Study on Water Transfer in Low Tarim River Basin

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Abstract. In order to clarify the principle of water diversion during the dry years of the Tarim River Basin, taking the water volumes at 75% and 90% of the dry season in the source region of the Tarim River as an example, the ecological and economic benefits of the source and mainstream areas under a certain amount of water were calculated respectively. Based on the differences in benefits, it is necessary to determine whether the amount of water in a dry year should remain in the source or in the mainstream. The results show that the following principles need to be followed in the basin for the dry years of water diversion: (1) The principle of being mainly water conservancy departments, supplemented by other relevant departments, and cooperating with each other should be adhered to. (2) Insist on giving top priority to social stability, ensure that residents produce water for their own lives, and take into account the principles of other water uses. (3) Adhere to the principle of moderate and flexible water dispatch in dry season. (4) Adhere to the principle of fairness and maximize benefits.

1. Introduction

Tarim River Basin is located in the arid region of northwest China, is China's largest inland river basin. Since the 1950s, uncontrolled exploitation and utilization of water and soil resources have resulted in a continuous decrease of water transmissibility in the mainstream of the Tarim River. In addition, due to high mountain blockages and very few precipitation, water resources are in short supply and water use conflicts have become increasingly acute, especially during the dry years the serious shortage of water resources poses a serious threat to the ecological environment and social security. In order to allocate water resources in Tarim River Basin scientifically and rationally, the Autonomous Region People's Government approved the implementation of the "Tarim River Basin Engineering and Non-Engineering Five-year Implementation Plan" in 2003. The implementation of these Regulations will ensure the sustainable economic and social development of Tarim River Basin and effectively solve the problems of integrated water resources management and unified dispatch between production and ecology, localities and corps, upstream and downstream, source and mainstream flows, Promote the
rational allocation of water resources in the Tarim River Basin, efficient use, Protect limited water resources and other aspects have played a guiding role, Embody the development concept of "priority of environmental protection and establishment of ecological establishment" formulated by the autonomous region people's government. It is of great significance to realize the ecological security and the prosperity and stability of economy and society as a whole in southern Xinjiang and even Xinjiang. However, due to the lack of a clear proposal for the principle and measure of water allocation in the dry years, in the dry years, the wading conflicts in the watershed caused by the shortage of water resources have become increasingly prominent and frequent. For example, in 2009, the Tarim River encountered a 60-year incident during the dry year, the amount of water flowing from the source into the mainstream is greatly reduced, and the river breaking up reaches 1,100 km. The Aksu River is the largest source of the Tarim River and the only river that supplies the Tarim River with perennial water. However, in 2014, the Aksu River suffered a 100-year special dry year [1-4]. When the source flow appears 50 years or 100 years when the dry years, is the principle of protecting the source flow or Paul Paul flow need to be clearly defined. However, since the issue is very acute and involves social stability, economic development and the relocation of residents. Therefore, it is not a water conservancy department that can be determined, but needs to be organized by the autonomous regional people's government to jointly develop a multi-sectoral government.

2. Materials and Methods

2.1. Research Area Overview
The Tarim River is the fifth largest inland river in the world and the largest inland river in China [5]. The basin is located in southern Xinjiang in the arid region of northwestern China. Between the Tianshan Mountain Range and the Kunlun Mountains, the total length of the river from the source of the Yarkant River is about 2350km, of which the main stream is 1321km long from Alar to Taitama. Tarim River and the Central Tarim Basin nine major water system 144 rivers [6], an area of 102 × 104km². However, because of human activities on large-scale utilization and exploitation of water resources in the basin, there is only surface water contact with the mainstream of the Hetian, Yarkand and Aksu rivers and the mainstream [7]. In addition, the open-hole river supplies water to the lower reaches of the mainstream through the reservoir-tower trunk canal to form the current "four-source-one-dry" distribution pattern in the Tarim River Basin [8, 9]. The rest of the water due to dry water into the Tarim River without water.

The Tarim Basin includes 42 prefectures (cities) and 56 agro-forestry parlors in Bayinguoleng Mongol Autonomous Prefecture, Aksu Prefecture, Kashi Prefecture, Kizilsu Kirgiz Autonomous Prefecture and Wada in southern Xinjiang [10]. The Tarim Basin is a multi-ethnic settlement, Within the basin are Uygur, Han, Hui, Kazak, Mongolia and other 18 ethnic groups, the population is 9849000. The level of basin economic development is relatively low, with GDP accounting for only about 25% of Xinjiang [11].

2.2. Data sources
Data in this paper are derived from the Aral River surface runoff monitoring data from the Aksu River, the Hetian River, the Yarkand River and the starting point of the Tarim River mainstream from 1957 to 2013 provided by the Tarim River Basin Authority. The yield and price data of the major cash crops in the watershed come from "Statistical Yearbook of Xinjiang" and "Statistical Yearbook of Xinjiang Production and Construction Corps".

2.3. Research methods

2.3.1. Dry Year Division. In general, the year when the average annual flow is less than the average annual flow is the dry year. According to the Pearson III frequency distribution curve of river water system over many years, when the annual frequency of water inflow is between 50% and 75%, it is
generally defined that the water system of the river is in the dry season. When the annual frequency of water is between 75% ~ 90%, the river system is called dry years. When the frequency of incoming water is less than 90%, the flow of the river system in that year is called the special dry year, and the specific calculation process of the incoming water frequency can be referred to [12, 13].

2.3.2. Calculation of ecological benefits. The ecological benefit is mainly the ecological service value brought by the water supply of natural vegetation. In this paper, the eco-efficiency is calculated based on the valuation method of monetary value based on the Tarim River ecological service value scale proposed by Baiyuan et al. [14]. The calculation of ecological service value is based on the method of Constanza et al. [15], which is calculated as:

\[ ESV = \sum_{i=1}^{6} \sum_{j=1}^{9} e_{ij} S_i V \]  

Where, \( ESV \) is the total ecological service value of the ecosystem in the study area, \( e_{ij} \) is the value of the \( j \) ecological service function equivalent of the \( i \) type of land in the subscale, \( S_i \) is the area of type \( i \) land use and \( V \) is the economic value of providing food production services per unit of farmland ecosystem. \( V \) can be calculated according to the following [16].

\[ V = \frac{\sum_{i=1}^{7} m_i p_i q_i}{M} \]

Where, \( i \) is the type of crop, the main crops are rice, wheat, corn and beans; \( p_i \) is the current price of \( i \) kinds of food crops (yuan / t); \( q_i \) is the yield per unit area of food crops (t / hm\(^2\)); \( m_i \) is the area of food crop (hm\(^2\)); \( M \) is the total area of food crops (hm\(^2\)).

2.3.3. Calculation of economic benefits. The economic benefit is mainly the agricultural income obtained from diversion irrigation. Based on the cotton widely planted in Tarim River Basin, the economic benefit is calculated as:

\[ E = W \cdot CP \]

Where \( E \) is the economic benefit (yuan), \( W \) is the irrigation water (m\(^3\)), \( \lambda \) is the irrigation quota (m\(^3\)/hm\(^2\)), \( C \) is the cotton yield per unit area (kg / hm\(^2\)), \( P \) is the cotton price (yuan/kg).

3. Results

3.1. Understanding of water diversion in dry season

"Tarim River Basin Engineering and non-engineering five-year implementation plan" and "on the issue of the Tarim River Basin," four sources and one dry "surface water allocation plan and other programs notice" (Xinzhenghan [2003] No. 203) Source and dry "75% of the dry year and 90% guaranteed rate of water under the region and the Corps were allocated water consumption. Specific to the mainstream of the Tahe River, when the Alar influx of water is greater than or equal to 75% of annual water (37.94 × 108m\(^3\)), to ensure that the national economy water; When the amount of water is less than 75% of the guaranteed amount of water, agricultural irrigation is damaged and the national economy is supplied at 90% of the average for many years. However, these two regulations do not give a clear principle of distribution to the amount of water in the dry season. In the Tarim River Basin, the water resources in the plain water year and the abundant water year basically can bear the water demand of the watershed, and put forward the principle of "increase, decrease, decrease" the water
distribution, which is easy to control and the contradiction between supply and demand of water resources is alleviated and concealed. Worth noting is the special dry years. For example, in 2009, when the Tarim River hit a special dry year of 60 years, the amount of water entering the mainstream dropped drastically and the length of the river breaking up to 1,100 kilometers. The large-scale water shortage not only harmed the healthy economic development but also caused serious ecological catastrophe and social crisis. Even in the relatively over-abundance of incoming water from 2010 to 2012, due to the prominent contradiction between water use and water supply, the number of water-related disputes and water-related illegal activities in the basin reached 52 and 432, respectively, showing a clear growth trend (Table 1). Therefore, once the dry years encounter, the contradiction between supply and demand of water resources will intensify day by day; Especially in the dry season, when the source water flow can only or can’t meet the requirements of the source area itself, the principle of “increasing and decreasing the water supply” is not applicable, so it is urgent for the water resource management department to propose a reasonable water allocation principles and programs. In 2014, as the Aksu River, with more than 70% of incoming water from the mainstream of the Tarim River, suffered a 100-year special dry-water year, many of the contradictions previously concealed will inevitably occur and the situation is grim.

### Table 1. The Tarim River water disputes and violations investigation and statistics

| Year | Water dispute settlement | Violations is accepted |
|------|--------------------------|------------------------|
|      | Total Consult | Government treatment | Basin institution management | Total | Watercourse project | Water engineering case | Water resources case | Other cases |
| 2010 | 12 | 6 | 2 | 4 | 122 | 52 | 2 | 41 | 78 |
| 2011 | 18 | 5 | 1 | 13 | 135 | 61 | 1 | 53 | 22 |
| 2012 | 24 | 4 | 1 | 18 | 175 | 56 | 1 | 89 | 29 |
| Total | 52 | 15 | 2 | 35 | 432 | 167 | 4 | 183 | 78 |

3.2. Comparison of the benefits of unilateral water resources in dry season

As for the whole Tarim River Basin, due to the utilization level of water resources, the population and the level of socio-economic development, there are differences in the economic benefits, ecological benefits and social benefits of a certain amount of water in the source and mainstream areas. In addition, the water flow in the source area flows into the mainstream area, causing natural leakage such as seepage and overflowing of the river channel, which will inevitably lead to the reduction of water for production and living in the mainstream area. Therefore, by comparing and analyzing the difference of economic, social and ecological benefits caused by a certain amount of water in the source area and the mainstream area, we can scientifically formulate the principle of water allocation and distribution in dry years.

In the source region of the Tarim River, taking the amounts of water at 75% and 90% of the dry season as an example, the amount of water under different water frequencies is set as the amount of water that can be used for drainage in the source area. The combined benefits are generated to determine whether the amount of water in a dry year should remain in the source stream or into the mainstream. According to Table 2, it is assumed that in the low flow year, the Tarim River can supply 1.742 billion m$^3$ of water into the main stream, and the irrigated area that can be guaranteed is 1.591 thousand square kilometers. If planting cotton in the Tarim river basin, which can produce economic benefits of 5.73 billion yuan, therefore, the economic output of per cubic meter of water is 3 yuan.
Table 2. Different frequencies of runoff water and water flow to different sources

| Origin coming water | Origin in total | Aksu River Basin | Yarkant River Basin | Hotan River Basin |
|---------------------|-----------------|------------------|---------------------|------------------|
| 75%                 | 173.67          | 72.51            | 65.06               | 36.1             |
| 90%                 | 156.25          | 66.78            | 58.47               | 31               |
| Differences in water| 17.42           | 5.73             | 6.59                | 5.1              |

Unit: 10^8m^3

In the Tarim River Basin, there is a large amount of natural water loss during the discharge of water from the source area to the main stream, and this part of the water loss is mainly supplied by natural vegetation on both banks of the river with the supply of groundwater and is an important component of ecological water in the basin. Part, and can produce some ecological benefits. According to the related study [17], the river losses in the Aksu, Yarkand and Hetian basins during the dry season account for about 14%, 32% and 33% of the water inflow respectively, and the river damage in the source area is 4.59 × 10^8 m3. Therefore, the amount of available water for irrigation into the mainstream Aral section is 12.83 × 10^8 m3, which will ensure the irrigated area of 118 million mu and generate economic benefits of 2.83 billion yuan. According to the research results of Lei Zhidong et al. [18], the annual natural water consumption of the natural vegetation in the Tarim River Basin is at a good level of natural ecology. According to the comprehensive calculation, the source area can be used for the discharge of 17.42 × 108m3 of water, the amount can protect 172.2 mu of natural vegetation area (Table 3).

Table 3. The dry season three river loss and protect the natural vegetation area

| Origin | Aksu River Basin | Yarkant River Basin | Hotan River Basin | Total |
|--------|-----------------|---------------------|-------------------|-------|
| River loss amount(10^8m^3) | 0.80 | 2.11 | 1.68 | 4.59 |
| Security area | 30.1 | 79.0 | 63.1 | 172.2 |

According to the relevant research results [19], the distribution area ratio of forestland and grassland in the three sources of the Tarim River is shown in Table 4, and the ecological benefit calculated by the three-source flow is 840 million yuan. Therefore, if the source area is drained to the mainstream Alar in the dry season of 17.42 × 108m3, the total available profit will be 3.67 billion yuan, while the economic benefit of the single-part water will be 1.6 yuan and the total benefit output will be 2.1 yuan.

Table 4. Water resources in the headwaters of the woodland and grassland area accounted for the proportion of area

| Vegetation types | Aksu River Basin | Yarkant River Basin | Hotan River Basin |
|------------------|-----------------|---------------------|------------------|
| Woodland         | 17%             | 32%                 | 42%              |
| The grass        | 83%             | 68%                 | 58%              |

Unit: %

According to Ling et al.’s research results [20, 21], the river damage in the upper reaches of the Tarim River (Alar to British Bazaar) accounts for 54% of the water inflow during the dry season, so the available discharge from the source area to the irrigation at the Yingbaza section .The amount of water (Alar to Yingbacha section) is 5.9 × 108m3, which can guarantee an irrigation area of 543,000 mu and generate economic benefits of 1.3 billion yuan. The river loss from the mainstream Alar to Yingbaza is 6.93 × 108m3, which can protect 2.597 million mu of natural vegetation. Using the interpretation of the remote sensing images of the mainstream of the Tarim River, woodland and grassland account for 29% of the natural vegetation and 71%, combined with the ecological service equivalent value of two types of vegetation, the ecological benefits of the river reaches 1.19 billion
yuan. Therefore, if the source area is discharged to mainstream Yingbaza in $17.42 \times 10^8$ m$^3$ of water during the dry season, the total benefit generated will be 3.33 billion yuan. At this time, the economic output of single-party water will be 0.75 yuan and the total benefit output will be 1.9 yuan.

According to the above studies, the total benefit from certain amount of water in the Tarim River Basin during the dry season is higher in the source area than in the mainstream area (Table 5). In addition, from the point of view of social benefits, the population in the source area of the Tarim River is about 4,869,000, which is 15.7 times that of the mainstream. In the dry season, first of all, the protection of source water is more conducive to promoting social stability in the entire basin.

### Table 5. Benefit analysis table of Headstream Area and main stream area of Tarim River Basin

| Benefits Origin | Alar | Yingbaza | Qiala |
|-----------------|-----|----------|-------|
| The individual seafood is out of value | Econom | Econom | Ecolog | Econom | Ecolog | Econom | Ecolog | Total benefit |
| 3 | 1.6 | 0.5 | 2.1 | 0.75 | 1.15 | 1.9 | 0.32 | 1.48 | 1.8 |

Unit: Yuan

### 4. Conclusion

Based on the above analysis, we believe that the Tarim River Basin in the dry season, the principle of water transfer:

(1) Adhering to the principle that the competent department of water conservancy, other relevant departments are supplemented, and the various parts cooperate with each other. Water diversion during the dry season is not only a wading management project for the water conservancy department, but also closely linked to other water sectors such as land, agriculture and forestry. Only through cooperation among various departments can the water diversion plan be implemented smoothly and implemented as soon as possible.

(2) Insist on giving top priority to social stability, ensure that residents produce water for their own lives, and take into account the principles of other water uses. In the type of water, first of all, to protect the production and domestic use of water, followed by ecological water; especially in the dry season, should pay great attention to the social benefits of water diversion, and gradually reduce the ecological water. According to the results of previous studies on ecological water demand, the desert riparian forests in the Tarim River Basin are mainly deep-rooted plants. A flood irrigation interval of 3 to 5 years will not lead to obvious degradation of vegetation.

(3) Adhere to the principle of moderate and flexible water dispatch in dry season. In the special dry year, the amount of water should first ensure the production and domestic water use of the source and main streams, but it should at least fully meet the ecological water demand of the basin once every 3 to 5 years. The source of the dry period in the dry years, we must first ensure that the source of water for production and domestic use, and flood season should be compensated for the amount of water deficit. Therefore, in the year, there is no need to ensure the ecological water quantity every year. During the year, the amount of water discharged from the source to the mainstream will not be guaranteed on a monthly basis. Therefore, the water amount regulation should be moderate and flexible.

(4) Adhere to the principle of fairness and maximize benefits. In the area of water, should first ensure that the watershed source area of irrigation water, followed by the mainstream upstream, then the middle and lower reaches. From the perspective of economic efficiency, the output of unilateral water in the source area was 3 Yuan, while it dropped to 1.6 Yuan, 0.75 Yuan and 0.32 Yuan, respectively, to the main stream Alar, Ying Bazaar and Chala respectively, showing a marked decrease. According to the comprehensive analysis of ecological benefits, the benefits of unilateral aquatic products from the source to the mainstream of Chala in the main stream are reduced by 40% as a whole. Therefore, the benefits of reduced water flow can be maximized in dry season.
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