Effect of Climate Variability and Human Activities on Runoff in the Jinghe River Basin, Northwest China

YAO Jun-qiang1,2,3, ZHAO Qiu-dong4, LIU Zhi-hui4

1 School of Resources and Environment Science, Key Laboratory of Oasis Ecology of Ministry of Education, Xinjiang University, Urumqi 830046, China
2 Xinjiang Climate Center, Xinjiang Meteorological Administration, Urumqi 830002, China
3 Institute of Desert Meteorology, China Meteorological Administration, Urumqi 830002, China
4 Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China
5 Institute of Arid Ecology and Environment, Xinjiang University, Urumqi 830046, China


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Abstract: Much attention has recently been focused on the effects of climate variability and human activities on the runoff. In this study, we analyzed 56-yr (1957–2012) runoff change and patterns in the Jinghe River Basin (JRB) in the arid region of northwest China. The nonparametric Mann–Kendall test and the precipitation-runoff double cumulative curve (PRDCC) were used to identify change trend and abrupt change points in the annual runoff. It was found that the runoff in the JRB has periodically fluctuated in the past 56 yr. Abrupt change point in annual runoff was identified in the JRB, which occurred in the years around 1964 and 1996 dividing the long-term hydrologic series into a natural period (1957 – 1964) and a climate and man-induced period (1965 – 1996 and 1997 – 2012). In the 1965 – 1996 period, human activities were the main factor that decreased runoff with contribution of 88.9%, while climate variability only accounted for 11.1%. However, the impact of climate variability has been increased from 11.1% to 47.5% during 1997 – 2012, showing that runoff in JRB is more sensitive to climate variability during global warming. This study distinguishes the effect of climate variability from human activities on runoff, which can do duty for a reference for regional water resources assessment and management.

Keywords: Water resource; Runoff; Climate variability; Precipitation; Jinghe River Basin

Introduction

With the intensification of water shortage problems and the increasing water-related disaster events globally (Chen et al. 2013; IPCC 2013), the effects of climate variability and human activities on hydrological cycle have been a focus of global hydrology research (Ren et al. 2002; Scanlon et al. 2007; IPCC 2007), and related research throughout the world (Bronstert et al. 2002; Legesse et al. 2003; Pfister et al. 2004; Xu 2005; Piao et al. 2007) for over a decade. Climate variability is believed to have led to global warming and changing patterns of precipitation and evaporation by intensifying the global hydrological

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cycle (Brutsaert and Parlange 1998; IPCC 2007). Human activities have changed the temporal and spatial distribution of water resources through land use/land cover change, reservoir construction, river diversion, and other engineering and management practices (Ye et al. 2003; Milly et al. 2005). In continental arid regions, the effects of climate variability and human activities on runoff are significantly more sensitive, and these effects have resulted in serious eco-environmental degradation and water resources crises (Liu and Xia 2004; Ma et al. 2008; Jiang et al. 2011). Quantitative evaluation of these effects is important for regional water resources assessment and management.

Studies on the effect of human activities have mainly focused on the relationship between land use change and runoff (Scanlon et al. 2007). Ren et al. (2002) estimated the effect of human activities on the runoff by computing the impacts on each component of a water balance equation. This method, however, is limited because it is difficult to count the direct effect of human activities on each component for the water supply and water utilization, factors which are complex and subject to rapid change. New attempts, including regression analysis (Ye et al. 2003; Tian et al. 2009), runoff coefficients analysis (Wang et al. 2013), sensitivity analysis (Dooge et al. 1999; Milly and Dunne 2002; Jiang et al. 2011), and hydrologic model simulation method (Jones et al. 2006; Wang et al. 2008; Liu et al. 2010), have been made recently to address this problem. This hydrological sensitivity analysis method (HSAM) has in recent years been used to separate the effects of climate change and human activities on runoff in the Wuding River Basin, Shiyang River Basin, and Kaidu River Basin (Li et al. 2007; Ma et al. 2008; Chen et al. 2013). HSAM is a framework for evaluating the sensitivity of the annual runoff to precipitation and potential evapotranspiration (Dooge et al. 1999; Milly and Dunne 2002). These researches showed that the impacts of climate change and human activities on runoff were more significant in arid areas than that in more humid areas.

The Jinghe River Basin (JRB) was selected as our study area. It has an area of 12,215 km², and the river is a main tributary of the North Tianshan Mountains in northwestern China. The Jinghe River provides crucial water resource supplies to Ebinur Lake in northwestern China. Owing to rapid socio-economic development and climate change, quality and quantity of available water resources within the JRB have changed (Zhang 2011). Water crises, including drying up of lakes and ecosystem degradation, have occurred frequently. To develop water resources sustainably for the JRB, quantitative assessments of the effects of climate change and human activities on runoff are important.

Many studies investigating climate change and human activities and hydrological responses in the JRB and surrounding area have been published (Mu et al. 2007; Sun et al. 2010; Bai et al. 2010; Zhang et al. 2011; Liu et al. 2011). However, these studies have not systematically and quantitatively estimated the effects of climate change and human activities. The objectives of this study, therefore, are to: (1) determine trends and abrupt change points in annual runoff of the basin and (2) quantitatively estimate the effects of climate change and human activities on runoff.

1 Study Area

The Jinghe River starts from the north slope of the Ponoramio Mountain and ends in the Ebinur Lake which is located in Jinghe county of Xinjiang (Figure 1). The Jinghe River flows from south to north approximately 114 km and covers a basin area of the 1419 km² which is above of the Jinghe Hydrological Station. Administrative boundaries are within 81°46’ – 83°51’E and 44°02’– 45°10’N, and cover an area of approximately 12,215 km²(25% of the Ebinur Basin), in which the land is divided into mountains (6882 km²), plains (6791 km²) and water area (542 km²). The topography of the basin is high in the southern part and low in the northern part. The annual mean temperature is 7.8°C, extreme minimum and maximum temperatures are -36.4°C and 41.5°C. The annual mean precipitation is about 252 mm during past 50 years, and varies from 100 mm in the north to 700 mm in the south. The annual average potential evaporation is about 1625 mm. The annual runoff is mainly concentrated in the rainy season from June to August, which accounts for 65% of the annual total. The long-term annual runoff of the Jinghe River is