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Relationships among environmental factors influencing soil erosion using GIS (Khiav Chay Watershed, Ardabil Province)

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Abstract

One of the biggest problems of natural resources is soil erosion. Effective land management to prevent soil loss requires prediction for large areas. Usually, empirical relations are used for investigating soil erosion in watershed areas. The case study is took place in Khiav Chay Watershed, Ardabil Province. In the current study, environmental factors, influence in water erosion of the area, investigated in four categories, including topographic, soil & ground, vegetation and human factors. From environmental factors influencing soil erosion, NDVI, land use and drainage density were studied and related maps produced and compared in two time series using aerial photos (1968) and satellite images (2007). For estimating specific erosion, EPM model was used. Work unit map was made and crossed with environmental factors map as independent variables (NDVI, land use and drainage density) and specific erosion map as a dependent variable and then effective areas of each parameters specified.

Keywords: Soil erosion, environmental factor, Erosion Potential Method, Geographic Information System

Introduction

Soil erosion by water is the most important land degradation problem worldwide (Eswaran et al., 2001). Water erosion is controlled by climatic characteristics, topography, soil properties, vegetation, and land management. Detachment of soil material is caused by raindrop impact and drag force of running water. Detached particles are transported by overland flow (sheet- or interrill erosion) and concentrated flow (rill erosion) and deposited when flow velocity decreases (Lal, 2001). Gullies can develop as enlarged rills, but their genesis is generally more complex, involving sub-surface flows and sidewall processes (Bocco, 1991).

Satellite images and the parameters derived from their composite bands such as Normalized Difference Vegetation Index (*NDVI*) (Momeny and Saradjian, 2007 and Jong et al, 1999) and Geographic Information System (GIS) are used so widespread in the soil erosion researches (King et al, 2005; Bou Kheir et al, 2006 and Miller et al, 2007).

In the study area, due to high precipitation and high slope probably and geological situation in the region, various types of water erosion is seen. Thus the aim of this research is to find the relationships among environmental factors influencing soil erosion in Khiav Chay watershed and estimates of water erosion in two time series and compare them with each other to evaluate the erosion risk.

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Material and Method

The study area is located in the southeastern regions of Sabalan Mountain in Ardabil Province between longitudes 47°-38' to 47°-50' and latitudes 38°-12' to 38°-32'. It covers approximately 800 km^2 with 2325 m.s.l of mean elevation. The mean annual precipitation is 400-600 mm, increasing with elevation. The outlet of watershed is connected to Gara su river and discharge of all runoff is through this way.

Research for this study was as follows:

Investigation of variable environmental factors causing water erosion in 1968 and 2007

Vegetation cover, land use and drainage density are three important variable factors affecting the soil erosion which studied in this research.

Vegetation cover

Vegetation cover is one of the very changeable factors during the time. During 39 years (1968-2007), vegetation cover has been changed spatially and has been decreased remarkably. Study of vegetation cover condition has been done via aerial photos, satellite images and NDVI.

Vegetation maps were prepared in two time series, in the first section (1968) using aerial photos and in the second section (2007) using satellite image, GIS software and remote sensing capabilities to reach out.

Prepared NDVI for the region was calculated and classifieds according to equation [1] which was performed by using GIS and ILWIS software, bands 3 and 4 of Landsat images and "NDVI" algorithm.

$$NDVI = \frac{ETM\,4 - ETM\,3}{ETM\,4 + ETM\,3} \qquad [1]$$

where ETM3 and ETM4 is respectively visible (red) and near-infrared region in Landsat images. This relatively simply algorithm produces output values in the range of -1.0 to 1.0. Increasing positive NDVI values, shown in increasing shades of green on the images, indicate increasing amounts of green vegetation. NDVI values near zero and decreasing negative values indicate non-vegetated features such as barren surfaces (rock and soil) and water, snow, ice, and clouds.

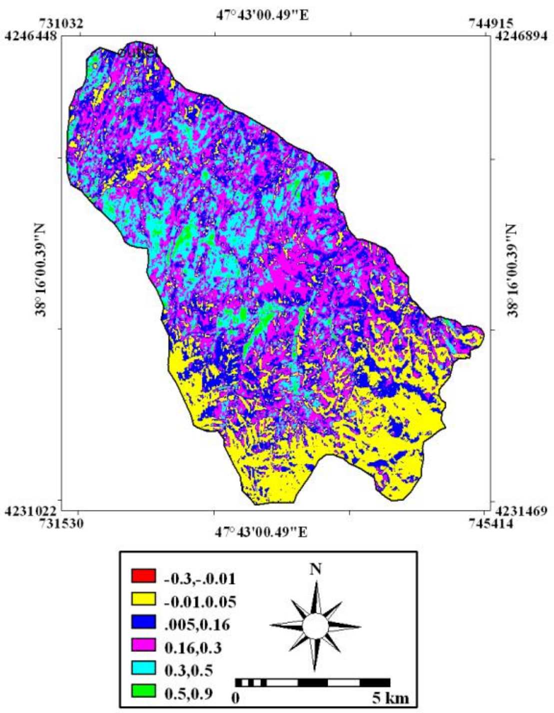

Figure 1. NDVI map (1968)

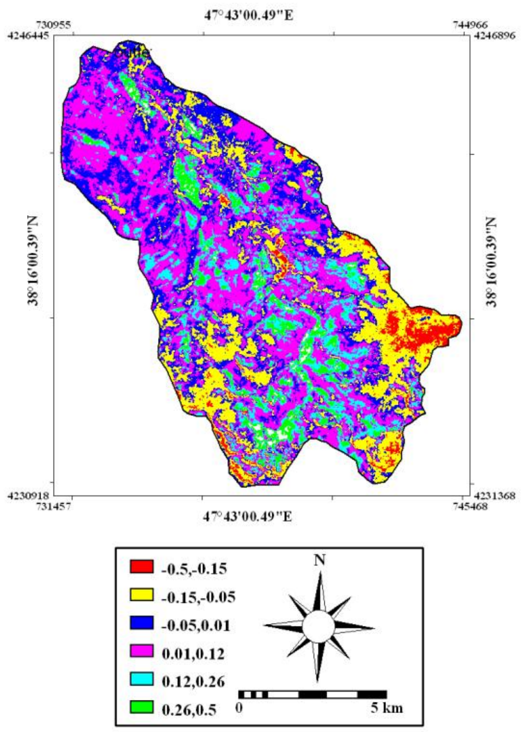

Figure 2. NDVI map (2007)

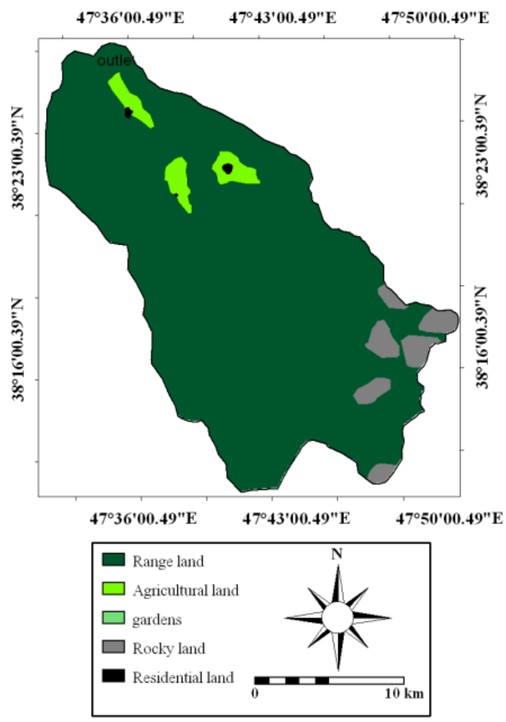

Figure 3. Land use map (1968)

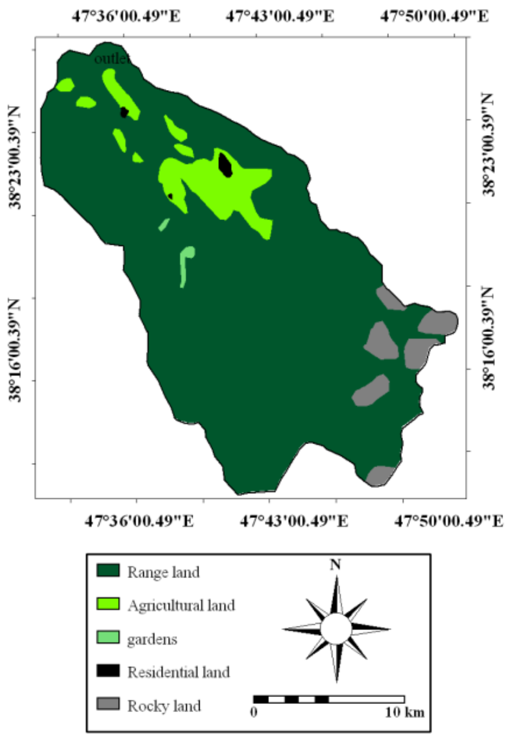

Figure 4. Land use map (2007)

Land use

Land use describes the various ways in which human beings make use of and manage the land and its resources. The study of land use changes in two time sections 1968 and 2007 was done. Land use maps in 1968 were prepared from the aerial photos at a scale of 1:20,000 and in 2007 were generated by the use of satellite images, Landsat Enhanced Thematic Mapper (ETM+) data, and five different users like as range land, agricultural land, gardens, residential and rocky land were derived. Figure 3 and 4 are shown the land use maps in 1968 and 2007.

Drainage density

Drainage density is the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin. It is a measure of how well or how poorly a watershed is drained by stream channels. It is equal to the reciprocal of the constant of channel maintenance and equal to the reciprocal of two times the length of overland flow. Drainage density maps in two time sections 1968 and 2007 were prepared by using topographic map (1:50,000 scale, 20 m contour interval), aerial photos and satellite images in GIS environment.

Assessment of soil erosion by using EPM model

The erosion potential method is a model for qualifying the erosion severity and estimating the total annual sediment yield of a catchment area. This model is initially developed in Yugoslavia by Gavrilovic (1988). EPM considers six factors such as; surface geology and soils, topographic features, climate (including mean annual rainfall and mean annual temperature) and land use. From these factors; exposed rock and soil, topography and climate are limited in natural class, but land use effect is depended on the human activities. The erosion potential method calculates the coefficient of erosion and sediment yield (Z) of a catchment area using the following equation:

$$Z = y * Xa * (\psi + I^{0.5}) \quad [2]$$

Where, *y,* is the coefficient of rock and soil resistance, from 2.0 to 0.25; *Xa,* is the land use coefficient, from 1.0 to 0.05; *Ψ,* is the coefficient value for the observed erosion processes, from 1.0 to 0.1, based on the severity of erosion. The factor *I* is the average land slope in percentage (Solaimani, 2007). For sediment production, the following equation was used:

$$Wsp = T * H * \pi * Z^{1.5} \quad [3]$$

Where, *Wsp,* is the average annual specific production of sediment per m3/km2/y, *T* is temperature coefficient, which is calculated as:

$T = (t/10 + 0.1)^{0.5}$ [4]

With t = the mean annual temperature in degrees Celsius, *H* = the mean annual amount of precipitation in mm/y, and *Z is* the coefficient of erosion which was calculated from Eq. 2.

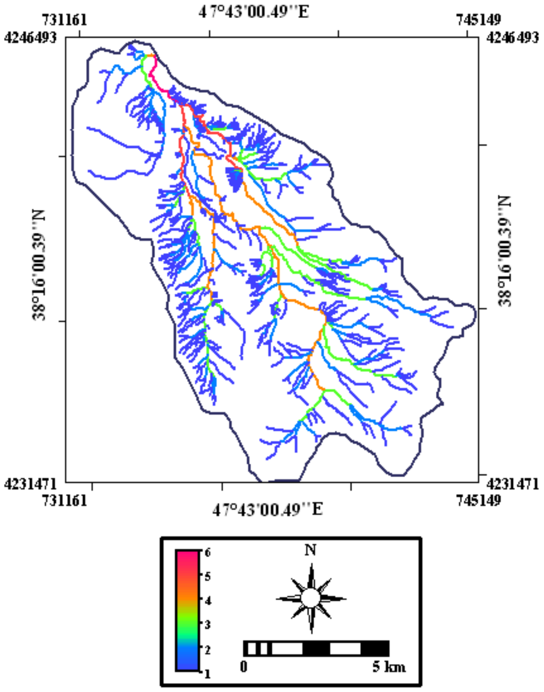

Figure 5. Drainage density map (1968)

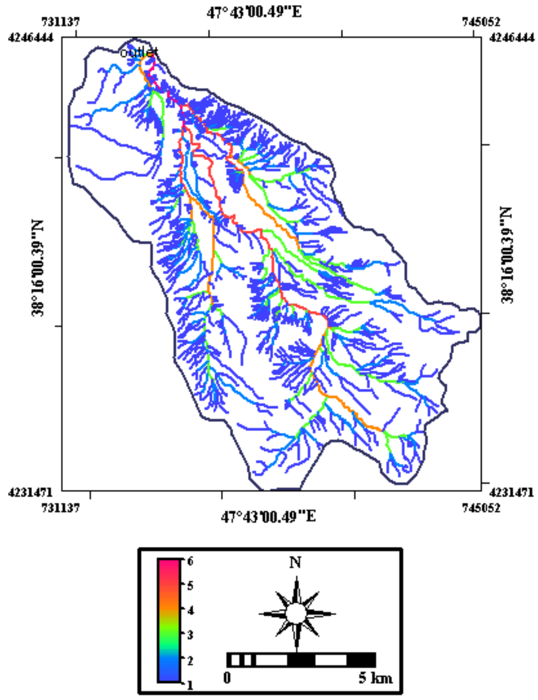

Figure 6. Drainage density map (2007)

Comparison of soil erosion's result in two time sections

At this stage, soil erosion's result in two time sections were compared and changes were determined.

Results

According to analyzes of land use maps in mentioned two time sections, the percentage of range land in 1968 (92.23%) has changed to 88.25% in 2007. Agricultural land has been changed from 2.7% in 1968 to 6.8% in 2007 and residential land due to 39 years increase from 0.16% to 0.33% which is show that during the last 40 years with increasing population, residential land increased and range land decreased. Drainage density in 1968 was 2.96 km/km^2 whereas this parameter was increased to 4.16 km/km^2 in 2007 that represents an increase of erosion as rill erosion in the area.

The results of the risk of erosion (Z coefficient in EPM model) showed that in 1986, 46.03% of lands were in class of very severe erosion, 30.92% in severe erosion class, 18.4% in mediocre class, 2.47% in low erosion class and 2.16% in very low erosion class. In 2007 45.01% of lands were in class of very severe erosion, 31.25% in severe erosion class, 18.08% in mediocre class, 2.33% in low erosion class and 2.22% in very low erosion class and comparison of erosion intensity in mentioned times showed that amount of erosion during the time has increased.

By placing prepared maps in the erosion equation, specific erosion map in two time section obtained and amount of specific erosion in these times calculated.

The amount of specific erosion in 1968 was 2237.49 m^3/km^2 yr while this amount in 2007 has increased to 12252.44 m^3/km^2 yr.

Conclusion

Study of environmental factors and water erosion changes during the 39 years showed the remarkable variations in spatially distribution patterns of erosion types In most times, because of need to studying as time series and for its problems, these factors are studied incompletely, while we must regard to their inherent variability during the time. Factors of vegetation cover, land use and drainage density are very changeable in the study area that cause remarkable variations in the area percentage of each water erosion types. In the study area, during the time, the drainage density factor has been increased and with its increasing, the percentages of each type of water erosions have been increased, too. According to decreasing of vegetation density, sheet and rill erosions have been increased, but no well-defined relations were detected in channel and riverbank erosions. Also, land use type and its changes during the time, had been a significant rule in formation of different types of water erosions. This study showed that using GIS and RS capabilities with together and applying them in related with the time variations, could help effectively in studying water erosion and land management.

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