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SOIL EROSION RISK MAPPING USING USLE/GIS METHODOLOGY IN ROZE-CHAY CATCHMENT, NORTHWEST IRAN

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Abstract

Soil erosion by water is a serious environmental problem all over the world, particularly in semi-arid regions like Iran, where agricultural water quality and productivity potential of soils have been decreased as a direct consequence of this process. Therefore, the development of a model assessing soil erosion potential and proportional risk maps, would help to protect soil and water resources. Among the empirical models, Universal Soil Loss Equation (USLE) is a widely accepted model developed for soil erosion prediction. The aim of this study was to assess erosion risk by integrating the USLE model and GIS techniques in Roze-Chay catchment, northwest Iran. The map of the USLE factors was produced as follow: rainfall erosivity factor (R) map was interpolated from data point taken from the meteorological stations; Soil erodibility factor (K) map was created by determining the particle size distribution and organic carbon of the 98 soil samples from the study area; Topographic factor (LS) was derived from digital elevation model (DEM); Cropping-management factor (C) was computed from NDVI values derived from Landsat-TM data. Assuming no erosion control practices in the catchment, Conservation practice factor (P) was set to be a unit, in calculations. The results showed that the annual average soil loss for the Roze-Chay catchment was 57 Mg.ha^{-1}.ya^{-1} in 2015. The erosion risk map showed that, 33.6% of the total area has a low erosion risk with annual average soil loss of less than 10 Mg.ha^{-1}.ya^{-1}, but the area of 265 km^2 (≈ 59%) in the catchment showed high to highly severe erosion risk, which should be protect by appropriate conservation practices. The high erosion risk of the catchment can be related to the topography and low levels of the vegetation cover. The developed soil erosion risk map can be used to highlight the erosion risk areas and therefore, assist the farmers and decision makers in implementing suitable conservation program to control soil erosion.

Key words: *soil loss, Geographical information system, USLE, Roze-chay catchment.*

INTRODUCTION

Soil erosion is considered as one of the most important environmental problems leading to significant reduction of soil fertility and crop yields (Olivares et al., 2011).

In the northwest of Iran, water erosion affects negatively agricultural productivity and reduces water and soil quality (Vaezi and Bahrami, 2014).

Therefore, the assessment of erosion risk at the watershed scale can be very useful to establish conservation measures and soil and water management plans.

Universal soil loss equation (USLE) is the most widely used erosion model throughout the world to estimate average annual soil loss resulting from rill and sheet erosion (Erdoghan et al., 2007; Belasri and Lakhouili, 2016). USLE model can be integrated with geographic information systems (GIS) which allow preparing erosion risk maps in larger areas. In a GIS environment, the USLE can be applied to determine soil erosion risk quantitatively and spatially (Lufafa et al., 2003).

The aim of this study was to assess erosion risk by integrating the USLE model and GIS techniques in Roze-Chay catchment, northwest Iran

MATERIALS AND METHODS

Study area. Roze-Chay catchment is located in the northwest of Iran and approximately 10 km south of Urmia city, west Azarbayjan province. Roze-Chay catchment covers an area of 453 km^2 (Figure 1).

The climate of the region is characterized as semiarid with average annual precipitation of 313 mm.

The minimum and maximum monthly temperature are -2^{o}C and 24^{o}C, respectively.

USLE model. USLE (Wischmeier & Smith, 1978) was used to estimate annual soil loss.

USLE quantitatively estimates soil erosion with the following empirical equation (Eq. 1):

$$A = RK(LS)CP \quad (1)$$

Where: A is the average annual soil loss in (Mg ha^{-1} year^{-1}); R is the rainfall-runoff factor (MJ mm ha^{-1} hr^{-1} yr $^{-1}$); K is the soil erodibility factor (Mg h MJ^{-1} mm^{-1}); LS is the topographic factor, C is the cover-management factor; P is the supporting practice factor.

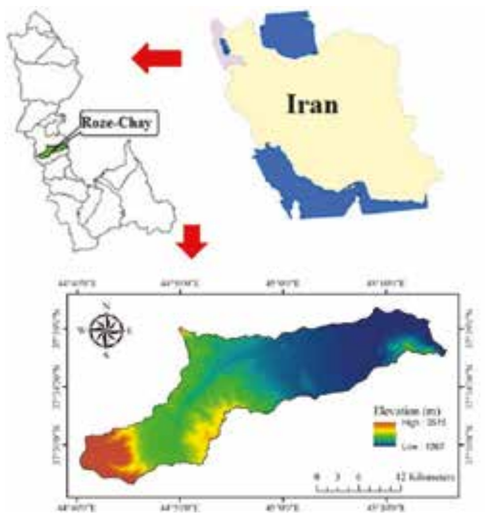

Figure1. Map of Study area

R factor. Rainfall-runoff erosivity factor is derived from the 20 years (1993-2012) precipitation records of 66 meteorological stations in the west Azarbayjan province. The annual R factor was calculated from the following empirical equation (Eq. 2), proposed by Ferro et al. (1999):

$$R = 2.7015\left[\left(\frac{1}{N}\sum_{j=1}^{N}\sum_{i=1}^{12}\frac{p_{i,j}^{2}}{P_j}\right)^{1.41}\right] \quad (2)$$

For the period of N years, $p_{i,j}$ is the rainfall depth in month i (mm) of the year j and P_j is the total rainfall for the same year.
Erosivity map of the West Azarbayjan province was prepared by kriging interpolation method and then the R map of the Roze-Chay catchment was extracted from the province map.

K factor. Total of 98 topsoil (0-15 cm) sample were collected from the catchment by stratified randomized sampling design and erodibility factor was calculated for each sampling point using the following equation (Eq. 3):

$$K_{\left(\frac{Mg\,ha\,h}{ha\,MJ\,mm}\right)} = 2.8 \times 10^{-7} M^{1.14}(12 - a) \quad (3)$$

Where: *M*=(*% silt+% very fine sand*)×(*100-% clay*) and *a* is the percentage of organic matter. Kriging interpolation was used to create a continuous map of K factor from the sample points.
LS factor. Topographic factor was calculated using the digital elevation model and the equation (Eq. 4) (Moore and Burch, 1986):

$$LS = \left[\frac{A_s}{22.13}\right]^{0.4}\left[\frac{\sin\beta}{0.0896}\right]^{1.3} \quad (4)$$

$$A_s = Flow\ accumulation \times cell\ size$$

Where Flow accumulation is the number of cells contributing in a given cell, cell size is the pixel's side, β is the slope angle in degrees.
C factor. Cover-management factor was calculated from the Landsat 7 satellite image (year 2015) through the Normalized Difference Vegetation Index (NDVI).
The following equation (Eq. 5) proposed by Van der Knijff et al. (1999) was used to prepare a C factor map:

$$C = exp\left[-2 \times \frac{NDVI}{1 - NDVI}\right] \quad (5)$$

P factor: supporting practice factor set to be 1 for the entire study area, assuming no support practice in the catchment.

RESULTS AND DISCUSSIONS

The maps prepared for R, K, LS, and C factors (Figures 2, 3, 4 and 5) of the USLE model were integrated using Equation (1) within the raster calculator option of the ArcGIS spatial analyst in order to quantify and provide erosion risk map for Roze-Chay catchment.

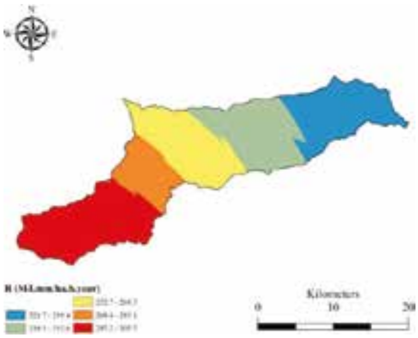

Figure 2. Rainfall-runoff erosivity factor

After the multiplication of the 4 factors, the resulting soil erosion map (Figure 6) was empirically classified into 7 classes: for soil loss < 5 Mg ha^{-1} yr^{-1} the erosion risk characterized "very low", for 5-10 Mg ha^{-1} yr^{-1} "low", for 10-20 Mg ha^{-1} yr^{-1} "moderate", for 20-40 Mg ha^{-1} yr^{-1} "high", for 4-80 Mg ha^{-1} yr^{-1} "very high", for 80-160 Mg ha^{-1} yr^{-1} "severe", and for soil loss >160 Mg ha^{-1} yr^{-1} "highly severe" erosion risk.

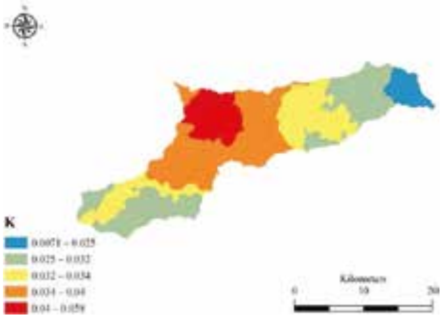

Figure 3. Soil erodibility factor

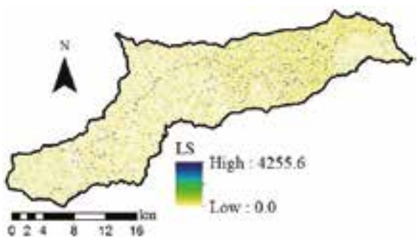

Figure 4. Topographic factor map

Soil erosion risk map showed that the annual average soil loss for the Roze-Chay catchment was 57 Mg ha^{-1} ya^{-1} in 2015.

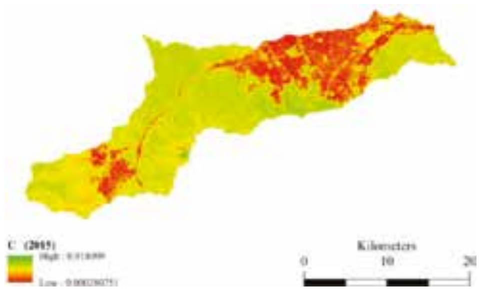

Figure 5. Cover-management factor map

The erosion risk map also showed that, 33.6% of the total area has a very low and low erosion risk with annual average soil loss of less than 10 Mg ha^{-1} ya^{-1}, but the area of 265 km^2 (≈59%) in the catchment showed high to highly severe erosion risk, which should be protected by appropriate conservation practices (Figure 7).

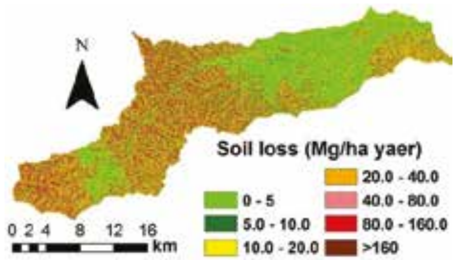

Figure 6. Erosion risk map of the Roze-Chay catchment

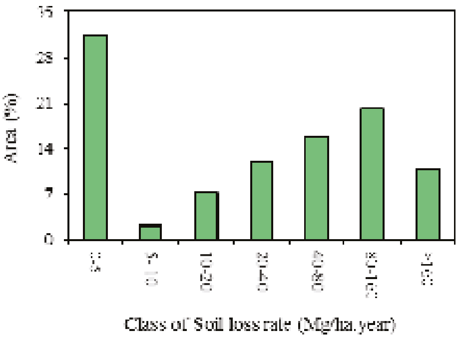

Figure 7. Percentage area of Roze-Chay catchment belonging to each soil loss class

Soil erosion map of the Rze-Chay watershed clearly indicates that the highest soil loss values are spatially correlated with the steepest slopes which shows the high sensitivity of the USLE model to the topographic factor (Moore and Wilson, 1992).

CONCLUSIONS

Erosion risk map of the Roze-Chay watershed, based on USLE model, showed that the most of the catchment has high to highly severe erosion risk, which should be protected by appropriate conservation practices. The high erosion risk of the catchment can be related to the topography and low levels of the vegetation cover. Low erosion risk areas are located at the east parts of the catchment where the topographic factor has low value due to the gentle slopes. Spatial patterns of soil loss shows a clear correlation between topography and soil loss values which may be related to the high sensitivity of USLE model to topographic factor.

Finally, the present study has confirmed that GIS techniques are low cost tools and simple for modeling and mapping soil erosion. The developed soil erosion risk map can be used to highlight the erosion risk areas and therefore, assist the farmers and decision makers in implementing suitable conservation program to control soil erosion in Roze-Chay catchment.

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