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# Distinguishing human and climate influences on streamflow changes in Luan River basin in China

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ABSTRACT

Climate variability and human activities have received significant attention in recent years. We assessed streamflow record in the Luan River basin in the period 1956–2000 in response to climate variation and anthropogenic factors. Analyses of annual and seasonal series showed that the streamflow had a significant decreasing trend, with an abrupt change point in 1979. Human activity had more effects on streamflow changes than climate, for the change of annual streamflow, climate variability contributed 40.89%, and human activities contributed 59.11%; for the change of seasonal streamflow, climate variability contributed 43.53% (wet season) and 7.15% (dry season), and human activities contributed 56.47% (wet season) and 92.85% (dry season). In effects of human activity, reservoir regulation had a larger proportion than land-use change, it contributed 38.86% in the changes of annual streamflow, while land-use change contributed only 20.26%; and for the change of seasonal streamflow, reservoir regulation contributed 39.48% (wet season) and 52.14% (dry season), while land-use change contributed only 16.99% (wet season) and 40.71% (dry season).



## 1. Introduction

It is widely recognized that streamflow changes are influenced by both climate variability and human activities (Piao et al., 2007). Climate variability resulting in temperature rises and changes in precipitation has significant impacts on regional streamflow (Chen et al., 2006; Huo et al., 2008). Human activities such as deforestation, land use changes, irrigation and dam construction can also lead to significant hydrologic alterations (Sahagian, 2000). Within the last decades, water quantity and quality have become increasingly serious issues for water resources management at catchment and/or regional scale (Tomer and Schilliing, 2009; Lakshmi et al., 2012).

Haihe basin in China is a water-scarce area that has experienced prolonged drought during the 1980s and 1990s. During the recent 30 years, the runoff from the mountain region has decreased sharply (Cong et al., 2010; Bao et al., 2012a). The annual runoff has a decreasing trend in most rivers, such as in Luan River (Wang et al., 2013; Xu et al., 2013), Chaobai River (Wang et al., 2009; Ma et al., 2010), and Zhang River (Wang et al., 2013). Many previous studies analyzed the reasons for the decrease of runoff. Wang et al. (2009) estimated the contribution of land use change to be 68% and 70% respectively in Chao River and Bai River; Bao et al. (2012b) reported that human activities were the main driving factor in the northern and southern parts of Haihe basin; Xu et al. (2013) concluded that the impact of local human activities accounted for 79.5% of the estimated decrease in annual inflow for the Panjiakou Reservoir in Luan River.

However, most of studies apply the hydrological to analyze the effects of climate change and human activities, such as VIC model (Bao et al., 2012b) and GBHM model (Xu et al., 2013). Although the models are powerful tools for such research, the results of studies have numerous uncertainties caused by shortcoming in the structure, parameter calibration, and scale problem. Furthermore, the models require a large amount of data including meteorological, hydrological and topographical details. The alternatives of statistical and graphical methods have proved to be effective choices to detect streamflow response to various disturbances (Zhang et al., 2014). Long-term records of hydrological data show temporal variations in runoff influenced by climate and land cover changes. Analyses of such changes from long-term hydrological data can identify not only runoff changes in a catchment, but also decipher the influences of climate change and human activities (Zhang et al., 2011a, 2011b).

Luan River is one of the largest water supplies of Haihe basin with strong human activities. The objectives of this study were to determine: (1) trends and abrupt change points in the annual streamflow in the Luan River basin; and (2) the proportion of streamflow change attributable to climatic variability and human activities influences.

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## 2. Materials and methods

### 2.1. Study area

The Luan River basin is one of sub-basins in Hai River basin, bounded by 39°44′–42°44′N and 115°33′–119°36′E (Fig. 1). The region has a total area of 44750 km$^2$, accounting for 14.06% of the entire area of Hai River basin. The topography is characterized by low mountains and hilly landscapes, with elevation varying from 24 to 2150 m above sea level. The region has a semi-humid continental monsoon climate with a mean annual temperature of 7.6 °C. Precipitation is temporally variable, the amount in June–September can account for more than 80% of all year (Fig. 2). The mean annual precipitation is 520 mm.

### 2.2. Data

All data for annual precipitation and runoff were obtained from the Hydrological Yearbook of PR China. These data have not been published but are printed and available for internal use. The location of all hydrologic stations can be seen in Fig. 1. The adjusted streamflow records were obtained from the China Institute of Water Resources and Hydropower Research (http://www.iwhr.com) and the "national integrated water resources planning". Meteorological data were obtained from the China Meteorological Data Sharing Service System (http://cdc.cma.gov.cn/), the meteorological stations are also seen in Fig. 1. The land use map of this region was derived from Data Sharing Infrastructure of Earth System Science (http://www.geodata.cn/).

### 2.3. Methods

#### 2.3.1. Mann–Kendall trend detection

Mann–Kendall test is one of the most widely used non-parametric tests to detect significant trends of climatic variables in

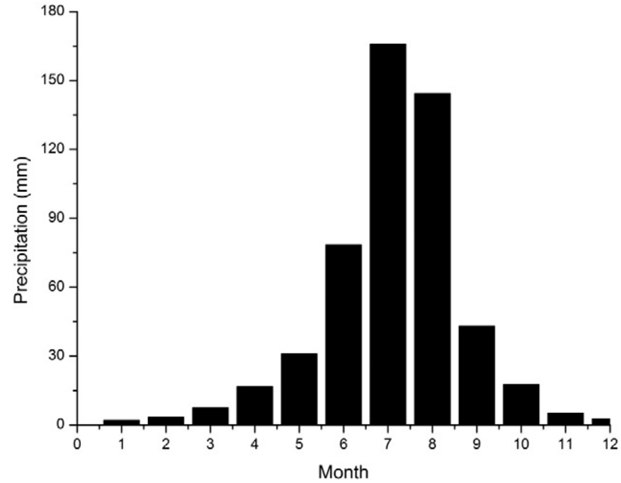


**Fig. 2.** Mean monthly precipitation in Luan River basin.

time series (Hamed, 2008; Liang et al., 2010). It is based on the statistic S:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\left(x_j - x_i\right) \tag{1}$$

$$sgn(x) = \begin{cases} 1, & if \quad x_j - x_i > 0 \\ 0, & if \quad x_j - x_i = 0 \\ -1, & if \quad x_j - x_i < 0 \end{cases} \tag{2}$$

where $x_i$ and $x_j$ are two generic sequential data values of the variable, and $n$ is the length of the data set.

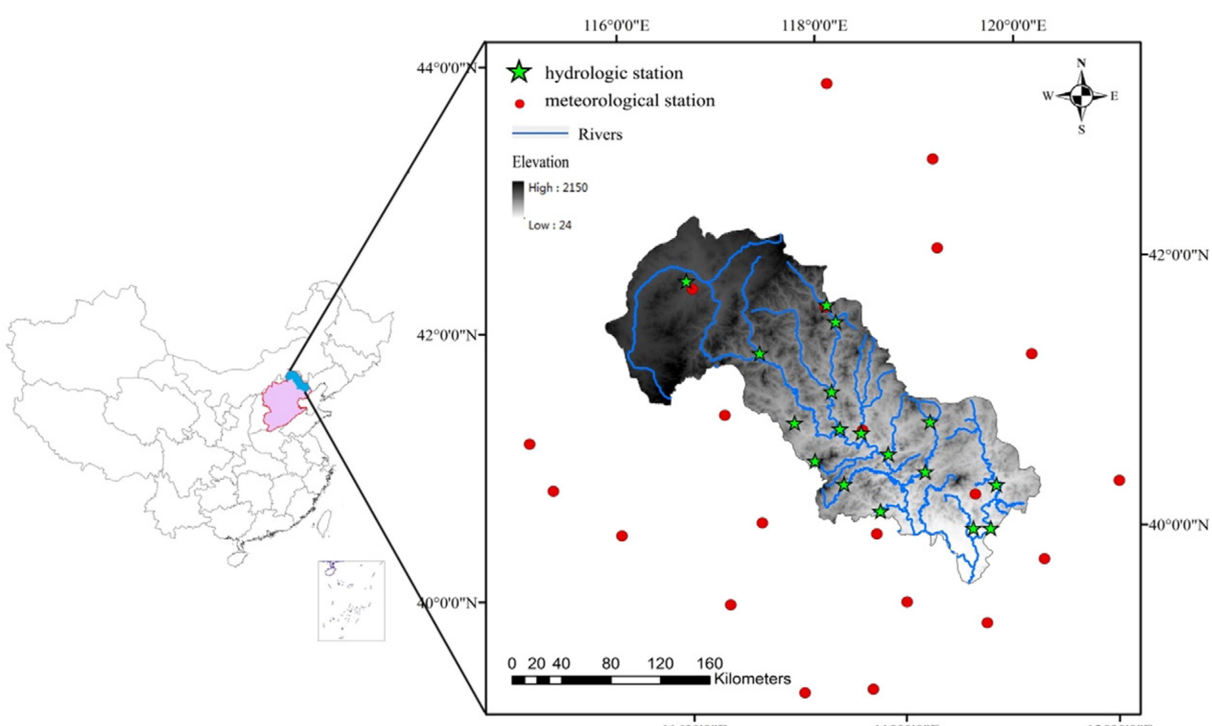


**Fig. 1.** Location of Luan River basin in China.