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Water Resource Development and its Influence on Eco-environment in the Mainstream of Tarim River, China

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Abstract: This paper outlines the influence of water resource development on the hydrological conditions and ecology of the mainstream of the Tarim River basin during last 50 years. Due to large-scale reclamation in the upper reaches, the discharge in the lower reaches decreased significantly, many terminal lakes dried up, and the water quality is getting worse. Such hydrological changes have resulted in seriously environmental degradations, such as soil salinization, vegetation degeneration and desertification and so on. In addition, the "Green Corridor" in lower reaches fading away gradually, and the Taklimakan Desert and the Kurmtag Desert are closing up to each other. In order to protect the environment and maintain sustainable development in the region, a holistic planning should be put forward and carried out timely. It should take into consideration the interests of the upper, middle and lower reaches, distribute and use the water resources rationally, and coordinate the relationship between economic development and environmental protection.

Key words: Water resources development, hydrological effects, environmental degradation, Tarim River.

The Tarim River is the largest inland river in China and is also a famous continental river in the world. It originates from Tianshan and Kunlun Mountains and runs through the whole Taklimakan Desert. In the early years, all larger tributaries in the Tarim basin merged into the Tarim River and finally drained into the Lop Nor (Mao, 1998). However, influenced by human activities, especially after the large-scale reclamation in 1958, most tributaries of the Tarim River could not discharge into the mainstream except Aksu, Hotan and Yarqant River (Rao, 1998 and Xia, 1998). The Tarim River, as we call it now, is the river from the confluence of the Aksu River, the Yarkant River and the Hotan River to the Taitmar Lake. The mainstream of the Tarim River has a length of 1321 km (Fig. 1), with an area of 4.6 x 10^4 km^2 and population of about 7.48 x 10^4.

With the increase of land reclamation in the three tributaries, the water discharged into the mainstream of Tarim Basin decreased rapidly in the last 50 years. This has adversely affected hydrology and ecology of the region. So it is essential to understand the present status and develop effective remedial measures.

Natural Environment

Climate

Situated far from oceans and separated by the surrounding mountains, the climate is typical continental. It is warm, dry, windy and has large evaporation losses. The mean

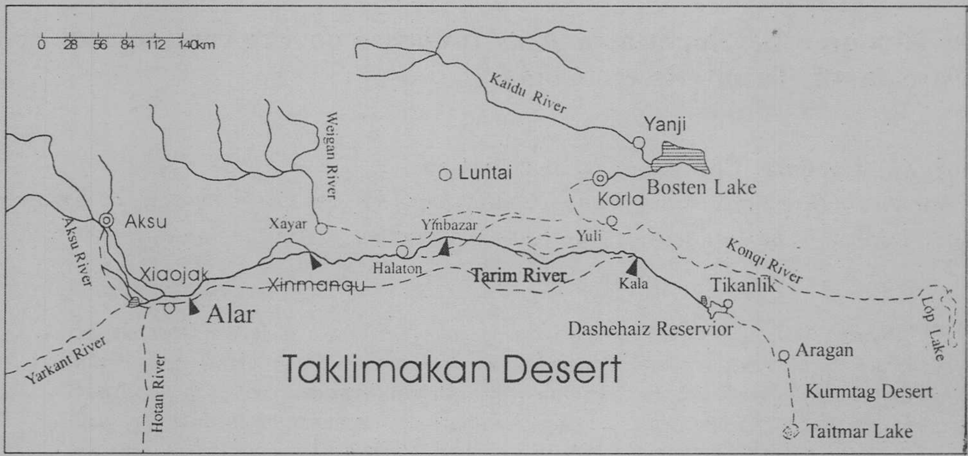

Fig. 1. Sketch map of Tarim River basin.

annual precipitation is 55 mm at the middle reaches, 35 mm at the lower reaches, 17 mm at Ruoqiang and only 1.9 mm at Qiemo. The annual evaporation is 2100-3000 mm, equivalent to 40-100 times the rainfall. The annual mean relative humidity is 40-50%. It is one of the driest areas in China, even in the entire world. The prevailing wind direction is NE and NW. The annual accumulated temperature is around 4100-4300°C. The sunshine period ranges from 2811 to 3133 hours and the frost-free period is between 185 and 214 days.

Soil

Influenced by the climate, the alluvial plain has the characteristics of desertic soil (Cheng, 1993). The effect of the biological elements on soil is weak. The terrain, parent materials and moisture play an important role in the soil formation. There is much meadow and boggy soil in flood-affected regions. The sandy soil is widely distributed particularly on the south bank. The organic matter content in the soil is usually low between 0.5-1.5% due to sparse vegetation and biomass.

Vegetation

In the desert alluvial plain where droughts are common and soils are sandy and saline the vegetation is low in diversity, simple in structure having loose growth (Huang *et al.*, 1998). The main vegetation includes members of families Salicaceae, Tamaicaceae, Chennopodiaceae and Leguminosae. The typical plants include *Populus euphratica*, *Tamarix ramosissima*, *Halodendron* and *Haloxylon ammoderdron*. The region is one of the major area of the Diversifolia Schrenk forests in the world (Song *et al.*, 2000).

Water Resources Development and Problems

Due to shortage of rainfall, there is no water flow in the mainstream of the Tarim River. The flow depends on its three source branches and is limited by the exploitation and utilization of the upper sources. In addition, these three branches can only flow into the Tarim River during flood period. The water that can flow into the mainstream is 46.59 x 10^8 m^3, of which the Aksu,

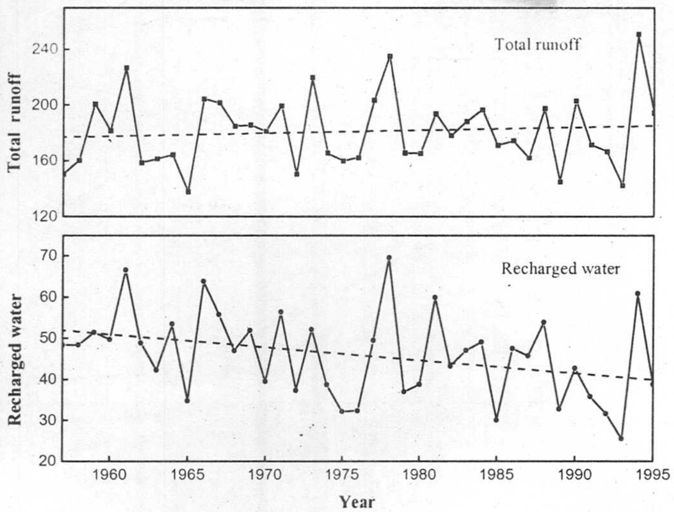

Fig. 2. Total water in three branches and water discharged into the mainstream.

Hotan and Yarkant River contribute 72%, 22.5% and 5.5%, respectively.

According to ^{14}C dating data, the Tarim River basin is already under the influence of human activities since 3800 BP (Wang, 1998). Since then the original water system has changed. During Han to Qing Dynasty, water was mainly used for agriculture and animal husbandry and water demand was small. After 1949, water was exploited mainly for agriculture. With population increasing and more farmland coming under irrigation in upper reaches, the conflict of water development among upper, middle and lower reaches became acute. This not only interfered with economic development, but also created a series of environmental problems.

Water shortage and serious wastage

Water resources in Tarim River basin are both deficient and misused. Even today the traditional multi-channel irrigation method is widely used. In most places, large irrigation quotas and intensive irrigations are common. According to statistics, the gross irrigation quotas in Tarim River basin are about 15,000-20,000 m^3 ha^{-1}, and sometimes reach 22,500 m^3 ha^{-1} (Fang, 2001; Yang, 2000) and the utilization coefficient of the channel system is 0.30-0.45 (Song, 2000). In the upper and middle reaches, the channeled water factor is 80%, but the net utilization factor is only 20%, thus about three-fourths of the water is wasted. So, the water consumption for an agricultural 10,000-*yuan* output value is very high. For instance, in upper, middle and lower reaches, the amounts are 173.4 x 10^4 m^3, 215.9 x 10^4 m^3, and 11.5 x 10^4 m^3, respectively (Zhou, 1998).

Irrational water resource distribution

According to hydrological data, the total amount of runoff originated from the river sources has little changed since 1950, but

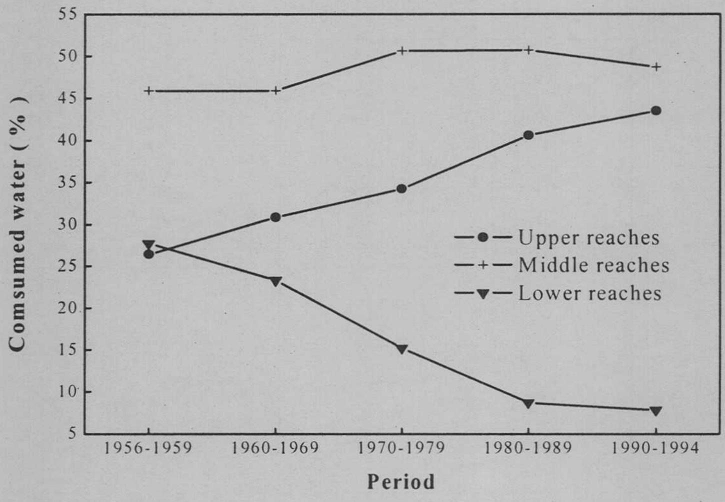

Fig. 3. Percentage of water consumption along Tarim River.

water discharged into the mainstream has decreased drastically (Fig. 2). This indicates increased consumption of water among three branches. For example, water in the Alar section in 1960s was about 50.57 x 10^8 m^3, but in 1990s declined to 40.4 x 10^8 m^3, a decrease of 20%. The water discharged into Tarim River from Aksu River decreased from 33 x 10^8 m^3 to 31 x 10^8 m^3, the Yarkant River from 5.95 x 10^8 to nil, and the Hotan River from 11.5 x 10^8 m^3 to 9.3 x 10^8 m^3. According to statistics, the irrigated farmland in three branches was about 35.2 x 10^4 ha in 1949 and increased to 76.74 x 10^4 ha in 1992.

Besides imbalance in river source and mainstream, there also exist disparities among upper, middle and lower reaches in water consumption on the mainstream. From 1950s to 1990s, the water consumption pattern among upper, middle and lower reaches had greatly changed (Fig. 3). For example, during the 1950s, the water consumption was about 14.8 x 10^8 m^3 and 15.6 x 10^8 m^3 in the upper and lower reaches, respectively. While in 1990s it was 17.7 x 10^8 m^3 and 2.7 x 10^8 m^3 (Li and Zhou, 1998).

Lack of unified management

The management system for water resources in Tarim Basin is incomplete. There is no uniform scheme to distribute water between the upper, middle and lower reaches (Fig. 3). There are 138 diversion canals from upper to middle reaches, but they have no control sluice (Wupuerjiang, 1999; Ji *et al.*, 1998). To manage water resources effectively, the Tarim River Basin Administration was set up in 1993, but the results are not encouraging. Hence it is necessary to change the management system and establish a new management organization to unify water management, and co-ordinate water usage.

Hydrological Effects on Environment

Natural water bodies

Water flow into the Tarim River from the three tributaries is gradually decreasing,

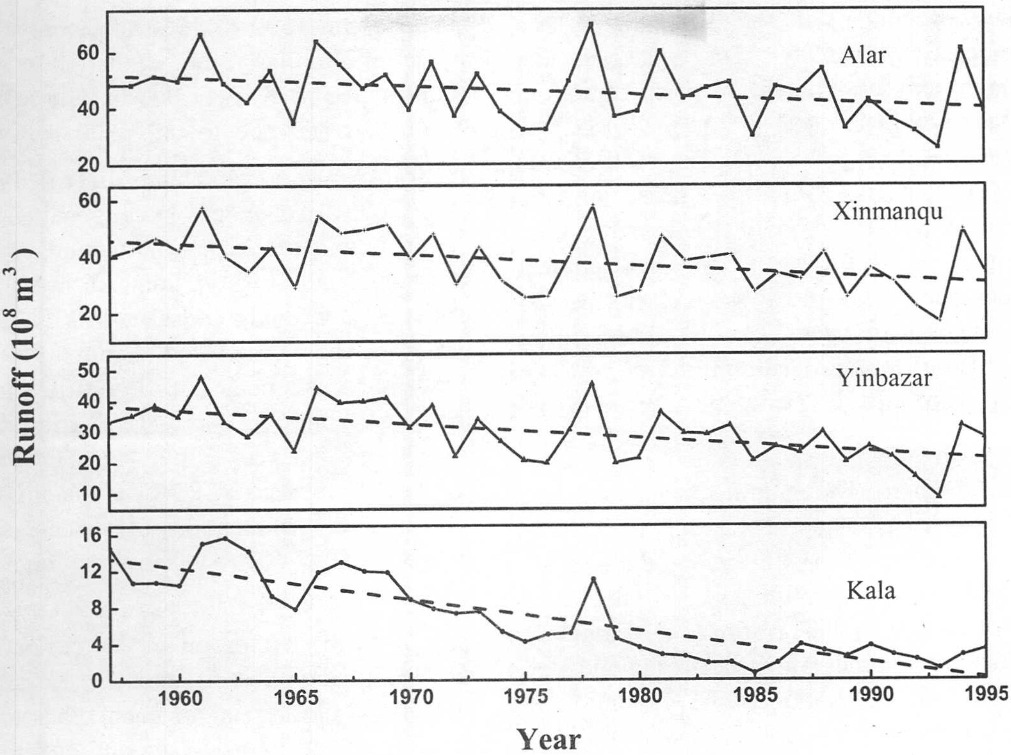

Fig. 4. Runoff changes among each station in Tarim River.

although their annual runoff from the mountain areas is about 181 x 10^8 m^3. From 1960s to 1990s, the water discharged into mainstream decreased by 20%. Meanwhile, the water discharged into middle and lower reaches decreased (Fig. 4). The water flow through Kala section in the lower reaches decreased from 13.5 x 10^8 in 50s to only 1.97 x 10^8 in 1997. In such a case, about 320 km riverbed at the lower reaches has dried up since 1970. The Lop Lake has been the largest terminal lake in Tarim River, its surface area was about 1900 km^2 in 1930, but in 1963 it decreased to 660 km^2 and dried up totally in 1972 (Tursun *et al.*, 2000). The Taitmar Lake had a surface area of about 88 km^2 in 1962, but it also dried up in 1981. With the decrease of surface water, the groundwater levels has also fallen, especially in its lower reaches. For example, from Aragan to Lop Lake, the level of groundwater was only 1-4 m in 1950-1960, but in 1996 it was lower than 16 m.

Eco-environmental impact

Water quality deterioration: With the increasing of reclamation in the upper reaches, the large amount of saline water and the drainage irrigated water is seeped into the river course, thus deteriorating the water quality in lower reaches. In the past 30 years, according to data of Alar, Xinqiman and Kala Hydrological Station.

the salt content in the Tarim River has increased gradually. For example, the maximum salt content in Alar station in 1960 was 1.28 g L^{-1}, but in 1981-1984 increased to 4.0 g L^{-1}, and in 1998 it was 7.8 g L^{-1}. Based on the current organic carbon content in desertified lands, total emissions of C due to the hydrological degradation into the atmosphere in the last 30 years have been 112.2 Tg, representing 28.3% of organic carbon in the surface 1.0 m soil profile (Feng and Cheng, 1998).

Vegetation degradation and wild animal dwindlement: The natural forests along the riverbanks provide a natural protection. However, in the past 50 years, there exists differences between the upper and the lower reaches due to the irrational development of water resources and the lack of knowledge about the importance of maintaining ecological balance. As a result, *Populus euphratica* has declined by two thirds and the biomass has decreased by half between the years 1958 and 1978. After reclamation, the area of forest having *P. euphratica*, *E. angustifolia* trees, declined from 400 x 10^3 ha in 1958 to 175 x 10^3 ha in 1978. The rate of decrease was 56.9%. The timber accumulation declined from 383.9 x 10^4 m^3 in 1958 to 239.6 x 10^4 m^3 in 1978, at a rate of 37.6% (Cheng, 1993). From 1958 to 1978, the area of *Populus euphratica* in lower reaches has sharply reduced by 69.6% and the timber accumulation declined by 77.1%. Meanwhile the shrub and meadow area also declined by 200 km^2 in lower reaches (Song *et al*., 2000).

The wild life population also showed a decreasing trend. According to statistics, there were 10,000 wild camels in the 18th century, and 1500 in 1980s, but only 800 at present. Similarly, the population of wild deer in 1970s was 11,000 in the whole basin, and declined to only 300 in 1980.

Soil salinization and land desertification: Hydrological changes have resulted in degradation of aquatic habitats and substantial land degradation. According to statistics between the 1960 and 1990, 12,300 km^2 land has desertified. From 1959 to 1983, the percentage of desertified land increased from 69.23% to 80.6% in middle and lower reaches. While in the lower reaches it increased by 22.05%. In addition, the area of salinization also increased, making up 35-40% of the total area in the whole region.

Due to the expansion of desertification the Taklimakan Desert and the Kurmtag Desert are closing up to each other. The distance of the two deserts shorten by 60 m in the last 30 years, and are still advancing by 3-5 m per year (Zhu *et al*., 2000).

With the environmental deterioration, especially land degradation, the dust storms have increased both in intensity and frequency. In 1970s the days of strong wind were 5 in one year, but at present this figure has increased to 15 days.

Conclusions and Suggestions

As the largest inland river, the Tarim River watershed supports cotton at state level and is important for grain and famous quality fruits in Xinjiang. It is rich in petroleum and natural gas resources, and will be important for energy and petrochemical industry in China in the 21st century. With the irrational utilization of natural resources, especially water resources, many environmental problems have come up in the last 50 years. This has not only seriously constrained local economic development, but also affected sustainable development of the region. It is urgent to take adaptive measures to protect, harness and rehabilitate the environment.

With the environmental deterioration in Tarim River basin, both scholars, and the government began to pay more attention to it. From 1998 the government began to take countermeasures to protect the environment. These include: to strengthen management, to build reservoir in mountain front, to divert water from Konqi River and to return land use from farming to forestry and grassland and so on. In fact, the water resources have great potentials if some effective management and water-saving technologies are adopted. So, the prime task is to develop sustainable practices for management of water resources and motivate people to conserve water. The second strategy is to popularize water saving irrigation technologies, like drip and sprinkler irrigation, to build diversion canals and to abandon some plain reservoirs. The third measure is to adjust agricultural structure, increasing the animal husbandry and forestry. Finally, ground-water resources need to be gainfully exploited.

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