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Modeling of Soil Erosion from Rains and Wind Using Remote Sensing andGeographic Information Systems

Ayhan CAMUROGLU
Lüleburgaz MunicipalityParksandGardensDirectorate,
Kırklareli Turkey

Selcuk ALBUT
TekirdagNamik Kemal University, AgriculturalFaculty
Department of BiosystemsEngineering
Tekirdag -Turkey

ABSTRACT

Soil erosion is a growing problem especially in areas of agricultural activity where soil erosion not only leads to decreased agricultural productivity but also reduces water availability. Revised Universal Soil Loss Equation (RUSLE) is the most popular empirically based model used globally for erosion prediction and control. Remote sensing and GIS techniques have become valuable tools,especially when assessing erosion at larger scales due to the amount of data needed and the greater area coverage. The present study area is a part of the Thracian region with undulating topography, with a risk of soil erosion. In the present study, an attempt has been made to assess the annual soil loss caused by water and wind in the province of Krklareli using RUSLE in GIS framework. Such information can be of immense help in identifying priority areas for the implementation of erosion control measures. The soil erosion rate was determined as a function of land topography, soil texture, land use/land cover, rainfall erosivity, and crop management, and practice in the province using the Revised Universal Soil Loss Equation (for Kırklareli), remote sensing and GIS techniques. The rainfall erosivity R-factor of RUSLE was found from 40,48-375,00 and the soil erodibility K-factor varied from 0,00 -0,40. Elevations in the province varied between 10 and 1031 m having LS factor values ranging from 0 –17,34. The C factor was found using the CORINE 2018 data. The P-value was computed from existing cropping patterns in the province. The annual soil loss estimated in the province using RUSLE is 10,0 ton/ha/yr.

Keywords*Soil erosion, RUSLE, Kırklareli, CORINE, QGIS*

I. Introduction

Today, soil degradation with erosion due to rainfall and wind is a serious problem especially in developing tropical and subtropical countries. Erosion is a natural geomorphic process that occurs continuously on the earth's surface. However, the acceleration of this process by anthropogenic degradation can have serious effects on soil and environmental quality.

56% of our country consists of mountainous lands [1]. Turkey's topography and climatic dynamics of this aspect, it is quite susceptible to erosion formation. In order to take control measures, which have an important place in combating erosion, areas where erosion is effective should be determined quickly. 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].

In the light of the developments in technology, mostly Remote Sensing (RS) and Geographic Information System (GIS) techniques have been used in agriculture. Determining the amount and distribution of available agricultural land in agricultural activities plays an important role in better planning of the country's agriculture [3].

Soil erosion has negative economic and environmental effects [4]. The economic impacts are due to the loss of farm income due to the decrease in on-site and off-site incomes and other damages affecting the plant / animal production negatively. Soil erosion has both on-site and off-site effects on productivity. In situ efficiency loss of soil erosion is due to three reasons. The first of these is short-term productivity losses and these are factors such as loss of crop yield, loss of seeding, loss of input (seed, fertilizer), loss of water, additional tillage, time loss due to delayed planting. The second is long-term productivity losses and these are losses such as top soil loss, decrease in soil structure, decrease in soil organic matter content, soil cultivation erosion. The third factor is the reduction in land / soil quality, and these are factors such as temporary decrease in land / soil quality, temporary pollution of surface water by chemicals from sediment. The non-situational economic impact of soil erosion also depends on three reasons. The first of these is seedling deaths due to short-term effects, flooding of the low floor area, chemical effects on seedlings, delayed planting. Its long-term effects are the burying of top soil by infertile soils, change in drainage conditions and changing the slope with tillage erosion. The third and last effect is the reduction in land / soil quality, including temporary decrease in land / soil quality due to floodplains, changes in the soil-water regime and water layer, and additional water management (irrigation, drainage, etc.).

Obtaining agricultural land, excessive and irregular grazing, destruction of forests, etc. anthropogenic impact and erosion is accelerated by the increasing violence in Turkey Besides the natural factors [5].

Erosion is one of the important environmental problems that our country has to tackle. While erosion is observed in an area of approximately 25 million hectares per country in the European Union countries, 57 million hectares are seen in our country. Although erosion is considered as an ecological problem alone, it occasionally causes hunger and migration. Approximately 500 million tons of fertile soil is lost every year. It reveals how great a threat erosion is for our country, that 99% of our soils are affected by water erosion and 1% by wind erosion [6].

In this study, databases of erosion caused by precipitation and wind in Kırklareli province will be created. All data will be processed using Remote Sensing and Geographical Information System software (QGIS) and the results obtained will be accessed on the internet. The first part of the study, which consists of three main parts, includes source research and definitions. In the second part, the material and method used in the study are explained. In the third part, the results obtained in the study were summarized, suggestions were made and presented for discussion.

II. Material and Method

Research area is Kırklareli province, and human-induced land degradation, such as industrialization and urbanization, continues to grow day by day due to multifaceted socio-economic and environmental factors. For these reasons, the research area was chosen in the province of Kırklareli on the grounds that it will serve as a model for evaluating the current soil erosion risk and soil erosion situation due to possible water and wind use of remote sensing and geographical information systems. Place, northwest of Turkey, is on the European continent in the Marmara region of Turkey and is situated in cut Thrace. Because of its position in the country, it is situated between 41°13'34"and 42°05'03" northern latitudes and 26°54'14"and 28°06'15" east longitudes. The elevation is 203 metres. The province has 6,466.85 km2 of land area. Bulgaria is 58 km from the East with a frontier range of 159 km from the north. It is surrounded by the coastlength of the Black Sea, Edirne from the west, Istanbul from the southeast and Tekirdağ from the South (Fig.1). In these municipalities there are 8 districts, 21 counties, 108 districts and 179 villages, according to TURKSAT data of 01 February 2019.

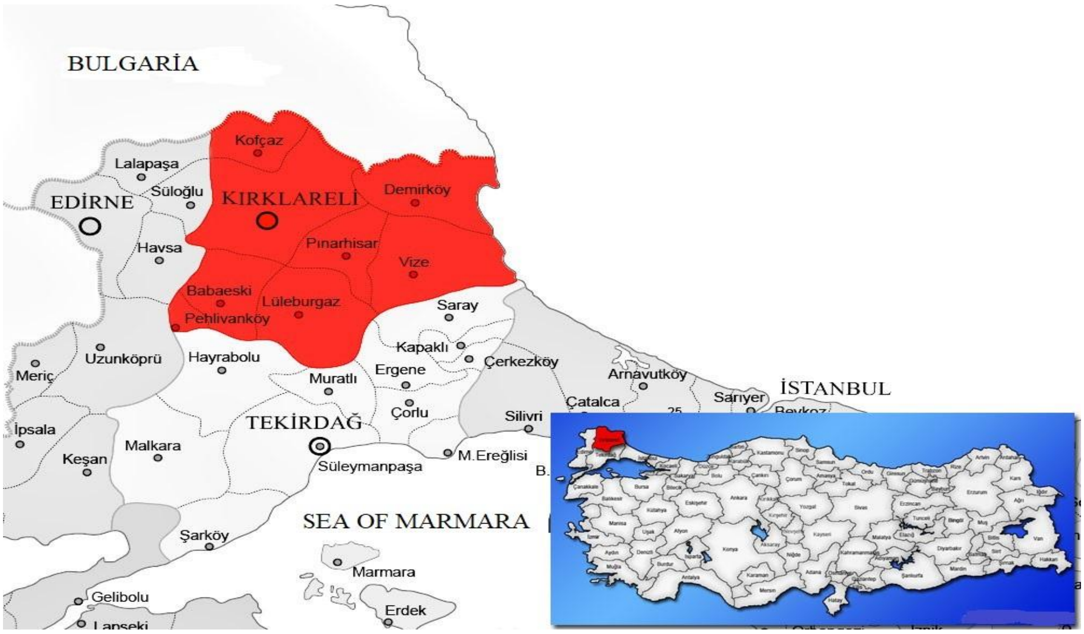

Fig.1. Kırklareli province location map

A. *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 platorms: 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 colaborators [7], [8].

B. *CORINE Land Cover Data*

The pan-European component is coordinated by the European Environment Agency (EEA) and produces land cover / land use (LC/LU) information in the CORINE Land Cover data, High Resolution Layers, Biophysical parameters and European Ground Motion Service [9]. The CORINE Land Cover is provided for 1990, 2000, 2006, 2012, and 2018. This vector-based dataset includes 44 land cover and land use classes. The time-series also includes a land-change layer, highlighting changes in land cover and land-use. The high-resolution layers (HRL) are raster-based datasets which provides information about different land cover characteristics and is complementary to land-cover mapping (e.g. CORINE) dataset (Table-1) [9].

C. Preparation of Data Elevation Model (DEM) Map

The Kırklareli DEM maps were created using NASA-ALOS satellite images. The plugin "SRTM Downloader" in QGIS was used to prepare DEM maps for Kırklareli province. The resolution of the ALOS satellite images, consisting of 5 sections that cover the entire Kırklareli province, is 16.5x16.5 m. With the aid of the "Raster / Miscellaneus / 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 Kırklareli, the DEM map was determined with the command "Raster / Extraction / Clip Raster By Mask Leyer" according to the provincial borders (Fig.2).

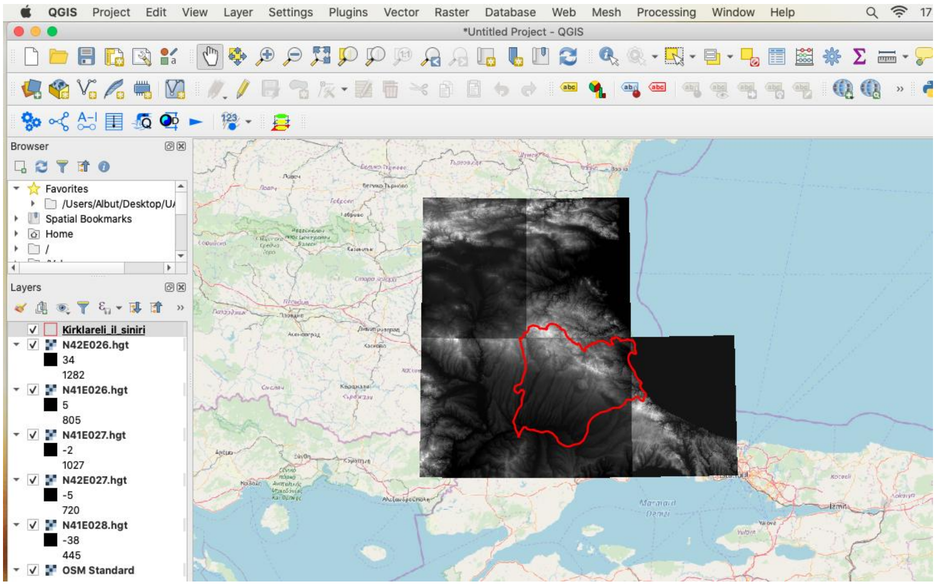

Fig.2. Preparation of Kırklareli DEM map

D. *Potential Estimation of Soil Loss Distribution (A)*

According to the RUSLE model, the potential soil loss of the area was multiplied by placing it in the GIS method and thus the potential soil loss of the Kırklareli province was estimated as (ton / ha / yr) (1).

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

In GIS environment, the factor of slope and slope length (LS), precipitation erosion factor (R), soil erosion sensitivity factor (K), plant management factor (C), and soil protection measure factor (P) was obtained as one sheet. Soil loss suitable for agricultural production is 10 tons/ha/yr according to Morgan (1995). This tolerable amount has been taken into account when determining soil loss rates for the classes.

The primary method of this research is the modeling of the soil erosion process based on the integrated RUSLE equation using the Open Source GIS technique (using QGIS software and its add-ons). The QGIS software is used in particular to prepare and standardize certain input data; the GRASSGIS plugin also fulfills the key tasks of analysis, estimation, creation, transformation, incorporation of map coefficients into the model, statistics, current situation, potential erosion. The flow diagram for the following research method is shown in Fig. 3 [10], [11], [12], [13].

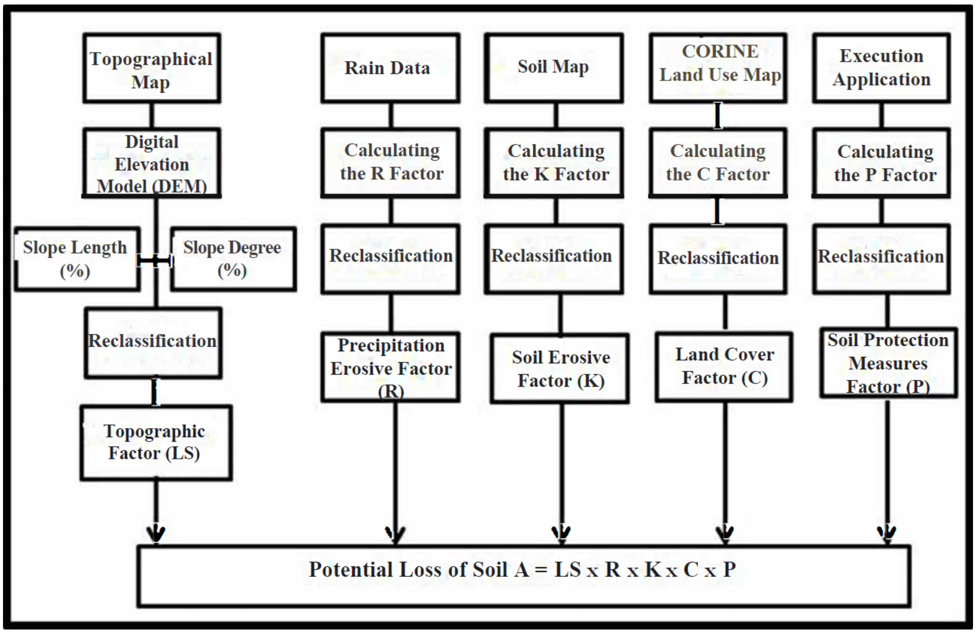

Fig.3. Modelling flowchart fort he soil erosion.

E. Calculating Precipitation Erosion Factor (R)

Meteorological data of several years were used in the calculation of the R coefficient in the RUSLE model, taken from 9 meteorological stations in the province of Kırklareli and its surroundings, which is a research field of the General Directorate of Meteorology. The Arnoldous (1980) Modified Fournier Index (MFI) formula, one of the formulas developed to find the value of the "Erosion Index," was used to measure the R value (2) [14], [15], [16], [17].

$$MFI = 1 = 112 pi2p \qquad (2)$$

Equality; Pi monthly precipitation (mm) is expressed as annual precipitation (mm) average of P. Equation used in the Erosive Factor (R) calculation for precipitation (3);

$$R = (4{,}17\ MFI) - 152 \qquad (3)$$

F. Calculating soil erosion sensitivity (K)

The erodibility of soils is largely due to the physical and chemical properties of the soil that form its internal structure. In other words, the hydraulic permeability of the soil depends on the organic material properties, texture and structure. Although some soils are resistant against the same erosive forces, some other soils are easily dissolved and eroded [18]. K Factor is the expression of soil lost from hectare in tons with unit erosion index on a land with a slope of 9% and a slope length of 22.1 m.

A method has been developed for determining the K value using silt and very fine sand (%), sand (%), organic matter (%), soil parameters for structure and permeability [13], [19].

The soil map obtained from the Kırklareli Atatürk Research Institute for Soil, Water, and Agricultural Meteorology was used in the K factor calculation. The map is opened numerically in the QGIS software and simplified from the options in the "Attributes Table" according to the Major Soil Groups function. This was changed to the Kırklareli soil database, in other words. This process is achieved by combining the values of the same class category with the aid of the QGIS software plugin "Vector/Geoprocessing Tools/Dissolve". Classification process for Kırklareli province is conducted according to soil erodibility values (K factor). Finally, the values of the K factor were calculated for the province of Kırklareli, the areas covered by them and the proportional distributions.

G. Calculating Land Cover Factor (C)

An approach from CORINE 2018 data using remote sensing technology and GIS is recommended when calculating the C coefficient in the RUSLE model. Via these data the calculation of the C coefficient in the RUSLE model becomes easier.

In general, the data needed for the analysis are data on soil, land use, topography, vegetation, and climate. It reviewed the literature on the subject, providing information on remotely sensed data and geographic information systems in Turkey and in the world of modeling erosion, soil loss assessment models and modeling. Our land was chosen using GIS techniques, and research was conducted on it [18], [20].

H. Calculating soil erosion sensitivity (LS)

With the aid of NASA-ALOS satellite images, the Kırklareli DEM model was created to produce Kırklareli Slope Length and Slope Degree Factor (LS). The sub-modul operation in the QGIS application's GRASS extension raster sub-module was added to the Kırklareli DEM model improved DEM map [15].

I. Potential Soil Loss Distribution (A) Calculation

According to the RUSLE model, the potential basin soil loss (A = R * K * LS * P * C) has been multiplied by replacing it in the GIS setting and thus the potential soil loss of the province of Kırklareli is estimated as (tons/ha/yr). According to Morgan (1995) the appropriate soil loss is 10 tons/ha/yr for agricultural production. This tolerable limit was taken into consideration when defining classes of soil loss rates.

The resolution values of all images in raster format to be used to measure possible soil loss are corrected as 30 m * 30 m.

The values of K, R, C, LS factors and images in the RUSLE formula and measured in the QGIS application are used in the Geotiff raster format, the "Raster / Raster calculator" command in the QGIS application Raster command.

The Geotiff formatted maps were written in the process window that opens, instead of the values in the equation "A = R * K * LS * P * C" that we use to measure the A value, and the R factor was measured visually in the format of raster data (Fig.4).

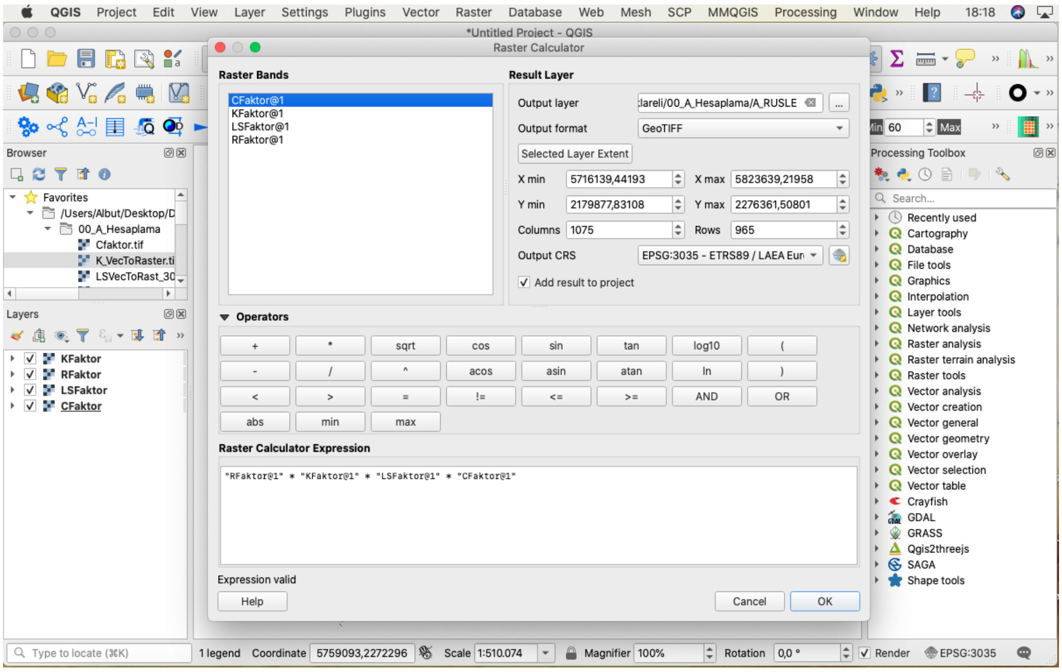

Fig.4. Calculate with the "Raster Calculation" command from the QGIS application Raster Info.

III. RESULTS AND DISCCUSSION

Results of factors LS, R, K, C and P in the RUSLE equation obtained from the research are given in this section.

J. LS Factor

The results and ratios of the LS values obtained by using the DEM map for Kırklareli province are given below (Table 1 and Fig.5).

TABLE I. LS VALUES

LS CLASS	COVERED AREA (km²)	THEIR RATIO COVERED (%)
0-2	5.703,80	88,20
2-5	612,30	9,47
5-10	137,76	2,13
10-17,34	12,92	0,20
Total	**6.466,78**	**100,00**

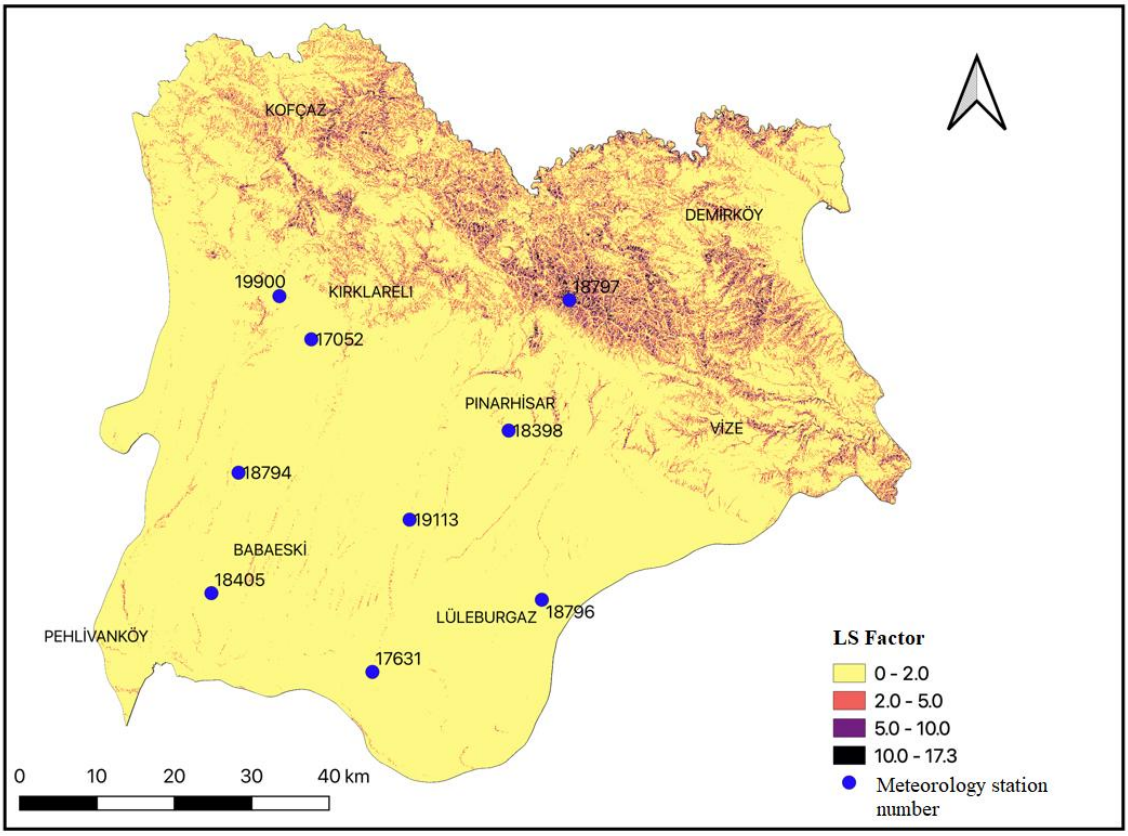

Fig.5. LS factormap of province Kırklareli.

In Kırklareli Province, LS values are in 4 classes and vary from 0 to 17.34. As the table shows, areas with LS values between 0-2 cover most research area (5.703.80 km² and 88.20 per cent). Areas with LS values between 2-5 are 9.47 percent (612.30 km²), areas with LS values between 5-10 percent are 2.13 (137.76 km²), and areas with LS values between 10 and 17.34 are 0 percent, 20 (12.92 km²) are spread. When examining the LS Factor distribution map (Figure 5), generally low LS values are observed from the middle to the south in the SW part of the region, and high LS values are observed in the mountainous areas close to the sea, i.e. in the north and north-east parts of the region. The results are displayed on the research area's LS factor map in Figure 5.

K. R Factor

The locations of the meteorological stations in the province of Kırklareli, station altitude in metres, latitude and longitude, and annual average rainfall in mm type, Arnoldous formula (1980), CFC values and R factor values are all given in Table 2and Fig.6.

TABLE II. KIRKLARELİ MFI AND R-FACTOR VALUES

ID	Station Name	Altitude (m)	Latitude	Longitude	AnnualAveragePrecipitation	MFI	R FACTOR
18405	Babaeski	89,00	41,443300	27,062200	662,56	61,1153	102,8508
1879	Yenimahall	107,00	41,5833	27,10440	561,20	57,477	87,679

4	e-Babaeski		00	0		1	5
17052	Kırklareli	233,00	41,738200	27,217800	615,14	54,9849	77,2870
17631	Lüleburgaz -TİGEM	44,00	41,351300	27,310800	562,45	52,0971	65,2449
18796	Ahmetbey	108,00	41,434200	27,573300	466,72	56,7402	84,6066
18398	Pınarhisar	265,00	41,631100	27,523600	534,37	46,1316	40,3688
19113	Celaliye-Lüleburgaz	127,00	41,528140	27,369300	636,70	84,6377	200,9392
18797	Mahyadağı -Pınarhisar	1020,00	41,782200	27,619200	1125,95	126,8002	376,7568
19900	Kırklareli Uni.	270,00	41,788442	27,168334	512,30	75,6473	163,4492

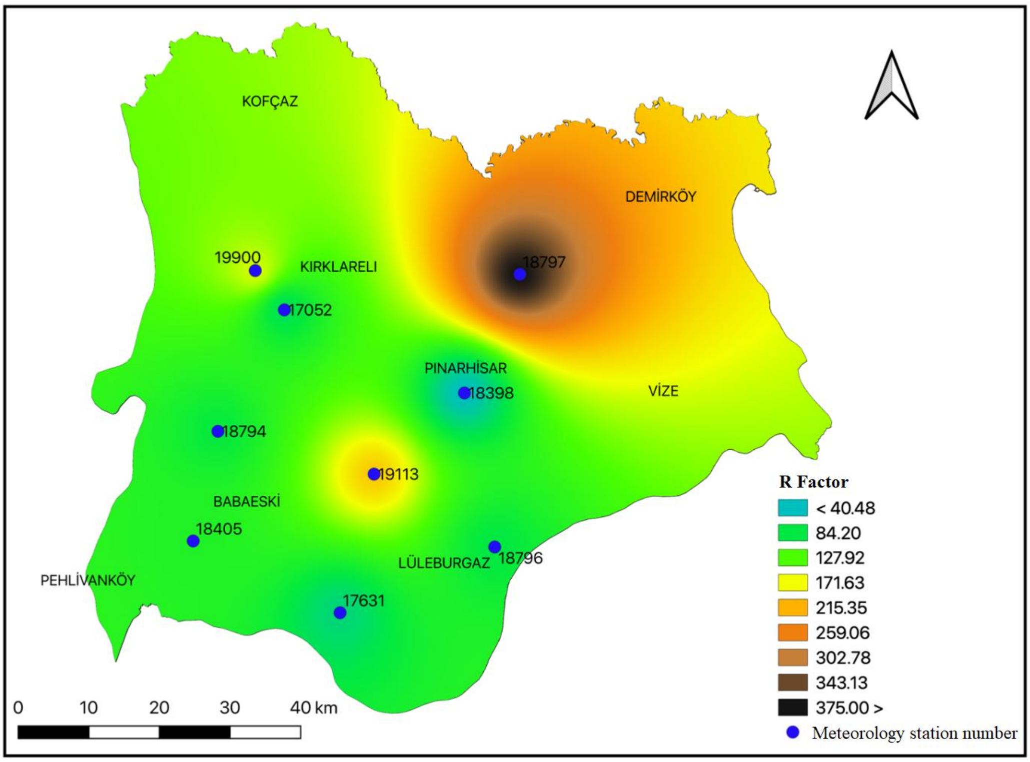

Fig.6. Rfactormap of province Kırklareli.

As can be seen from the map of factor R (Figure 6), elevation plays an enormous role on R values. When we compare the region's map of elevation and the map of factor R, we see that the sections with high R values correspond to the province's high places, that is, they decrease when one goes from north to south. In the higher parts of the province's Mahya Mountains the areas with the highest R value appear. Furthermore, if the rainfall is expected to increase due to the rise in altitude, this relationship would be seen as natural. Again, R values display a small increase around the village of Celaliye, in the central part of the province. The fall in district values at Pınarhisar is alarming. The values drops on the foothills of the mountains.

L. K Factor

The interpolation method was used as a geostatistical method to spread the point-specific K values obtained in Kıklareli province over the surface of the study area and the K factor map (layer) of the site was obtained (Figure 7). This layer was formed according to the degree of erosion of the soils, and the areal and proportional distributions of the K factor classes were calculated by classifying them according to the K factor classes for the province of Kırklareli. The results are given in the table below (Table 3).

TABLE III. SOIL CLASSIFICATION AND K FACTOR VALUES OF KIRKLARELI PROVINCE

Soiltype	Description	K factor	Ares (km^2)	Ratio (%)
S	Alluvial BeachSwamp Soil	0,15	12,97	0,20
V	Vertisols	0,10	1.001,22	15,48
U	Non-calcareousBrown Soil	0,21	1.396,49	21,59
R	Rendzinas	0,12	11,21	0,17
X (another)	Settlements and veWater Surfaces	-	92,17	1,43
K	Colivial Soils	0,17	17,11	0,26
N	Non-calcareous BrownForest Soil	0,29	3.227,15	49,90
M	Brown Forest Soil	0,20	350,62	5,42
A	AlluvialSoil	0,15	357,92	5,53
	TOTAL		6.466,85	100,00

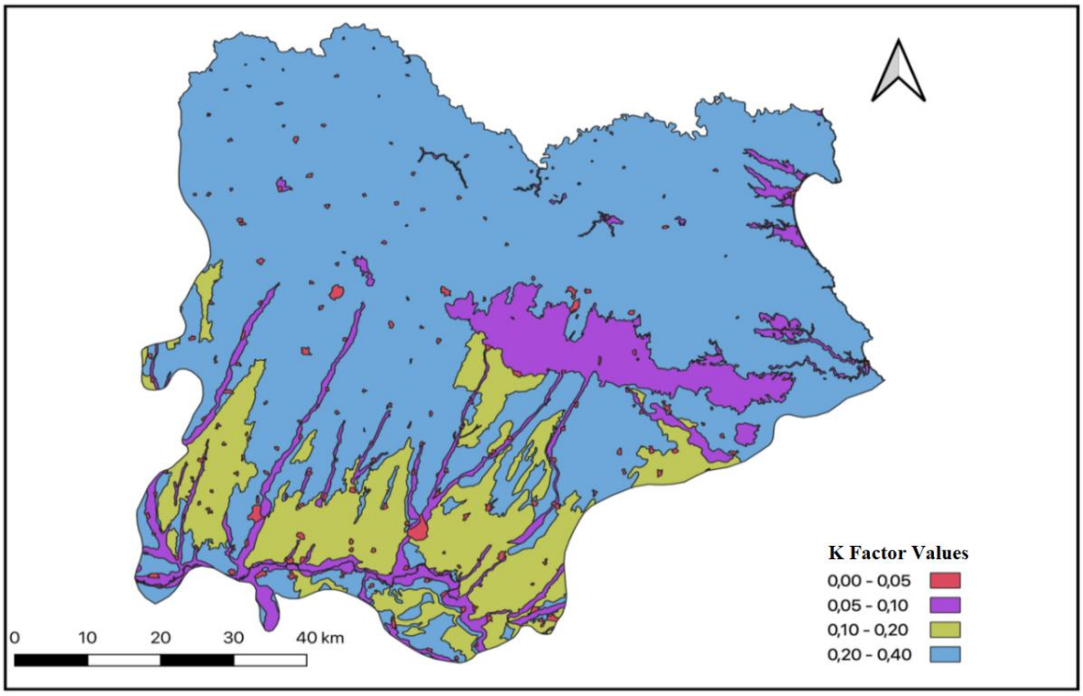

Fig. 7. Kfactormap of province Kırklareli.

M. C Factor

According to the Land Cover / Use Classification developed by the CORINE European Environment Agency, Kırklareli Land Cover Factor (C) provides agricultural land classes and land use maps generated at Kırklareli province level by means of satellite images and the area data obtained on those maps in the QGIS programme. (Tab. 4 and Fig. 8).

TABLE IV. THE AREA AND RATES DETERMİNED FOR KIRKLARELİ PROTECTED BY THE RUSLE C FACTOR VALUES

Soiltype	Description	K factor	Ares (km^2)	Ratio (%)
311	BroadleafForest	0,001	1.869,28	28,91
312	ConiferousForest	0,010	80,24	1,24
313	MixedForests	0,050	106,95	1,65
322-324	Shrubbery, PlantChange Areas	0,038	556,43	8,60
231-321	Meadow Pasture	0,090	370,52	5,73
221-222	Vineyards and Orchards	0,180	6,51	0,10
211-212-213	CultivatedAgriculturalLands	0,280	2.566,86	39,69
242-243	EmptyAgriculturalLands	0,500	670,10	10,36
511-512	Water Surfaces	0,001	42,91	0,66
331-333	Bare Lands	1,000	47,25	0,73
112-411	Other areas of use	-	149,80	2,33
	TOTAL		6.466,85	100,00

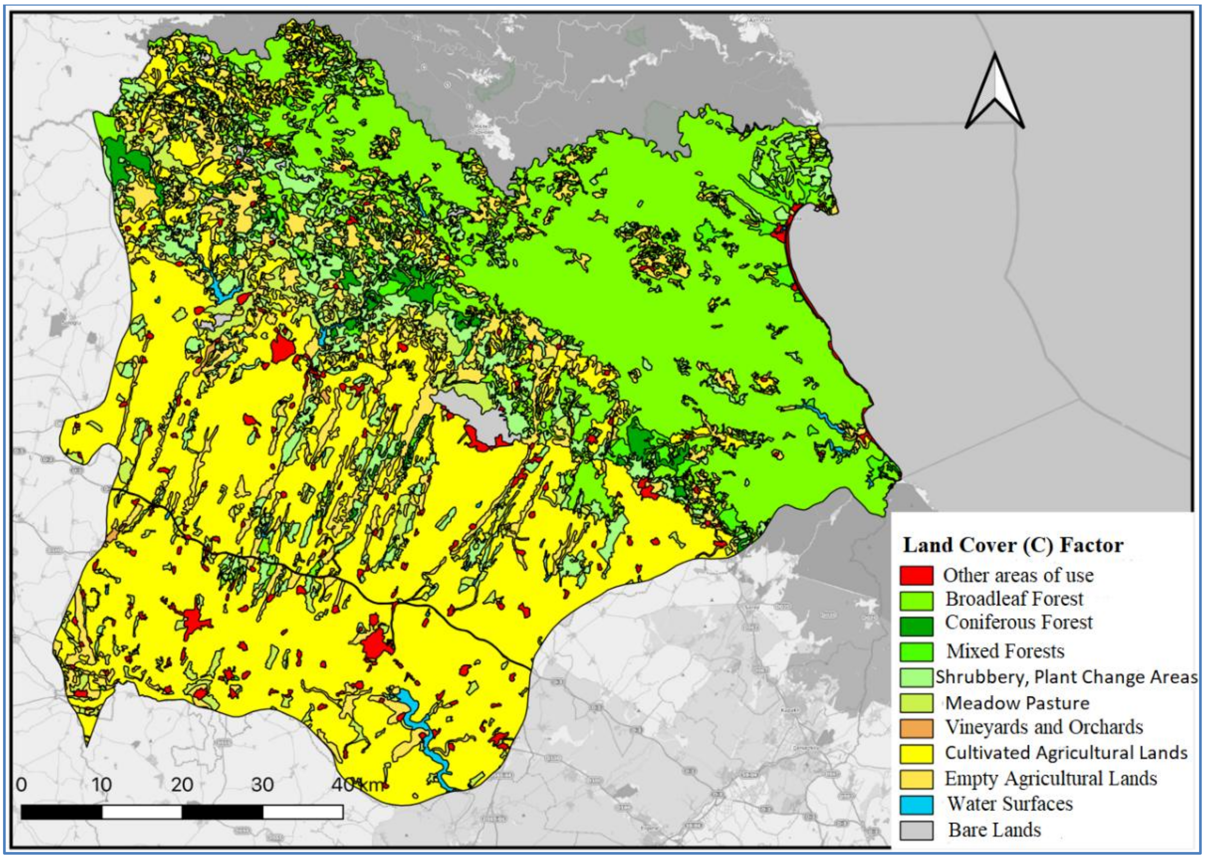

Fig. 8. C factormap of Kırklareli provincecalculatedfrom CORINE 2018.

It is understood that, as it includes more up-to - date data, the base data map prepared with CORINE provides more reliable results. The rate of areas exposed to erosion was, moreover, quite low. It should not be forgotten that the amount of erosion from sloping lands is higher than that of other fields. Areas of higher breakup and degradation in the northern portion of the study region are at higher risk of erosion. How major land use and land cover have on erosion should not be ignored. It was found that the map with a low amount of erosion has higher areas of oak and forest which reduced the amount of soil loss. The hazard of erosion seen in agricultural areas has been observed to be closer.

Study region where the slope is low has found cultivated agricultural areas. It is noteworthy that broad-leaved trees, shrubbery, meadows, and pasture areas are located in high places in the Yıldız Mountains, where the altitude in the north of the region is rising. These areas are places that, for different purposes, can not be opened up to agriculture and are mainly used as pasture for livestock activities.

N. P Factor

The Element (P) of Kırklareli Soil Conservation Measures represents soil management activities. Depending on whether the soil is cultivated in the slope direction or perpendicular to the slope or by rotation, erosion processes may be accelerated or slowed down. Within the framework of this analysis no soil conservation measure was identified in the agricultural areas within the Kırklareli boundaries. For this reason the value of 1.0 was accepted as constant for soil protection measures in the relevant erosion model. This means that Elements P will not influence the erosion calculation process. This value of 1.0 is the P factor value to be taken in the RUSLE model when there is no application in the studied field for soil security calculation (Wischmeier and Smith, 1978).

O. Potential Estimation of Soil Loss Distribution (A)

According to the RUSLE model, this was compounded by putting it in the GIS setting to determine the province's potential soil loss and as a result estimated the Kırklareli province's potential soil loss.

The spatial and proportional risk classes for the distribution of land loss in the province of Kırklareli are given in Table 5. Low soil loss occurs in the province of Kırklareli at a rate of 92.31 per cent with

1-5 erosion distribution values in a region of 5969.23 km². Light level soil loss is 3.68 per cent at second level.

TABLE V. POTENTİAL RATE OF EROSİON İN KIRKLARELİ PROVİNCE

Erosion class	Erosion dispersion value	ClassofVulnerabletoerosion	Area (km^2)	Rate they cover (%)
1	0 – 1	Very low	59,79	0,92
2	1 – 5	Low	5969,23	92,31
3	5 – 10	Light	238,18	3,68
4	10 – 20	Middle	102,05	1,58
5	20 - 50	Strong	62,87	0,97
6	50 -100	Severe	27,69	0,43
7	100>	Extremely Severe	7,03	0,11
	TOTAL		**6.466,85**	**100,00**

The Kırklareli Province Soil Loss Map obtained through the multiplication of variables Rusle-R-K-LS and C is given in Figure 9. Soil loss in the province of Kırklareli was found to be 10.0 ton/ha/yr.

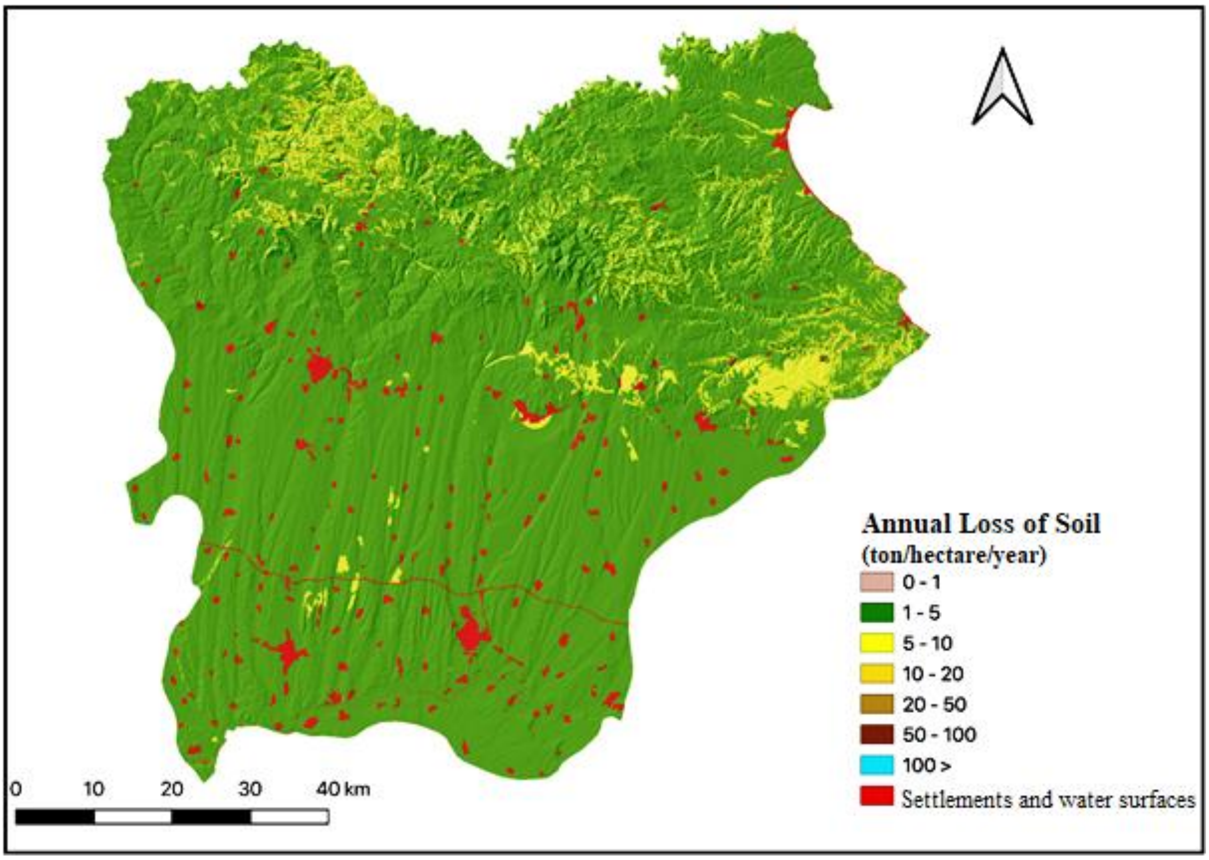

Fig. 9. Potentialerosionmap of Kırklareli province

Possible risk of erosion is shown to be minimal when analyzing the distribution chart of potential groups of risk of erosion. If a generalization is made, the possible risk of erosion in the plain and near-flat plain parts and in the areas around them is seen to be minimal. On the other hand, the possible risk of erosion is seen to be high in the high parts of Yıldız Mountains in the north where the elevation and slope values are high.

IV. CONCLUSIONS

Potential erosion is a phase where the erosion process is not viewed as an effect of human causes, technologies and cultural traditions. Method models and physically based models give advantages over simple statistical empirical models when describing simply and efficiently individual processes and components causing erosion. The drawbacks of these models, however, are that the mathematical representation of a natural operation can only be approximate, and parameter estimation difficulties remain. RS and GIS techniques are very effective modelling methods for soil erosion and risk assessment for erosion. In Kırklareli Province, remote sensing and open source GIS software (QGIS) is an approach to soil erosion research methods. RUSLE, which is the most commonly used model, was used in this study to calculate the volume and spatial distribution of erosion and sediment load generated as a result of it. This research also added methods for modeling soil erosion using the RUSLE equation using the data from CORINE 2018 for C-factor interpolation. With this study , potential soil erosion status map for the Kırklareli area was generated with RS and GIS, which was clearly analyzed using RUSLE and QGIS technology in terms of spatial distribution.

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