An Assessment of Soil Erosion using Rusle Model: A Case Study from the Marmara Region

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Abstract

The aim of the study is applying the Revised Universal Soil Loss Equation (RUSLE) with the help of remote sensing and geographic information system techniques to calculate soil loss and to map soil erosion of the Marmara Region of Turkey in the changing climate conditions between 1989 and 2017, and also to make future projection of soil erosion for the years between 2020 and 2049. This model is composed of variety of factors associated with climate, vegetation, soil and topography.The results of the study showed that according to the two scenarios of the Regional Climate Model RCP 4.5 (optimistic), and RCP 8.5 (pessimistic), the future soil loss of the Marmara Region in the changing rainfall events is higher than the results of the historical data. The soil loss results for the time interval 2020-2049 of the scenario RCP8.5 is 61% higher than the results of the scenario RCP4.5. Also, the soil loss results of the historical data of the Regional Climate Model showed that the soil loss range from 0 to 24,298 Mg. ha^{-1}. $year^{-1}$ during the time interval 1989 – 2017 in the Marmara Region, and also the average soil loss is 12,2 Mg. ha^{-1}. $year^{-1}$.

Keywords: soil erosion, RUSLE Model, Regional Climate Model, Marmara region, Turkey

1. Introduction

Revised Universal Soil Loss Equation (RUSLE) (Renald et al. 1997) is an empirical erosion model which was founded on the Universal Soil Loss Equation, USLE (Wischmeier and Smith 1978). The model USLE was created by the United States Department of Agriculture (USDA) in 1978. The most remarkable difference between the models USLE and RUSLE is the model RUSLE includes a computer program to make calculations easier and it also includes the analysis of research data which is not available in the model USLE. The model RUSLE indicates how land use, soil, topography affect rill and inter rill soil erosion originated from rainfall and surface runoff (Renard et al. 1997). Equation of RUSLE has been the most widely used model application to estimate soil erosion loss. However, the USLE model was originally designed for soil loss prediction in croplands on gently sloping topography (Wischmeier and Smith 1978). When it comes to the RUSLE, the model has developed its applications to different situations, such as rangelands, forests, and disturbed areas (Renard et al. 1997). Moreover, in order to make soil erosion loss prediction, and its spatial distribution feasible with reasonable costs and better accuracy in larger areas geographical information system (GIS) and remote sensing technology are used in the model RUSLE (Millward and Mersey 1999; Wang et al. 2003).

2. Method

Five major factors (rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), land cover management (C) and conservation support practice(P)) are represented in USLE/RUSLE to compute approximate annual average soil erosion through the equation below (Renard et al. 1997):

$$A = R \times K \times LS \times C \times P \quad (1)$$

where, A is the mean annual loss in $Mg.ha^{-1}.year^{-1}$, R is the rainfall and runoff erosivity factor in $MJ.mm.ha^{-1}.year^{-1}$, K is the soil erodibility factor in $Mg.MJ^{-1}.mm^{-1}$, LS is the slope and length factor, C=land cover management factor (dimensionless), P=conservation and support practice (dimensionless).

The R factor were calculated for 29 years period including the years between 1989 and 2017. In order to make future projection of soil erosion between the years 2021 and 2049, the rainfall data were run under two climatic scenarios of the Regional Climate Model RegCM4.3.4. In order to make projection of the precipitation data RCP4.5 and RCP8.5 scenarios from outputs of 3 Global Circulation Models (HadGEM2–ES, MPI-ESM-MR, GFDL-ESM2M) were used. The K factor is related to organic matter content, soil texture, soil permeability class, and other various factors, and it is mostly determined by the soil type (Renard et al. 1997). In this study, the open source of the FAO Digital Soil Map of the World (DSMW) were used. The FAO Digital Soil Map of the World is the digitized version of the FAO-UNESCO Soil Map of the World. In the data the soil units estimates are provided for physical (% sand, % silt, % clay, bulk density) and chemical properties in the topsoil and subsoil. The LS factor is the topographic factor represents the ratio of the soil loss under given condition to that at a site with the standard slope steepness of 9% and slope length of 22.6 m (Ganasri et. al. 2016). To estimate the LS factor a DEM (Digital Elevation Model) in ArcGIS software was created by digitizing contour lines from topographic maps (Rozos et al. 2013). Geographical Information Systems analyses allow users to make slope steepness (S) and slope length (L) raster covers by various methods (Gaubi et al. 2015). The C Factor is the crop management factor defined by RUSLE Model, and it is dimensionless factor among others. The remotely sensed data have been used to make estimations of the C factor distribution based on land use and land cover classification results. the P factor value for the study area for both historical, present and the future projection data is taken as 1. To take 1 as the P factor value is a common solution where there is not enough conservation support practices for the study area (Latocha et. al. 2016).

3. Results

The R Factor values of the historical data of the Regional Climate Model (1989-2017) range from range from 1587,77 to 49939 $MJ.mm.ha^{-1}.year^{-1}$. The R Factor values of the RCP 4.5 scenario data of the Regional Climate Model (2020-2049) range from 1404,85 to 35026,7 $MJ.mm.ha^{-1}.year^{-1}$. The R Factor values of the RCP 4.5 scenario data of the Regional Climate Model (2020-2049) range from 1404,85 to 35026,7 $MJ.mm.ha^{-1}.year^{-1}$.

The K Factor values range from 0,049204 to 0,171464 $Mg.Mj^{-1}.mm^{-1}$. The higher K factor values are representative of the higher potential of the soil to erode the top soil.

The LS distribution map of the Marmara Region created in DEM the LS values range from 0 to 45,28888. The estimation of the C Factor became the most time spent part of the study, because of the hardness of running the satellite images in ArcGIS software and finding the best fit satellite images for the borders of the region. After fitting the best satellite images for the study area, the red, the green and the blue bands of the satellite images were selected in order to examine the vegetation cover. In Arcgis software, the composition of these raster form of these three bands 4, 3 and 2 were done in the composite bands tool. After composing the bands on the software, the image analysis tool were used and the processing option was used to make NDVI. The C factor ranges from 0 to 1. The P factor was taken as 1.

According to the two scenarios of the Regional Climate Model RCP4.5 (optimistic), and RCP8.5(pessimistic), the future soil loss of the Marmara Region in the changing rainfall events is higher than the results of the historical data. The soil loss results for the time interval 2020-2049 of the scenario RCP8.5 is 61% higher than the results of the scenario RCP4.5. As final words, the soil loss results of the historical data of the Regional Climate Model showed that the soil loss range from 0 to 24,298 $Mg.\ ha^{-1}.\ year^{-1}$ during the time interval 1989 – 2017 in the Marmara Region, and also the average soil loss is 12,2 $Mg.\ ha^{-1}.\ year^{-1}$.

References

Gaubi I, Chaabani A, Mammou A, Hamza M.H. (2016), A GIS-based soil erosion prediction using the Revised Universal Soil Loss Equation (RUSLE) (Lebna watershed, Cap Bon, Tunisia).

Ganasri B. P., Ramesh H. (2016), Assessment of soil erosion by RUSLE model using remote sensing and GIS – A case study of Nethravathi Basin, 953-961.

Latocha A., Szymanowski M., Jeziorska J., Stec M., Roszczewska M.(2016), Effects of land abandonment and climate change on soil erosion – An example from depopulated agricultural lands in the Sudetes Mts., SW Poland.

Millward A., Mersey J. E. (1999), Adapting the RUSLE to model soil erosion potential in a mountainous tropical watershed., Catena 38, 109–129.

Renard K. G., Foster G. A., Weesies G. A., McCool D. K. (1997), Predicting soil erosion by water: a guide to conservation planning with RUSLE. USDA, Agriculture Handbook No. 703, Washington, DC.

Rozos D, Skilodimou H.D., Loupasakis C., Bathrellos G.D. (2013), Application of the revised universal soil loss equation model on landslide prevention. An example from N Euboea (Evia) Island, Greece. EnvironEarth Sci, 70, 3255-3266.

Wang G., Gertner G., Fang S., Anderson A. B. (2003), Mapping multiple variables for predicting soil loss by geostatistical methods with TM images and a slope map. Photogrammetric Engineering and Remote Sensing, 69, 889–898.