Assessment and environmental zoning of soil erosion potential using RUSLE model (Case study: Gharahsoo watershed)

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Received: June 5, 2017 Accepted: April 6, 2016

Extended Abstract

Introduction

Soil erosion is one of the serious land degradation processes, which can be exacerbated by intensification of land utilization, land degradation and global climate change. Overgrazing by livestock, unsustainable agricultural practices, over cropping and deforestation, commercial and industrial development, urban expansion, and road construction are the possible causes that accelerate the removal of soil material, which can make serious environmental problems and disastrous economic consequences. So, estimation of soil erosion potential rate and identification of critical soil loss-prone areas is necessary for the best soil conservation management. Therefore, it is necessary to take actions such as management, conservation, and control in the watershed to restore the soil production potential and to prevent further damages. Generally, experimental methods and field observations are often time consuming and costly in developing countries. Therefore, use of alternative and less expensive methods such as various erosion risk models are more desirable to predict and assess of soil erosion rate. The zoning models of soil erosion potential identify critical areas to erosion. Awareness of erosion rate in watershed helps planners and managers to identify critical areas of the watershed as well as to select and prioritize appropriate practices and conservation strategies to control erosion and conservation of natural resources. A wide range of empirical models has been developed to quantify and assess the soil loss. Revised Universal Soil Loss Equation (RUSLE) is one of the most widely used erosion models to soil loss predictions that introduced by Wischmeier and Smith in 1965. The advantage of this model is its convenience in implementation and compatibility with GIS technique, which can be considered as an efficient approach for estimating the magnitude and spatial distribution of erosion. In conclusion, the study shows the application of the RUSLE model in estimating the total annual erosion rate in Gharahsoo watershed, north of Iran. By applying erosion models, we are able to identify the areas with high erosion potential in watershed, and then prioritize them for soil conservation schemes.

Material and Method

The study area is situated in Golestan Province, south of Caspian Sea in Iran. The area of Gharahsoo watershed is 1769 Km^2, which is located between latitudes 33° 36′-37° 00′ N and longitudes 54° 00′-54° 45′ E. Soil erosion is one of the environmental problems that can be considered as a serious threat for natural resources, agriculture, and the environment in this watershed. This study aimed to qualitative estimation of annual soil loss in the Gharahsoo watershed, northern Iran, using the RUSLE model in Geographic Information System (GIS) technique framework. The soil erosion parameters were evaluated for this model applying different methods. The parameters involved: soil erodibility factor (K), rainfall erosivity factor (R), land cover management (C), slope length and steepness factor (LS), and support practice (*P*). The *R*-factor map was obtained from the rainfall data, the *K*-factor map was obtained from the litological map, the *C* factor map was generated based on Landsat-ETM image, and the *LS*-factor was generated by using digital elevation model with a spatial resolution of 30 m. Because the watershed doesn't have conservation practices, the *P*-factor map was assigned the value of 1.0 for the watershed. The spatial distribution of soil loss in the watershed was generated by overlaying and multiplying pixel-by-pixel soil erodibility factor, rainfall erosivity factor, land cover management, slope length and steepness factor, and support practice.

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Discussion of Results

RUSLE is an empirically based model that ability to estimate average annual soil loss and sediment yield based on spatially distributed input data such as rainfall pattern, soil type, topography, crop system, and management practices in a Geographic Information System environment. After establishing the set of factors, input factors should represent as map layer in the GIS-based database to quantify, evaluate, and generate the map of soil erosion potential.

Soil erodibility factor (K)

The soil erodibility factor determines intrinsic susceptibility of soil particles to detachment and transport by runoff and raindrop impact according to soil texture, organic matter, and permeability. For the present study, the soil erodibility (*K*-factor) was generated with the use of the soil map provided by the Soil Geographic Data Base of Iran at the scale of 1:100,000. By considering the particle size, permeability class, and organic matter content, the *K*-value for the soil types were obtained from the USDA soil erodibility nomograph (Fig. 2). Soil erodibility values vary from 0.08 to 0.48 t ha MJ^{-1} mm^{-1}.

Rainfall erosivity factor (R)

The rainfall factor determine the erosive power of rainfall to soil erosion that kinetic energy of rainfall (A storm's maximum 30-min precipitation intensity) is used for indication of erosive power. If the values of these factors have not recorded at meteorological stations, researchers can use readily available rainfall values like annual rainfall that have correlated with *R*-values. In the presented study, the annual and monthly precipitation data for calculation of rainfall erosivity factor was derived from the Meteorological Organization. This data imported into ArcGIS as a point layer and were used for calculating the Fournier index and R factor using Equations (3), (4), and (5). In next stage, the spatial interpolation techniques such as Inverse Distance Weighted (IDW) method were used to generate a rainfall erosivity maps. The *R*-factor was in the range 3.9 to 274.2 MJ mm ha^{-1} h^{-1}. The highest *R*-values prevail in the southern part of watershed and the lowest occurs in the upper of watershed.

Land cover and management factor (C)

The land cover management factor (*C*) reflects the effect of vegetation cover on soil erosion. Plant cover can protects the soil surface from runoff velocity. In order to determine the C factor coefficient, the NDVI layer is required. The NDVI layer was produced by Landsat–ETM^+ satellite image. The NDVI values vary between -1.0 to +1.0. Healthy vegetation (with photosynthetic activity) absorbed the light red spectrum (R) by plant chlorophyll and reflected the infrared spectrum (IR) by water-filled leaf cells. Therefore, NDVI values for green vegetation will be positive. In addition, areas with low vegetation cover, bare lands, and residential areas usually show NDVI values between -0.1 and +0.1. Clouds and water resources show negative and zero values. Then the *C* factor layer produced according to NDVI values. The *C* factor inversely correlates with the NDVI factor. The *C* factor coefficient was in the range 0.002 to 1.0. As a result, the mean *C* values range inside the watershed from 0.002 for the forest class to 1.0 for the bare land and residential area categories.

Slope length and steepness factor (LS)

The slope length and steepness factors (*LS*) are topographic factors that reflect the effect of topography on soil erosion. The LS calculation was performed using flow accumulation and slope steepness. The flow accumulation and slope steepness was generated based on DEM layer with a pixel size of 30 m using Arc hydro extension in ArcGIS software. In next stage, the sinks in DEM layer were identified using the "sink" tool and were filled using the "Fill" tools. Then, the filled DEM was used as input to calculate the Flow Direction and Flow Accumulation for each cell. In addition, the steepness was generated in Surface raster tool. In next stage, the *LS* factor was computed using Raster Calculator in ArcGIS according to Equation (6). The *LS* factor values in the watershed vary from low 0 to high 32.6%. The highest *LS*-values are associated with steep slopes greater than 15°-20° and 20°-30° slope category in the middle and lower of the Gharahsoo watershed. The lowest *LS*-values consist in flat areas.

Support practice (*P*)

The support practice factor (*P*) reflects the effect of land management such as terracing, counter tillage, etc. in reduced soil erosion and runoff velocity. The *P*-value ranges from 0 to 1, the value close to 0 indicates good conservation action and the value close to 1 represents poor conservation action. Because most regions in

Gharahsoo watershed have no conservative practice management, so the *P* factor coefficient has been assigned as 1.0.

The annual soil loss

When all factors required for the RUSLE were prepared, these data layers were overlaid and multiplied pixel-by-pixel for soil loss per year according to the RUSLE equation. The annual soil erosion value varies between 0 to 54 t ha^{-1} yr^{-1}. The spatial patterns of annual soil loss rates represent that areas with moderate to severe erosion risk are located in the north and southern parts of the study area, while areas with low erosion to moderate risk are located in the central parts of the watershed. In the next stage, the annual soil erosion map was categorized to five risk classes to easy spatial management. The results showed that about 65.9% of the study area is classified under moderate to high erosion risk (>15 ton h^{-1} y^{-1}), while the rest of the area (34.1%) is classified under low to very low potential erosion risk. In terms of actual soil erosion risk, the spatial distributions of erosion risk classes were 20.6% as very low, 13.5 as low, 9.1% as moderate, 4.2% as high, and 52.6% as very high.

Conclusion

Soil erosion is the most important environmental challenges at developing countries, which can have negative impacts such as soil fertility decline, soil salinization, sedimentation in agricultural lands and water storage facilities. A quantitative assessment of average annual soil loss for Gharahsoo watershed was undertaken applying GIS based well-known RUSLE equation. Potential soil loss was obtained by overlaying six factors such as rainfall erosivity, soil erodibility, slope length and steepness, cover management, and support practice. The results showed that soil loss rate varies from 0 to more than 650 tons per hectare per year. The results show that 65.9% of the extent in the watershed is in moderate (9.1%) to high (56.8%) erosion potential. In the studied watershed, the land use pattern in potential areas to soil erosion indicates that areas with natural forest cover in the have minimum rate of soil erosion, while areas with human intervention have higher rates of soil erosion. By reviewing the value of parameter *A* and correlation coefficient of the study area, we noted that the cover management and slope length and steepness factors were more influential than the others. The highest amounts of erosion have occurred in the north and southern regions. In the central parts of the watershed, in spite of high values of *LS* factor (10– 30), the areas depict low to moderate erosion potential. This is due to the dense forest coverage in the region that decreases the energy of rain droplets. In the southern part of the watershed, the erosion rate increased by factors such as steep slopes and medium vegetation density. In addition, the results of this study showed that the factor of cover management with the highest coefficient (0.69) had the most effect in estimating annual soil loss potential in the watershed. According to result, it is appropriate to plantation of tree on steeper slopes, and plantation of tree crops on moderate and slightly steep slopes to protector of soil from the energy of the raindrops and control of soil erosion. The predicted amount of soil loss and its spatial distribution can provide a basis for comprehensive management and sustainable land use for the watershed. Areas with high and severe soil erosion warrant special priority for the implementation of controlling practices.

Keywords: potential annual soil loss, rainfall erosivity factor, RUSLE, zoning of soil erosion.