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Çapakçur Havzasında (Bingöl Türkiye) Toprak Kayıplarının RUSLE Metodu ile Tahmini ve Sediment Verimi ile Karşılaştırılması

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ÖZET

Bu çalışmada yüksek erozyon riski bulunan Çapakçur havzasında toplam ve net erozyonun belirlenmesi amaçlanmıştır. Bu doğrultuda Çapakçur havzasında yıllık toprak kaybı, RUSLE modeli kullanılarak tahmin edilmiştir. Net erozyon ise Çapakçur çayının 2019 yılı boyunca aylık debi ve sediment konsantrasyonlarının belirlenmesi ile doğrudan ölçülmüştür. Çapakçur havzasında meydana gelen toprak kaybı 96916.20 ton yıl^{-1} olarak tahmin edilmiş ve Çapakçur çayından taşınan toprak miktarı ise 68656.09 ton yıl^{-1} olarak gerçekleşmiştir. Havzada, sediment iletim oranı (SDR) 0.78 olarak hesaplanmıştır. Bu oran Türkiye ortalamasının (0.23) oldukça üstündedir. Havzadaki eğim uzunluğu ve derecesinin yüksek, yağış ve vejetasyon kapalılık oranının düşük olması SDR'nin yüksek olmasının ana nedenidir. Yüksek SDR nedeniyle havzanın verimli olan üst toprak katmanı Murat Nehrine taşınmaktadır. Bu durum hem toprakların verimsizleşmesine hem de kısıtlı olan tatlı su kaynaklarının kirlenmesine neden olmaktadır. Havzada bitki örtüsü ve amenajman, uygulamalarının iyileştirilmesi için ağaçlandırma ve teras, tel kafes ve oyuntularda taş duvar gibi toprak koruma uygulamalarının arttırılması gerekmektedir.

Toprak Bilimi

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 18.01.2022
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Anahtar Kelimeler
Havza yönetimi
RUSLE
Toprak erozyonu
Sediment taşıma oranı
Toprak ve Su Koruma

Estimation of Soil Losses in Çapakcur Watershed (Bingol, Turkey) Using RUSLE Method and Comparison of Predicted Soil Losses with Sediment Yield

ABSTRACT

The present study aimed to determine the total and net erosion in the Capakcur watershed, which has a high erosion risk. Accordingly, annual soil loss in the Capakcur watershed was estimated using RUSLE method. Net erosion was determined directly by measuring the monthly flow rate and sediment concentrations of the Capakcur stream, which originated from the Capakcur watershed and flowed into the Murat River throughout 2019. Estimated soil loss in the Capakcur watershed was 96916.20 ton yr^{-1}, and the amount of soil transported from the Capakcur stream was 68656.09 ton yr^{-1}. Sediment delivery ratio (SDR) was calculated as 0.78. This ratio was well above the average SDR of Turkey (0.23). Topographic factors such as slope length and degree, rainfall, and low vegetation cover ratio in the watershed are the main causes of the high SDR. Due to the high SDR, the fertile surface soil layers of lands in the basin are carried to the streams. This causes both decrease in fertility in soils and pollution of the limited freshwater resources. In order to improve vegetation and management practices in the watershed, soil protection practices such as afforestation and terraces, wire cages and stone walls in gullies should be increased.

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INTRODUCTION

Erosion is a global threat that plays a significant role in the degradation of important natural resources such as soil and water. Approximately 85% of land degradation in the world is related to soil erosion, which has resulted, directly or indirectly, in a 17% loss in agricultural productivity since World War II (Oldeman et al., 1990; Angima et al., 2003). Soil erosion reduces the quality of natural resources and can cause major environmental disasters (drought, floods). The negative ecological and social impacts of erosion constrains the sustainable regional development (Pan and Wen, 2014).

Soil erosion varies with the changes in the conditions of biophysical environment, including soil texture, climate, land conditions, ground cover and their interactions. Soil erosion, a dynamic, complex, and irregular process, occurs as a result of the effect of many factors. The most important factors affecting the soil erosion mechanism are land shape, slope, land area, and land use. The direction and impact of the slope play an important role in the runoff mechanism. High slope increases the runoff and reduces the amount of water infiltrating into the soil (Meral et al., 2019). Soil erosion is often the dominant cause of topsoil loss (Onori et al, 2006; Kouli et al., 2009). The soil cover (plants, organic wastes, etc.) decreases the surface area of soil susceptible to raindrop effect and also reduces the runoff velocity. Therefore, no-tillage or reduced tillage practices are considered appropriate management practices to reduce soil erosion in agricultural areas due to the residues on soil surface and a decrease in runoff (Fu et al., 2006). Rainfall (R) plays an important role as a trigger in the initial phase of erosion. The previous studies have emphasized that rainfall and rainfall intensity are the most critical factors (Mohamadi and Kavian, 2015; Katebikord et al., 2017).

Serious efforts have been carried out to develop soil erosion models around the world. Usually, a quantitative evaluation is needed to make conclusions about the extent and magnitude of soil erosion problems (Prasannakumar et al., 2012). Effective management strategies can be developed on a regional basis using the quantitative data obtained from local measurements. Erosion models can be also used to develop alternative land management scenarios using both measured and unmeasured basins and to make decisions for natural resource management (Fıstıkoğlu ve Harmancıoğlu, 2002). Various approaches and models have been developed to evaluate soil water erosion and predict soil erosion risk. Each approach or model has its characteristics and application purposes (De Vente and Poesen, 2005; Boardman, 2006). Experimental (USLE and RUSLE), conceptual (AGNPS and SWAT) and physically based models (EROSEM and CREAMS) have been used frequently for soil erosion and sediment transport (Farhan and Nawaiseh, 2015). One of the most widely used experimental models to evaluate soil and gully erosion is the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith in 1978. Initially, soil erosion estimation in cultivated lands using USLE was developed for slightly sloping topographic areas. The revised versions (RUSLE, MUSLE) have are the most commonly used and well-known and universally accepted and implemented empiri-cal soil erosion estimation model methods in the world for soil loss estimation (Wischmeier and Smith, 1978; Jha and Paudel, 2010, Shit et al., 2015; Ghosal 2020; Meral et al, 2021).

In erosion modelling, Sediment Delivery Ratio (SDR) has been treated as a constant parameter for a long time; however, there has been increasing interest in accounting for deposition and applying spatially variable or regionalised SDR (Ali and De Boer, 2010; Vigiak et al., 2012). The sediment delivery ratio (SDR) is the ratio of sediment yield to total surface erosion. The importance of the SDR and the sources for the region to be impacted by the catchment sediment, the transport system, the texture of the erosion content, the urbanization and land cover, etc., must be determined. Rainfall erosivity, soil erodibilty, land use cover, and topography are significant factors affecting sediment yield and sediment distribution. Sediment delivery to a given watercourse is increasing as catchments are progressively modified by human activities such as deforestation, agriculture expansion, construction, and urbanization (Dong et al.; Dutta, 2016; Berta et al., 2020; Joshi and Yadav, 2021). The RUSLE model was used with (SDR) to determine the life ratios in arid basins of Turkey (Saygın et al., 2014). SDR is defined as the fraction of grosserosion that is transported from a given catchment ina given time interval (Lu et al., 2006). Sediment yield can be quantified by multiplying gross erosion and sediment delivery ratio (Llena et al., 2021; Alencar et al., 2021).

Land use status and vegetation, especially precipitation and topographic factors, have an effect on the severity of erosion (Kijowska-Strugała et al., 2018; Wubie and Assen, 2020). Soil erosion generally consists of three stages: decomposition of soil aggregates, transport of decomposed material, and accumulation of this material (Foster, 1982). Soil losses estimated using empirical equations and sediment load transported from the same area are not directly related to each other. However, it gives an idea about the production, storage, and transportation of sediment formed in the watershed in relation to environmental processes (Fayas et al., 2019). While estimating the total amount of displaced soil using soil loss estimation equations, the net erosion is determined by calculating the amount of sediment carried in the rivers (Jain and Kothyari, 2000; Thomas et al., 2018). Many methods have been developed to estimate SDR (Boyce, 1972; Williams, 1977).

The present study aimed to estimate total soil loss in the Capakcur watershed (Bingöl), where the Capakcur stream with high sediment concentration crosses, to determine the sediment yield by periodic sediment and flow measurements in the Capakcur stream, and to determine the SDR using the data obtained. Accordingly, the soil loss occurring in the Capakcur watershed was determined using the revised soil loss estimation equation (RUSLE).

MATERIAL ve METHOD

The present study was carried out in Capakcur watershed, located in the upper Fırat Basin which is a part of Eastern Anatolia Region of Turkey (Figure 1). The study area is located between 38° 51'N, 40° 16'E and 38° 53'N, 40° 28'E. The coverage of study area is 9556.87 ha and has a very rugged topographic structure. The altitude of the watershed ranges from 1150 m to 2500 m. The average altitude is 1650 m, the total annual precipitation is 949 mm, the number of snowy days is 117, and the number of days covered with snow is 76 (Figure 2).

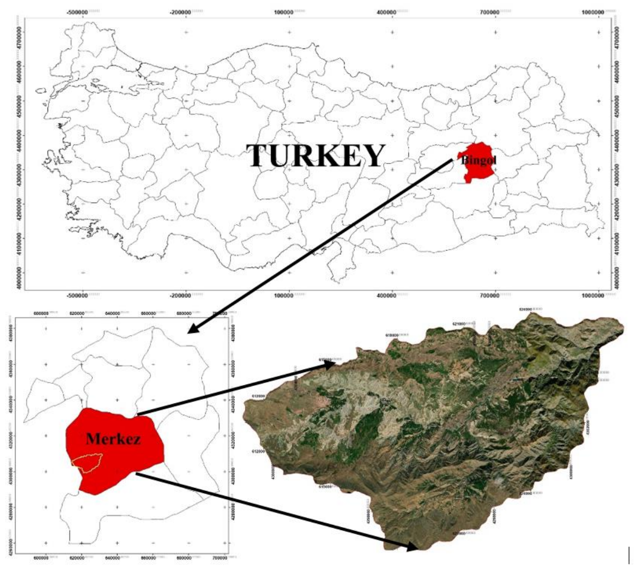

Figure 1. Location of Capakcur watershed, Southeast Turkey.
Şekil 1. Çapakçur havzasının konumu

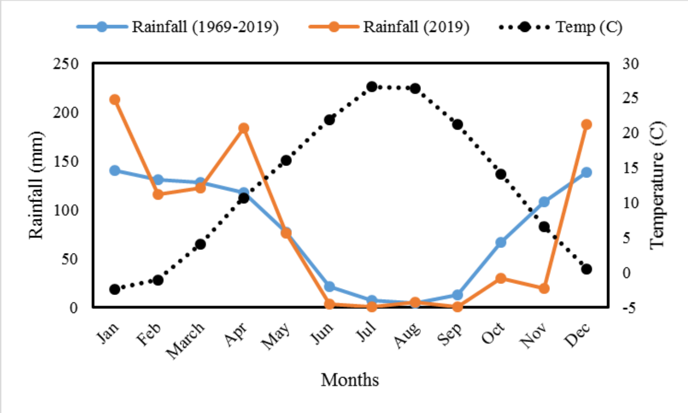

Figure 2. Climate data for period of 1969-2019
Şekil 2. 1969-2019 dönemi için iklim verileri

Data Sources

Surface soils (0-20 cm) were sampled to determine the soil erodobility factor (K) of the study area. Soil samples were collected from approximtely the corners of 500m x 500m grids (Carter and Gregorich, 2007). Total of 428 surface soil samples were collected throughout the basin. For the calculation of rainfall and runoff erosivity factor (R), long-term climate data of the meteorology station closest to the study area were used. Digital elevation model (DEM) data of the Capakcur watershed with a resolution of 15m x 15m was obtained to determine the slope length and slope degree factor (LS). DEM data was generated used ArcGIS Pro software using isohips curves.

The DEM data was passed through Fiil skins, Flow direction and Flow accumulation processes, respectively, using the ArcMap software, and the LS factor codes of the area were produced. Land use and land cover factor (C) obtained from CORINE Land Cover 2018 (URL 1) and soil protection measures factor (P) were obtained from the map and numerical data produced in the rehabilitation study conducted by the Ministry of Agriculture and Forestry, General Directorate of Combating Desertification and Erosion in 2015 (Anonymous, 2015). In the study, periodic water sampling and flow measurements were carried out from the exit point of the watershed to determine the amount of sediment carried in the Capakcur stream.

Methods

The Revised Universal Soil Loss Equation (RUSLE) model was used to estimate soil losses from the Capakcur watershed. In addition, the monthly sediment load carried in the Capakcur stream was measured to determine the amount of sediment carried from the basin.

Description of RUSLE Model

The RUSLE model was used due to the easy integration of spatial analysis with GIS (Wischmeier and Smith, 1978). The RUSLE model is expressed by the following equation (Renard et al., 1997);

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

In the quation; A is average soil erosion per unit surface (t/ha·year), R is rainfall and runoff erosivity factor (MJ·mm/ha·h·year), K is soil erodibility factor (t ha h/ha MJ mm), LS is slope length and slope steepness factor, C is vegetation cover, management, and culture practices factor, P is mechanical practices factor.

Rainfall has a significant impact on the occurrence and severity of erosion (Wischmeier and Smith, 1978; Fraser et al., 1999; Nearing, 2001). The R factor is a function of the diameter of each raindrop, duration of rainfall, mass, the intensity of rainfall, and the falling rate of raindrops (Renard et al., 1997). Current monthly and annual rainfall data for 58 years (1961-2019) collected from the Bingöl meteorology station (38°53'04.9"N 40°30'02.5"E), located at 1145 m altitude, were used to calculate the R factor using the a commonly used equation (Eq 2) (Wischmeier and Smith, 1978).

$$R=\sum_{k=1}^{12} 1.735 \times 10^{\left(1.5\log_{10}\left(P_i^2/P\right)-0.08188\right)} \quad (2)$$

In the equation; R refers to erosion power of precipitation (MJ mm ha^{-1} $hr^{-1}y^{-1}$), Pi (mm) to average monthly rainfall, and P (mm) to total annual rainfall. For the Bingöl meteorology station, the 58 year average total rainfall was measured as 949 mm. The altitude of the study area is higher than the meteorology station. The R-value calculated according to this station does not exactly represent the Capakcur watershed. Accordingly, the R factor was calculated for each point sampled from the watershed using the following equation (Eq. 3) (Toy and Foster, 1998).

$$R_n = R_r (P_y/P_r)^{1,75} \quad (3)$$

Where; Ry is the corrected R-value for the location with the unknown R variable; Rr is the R-value for the reference station with known R variable; Py is the average annual rainfall (mm) for the location with unknown R variable, and Pr is the average annual rainfall (mm) for the reference station with known R variable. The precipitation erosion factor map for the Capakcur watershed was created by Inverse Distance Weighted (IDW) interpolation using the obtained point precipitation values with ArcGIS (Pro).

The parameters required to calculate the soil erodibility factor (K) of the Capakcur watershed were determined. Accordingly, 428 soil samples from the study area were prepared for analysis after preliminary preparations (such as drying, grinding, sieving). The particle size distribution of the soils was carried out according to the hydrometer method stated by Gee and Bauder (2002). Organic matter content (OM) of soils was determined according to Walkley and Blake metthod (1934). Permeability values of soils (disturbed samples) were determined using constant water level hydraulic permeability sets (Klute and Dirksen, 1986). The structural properties of each sample were classified as specified by Dexter (1988). Aggregate stability analysis was performed according to the wet sieving method (Kemper and Rosenau, 1986). Using these parameters, the K factor for each point was calculated using the following equation (Eq 4).

$$100 \times K = (2.1 \times 10^{4})\times(12-OM)\times M^{1.14} + 3.25 \times (S-2) + 2.5 \times (P-3)/d \quad (4)$$

In the equation; K is the soil erodibility factor to erosion, OM is the organic matter, S is the soil structure class code (1-6), P is permeability (1-4), M: Grain size distribution parameter, d: Conversion coefficient to the metric system. The following formula (Eq 5) was used to calculate the M factor in this equation (Wischmeier and Smith, 1978).

$$M = (\%Silt + \%Sand) \times (100 - \%\,Clay) \quad (5)$$

The length and degree of the slope are parameters directly related to the severity of erosion (Khare et al., 2017). In a standard USLE parcel with a slope of 9% and a length of 22.1 meters, LS value is equal to 1 and LS values are not absolute values (Wischmeier and Smith, 1978). Since the study area has a very heterogeneous topography, a DEM (Digital Elevation Model) was created by digitizing contour lines from topographic maps in the ArcGIS software to estimate the LS factor (Rozos et al., 2013). LS values were calculated using the following formula (Eq 6) developed by Moore and Burch (1986) using the ArcGIS Pro software "flow direction" function.

$$LS = (L/22.13)^{0.4} \times (0.01745 \times \sin\theta/0.0896)^{1.4} \times 1.4 \quad (6)$$

Here: L is flow accumulation x cell resolution (DEM) and θ is "slope in degree". To compute LS factor using DEM in Arc MAP follow the following steps (Fig 3).

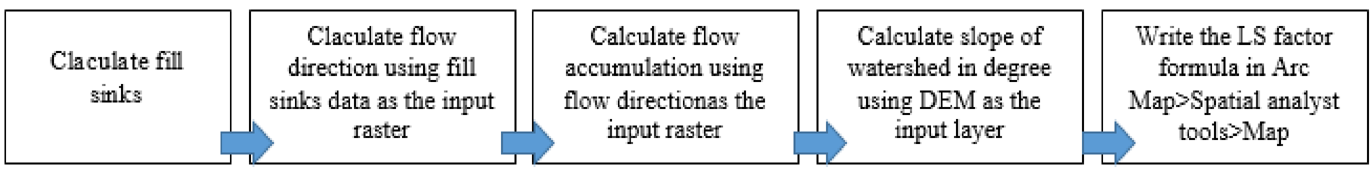

Figure 3. Methodology flow chart of Calculating LS factor using GIS
Şekil 3. CBS kullanarak LS faktörünü hesaplamanın metodoloji akış şeması

Forest stand maps of the study area produced by the General Directorate of Forestry and the CORINE 2012 data sets produced by the Department of Information Technologies of the Ministry of Agriculture and Forestry were used to obtain this data cover and management factor (C), (Panagos et al., 2015). However, in soil sampling studies, the land-use status (estimated vegetation coverage rate, vegetation type) of the sampling point was noted. Thus, C values were assigned to the area represented by each soil sampling point. C values assigned according to different land cover are given in Table 1. C values are classified according to Kayet et al. 2018 and Meral 2021.

Table 1. Land use in the Capakcur watershed and the corresponding C factor code
Çizelge 1. Çapakçur havzasında arazi kullanımı ve buna karşılık olan C faktör kodu

Land use/Land cover Type	C factor
Fallow	1
Dry fallow	1
Agricultural crop (Wheat)	0.4
Agricultural crop (corn)	0.45
Poorly managed pasture	0.25
Settlement	0.1
Dense forest	0.15
Natural shrubs	0.15
Water bodies	0.1
Fruit orchards	0.4

Support and Conservation Practices factor (P) is defined as erosion prevention applications to reduce soil loss by erosion. The measures taken to keep the free soil particles close to the source and to prevent the further transport of the particles are calculated to determine the value of the P factor,. P-value takes a value between 0 and 1, according to soil protection measures. P-value is assigned as 1 for areas where no protection application is applied (Renard et al., 1994). In the Capakcur watershed, some soil protection and erosion prevention practices were carried out by the General Directorate of Combating Desertification and Erosion in 2015 (ÇEM, 2015). Within the scope of these applications, terraces, stone walls, and wire cage structures were established in the work area. Within the scope of this study, a P factor value was assigned for each application area (Table 2).

Table 2. Soil protection practices in the Capakcur basin and the corresponding P factor codes
Çizelge 2. *Çapakçur havzasında Toprak koruma uygulamaları ve buna karşılık gelen P faktör kodları*

Soil conservation practices	P Value
Non practice	1.00
Contouring	0.60
Contoru strip-cropping	0.35
Terrracing	0.15

Soil erosion severity classes and mapping

After calculating the R, K, LS, C, and P factors, which are the components of the RUSLE equation for the Capakcur watershed, all the base maps were created. Considering that the maps produced had the same resolution (15 m x 15 m pixels), using the ArcGIS software and the "Raster Calculator" command (multiplying all the created maps with each other), the annual soil loss of the watershed ($tons.ha^{-1}.yr^{-1}$) were determined and mapped. To create the soil erosion sensitivity map of the Capakcur watershed, soil erosion severity was grouped into five classes (low, medium, high, very high, and extremely high) according to the estimated pixel-level soil loss values (Singh and Panda, 2017; Fayas et al., 2019).

Sediment Yield (SY)

The Capakcur stream is the merging of many small streams in the Capakcur watershed. This water source rises at an altitude of approximately 2400 m, moves 50 km from west to east, and flows into the Murat River, the largest branch of the Fırat River (Fig 4).

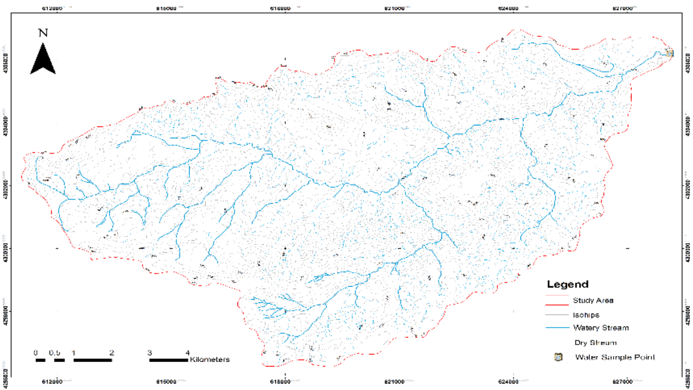

Figure 4. Water collection network of Capakcur stream in the basin
Şekil 4. Çapakçur çayının havzadaki su toplama ağı

Sediment yield (SY) is defined as the amount of sediment measured at a reference point for a certain period and is given as tons/year or spatially tons/year/km^2, m^3/year/km^2 (Verstraeten and Poesen, 2001). The net erosion in the watershed was determined by calculating the amount of sediment carried from the Capakcur stream. In this context, water samples were collected on the Capakcur stream at the exit of the Capakcur watershed, and the amount of sediment was determined in the laboratory.

Water samples taken three times amonth (periodic sampling was done every 10 days.) rom Capakcur stream were analyzed gravimetrically by filtration, drying, and weighing processes in the laboratory (Walling, 1994). The amount of solid matter per unit volume is taken as the ratio of the dry sediment weight to the volume of the water + sediment mixture (Mermer, 1996). The following equation (Eq 7) was used to determine the amount of sediment in water samples.

$$SC=DSW/((wv+Sv)) \quad (7)$$

where: SC: sediment concentration per unit volume (mg/L), DSW: dry sediment weight (mg), wv + Sv: volume of water sample taken from the stream (L). Flow velocity was measured simultaneously with water sampling from the Capakcur watershed. Flow velocity measurements were carried out using a digital velocity measurement device (Fig 5).

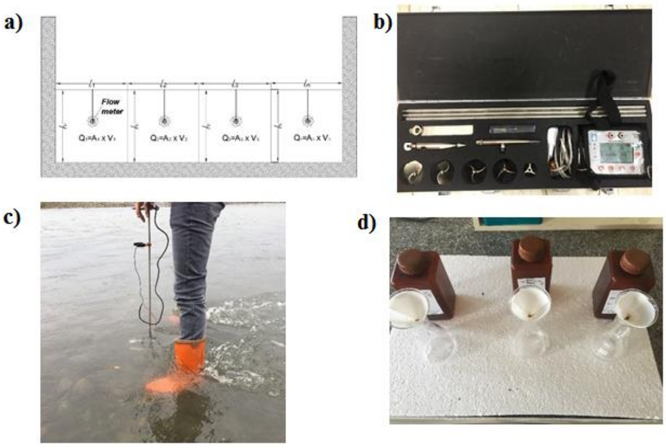

Figure 5. Flow and sediment measurement at the exit point of the watershed in the Capakcur stream. a) water bed section and definitions at the measurement point b) digital flow meter used in flow measurement, c) measurement of water velocity with digital flow meter, (the device was calibrated before measurements), d) Determination of the sediment content of water samples taken from the Capakcur stream.

Şekil 5. *Çapakçur çayında havzanın çıkış noktasında debi ve sediment ölçümü. a) ölçüm noktasındaki su yatak kesiti ve tanımlamalar b) debi ölçümünde kullanılan digital flow meter, c) digital flow meter ile su hızının ölçülmesi, (ölçümlerden önce cihazın kalibrasyonu yapılmıştır), d) Çapakçur çayından alınan su örneklerinin içeriğindeki sediment miktarının belirlenmesi*

Both water sampling and flow measurements were carried out separately for each 10-cm-depth (h1, h2,..) and each 1 m. stream width (L), and the average values were recorded. Thus, the velocity of the water flowing through a certain waterbed section was measured at the time of water sampling. Using the obtained data, the flow rate of water was measured with the help of the following equation (Eq 8).

$$Q=A \times V \quad (8)$$

Where: Q: flow rate (m^3/sec), A: streambed cross section area (m^2), V; flow velocity (m/sec). Sediment yield was calculated using the following equation (Eq 9).

$$SY=Q \times SC \times k \quad (9)$$

where: SY: sediment yield (ton/year), SC: sediment concentration, k:conversion coefficient (from mg/sec to ton/year).

Sediment delivery ratio (SDR)

The sediment delivery ratio (SDR) was determined using the estimated erosion amount (SE) from the watershed using the RUSLE equation and the sediment yield (SY) measured in the Capakcur stream in 2019. Sediment delivery rate (SDR) is defined as sediment yield from an area divided by gross erosion in the same area. It is calculated using the following formula (Eq 10) (Nguyen and Chen, 2018).

$$SDR=SY/SE \quad (10)$$

where: SDR: sediment delivery ratio, SY: sediment yield, SE: total soil erosion,

In recent years, SDR was estimated using some equations and GIS methods. Traditionally, delivery ratio estimation equations have been developed by correlating the basin characteristics with the measured sediment yield divided by the estimated gross erosion (Williams, 1977). However, in the present study, SDR was directly determined by estimating soil losses from the Capakcur watershed with RUSLE and directly measuring the sediment carried from the watershed.

Statistical evaluation

Data analysis for each of soil properties were conducted, exploratory data analysis was carried out calculating minimum, maximum, arithmetic mean, standard deviation, the coefficient of variation (CV), skewness were calculated. The effect of land use type (forest, pasture etc.) on AS was analyzed. The mean AS values of land use types were compared.The SPSS 16.0 software was used for statistical evaluations. The effect of land use type on AS was evaluated by one-way analysis of variance (ANOVA) ($P < 0.05$). The Duncan homogenity test was adopted to group statistically different mean values.

RESULTS and DISCUSSION

Prediction of Soil Loss

The R factor value of the watershed was between 400.72 and 497.93 Mj mm.ha^{-1}.h^{-1}.yr^{-1} with an average of 449.32 Mj mm.ha^{-1}.h^{-1}.yr^{-1}. These equations were solved with the assumption that every 300 m height increase will cause a 50-mm-increase in rainfall. The obtained R factor values corresponded to the values calculated by the General Directorate of Combating Desertification and Erosion (Erpul et al., 2018). The R factor values calculated for the Capakcur watershed were 427.46 and 499.26 Mj mm.ha^{-1}.h^{-1}.yr^{-1}. In regions with dominant continental climate (Li and Fang, 2016), such as the Capakcur watershed, the exposure of the soil surface to heavy rain is effective in the occurrence of water erosion and floods (Diodato et al., 2017). Previous studies indicated that low intensity long-term rainfall and short-period repetitive low-intensity rainfalls contribute significantly to total soil erosion (Baartman et al., 2013). This effect is more apparent in poor vegetation cover. R factor plays an important role in increasing the severity of erosion since a significant part of the Capakcur watershed has a bare soil surface.

Descriptive statisticsof the Capakcur watershed soils are given in Table 3. The average sand content was higher than clay and silt. Generally, areas other than some agricultural areas have a sandy texture. The average organic matter (OM) content was above 2% throughout the watershed. In a previous study in the basin, it was reported that OM content varied according to the land-use status. The highest OM content was found in forest areas, while the lowest was found in bare soils (Demir and Ersoy Mirici, 2020). The saturated hydraulic conductivity (HC) values were between 0.36 and 8.01 cm/h with an average HC of 4.23 cm/h. This value was classified as "moderately fast" (Warrick, 2003). The AS values were 2.25 and 90.90% with an average value of 40.07%. Variability of the properties in terms of coefficient of variation (CV) was classified as low (<15%), medium (15-35%) and moderate (>35%) (Mallants et al 1996). In this case, Silt showed medium variation, other parameters showed high variation.Tthe K factor of the Capakcur watershed was presented in Fig. 7.

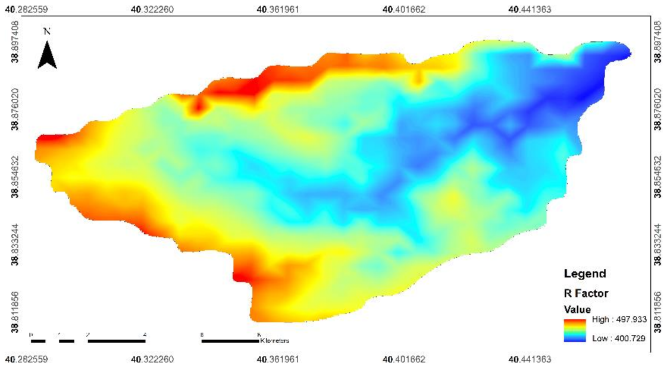

Figure 6. R factor map of Capakcur watershed
Şekil 6. Çapakçur havzası R faktörü haritası

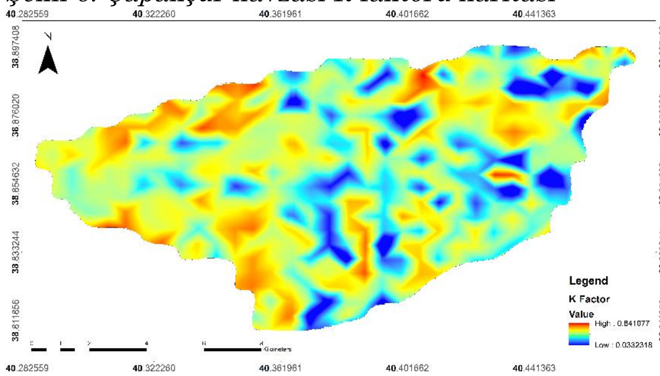

Figure 7. K factor map of Capakcur watershed
Şekil 7. Çapakçur havzası K faktörü haritası

Table 3. The area and percentage of soil loss values and classes in Capakcur watershed
Çizelge 3. Çapakçur havzasında toprak kaybı değerleri ve sınıflarının alan ve yüzdesi

Soil Properties	N	Min	Max	Mean	Std. Deviation	%Cv	Skewness
Clay (%)	428	2.00	33.36	13.14	5.54	42.16	1,26
Silt (%)	428	5.50	36.00	18.19	6.52	35.84	0,92
Sand (%)	428	36.61	89.50	68.65	9.06	13.19	-0,78
OM (%)	428	0.00	11.76	2.36	2.25	95.33	2,03
AS (%)	428	2.25	90.90	40.07	18.58	46.36	0,20
K (cm/h)	428	0.36	8.01	4.23	1.83	43.26	-0,05

OM: Organic matter, AS: Agregate stability, K:Permability. Skewness's STD. of AS values was calculated as 0.118.

K factor values of the Capakcur watershed were between 0.033 and 0.841. K factor was lower in forest areas with relatively high organic matter content and plains with high sand content. However, the K factor was higher in the west of the watershed where the silt content was high and the organic matter content was low. Liu et al. (2020) reported that the silt percentage and OM content of the soils directly affect the K factor. The slope length and steepness factor (LS) is an important due to the impact on the severity of soil loss in the Capakcur watershed. The slope in 50.36% of the watershed area was more than 40% (Table 4). This further facilitates runoff and therefore erosion on steep slopes.

The LS factor distribution map of the Capakcur watershed is given in Fig. 8. The LS values were between 0 and 107.238. The LS factor values were high in the southern parts of the watershed with sharp and steep slopes. The interaction of L and S has an effect on the magnitude of erosion. Accordingly, the effect of L and S should always be considered together (Edwards, 1987). The increase in slope length and slope height causes higher delivery speeds and therefore higher erosion (Haan et al., 1994)..

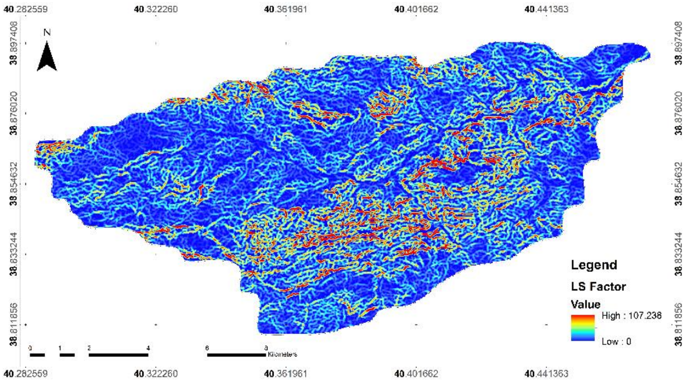

Figure 8. LS factor map of Capakcur watershed
Şekil 8. Çapakçur havzası LS faktörü haritası

Table 4. Slope degrees and the area they cover in the Capakcur watershed
Çizelge 4. Çapakçur havzasında eğim dereceleri ve kapladıkları alan

Slope (%)	Area (Ha)	Rate (%)
0-12	650.822	6.81
12-20	738.746	7.73
20-40	3354.461	35.10
40-60	3080.179	32.23
60<	1732.661	18.13
Total	9556.87	100

The type of the existing vegetation cover and the coverage area of the watershed were determined by field observations. The Capakcur watershed has a generally poor vegetation cover. The vegetation cover area in the watershed was 34.8%. This ratio was very close to the vegetation covering ratio of 31.8% determined by Demir and Ersoy Mirici (2020) using GIS. The C factor distribution map of the watershed is given in Fig 9. The C factor value in the watershed varied between 0.103 and 1. The Capakcur watershed has a very low topsoil coverage. The proportionality of forest, pasture, and agricultural lands resulted in a high average C factor (Cmean: 0.55). This average ratio was estimated to be 0.1043 in the European Union (Panagos et al., 2015). To reduce the erosion power of the C factor in the basin, it is necessary to make afforestation and soil conservation practices, especially in uncovered areas, and agricultural lands without tillage. Soil protection management practices (reduced/ no-tillage, use of cover plants, and plant residues) have been reported to reduce the C factor by an average of 19.1% in farming areas (Panagos et al., 2015).

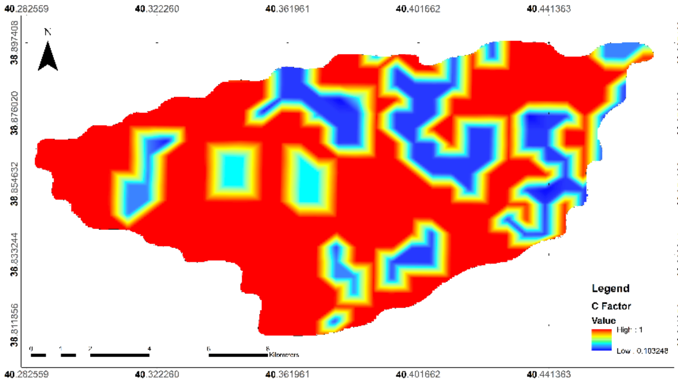

Figure 9. C factor map of Capakcur watershed
Şekil 9. Çapakçur havzası C faktörü haritası

In the Capakcur watershed, an improvement (erosion prevention and soil protection) study was carried out by GDF in 2015. In this context, soil conservation and erosion control (terrace, wire mesh) studies were carried out on a 506.9-hectare section. Accordingly, the P factor distribution map of the watershed was prepared (Fig 10). The P factor value in the Capakcur watershed varied between 0.4 and 1.

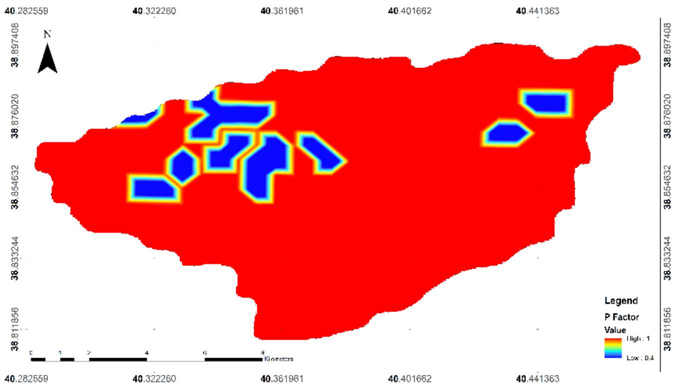

Figure 10. P factor map of Capakcur watershed
Şekil 10. Çapakçur havzası P faktörü haritası

The RUSLE soil loss (A) prediction map of the Capakcur watershed was produced by multiplying the R, K, C, LS, and P factors in the GIS environment. The distribution map of the estimated soil loss ($ton.ha^{-1}.yr^{-1}$) from the watershed is given in Figure 11.

The estimated soil loss in 66.14% of the Capakcur watershed was lower than 5 $ton.ha^{-1}.yr^{-1}$ (Figure 11). This is a low value according to the erosion susceptibility classification system. The occurrence of low soil loss in approximately 2/3 of the watershed is important in terms of soil management practices. The estimated soil loss in 14.73% of the area was 5-12 $ton.ha^{-1}.yr^{-1}$ (low). In the 7.2% area where moderate soil loss occurred, the estimated soil loss was between

12 and 25 ton.ha-1.yr-1. The estimated soil loss in an area of 682.53 ha where soil loss was classified as "high" was 25-60 ton.ha^{-1}.yr^{-1}. More than 60 tons.ha^{-1}.yr^{-1} land loss occurs in an area of 456.77 ha in the watershed where land losses are estimated as "severe" or "very high". According to these data, the total yearly soil loss from the watershed was found to be 96,915.20 tons. The average annual amount of soil loss per unit area from the watershed was determined to be 10.14 tons.ha-1. Every year, 642 million tons of soil erosion as a result of water erosion are displaced in Turkey. This value corresponds to an average of 8.24 tons of land per hectare (Erpul et al., 2018). The annual soil loss calculated in the Capakcur watershed is 18.77% higher than the average of Turkey. In the Fırat-Dicle main basin, where the Capakcur watershed is located as a sub-basin, the annual soil loss is 4.9 million tons.yr^{-1}. Thus, annual soil loss in the Capakcur watershed is higher than the loss of both Turkey and the Fırat-Dicle main basin.

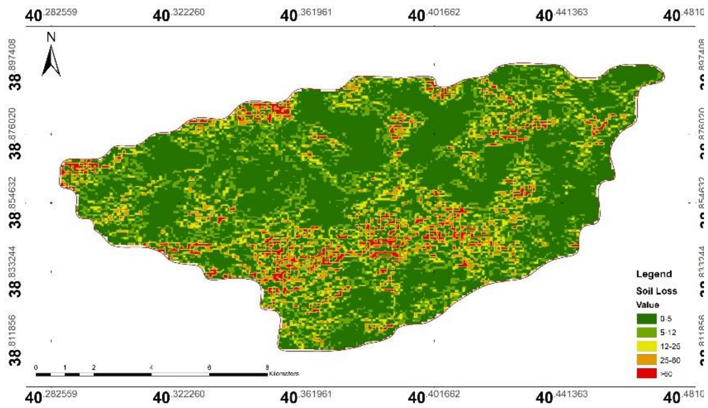

Figure 11. Erosion severity and soil loss map of Capakcur watershed

Şekil 11. Çapakçur havzasının erozyon şiddeti vetoprak kaybı haritası

Sediment Yield in Capakcur Stream

The Capakcur stream, which is formed by the combination of streams and runoff waters in the Capakcur watershed, passes through the Bingöl province center and flows into the Murat River. At the exit point of the watershed, the sediment concentration was determined periodically by sampling water from the Capakcur stream monthly during 2019. Also, the flow rate of the Capakcur stream was measured and the sediment load was determined using the equations (Fig. 12). The sediment concentration in the measurements made in Capakcur stream varied between 0.39 and 1.53 gr.L. However, the flow rate varied between 0.71 and 3.2 m^3.s. The monthly sediment amount delivered from the entire watershed varied between 769.82 and 11,540.36 tons. Total amount of soil lost due to the annual sediment carried from the watershed was 68,656.09 tons. In other words, the average amount of soil lost due to the sediment carried in the Capakcur watershed was 7.18 ton.ha.yr^{-1} (Fig. 13).

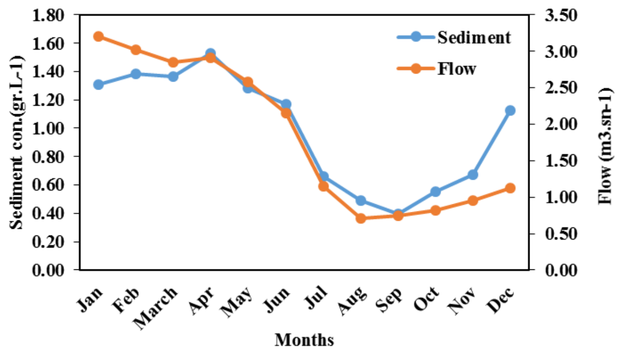

Figure 12. Monthly average sediment load and flow rate CS

Şekil 12. Çapakçur çayının aylık ortalama sediment yükü ve debi miktarı

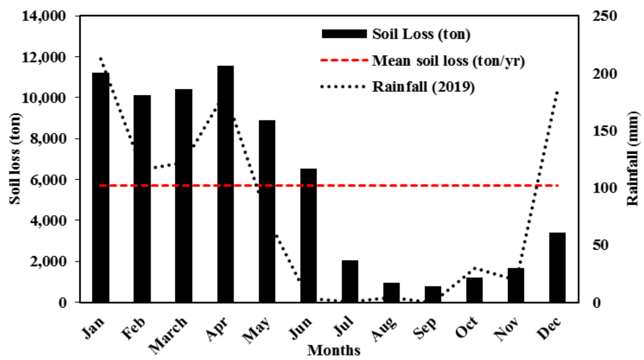

Figure 13. Amount of soil transported from Capakcur stream

Şekil 13. Çapakçur çayından taşınan toprak miktarı

In the present study, although sediment and flow rate measurements were carried out 3 times a month in the Capakcur stream, the data obtained may not reflect the actual results. On the other hand, the widely used sampling method is restrictive for spatial and temporal measurement of sediment and causes a heavy workload. These limitations and technological advances have led to methods that rely on sound or light travel in water. Therefore, measurements must be made continuously and instantaneously. Accordingly, it is necessary to use digital technologies in sediment and flow measurements in rivers in recent years (Meral et al., 2018). However, the measurements made in the present study (36 measurements/year) were predicted to be close to the actual result.

Sediment Delivery Ratio (SDR)

The sediment delivery rate (SDR) was directly calculated using the measurements made in

Capakcur stream and the estimated amount of soil loss in the watershed. The estimated amount of soil loss in the study was 96,915.20 tons.yr^{-1} while the amount of sediment carried by the Capakcur stream was 68 656.09 tons. yr^{-1}. According to these values, 70.81% of the estimated soil loss in the Capakcur watershed was realized as the net erosion. Therefore, SDR in the Capakcur watershed was determined to be 0.78. In the watershed where the summer months are arid, total annual precipitation is much lower than total evaporation. This increases the susceptibility of soils to erosion along with the wetting-drying process. The amount of moisture contained in pre-rainfall soils has an effect on the SDR variability (Santos et al., 2017). Also, it is effective on SDR in case of land use (agriculture, forest, pasture, etc.) (Pınar et al., 2020). Of the erosion in Turkey, 53.66% occurs in pastures, 38.71% in agricultural areas, and 4.17% in forest areas. It has been reported that 47.55% topography, 34.82% vegetation, 14.26% rainfall, and 3.36% soil factors had an effect on vegetation in Turkey. However, SDR has been reported to be 0.24 SDR in Turkey (Erpul et al., 2018). This ratio is considerably lower than the SDR determined in the Capakcur watershed. This requires effective planning of soil protection practices in the Capakcur watershed. The higher SDR is attributable to the above-average rainfall in certain months in 2019 in addition to the high annual rainfall in the watershed. The amount of rainfall in the Capakcur watershed in 2019 was the highest in January and April (212.6 mm and 183 mm, respectively). During these months, the flow rate and sediment concentration in the Capakcur stream increased compared to other months. This shows that the ratio of rainfall to runoff is high in this watershed. The dominance of the R factor, i.e. rainfall over the erosion severity in the watershed and the fact that a large part of the watershed has a slope of 40% or more increases the surface flow rate. Doğan Demir ve Demir (2016) have reported that there was a linear relationship between the amount of rainfall and the amount of sediment carried in the Palu watershed, which also includes the Capakcur watershed. The sediment delivery rate is affected by many highly variable physical properties of a watershed. It varies according to the drainage area, slope, relief-to-length ratio, flow-precipitation factors, land use/land cover, sediment particle size, etc. (Ouyang and Bartholic, 1997). The excess of steep slopes in the Capakcur watershed limited the accumulation of eroded soils, transmitting the vast majority to the Capakcur stream through gulleys (Figure 14).

Figure 14. The detachment area and Deposition area as a result of severe erosion in the Capakcur watershed, a large part of which is bare area, and high sediment concentration in the Capakcur stream due to the high SDR.

Şekil 14. Büyük bir kısmı çıplak alan olan Çapakçur havzasındaki şiddetli erozyon ve yüksek SDR nedeniyle Çapakçur deresinde yüksek sediment konsantrasyonu sonucu oluşan taşınma alanı ve çökelme alanı.

One of the most important reasons for the high annual soil cup and SDR in the Capakcur watershed is the current land use status of the watershed. The land-use case has significant effects on erosion (Sharma et al., 2011). Bare areas without vegetation constitute a large part of the watershed area. The vulnerability of soil aggregates in these areas to the crushing effect of rain increases the potential for erosion. Many studies have shown that land cover reduces erosion and increases the physicochemical properties of the soil (Wijitkosum, 2012; Alkharabsheh et al., 2013; Zaimes et al., 2017). In the present study, the effect of different land use on the aggregate stability of soils in the Capakcur watershed was evaluated (Table 5).

Table 5. Effect of land use-cover on agregat stability
Çizelge 5. Arazi kullanım örtüsünün agrega stabilitesi üzerindeki etkisi

Land Use	N	Mean±SD
Barren are soils (BAS)	290	40.82±18.3b
Degraded Forest Soils (DFS)	103	35.32±18.6b
Forest Soils (FS)	19	58.41±8.89a*
Agriculture and Pasture Soils (APS)	15	32.12±14.98b

*(p<0.05)

The results showed that the land use or land cover has a statistically significant effect on the aggregate stability of soils. In soil sampling from areas with fertile forest cover (FC), the average AS was determined to be 58.41%. On the other hand, AS values of BAS, DFS, and APS areas were found in the same group and lower. It is also difficult to obtain a consistent correlation between aggregate stability and other important soil properties such as soil erosion or scaling potential. However, it affects the movement and storage of aggregates and the soil pore structure, the course of erosion, and biological activity (Amezketa, 1999). Numerous studies reported close relationships between AS and soil erosion. In these studies, it has been reported that soil erosion decreased with the increase in AS (Shainberg et al., 1992; Le Bissonnais, 1996). This indicates that land use or land cover has a direct or indirect effect on erosion. Performing afforestation activities especially in bare areas in the Capakcur watershed and increasing the vegetation rate will both improve soil properties and reduce the severity of erosion.

CONCLUSIONS AND SUGGESTIONS

The Capakcur watershed has a high erosion capacity due to its topographic structure, agricultural activities (grazing, tillage etc.), vegetation, and precipitation regime. The Capakcur watershed had a high erosion-generating capacity after the rehabilitation studies. Annual total erosion occurring in the watershed was 10.14 tons.ha^{-1} which is considerably higher than the average (8.24 tons.ha^{-1}) of Turkey and the Euphrates and Tigris basins (9.1 tons/ha). The results showed that 19.09% of the basin area was exposed to soil loss of 12 tons.ha^{-1} or higher. This value is high in spite of some soil conservation practices (terrace, wire mesh, stone wall over the gully, etc.) carried out in the watershed in 2015. The high slope and length of the slope in the watershed, the low vegetation closure ratio on the ground, and the fact that rainfall is an effective factor cause high erosion and sediment delivery ratios. Here, it is necessary to increase the ratio of the cover and management factor in the watershed within the scope of effective combat against erosion. It is difficult to stop the severity and magnitude of soil erosion. However, it can be reduced by proper land use management and adequate support practices to protect the fertile topsoil in the watershed. Institutions authorized in this regard prioritize these areas on the soil loss map in soil conservation studies. On the other hand, the equations and estimation methods used to determine the net erosion in the watershed are undoubtedly very useful. However, using technologies (acoustic and laser beam) in which sediment transported from the watershed in territorial waters can be measured instantaneously and continuously will contribute to the fight against erosion in a more effective way. Because instant data obtained by the use of these technologies allows the continuous updating of soil management strategies.

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Researchers’ Contribution Rate Declaration Summary

Authors declares that the contribution of the authors is equal.

Conflicts of Interest Statement

Authors have declared no conflict of interest.

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