

Assessment Of Soil Erosion Based On The Method USLE; Çorum Province Example

Fazlı Engin TOMBUŞ, Mahmut YÜKSEL, Murat ŞAHİN, İbrahim Murat OZULU and Mustafa COŞAR, Turkey

Key words: Soil erosion, USLE (Universal Soil Loss Equation), Geographic Information Systems

SUMMARY

The factor which damages and reduces the productivity of our soils, one of the most important natural resources, is soil erosion. Soil erosion causes serious financial losses in the countries whose economies are dependent to efficiency and workability of soils. In our country, it's thought that the average annual amount of soil which move up to the seas or lakes is 500 million tons. Therefore, it is necessary to protect productive agricultural land and bring the soil erosion which affects the structure of soils adversely under control. Also, it's necessary to determine the areas which are under the threat of soil erosion firstly for taking erosion protection measures. There aren't any current erosion maps other than the applications in the selected pilot areas.

Turkey's first, detailed and only erosion map was prepared by TOPRAKSU by benefiting the land survey carried out between 1966–1971 and aerial photographs. These maps are results of long, intensive works and were published in 1981 and now was outdated.

Some developed countries in the world produce various soil erosion models by taking the specifications of their own area into consideration. The most common of these models are USLE, CORINE, ICONA, LEAM, MOSES...etc. While some of these models make soil erosion risk assessment some present current erosion conditions and some of them specify the potential soil erosion quantitatively. The Universal Soil Loss Equation (USLE) method, used at calculating the soil loss at the work area or basin in a year at unit area per unit of time, is also a commonly used and efficient model for determining the precautions against soil erosion at areas under soil erosion threat.

In this study it is aimed to determine and evaluate the soil loss in the west region of Çorum with the help of commonly used Geographic Information Systems according to USLE model.

Assessment Of Soil Erosion Based On The Method USLE; Çorum Province Example

Fazlı Engin TOMBUŞ, Mahmut YÜKSEL, Murat ŞAHİN, İbrahim Murat OZULU and Mustafa COŞAR, Turkey

1. INTRODUCTION

Erosion is one of the biggest ecological problems which threaten our national reserves for our country as well as whole world. Turkey is located in Southern West/ Middle Asia- North Africa zone, where is under high erosion effect and mostly become desert. Due to erosion the amount of earth moved to sea, dams and lakes is detected about 500 millions tons according to sediment measurement which applied in 26 basins in our country (ÖZEL, M., et. al., 1998).

Fertile soils by carrying erosion fills dam lakes and reduces dams economical life, hence economy of country get harmed big amount. To specify hazard and damage of soil erosion is very important for this reason.

The most widely used and supported soil conservation tool is “Universal Soil Loss Equation, USLE”. USLE is an empirical equation derived from more than 10,000 plot-years of data collected on natural runoff plots and an estimated equivalent of 2,000 plot-years of data from rainfall simulators. The current major USLE guideline manual, Agriculture Handbook 537 was published in 1978. The annual soil loss is estimated from a number of factors that have been measured for all climates, soil types, topography and kinds of land. These factors are combined in a number of formulas in USLE, which returns a single number, the computed soil loss per unit area, equivalent to predicted erosion in ton hectare⁻¹ year⁻¹. This technique helps to predict erosion and orients farmers which farming methods to use. It also identifies erosion-sensitive areas, “but it does not compute sediment yields from gully, stream bank, and streambed erosion” (Wischmeier and Smith, 1978). Although originally developed for agricultural purpose, use of USLE has been extended to watershed with other land uses (Yılman, Ebru F., 2009).

This study was establish to predict the average of soil loss (tons/hectare) per year by combining the USLE method and geographic information system tools Arc GIS.

2. MATERIALS AND METHODS

2.1. Study Area

The city of Çorum is situated in the area where the Black Sea Region joins Central Anatolia. Çorum is surrounded by the cities of Amasya in the east, Çankırı in the west, Yozgat in the south, Kırıkkale in the southwest, Sinop in the north, Samsun in the northeast and Kastamonu in the northwest. With its area of 12.820 km², the city constitutes approximately 1.6% of the total area of the country. The city is located between north latitudes 39° 54' – 41° 20' and east longitudes 34° 04' -35° 28'.

In this study, data and digital maps of “General Directorate of Rural Services” which contains soil reports Çorum city lands and Yeşilirmak Basin were used. By using the digital elevation model Arc Hydro tool, basin border were tried to specify, in first part of study. Using sub basin borders, specific working area is limited in the figure 1. below.

The selected study area is approximately 4014.50 hectares. Study site is located at an altitude between 356 and 2095 m above sea level in the west of Çorum province. The region has an arid climate with a long-term annual average precipitation of 446 mm and average temperature is 21. °C in summer and –0.5 °C in winter.

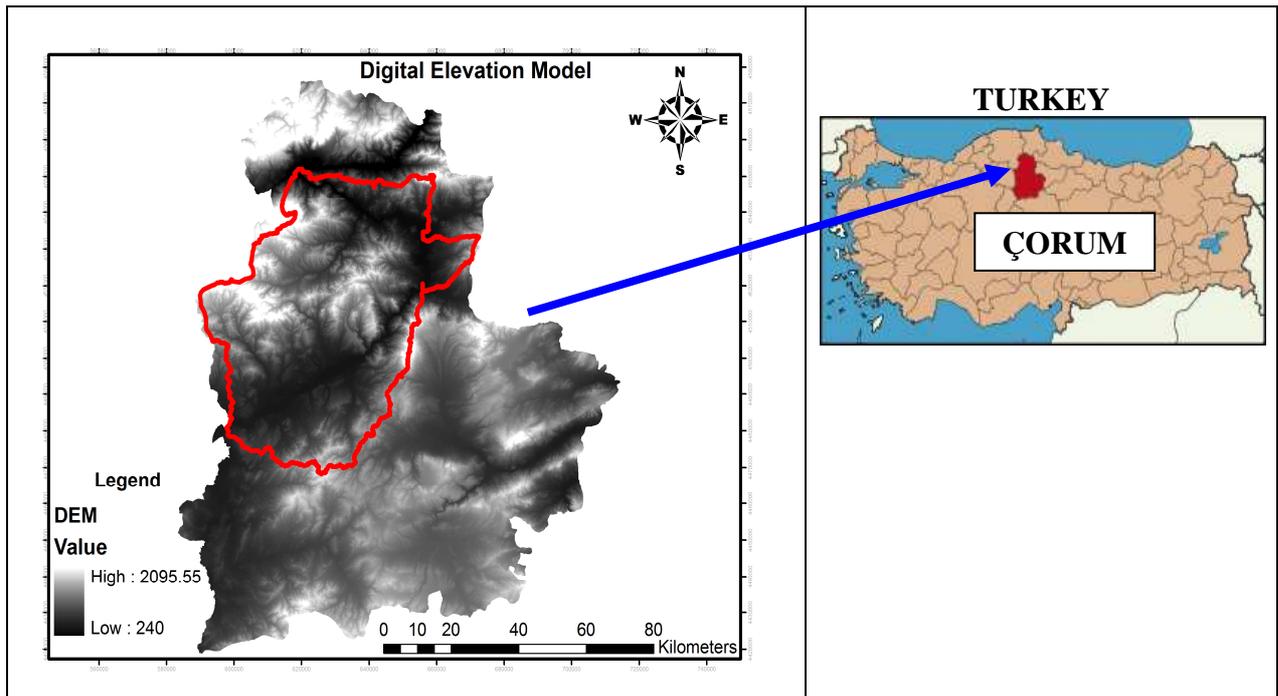


Figure1. Map of Study area

2.2. Method

The universal soil loss equation is an empirical model developed by Wischmeier and Smith (1978) to estimate soil erosion from fields. Mathematically the equation is denoted as:

$$A \text{ (tons/ha/year)} = R * K * L * S * C * P \quad (1)$$

A = Annual soil loss

R = Rainfall and runoff erosivity index

K = Soil-erodibility factor

L = Length of slope factor

S = Degree of slope factor

C = Cropping-management factor

P = Conservation practice factor

2.2.1. Rainfall Erosivity Factor (R)

R factor is the coefficient of the average erosion by rain (J/m^2). Rain is a direct impact to the surface of soil; its kinetic energy is destroying the soil structure and brings the soil components together with runoff water. According to Wischmeier and Smith (1978), the R coefficient is calculated based on maximum rain volume in 30 minute, the equation is following:

$$R = EI_{30}/1000 \quad (2)$$

In which:

E is kinetic energy of the rain (J/m^2)

I is the maximum rain volume in 30 minute (mm/h)

However in Turkey and also in many other countries, to record enough number of the E_i is difficult, so the equation (2) is hardly applied in many areas as Turkey. Researchers give other solution for R factor. It was suggested calculating by the average rainfall year or month. Almost of the researchers given the correlate coefficient in this case is from 0.8 – 0.9. According to Ha N.Tr (1996), the R coefficient can be calculated based on the average rainfall year, the equation is following:

$$R = 0,548257P - 59,9 \quad (3)$$

In which

P is the average rainfall year (mm/year) (Nguyen Ma. Ha., 2011).

In addition, Toy and Foster say that, where no rainfall data are available to compute the R value by standard methods, an estimate of R may be made based on the difference in elevation using the relation below:

$$R_{\text{new}} = R_{\text{base}} (P_{\text{new}}/P_{\text{base}})^{1.75} \quad (4)$$

where:

R_{new} = the new value for R at the desired new location when an R value is not available from a map,

R_{base} = R value at a base location where R is known,

P_{new} = the average annual precipitation at the new location, and

P_{base} = the average annual precipitation at the base location (Toy, T. and Foster G. R., 1998, Ozcan, U., et. al., 2008).

Çorum Meteorology Station R value (37.5) is calculated by interpolation from the iso-erodent map of Turkey prepared by Doğan (1987). The study area has a meteorological station at the altitude 776 m (Çorum Meteorology Station), and altitude in the area is between 356 - 2095 m. R values of unknown elevations were computed by using DEM in ArcGIS and equation (4) by assuming a 50 mm increase of precipitation with each 300 m increment in altitude. The layer of the rainfall erosivity factor R calculated and mapped by equation (4) using the DEM of the study area is shown in Fig. 2.

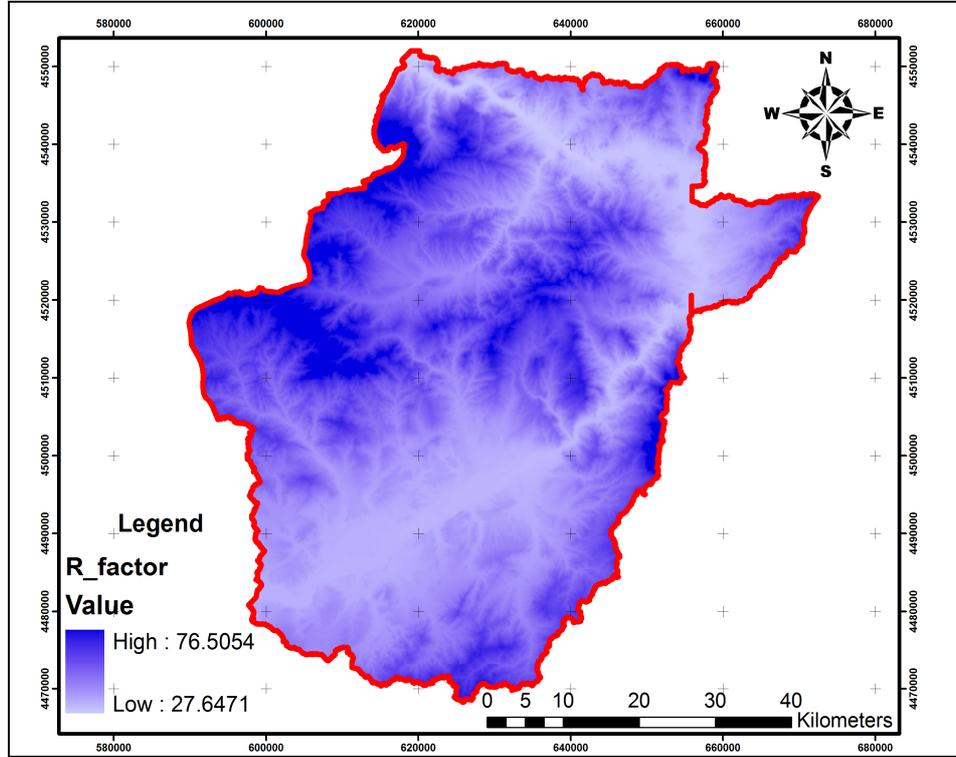


Figure 2. R factor layer

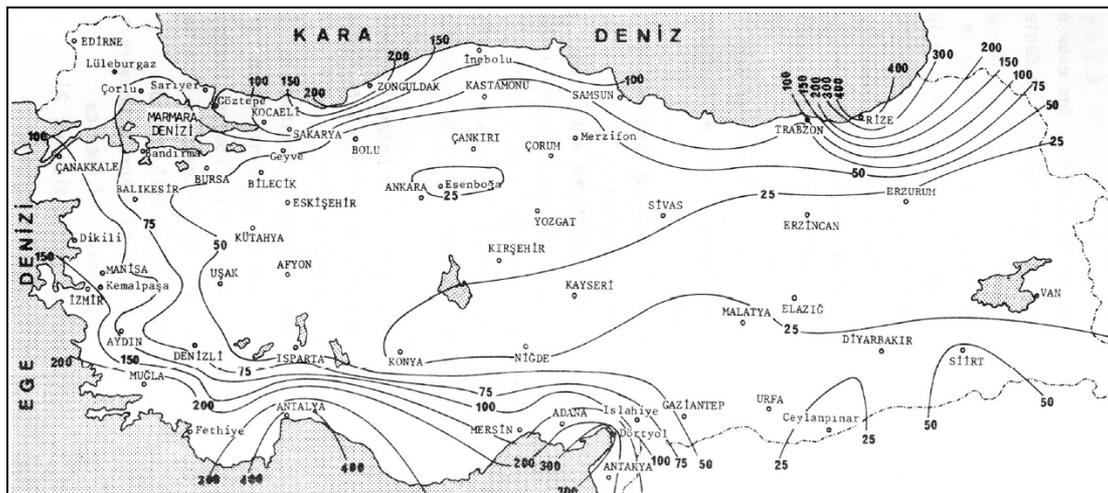


Figure 3. Iso-erodent map of Turkey prepared by Doğan (1987)

2.2.2. Soil Erodibility Factor (K)

The soil erodibility factor (K), represents both susceptibility of soil to erosion and the amount and rate of runoff, as measured under standard plot conditions. In this study, information required for the determination of the K factor values was obtained from earlier reports (TURTEM). Determined K values based on locally measured soil properties and using soil erodibility factor nomograph for great soil groups in Turkey. These values were annual averaged corresponding to homogeneous different soil groups. K values for study area are shown in Table 1.

Table 1. K factor value

Soil Symbol	Great Soil Groups in Turkey	K Value
A	Alluvial Soils	0.15
B	Brown Soils	0.13
C	Chestnut Soils	0.22
F	Reddish – Brown Soils	0.04
H	Hydromorphic Alluvial Soils	0.15
K	Kolluvial Soils	0.18
M	Brown Forest Soils	0.20
N	Noncalcic Brown Forest Soils	0.29
Ck, Iy etc.	Bare Rocks, River Bed etc.	0.001

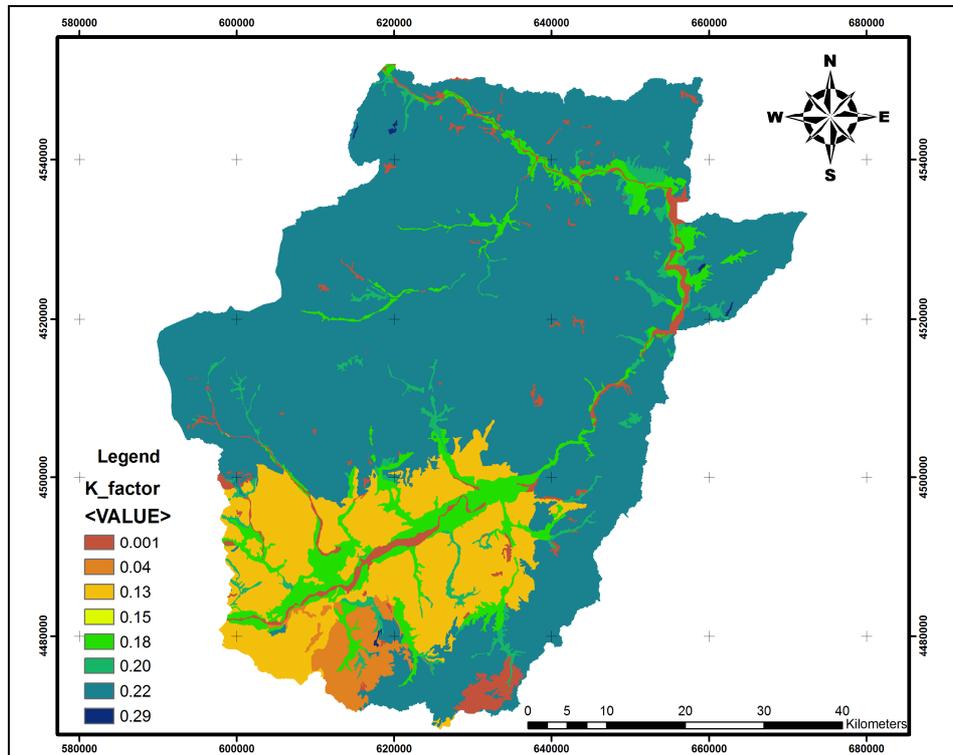


Figure 4. K factor layer

2.2.3. Slope Length and Slope Steepness (LS)

The slope length and slope steepness can be used in a single index, which expresses the ratio of soil loss as defined by (Wischmeier and Smith 1978).

$$LS = (X/22.1)^m (0.065 + 0.045 S + 0.0065 S^2) \quad (5)$$

Where

$$X = \text{slope length (m) and } S = \text{slope gradient (\%)}$$

Slope percentage layer was derived from digital elevation model (DEM) of the study area and slope length was assumed to be fixed as 20 m for each pixel. The values of X and S were derived from DEM. To calculate the X value, Flow Accumulation was derived from the DEM after conducting FILL and Flow Direction processes in Arc Hydro tool.

$$X = (\text{Flow accumulation} * \text{Cell value}) \quad (6)$$

By substituting X value, LS equation will be:

$$LS = (\text{Flow accumulation} * \text{Cell value} / 22.1)^m (0.065 + 0.045 S + 0.0065 S^2) \quad (7)$$

Moreover slope (%) also directly derived from the DEM using ArcGIS . The value of m varies from 0.3 –0.5 depending of the slope as shown in table 2. (Yılman, Ebru F., 2009). The result of the analysis is shown in figure 5.

Table 2. m value

Slope (%)	Slope (%) ≤ 3	Slope (%) = 4	Slope (%) ≥ 5
m -value	0.3	0.4	0.5

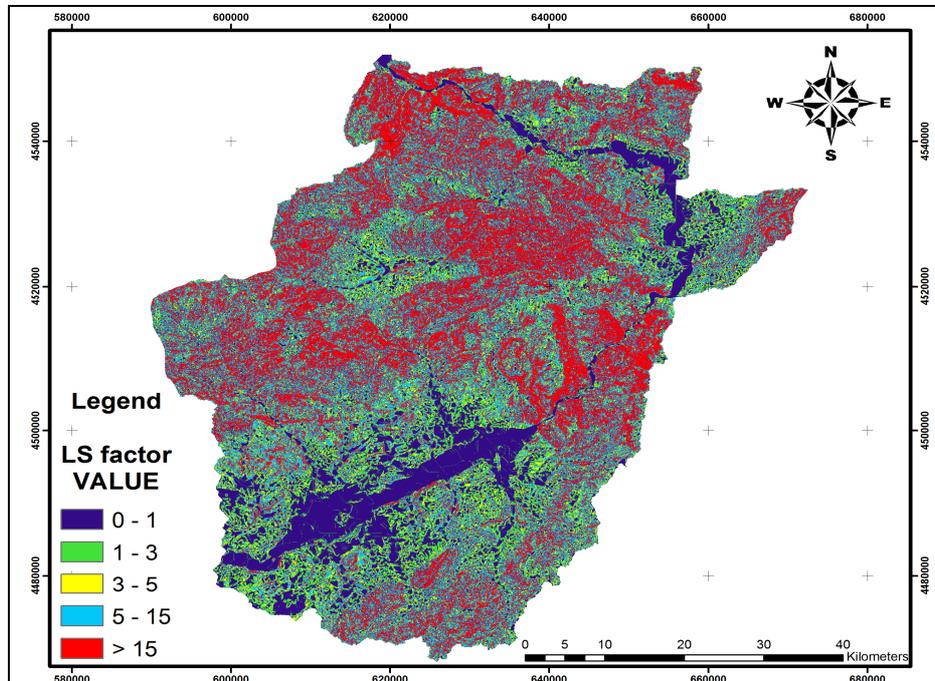


Figure 5. LS factor layer

2.2.4. Cropping-Management Factor (C)

The C factor is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow. It measures the effect of canopy and ground cover on the hydraulics of raindrop impact and runoff; of cover and management the amount And rate of runoff; of coverage and management on soil structure, organic matter, soil tilth, evapotranspiration and other soil characteristics; of carryover from previous land use when land use changes; and of roughness from tillage or other disturbances (Pierca, E. J. et. al., 1986).

The land use map was used for analyzing the C value. After changing the coverage to grid, a corresponding C value was assigned to each land use classes using reclass method in ArcGIS as given by (İrvem and Tulucu, 2004) (Fig. 6).

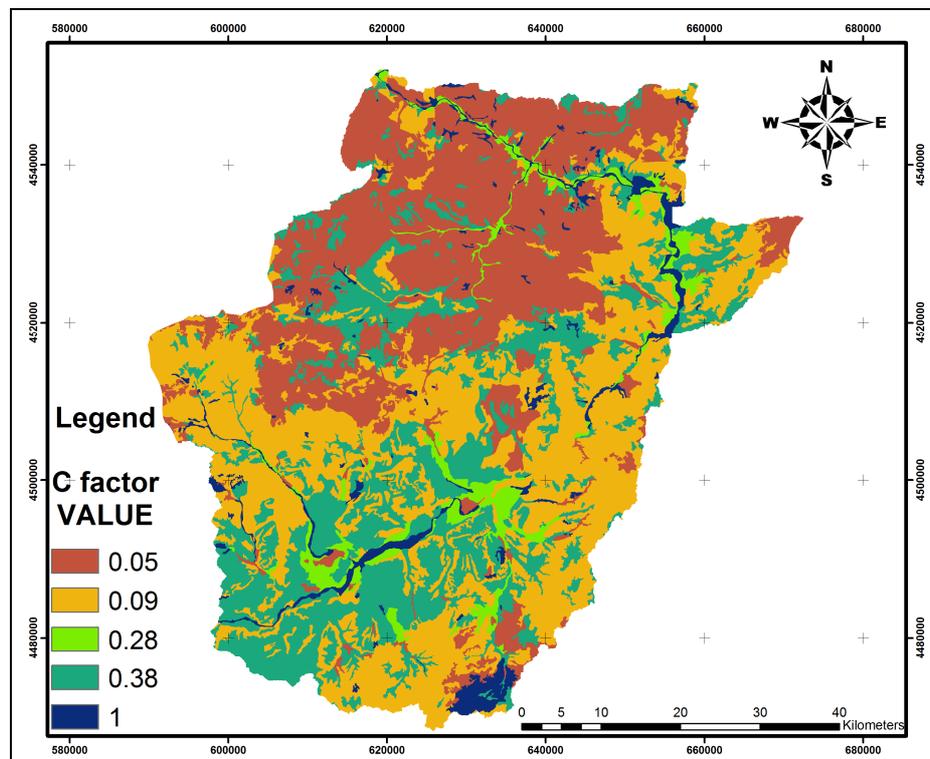


Figure 6. C factor layer

2.2.5. Conservation Practice Factor (P)

By definition, factor P in the USLE is the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope culture. Improved tillage practices, sod-based rotations, fertility treatments and greater quantities of crop residues left on the field contribute materially to erosion control and frequently provide the major control in a farmer's field (Wischmeier and Smith, 1978).

Assuming no support practice in the study area, it was not used in calculations (P factor = 1).

3. RESULT AND DISCUSSION

After completing data input procedure and preparation of R, K, LS and C maps as data layers, they were multiplied in the GIS to provide erosion risk map which shown (Fig. 7) spatial distribution of soil loss in the study area.

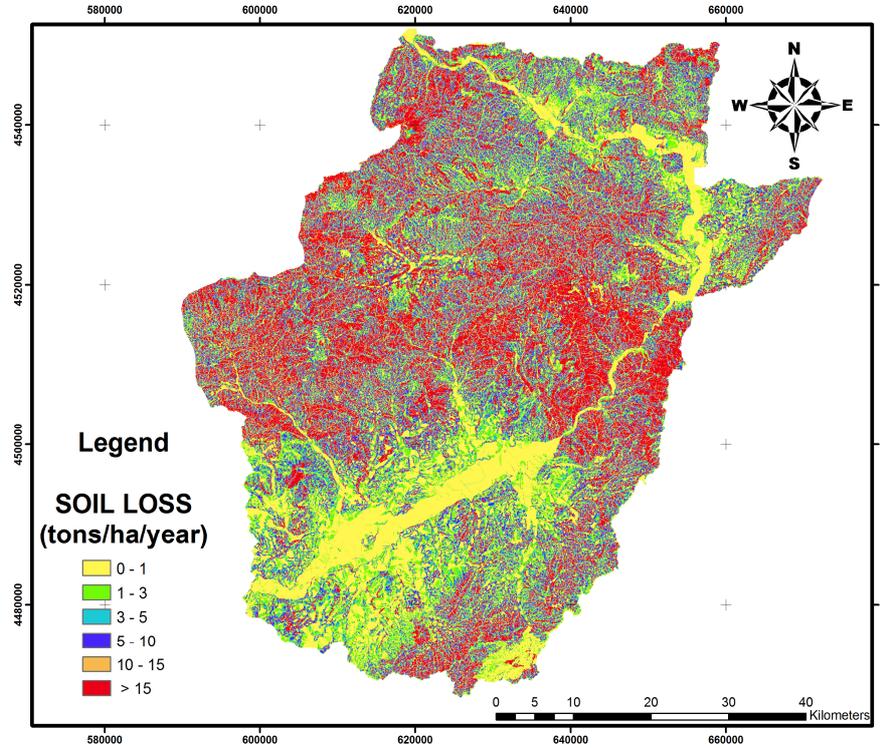


Figure 7. Amount of soil loss in study area

Table 3. listed the statistic of the soil loss value in study area.

Table 3. The degree of the soil loss potential in study area

Soil Loss Potential (ton/ha/year)	Area (Ha)	% Total Area
0 – 1	1150.59	28.66 %
1 – 3	534.63	13.32 %
3 – 5	419.62	10.45 %
5 – 10	703.40	17.52 %
10 – 15	399.12	9.94 %
>15	807.14	20.11 %
Total	4014.50	100.00 %

Approximately 29% was predicted to have soil loss between 0 ton/ha/year to 1 ton/ha/year. The soil loss ranges between 1 ton/ha/year to 3 ton/ha/year was estimated 13%. The soil loss ranges between 3 ton/ha/year to 5 ton/ha/year was estimated 10%. The soil loss ranges between 5 ton/ha/year to 10 ton/ha/year was estimated 18%. The soil loss ranges between 10

ton/ha/year to 15 ton/ha/year was estimated 10%. Serious rate soil loss (greater than 15 ton/ha/year) was obtained approximately 20% of the total soil loss prediction at west region of Çorum. The mean annual soil loss of the working area is 28.85 ton/ha/year.

REFERENCES

1. Nguyen Manh Ha. (2011). “Application USLE and GIS Tool to Predict Soil Erosion Potential and Proposal Land Cover Solutions to Reduce Soil Loss in Tay Nguyen”, FIG Conferance 2011, Marrakech, Morocco
2. Wischmeier, W.H and Smith, D.D: Predicting Rainfall Erosion Losses, USDA Agr. Res.Serv. Handbook 537, 1978.
3. Okalp, Kıvanç (2005). “Soil Erosion Risk Mapping Using Geographic Information Systems: A Case Study On Kocadere Creek Watershed, Izmir”. Ph.D thesis, Middle East Technical University , Turkey
4. Yılman, Ebru, F. (2009). “Predicting Soil Loss In The Catchments Of Eldivan Sarayköy-II Dam (Çankırı), By The RUSLE Methodology”, M. Sc. thesis, Ankara University , Turkey
5. Ozcan, U., et. al. (2008). “Use of USLE/GIS technology integrated with geostatistics to assess soil erosion risk in different land uses of Indagi Mountain Pass–Çankiri, Turkey”, Environmental Geology, 53 , pp. 1731–1741
6. Foster, G. R., et. al. (1981). Conversion of the Universal Soil Loss Equation to SI metric units. Journal of Soil and Water Conservation 36(6):355-359.
7. Toy, T. and Foster G. R. (1998). “Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands”
8. Pierca, E. J. et. al. (1986). “Field Estimates of C Factor: How Good Are They and How Do They Affect Calculations of Erosion?”, Soil Conservation: An Assessment Of The National Resources Inventory, Volume 2 , pp. 63-75
9. ÖZEL, M., et. al. (1998). “Dalaman Basin Erosion Mapping Pilot Project With Satellites”, TUBITAK, Kocaeli, Turkey
10. Özden, S. and Özden M. (1997). “Turkey Soil Erosion Estimation Model”, Soiland Fertilizer Research Institute, Turkey
11. İrvem, A., and Tülücü, K. (2004). Coğrafi Bilgi Sistemi ile Toprak Kaybı ve Sediment Verimi Tahmin Modelinin (EST) Oluşturulması ve Seyhan-Körkün Alt Havzasına Uygulanması. <http://fbe.cukurova.edu.tr/makale/cografibilgisistemi.pdf>. (10.08.2006).

URL 1: Application of GIS for Modeling Soil loss rate in Awash River Basin, Ethiopia
(<http://www.iwmi.cgiar.org>)

BIOGRAPHICAL NOTES

Fazlı Engin Tombuş is currently a Lecturer at the Vocational School Department of Technical Programs Map and Cadastre Program of the Hitit University in Turkey.

Mahmut Yüksel works as a Professor at Department of Soil Science and Plant Nutrition Of Ankara University

Murat Şahin is currently a Lecturer at the Vocational School Department of Technical Programs Map and Cadastre Program of the Hitit University in Turkey.

İbrahim Murat Ozulu is currently a Lecturer at the Vocational School Department of Technical Programs BİLGİSAYAR Program of the Hitit University in Turkey.

Mustafa Coşar is currently a Lecturer at the Vocational School Department of Technical Programs Map and Cadastre Program of the Hitit University in Turkey.

CONTACTS

Fazlı Engin TOMBUŞ

Hitit University Vocational School

Department of Technical Programs

Map and Cadastre Program

Samsun Cad. No : 99 Posta Kodu:19169

Çorum

TURKEY

Tel. +90 364 2230800

Fax + 90 364 2230804

Email: fengintombus@hitit.edu.tr / engintombus@yahoo.com