Journal of Integrative Agriculture 2017, 16(2): 377–388

Available online at www.sciencedirect.com

ScienceDirect

RESEARCH ARTICLE

Assessment for soil loss by using a scheme of alterative sub-models based on the RUSLE in a Karst Basin of Southwest China

CHEN Hao[1, 2], Takashi Oguchi[2, 3], WU Pan[4]

[1] School of Political Science and Public Administration, Huaqiao University, Quanzhou 362021, P.R.China
[2] Department of Natural Environment Studies, The University of Tokyo, Kashiwa 277-8568, Japan
[3] Center for Spatial Information Science, The University of Tokyo, Kashiwa 277-8568, Japan
[4] College of Resources and Environmental Engineering, Guizhou University, Guiyang 550025, P.R.China

Abstract

Accurate assessment of soil loss caused by rainfall is essential for natural and agricultural resources management. Soil erosion directly affects the environment and human sustainability. In this work, the empirical and contemporary model of revised universal soil loss equation (RUSLE) was applied for simulating the soil erosion rate in a karst catchment using remote sensing data and geographical information systems. A scheme of alterative sub-models was adopted to calculate the rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management (C) and conservation practice (P) factors in the geographic information system (GIS) environment. A map showing the potential of soil erosion rate was produced by the RUSLE and it indicated the severe soil erosion in the study area. Six classes of erosion rate are distinguished from the map: 1) minimal, 2) low, 3) medium, 4) high, 5) very high, and 6) extremely high. The RUSLE gave a mean annual erosion rate of 30.24 Mg ha^{-1} yr^{-1} from the 1980s to 2000s. The mean annual erosion rate obtained using RUSLE is consistent with the result of previous research based on *in situ* measurement from 1980 to 2009. The high performance of the RUSLE model indicates the reliability of the sub-models and possibility of applying the RUSLE on quantitative estimation. The result of the RUSLE model is sensitive to the slope steepness, slope length, vegetation factors and digital elevation model (DEM) resolution. The study suggests that attention should be given to the topographic factors and DEM resolution when applying the RUSLE on quantitative estimation of soil loss.

Keywords: soil erosion, RUSLE, GIS, Karst Basin

1. Introduction

Soil erosion has long been recognized as a severe and worldwide environmental issue. It threatens agriculture, natural resources, environment and human sustainability (Rahman *et al.* 2009; de Vente *et al.* 2013). During the late 20th century, nearly one-third of the world's arable land was devoured by soil erosion at an erosion rate of more than 10 million ha yr^{-1} (Pimentel *et al.* 1995). Since the ever-increasing population with its basic food needs, the conservation of valuable soil resource has become an urgent task. In order to assess the far-reaching socioeconomic and environmental implications of soil erosion and to develop control measures, accurate estimation of soil erosion loss or evaluation of soil erosion risk on different temporal and

Received 18 March, 2016 Accepted 26 October, 2016
CHEN Hao, Tel: +86-595-22693526, E-mail: chenhao@hqu.edu.cn; Correspondence WU Pan, E-mail: pwu@gzu.edu.cn

doi: 10.1016/S2095-3119(16)61507-1

spatial scale is needed (Boardman and Poesen 2006).

Many models, such as the universal soil loss equation (Wischmeier and Smith 1965), the water erosion prediction project (Nearing *et al.* 1989) and the European soil erosion model (Morgan *et al.* 1998) were developed to quantify the soil erosion. In practice, the revised universal soil loss equation (RUSLE) is most widely accepted model and extensively used for prioritization of predicting soil erosion loss (Renard *et al.* 1997; Alexakis *et al.* 2013). Its popularity owes to the property of parsimonious data, compatibility with the remote sensing (RS) and geographical information system (GIS) technologies, and the ability of supplying a platform to support multi-level and hierarchical resources and to integrate the information in a comparative theoretical framework.

For accurate assessment of soil erosion loss by the RUSLE, it is crucial to validate the effectiveness of the model. It is well known that the RUSLE was hardly observed to evaluate "exact" soil losses (Tetzlaff *et al.* 2013). Therefore, some studies evaluated the effectiveness of the RUSLE model based on the measurement of reservoirs deposited sediments (Lee and Lee 2006) and 137Cs budget (Onori *et al.* 2006). Moreover, some of the input parameters of RUSLE require extensive filed and laboratory studies, so that in most of the cases, alternative approaches were used in the calculation of these parameters instead of original approaches (Tanyaş *et al.* 2015). The selection of these sub-models plays an important role on evaluating the RUSLE accuracy (Kinnell 2010). The sub-models may result in over-estimating or under-estimating soil erosion values without considering the details of hydrological and erosion processes (Feng *et al.* 2016). Given above, some studies validated not only the RUSLE model, but also the sub-models based on the RUSLE (Tanyaş *et al.* 2015).

However, a few of studies that estimated the accuracy of RUSLE and its sub-models have been done in some specific environments, especially for the karst terrains (Kheir *et al.* 2008; Xu *et al.* 2008b). The karst landscape accounts for almost 20% of the continents and more than a quarter of the world's population lives there (Ford and Williams 2007; De Waele *et al.* 2009). The studies using the RUSLE in the karst landscape could be divided into two types: 1) studies without evaluating the accuracy of the RUSLE and its sub-models (Xu *et al.* 2008a, b) and 2) studies evaluating the accuracy of the RUSLE but without the accuracy of its sub-models (López-Vicente and Navas 2009; Feng *et al.* 2016). The fact that few researches were found in the karst landscape was due to the fragile ecosystems and the insufficient data or information (Kheir *et al.* 2008; Xu *et al.* 2008b; Feng *et al.* 2016).

This study was conducted in Mawoshan Karst Basin of Guizhou Province, China. Guizhou Province, located in the center of the Asian karst, has been suffering the damage of soil erosion (Wan 2003; Wang *et al.* 2004). With the aggravation of soil loss in this area, soil erosion in Guizhou has attracted the researchers' attention (Zhang 1999; Wang *et al.* 2008; Xu *et al.* 2008a; Xie *et al.* 2010b; Chen *et al.* 2012). Therefore, the successful application of the RUSLE and its selected sub-modles in the Mawoshan Karst Basin with typical karst terrain and ungauged characteristics are valuable for its popularization in the karst landscape. Therefore, it is necessary and urgent to build an appropriate model to assess soil erosion rate in the karst landscape. Mawoshan, is as a typical karst basin, was chosen to be the study area. The RUSLE and its selected sub-models were applied to estimate soil erosion rate. The objectives of this work are: (i) to assess the soil erosion rate and its spatial distribution by RUSLE, GIS and RS in a typical and ungauged karst basin, (ii) to evaluate the effectiveness of the RUSLE and the selected sub-models for the parameters in the RUSLE, and (iii) to analyze the sensitivity of the RUSLE with parameters and resolutions.

2. Materials and methods

2.1. Study area

Mawoshan Karst Basin (Fig. 1) with a surface area of 16.29 km^2 and a depositional area of 0.74 km^2, is situated at Weining County located in Wumeng Mountains between eastern Yunnan and northwestern Guizhou provinces, China. The elevation ranges between 2 229 and 2 819 m. It currently has a subtropical monsoon climate with mean annual sunshine time of 1 800 h. Mean annual temperature is 11.2°C with seasonal variability from 3.9°C in January to 17.0°C in July (ACW 1989). The mean annual precipitation is 850 mm, most of which occurs in summer seasons (from June to September). The precipitation in summer is responsible for 70% of the whole year. Corroded depressions, peak forests and peak clusters constitute the complicated topography of karst landforms. And the landscape is highly cultivated which leads to rocky desertification with the vegetation deterioration and extensive exposure of basement rocks (Wu and Xie 2011). The predominant existent species are *Pinus* and *Quercus spinosa* David ex Franch. The lithology is mainly composed of limestone and dolomite.

2.2. Datasets

Three main datasets were used to support the estimation of soil loss in the study area. The first dataset is the present inventory. This dataset includes inventory record of meteorological data (Table 1) in the Weining Weather Station (104°17´E, 26°52´N), satellite imagery from the AVNIR-2 sensor of ALOS, soil map of 1:650 000 scale and topographic maps at scales of 1:10 000 and 1:50 000 from