Catena 166 (2018) 279–289

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Spatial-temporal changes of rainfall erosivity in the loess plateau, China: Changing patterns, causes and implications

Saiyan Liu[a], Shengzhi Huang[a,*], Yangyang Xie[b], Guoyong Leng[c], Qiang Huang[a], Lu Wang[a], Qi Xue[a,d]

[a] State Key Laboratory of Eco-hydraulics in Northwest Arid Region of China, Xi'an University of Technology, Xi'an 710048, China
[b] Yangzhou University, Yangzhou 225127, China
[c] Environmental Change Institute, University of Oxford, Oxford OX1 3QY, UK
[d] Yulin Municipal Water Affairs Bureau, Yulin 719000, China

ARTICLE INFO

Keywords:
Rainfall erosivity
Large-scale atmospheric circulation patterns
Sediment load
The loess plateau
The Jing River basin

ABSTRACT

Rainfall erosivity is one of the key factors influencing soil erosion by water. Improved knowledge of rainfall erosivity is critical for prediction of soil erosion and the implementation of soil and water conservation plan as well as sediment management projects under climate change. In this study, the Jing River Basin (JRB), a typical eco-environmentally vulnerable region of the Loess Plateau in China was selected as a case study. Spatial-temporal changing patterns of rainfall erosivity in the JRB were first examined, followed by detailed investigations of the underlying causes through exploring the relations among annual rainfall, large-scale atmospheric circulation patterns and rainfall erosivity using the cross wavelet technique. Furthermore, implications of changing rainfall erosivity for sediment load and vegetation cover were analyzed. Results indicated that: (1) the year 1985 was a turning point in the time series of annual rainfall erosivity, demonstrating the non-stationary feature. Seasonal rainfall erosivity showed a spatial gradient with decrease from the upper to the lower stream. Rainfall erosivity was the largest in summer, and has increased significantly in the eastern basin; (2) annual rainfall erosivity showed a strong positive correlation with annual rainfall amount, implying that decrease of rainfall may have led to the reduction of rainfall erosivity in recent decades; (3) El Niño-Southern Oscillation and Pacific Decadal Oscillation were correlated with rainfall erosivity during 1982–1991, suggesting that large-scale atmospheric circulation patterns have strong influences on the changing patterns of rainfall erosivity; (4) changing rainfall erosivity had negligible impacts on the variation of vegetation cover (as indexed by the Normalized Differential Vegetation Index), but has detectable influence on sediment discharge which was further modulated by local soil and water conservation practice since the 1970s. These findings are helpful for prediction of soil erosion and adaptation strategies through local soil erosion control measures and sediment control projects.

1. Introduction

Soil erosion by rainfall is a severe ecological and agricultural concern, with large impacts on social and economic development worldwide by reducing agricultural productivity and increasing the risk of landslide activity (Panagos et al., 2015) and eco-environment deterioration (Lee and Heo, 2011). Furthermore, transportation of eroded particles through runoff could favor the deposition of sediment, resulting in loss of reservoir storage (Jebari et al., 2012). Therefore, accurate prediction and evaluation of soil erosion is of great importance for soil erosion control and sediment management (Lee and Heo, 2011). The Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) and its revised version RUSLE (Renard et al., 1997) have been the most widely used empirical models for assessing and predicting soil erosions by water. In these models, soil loss is a function of rainfall erosivity (R factor), soil erodibility (K factor), slope length (L factor) and steepness (S factor), cover (C factor) and conservation practices (P factor). Among these factors, rainfall erosivity, defined as the potential capability of rainfall to erode soil, is recognized as the key factor influencing soil erosion by water (Hoyos et al., 2005; Lee and Heo, 2011; Panagos et al., 2015; Ballabio et al., 2017).

Understanding the change patterns of rainfall erosivity expressed in terms of rainfall amount and intensity (Hoyos et al., 2005) is critical for soil erosion modeling, soil and water conservation planning, soil loss

* Corresponding author at: State Key Laboratory Base of Eco-Hydraulic Engineering in Arid Area, Xi'an University of Technology, Xi'an 710048, China.
E-mail address: huangshengzhi7788@126.com (S. Huang).

https://doi.org/10.1016/j.catena.2018.04.015
Received 12 September 2017; Received in revised form 10 April 2018; Accepted 12 April 2018
0341-8162/ © 2018 Elsevier B.V. All rights reserved.

recurrence analysis (Xie et al., 2016), sediment management, water quality modeling (Lee and Heo, 2011), non-point source pollution assessment (Xie et al., 2016), landslide and flood risk assessment (Panagos et al., 2015) and agricultural management (Maracchi et al., 2005). Under a changing climate, terrestrial hydrological cycle has accelerated (Trenberth, 2011) with more frequent extreme rainfall (Santos et al., 2011; IPCC, 2013; Huang et al., 2015a, 2015b; Liu et al., 2017; Fang et al., 2017). Extreme rainfall, especially those rainfall events with strong intensity and short duration, tend to be more erosive (Wei et al., 2007; Huang et al., 2016a, 2016b, 2016c; Fang et al., 2018; Huang et al., 2018). Therefore, improved knowledge of the changing characteristics of soil erosion is important for making soil conservation and sediment control strategies.

Recently, evaluation of rainfall erosivity has been well documented in the literature (Ramos and Durán, 2014). For example, Panagos et al. (2015) investigated the changes in annual rainfall erosivity in Europe and identified Mediterranean and Alpine as vulnerable regions where thunderstorms have become more frequent than in other areas. Ballabio et al. (2017) presented a study on monthly rainfall erosivity and found an increasing tendency of erosivity during the winter and summer seasons in Western and Eastern parts of Europe. Vrieling et al. (2010) showed that the highest erosivity in Africa was distributed along the west coast and northern half of Madagascar. At regional scale, Hoyos et al. (2005) revealed remarkable differences in rainfall erosivity between wet and dry seasons in Colombian Andes. Borrelli et al. (2016) investigated the spatio-temporal distribution of rainfall erosivity in Italy based on a gridded map of rainfall erosivity. Oliveira et al. (2012) found that rainfall erosivity in Brazil has a spatial gradient with increase from east to west, and the lowest and highest rainfall erosivity were located in the northeast and north parts of the country, respectively. Mello et al. (2015) compared the performance of regression-kriging method for R factor prediction with other methods, and demonstrated its greater prediction accuracy for developing R factor maps for Brazil. Based on 270 years of data, Bonilla and Vidal (2011) found an increasing trend in rainfall erosivity in central Chile. Angulo-Martínez and Beguería (2009) showed distinct spatial and seasonal patterns of rainfall erosivity in the Ebro Basin, Northeastern Spain. In China, an increasing trend of annual erosivity was observed in the arid zone, while a decreasing trend was found in the sub-humid zone, and no evident trends were detected in the semi-arid zone (Yang and Lu, 2015). Recently, increasing trends of spring and winter rainfall erosivity have been reported in the Yunnan Plateau, Southwest China (Gu et al., 2016).Previous studies have well advanced our knowledge of changing patterns of rainfall erosivity under the background of climate change, which showed that rainfall erosivity mainly depended on precipitation seasonality, temperature and other bioclimatic factors (Panagos et al., 2015; Ballabio et al., 2017).

It has been well demonstrated that large-scale atmospheric circulation patterns, including El Niño–Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO), are responsible for the spatial and temporal variability of rainfall (Croitoru et al., 2015; Limsakul and Singhruck, 2016; Liu et al., 2018). Given the fact that rainfall erosivity is closely linked with rainfall pattern (Panagos et al., 2015), investigation of the teleconnection between atmospheric circulation patterns and regional rainfall erosivity would thus shed light on the mechanism behind the changes in rainfall erosivity. To date, limited studies have been conducted in this regard. Angulo-Martínez and Beguería (2012) found that rainfall erosivity became stronger during the negative phases of North Atlantic Oscillation (NAO), the Mediterranean Oscillation (MO) and the Western Mediterranean Oscillation (WeMO) in Northeastern Spain. However, their analysis was mainly based on the rank test, which can only reveal general relationships between atmospheric circulation patterns and rainfall erosivity. A more advanced approach such as the cross wavelet analysis is required to explore the correlations in both time and frequency fields (Huang et al., 2015a), which is of important significance for prediction of soil erosion.

Besides its effects on soil erosion, rainfall erosivity may exert impacts on plant growth. Djebou et al. (2015) found that vegetation coverage variation was closely related to the variability of rainfall. Significant correlation between rainfall and NDVI (normalized difference vegetation index) have also been observed worldwide (Li et al., 2003; ChamailléJammes and Fritz, 2009; He, 2014). Although previous studies have enhanced our understandings on the relationship between rainfall magnitude and vegetation coverage, the effect of rainfall erosivity on vegetation cover has not been well demonstrated. Indeed, landslides, floods and soil erosion could effectively change vegetation structure and composition for long time periods at large scale (Sun et al., 2013). Hence, knowledge of vegetation coverage response to changing rainfall erosivity can help guide soil conservation practices.

Loess Plateau in China is featured with highly erodible loess layers. Centuries of unsustainable farming practices and huge population growth have led to severe environmental degradations in the Loess Plateau. The susceptibility of Loess Plateau to soil erosion hazard is found to be mostly influenced by a few erosive rainfall events that are short and intense (Xin et al., 2011). Previous studies have well examined the long-term trend of annual erosive rainfall and annual rainfall erosivity in the study region (Xin et al., 2011; Yue et al., 2014), but few have explored the implications of rainfall erosivity on vegetation coverage and sediment load variations, which have great implications for local soil and water conservation, sediment management and ecological restoration.

The main objectives of this study are: (1) to examine the changing patterns of rainfall erosivity in a river basin in the Loess Plateau, and assess whether its stationarity is valid or not; (2) to explore the possible causes of rainfall erosivity variation from the perspective of local-scale and large-scale climate changes; (3) to investigate the impacts of changing rainfall erosivity on the variations of local vegetation coverage and sediment load.

2. Study area and data

2.1. Study area

The Jing River Basin (JRB) located in the central part of the Loess Plateau (106.2°E–109.1°, 34.8°N–37.4°N), was selected as the study region. It is the secondary tributary of the Yellow River Basin (YRB) and the largest tributary of the Wei River Basin (WRB) in China (Fig. 1). The drainage area of JRB is 45,400 km^2, directly supporting a population of 6 million. Mean annual rainfall is approximately 545 mm with nearly 60% concentrated in summer (from June to August). Loessial soil and dark loessial soil are the typical soil types across the basin, which are highly erodible. Forest coverage rate in the basin is only about 6.5%.

Extensive rainfalls in summer combined with the erosion-prone soils, steep landscapes and low vegetation coverage make JRB one of the most sediment-laden tributaries of the YRB. It was recorded that annual average sediment transported into the JRB is approximately 2.6×10^8 t, accounting for nearly 14% of sediment load of the YRB (Xin et al., 2011). In order to reduce soil loss, a series of conservation measures including Grain for Green Projects have been implemented since 1970s (Xin et al., 2011), which have greatly improved vegetation cover, leading to changes in surface hydrology (Li et al., 2009).

There are nine meteorological stations (Fig. 1 and Table 1) in the study region. Detailed information of these stations is provided in Table 1. In addition, there is a hydrological station Zhangjiashan in the lower reaches of the JRB, which controls the whole basin.

2.2. Data

Daily rainfall data (1960–2010) obtained from the National Climate Center (NCC) of the China Meteorological Administration (CMA) were analyzed in this study. To examine the relationship between rainfall erosivity and large-scale atmospheric circulations, correlations between

Download English Version:

https://daneshyari.com/en/article/8893553

Download Persian Version:

https://daneshyari.com/article/8893553

Daneshyari.com