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Eco–water conveyances applied to control desertification at the lower reaches of the Tarim River

YE Mao, XU Hailiang, SONG Yudong
(Xinjiang Institute of Ecology and Geography, CAS, Urumqi 830011, China)

Abstract: The lower reaches of the Tarim River are one of the areas suffering from most severe sandy desertification in Xinjiang, Northwest China. Irrational utilization of water and land resources results in eco-environmental deterioration in the Tarim River. In May 2000, the local government carried out the water conveyances project in the Tarim River. The influence of water conveyance on desertification reversion is analyzed and discussed according to the monitoring data in the past three years. Based on monitored data of the nine observed sections, along the channel of conveyance, the intensity and scope of desertification reversion in the upper reaches are larger than those in the lower reaches. Dynamic changes of desertification reversion are more obvious from the channel of conveyance to its two sides. However, the range of influence and intensity of desertification reversion is limited at present. It is suggested that the way and range of water conveyances should be adjusted in the future.
Key words: eco-water conveyances project (EWCP); the Tarim River; desertification reversion; influence
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1 Introduction

The Tarim River (Figure 1), located in the Xinjiang Uygur Autonomous Region in Northwest China, is the largest inland river in China. The annual average precipitation of the Tarim River varies from 17.4 mm to 42.0 mm while the annual average evaporation is from 2500 mm to 3000 mm. It is a zone which has a warm temperate continental climate and extreme dry desert climate. It is usually referred to the mainstream from Xiaojiake to the Tetima Lake with a length of 1321 km. The water resources are all supplied by its headstreams without runoff yield of its own.

However, over population and the fragile eco-environment are putting the water resources under pressure. In the past 50 years, the eco-environment of the Tarim River has deteriorated due to the irrational utilization of water resources especially at the lower reaches of the Tarim River. For instance, the end lake, Tetima Lake, dried up about 30 years ago. Consequently, the stream flow has been cut off by 320 km; groundwater depth along the Tarim River declined by a large margin; large-scale wetlands disappeared; large tract of farmlands degraded to desert; and natural vegetation waned and land desertification deteriorated greatly. Up to 2000, desertified land in the studied areas surpassed 90% (Cui, 2000; Liu, 2001), in which the severely desertified land reached 70.16×10^4 ha, 52.71% of the total of the lower Tarim. Natural *Populus euphratica* forest areas decreased from 5.4×10^4 ha in the 1950s to 1.64×10^4 ha in the 1970s, to 0.67×10^4 ha in the 1990s; and natural grassland declined by 1.07×10^4 ha from 1988 to 2000.

The local government of Xinjiang has put 10.7 billion yuan into the improvement of the eco-system of the Tarim River. In May 2000, eco-water conveyances project (EWCP) to the

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Author: Ye Mao (1977-), Ph.D. Candidate, specialized in water resources exploitation and ecological economics in arid zone. E-mail: yemao1111@163.com

Figure 1 Sketch map of the Tarim River

Tarim River was carried out to control desertification and save the dying natural vegetation. Unfortunately, few experts touched the water conveyances method to control desertification. Based on the monitored data from 2000 to 2002, the effect of water conveyances on desertification reversion and desertification characteristics after conveyances are discussed.

2 Method and data collection

The "linear style" water conveyances method was adopted in order to dredge the watercourse and supply abundant water. The eco-water is conveyed from Bosten Lake to Daxihaizi reservoir at the beginning, then reaches the Akagan area through the Qiwenkuer River (a branch of the lower reaches of the Tarim River), and finally flows into the Tetima Lake along the old channel of the Tarim River. The whole distance is 321 km long. Up to November 2002, there had been five times of water conveyances to the lower reaches of the Tarim River continuously with a volume of 10.15×10^8 m^3 conveyed from 2000 to 2003 (Xu, 2003).

There are nine monitored sections as the experimental sites at the lower reaches of the Tarim River. Each section is set to be 35 km long. The monitored data at each experimental site include groundwater depth, the water and salt content and the distance from the Tarim River channel before and after conveyances (Table 1).

Table 1 The basic data about eco-water transport in the lower Tarim River

Water transport times	1st time	2nd time	3rd time	4th time	5th time
Beginning time	2000-05-14	2000-11-03	2001-04-01	2001-09-12	2002-07-20
Lasting days (d)	61	104	97	67	118
Water volume ($\times 10^4$ m^3)	9883.18	22000	18400	19700	31500
Water flowing location	Abudale	Alagan	Alagan	Tetima Lake	Tetima Lake
Distance from Daxihaizi reservoir (km)	About 70	146	About 170	321	321

3 Results and analyses

3.1 Relationships between groundwater, natural vegetation and desertification

Desertification is often related with vegetation deterioration. Lack of natural vegetation coverage is a good indicator of desertification. Under the control of arid climate, groundwater is the most important water source to the zonal natural vegetation of the Tarim River, which mainly includes mild shrub and half-shrub desert plants. Only if it acquired groundwater would a wide tree-shrub-grass zone along the Tarim River be formed, composed by *Populus euphratica*, shrub and herbaceous plants. Large-scale azonal vegetation of the flood plain would revive. Statistical data indicate that the relation between groundwater level and vegetation can be described as the following.

$$Y = -0.1597 \ln X + 0.3927$$

where $R^2 = 0.6097$; Y = vegetation coverage; and X = groundwater level.

However the demands of different vegetation types for groundwater and resistance to drought are different (Feng, 2000). Several studies have revealed that most of the herbaceous plants are extinct when groundwater level is beyond 4 m, some shrubs such as *Nitraria*, *Halimodendron halodendron* also cannot survive while beyond 5 m (Song, 2000).

Describing the desertification process usually adopts some indexes such as vegetation coverage, soil water content and species diversity. However, these indexes do not exactly explain spatial heterogeneity phenomena. We should consider the structural characteristics of desertification.

Desertification degree is put forward by Wu Zheng (1987). This article adopts the terms as vegetation coverage, sand percentage and desertification degree. In order to describe conveniently, the sandy desertification is classified into four grades according to its extent: potential desertification, lower desertification, moderate desertification and severe desertification, marked with 1, 2, 3 and 4, respectively (Xu Hailiang, 2004).

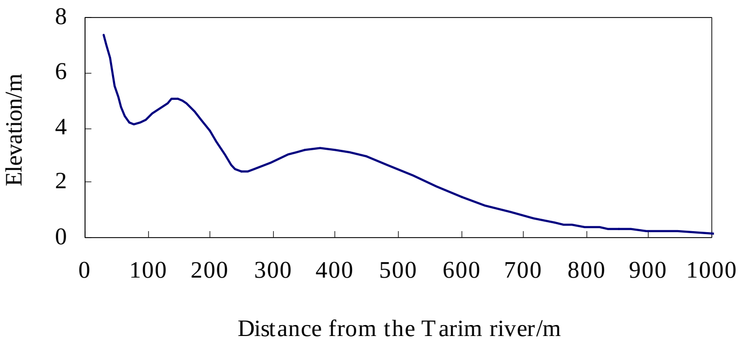

Figure 2 Elevation of groundwater level with different distances of water conveyances

3.2 Environmental factor change after water conveyances

Before water conveyance, the groundwater level of most sections away from the Yingsu hydrologic station declined to 8-12 m (time: May, 2002) which is beyond the most critical level of vegetation; meanwhile, the soil water content in vegetation root systems is also far below the wilting coefficient. Some vegetated lands such as *Populus euphratica* forest, saline meadow and halophilous shrub are turning to desertified land. The ability to resist wind erosion is also going down (Zhao, 2000; Feng, 2000). However, the eco-environment in this study changed obviously after water conveyances. For example, the average groundwater level of the nine sections along the channel of conveyances increases markedly (Figure 2).

Natural vegetation has distinct response to the groundwater. Seen from ecological parameter, both vegetation coverage and richness change obviously (Figures 3 and 4).

Some herbaceous vegetation such as *liquorice*, *Alhagi*, *sparsifolia*, *Kyndyt*, *phragmites* begins to revive. Some main community species of *Populus euphratica* and *Tamarix chinesis* grow strongly.

3.3 Spatial changes of desertification after water conveyances

The studied sections show that groundwater level declined as much as 9 m, even as low as 11 m in some sections before water conveyances, which is far beyond watershed eco-water level of the main community vegetation such as *Populus euphratica* and *Tamarix ramosissima*. Desertification is serious. But after water conveyances, desertification reverse shows a favorable trend (Figures 5-8).

Figures 5-8 show the varying degrees of desertification in different sections. Before water conveyances, Akdun section is characterized by moderate desertification while the lower reaches of Yingsu are mostly in the severe desertification category (Han Qing, 1984; Zhou Xingjia *et al*., 1990; Wang Ranghui, 2000). But after water conveyances, there is an obvious reverse of the trend. Reverse intensity of desertification gradually weakens with the increase of the distance from the channel of conveyances.

In the Akdun section, at a distance of 20 km from Daxihaizi Reservoir, the range of desertification reverse is 3.5 km. As a result of water overflow, the 1-km distance range from the channel of the conveyances to its sides changes to the first grade desertification, or potential desertification. Natural vegetation response is obvious, with the coverage being over 60% , and there are small plots and blown sand. The 1~3.5-km-distance range belongs to the second grade desertification, with vegetation coverage being about 20%-30%, and there are minor blowouts and little blown sand. On the whole, degrees of desertification increase by one grade after another.

In the Yingsu section, at a distance of 54 km from Daxihaizi reservoir, the range of desertification reverse is 500 m. The 200-m-distance range responses apparently, which belongs

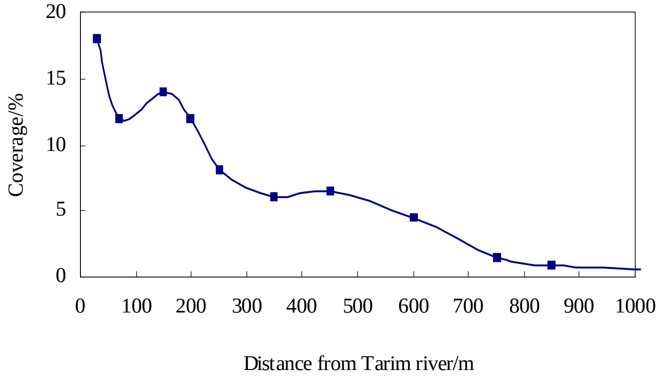

Figure 3 Effect of conveyances on vegetation coverage in the lower Tarim River

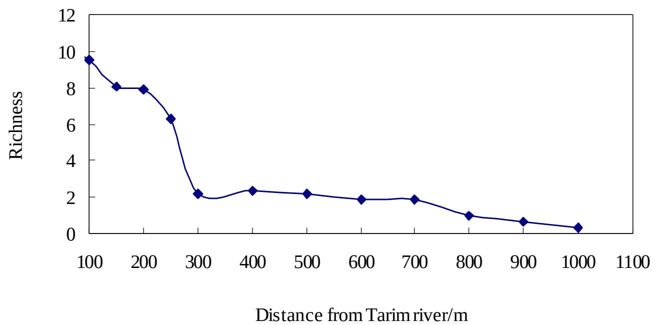

Figure 4 Effect of conveyances on vegetation richness in the lower Tarim River

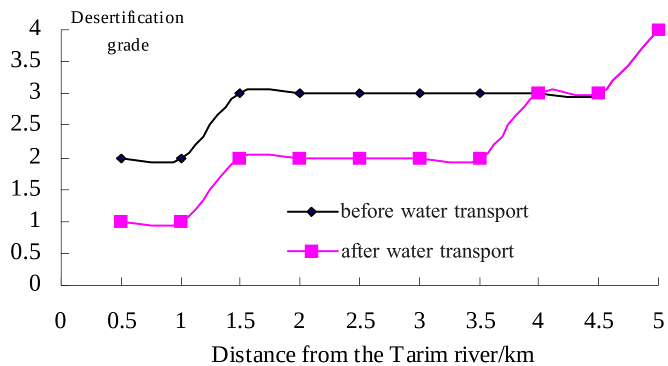

Figure 5 The change of desertification degree in Akdun

to the second grade of desertification. In the 200~500-km-distance range, the degree of desertification decreases from the fourth grade to the third grade. The vegetation coverage increases by 10%. The blown sand area is below 40%. However, when beyond the 500-m-distance range, vegetation coverage falls sharply below 10% , and deflation phenomenon still existed. That belongs to the severe desertification, namely the fourth grade.

In the Alagan section, at a distance of 145 m from Daxihaizi reservoir, the range of desertification reverse is 300 km. The degree of desertification in most ranges declines from the fourth grade to the third grade.

In the Kaogan section, which is 263 km away from Daxihaizi reservoir, the range of desertification reverse is only 100 m. There are no changes fundamentally from Kaogan area to Tetima Lake. Natural vegetation is scarce except few dead plants. Blown sand almost covers the ground surface.

Based on the above analysis, we can draw conclusions that the range of desertification reverse shows a triangular distribution regularity in the lower Tarim River, which is composed of the hemline--Daxihaizi Reservoir, the top--Kaogan section, and the middle axe--the channel of conveyances. This regularity presents spatial changes in both vertical and horizontal levels.

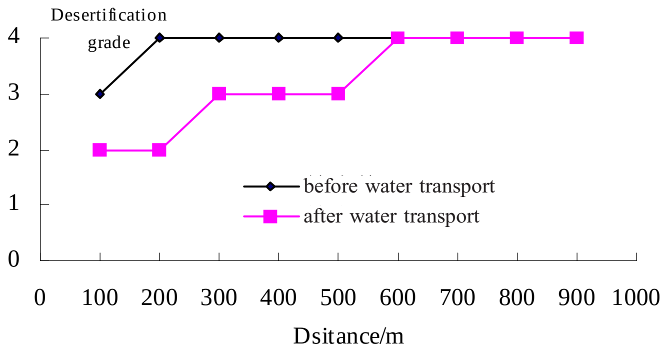

Figure 6 The change of desertification degree in Yingsu

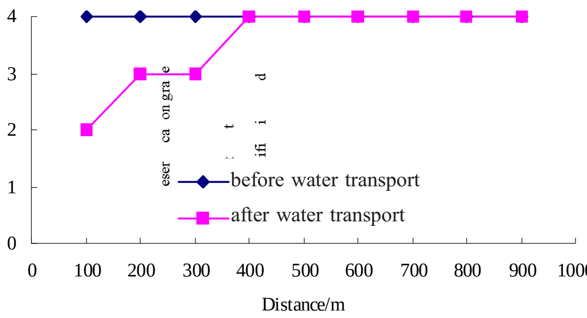

Figure 7 The change of desertification degree in Alagan

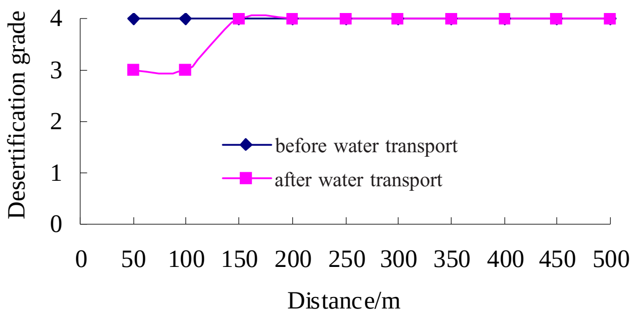

Figure 8 The change of desertification degree in Kaogan

4 Discussion

Arid climate and water scarcity are the main controlling factors of desertification in the Tarim River. Water scarcity and irrational utilization restrict organic growth. Unconsolidated sand shows land fragibility, which is the internal cause of desertification. Arid climate and frequent winds are the external cause of desertification. The internal and external causes constitute potential factors to the unstable environmental complication. This complexity also exists in water scarcity and unstable environment in return, which forms an unstable aggregated effect (Zhu, 1994). There are no intensive climate changes in the lower Tarim River in the last 50 years (Yang, 2000). One of the important reasons for aggravating desertification is the river's drying up and over-grazing. Fortunately, ecological watering, as a strong external force, changes this state. In some of the desertified areas of the middle and lower Tarim River, self-recovery flexibility of the eco-system has not been completely lost. With the rise of the groundwater level, some dying vegetation and main community plants such as *Populus euphratica*, *Tamarix chinesis* have begun to partly revive after the supply of adequate water, which effectively prevents wind from blowing sand directly by fixing sandy land and weakening wind deposition. In addition, the rise of groundwater level accelerates the movement of water on the soil surface and strengthens the capability to resist wind deflation and desertification so that desertification has been controlled to a certain degree. It is worth saying that vegetation has already been severely degenerated even to death as a consequence of long-term dessication and the ability of the ecological system to recover has also been curtailed in the severely desertified area in the lower Tarim River (especially from Kaogan to Tetima Lake). Therefore, if only depending on intermittent irrigation, it seems very difficult or impossible for desertification to be reversed in a short period of time.

In general, the desertification reverse areas are limited, whose ranges are smaller than those of groundwater response and the vegetation change. The influence of desertification reverse on the entire lower Tarim River is feeble. At least at present, it is still difficult to reverse the desertification trend. Those facts identify that on the one hand, controlling desertification will take a long time. It is impossible to solve this problem in two or three years. On the other hand, using the actual line system of watering has been limited to improve the state of desertification reverse. Desertification reverse in the Akdun area appears to be having a positive effect. There are two reasons: one is its desertification extent is not as severe as in the other areas and the other, river overflows attribute part of it.

5 Conclusions

Our conclusions from the results and from the discussion given above are as follows:

(1) In some points, water conveyances to the Tarim River have an obvious function to control desertification. After conveyances, improvement of water condition results in natural vegetation revival effectively. Accordingly desertification in the study area slows down.

(2) Seen from the spatial changes of degree of desertification, there are distinct characteristics in two-dimensional space. At horizontal level, degree of desertification is greater with the increase of the distance from Daxihaizi Reservoir. At vertical level, degree of desertification is greater with the increase of the distance from the channel of conveyances to its sides.

(3) Seen from the ranges of desertification reverse, at the Akdun section, the degree of desertification changes obviously in about a 3.5-km distance range. The reverse range of the Yingsu section are less than 500 m, while the reverse ranges of the Alagan and Kaogan sections are 300 m and is less than 100 m respectively. Those changing ranges show that the effect of water conveyance on controlling desertification is feeble. Because there are differences between control of desertification and reverse of desertification, it is necessary that the style and range of water conveyances should be adjusted based on the current condition of desertification in the lower Tarim River. We can adopt the "linear style" conveyances connected with "space style" drainage (Wang Genxu, 2002), or other effective measures to recover the eco-environment.

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