Catena 113 (2014) 306–313

Contents lists available at ScienceDirect

Catena

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

A new approach for regional scale interrill and rill erosion intensity mapping using brightness index assessments from medium resolution satellite images

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A R T I C L E I N F O

Article history:
Received 21 January 2013
Received in revised form 20 June 2013
Accepted 13 August 2013

Keywords:
Interrill and rill erosion intensity
Brightness index
Landsat ETM+ imagery
Geographic information system (GIS)
Golestan dam watershed
Ancillary layers

A B S T R A C T

Having accurate soil erosion intensity/type maps using satellite imagery is not generally a difficult task. However, there are still difficulties for the generation of small scale erosion features at regional and national levels. It is even more problematic when high-resolution satellite images cannot be used due to their high cost at a regional level. The principal objective of this study is to investigate the applicability of brightness value to generate accurate interrill and rill erosion intensity maps using medium resolution satellite images at a regional level. In this study, Landsat ETM+ images are used and the Golestan dam watershed with an area of 4511.8 km^2 located at northeast of Iran is selected as the study area. In order to generate a Homogeneous Land Unit (HLU) map, three ancillary layers including slope, landform, land use and land cover, are overlayed on each other. The HLUs are used in a supportive role for identifying appropriate sampling points across the entire study area, at which the degrees of interrill and rill erosions are measured. The ground-truth erosion information collected at the 1328 locations is divided into training and reference data sets. Using the Tasseled Cap transformation technique, the brightness value of each pixel at the beginning (May), middle (July) and end (September) of growing season is obtained. By subtracting the May brightness value (B_M) from the July one (B_J), and the July brightness value from the September one (B_S), two new brightness images representing the brightness variations over May–July (B_{MJ}) and July–September (B_{JS}) are created. The two new brightness images are combined to generate a map where its pixels indicate the state (i.e. increase, I, decrease, D, and constant, C) of brightness variation over the two growing seasons. Using the measured interrill and rill erosion information at the training sampling locations, a unique relationship is found between the trend of brightness variation and the erosion intensity. This relationship is validated using the reference data sets. The results show that the proposed method is able to produce an interrill–rill erosion intensity map with an overall field-checked accuracy of 96% at this study location. The main advantages of this method are its high accuracy, its lower demands on time and funds for field work, and the ready availability of required data.

1. Introduction

Long recognized as a serious worldwide land degradation problem, soil erosion has a strong negative impact on the environment by reducing soil productivity and increasing sediment and other pollution loads into receiving water bodies (Morgan, 2005). The importance of soil erosion type/intensity maps in natural resources, agricultural, soil conservation, land management and water resources management planning and development has been recognized for decades. Over the past decades, many models have been introduced and used for creating soil erosion maps (Flanagan et al., 2001; Parsons and Wainwright, 2006; Renard et al., 1997). New technologies (e.g. satellite data) and increased computing power have led to the development of new models in the context of soil erosion mapping (Morgan, 2005). Remote sensing provides detailed information over large regions with a regular revisit capability, and can greatly contribute to regional erosion assessment (Siakeu and Oguchi, 2000; Vrieling et al., 2008). Satellite imagery can assist soil erosion assessment/mapping through (i) automatic identification of large scale erosion (Vrieling et al., 2007) and its consequences (Jain et al., 2002), (ii) the assessment of erosion controlling factors (King et al., 2005; Vrieling et al., 2008), and (iii) the interpretation and

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http://dx.doi.org/10.1016/j.catena.2013.08.012

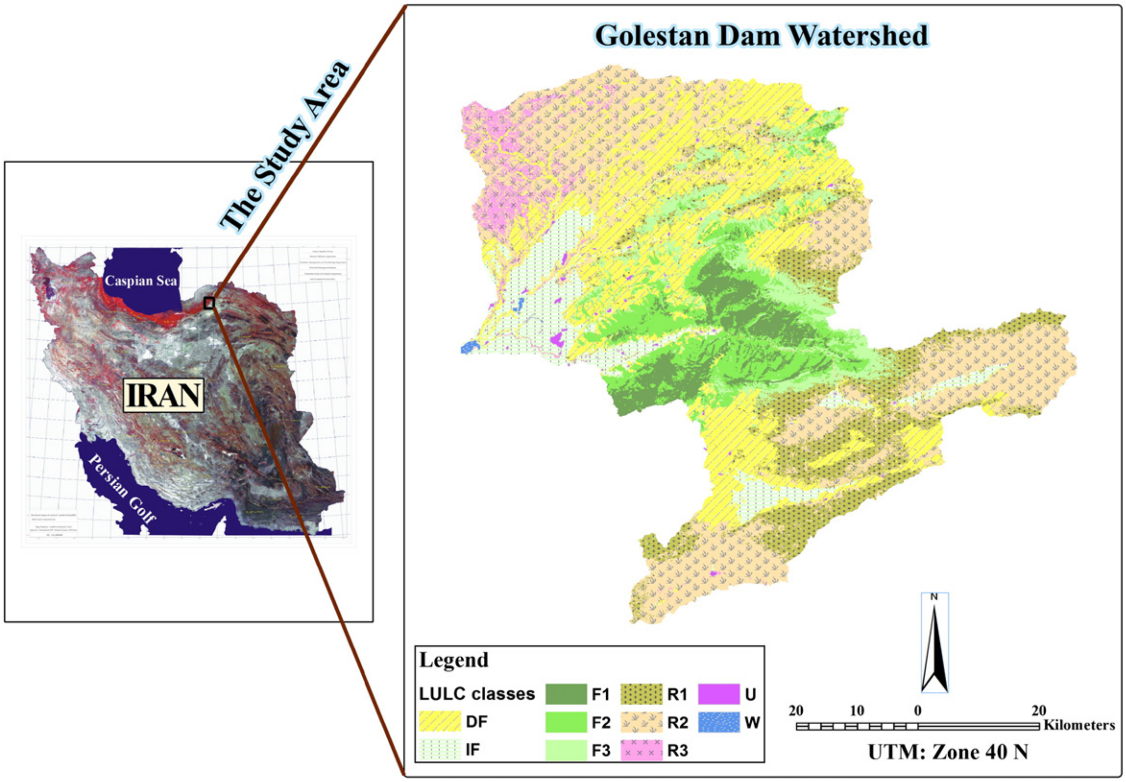

Fig. 1. Location of the study area.

classification of soil erosion using satellite data combined with additional data sources (ancillary layers).

In the first case, where high-resolution satellite data are used, large-scale erosion types (e.g. gully and badland) can be identified automatically from the satellite data. In the second case, a variety of erosion controlling factors such as vegetation, topography, climate, and soil characteristics can be obtained from satellite imagery (King et al., 2005). These data can then be used in a range of empirical models, leading to the quantitative assessment of small-scale erosion features. For instance, the empirical Universal Soil Loss Equation (USLE) can be used, in which long-term mean interrill and rill erosions are assessed (Wischmeier and Smith, 1978). Similarly, the USLE, its revised (RUSLE) and modified (MUSLE) versions (Renard et al., 1997; Smith et al., 1984), the Water Erosion Prediction Program (WEPP) (Flanagan et al., 2001), and the European Soil Erosion Model (EUROSEM) (Morgan, 1995; Morgan et al., 1984) can be used in which erosion controlling factors extracted from satellite data at basin or even regional scales play a role in assessing/mapping erosion intensities (de Vente and Poesen, 2005). The development of such models based on these factors is problematic as a number of these factors are difficult to be assessed, and are not constant in space and time and interact with each other (de Vente and Poesen, 2005). In addition, fixed data requirements, and the fact that these models are developed for a certain region, scale, or specific process and that they only provide a mean quantitative assessment of erosion phenomena, are drawbacks to their general use (Rudra et al., 1998; Vrieling, 2006). Although outputs of such models are helpful in prioritizing conservation projects within a watershed, they cannot provide detailed information of map erosion features (Poesen et al., 2003).

In the third case, erosion types/intensities can be differentiated using satellite data combined with some ancillary layers (Dymond et al., 2002; Focardi et al., 2008; Healey et al., 2005; Vrieling et al., 2008). Remote sensing data provides detailed information over large regions with a regular revisit capability, and can greatly contribute to regional erosion assessment (Siakeu and Oguchi, 2000; Vrieling et al., 2008). For instance, Liberti et al. (2008) mapped badland areas using landsat TM/ETM satellite imagery with the aid of some morphological maps. Vrieling et al. (2008) created soil erosion risk maps using a time series of MODIS (Moderate Resolution Imaging Spectroradiometer) and ASTER (Spaceborne Thermal Emission and Reflection Radiometer) images plus a digital elevation model (DEM) and temporal rainfall data. They reported a strong relationship between the normalized difference vegetation index (NDVI) and erosion risk. However, most approaches using remotely sensed data have concentrated on mapping large-scale erosion features (e.g. gullies) and erosion risk (King et al., 2005), but little has been done with regard to creating maps showing the erosion intensity classes over the land surface by interrill and rill processes (de Vente et al., 2008). It should also be noted that medium resolution satellite data alone cannot provide appropriate information for mapping small scale erosion features like interrill and rill (Alewell et al., 2008; Vrieling, 2006). A review of existing approaches for erosion types/intensities mapping shows that although the application of high-resolution satellite images (e.g. QuickBird, GeoEye and IKONOS) may lead to very accurate soil erosion type/intensity maps, these data are not accessible for all countries (such as the study area of this project: Iran), and are very expensive if used at the regional and national scales. Thus, it can be seen that there is a gap in the literature and in practice for methods with the capability of creating soil erosion maps (particularly small scale soil erosion features) that use medium resolution satellite images at the regional and national scales (Vrieling, 2006).

The principal objective of the present study is to investigate the applicability of the brightness index (Tasseled Cap) variation over the growing season to generate accurate interrill and rill erosion intensity maps using medium resolution satellite images and some ancillary layers at a regional level.

2. The study area

With an area of 4511.8 km^2, Iran's Golestan dam watershed is located between 55° 21′ and 56° 28′ E longitude, and 36° 44′ and 37° 49′ N