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Estimation of Slope Length (L) And Slope Steepness Factor (S) of RUSLE Equation by QGIS

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Abstract
Soil erosion is an increasing problem in areas where agricultural activity not only reduces agricultural productivity, but also reduces the availability of water. The most popular empirical-based model used globally for erosion prediction and control is the Regulated Universal Soil Loss Equation (RUSLE). As they evaluate erosion at larger scales due to the amount of data required and the wider area coverage, GIS techniques have become important instruments. A part of the Thrace region with an undulating topography with the risk of soil erosion is the current study area. In this study, an attempt was made to evaluate the annual soil loss due to precipitation and wind in the province of Tekirdağ using the Regulated Universal Land Loss Equation (RUSLE) within the framework of GIS. Elevations in the province varied between 10 and 917,26 m having LS factor values ranging from 0 –125,06.

Keywords:Soilerosion, RUSLE, LS factor, QGIS, Tekirdag*

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I. INTRODUCTION

Today, soil erosion caused by rainfall and wind is a serious problem, particularly in developing tropical and subtropical countries. Erosion is a natural geomorphic process that continually takes place on the surface of the earth. Accelerating this process through anthropogenic degradation, however, can have serious effects on the quality of the soil and the environment.

Mountains cover 56 percent of Turkey [1]. Turkey's topography and climate dynamics are quite susceptible to the formation of erosion in this regard. Areas where erosion is effective should be rapidly identified in order to take control measures that play an important role in combating erosion. Erosion studies carried out on large lands with methods based on traditional land surveys are labor-intensive and costly and take a long time [2]. Most Remote Sensing (RS) and Geographic Information System (GIS) techniques have been used in agriculture in light of technological developments. In the better planning of the country's agriculture [3, 4], the determination of the quantity and distribution of available agricultural land in agricultural activities plays an important role.

To estimate soil erosion from cultivated areas on a hill, the RUSLE (Regulated Universal Soil Loss Equation) equation, one of the commonly used erosion models, was developed.

The RUSLE equation is $A = R.K.L.S.C.P$ In equation, (A) average annual soil loss (mass/area/year); (R) index of precipitation wear; (K) soil erosion factor; (L) factor of slope length; (S) factor of slope steepness; (C) factor of vegetation and (P) factor of protection [5].

The LS factor represents the degree of slope and the slope length in the RUSLE equation and is defined as the horizontal distance of the surface flow to a channel, either to a channel constructed as a terrace channel of conversion or from the point where the surface flow takes place, where the slope decreases and accumulation begins. The LS factor represents the rate of soil loss on a 22,13 m long field with 9% slope and other conditions being the same. LS values are not absolute values, but the LS value in a land with this feature is 1 [6]. As it is very difficult to calculate the LS factor directly from the field, studies on the calculation of the LS value in the GIS environment have been conducted by various researchers. [7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18]. By obtaining the LS value, these scientists proposed different equations, and the constant numbers and algorithms they use are distinct. The slope degree and the flow sum are however, common to all in contrast to this situation. All these studies show that all researchers accept no single equation.

The biggest problem in the calculation of the LS factor, according to the literature, is that the slope shape such as concave, convex, stepped, straight / linear and others is different and the slope length in mountain areas where the altitude is high.

Drainage density per 1 km^2 is defined as the mean stream length. It is obtained by dividing the total length by the basin area of all natural branches that carry water within the basin. A well developed drainage system and rapid runoff are indicated by the high drainage density. In areas where the bedrock is hard and resistant to erosion, such as granite, quartzite, silica and sandstone, low drainage density develops in areas where the bedrock is resistant to erosion, high drainage density is observed under sparse vegetation on low cohesion sandy spindle deposits that easily erode [19].

II. MATERIALS & METHOD

2.1. Research Area

Tekirdag is one of the three cities where is in the northwest of the Sea of Marmara, is located in the European continent, less hilly, is situated on land enriched with alluvium. Tekirdağ province is located on the coordinates of 26˚43 ’- 28˚08’ east longitudes and 40˚36 ’- 41˚31’ northern latitudes. It is surrounded by Istanbul to the east, Edirne and Çanakkale to the west, Marmara Sea to the south and Kırklareli to the north and the Black Sea with a short coast.

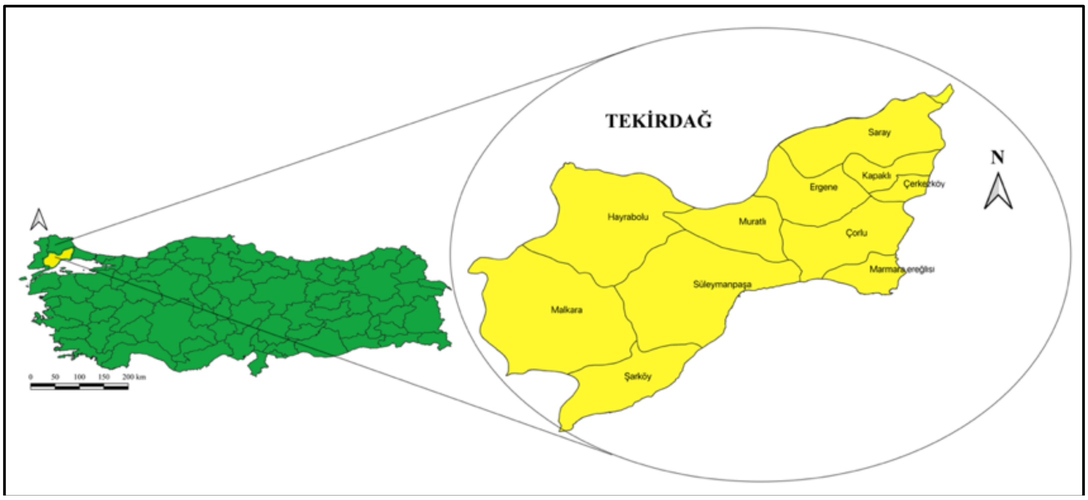

Figure 1. Research area

2.2. What is QGIS & Why QGIS?

From the QGIS website, "QGIS is a user-friendly Open Source Geographic Information System (GIS) licensed under the GNU General Public License. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, Unix, Mac OSX, Windows and Android and supporting various vector, raster, and database formats and functionalities.". That means the code is available for you to read or modify, should you choose to, but you don't have to. QGIS is an open source, community-driven desktop GIS software that allows users to visualize and analyze spatial data in a variety of ways. There are many reasons to use QGIS, but here are a few:

- It's a robust, powerful desktop GIS
- Runs on all major platforms: Mac, Linux, & Windows
- Free of charge, all access (no paid add-ons or extensions)
- Frequent updates & bug fixes
- Responsive, enthusiastic community
- Integration with other geospatial tools & programming languages like R, Python, & PostGIS
- Access to analysis tools from other established software like GRASS and SAGA
- Native access to open data formats like geo JSON & Geo Package Comes in a more than 40 languages, making it easier to work with a larger variety of collaborators [20, 21].

2.3. Preparation of Data Elevation Model (DEM) Map

The method described below was followed in this study to calculate the LS factor in the GIS environment. The Tekirdag province DEM maps were created using NASA-ALOS satellite images. The plugin "SRTM Downloader" in QGIS was used to prepare DEM maps for Tekirdag province. The resolution of the ALOS satellite images, consisting of 5 sections that cover the entire Tekirdag province, is 16.5x16.5 m. With the aid of the "Raster/Miscellaneous/Merge" command, DEM images, each consisting of 5 pieces, were combined as one object. In the next step, with the aid of the vector-based layer map showing the provincial borders of Tekirdag, the DEM map was determined with the command "Raster/Extraction/Clip Raster By Mask Layer" according to the provincial borders (Fig.2).

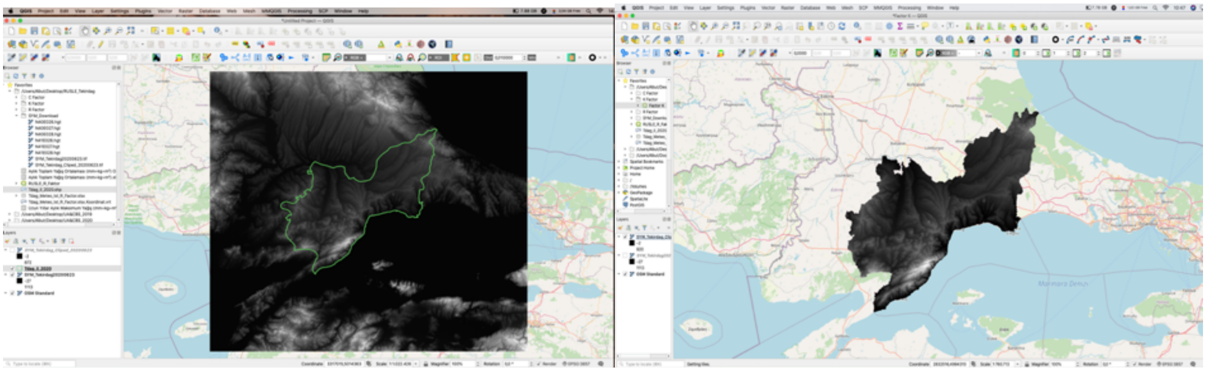

Figure 2. Preparation of Tekirdag DEM map

2.3. Creating a map of the LS factor.

The steps followed in the LS factor calculation with QGIS 3.14 in the region of analysis are shown in the flowchart in Fig3.

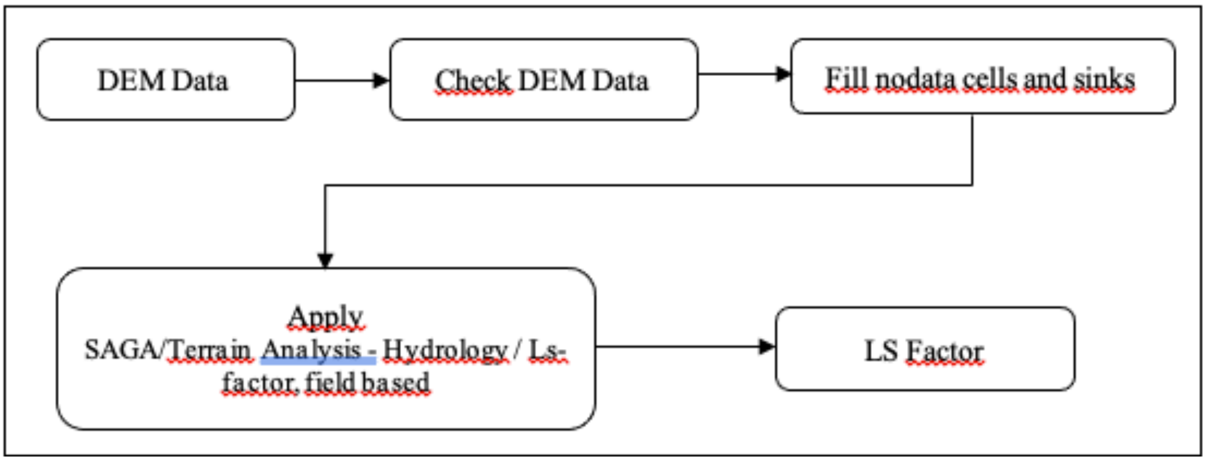

Figure 3. Using flowchartwithfactorLS

"The "SAGA/Terrain Analysis-Hydrology/Fill Sinks (Wang and Liu, 2006)" analysis process was performed in the "Porcessing Toolbox" script of the QGIS application to correct the defective areas on the DEM map.

With the help of the DEM map, the stage of creating the topographic and basin characteristics of the province of Tekirdağ was initiated. The LS factor operation was performed on the corrected DEM map. LS factor operation was performed for his process, in the corrected DEM map. For this operation, the operation "SAGA / Terrain Analysis - Hydrology / Ls-factor, field based" was run from the SAGA analysis tools under the Processing Tools command in the QGIS tool to calculate the LS factor (Fig.4).

The LS factor was prepared as a map with the reclassification process consisting of 4 classes belonging to the province of Tekirdağ. “GRASS / Raster (r *) / r.to.vect” sub-module in the GRASS raster plug-in sub-module for the conversion process to vector data format for the purpose of calculating the size and percentage of the areas covered by LS factor values from the LS factor map obtained as raster data. The module was implemented. Using the values in the map attribute table to obtain the map (Fig.5),

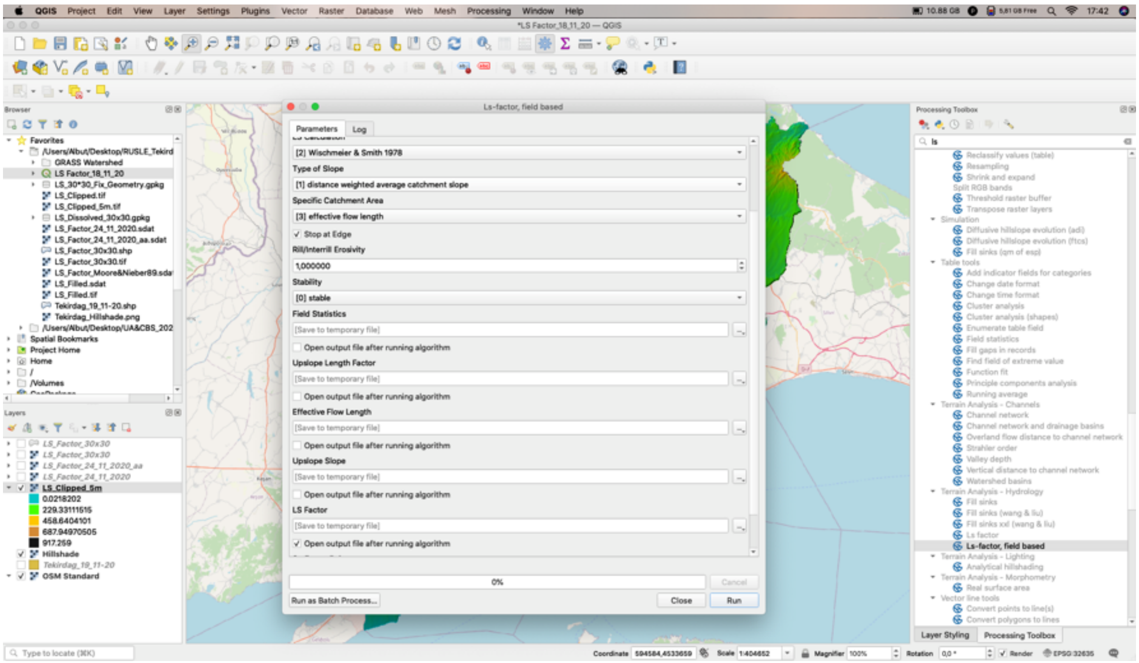

Figure 4. The SAGA analysis tools processing

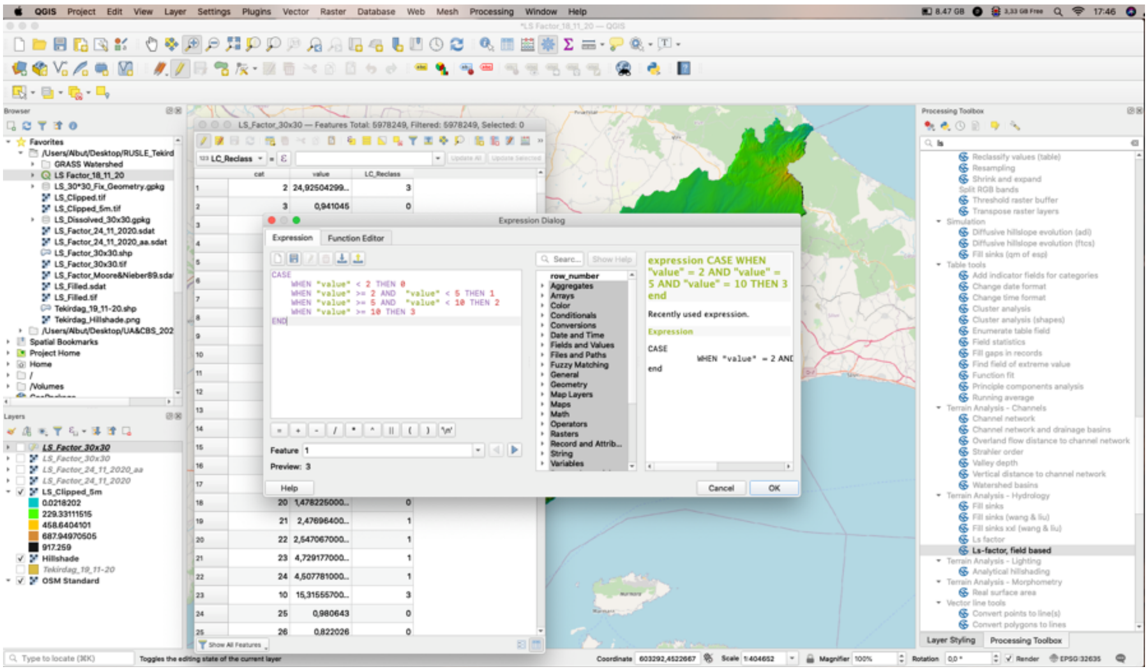

Figure 5. LS Factor map reclassification for Tekirdağ province

III. RESULT AND DISCUSSION

To generate the LS factor, Tekirdağ's Entry DEM model was used. The SYM model was constructed with the help of NASA - ALOS satellite images. For the Tekirdağ DEM model enhanced DEM map, a sub-module operation in the GRASS plug-in raster sub-module of the QGIS application was applied. The DEM model is the basic input to calculate the erosion caused by the LS factor.

LS coefficients calculated using the Map Calculation module in GRASS GIS in Table 1 are given. In order to obtain the LS value in Tekirdağ province, the slope map (S) was first created from the digital land model related to the basin; then surface preparation, flow direction determination, flow sum calculation (L) processes were carried out. The field's LS Factor was obtained by replacing the slope (S) and slope length (L) achieved in the equation proposed by Wischmeier and Smith (1978). The artificial results and rates of LS values obtained in Tekirdağ Province are set out below in this context (Table 1).

Table 1. Tekirdağ region's LS factor values.

LS Class	COVERED AREA (km²)	THEIR RATIO COVERED (%)
0-2	5.465,22	87,14
2-5	563,84	8,99
5-10	221,58	3,53
10-125,06	21,03	0,34
Total	6.271,67	100,00

In the province of Tekirdağ, the LS values are in 4 classes and range from 0 to 125,06. Areas with LS values between 0 - 2 cover most of the area in the research area (5.465,22 km^2 and 87,14 percent), as can be seen from the table. LS values between 2 - 5 are 8,99% (563,84 km^2), areas with LS values between 5 - 10 are 3,53% (221,58 km^2) and areas with LS values between 10 and 125,06 are 0,34% (21,03 km^2). Low LS values are generally observed in the north and northwest part of the region from the middle part to the south when the LS factor distribution map (Figure 6) is examined, and high LS values are observed in the mountainous areas near the sea in the south and south-west parts of the region. Figure 6 shows the results of the LS factor map of the research area.

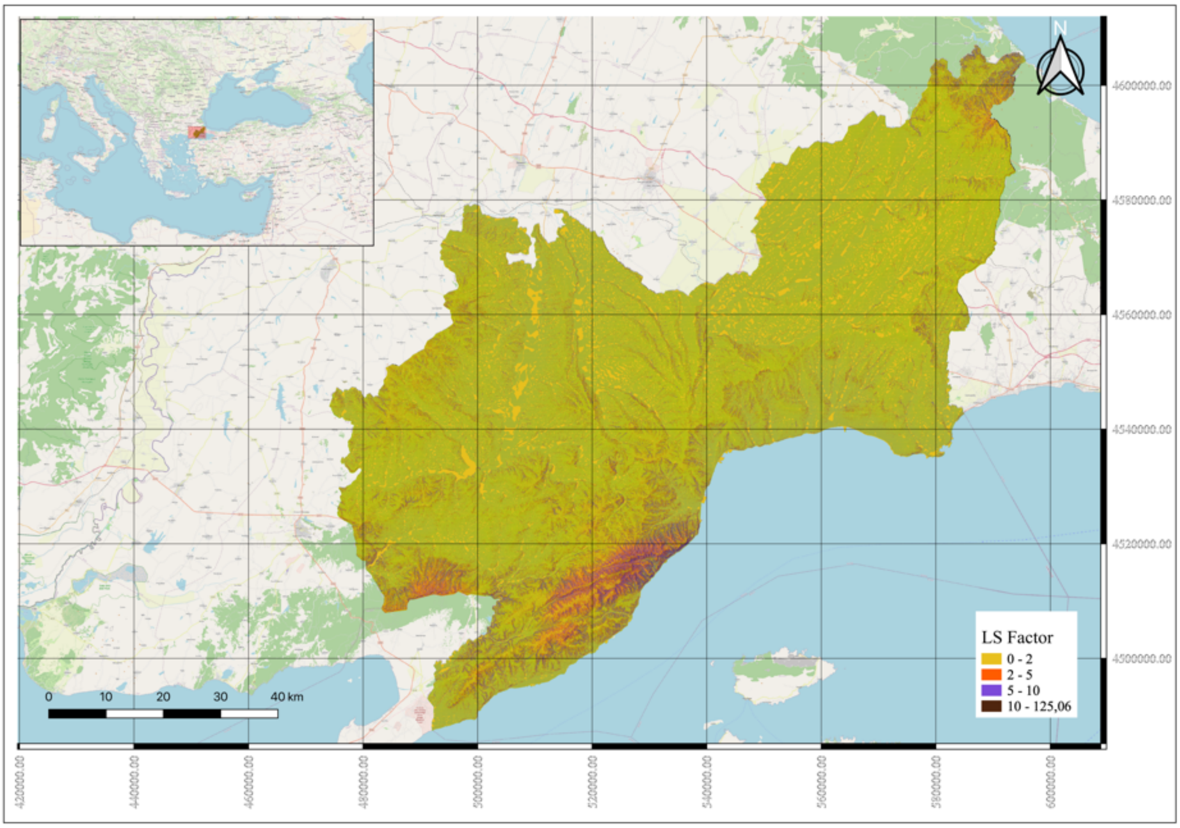

Figure 6. LS factor map of province Tekirdağ

IV. CONCLUSION

Potential erosion is a stage in which the process of erosion is not considered to be an effect of human causes, technologies and traditions of culture. Method models and physically based models offer advantages over simple empirical statistical models when individual processes and components causing erosion are described simply and efficiently.

However, the disadvantages of these models are that the mathematical representation of a natural operation can only be approximate and there remain difficulties in parameter estimation. RS and GIS techniques are very effective methods of soil erosion modelling and erosion risk assessment. Remote sensing and open source QGIS software in Tekirdağ province is an approach to soil erosion research methods.

In this study, RUSLE, which is the most commonly used model, was used to calculate the erosion and sediment load volume and spatial distribution generated as a result of it. This study also added methods to model soil erosion using the RUSLE equation using NASA-ALOS satellite image data from the LS-factor DEM map.

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