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An assessment of erosivity distribution and its influence on the effectiveness of land use conversion for reducing soil erosion in Jiangxi, China

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ABSTRACT

Rainfall and land use conversion are important factors influencing soil erosion. Differing from the stationary land use type, land use conversion is a process of dynamic change usually spanning several decades. Soil erosion modeling using historic land use data offers an opportunity to study the impacts of actual land use conversion on soil erosion. However, rainfall has been taken into account only in a few studies because its spatio-temporal distribution often varies greatly over a long period of time. In this article, the erosivity index was used to quantify the erosive force of rainfall. Based on entropy theory, erosivity distribution of study area during the 1988 to 2013 period was analyzed. Two extreme zones, Zone I and Zone II, with highest and lowest annual erosivity, respectively, were identified. The intensity of soil erosion among land use types are: farmland > orchard > grass/open forest > shrub > forest. Zone I has severer soil erosion than Zone II. The effectiveness of land use conversion for reducing soil erosion varies between different erosivity zones. Farmland–forest conversion is considered as the first choice to reduce soil erosion when land use conversion is implemented. The conversions of farmland–grassland and farmland–open forest can be used as important supplements to conversion of farmland–forest in low erosivity zone of the study area, although they do not perform well under higher erosivity situation.

1. Introduction

Soil erosion is a primary cause of soil degradation throughout the world (Flanagan, 2002), and is significantly threatening the sustainable development of society and environment (Singha et al., 2006). As a complex process, soil erosion is determined by mutual interaction of numerous factors.

Land use is one of the most important factors influencing the susceptibility of a region to soil erosion (Fullen, 1998; Kosmas et al., 1997). A lack of adequate land use planning can accelerate water soil erosion and create major environmental problems (Cebecauer and Hofierka, 2008; Durán Zuazo et al., 2006). Undoubtedly, the conversion of land use can significantly influence soil erosion by changing vegetation cover, soil properties (Kosmas et al., 2000), characteristics of runoff and later the climatic conditions (Hernández et al., 2005; Wei et al., 2010a,b) in a region. Assessing the response of soil erosion to land use change is important to understand the efficiency of land use modification (e.g. 'Grain for Green' program) (Deng and Shang, 2012).

Soil erosion, however, is strongly affected by many other factors besides land use. Rainfall can cause soil erosion by means of rain-splash and runoff when reaching the ground (Kinnell, 2005). The erosivity index, which is usually implemented in the mathematical model (e.g. Universal Soil Loss Equation USLE and its revised form RUSLE), can effectively stand for the ability of rainfall to detach soil particles by considering rainfall amount and intensity (Sanchez-Moreno et al., 2014). Thus, soil erosion can be linked directly with rainfall characteristics by erosivity index.

The spatio-temporal heterogeneity of rainfall erosivity has a great influence on spatial distribution of soil erosion (Ma et al., 2009). In addition, classification of the erosivity distribution zones will provide a set of zones with their unique temporal and spatial distribution characteristic. Soil erosion may thus vary greatly in various zones of erosivity distribution in large scale. Addressing the response of soil erosion to different land use conversion types and different erosivity distribution zones is therefore important for land use structure adjustment and vegetation restoration. However, many studies assessed the impacts of different land use conversion on soil erosion simulated by using different models in long time scale (Muller et al., 2009; Wendt and Corey, 1980; Yuan et al., 2007; Zhang et al., 2014b). The impacts of erosivity were seldom studied because the accurate estimation of its spatio-temporal distribution over large areas is complicated and difficult.

Fortunately, entropy theory provides a possibility to delineate rainfall erosivity distribution zones on large scales. Entropy is a measure of unpredictability of information content. The entropy concept was introduced by Shannon (1948) to measure the uncertainties of random

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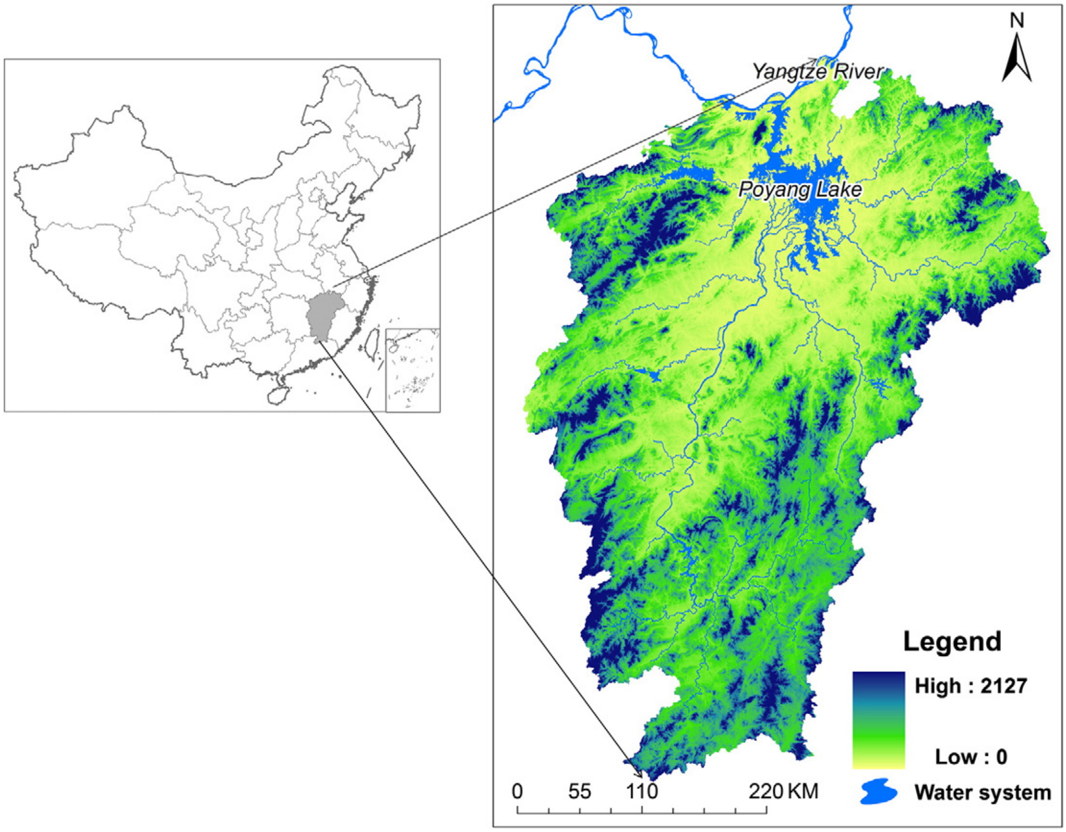

Fig. 1. Geographic location of Jiangxi province. The detail shows the Digital Elevation Model shaded-relief of the study area.

variables. Later, the researches on applying entropy theory to quantitatively assess uncertainties of hydrologic variables have become a research focus (Liu et al, 2013; Singh, 1997). The studies on features of meteorological system demonstrated that meteorological factors of the terrestrial atmosphere have the characteristic of self-similarity (Monin and Obukhov, 1954), which exists from free troposphere to boundary layer of the atmosphere (Nieuwstadt, 1984; Shao and Hacher, 1990). In addition, information transmission between meteorological stations was found by Yang and Burn (1994). The research showed that meteorological stations can be treated as recipients of dynamic signals from hydrometeorological parameters (e.g. precipitation) and these parameters have similar characteristics and are also spatially related across a given region. Consequently, meteorological observation system can be treated as a signal communication network. It provides the theoretical basis for the application of entropy theory in erosivity distribution zoning.

Soil erosion modeling using historic land use data offers a unique opportunity to study impacts of actual land use changes on erosion (Jordan et al., 2005). With the rapid development of GIS and RS technology, quantification modeling has become a widely accepted method that is considered the most scientific approach for future study for revealing soil erosion on a large scale (Xu et al., 2012). Some common or less common distributed hydrological models used for valuation of soil erosion are the Revised Soil Loss Equation (RUSLE) (Renard et al., 1991) (a revised method of USLE methodology), Water Erosion Prediction Project (WEPP) (Flanagan and Nearing, 1995) and the Soil and Water Assessment Tool (SWAT) (Antje and Martin, 2009). All these models study the phenomenon of soil erosion by attempting to estimate the volume of soil loss. However, RUSLE has been proved to be the one of the still most commonly used and tested methodology over many years from different researchers all over the world (Renard et al., 1997). It has been frequently applied to assess soil erosion risk and to guide development and conservation plans for soil erosion control in areas of different sizes and environmental conditions (Angima et al., 2003; Brooks et al., 2014; Fernandez et al., 2003; Zhang et al., 2014a). For example, using RUSLE and GIS, Terranova et al. (2009) conducted a comparison of soil erosion risk among four scenarios (one present scenario and three hypothesized scenarios) in the Mediterranean environment. His study highlighted the effectiveness of some antierosive measures and the increased intensity of erosive processes as a consequence of forest fires. Xu et al. (2012) carried out a risk assessment of soil erosion in different rainfall scenarios by RUSLE. It was found that greatest amount of attention should be paid to the prevention of soil erosion in July rather than September in Baohai Rim, China.

The validities and limitations of the RUSLE model are already known. The limitation is the obtained values of soil erosion must be employed

Table 1
Landsat image description.

Time	Sensor	Path	Row	Resolution
1988	TM	120–123	39–41	30 m
2013	OLI	120–123	39–41	30 m

Table 2
Descriptions of the land use classes identified.

Class name	Description
Farmland	Areas consisting of paddy land and dry land
Forest	Natural forest and plantation forest (canopy density > 0.3)
Open forest	Forest with canopy (0.1 < density < 0.3)
Shrub	Low woody plant (<2 m) with multiple stems (canopy density > 0.4)
Orchard	Area devoted to the cultivation of fruit or nut trees
Grass	Areas in which grasses are dominant (canopy density > 0.05)
Construction land	Residents and transportation and industries area
Water area	Area covered with lakes, rivers, and ponds
Bare land	Areas with little or no vegetation consisting of exposed soil/rocks