; drainage pattern

Introduction

Transitioning from picking, fishing, and hunting for foods in the wilderness to primitive agriculture, human's production had experienced about 10,000 years, but the most drastic impacts on the environment were mainly concentrated over the recent 2000 years (Han 2000). Dryland is an important base for human settlement, and once produced some most brilliant ancient civilizations in the world. Water is one of the most important natural resources in the arid and semiarid areas, and directly affects human settlement. Current utilization pattern of water resources is a reflection of the historical behavior of humans. Analysis of understanding the relationship between human settlement and drainage patterns is essential for improved understanding of the relationship between human activities and water resources. Xu

et al. (2016) investigated the relationship between geographic distribution of archaeological sites of different periods of ancient civilizations, climate, and environmental change in the Poyang Lake Basin between 10.0 and 2.8 ka BP. Scott Anderson, Roger, and Stillick (2013) discussed the relationship among vegetation change, fire, and human settlement over the past 800 years in the Sierra Nevada, CA, USA and found this period witnessed significant expansion of Native Americans, and then Euro-American populations. Haldorsen and Treidel (2012) found groundwater springs often formed habitats for animals and humans and the permanent settlements for families and tribes in dry areas.

China is one of the famous ancient civilizations in the world, and the practice of channeling water to develop agriculture in the arid area started thousands

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Figure 1. The map of the Minqin Basin.

of years ago. Through the water resource projects, China expanded its cultivated land, increased its population, and developed its economy. The Shiyang River Basin (SRB), located in the eastern part of the Hexi Corridor in Gansu Province, Northwest China, is an area that has experienced most severe water supply–demand conflicts in the country over the past 2000 years. The Minqin Basin is in the lower reach of the SRB, and over the recent centuries, the increasing human activities have brought many ecological problems such as declining groundwater level (Xiao et al. 2007; Sun et al. 2009; Zhang et al. 2012; Chen and Feng 2013), the disappearing terminal lakes and the reducing vegetation (Xiao et al. 2007; Feng et al. 2011). As a microcosm of the arid areas in Northwest China, the Minqin Basin is an ideal place for studying the dynamic relationship between human activities and drainage patterns and environmental changes during the past 2000 years. Although some studies have analyzed the evolution of man–land relationship (Miao and Wang 2000; Zhu 2002), investigated the extent of ancient oasis in Han and Tang Dynasties (Li 1989; Li 1990; Li 1998; Li 2003), and discussed the causes of desertification (Wang et al. 2002; Wang 2003; Lv 2003; Xie, Chen, and Qi 2009), few studies have thoroughly discussed the relationship between human settlement and the drainage pattern.

This study explores how human settlements changed the patterns and distributions of the river systems over both time and space over the past 2000 years. The results provide important information for sustainable management of water resources in both the Minqin Basin and similar arid areas in Northwest China and beyond.

The study area

The Minqin Basin is situated in the downstream of the Shiyang River. The SRB is located in the crossbelt of Chinese Eastern Monsoon Region, Qinghai–Tibetan Alpine Region, and Northwestern Arid Region. Far away from oceans and with dry climate, the landscape of the SRB is made up of deserts, gobi, steppe, and oasis. The SRB has the largest population, the highest degree of water resources utilization, and the most sharpened conflicts between water supply and demand in the three inland river basins (or terminal lakes) – Shule, Heihe, and Shiyang, in the Hexi Corridor.

The Minqin Basin is surrounded by the Tengger Desert in the east and Badain Jaran Desert in the north and west, separated by the Yabulai Mountain. The south of the Minqin Basin is bounded by a number of arc-shaped low mountains. As an inland desert region, the oasis accounts for about 10% of the basin. The topography is quite flat, with an altitude between 1295 and 1460 m above sea level, with the slope ranging from 5‰ to 1‰. The only surface water resource is from the Shiyang River. The oasis has a length of about 100 km from south to north and width of about 20–30 km from east to west, including 16 townships and two state farms, with a population of 231×10^3 . The irrigation in the Minqin Basin totally depends on the river and wells. The irrigation area is divided into three parts: Baqu, Quanshan, and Huqu (Figure 1). Due to overexploitation of limited water resources over the past hundreds of years, the Minqin Basin has become an infamous area for worsening ecological services: drying up rivers, depleting groundwater, degraded vegetation, intensified

salinization, and the increasing hardship for the local residents.

Methods

This research employs a multidisciplinary approach to reconstruct human settlements and the patterns and distributions of river systems over both time and space over the past 2000 years. The data used include digital remote sensing (RS) images (such as aerial photos taken in 1960s collected from Library of Lanzhou University and the Landsat Thematic Mapper (TM) images acquired in 2015 downloaded from USGS website, <https://glovis.usgs.gov/>), historical documents (such as the historical books of Minqin County from the Museum of Minqin County), maps, and GPS-aided field surveys. The RS images were used to determine the distribution of ancient channels and oases by using visual interpretation, while the archaeological data and historical documents (provided by the Museum of Minqin County, the special institution of cultural relic management of the Minqin County) were used to determine the times of historical objects.

The procedures of this study are to (1) identify one typical ancient area; (2) survey the ancient human activity trace, especially ancient channels and reclaimed land in the field; (3) through contrasting with the remote sensed images, set up the

interpreting keys by using shape, size, space arrangement, texture and color; (4) interpret the RS image by visual methods; (5) determine the times of the old oases; and finally (6) analyze the spatial and temporal changes of the drainage patterns and human settlement (Figure 2). The human activities in Minqin Basin can be traced back to thousands years ago. Figure 3 is an illustration on the dynasties the Minqin Basin has experienced and through the figure people can easily have a correspondence between the major events and the times they occurred. Meanwhile, Figure 4 is an illustration of changes in population quantity of Minqin in the past 2000 years (from 102 BC to 2015).

From Shajing Culture to the Hun period (before 121 BC) – natural drainage system period

The Shajing Culture, named after being first discovered in the Shajing area of Minqin County, is a kind of painted pottery culture in the late Chinese Bronze Age. The central area was located across the western and southwestern edge of the Tengger Desert. The age of the Shajing Culture can be traced back to about 800–600 BC (Liang 1997). The Shajing People were thought as the earliest residents in Minqin (Committee on Chorography Compilation of Minqin County (CCCCMC) 1994) and relied on

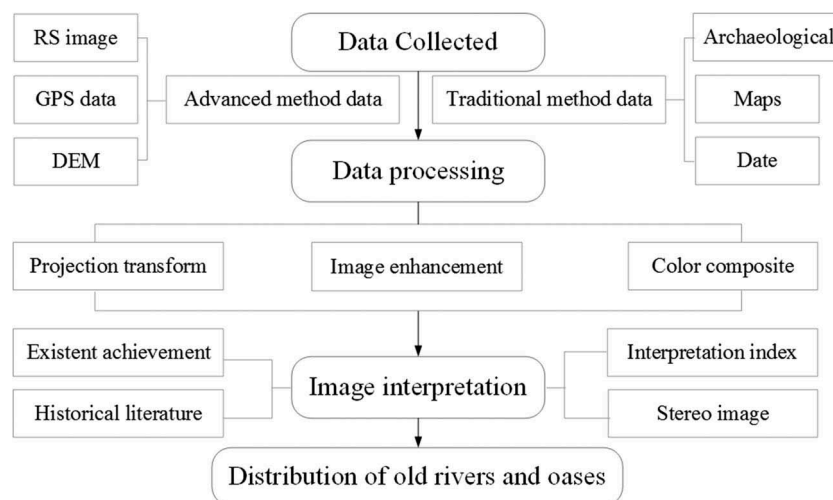


Figure 2. The flowchart of rebuilding spatial changes of the Minqin river systems in historical times.

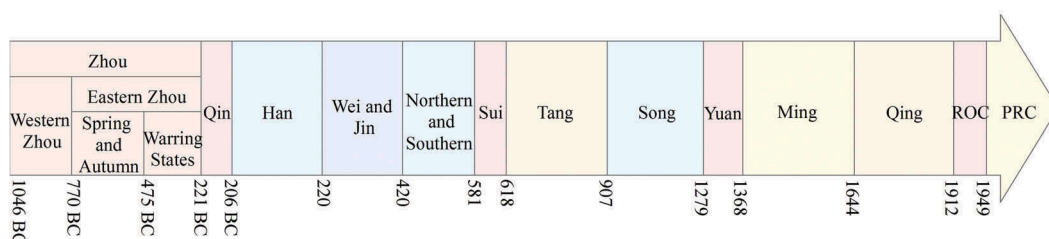


Figure 3. The major dynasties occurred in the Minqin Basin.

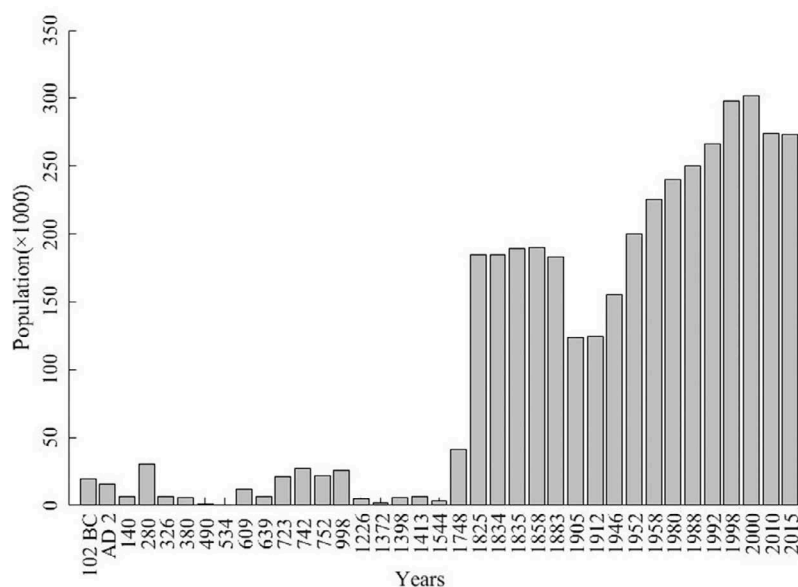


Figure 4. The changes in human population in the Minqin Basin over the past 2000 years (from 102 BC to AD 2015).

hunting for their lifty (Pu 1989). Settled along the rivers, the Shajing people were mainly engaged in hunting and their ability of changing the nature was very weak. So it is conceivable at that time the drainage pattern was at the natural state.

From the Warrior States period (475–221 BC) to the Qin Dynasty (221–207 BC), the Huns occupied the whole Hexi Corridor including the Minqin Basin. The Minqin Basin appeared like a lake named “Xiutuze,” named after the King of the Huns- “Xiutu” (Li 1986). The Huns were a nomadic group, they “migrated according to the distribution of water and grass, no castle and no ploughing,” and the production level was very low. At that time, the Huns lived in the Hexi Corridor with a population of roughly 50,000 (Gu 1984), the majority of oases were the beautiful grassland, and mountains were covered by the forest (Zhao 1986). Therefore, it is believed that the human use of water resources was only limited to drinking water supply for both human and livestock, and the drainage pattern was also at the natural state and the human settlement was distributed along the rivers.

The Han to Weijin period (121–316 BC) – migration of people and construction of canals

The Han period

In the early Western Han Dynasty (121–128 BC), the Emperor Hanwu launched three battles against Hun People and achieved a decisive victory. Since then the Minqin Basin was incorporated into the territory of the central plains dynasty. Large numbers of people

in Central China were moved to the Hexi Corridor, and the system of prefectures and counties was set up. The Han Dynasty established the Wuwei Prefecture in the SRB, which contained 10 counties. Two of them, Wuwei and Xuanwei, were in the Minqin Basin. Later, the population of the two counties reached about 20,000, and during the Eastern Han Dynasty (AD 25–220), Xuanwei alone had 10,000 residents (Liang 1997).

At that time, there was abundant water in the Shiyang River, and large rivers and lakes existed in the Minqin Basin. The agricultural production showed a prosperous phenomenon. The Han Dynasty left a lot of town sites and the burial sites in the Minqin Basin (Figure 5(a)). The Sanjiaocheng site is located in the Xishawo Desert, the north edge of the Minqin Basin, with a width of 120 m and a length of 200 m, altitude 1336 m above sea level. In the north of the site, there were two large ancient ditches (4 m in width) clearly extended in east–west direction, intersected at about 30°, the south ditch length is about 200 m, and the distance to Sanjiaocheng is about 200 m. However, the north one can be tracked very far in the east (about 3.3 km) and disappeared near the modern oasis. Some parts of the ditches have silted up, but their boundaries are still clear. These ditches could be a facility used for defense, drainage, or irrigation. Such ancient ditches can be observed in many areas in the Xishawo Desert, and they are strong evidences of ancient water resource utilization.

The newly immigrated people to the Minqin Basin would inevitably choose the areas with the best water condition to reclaim. This would change parts of the natural water system to artificial water system and the

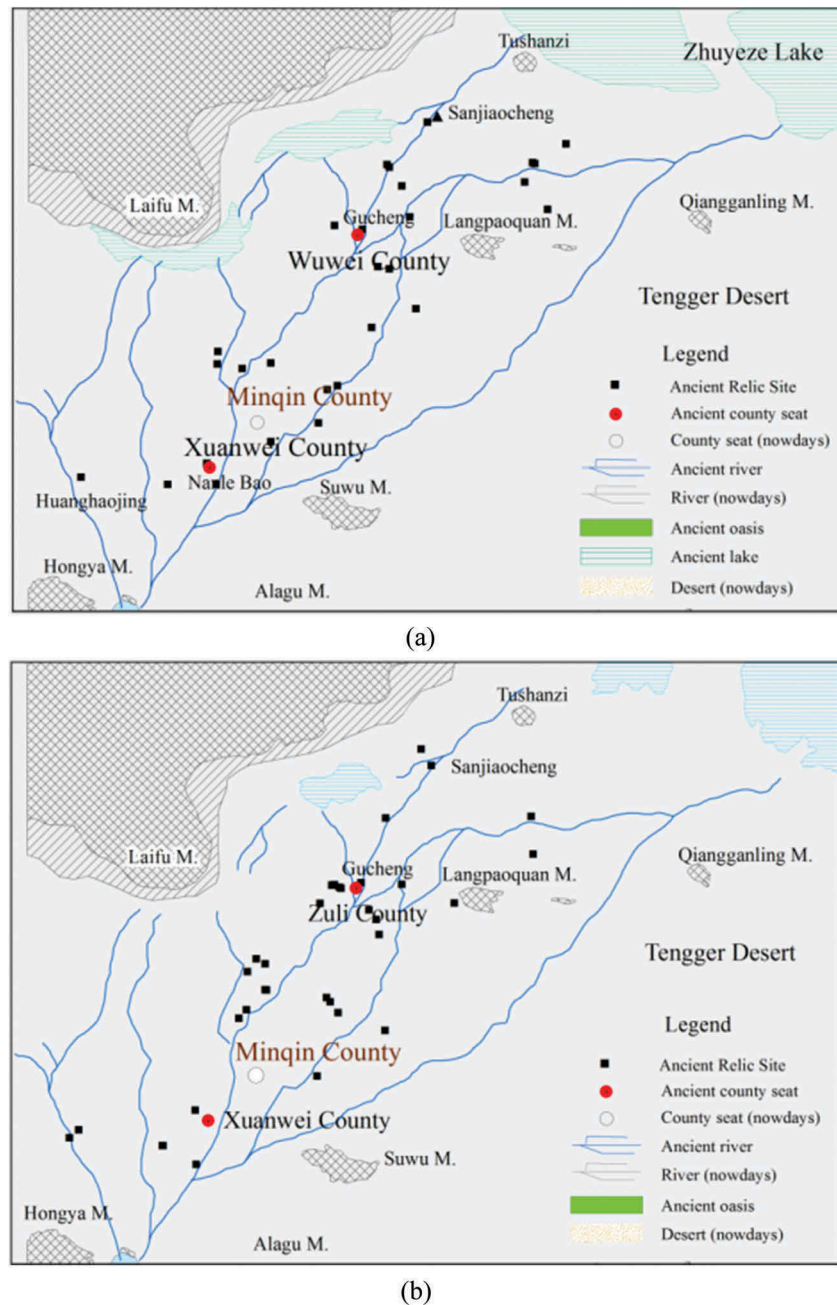


Figure 5. The archaeological sites and rivers in (a) the Han Dynasty and (b) Wei Jin Dynasty.

natural oasis to artificial oasis. On the enhanced TM images acquired in 2015, it can be clearly seen that a series of ancient rivers distributed in the Minqin Basin. Combining with the ancient sites, relics, and historical literatures, the distribution of the drainage pattern in the Han Dynasty can be identified (Figure 5(a)). From Figure 5, we can see the water system started from the foothill of the Hongya Mountain and flowed to the north like a fan in shape, and the distribution of the ancient relic sites is closely related to the ancient rivers. The human mainly used the main streams and tributaries located in the middle reaches of the basin to conduct agricultural production. Those rivers mainly served to discharge floods were presumably dominated by swamp aquatic plants.

The Wei and Jin period (AD 266–316)

In the Western Jin Dynasty (AD 266–316), due to the political turmoil, many of central plains people fled to the Hexi Corridor. From the fourth to the middle of the fifth century, the migrated mainland people to the Hexi Corridor were not less than 200,000 (Zhao 1990). In the Minqin Basin, in order to settle those incoming people, the Former Liang government set up a special county named Zuli to house them. The governor built canals to deliver water to reclaim the land, transforming all the barren land of Wuwei and Xuanwei Counties in Han Dynasty to farmland, and extending the range to the areas named Duanzihaochaiwan and Qinfengtian.

Field investigation shows that the relics of the Wei-Jin period (AD 220–420) were widely distributed in the Minqin Basin. It indicates that this period was very prosperous. Figure 5(b) shows that the human activities kept a good inheritance and continuity with the Han Dynasty, and local residents made full use of the water that the natural water system provided.

Northern and Southern Dynasties (420–581) to Yuan Dynasty (1271–1368) – depression period

The Northern and Southern Dynasties were a long and depressive period in the Minqin Basin history. In the Northern Wei period (386–534), the Minqin Basin had only one County (Xuanwei) with a population of just 373,000 (Liang 1997). Since then, there was no county-level government anymore (Wang 1991). During the Tang Dynasty (618–907), Wuwei County was the only local government in the Minqin Basin which just remained for 27 years. In the other periods, there were only a few military installments for security purpose (Li 1990). In the later Period of Tang (764–861), the Hexi Corridor was occupied by the Tubo people (the predecessor of Tibetan) and livestock became the main production sector. Later, the Minqin Basin was ruled by the Western Xia (1038–1227) for more than 180 years, and then transitioned to the Mongol Yuan Dynasty (1271–1368). To the end of the Yuan Dynasty, there was only one residential settlement – Xiaohetan Town (located now in the Minqin County) and it almost was a ghost town (Committee on Chorography Compilation of Minqin County (CCCCMC) 1994).

The Dangxiang and Mongol people lived a nomadic lifestyle, and the Minqin oasis was mostly abandoned. The weak government and poor administration led to low utilization of water resources. At that time, the Minqin Basin must have experienced a number of floods because the rivers changed their courses, and the lakes shifted their locations. Essentially, the rivers in this period might be in a state of “swinging by themselves.”

Ming Dynasty (1368–1644) – second great development period

River system

In the Ming Dynasty, the rivers in the Minqin Basin were mainly Xihe River (West River) and Dongda River (East River). The Xihe inside the Ming Great Wall often flooded, the water in the left bank finally flowed into the Daxi River, but the water in the right bank was used for irrigation, and the remaining water flowed bifurcately to the north of the County. During this period, many historical records reported

activities for harnessing the West River, for example, in the summer of the 18th year of Emperor Hongwu ruling (1385), 500 soldiers were dispatched to dredge the river and 45 river frusta were built (Xie and Xie 2000). In the August of the 42nd year of Emperor Jiajing ruling (1563) and the second year of Emperor Tianqi ruling (1622), many dikes were built along the West River (Xie and Xie 2000).

The Dongda River was the river flowing farthest eastward. The river had the length nearly 100 km and width 200 m–5 km (Committee on Water Conservancy Chorography Compilation of Minqin County (CWCCM) 1994). The Dongda River often ran wildly and often flooded in the section of today’s eastern oasis in the Minqin Basin. Historical records reported many activities on managing the Dongda River such as repairing river banks and planting trees in the 26th year of Emperor Jiajing ruling (1547).

As to lakes, the literature mentioned seven lakes’ names, but the most famous was the Liulin Lake (named according to widespread *Tamarix Chinensis*). The reason why the modern people call the northern part of the Minqin Basin “Huqu,” meaning “lake area,” rooted in this lake. The ninth year of Emperor Xuande (1434) was the earliest recording of this lake (Xie and Xie 2000). At that time, the Liulin Lake should be a swamp aquatic region and the abundant water would flow out to the east (Committee on Water Conservancy Chorography Compilation of Minqin County (CWCCM) 1994).

In addition, the historical records also recorded both the severe droughts and floods in the Minqin Basin during the Ming Dynasty, which caused significant farmland losses and human fatalities.

Human settlement

In the Ming Dynasty, the Minqin Basin, located in the northwest frontier, was often invaded by Mongolians. In order to consolidate the frontier, the Ming Dynasty migrated people in to reclaim barren land in this area. In the fifth year of Emperor Hongwu ruling (1372), “more than 2,000 people from Shanxi and Henan provinces were immigrated to and settled down in Caiqi and Qingsong (the old place names, Caiqi is nowadays Caiqi Township and Qingsong is in the west Xuebei Township)” (Xie and Xie 2000). The human settlements in this period were just in places such as Qingsong Castle and Zhenfan Town. Later, the Ming government moved more and more people to this area. In the earlier period of the Ming Dynasty, Linhewei (i.e. Zhenfanwei later, now named Minqin County) had over 1900 garrison soldiers. By the 19th year of Emperor Hongwu ruling (1386), the population reached 7027 people. By the year 1396, the farmers had reached to 5500. By the 15th year of Emperor Yongle ruling (1417), the Minqin population increased

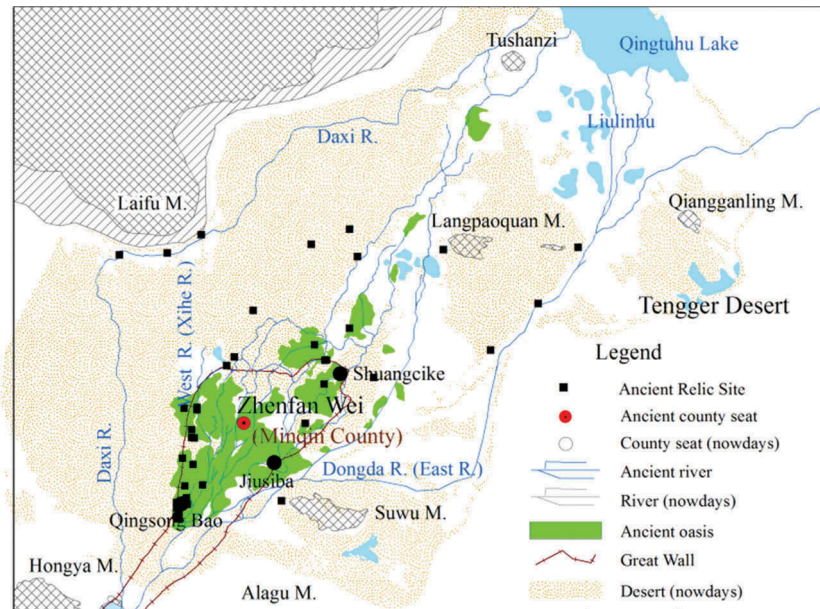


Figure 6. The archeological sites and rivers in the Ming Dynasty.

to 2413 households, with 6517 people (Xie and Xie 2000). It would be over 10,000 if including troops (Liang 1997). By the year 1627, Minqin had 3567 households, with 10,573 people. To the year 1633, there were 5533 households and about 30,000 people. Large area of land was reclaimed and the agricultural development reached its second climax in the basin.

In the Minqin Basin, the Ming government built half-round Great Wall, which became the main boundary of Zhenfanwei. The area inside the Great Wall was densely populated and agricultural production presented thriving scene, but the area outside the Great Wall was very desolate. In fact, it was the pastures of Mongolians. In the middle period of the Ming Dynasty, the reclamation activities broke through the limit of the Great Wall, and some areas north to the Great Wall were also reclaimed (Xie, Chen, and Qi 2009).

As shown in Figure 6, the Great Wall in the Ming Dynasty distributed in the southern part of the Minqin Basin. The rivers presented fan-shaped distribution, with Zhenfanwei Town as the center and the human settlements mainly concentrated in the area inside the Great Wall.

Water shortage and desertification

It seemed that the phenomenon of water shortage in the Minqin Basin first appeared in the Ming Dynasty (1368–1644). In the fourth year of Emperor Xuande ruling (1429), Zhenfanwei especially set an officer, Water Magistrate, to be responsible for water conservancy. This showed water management was an important affair and needed a special agency to be in charge of it. By the 24th year of Emperor Wanli ruling (1596), the local government – Zhenfanwei in the Minqin Basin began to tax on water, which

showed that the irrigation water supply was limited and needed to be regulated institutionally (Committee on Water Conservancy Chorography Compilation of Minqin County (CWCCM) 1994).

In historical literatures, the records about the sandstorms in the Ming Dynasty period were very common. The years 1438, 1448, 1473, 1560, 1584, etc. all recorded the occurrences of very severe sandstorms. The sandstorms not only buried farmlands but also destroyed human habitats, causing serious famine and many abandoned homes (Xie and Xie 2000). In the year 1630, the sandstorms forced 26,000 farmers living near the County Administration to move to the places 20 km away. The original settlement places such as Dong'an Castle, Hongsha Castle, and Laoye Temple, etc., which were located at Zhongshawo, were all abandoned in this period.

The Qing Dynasty (1644–1911) – continuous development and emerging ecological problems

The changes of lakes

In the Qing Dynasty (1644–1911), due to the decrease of water amount from the upper reaches, many large lakes in Minqin Basin shrank further and led to the formation of many scattered small lakes, but water surface was still large compared to the present time. Statistics showed that there were as many as 76 place names containing “lake” on the modern map of the Minqin Basin which were generally inherited from the Ming and Qing Dynasties, although those places are villages, farmlands, barren lands, and even deserts nowadays. According to the historical literature, the large lakes were Yuhai,

Qingtu Lake, Liulin Lake, Liuba Lake, etc. (Xie and Xie 2000).

Among them, the Yuhai was the most northeastern lake and evolved from the former East Sea (Baiting Sea), had several miles in perimeter (Liang 1997) in the Qing Dynasty, and eventually dried up around 1840 (Li 2002). The Qingtu Lake is the remnants of the Xiutuze Lake, still showing certain water. In the year 1856, due to too much water flowing into it, the Qingtu Lake became a threat to local residents, and as a result they moved to dry areas one after another, abandoning their houses and farmlands. In the year 1908, the Qingtu Lake was still 15–20 km in east–west direction and 30–35 km in north–south direction (Xie and Xie 2000). The Liulin Lake was still a large lake and in the year 1655 was as large as a sea (Xie and Xie 2000). But the Lake was reclaimed in the Emperor Yongzheng period (1723–1735) and its surface area had shrunk significantly. The Liuba Lake's retreat is also very remarkable. In the 43rd year of Emperor Kangxi ruling (1703) a proposal was made to reclaim the land along the lake, and by the 60th year (1721), a surveyed reported that there were more than 1842 ha of the barren land around the lake. This indicates the lake had shrunk and its surrounding area could be reclaimed to farmland (Xie and Xie 2000).

Reclamation of oases and change of river systems

In the Qing Dynasty, the rivers still existing in the Minqin Basin were the Xi River, Dong River, and Daxi River. In the 18th year of Emperor Shunzhi ruling (1661), a river cruise in a wood boat was made from the County Administration to the Yuhai Lake (approximately 100 km) (Xie and Xie 2000), which showed the water

amount of the Xi River was large enough to support a boat. The Dong River originated from the Moshan Mountain, after filling up the Liulin Lake, flowed into the Baitinghai Lake (Figure 7) (Committee on Water Conservancy Chorography Compilation of Minqin County (CWCCM) 1994). The Daxi River was known as a spillway during that time (Li 2003), but in the year 1868, to keep the water of the Xi River from flowing away to the Daxi River, the local residents dug a ditch to divert all the water from the Daxi River to the Xihe River, causing the Daxi River to dry up (Committee on Water Conservancy Chorography Compilation of Minqin County (CWCCM) 1994).

The most striking event during the Qing Dynasty (1644–1911) was the reclamation of the Liulin Lake area, which altered the pattern of river system all over the basin remarkably. During the Ming Dynasty (1368–1644), the Liulin Lake area was the region where the Mongolian people hunted casually (Xu 1997). Facing the pressure of “more people and less land, and inadequate grains for living” (Xie and Xie 2000) during the Qing Dynasty, in the 12th year of Emperor Yongzheng (1734), the upper reaches of the Xihe River were dammed up and the Dongda River were straightened out, so as all the water from the both rivers was led to the Liulin Lake. Subsequently, one large main canal was built first, and the smaller canals in the east, middle, and west branches of the main canal were built to make the Xihe River flow northward liking a chicken foot (Figure 7). Every large main canal had several branch and lateral canals and hundreds of dams, gates or bridges. In order to administer farming activities, a special organization – the Liulin Lake Water Use Chief was also set up (Xu 1997).

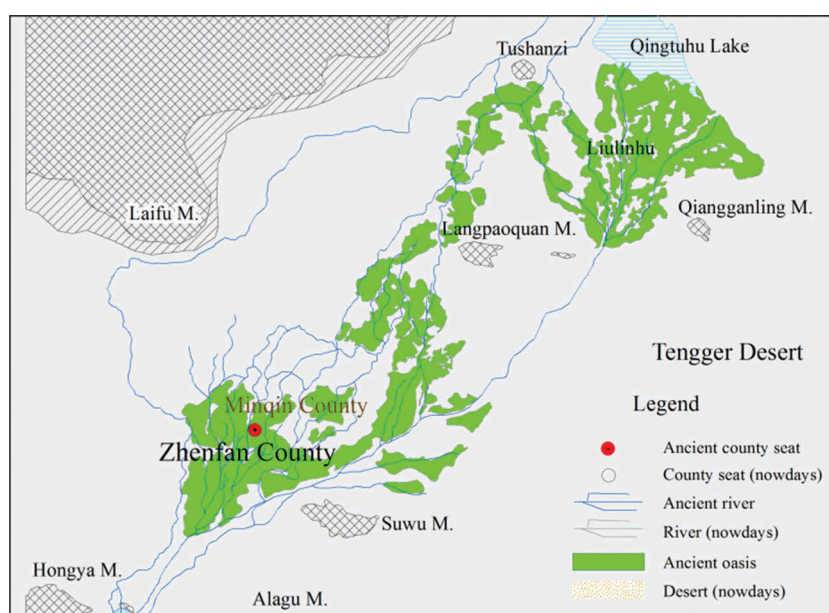


Figure 7. The distribution of rivers in the Qing Dynasty.

The development of barren land had doubled in the Minqin oasis by the end of Qing Dynasty and the landscape of the Liulin Lake region changed from natural aquatic environment to farmland. This also greatly enlarged the residential area. By the Qianlong 28th year (1763), there were about 2151-ha land had been developed and the grain production significantly increased, accounting more than half of the grain output in the whole county (Xu 1997). By the year 1795, the Liulin Lake region had more than 2765 ha of farmland, and proposals were made to “halt the reclamation activities” (Xie and Xie 2000). In the 18th year of Emperor Jiaqing ruling (1813), the reclamation of the Liulin Lake area was prohibited to reduce the water consumption (Xie and Xie 2000). But the prohibition was strictly enforced and by the fifth year of Emperor Daoguang ruling (1825), the cultivated land still reached 2520 ha.

The consequences of reclamation

In the late Qing Dynasty, the population of Minqin Basin had reached 184,500. Due to the shortage of irrigation water, the Liulin Lake region and adjacent newly developed area could be only irrigated once a year, a significant change from the irrigating farmland four times per year under normal conditions, and the residents began to select new places for reclamation (Li 1987, 1990). The conflicts between the upper and lower reaches became increasingly contentious and water lawsuits were filed more frequently. The years 1722, 1725, 1727, 1737 all were the years with massive lawsuits (Committee on Water Conservancy Chorography Compilation of Minqin County (CWCCM) 1994). By the Jiaqing ruling

(1796–1820) and Daoguang (1821–1850) ruling, far more lawsuits were filed with the Liulin Lake Water Use Chief (Xie and Xie 2000).

In the late Qing Dynasty, the threat of blown sand was still serious. In the third year of Emperor Daoguang ruling (1823), more than 200 beasts were blown into canals and ponds and drown. In the 10th year of Emperor Guangxu ruling (1884), a clay sculpture was even blown down. The City Wall of the Zhenfan County was buried by sand many times and had to be dug out by manpower. A lot of forts and settlements, such as Chenmei, Liuba, Qingsong, Nanle, and Shashan, were all abandoned during this period (Li 1990). The expanding desertification was attributed to the large-scale human reclamation and farming activities.

Modern times (since 1950s) – ecological deterioration and restoration period

Water conservancy construction

Since the founding of The People’s Republic of China in 1949, residents in the Minqin Basin began to repair the old drainages and rivers, excavate new drainage canals, and use water mills for irrigation. In 1957, the Neihe River and Waihe River were artificially merged. In 1958, a large reservoir, the Hongyashan Reservoir was built on the middle reach of the Shiyang River, The Dadong River was straightened and the Waihe Channel was constructed to regulate the surface water resource in the middle reach of the Shiyang River. From 1950 to 1985, a total of 5558 segments of canals with a total length of 4138 km were constructed (Committee on Chorography

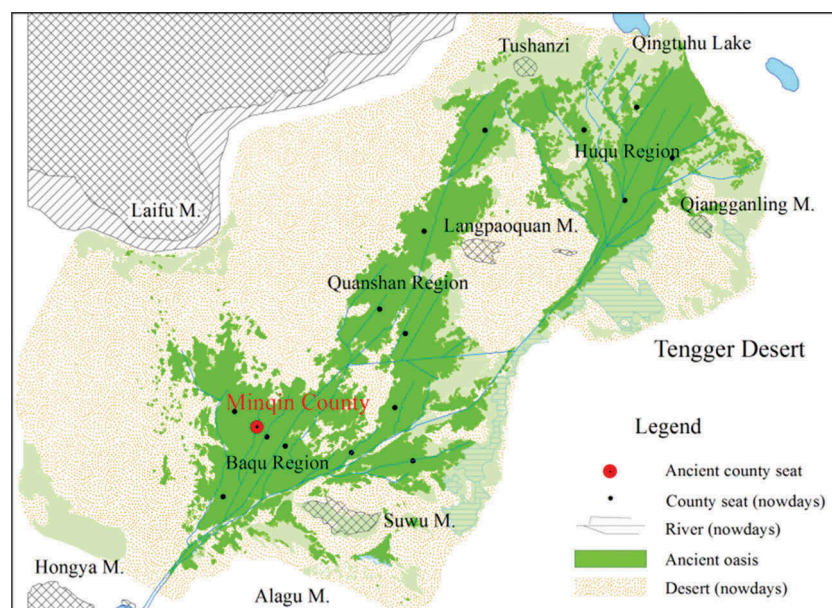


Figure 8. The distribution of oases and rivers at present.

Compilation of Minqin County (CCCCM) 1994). A large-scale extraction of groundwater also started. Since the 1970s, there were a total of 13×10^3 electronic pumping wells have been dug in the Minqin Basin (Shi 2000). These projects resulted in a rapid expansion of the irrigation area and in turn, a significant increase in grain output (Figure 8).

The construction of reservoirs and irrigation canals and improved canal linings to control runoff in the upper and middle reaches of the Shiyang River resulted in the depletion of springs and reduced water yield in the Minqin Basin (Zhu and Chen 1994). By the late 1980s, a total of 20 reservoirs, 15,600 electric pumping wells, and a large number of water and irrigation engineering projects had been built over the SRB. The total irrigation area had doubled compared to that in the 1950s (Zhu and Chen 1994).

Recent water management programs

The decreasing flow to the lower reach of the Shiyang River due to the increasing withdrawals of the river flow for agricultural irrigation and municipal supplies in the middle reach resulted in serious ecological problems in the Minqin Basin: water area reduction, groundwater depletion, vegetation and grassland degradation, soil salinization, water quality deterioration, and desert expansion. The Qingtu Lake and Baitinghai Lake dried out respectively, and many other lakes had mostly been buried by sand dunes. The Dadong River has completely dried up and become a wide and shallow sand channel, a source of blowing sand (Committee on Water Conservancy Chorography Compilation of Minqin County (CWCCM) 1994). In 2004, there had been more than 80 sandstorm days in the SRB.

In 2007, the “Key Management Plan of the Shiyang River Basin” was issued by Gansu Provincial Department of Water Resources and Gansu Development and Reform Commission. After years of implementation, by the end of 2015, the forest coverage rate increased from 12.06% in 2009 to 19.5% in 2015 (Ma 2016), non-forest vegetation coverage increased from 5–20% before 2007 to more than 40% (Ma 2014) in the Wuwei Prefecture. In the Minqin Basin, groundwater extraction decreased 83.4% from 2007 to 2015, and the groundwater table has risen each year since 2007. By the year 2010, the Qingtu Lake had formed a 3–22.36 km² seasonal water surface compared to 2007 (Ma 2016). Among the 96 closed irrigation wells in Jiahe Township 7 have become artesian wells. Over 6667 ha of vegetation had been restored in the Huang’antan area, and vegetation coverage increased from 28% in 2007 to 45% in 2015 (Ma 2016). The number of sandstorms has significantly decreased.

However, those management programs and activities are only effective in a limited number of areas where water resources such as the groundwater are still available. Most of the areas have yet to see the signs of improvement in ecological systems and environmental conditions. It may take decades of continuous implementation of water management programs to rehabilitate the ecosystem in the Minqin Basin.

Discussion and conclusions

By analyzing the changes in the patterns of human settlement and the distribution of river systems in the Minqin Basin over the past 2000 years, it can be seen that in the Shajing and Huns times, the people in the Minqin Basin had a livestock-based primitive lifestyle, and the use of water resources was just to satisfy the drinking demands of both human and animals. Entering the Western Han Dynasty, large-scale utilization of water resources started to emerge. In the Wei–Jin period, the basin was continually being developed and the oasis expanded dramatically to start a prosperous period of economic development, although the duration was very short. From the Northern and Southern Dynasties to the Yuan Dynasty, in nearly 1000-year period, the agricultural production was depressed, the population was small, and the river system was essentially at the natural state. From the Ming Dynasty on, the immigrants increased rapidly, the corresponding water resource utilization activities grew significantly, and large tracts of oases were formed. The Qing Dynasty kept the Ming Dynasty’s trend and the population increased drastically. The momentum in the water resource utilization continued and many more water engineering projects were built. Since the founding of The People’s Republic of China in 1949, a large number of reservoirs and water transfer projects were built, huge amount of ground water has been extracted, the water utilization has reached a climax unprecedented over the past 2000 years, and the artificial oases have expanded beyond the carrying capacity of the available water resources in the Minqin Basin.

Over the past 2000 years, with the fast advancement in technological development, human’s ever-increasing ability has gradually changed the natural river system to semi-artificial and artificial systems in the Minqin Basin. But, the natural river system has always been the important base for human water resource utilization. Even with the modern artificial channels, we can still see “the traces” of the natural rivers. While the large-scale development of water resources had improved the agricultural production and the quality of life, the overexploitation of the limited water resources has resulted in the chronic

water shortage and serious deterioration of the ecosystems in the Minqin Basin.

Through the above analysis, the main findings of this study are as follows:

- (1) The relationship between human settlement and changes in the distribution of water resources was closely intertwined and complementary over the past 2000 years. Human settlement changed the distribution of water resources and the altered drainage systems, in turn, accelerated the expansion of human settlement.
- (2) Stable social environment and rational governmental policies are the prerequisite of governance in water management.
- (3) A deep understanding of the watershed hydrological process is essential for sustainable utilization of water resources. Believing the groundwater as inexhaustible, the large-scale, vigorous well-drilling boom by both water resources managers and the general public in the Minqin Basin to compensate the reducing river flow from the upper reach of the Shiyang River in the 1970s planted a deep seed for the subsequent deterioration of the ecosystems decades later.
- (4) The upstream activities have deep impacts on the hydrological processes and water resources of the downstream. In ancient times, the human activities in the upper and middle reaches of the Shiyang River were relatively limited, especially in the periods before the Qing Dynasty, there was enough water flowing downstream, and the downstream was even often flooded. Once the water withdrawals for agricultural irrigation and economic development in the upstream intensified, frequent and severe water shortages and related changes in the drainage patterns occurred downstream.
- (5) Human activities are the main driver for the deterioration of ecosystems in arid areas. Since the late Qing Dynasty, especially the 1950s, the exponential growth in human population and the associated large-scale development and utilization of water resources in the Minqin Basin have resulted in the unprecedented deterioration of ecosystems. This type of phenomena is common in the lower reaches of the inland rivers of Northwest China, such as the Heihe River and the Shule River in the Hexi Corridor, Gansu Province, and the Keriya River and the Tarim River in Xinjiang Uygur Autonomic Region. Therefore, paradigm shift and changes in human behavior are the prerequisite for water sustainability and ecological security in arid Northwest China and beyond.

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