



Review

Ecosystem restoration and conservation in the arid inland river basins of Northwest China: Problems and strategies



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ABSTRACT

Groundwater-dependent ecosystems (GDEs) in the lower reaches of arid inland river basins of Northwest China have degraded because of a decrease in water supply caused by excessive socio-economic development in the middle reaches of the river. The degraded GDEs have resulted in serious eco-environmental problems, such as drying of terminal lakes, river channel shifts, declines in riparian forest, desert activation, intensification of desert dust storms, and salinization of secondary soils. These problems have further hindered local and regional efforts at sustainable development. An ecosystem conservation and restoration project was initiated in 2000 in order to deal with the eco-environmental problems. The project has been underway for 15 years, but problems still exist. Using the Heihe River and Tarim River basins as examples, this paper explains the ecological–environmental problems and their causes, describes with the status of ecosystem restoration and conservation, analyzes the problems in the ongoing ecosystem conservation and restoration, and suggests strategies for achieving sustainable ecosystem restoration in the lower reaches of the arid inland river basins of Northwest China.

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1. Introduction

Natural desert riparian woodlands in the lower reaches of inland river basins in Northwest China are groundwater dependent ecosystems (GDEs). These ecosystems maintain ecological stability and balance for the river basins (Xi et al., 2010; Zhu et al., 2009a,b). The groundwater comes from seepage from the river, which is recharged by upstream sources. If groundwater is recharged sufficiently over time, the natural desert riparian woods and the natural desert ecosystem develop in a balanced state. In the 1990s, however, serious ecosystem degradation began in the lower reaches when groundwater recharge decreased because of excessive social-economic development in the middle reaches, which is the local major grain producing area by irrigation agriculture. In the middle reaches, the cropland continuously extended with population and grain demand increasing, more and more amount of the runoff from the upper reaches was intercepted for using the crop irrigation before the runoff entering the lower reaches (Zhu et al., 2004; Xia et al., 2005). The result was the emergence of various eco-environmental problems in the lower reaches, such as river-flow interruptions, drying of terminal lakes, shrinkage of natural vegetation areas, land desertification, intensified sandstorms, soil salinization, and declining water quality (Xi et al., 2010; Zhang et al., 2011; Yan et al., 2014).

A series of ecological conservation and restoration projects were initiated in 2000 to address these problems and to work toward sustainable development of the inland river basins. The conservation and restoration projects included the Ecological Water Conveyance Project (EWCP), the establishment of nature reserves, and artificial forest planting. Fifteen years later, the ecological problems remain and conservation and restoration efforts continue. Therefore, a comprehensive assessment of the existing problems in ecological conservation and restoration and the effectiveness of corresponding countermeasures is imperative.

The Tarim River basin and the Heihe River basin are the largest and the second largest inland river basins, respectively, in Northwest China. The Tarim River (see Fig. 1(a)), located in the hinterland of the Taklimakan Desert, is an extremely arid continental river in a vulnerable ecological environment. Unbridled development and utilization of water resources over the past 50 years have led to ecological degeneration of the river (Feng et al., 2005). Therefore, in May 2000, the Chinese government invested 107×10^8 ¥ to artificially harness the Tarim River through the EWCP. Covering 321 km in length from the Daxihaizi Reservoir to the Taitema Lake (see Fig. 1(c)), the project aimed to conserve natural vegetation, control desertification, and restore the severely degraded ecosystems in the lower reaches of the river (Xu et al., 2007). A diversion canal to bring water from the Bosten Lake to the lower reaches was constructed (Aishan et al., 2013) and 15 intermittent water deliveries had been conducted by the end of 2014 (Chen et al., 2014).

The Heihe River is the second longest inland river in China (Fig. 1(a)). The Heihe River originates north of the Qilian Moun-

tain. Its upper reach extends above Yingluo Gorge, the middle reach is between Yingluo Gorge and Zhengyi Gorge, and the lower reach is from Zhengyi Gorge down to East and West Juyan Lake. The length of the lower reach is 333 km, and the drainage area is 80,400 km². The lower reach is about 176 km from Zhengyixia to Langxinshan, and is divided into the East River and the West River below the diversion in Langxinshan (see Fig. 1(b)). The two branches flows into East Juyan Lake and West Juyan Lake, respectively (see Fig. 1(b)). The Ejina Delta oasis forms around the East and West rivers in the interior of the Gobi desert and functions as an important ecological defense against sandstorms in Northwest China (Liu and Gan, 2004; Jiang and Liu, 2010).

In 2000, the Chinese government invested 23×10^8 ¥ to control desertification and restore the severely degraded ecosystem in the lower reaches of the Heihe River (Xi et al., 2010). To increase the amount of water delivered to the lower reaches, the Heihe River bed was lined with concrete and tributary lined channels were built as well, including one trunk canal, six branch trunk canals, and 116 branch canals that delivered water from upstream and midstream reservoirs to the lower reaches of the river (see Fig. 1(b)). Beginning in July 2000, there have been two to three annual releases of water from upstream reservoirs (above Shaomaying and the Langxin Mountain hydrologic stations) to deliver water to the lower Heihe River (Niu et al., 2011; Xi et al., 2010).

Using the Heihe River basin and Tarim River basin as examples, the goals of this paper were to: (1) describe eco-environmental problems and their causes, (2) explain the status quo of ecosystem restoration and conservation, (3) analyze the current problems in ecosystem conservation and restoration, and (4) suggest strategies for rational ecosystem restoration in the lower reaches of the arid inland river basins of Northwest China.

2. Eco-environmental problems and their causes

2.1. Land desertification

Land desertification is a land degradation phenomenon or process in which productivity of fragile ecological conditions declines due to intensifying human activity, economic development, resource usage, and environmental disturbance (Zhu, 1991). The major forms of land desertification are mobile sand dunes, fixed sand dunes, and semi-fixed dunes, which expand onto surrounding lands. In inland regions, desertification emerges when sand dunes move outward from the edge of deserts, or inner dunes are activated near oases due to excessive vegetation removal or irrational agricultural development. In the lower reaches of the Heihe River basin and Tarim River basin, both types of land desertification have occurred, as shown in Tables 1 and 2.

Table 1 shows that in the mid-1980s, the area of oases was 36.55×10^4 ha, or 5.17% of the total land area, and the area of land that had experienced desertification was 258.37×10^4 ha (36.53%). However, in 2000, the area of oasis declined to 33.28×10^4 ha, a rate

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