

Soil erosion assessment based on minimum polygons in the Yellow River basin, China

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Abstract

In the previous studies, a method was developed to assess soil erosion based on land use information. In this paper, we present another approach that uses environmental data to assess soil erosion. A soil erosion characteristic index EI is proposed, and its value is derived using the Analytic Hierarchy Process (AHP) technique based on standardized environmental information stored in minimum polygons that tile the erodible area under consideration. The approach is applied to a case study of the Yellow River basin, north China, where serious erosion is occurring. To represent different grades of soil erosion, the range of EI is divided into six levels according to standard grades of soil erosion intensity. The application indicates that the method deals properly with data scarcity, with the results giving a satisfactory representation of the characteristics of soil erosion in the Yellow River basin. The spatial–temporal distribution of EI in the Yellow River basin is predicted, and the results interpreted to give the long-term trend and state of soil depletion. Comparisons are given between EI and surveyed soil erosion zoning maps for the Yellow River basin at the end of the 1980s and 1990s. The output reliability and the approach applicability in smaller spatial scales are investigated in a case study of Zhifanggou basin.

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1. Introduction

Soil erosion is a major environmental problem in many parts of the world (Mitra et al., 1998), with China one of the worst affected countries. In China, soil erosion affects an area of 3.6×10^6 km², equal to about 37% of the total land area of the country (Ministry of

Water Resources of PR China, 2002). Water, wind and freeze–thaw soil erosion is widely distributed, whereas gravity-induced erosion from rock fall, landslide, and debris flow is more localized. The Yellow River basin contains the Loess Plateau, which is famous for its extreme soil erosion and a gullied landscape. Erosion from the Loess Plateau contributes about 30% of the total soil loss in China (Ministry of Water Resources of PR China, 2002).

Assessment and forecasting of soil erosion are core issues in land management and are influenced by numerous factors, including climate, topography, soil attribute, land cover, and human activity. Certain of

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these factors are strongly interdependent, making the quantification of soil erosion complicated and difficult to achieve. At present, soil erosion models are either empirical (or based on the laws of physics) or developed from remote sensing (or utilize artificial neural networks). Empirical models such as the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965, 1978), the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), and the Soil and Water Assessment Tool (SWAT) (Neitsch et al., 2001), require quantified data from field experiments and onsite monitoring, which are difficult to obtain in developing counties where datasets are usually not well constructed. Even where there are sufficient hydrological stations, the readings are hard to interpret. This is because the observed runoff and sediment discharge at stations located in the lower regions of the catchment (near the watershed outlets) may solely comprise records of delayed soil erosion effects from the interior slopes, especially in watersheds associated with a lower sediment delivery ratio (Han and Ni, 2001). Extrapolating results from standard test plots to large areas is also very difficult because of the inadequate number of sites, the unrepresentative characteristics of certain plots, and their spatial variability. Evaluation of watershed soil erosion based on data collected from areas of different sizes may also be distorted by an area differential effect, resulting in significantly misleading variations of model structures and coefficients (Ni and Li, 2003). Models based on the governing physics, such as the Water Erosion Prediction Project (WEPP) (Flanagan and Nearing, 1995) and the Griffith University Erosion System Template (GUEST) (Misra and Rose, 1996), can replicate the successive erosion processes; but due to the complexity of the model equations and the large number of parameters involved, the applicability of such models is restricted. Remotely sensed information models (Folly et al., 1996; Metternicht and Zinck, 1998; de Jong et al., 1999) are used to extract values for the factors affecting soil erosion that could then serve as input information to statistical models. Artificial Neural Network models have also been introduced to estimate soil erosion (Wang and Fang, 2000), but they still require further practices (Li et al., 2004). For regions where soil erosion data are scarce or unavailable, predicting soil loss from these models to a credible degree of precision is impossible.

Ni and Li (2003) proposed an approach to soil erosion assessment in terms of land use structure changes. They suggest that in regions without human influence,

similar environmental variables determine similar soil erosion characteristics. In general, the change of soil erosion characteristics may be represented by change of land use structure (described by a land use structure characteristic index SI) where human influence is apparent. By comparing environmental variables in test regions with that in a reference region without human influence, the land use structure in the test regions can be predicted, and then the index SI could be calculated. The dynamic development of soil erosion in an area could be investigated by inspecting SI in series periods of the area. Moreover, according to the ratio between the observed and expected SI for the test regions, the impact of human influence can be estimated reasonably well.

Accurately estimating sediment yields is very difficult using the current models, especially in uncalibrated areas. Researchers have shown that relative variation of soil loss in a year is probably more reliable than that on the absolute annual losses (Jetten et al., 1999). So, we try to estimate soil erosion in macro-viewpoint and provide more reliable results in the present paper. An approach to soil erosion assessment based on minimum polygons that cover the area of interest is proposed. Different with Ni and Li's model, the approach includes human impacts in the assessment. A soil erosion characteristic index (EI) is constructed, which makes use of environmental factors from soil erosion remote sensing surveys and field monitoring. The Analytic Hierarchy Process (AHP) is used to determine the weights of environmental factors to soil erosion. By identifying different environmental factors at different catchment scales, the approach has the capacity to meet the requirements of applications covering a broad range of scales. Furthermore, the approach properly deals with data scarcity, leading to a marked improvement in its assessment and prediction capabilities. As a case study, the assessment of soil erosion in the Yellow River basin is demonstrated, and the EI results are found to reproduce properly the soil erosion state and long-term trend. Based on the assessment results in terms of EI, the key sediment source areas could be identified, and rational conservation measures could be taken correspondingly. The series EI maps could reflect the distribution and variation of soil erosion in various river basins and would be of great help to decision making for water and soil conservation. To investigate the output reliability and the approach applicability of up scaling soil erosion, EI is also assessed by identifying scale-dependent environmental factors in a smaller area, Zhifanggou basin.

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