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Investigation of likely effects of land use planning on reduction of soil erosion rate in river basins: Case study of the Gharesoo River Basin

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ABSTRACT

We investigated the effects of land use planning on reduction of soil erosion rate in the Gharesoo River Basin, Golestan Province, Iran. For this, the Revised Universal Soil Loss Equation (RUSLE) was used in conjunction with Geographic Information System (GIS) to model potential soil erosion. The average potential soil erosion in the river basin was 18.65 $t\,ha^{-1}\,yr^{-1}$, with a standard deviation of 33.88 $t\,ha^{-1}\,yr^{-1}$. The severe and very severe erosion classes comprised 8% and 4% of the river basin, respectively. We found that all areas with severe and very severe erosion were located in agricultural land. Assessing the impacts of land use and slope confirmed importance of interaction between these factors in increasing soil erosion, especially in agricultural areas with steep slopes. We applied a land use planning to control and reduce soil erosion rate, with a specific focus on agricultural areas. For this purpose, the Multi-Criteria Evaluation (MCE) and Multi-Objective Land Allocation (MOLA) were implemented for agriculture, urban and industrial development, and afforestation. We used the output land use map from MOLA in the RUSLE model. The results showed a significant reduction of average potential soil erosion equal to 25.6% (from 18.65 $t\,ha^{-1}\,yr^{-1}$ to 13.86 $t\,ha^{-1}\,yr^{-1}$) when the MOLA land use plan was followed. Also, the area impacted by severe and very severe erosion classes were reduced by 25.50% and 42.59%, respectively. The results of this research emphasized that implementation of land use planning in the Gharesoo River Basin is helpful in controlling soil erosion. The method presented in this study can be a basis for sustainable and comprehensive management of river basins.

1. Introduction

One of the major global scale problems nowadays is the rapidly increasing food demand due to rapid population growth, which is followed by increasing conversion of forest land into croplands. Increasing agricultural lands regardless of control techniques, together with urban development and forest harvest are fundamental factors of soil erosion (Ustun, 2008). Soil erosion by water is one of the most important types of erosion and about one-third of the arable land around the world has been affected by soil erosion over the past 40 years. Soil erosion causes losing valuable top soil which is the most productive part of the soil profile for agriculture, water pollution, and reduces the ability of soil to mitigate the greenhouse effect (Sun et al., 2014).

Soil erosion occurs naturally when the force of wind, raindrops or runoff on the soil surface is higher than the cohesive forces that bind the soil together. Vegetation cover protects the soil from the effects of these erosive forces (May and Place, 2005). Human activities such as irrational land conversion and poor management activities destroy vegetation cover and increase the possibility of soil erosion. Also, soil parameters and topography strongly affect the soil erosion, but they are relatively stable and are not easily changeable and manageable. Therefore, the rainstorms, irrational land uses, and vegetation destruction have been considered as the main factors of soil erosion (Mohammad and Adam, 2010; Sun et al., 2014).

Several models have been developed to predict and estimate soil erosion by water, including Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1997), Water Erosion Prediction Project

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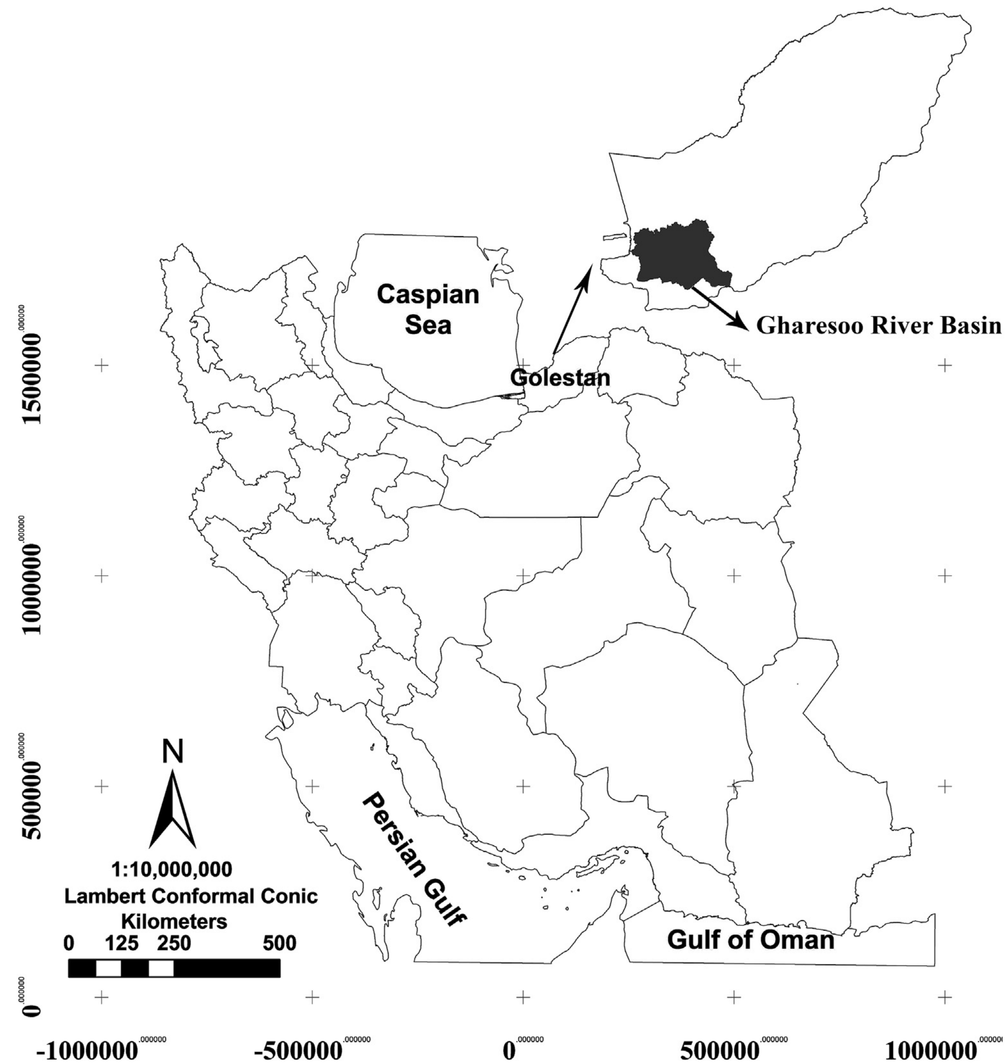

Fig. 1. Location of the Gharesoo River Basin in Golestan Province of Iran.

(WEPP) (Laflen et al., 1991), Soil Loss Estimation Model for Southern Africa (SLEMSA), Areal Non-Point Source Watershed Environment Response Simulation (ANSWERS), Erosion Potential Method (EPM), Modified Pacific Southwest Inter-Agency Committee (MPsiac), Chemicals Runoff and Erosion From Agricultural Management Systems (CREAMS) (Knisel, 1980), and Soil and Water Assessment Tool (SWAT) (May and Place, 2005).

RUSLE is a universally accepted method that can be used as an appropriate model for estimating potential soil erosion in vast areas with different types of land use and land cover such as agricultural land, forest and rangeland (Sun et al., 2014). RUSLE predicts potential soil loss due to water erosion as a function of rainfall erosivity, topography, soil erodibility, land use and land cover management, and control practices (Meshesha et al., 2012; Sun et al., 2014). The combination of RUSLE with Geographical information system (GIS) increases the predictive power of this model (May and Place, 2005). Considering that RUSLE factors are calculated by spatial data, GIS techniques provide useful tools to modify and map them. These techniques facilitate evaluation of soil erosion in large areas and in more detail (Karimi, 2011).

RUSLE have been used in a wide range of studies in the world to model spatial distribution of soil erosion (Prasannakumar et al., 2012; Alexakis et al., 2013; Sun et al., 2014; Rezaei et al., 2014; Kamangar et al., 2015) and investigate the effects of controlling measures on soil erosion rate (Meshesha et al., 2012; Andriyanto et al., 2015; Haregeweyn et al., 2017;). Meshesha et al. (2012) used RUSLE in Central Rift Valley of Ethiopia and found that the conversion of land during 23 years increased the rate of erosion by 80%, especially in croplands. Sun et al. (2014) concluded that soil erosion is significantly related to land use and topography in the Loess Plateau in China.

Reliability and validity of RUSLE have been confirmed in several studies. For example, Meshesha et al. (2012) illustrated that the overall accuracy of estimated erosion using RUSLE was 71.1% in Central Rift Valley. Also, Sun et al. (2014) found a significant relationship ($P < 0.01$) between erosion rate determined by field measurements and the estimates by the RUSLE. In addition, Andriyanto et al. (2015) showed a close relationship ($R^2 = 0.56$) between RUSLE results and field measurements.

In the present study, RUSLE was used in conjunction with GIS to model the spatial distribution of potential soil erosion by water in the Gharesoo River Basin, Golestan Province, Iran. The Gharesoo River Basin has been subject to multiple human pressures such as overexploitation of forest for fuel wood, clear-cutting of forest for agriculture, and rapid urban and industrial development without attention to the ecological suitability of land. So, implementation of mitigation measures is a necessity to control the risks arising from human activities, such as soil erosion. One way to investigate the possible outcomes of management and mitigation measures on soil erosion is through land use planning (Andriyanto et al., 2015; Haregeweyn et al., 2017). Andriyanto et al. (2015) illustrated that the soil erosion rate based on current situation and after sustainable land use planning in Kalikonto