



Effect of vegetation cover on soil erosion in a mountainous watershed

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ABSTRACT

We applied the Revised Soil Loss Equation (RUSLE) to assess levels of soil loss in a Geographic Information System (GIS). In this study, we used the *k*-NN technique to estimate vegetation cover by integrating Landsat ETM+ scenes and field data with optimal parameters. We evaluated the root mean square errors and significance of biases at the pixel level in order to determine the optimal parameters. The accuracy of vegetation cover estimation by the *k*-NN technique was compared to that predicted by a regression function using Landsat ETM+ bands and field measurements as well as to that predicted by the Normalized Difference Vegetation Index (NDVI). We used a regression equation to calculate the cover management (*C*) factor of the RUSLE from vegetation cover data. On the basis of the quantitative model of soil erosion, we explored the relationship between soil loss and its influencing factors, and identified areas at high erosion risk. The results showed that the *k*-NN method can predict vegetation cover more accurately for image pixels at the landscape level than can the other two methods examined in this study. Of those factors, the *C*-factor is one of the most important affecting soil erosion in the region. Scenarios with different vegetation cover on high-risk areas showed that greater vegetation cover can considerably reduce the loss of soil erosion. The *k*-NN technique provides a new method to estimate the *C*-factor for RUSLE erosion mapping. The quantitative model of different vegetation cover scenarios provides information on how vegetation restoration could reduce erosion.

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1. Introduction

Soil erosion by water is a worldwide environmental problem which degrades soil productivity and water quality, causes sedimentation and increases the probability of flood. The Upper Min River (UMR) watershed in the Upper Yangtze Basin is an environmentally fragile area due to deforestation and soil erosion. Up to 44% of the land has been described as degraded in the area (Ye et al., 2003; Wu et al., 2003).

Different methods have been developed to detect eroded areas and to assess erosion loss. For instance, the qualitative classification of soil erosion can be assessed by FAO (2006), and large and middle-size eroded areas can be directly identified with Landsat and SPOT imagery (Langran, 1983; Millington and Townshend, 1984); the quantitative soil loss can be modeled with the universal soil loss equation (USLE) (Wischmeier and Smith, 1978), its revised version (RUSLE) (Renard et al., 1997), the Soil Erosion Model for Mediterranean regions (SEMMED) (De Jong, 1994), ¹³⁷CS techniques (Zhang et al., 2003), and the Water Erosion Prediction Project (WEPP) hill slope model (Grønsten and Lundekvam, 2006). Of these models, the USLE and RUSLE are the most widely used, providing a convenient tool for soil loss evaluation by taking into consideration rainfall,

topography, conservation support practice, soil, and vegetation. Although they are empirical models for assessing long-term averages of sheet and rill erosion based on plot data, the calculation of their factors can be improved and adapted to enable their application to various spatial scales and region sizes in different environments using GIS (Warren et al., 1989). For better prediction of soil loss in complex terrain, the modelling of dispersed flow over the surface can improve the slope length and steepness factor (*LS*) (Tarboton, 1997). Of these six RUSLE factors, the cover management factor (*C*-factor) is an important one affecting soil erosion in a given region. However, modelling the *C*-factor for complex terrain is difficult.

The *C*-factor in the soil loss equation is defined as the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled, continuous fallow (Wischmeier and Smith, 1978). Land use classification is often used to map vegetation types that differ in their effectiveness to protect the soil. After classification, *C*-factors are assigned according to a qualitative ranking of vegetation types (Wischmeier and Smith, 1978; Morgan, 1995). However, the proportional vegetation cover varied widely even for the same vegetation type. The direct application of the *C*-factor from the RUSLE is based on prior land use (PLU), canopy cover (CC), surface cover (SC), surface roughness (SR), and soil moisture (SM) (Renard et al., 1997). However, assessing PLU, CC, SC, SR, and SM simultaneously for a large area not covered mainly by agricultural lands is difficult. The Normalized Difference Vegetation Index (NDVI), defined

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as the near infrared reflection minus the red reflection divided by the sum of the two (Tucker, 1979), was calculated from satellite images for C-factor estimation (Thiam, 2003; Wu et al., 2004) because green vegetation is more reflective in the near infrared part and less reflective in the red part of the spectrum. However, De Jong (1994) found that the relationship between Landsat-derived spectral indices and vegetation attributes was quite poor for Mediterranean France. The non-parametric *k*-nearest neighbour (*k*-NN) technique, widely used in a variety of forest estimation and biomass mapping applications over the years (Tokola, 2000; Franco-Lopez et al., 2001; Katila and Tomppo, 2001), provides a new method to map proportional vegetation cover. The *k*-NN technique is a non-parametric approach to predicting values of point variables on the basis of similarity in a covariate space between one point and other points with observed values for the variables (Tomppo, 1991). Using the *k*-NN method, we cannot only predict variables such as vegetation cover, aboveground biomass, and stand volume or parameters for each pixel, but also examine the covariance structure of field variables and produce pixel-by-pixel maps. In this study, we used the *k*-NN method to estimate vegetation cover data and produced a pixel-by-pixel map by integrating the satellite images and field data with optimal parameters.

The major objectives of this study were to produce a vegetation cover map using the *k*-NN method and testing the performance of this method, to quantitatively evaluate soil erosion at 25-m resolution for a 7400 km² area of the watershed using the RUSLE model with predicted factors, especially an improved C-factor, to test the relationship between soil erosion and its influencing factors, as well as to model soil loss risk under different vegetation cover scenarios.

2. Study area

The study area is located in the Upper Min River (UMR) watershed (Fig. 1), with an area of 23,040 km². The target watershed is in Sichuan province, Southwest China, between 31°–33° N and 102°–104° E. The Min River is also one of the most important tributaries of the Upper Yangtze River. The climate is governed by the northeast and southwest monsoons. A complex topography, with elevation ranges from 600 m to more than 6000 m a.s.l. (above sea level), results in steep gradients of rainfall on both spatial and temporal scale. The annual precipitation ranges from 405 mm to 1950 mm in different parts of the watershed, and around half of the precipitation falls in July, August and September (Zhou, 2008). The upper reaches of the Yangtze River are the region suffering from serious water erosion in China. Around 1.56 billion tons of soil is eroded in this region each year (MWR, 1999). The UMR watershed is fragile to water erosion due to steep terrain and deforestation. The forest cover had declined from 50% to 30% by 1950 and to 18.8% by the 1980s, and to only 5%–7% along the main river (Wu et al., 2003). At present, around 21% of the entire watershed has forest cover. The vegetation here ranged from subtropical evergreen broad-leaved forest to alpine meadows.

Our 625 inventory plots were randomly placed in the middle and upper reaches of the UMR watershed (Fig. 1) over an area of about 7400 km². The vegetation ranges from subtropical evergreen broad-leaved forest to alpine meadows. Slope angles range from 0 to 77.2° with a mean of 25.9° (Zhou et al., 2006). The area comprises three main soil orders (Alfisol, Semi-alfisol, and Semi-aquatic) and faces

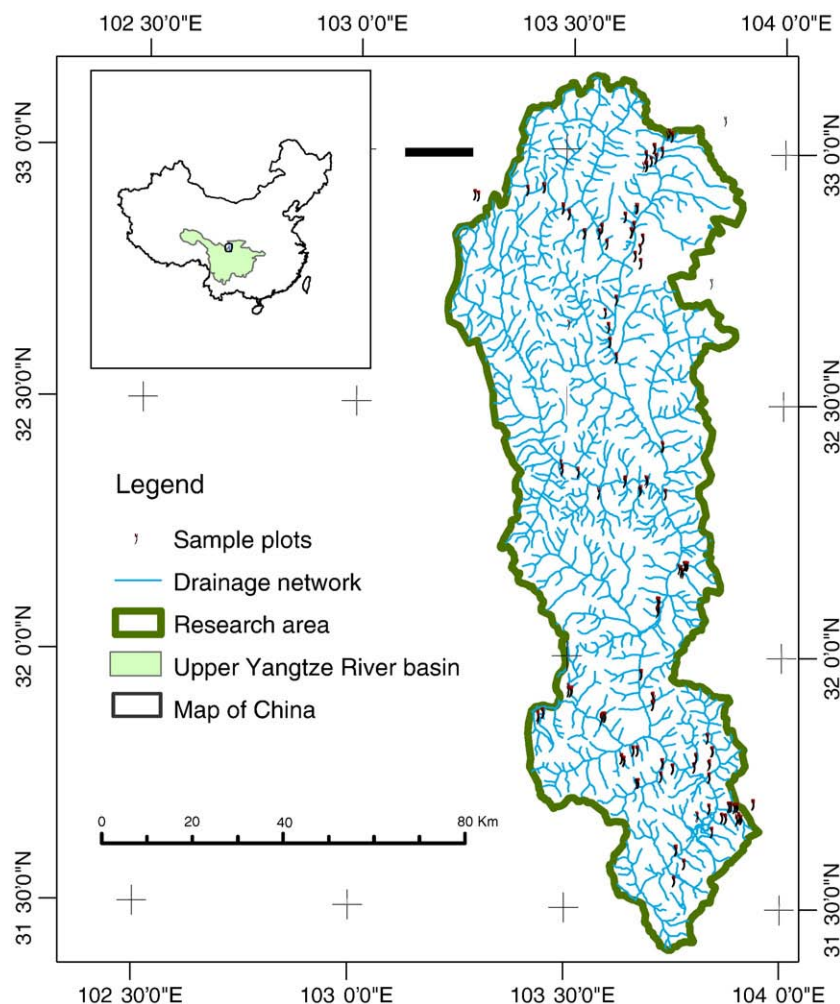


Fig. 1. Location of the research area and the sample plots.

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