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Characteristics of water erosion and conservation practice in arid regions of Central Asia: Xinjiang Province, China as an example

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Abstract

Located in the inland arid area of Central Asia and northwest China, Xinjiang has recently received heightened concerns over soil water erosion, which is highly related with the sustainable utilization of barren soil and limited water resources. Data from the national soil erosion survey of China (1985–2011) and Xinjiang statistical yearbook (2000–2010) was used to analyze the trend, intensity, and serious soil water erosion regions. Results showed that the water erosion area in Xinjiang was 87.6×10^3 km^2 in 2011, mainly distributed in the Ili river valley and the northern and southern Tian Mountain. Soil erosion gradient was generally slight and the average erosion modulus was 2184 t/(km^2 a). During the last 26 years, the water erosion area in Xinjiang decreased by 23.2%, whereas the intensity was still increasing. The driving factors from large to small impact included: population boom and human activities > vegetation degradation > rainfall and climate change > topography and soil erodibility > tectonics movement. Soil water erosion resulted in eco-environmental and socioeconomic losses, such as destroying farmland and grassland, triggering floods, sedimentation of reservoirs, damaging transportation and irrigation facilities, and aggravating poverty. A landscape ecological design approach is suggested for integrated control of soil erosion. Currently, an average of 2.07×10^3 km^2 of formerly eroded area is conserved each year. This study highlighted the importance and longevity of soil and water conservation efforts in Xinjiang, and offered some suggestions on ecological restoration and combating desertification in arid regions of Central Asia.

Keywords: Xinjiang; Soil water erosion; Soil and water conservation; Ecological restoration; Arid region

1. Introduction

Arid regions cover ~41% of the Earth's terrestrial area. Land degradation poses a great challenge for sustainable development. In future the rapid population growth to 9 billion by 2050, changing consumption patterns and climate change will add further pressure on land and soil resources. Currently over 2.6 billion peoples are affected by

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desertification globally (Millennium Ecosystem Assessment, 2005; Gabathuler, Liniger, Hauert, & Giger, 2009). Covering Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, and Xinjiang Province of China, Central Asia contains 80–90% of the world's temperate deserts (Li et al., 2015). Hence, Central Asia is a typical arid and ecologically fragile region. Due to climate change, precipitation and shrinkage of glaciers in this region are expected to increase (Hijioka et al., 2014), which would lead to increased surface runoff and even flood. Therefore, soil water erosion in Central Asia should not be overlooked, especially considering the serious desertification, land degradation, and drought problems there. Moreover, soil and water conservation in Central Asia are key scientific issues for sustainable development of the Silk Road Economic Belt (Dong et al., 2015).

Located in the inland area of Central Asia, Xinjiang Province of China contains most of the Tian mountain. The main geomorphologic units in Xinjiang from north to south are the Artai Mountain, the Junggar basin, the Tian Mountain, the Tarim basin, and the Kunlun Mountain. Each mountain–basin system can be further divided into high mountain zone (covered by ice and snow), middle/low mountain and hilly zone, oasis zone, desert–oasis ecotone, and desert zone (He, Li, Hong, Zhao, & Bai, 2013). Since the orography features elevation difference up to 7000 m, strong gradient in mean annual precipitation exists from < 50 mm in the deserts to > 900 mm in the windward slopes of the Tian Mountain (Böhner, 2006). The most serious water erosion of Xinjiang occurs as flow erosion in the middle/low mountain and hilly zone (i.e., the upper part of river basin), due to snowmelt flooding and heavy rain flooding in spring and summer (Zhang, Qiu, Bai, Chen, & He, 2002; Guo & Li, 2013). The problem of soil and water loss in Xinjiang has lacked sufficient attention for many decades. For example, from 2005 to 2007, a national comprehensive academic investigation on soil water erosion and ecological security was co–organized by the Ministry of Water Resources of China, the Chinese Academy of Sciences, and the Chinese Academy of Engineering, but no eroded area in Xinjiang was investigated. Recently, basic theoretical research on soil and water conservation in Xinjiang is receiving more attention and gained importance. In order to combat desertification induced by water erosion in Xinjiang, a synthesized soil and water conservation model based on erosion characteristics of this region is essential. Such a model might also be useful for protecting similar ecosystems and environments in other countries of Central Asia. Yet, English publications on Xinjiang's soil water erosion issues remain rare.

As such, the purpose of this study was to overview and: (1) explore the trend and intensity of soil water erosion in Xinjiang, (2) understand its driving factors and environmental impacts, and (3) discuss the progress of soil and water conservation measurements in Xinjiang.

2. Materials and methods

2.1. Study area

Located in the northwest of China, Xinjiang has a typically arid and continental climate. The Tian Mountain divides Xinjiang into two parts, north and south Xinjiang. According to Xinjiang statistical yearbooks, the average annual precipitation from 1991 to 2011 was 164.7 mm, while that of north Xinjiang was 239.9 mm, that of south Xinjiang was only 71.0 mm (Zhang et al., 2014). The highest monthly precipitation is in July for both north and south Xinjiang (Fig. 1a). The lowest monthly humidity index of north Xinjiang is in August (Fig. 1b), suggesting relatively high evaporation in this month. The highest monthly temperature of south Xinjiang is in July (Fig. 1c). The newly published soil and water conservation zoning in China (The Ministry of Water Resources of China, 2012) divided soil erosion area in Xinjiang into seven sub-regions (Fig. 2), i.e., (a) north part of Junggar basin, dominated by the north part of Gurbantunggut desert and the Altay Mountain; (b) north part of Tian Mountain, dominated by the north part of Tian Mountain, oases, and the south part of Gurbantunggut desert; (c) Ili river valley, circled by mountains; (d) north part of Tarim basin, dominated by the south part of Tian Mountain, oases, and the north part of Taklimakan desert; (e) Turpan–Hami basin, dominated by desert ecosystems; (f) west part of Tarim basin, dominated by the north part of Kunlun Mountain, oases, and the west part of Taklimakan desert; and (g) south part of Tarim basin, dominated by the north part of Kunlun Mountain and the south part of Taklimakan desert. Most of farmlands in Xinjiang are distributed in oases. The total farmland area is 41.2×10^3 km^2, of which irrigated lands occupy 38.1×10^3 km^2 (Jin, 2012). Major crops grown in this region are cotton, wheat, maize, and sunflower.