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# Reservoir Sediment Yield Prediction by RUSLE and the Effect of Data Resolution

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**Abstract**

Understanding and evaluating the interplay of RUSLE parameters and data resolution is crucial for accurate erosion predictions with respect to reservoir sedimentation. Correct assessment of erosion and resulting sediment yield is essential for addressing issues related to water quality, aquatic ecosystems, and the stability of infrastructure such as dams and bridges. In order to predict erosion and resulting sediment yield the slope length and steepness factor (LS) was derived from Digital Elevation Models (DEMs) obtained from diverse sources, including the Shuttle Radar Topography Mission (SRTM) and Advanced Land Observing Satellite (ALOS) at 30 m resolution, as well as TerraSAR-X and TanDEM-X DEMs at 12 m and 5 m resolutions provided by the State Hydraulic Works of Türkiye (DSI). Flow accumulation and slope steepness were computed to generate the LS factor, applying two distinct calculation methods for comparison. A GIS-based erosion prediction was implemented by RUSLE, incorporating R, K, C, and P factor datasets and validated by reservoir survey data. The influence of topographic resolution on sediment yield and erosion predictions was analyzed, revealing the sensitivity of model outputs to DEM resolution. Since RUSLE result depends on the quality of data its validation was necessary. This validation was carried out by the reservoir bathymetric surveys ($SY_{RS}$) of Borçka Dam ($SY_{RS}$=7.312 t/ha/yr) and Muratlı Dam ($SY_{RS}$=19.119 t/ha/yr). Sediment Delivery Ratios (SDR) of the reservoirs are

calculated by using Vanoni (1975) and USDR-SCS (1971) methods to relate RUSLE results with those reservoirs sediment yields. The analysis of the results showed that considering sediment yield of reservoir surveys ($SY_{RS}$) of the Muratlı and Borçka Dams, Moore and Burch equation using the DEM obtained from TerraSAR-X Satellite for 5 m resolution of the basin, predicts RUSLE LS parameter more accurately. The analysis of the results showed that when ESDAC K-factor is considered the percent differences between reservoir survey ($SY_{rs}$) for Muratlı and Borçka Dams and calculated sediment yield are 2% for Borçka Dam and 23% for Muratlı Dam, whereas when EPIC K-factor is considered those percent differences are 10.7% for Borçka Dam and 7.8% for Muratlı Dam.

Keywords: RUSLE, GIS, Sediment Yield, Reservoir Sedimentation, Muratlı and Borçka Watersheds

## 1. Introduction

Sediment accumulation poses a significant challenge for reservoirs associated with dams. Various factors, such as the geological characteristics of the river basin, topography, climatic conditions, drainage density, and patterns, along with urban development and forest clearance, collectively contribute to an increased sediment load within the basin. Consequently, the sedimentation process leads to a decrease in the storage capacity of the reservoirs. Although historical data on sediment flow and water levels have been utilized to estimate the sediment storage levels and the economic longevity of dams, inaccuracies persist due to the fluctuating nature of meteorological, hydrological, and anthropogenic factors. This has resulted in reservoirs filling up with sediment faster than initially projected. Particularly during brief, high-intensity flood events, a substantial volume of sediment can be carried into the reservoir, leading to a rapid reduction in storage capacity and overall lifespan of the dam. Researchers are particularly concerned about this issue

as dams play a crucial role in providing water for domestic and agricultural purposes, as well as generating hydroelectric power. The determination of sediment load transported by rivers remains essential for effectively managing sedimentation in dam reservoirs (Kokpinar et al., 2015; Darama et al., 2019).

Determining the quantity of sediment accumulated by rivers is essential for the estimation of sediment yield within a watershed. As outlined by Walling (1994), there exist three approaches for acquiring sediment yield data: (1) the utilization of continuously recorded discharge data along with their application to a previously established sediment rating curve, (2) the integration of continuously recorded discharge and sediment data, and (3) the utilization of data from reservoir surveys. Among these techniques, the periodic collection of data from reservoir surveys is viewed as a more reliable indicator of long-term sediment yield in a given basin (Kokpinar et al., 2015; Morris & Fan, 1997; Verstraeten & Poesen, 2002). In a research endeavor by (Munthali et al., 2011), employing Geographic Information System (GIS) and the PanEuropean Soil Erosion Risk Assessment model, the scholars sought to ascertain the hydrological potential for sediment, pinpoint regions characterized by significant sediment generation within the Songwe River watershed, and evaluate the probability of sediment accumulation in a proposed reservoir.

Even though there have been numerous advances in hydrological modeling, the prediction of erosion in large-scale mountainous regions still is a challenge, as there are limitations in terms of a lack of data and uncertainty in the representation of the terrain. Aksoy & Kavvas (2005) highlighted that empirical models such as RUSLE practically estimate erosion in large-scale basins, but they simplify erosion mechanics and struggle to deliver realistic results, especially in steep terrains. Hence, the assessment of erosion relies on GIS models that require parameter calibration and careful validation.

In recent years, advances in remote sensing, GIS, and hydrological modeling have provided valuable tools for examining erosion rates and resulting sediment yield. Integrating field observations with these technological advancements allows for a more comprehensive assessment of sediment dynamics, which is essential for developing effective management strategies. The Revised Universal Soil Loss Equation (RUSLE) is a widely used method for estimating soil erosion and resulting sediment yield, offering valuable insights into sediment yield and sediment delivery ratio (SDR) estimation.

RUSLE is broadly compatible with GIS, making it a proper framework in soil loss and sediment prediction. However, the studies show that to have an accurate prediction, the quality of input data, especially the slope length and steepness (LS) factor, which is dependent on the resolution of DEM, must be satisfied. In a study by (Ansari et al., 2024), they established that the LS factor has the most influence on soil loss prediction. The findings in the study also highlight the fact that RUSLE remains a powerful tool in sediment prediction that relies on accurate LS factor formulation, support practices factor (P) selection, and validation with measured data.

Sedimentation in reservoirs is one of the global hazards that must be studied as it highly impacts the lifespan of the dam and water quality. According to Asres et al. (2025), sedimentation rates in some Ethiopian reservoirs can reach 4–16% of their annual capacity. They also emphasize that building more dams won't be able to compensate for the continuous loss of silt. These infill rates are consistent with the basic facts that many reservoirs lose substantial storage (typically >1% $yr^{-1}$ on average) and that long-term sediment deposits can exceed design lifespans by orders of magnitude. These trends are being driven in part by climate and land-use change: warmer temperatures, more intense storms, wildfires, and altered cover are expected to amplify catchment erosion and sediment delivery to downstream dams (Pesci et al., 2023). Recent studies show that

climate change can influence sediment yield mainly by modifying rainfall erosivity (R factor) and the frequency of high-intensity storm events (Das et al., 2024; Gezici et al. 2025; Tuvshinjargal et al., 2024). However, despite this urgency, there is still a lack of trustworthy data on reservoir infill, which makes predictive management challenging (Yao et al., 2023).

RUSLE and SDR are frequently used together to predict sediment yield in the catchments. Integrating these with a GIS model for sediment analyses and finding erosion hotspots has been widely used in various studies (Kanito et al., 2023). According to experts, RUSLE should be calibrated with observations. To exemplify, Starks et al. (2023) found that depending solely on RUSLE will lead to widely different outcomes compared to the observed data. Despite these challenges, using field data can significantly improve model performance. Nistor et al. (2025) in a catchment in Romania showed that RUSLE estimates accounted for 70% of the measured accumulated sediment at the reservoir. On the other hand, Othman et al. (2023) had a successful model with less that 1% error using a calibrated RUSLE and SDR model in a dam in Iran's Zagros Mountains. Together, these studies demonstrate that integrating bathymetric surveys (and other field data) with RUSLE and SDR modeling is essential for quantifying reservoir sedimentation in complex basins and for validating predictive models.

This study aims to address existing knowledge gaps regarding erosion predictions through a multidisciplinary approach. By combining field surveys with GIS-based RUSLE modeling techniques, we seek to elucidate the factors influencing erosion predictions, including land use changes, hydrological characteristics, and geomorphological features. By integrating these findings within a GIS framework, we aim to spatially visualize sediment patterns and identify areas especially prone to erosion and sedimentation.

Despite the extensive application of RUSLE in soil erosion research, limited studies have specifically measured the impact of various DEM sources and resolutions on the calculation of the LS factor and, subsequently, erosion forecasts at the basin level. Similarly, comparative evaluations of several LS formulations across different topographic inputs are limited, particularly in mountainous watersheds like the Muratlı and Borçka Dams subbasins of the Çoruh Basin which is located North-East of Türkiye. Moreover, validation of modeled results against direct reservoir bathymetric survey data is rarely integrated into erosion studies, despite its importance for confirming predictive reliability. This study addresses these gaps by (i) comparing LS factor estimations derived from four DEM sources at different resolutions, (ii) assessing two commonly used LS factor formulations, and (iii) validating the results using sediment yields obtained from Borçka and Muratlı reservoir surveys. By bridging DEM sensitivity analysis with field-based validation, this study contributes new insights into the accuracy and uncertainty of RUSLE applications in complex terrains, with direct implications for reservoir sediment management and watershed conservation.

## 2. Study Area and Data

The Çoruh River and its tributaries are significant waterways in Turkey renowned for its hydroelectric potential, has seen the construction of multiple dams along its main course to harness this energy resource. However, unlike its energy-producing capacity, the river itself presents challenges due to its supercritical flow regime and sediment-carrying capacity, which is particularly problematic for dam reservoirs. While studies have focused on sedimentation within a single reservoir on a micro-scale basis, sedimentation in a two or more reservoir system on the same river, remains unexplored.

Assessing sediment yield at a basin level is pivotal for determining the effective capacity of hydroelectric dams. Unconventionally, dams in the Çoruh River Basin were built downstream to upstream, driven partly by hydropolitical considerations. This sequencing commenced with the Muratlı Dam in 2005, followed by the Borçka Dam in 2008, the Deriner Dam in 2012, and the Artvin Dam in 2015. Consequently, Muratlı and Borçka Dams, positioned downstream, initially accumulated sediment naturally transported by the river. Meanwhile, sediment from adjacent slopes was redirected to the river during the construction of the Deriner and Artvin Dams.

The initial sedimentation of Muratlı Dam reservoirs began in 2005, followed by Borçka Dam reservoirs in 2008, filling their dead volumes more rapidly than anticipated. Subsequent bathymetric surveys conducted in 2017 for the Borçka Dam and in 2020 for the Muratlı Dam revealed significant reductions in their dead volumes, by 28% and 48%, respectively, over a span of 10-15 years.

Within the scope of the study, sediment yield of Borçka and Muratlı Dams are calculated by RUSLE considering the sediment delivery ratio (SDR) and validated by examining reservoirs survey data provided by DSI.

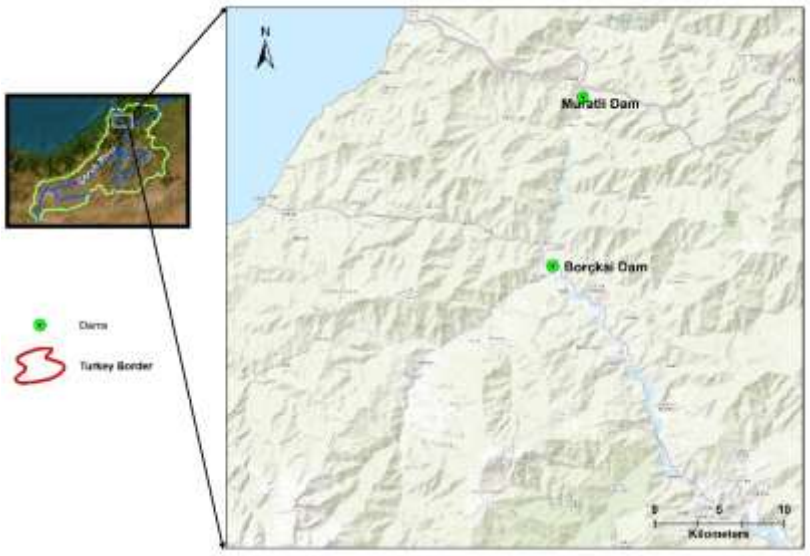



Fig. 1. The study area.

## 3. Erosion Prediction by RUSLE

Erosion occurs as a natural phenomenon driven by both wind and water forces. Research from the State Planning Organization (DPT) of Turkey in 2001 shows that water and rainfall are responsible for 99% of erosion within the country, with wind playing a minor role in the remaining 1%.

In the realm of erosion quantification, numerous methodologies have emerged in scholarly discourse, aiming to gauge soil loss attributed to water or rainfall on an annual basis. Among these methodologies, the Universal Soil Loss Equation (USLE) and its revised counterpart, the Revised Universal Soil Loss Equation (RUSLE), stand out as widely embraced frameworks. The RUSLE method, in particular, integrates various key variables contributing to erosion dynamics, including rainfall erosivity (R), soil erodibility (K), topographical attributes like slope length (L) and steepness (S), as well as considerations for cover-management (C) and support practices (P). Expressed as an equation, the RUSLE model embodies the relationship as follows:

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

Here, 'A' signifies the annual soil loss (t/ha/yr), 'R' represents the rainfall-runoff erosivity factor (in MJ mm/ha/h/yr), 'K' denotes the soil erosion sensitivity factor, 'L' corresponds to the slope length factor, 'S' embodies the slope steepness factor, while 'C' and 'P' encapsulate the cover management and support practices factors respectively. Figure 2 illustrates the flow chart of data needed for a RUSLE model in GIS environment.

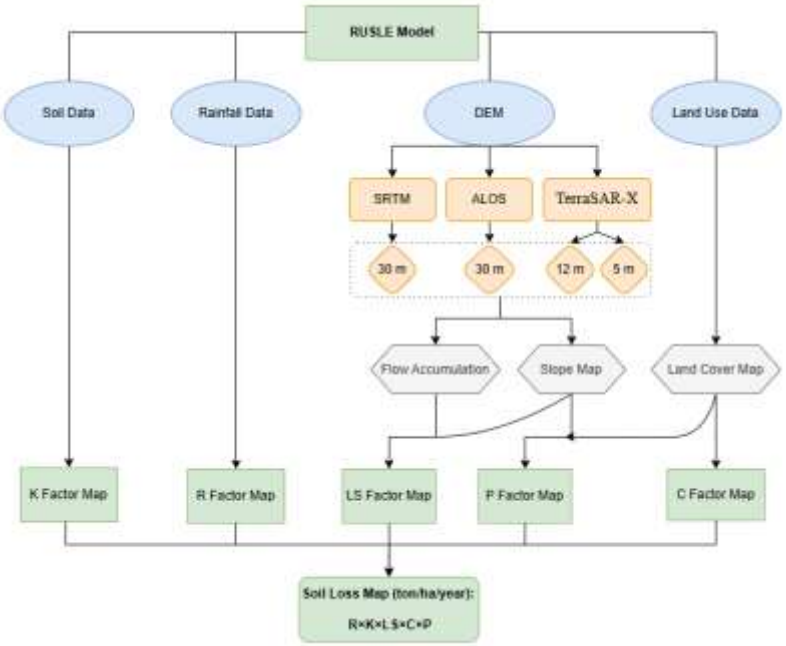



Fig. 2. RUSLE model data flow chart.

### 3.1. Rainfall Erosivity

The rainfall erosivity factor (R) in the RUSLE equation is considered within the rainfall-runoff interactions framework and is a key determinant influencing soil erosion mechanisms. This factor, denoted as R, embodies the influence of raindrop impact and elucidates the magnitude and velocity of runoff linked to precipitation occurrences. Specifically, it is characterized as the product of kinetic energy and the peak 30-minute intensity, serving as an indicator of the erosive potential inherent in rainfall events.

There are numerous methods in the literature to calculate the R factor. In this study, The R factor map is obtained from the European Soil Data Centre (ESDAC) (European Commission, n.d.; Panagos et al., 2012, 2022). The map was prepared in 2017 and at resolutions of 30 arc-sec (~1 km at the Equator). Figure 3 illustrates the R factor for the Muratlı and Borçka Dam basin. The equations used in calculating the R factor (Brown & Foster, 1987) are as follows:

$$EI_{30} = \left( \sum_{r=1}^{k} e_r v_r \right) I_{30} \tag{2}$$

where $e_r$ is the unit rainfall energy (MJ/ha/mm) and $v_r$ is the rainfall volume (mm) during the $r^{th}$ time period of a rainfall event divided into k parts. $I_{30}$ represents the maximum 30-minute rainfall intensity (mm/h) and $EI_{30}$ represents rainfall erosivity index for an individual event (MJ mm/ha/h). To compute unit rainfall energy ($e_r$) for each time interval, perform these steps:

$$e_r = 0.29\left[1 - 0.72e^{(-0.05i_r)}\right] \tag{3}$$

where $i_r$ is the rainfall intensity during the time interval (mm/yr). R is the average annual rainfall erosivity (MJ mm/ha/h/yr):

$$R = \frac{\sum_{j=1}^{n} \sum_{k=1}^{m_j} (EI_{30})_k}{n} \tag{4}$$

where n is the number of years recorded, $m_j$ is the number of erosive events during a given year j, and k is the index of a single event with its corresponding rainfall erosivity $EI_{30}$.

As illustrated in Figure 3, the rainfall erosivity (R-Factor) values in the Muratlı and Borçka Basin show notable regional variation. The northern portion of the basin, especially the regions with steep slopes and significant precipitation, has the greatest R-Factor values, surpassing 4,000 MJ mm/ha/h/yr. On the map, these areas are shown in orange and red. The southern and central

regions of the basin, on the other hand, exhibit much lower R-Factor values; the lowest is approximately 517 MJ mm/ha/h/yr (blue), indicating comparatively lesser rainfall erosivity. Variability in R-Factor values is impacted by topographical features, rainfall length, and intensity, all of which together define the basin's capacity for soil erosion.

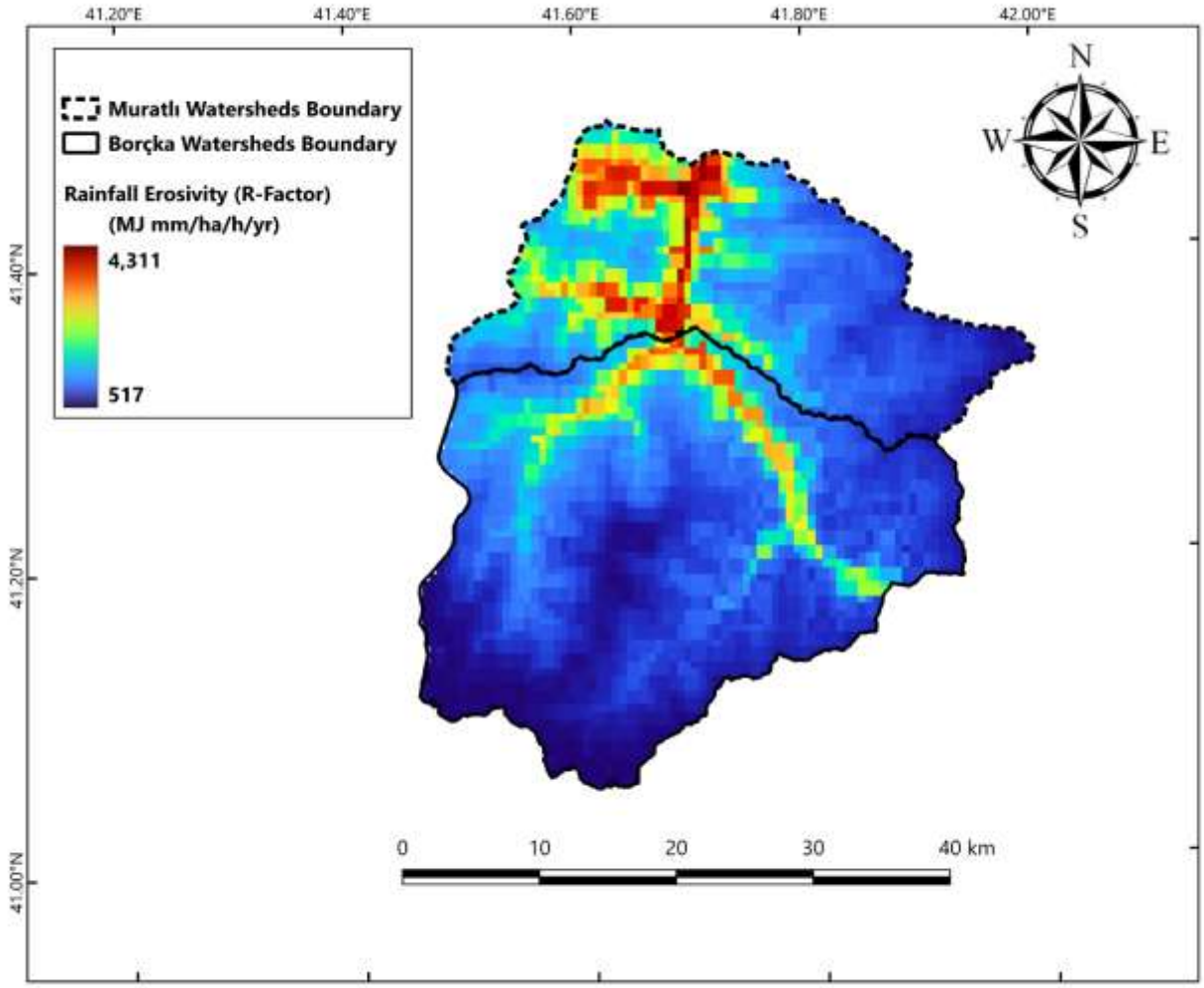



Fig. 3. Rainfall erosivity (R Factor) map of the Muratlı and Borçka Basin (values in MJ mm ha/h/yr).

### 3.2. Cover-Management Factor (C Factor)

The coverage factor spans from 0 (complete soil coverage) to 1 (no soil coverage). The C factor signifies the impact of soil-disturbing practices, vegetation, crop rotation, productivity level, soil

covering, and sub-surface biomass on soil erosion. Natural vegetation primarily contributes to mitigating water erosion (Kheir et al., 2008).

To calculate the C factor, first, a Land Cover map is needed. This map is provided by Copernicus Corine 2018 Land Cover data with 100 m resolution (EEA Geospatial Data Catalogue, n.d.). Figure 4 shows this map with land use types. For each land cover type, C factor values are collected from literature and set to obtain the C factor map (Chen et al., 2019; Panagos et al., 2015; Rozos et al., 2013). C factor map for the Muratlı and Borçka basin is provided in Figure 5. The C Factor changes depending on land cover in the Muratlı and Borçka Basin (Figure 5), therefore affecting the area's erosion vulnerability. With their lowest C values (0–0.05), densely vegetated areas—such as woods and grasslands shown in blue and green that provide great resistance against soil erosion. Conversely, places with higher C values (0.1–1.0) shown in yellow, orange, and red, mostly agricultural land or barren areas, where the lack of vegetation increases the soil's vulnerability to erosion. The northern and middle regions of the basin have lower C values because of better vegetative cover, but the southern and western sections often have higher values, suggesting more exposed terrain.

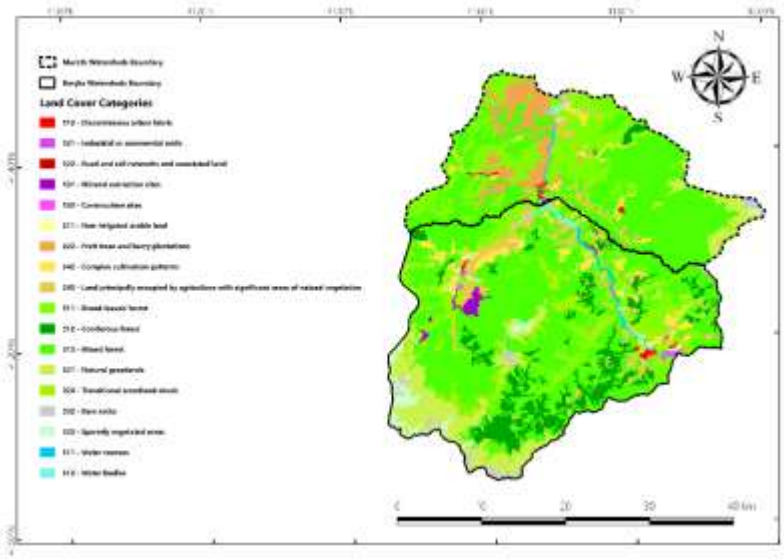



Fig. 4. Muratlı and Borçka Basin land cover map (Corine Land Cover 2018).

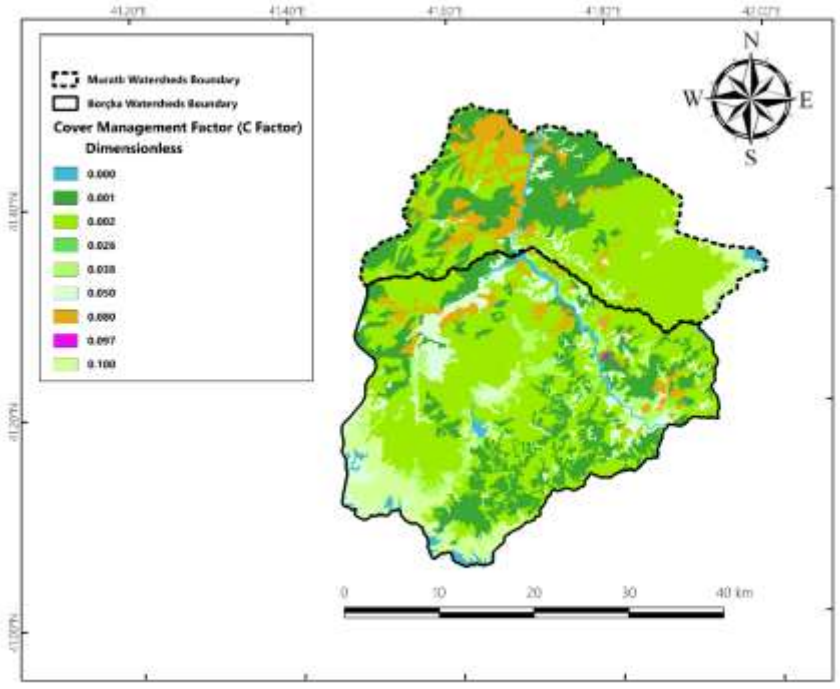



Fig. 5. Cover-management factor (C Factor) of Muratlı and Borçka Basin.

### 3.3. Support Practices Factor (P Factor)

The P factor represents the ratio of soil loss under a specific support practice to soil loss under conventional up and down slope tillage. Typically, the support practices factor adjusts the

estimation made by the RUSLE to account for management and tillage practices that safeguard the soil from erosion.

To provide a P factor map, first, a slope map of the study area with categorized percent units is provided (Figure 6) using the DEM map.

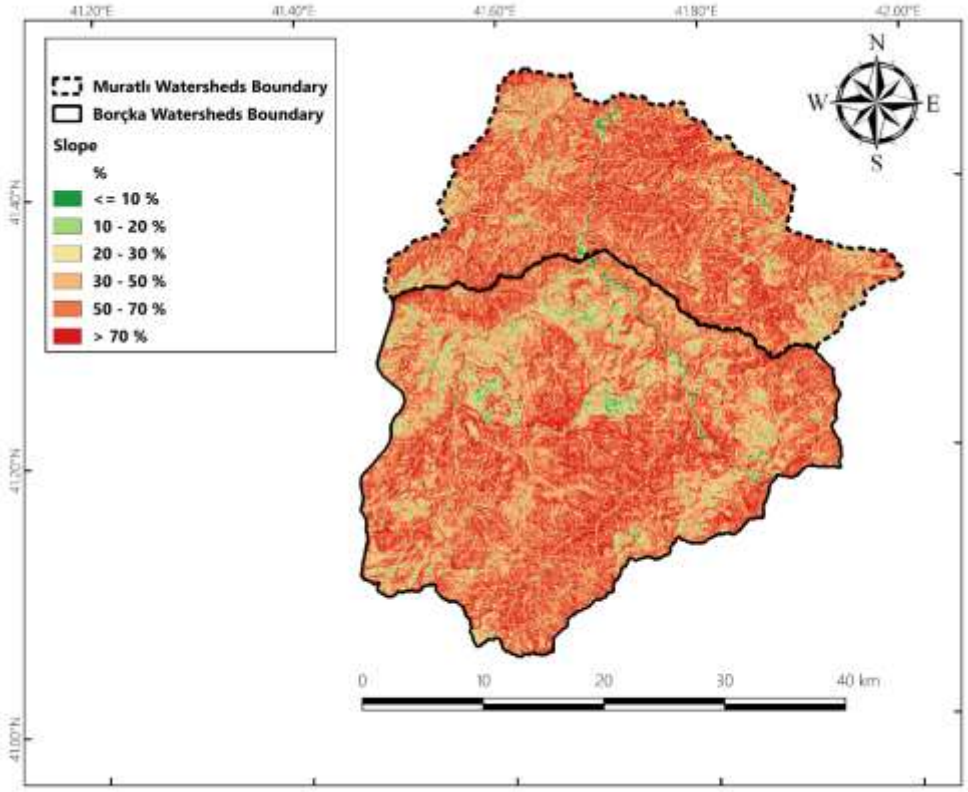



Fig. 6. Muratlı and Borçka basin slope map.

In this study, the P factor map was created using land use/land cover data and support factors.

The P values are collected from literature for different land cover and slope values, which is shown in Table 1 (Panagos et al., 2015; Wischmeier & Smith, 1978). The P Factor map, created using these values, is presented in Figure 7. In general, higher P values are assigned to areas lacking conservation practices, such as steep agricultural lands, rangelands, and bare soil, where erosion risk is greater.

On the other hand, plantations that use soil conservation methods like contour and strip cropping, as well as built-up regions, are linked to lower P values. Areas with mild slopes (0–5%) typically have lower values, especially in forests (0.03), agriculture (0.1), and rangelands (0.1), indicating better natural soil protection. This is because the P Factor rises with slope. But the P Factor increases as the slope gets steeper, indicating a higher risk of erosion. For instance, the P Factor can reach 0.7 in steep agricultural areas (>50%) and 0.75 and 1.0 in rangelands and bare soil, respectively. The lowest P levels are found in lower slope regions, like plains and water bodies, which provide superior defense against soil erosion.

Table 1. P factor Values for different land use types and slopes.

| Land Use Type | Slope (%) | P Factor |
|---|---|---|
| **Agriculture** | 0 - 5 | 0.1 |
| | 5 - 10 | 0.12 |
| | 10 - 20 | 0.14 |
| | 20 - 30 | 0.19 |
| | 30 - 50 | 0.25 |
| | > 50 | 0.7 |
| **Water** | - | 0 |
| **Urban Land** | - | 0.05 |
| **Forest** | 0 - 5 | 0.03 |
| | 5 - 10 | 0.05 |
| | 10 - 20 | 0.1 |
| | 20 - 30 | 0.15 |
| | 30 - 50 | 0.2 |
| | > 50 | 0.5 |
| **Rangelands** | 0 - 5 | 0.1 |
| | 5 - 10 | 0.13 |
| | 10 - 20 | 0.15 |
| | 20 - 30 | 0.2 |
| | 30 - 50 | 0.4 |
| | > 50 | 0.75 |
| **Bare Soil** | 0 - 5 | 0.25 |
| | 5 - 10 | 0.35 |
| | 10 - 20 | 0.45 |
| | 20 - 30 | 0.55 |
| | 30 - 50 | 0.75 |
| | > 50 | 1 |

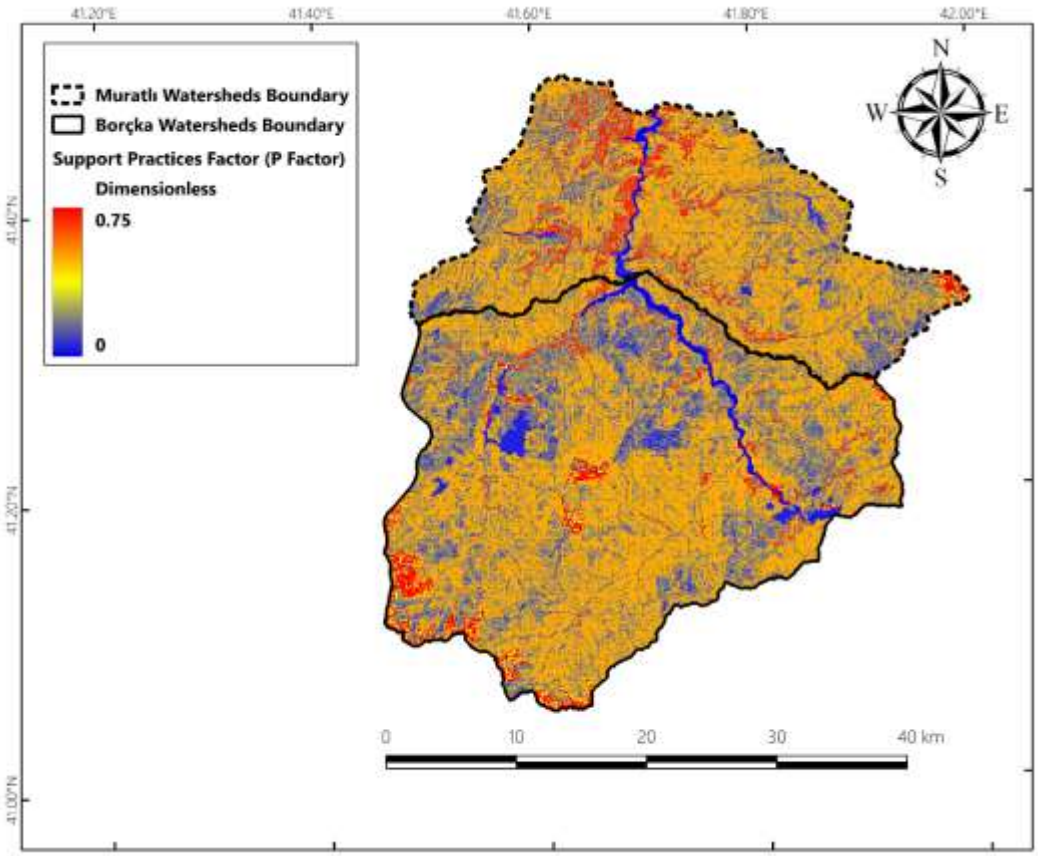



Fig. 7. Support practices factor (P Factor) of the Muratlı and Borçka Basin.

### 3.4. Soil Erodibility (K Factor)

The soil erodibility factor (K) pertains to how a particular soil and its profile respond over time to the erosive forces caused by rainfall and runoff. It reflects the rate at which soil is lost per unit of rainfall erosion for a given soil type. In the RUSLE model, Wischmeier's method is employed to assess the K factor of a soil type (Wischmeier & Smith, 1978). This method encompasses various soil properties such as particle size (silt, clay, and sand), organic matter content, soil structure, and permeability. The K factor map is provided by the European Soil Data Centre (ESDAC) (European Commission, n.d.; Panagos et al., 2012, 2022). Figure 8 illustrates the soil erodibility map for the study area (Muratlı and Borçka Basin). The soil erodibility was calculated using the Wischmeier and Smith formula below.

$$K = \frac{2.173 \times \left(2.1 \times M^{1.14} \times 10^{-4} \times (12 - a) + 3.25 \times (b - 2) + 2.5 \times (c - 3)\right)}{100} \quad (5)$$

where K is the soil erodibility factor (t h/MJ/mm), M is the percentage of the particles (% of very fine sand + % of silt × (100% clay)), a is the organic matter content (% C × 1.724), b is the soil structure and c is soil permeability.

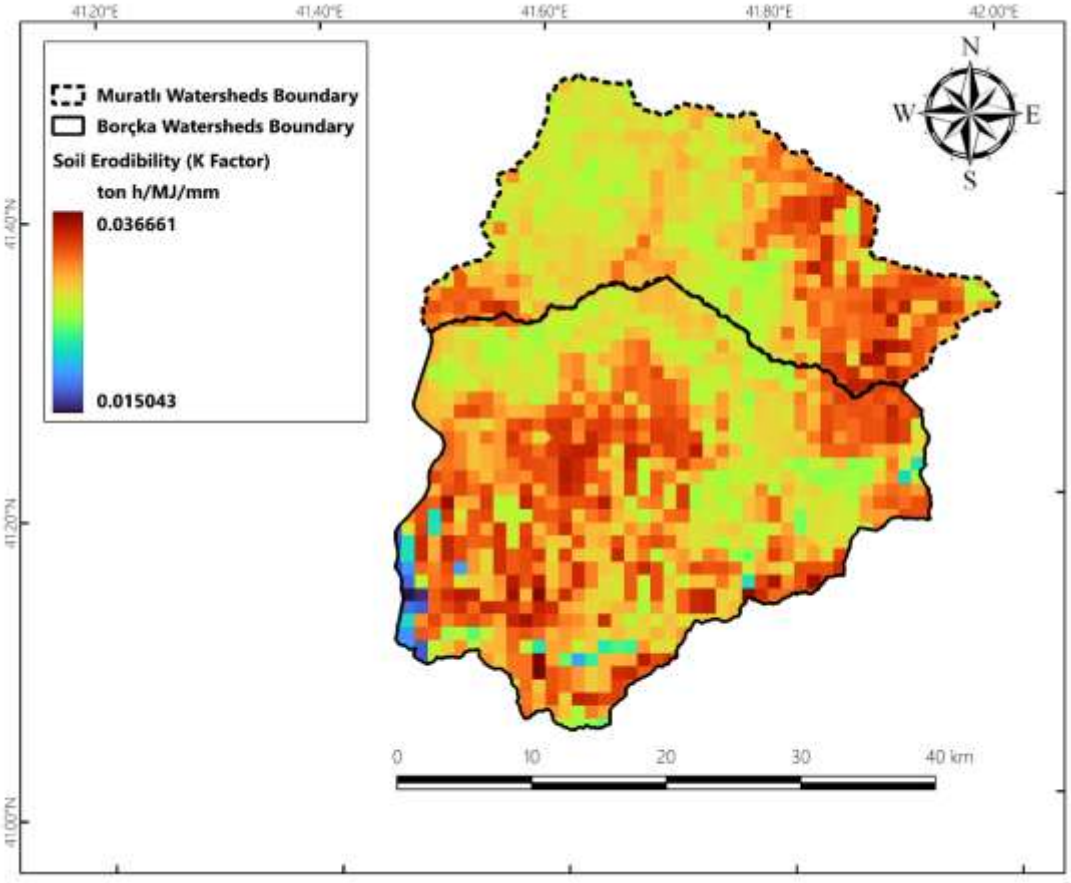



Fig. 8. Soil erodibility (K Factor) of the study area (Wischmeier & Smith, 1978).

To enhance the spatial accuracy of the study, the K factor was also calculated using high-resolution soil data based on the EPIC (Erosion-Productivity Impact Calculator) model (Williams, 1995). Unlike the Wischmeier method, which requires soil structure and permeability codes that are often unavailable in high-resolution spatial datasets, the EPIC model estimates K utilizing only organic carbon content and soil particle size distribution (sand, silt, and clay). This approach allowed for

the integration of finer-scale soil grids to capture local variations in erodibility that coarser datasets might miss.

$$K = 0.2 + 0.3\exp\left(0.0256 \times Sa \times \left(1 - \frac{Si}{100}\right)\right) \times \left(\frac{Si}{Cl + Si}\right)^{0.3} \times \left(1 - \frac{0.25 \times C}{C + \exp\left(3.72 - 2.95C\right)}\right) \times \left(1 - \frac{0.7 \times SN}{SN + \exp\left(-5.51 + 22.9SN\right)}\right) \quad (6)$$

Where, Sa: sand (%) Si: silt (%) Cl: clay (%) SN = 1 − (Sa/100) C: organic carbon

The soil data are provided by ISRIC - World Soil Information, and the high-resolution K factor map is shown in Figure 9.

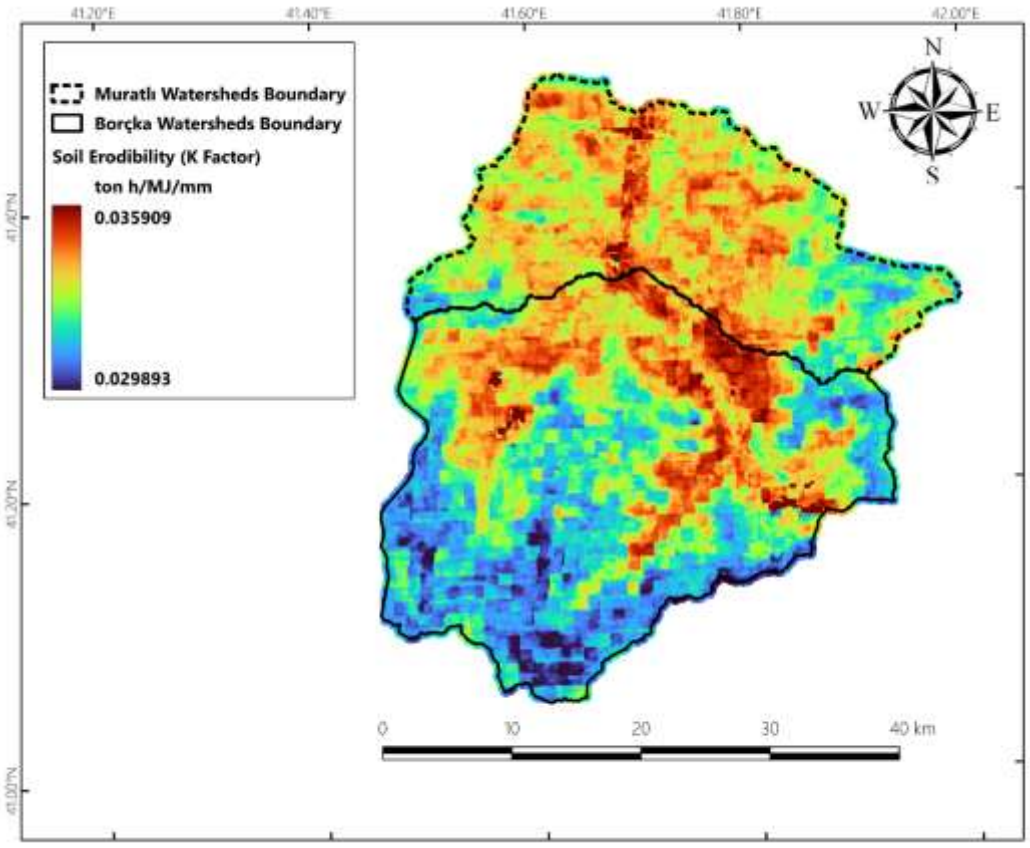



Fig. 9. Soil erodibility (K Factor) of the study area (Williams, 1995).

The K Factor values, indicating soil erodibility, vary across the study area as shown in Figures 8 and 9. In the central and northwestern parts, the K values are rather high, meaning soils are more prone to erosion of texture and material composition. On the contrary, the southern highland areas supply lower K values, meaning these are more stable soils, entailing lower susceptibility to detachment by rainfall and runoff. The spatial variation shown in this K Factor certainly widens its scope to indicate the differences in the soils present in the basin area, which in turn defines the erosion potential.

### 3.5. Slope Length and Steepness Factor (LS Factor)

The L and S factors within the RUSLE framework represent how topography influences erosion. Research has confirmed that increases in both slope length and steepness lead to higher overland flow and, consequently, increased erosion. Furthermore, it has been noted that changes in slope steepness have a greater impact on gross soil loss compared to changes in slope length. Therefore, topography, especially when the ground slope exceeds a critical angle, emerges as a significant factor in soil loss, primarily because it governs the rate of surface runoff.

The combined LS factor for the study area (Muratlı and Borçka Basin) was provided from a Digital Elevation Model (DEM) obtained from three different sources, Shuttle Radar Topography Mission (SRTM) with 30m resolution, Advanced Land Observing Satellite (ALOS) with 30m resolution, and TerraSAR-X, TanDEM-X satellite provided by DSI with 12- and 5-meters resolutions. Computing the LS factor involves considering factors such as flow accumulation and slope steepness, which were derived from the DEM.

To calculate the LS factor two methods are used in this study which are discussed below.

### 3.5.1. LS Factor Calculation by Moore and Burch (1986)

Moore & Burch (1986) developed an LS factor estimation method using DEM for complex terrain, based on unit stream theory, requiring flow accumulation and slope data. In this study, the previously mentioned DEM data was processed in QGIS to calculate the LS factor.

The LS factor was calculated using Eq. (5), which incorporates flow accumulation, and slope steepness.

$$LS = \frac{\left(Flow\ \ Accumulation \times Cell\ \ Size\right)^{0.4}}{22.13} \times \frac{\left(\sin slope\right)^{1.3}}{0.0896} \tag{5}$$

Here, flow accumulation represents the accumulated upslope contributing area for a given cell, LS denotes the combined slope length and steepness factor, cell size indicates the size of the grid cell (30, 12, and 5 meters in this study), and sin(slope) represents the sine of the slope degree value.

The LS factor values across the study area calculated for four different DEM data using the method of Moore and Burch (1986) is shown in Figure 10.

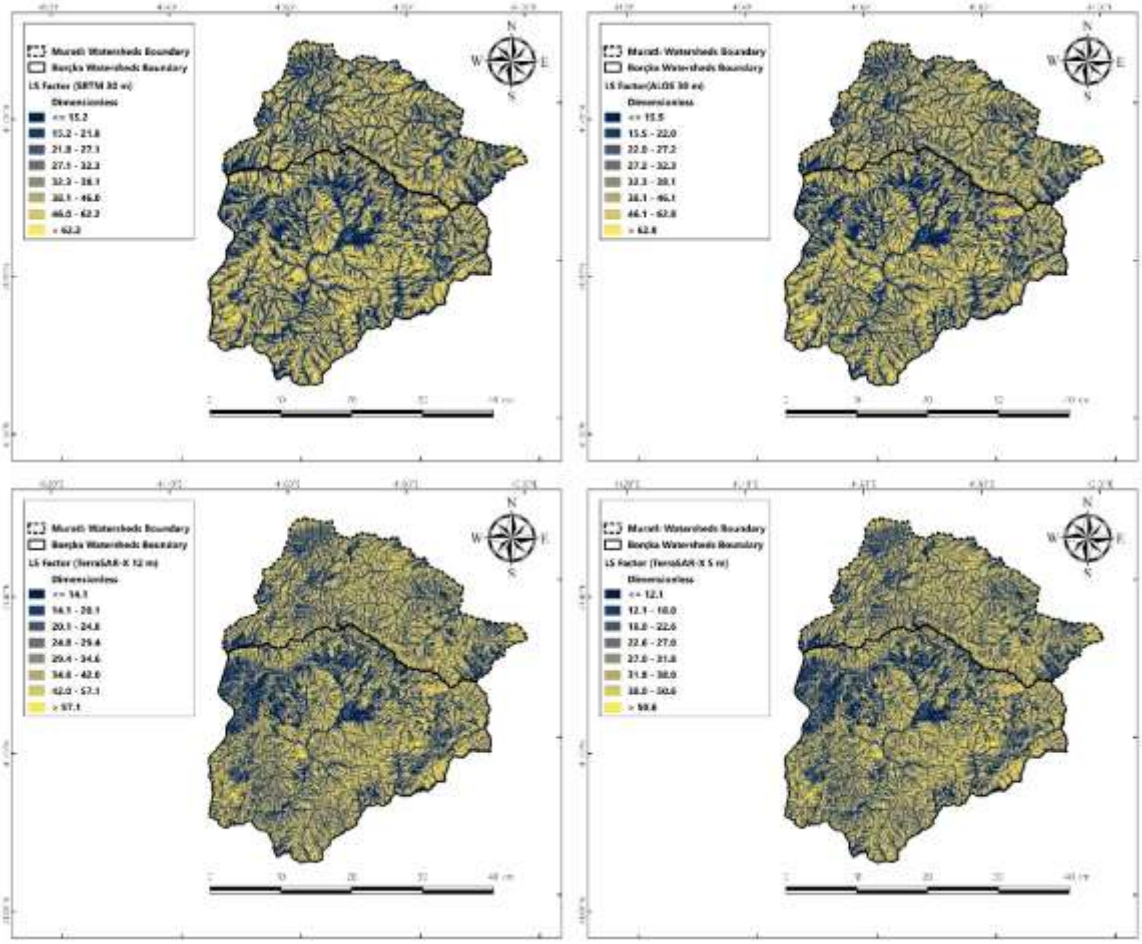


Fig. 10. LS Factor maps of Muratlı and Borçka Basin calculated by the method Moore and Burch (1986).

Figure 10 shows the LS factor's geographical distribution in the study area, which was obtained from four distinct DEMs (SRTM 30m, ALOS 30m, TerraSAR-X 12m and 5m). Because of the steeper slopes and longer slope lengths seen in mountainous areas, the maps constantly display higher LS values there, whereas the western and eastern parts display lower values. The impact of resolution on the accuracy of LS factor estimation is demonstrated by the fact that higher resolution DEMs (TerraSAR-X 12m and 5m) show more detailed fluctuations and generally higher LS values when compared to lower resolution DEMs (SRTM 30m and ALOS 30m).

### 3.5.2. LS Factor Calculation by Wischmeier and Smith (1978)

Wischmeier & Smith (1978) proposed an empirical equation for calculating the LS factor, combining slope length (L) and slope steepness (S), with a slope length exponent m derived from their experimental research (Eq. 6)

$$LS = \left(\frac{\lambda}{72.6}\right)^{m} \times \left[\left(65.41 \times \sin^2\theta\right) + \left(4.56 \times \sin\theta\right) + 0.065\right] \quad (6)$$

Here,

λ : Slope length in feet

θ : Angle of slope

m : 0.5 if slope > 5%, 0.4 if slope is between 3.5% and 4.5%, 0.3 if slope is between 1% and 3%, and 0.2 if slope is less than 1%

When we apply this equation to data from four different DEMs, we can see how topography – from gently rolling hills to steep slopes – influences the potential for soil loss. The LS factor maps calculated in GIS environment using this method are shown in Figure 11.

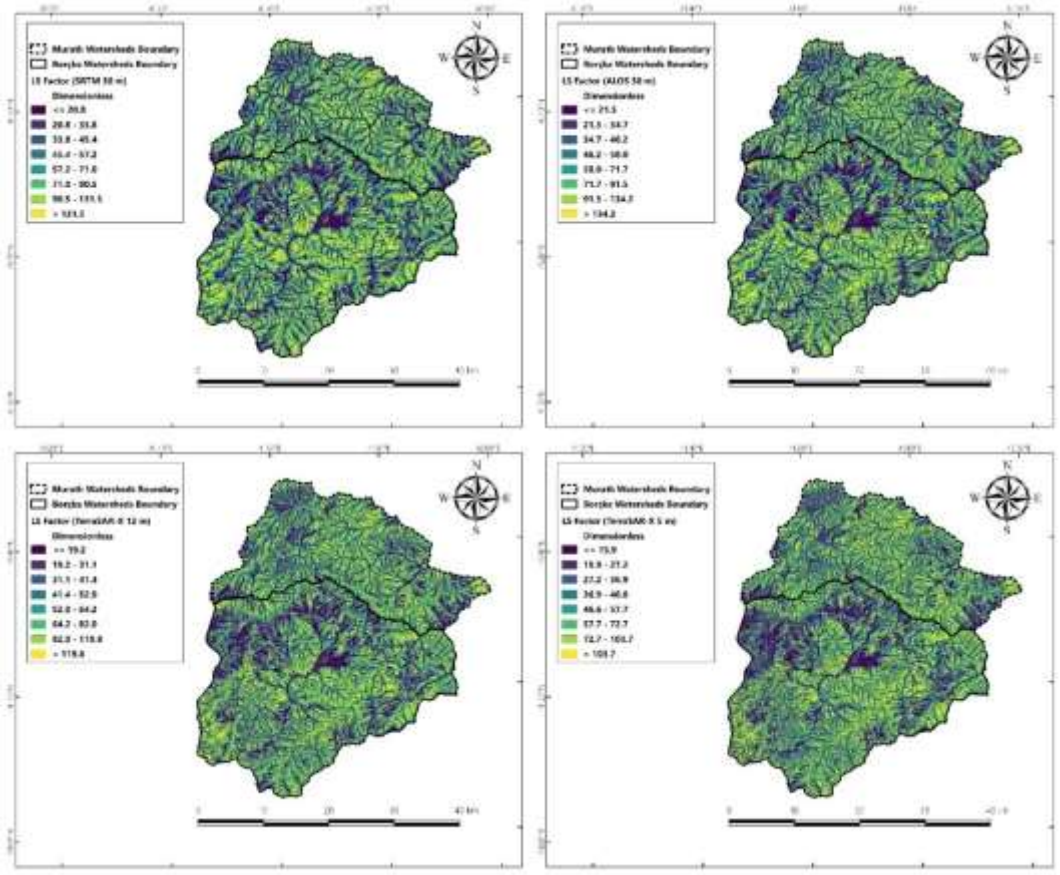


Fig. 11. LS Factor Maps of Muratlı and Borçka Basin by the method of Wischmeier and Smith (1978)

Figure 11 shows the LS factor distribution in the study area using four DEMs, revealing higher LS values in mountainous regions, indicating greater erosion potential due to steep slopes and long slope lengths. Lower LS values in the central valley suggest less erosion potential due to gentler slopes. The maps also demonstrate that higher resolution DEMs provide more detailed LS factor variations.

The Wischmeier and Smith (1978) method uses a uniform slope assumption, potentially overestimating LS in complex terrains. In contrast, the Moore and Burch (1986) method, which considers flow accumulation, offers a more realistic representation, especially in complex areas. Thus, the Moore and Burch method is generally preferred for RUSLE, particularly with high-resolution DEMs, for more accurate erosion assessments.

### 3.6. Average Annual Soil Loss

The data layers (maps) extracted for the K, LS, R, C, and P factors of the RUSLE model were combined using Eq. (1) within the raster calculator tool of QGIS. This integration aimed to assess, evaluate, and produce maps depicting soil erosion risk and severity for the study area (Muratlı and Borçka Basin).

As a result of analyzing, arranging, and making calculations the data obtained from open sources, the spatial distribution and amounts of erosion in the study area were obtained by applying the RUSLE method in the GIS environment and are presented in Figures 12 and 13.

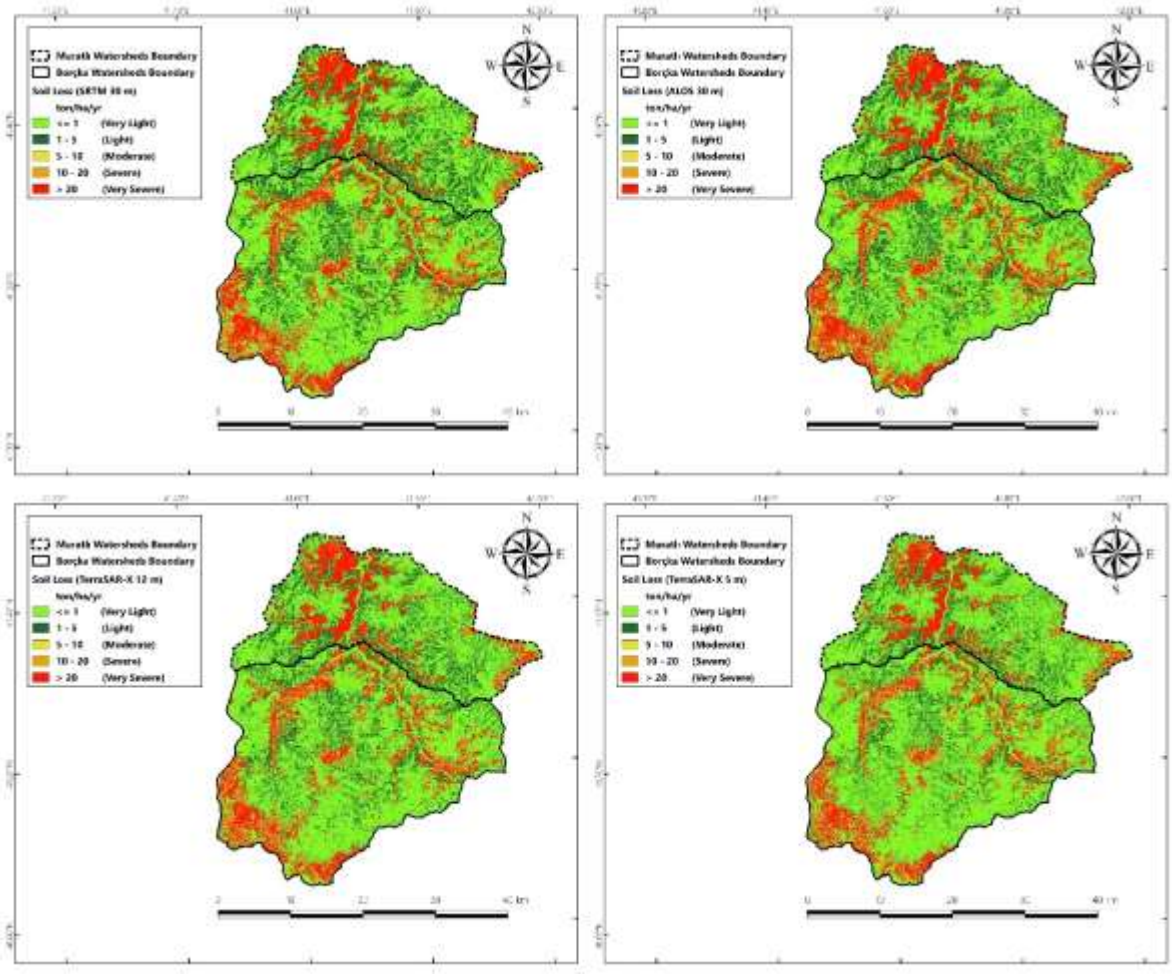


Fig. 12. Average annual soil loss in the study area using the Moore & Burch (1986) LS method and the ESDAC K-factor.

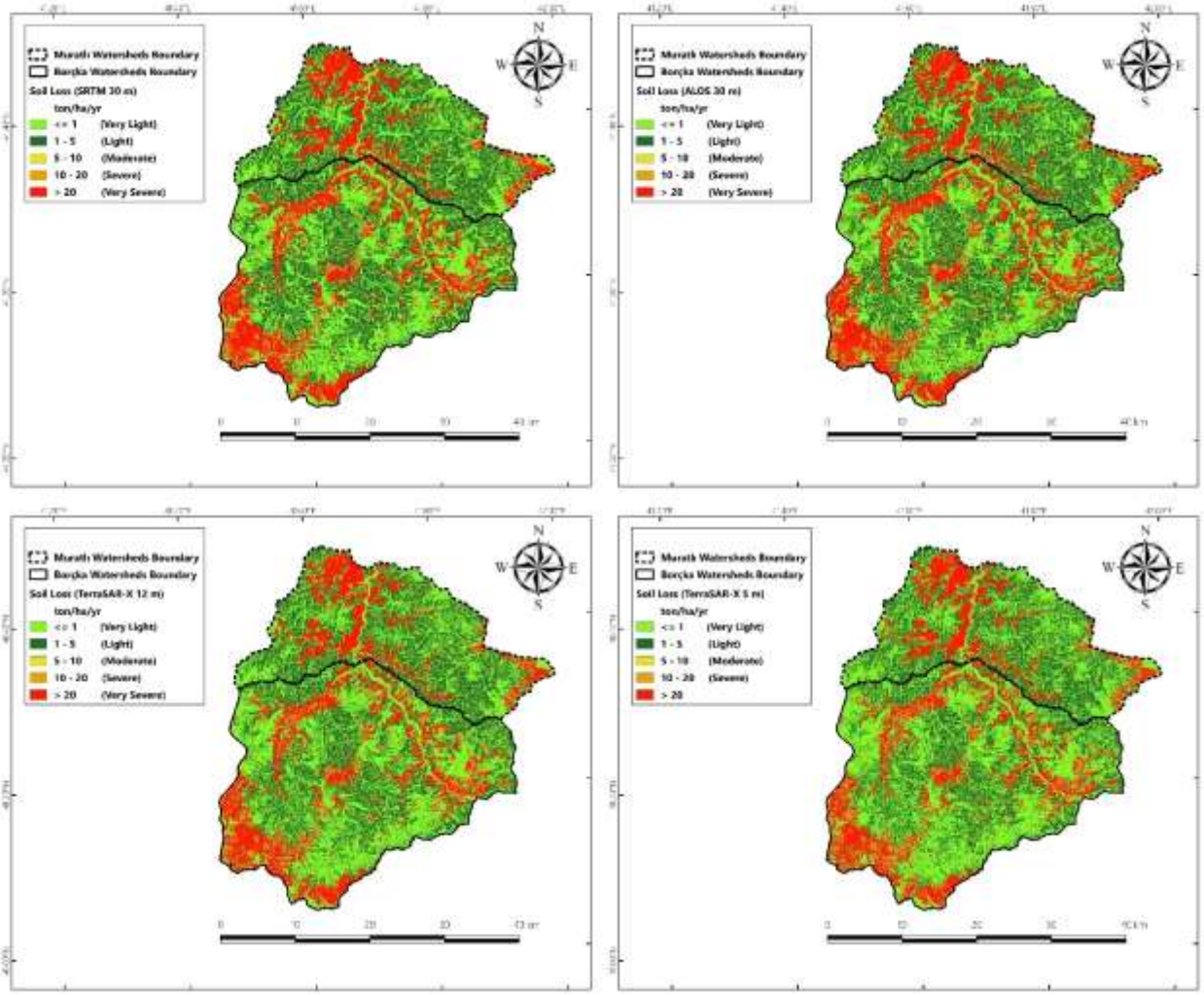



Fig. 13. Average annual soil loss in the study area using the Wischmeier and Smith (1978) LS method and the ESDAC K-factor.

Similarly, the soil loss of the study area is calculated using the EPIC model-derived K-factor and Moore & Burch (1986) and Wischmeier and Smith (1978) LS methods, and the maps are generated and can be seen in Figures 14 and 15.

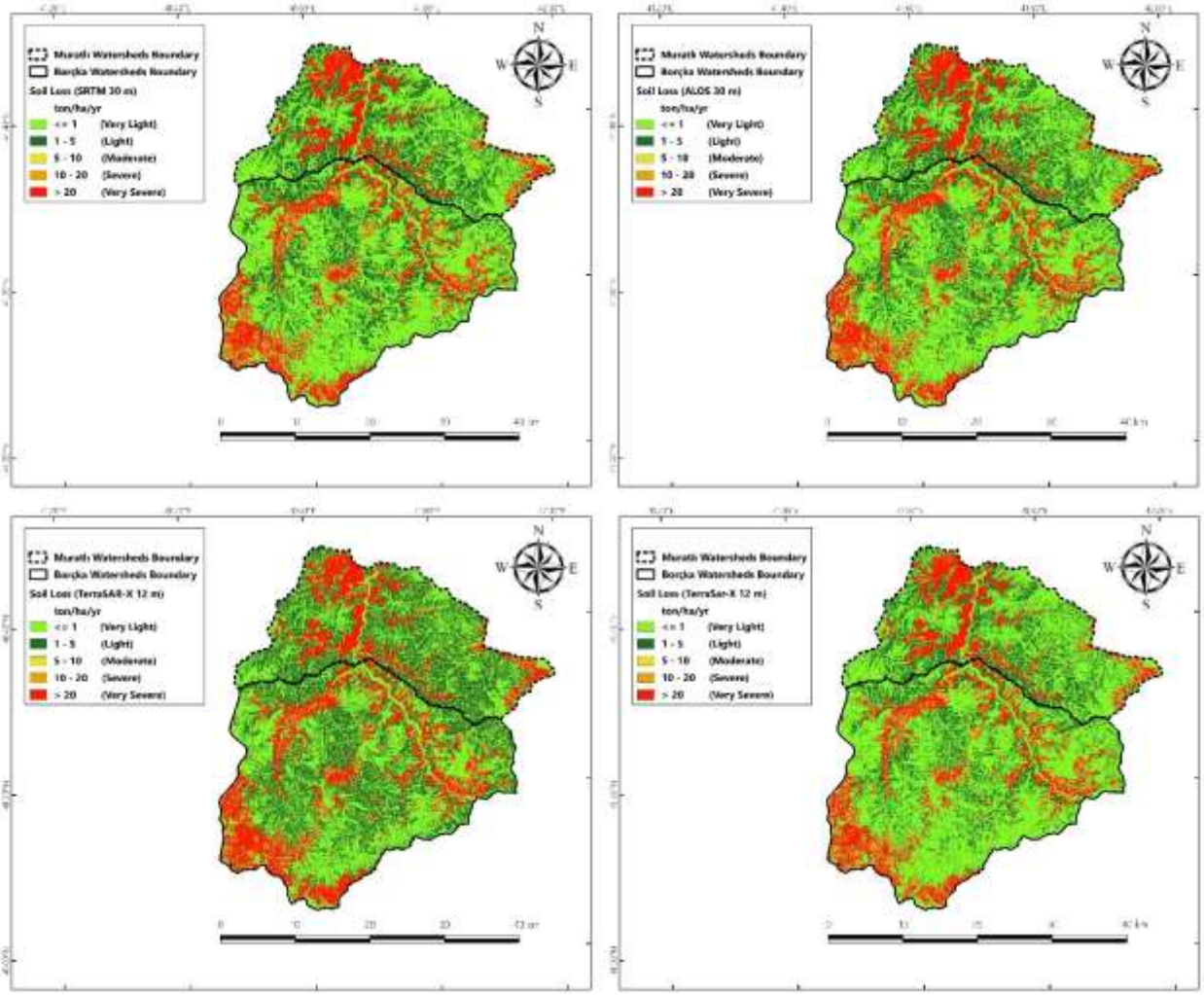



Fig. 14. Average annual soil loss in the study area (Muratlı and Borçka Basin) using the Moore & Burch (1986) LS method and the EPIC model-derived K-factor.

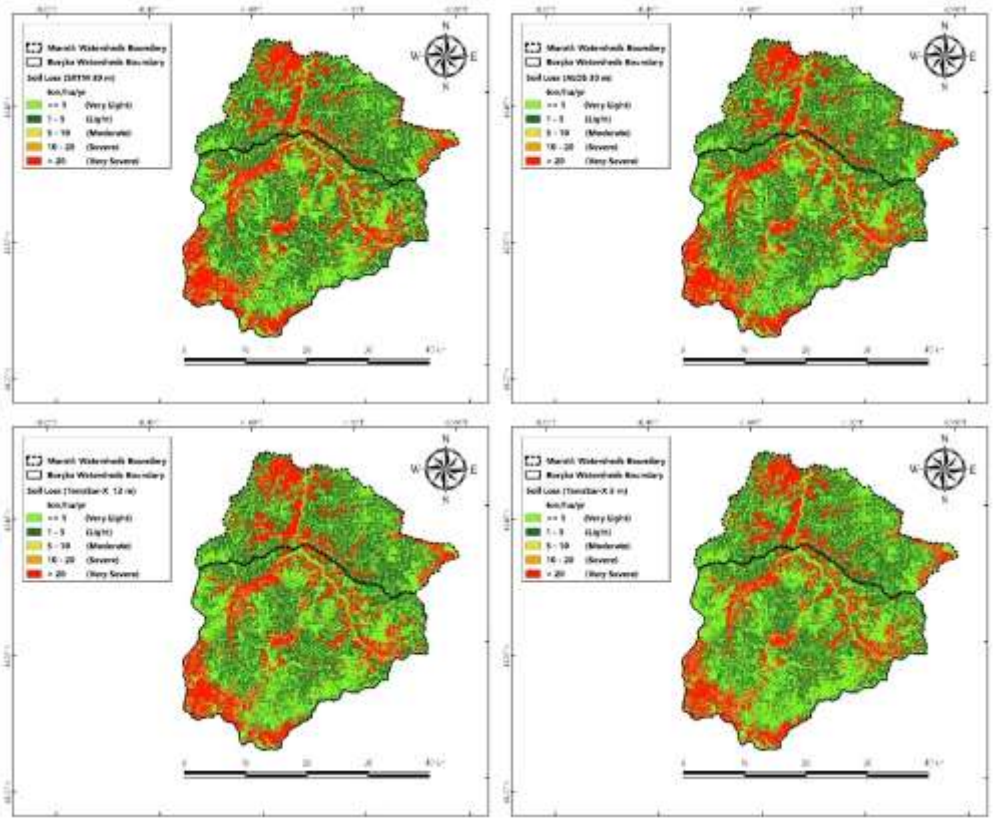


Fig. 15. Average annual soil loss in the study area (Muratlı and Borçka Basin) using the Wischmeier and Smith (1978) LS method and EPIC model-derived K-factor.

Accordingly, the average annual soil loss of all maps that may occur in the study is shown in Table 2.

Table 2. Average annual soil loss of Muratlı and Borçka watersheds (t/ha/yr).

| | **SRTM 30 m** | **ALOS 30 m** | **TerraSAR-X 12 m** | **TerraSAR-X 5 m** |
|---|---|---|---|---|
| **ESDAC K-factor** | | | | |
| **Moore and Burch** | 11.310 | 11.771 | 11.501 | 9.280 |
| **Wischmeier and Smith** | 22.187 | 23.707 | 23.034 | 18.127 |
| **EPIC model-derived K-factor** | | | | |
| **Moore and Burch** | 13.408 | 13.977 | 13.349 | 10.812 |
| **Wischmeier and Smith** | 26.499 | 28.312 | 26.798 | 21.095 |

To classify erosion severity, a range of erosion classes was determined based on the results of the RUSLE model. The classification scheme follows commonly accepted thresholds in the literature and aligns with national assessments of soil erosion. Specifically, the erosion severity ranges used in this study are derived from official water erosion statistics published by the Ministry of Agriculture and Forestry. Table 3 and 4 illustrate the erosion classes for the calculated soil loss across the basin.

Table 3. Areal distribution of soil erosion severity classes in the study area using the ESDAC K-factor.

| | | Moore and Burch | | | | Wischmeier and Smith | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SRTM 30 | ALOS 30 | TerraSAR-X 12 m | TerraSAR-X 5 m | SRTM 30 | ALOS 30 | TerraSAR-X 12 m | TerraSAR-X 5 m |
| **Erosion (t/ha/yr)** | **Erosion Class** | **Area (%)** | | | | | | | |
| **0 - 1** | **Very Light** | 40.5 | 40.6 | 43.4 | 46.3 | 26.8 | 26.7 | 28.7 | 31.9 |
| **1 - 5** | **Light** | 33.3 | 33.1 | 30.7 | 28.8 | 39.9 | 39.6 | 37.8 | 37.8 |
| **5 - 10** | **Moderate** | 3.9 | 4.0 | 4.2 | 4.2 | 7.7 | 7.7 | 6.5 | 6.4 |
| **10 - 20** | **Severe** | 4.8 | 4.8 | 5.2 | 5.3 | 4.5 | 4.6 | 5.0 | 4.7 |
| **> 20** | **Very Severe** | 17.4 | 17.6 | 16.5 | 15.4 | 21.1 | 21.4 | 22.3 | 19.2 |

Table 4. Areal distribution of soil erosion severity classes in the study area using the EPIC model-derived K-factor.

| | | Moore and Burch | | | | Wischmeier and Smith | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | SRTM 30 | ALOS 30 | TerraSAR-X 12 m | TerraSAR-X 5 m | SRTM 30 | ALOS 30 | TerraSAR-X 12 m | TerraSAR-X 5 m |
| **Erosion (t/ha/yr)** | **Erosion Class** | **Area (%)** | | | | | | | |
| **0 - 1** | **Very Light** | 49.1 | 49.1 | 51.8 | 54.6 | 32.8 | 32.7 | 35.4 | 38.3 |
| **1 - 5** | **Light** | 26.4 | 26.1 | 24.0 | 22.1 | 37.5 | 37.2 | 35.6 | 34.1 |
| **5 - 10** | **Moderate** | 4.0 | 4.0 | 4.3 | 4.5 | 6.0 | 6.0 | 5.7 | 5.4 |
| **10 - 20** | **Severe** | 5.3 | 5.3 | 5.5 | 5.6 | 4.5 | 4.6 | 4.8 | 4.8 |
| **> 20** | **Very Severe** | 15.2 | 15.4 | 14.4 | 13.3 | 19.3 | 19.5 | 18.5 | 17.3 |

Table 3 and 4 presents a comparison of erosion classifications across different DEM sources and LS calculation methods (Moore and Burch vs. Wischmeier and Smith) and K factor maps (ESDAC and EPIC model) for the study area.

Examining the data from both tables, two clear patterns emerge that affect how we interpret erosion risk. First, the choice of soil erodibility model matters considerably. The EPIC-derived K-factor (Table 4) systematically estimates a less severe erosion scenario than the ESDAC model (Table 3), shifting more area into lower severity classes. Second, the spatial resolution of the DEM has a measurable influence. Moving from 30-meter to 5-meter data consistently reduces the extent of the most severe erosion class while expanding the area classified as "Very Light." This shift suggests that finer-resolution models can resolve micro-topographic features that buffer soil loss, features which are aggregated and lost in coarser datasets. These findings confirm the overall erosion threat but also underscore the importance of model and data selection to avoid overestimation and enable more spatially accurate conservation planning.

The total erosion in t/yr for entire basin is shown in Table 5 for all calculated soil loss by using two different LS methods on four different resolution DEM and two different K factor maps, considering all RUSLE parameters.

Table 5. Comparison of total annual soil erosion estimates (t/yr) under different modeling scenarios.

| | **SRTM 30 m** | **ALOS 30 m** | **TerraSAR-X 12 m** | **TerraSAR-X 5 m** |
|---|---|---|---|---|
| **ESDAC K-factor** | | | | |
| **Moore and Burch** | 1,516,276 | 1,578,012 | 1,540,940 | 1,243,943 |
| **Wischmeier and Smith** | 2,974,455 | 3,178,329 | 3,087,824 | 2,429,715 |
| **EPIC model-derived K-factor** | | | | |
| **Moore and Burch** | 1,797,475 | 1,873,902 | 1,789,515 | 1,449,181 |
| **Wischmeier and Smith** | 3,552,048 | 3,795,758 | 3,592,351 | 2,827,586 |

## 4. Reservoir Sediment Yield (SY) Calculation

Sediment yield (SY) refers to the amount of sediment transported from a watershed by runoff and delivered to a stream over time. It can also be thought of as the total amount of sediment entering a reservoir at the downstream end of the watershed. SY can be estimated by reservoir surveys or stream sediment measurement programs. However, reservoir surveys are generally considered to be the more reliable method for long-term sediment yield (Morris & Fan, 1997).

In this study, sediment yield for the catchment areas of reservoirs was calculated using both reservoir surveys. SY can be calculated with the following general equation with reservoir surveys (Kokpinar et al., 2015).

$$SY_{RS} = \frac{SV \times \gamma_s}{TE \times A} \times 100 \quad (7)$$

Where:

$SY_{RS}$: Sediment yield calculated by reservoir surveys (t/km²/yr),

SV: Annual sediment accumulation rate (m³/yr),

$\gamma_s$: Unit weight of sediment in the reservoir (t/m³),

TE: Sediment retention efficiency of the reservoir (%),

A: Basin area (km²).

However, the values of $\gamma_s$ and TE are often difficult to determine. Therefore, they are estimated using various empirical equations.

Periodic reservoir surveys are necessary to analyze the changes in sediment accumulation in reservoirs over time. These surveys are conducted to determine the changes in the area and storage capacity of the reservoir. They typically provide the following information:

• The amount of sediment accumulated after the dam closure,

• Annual sediment yield from the basin,

• Future storage capacity trends of the reservoir,

• Horizontal and vertical distribution of sediment,

• Sediment density and sediment retention efficiency (TE) of the reservoir.

In this study, bathymetric field surveys conducted at certain periods for the reservoirs considered were examined. The sedimentation process was analyzed using bathymetric field measurements conducted for Borçka and Muratlı reservoirs. The reservoir survey data of both dams obtained from DSI is presented in Table 6.

Table 6. Reservoir area sediment accumulation information of Borçka and Muratlı Dams.

| Dam Name | Year of Survey | Years in Operation | Area (ha) | Projected Volume ($hm^3$) | Volume at Year of Survey ($hm^3$) | Difference ($hm^3$) | Annual Avg. Sediment Amount ($hm^3$) | Design Dead Storage Volume ($hm^3$) | Dead Storage Volume at Survey ($hm^3$) | Dead Storage Difference ($hm^3$) | Annual Avg. Sediment in Dead Storage ($hm^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Borçka | 2017 | 9 | 1014 | 418.98 | 323.9 | 95.08 | 10.56 | 268.2 | 194.69 | 73.51 | 8.168 |
| Muratlı | 2020 | 12 | 380 | 73.5 | 44.41 | 374.57 | 32.21 | 53.56 | 27.73 | 25.83 | 2.153 |

Accordingly, during the 9-year and 12-year period in which Borçka and Muratlı Dams were in operation, a total of 95.08 $hm^3$ and 374.57 $hm^3$ of sediment accumulated in the reservoir area and formed dead volume, respectively. SV was obtained as 10.56 $hm^3$ for Borçka and 32.32 $hm^3$ for Muratlı Dams from bathymetry data, and the average of the values obtained by taking sediment samples from ground stations in the region was taken for density. Accordingly, the unit weight of the sediment in the reservoir was determined as 1.3 $t/m^3$. The sediment retention efficiency (TE) of the reservoir is defined as the ratio of the amount of sediment accumulated in the reservoir against the total sediment input:

$$TE = \frac{V_{dep}}{Q_{TS}} \quad (8)$$

One of the most widely used methods for this calculation is the curve developed by (Brune, 1953). Brune's model assumes that TE depends on the ratio of reservoir capacity ($V_{res}$) and annual mean inflow ($Q_{inflow}$):

$$TE = f\left(\frac{V_{res}}{Q_{inflow}}\right) \quad (9)$$

If $V_{res}/Q_{inflow} \geq 1$, TE value is accepted as 97.5%. Since $V_{res}$/ 5660 =17.92 in sediment trap efficiency calculation (annual average flow is 5660 million $m^3$), TE is taken as 97.5%. Accordingly, reservoir sediment efficiency for Borçka Dam is; $SY_{rs}$ = 7.312 t/ha/yr and for Muratlı Dam is $SY_{rs}$ = 19.119 t/ha/yr as shown in Table 7.

Table 7. Reservoir sediment yield of Borçka and Muratlı Dams.

| Dam Name | Catchment area, A ($km^2$) | Annual sediment accumulation rate, SV ($m^3$/yr) × $10^6$ | Unit weight of sediment in the reservoir, $\gamma_s$ (t/$m^3$) | Sediment retention efficiency of the reservoir, TE (%), | Reservoir sediment yield, $SY_{RS}$ | |
|---|---|---|---|---|---|---|
| | | | | | (t/$km^2$/yr) | (t/ha/yr) |
| Borçka | 19255 | 10.56 | 1.3 | 97.5 | 731.239 | 7.312 |
| Muratlı | 22100 | 31.21 | 1.32 | 97.5 | 1911.925 | 19.119 |

## 5. Validation of RUSLE Results by Reservoir Survey Data

Since RUSLE calculation depends on several variables and data quality, its validation is crucial. To achieve this goal, reservoir sediment yield calculations are considered for validation.

According to official data obtained from DSI, The Borçka Dam deposits 7.312 t/ha/yr sediment in the reservoir considering the reservoir survey while 19.119 t/ha/yr sediment is deposited in the Muratlı Dam reservoir. To relate RUSLE results with reservoir sediment yield, it's required to calculate sediment delivery ratio (SDR).

In literature, several methods are presented for determining SDR which are closely related to basin characteristics. In Türkiye, DSI prefer either SCS Method or method proposed by Vanoni (1975) due to the Turkey's similar basins characteristics that are considered in the aforementioned methods.

Table 8. Equations for SDR for Çoruh River Basin.

| **Equation** | |
|---|---|
| **Vanoni (1975)** | $\mathrm{SDR} = 0.42(\mathrm{A})^{-0.125}$ |
| **USDA-SCS (1971)** | $\mathrm{SDR} = 0.51(\mathrm{A})^{-0.11}$ |

The watershed of Borçka and Muratlı Dams are generated in GIS environment and presented in Figure 16.

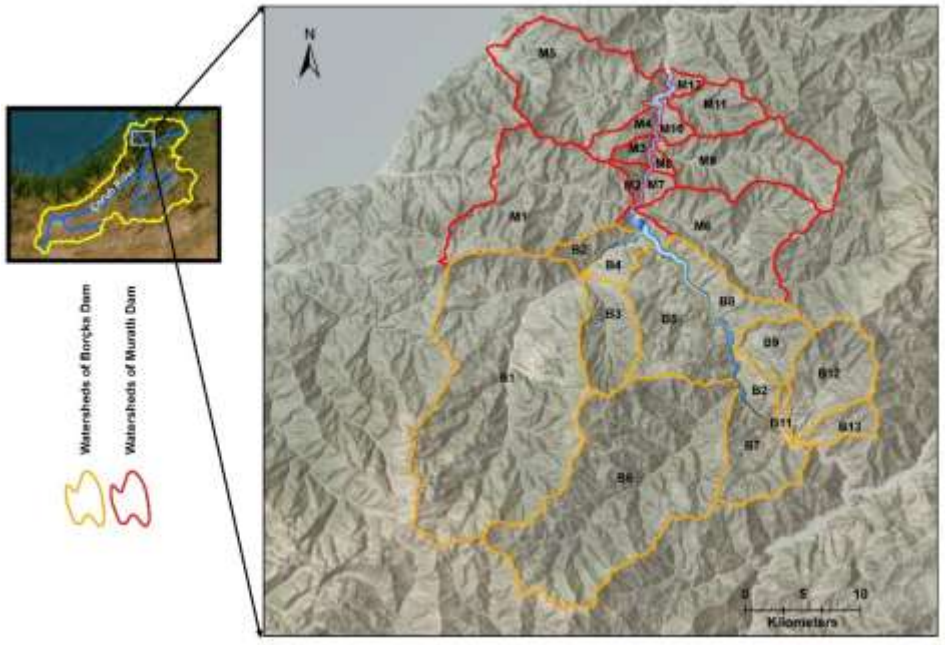



Fig. 16. Watersheds of Borçka and Muratlı Dams.

The watersheds of the Borçka and Muratlı Dams, shown in Figure 16, have their SDR values calculated using the USDA-SCS and Vanoni equations. The results are presented in Table 9.

Table 9. SDR values for watersheds of Borçka and Muratlı Dams.

| Watershed | SDR | | | |
|---|---|---|---|---|
| | Borçka Dam | | Muratlı Dam | |
| # | Vanoni | USDA - SCS | Vanoni | USDA - SCS |
| **1** | 0.3 | 0.23 | 0.26 | 0.34 |
| **2** | 0.43 | 0.35 | 0.39 | 0.47 |
| **3** | 0.38 | 0.3 | 0.38 | 0.46 |
| **4** | 0.43 | 0.35 | 0.35 | 0.43 |
| **5** | 0.35 | 0.28 | 0.27 | 0.34 |
| **6** | 0.31 | 0.24 | 0.27 | 0.35 |
| **7** | 0.37 | 0.29 | 0.38 | 0.47 |
| **8** | 0.39 | 0.31 | 0.41 | 0.50 |
| **9** | 0.4 | 0.32 | 0.28 | 0.35 |
| **10** | 0.43 | 0.35 | 0.37 | 0.46 |
| **11** | 0.48 | 0.39 | 0.31 | 0.39 |
| **12** | 0.37 | 0.29 | 0.40 | 0.48 |
| **13** | 0.42 | 0.34 | 0.45 | 0.51 |
| **Average** | 0.39 | 0.31 | 0.34 | 0.42 |
| **Weighted Average** | 0.26 | 0.23 | 0.28 | 0.27 |

Due to the varying watershed area and considering the contribution of each watershed to erosion, it is more convenient to consider the weighted average for predicting sediment yield to each reservoir. In addition, the SDR prediction of both equations is close to each other so that the average of SDR values is taken into consideration. Therefore, SDR is determined as 0.26 for Borçka Dam and 0.28 for Muratlı Dam.

After having determined the SDR values of each reservoir, reservoir sediment yield is calculated by considering the RUSLE results and the results for both reservoirs are given in Table 10. It should be noted that LS prediction equation of Wischmeier and Smith results is more reliable considering the $SY_{rs}$. Moreover, the DEM obtained from ALOS satellite leads to more accurate predictions.

Table 10. Calculated sediment yield and reservoir sediment yield data for the Borçka and Muratlı Dam watersheds using ESDAC K Factor.

| K-Factor | Watershed & Model | SYrs | SRTM 30 m | ALOS 30 m | TerraSAR-X 12 m | TerraSAR-X 5 m | % Diff (SRTM) | % Diff (ALOS) | % Diff (TX12) | % Diff (TX5) |
|---|---|---|---|---|---|---|---|---|---|---|
| ESDAC | **Borçka Dam** | | | | | | | | | |
| | Moore and Burch | 7.312 | 8.342 | 8.839 | 7.713 | 7.164 | 14.09% | 20.88% | 5.48% | -2.03% |
| | Wischmeier and Smith | 7.312 | 16.378 | 17.924 | 15.568 | 14.052 | 123.99% | 145.13% | 112.91% | 92.17% |
| | **Muratlı Dam** | | | | | | | | | |
| | Moore and Burch | 19.12 | 17.198 | 18.018 | 16.352 | 14.776 | -10.05% | -5.76% | -14.48% | -22.72% |
| | Wischmeier and Smith | 19.12 | 33.893 | 36.602 | 32.19 | 29.228 | 77.27% | 91.44% | 68.36% | 52.88% |
| EPIC | **Borçka Dam** | | | | | | | | | |
| | Moore and Burch | 7.312 | 9.326 | 9.888 | 8.784 | 8.092 | 27.55% | 35.23% | 20.13% | 10.67% |
| | Wischmeier and Smith | 7.312 | 18.248 | 19.99 | 17.52 | 15.815 | 149.56% | 173.39% | 139.61% | 116.28% |
| | **Muratlı Dam** | | | | | | | | | |
| | Moore and Burch | 19.12 | 20.553 | 21.534 | 19.065 | 17.63 | 7.50% | 12.63% | -0.28% | -7.79% |
| | Wischmeier and Smith | 19.12 | 40.525 | 43.777 | 38.462 | 34.883 | 111.96% | 128.97% | 101.17% | 82.45% |

## 6. Results and Discussion

This study evaluated the effects of two popular LS factor formulations on erosion estimates: Moore and Burch (1986) and Wischmeier and Smith (1978). Regardless of the DEM resolution employed, the results demonstrated that the Wischmeier and Smith approach consistently yielded larger soil loss compared to the Moore and Burch method. This disparity results from the two methods' different approaches to flow buildup and slope steepness. While the Wischmeier and Smith formulation typically yields steeper slope estimations, which increase erosion rates, the Moore and Burch equation more clearly integrates flow accumulation, which frequently results in lower LS values in particular terrains.

The interplay between LS factor selection and DEM resolution adds another layer of uncertainty to the analysis. As resolution increases (i.e., from 30 m to 5 m), the calculated LS values tend to decrease due to more refined slope and flow accumulation computations. This explains why the lowest erosion estimates were observed with the DSI 5 m DEM, particularly when using the Moore

and Burch method. Conversely, coarser-resolution DEMs overestimate slope lengths, leading to exaggerated erosion predictions. These findings highlight the need for careful consideration when selecting LS factor formulations, as different equations may introduce biases in the results, especially when applied to varying topographic resolutions.

Reservoir sediment yield ($SY_{rs}$) obtained from the bathymetric field measurements of the Muratlı and Borçka reservoirs compared with the calculated sediment yield by using Moore and Burch (1986) and Wischmeier and Smith (1978) formulations considering K-factors of ESDAC and EPIC for both dams. The comparison of the results showed that by considering K-factors of ESDAC and EPIC, Moore and Burch (1986) formulation is more accurate than Wischmeier and Smith (1978) formulation when the DEM resolution becomes finer.

A key aspect of this study was the evaluation of soil erosion across multiple DEM resolutions, allowing for a comparative assessment of how different spatial scales influence erosion predictions. The results demonstrated a clear trend: finer-resolution DEMs consistently produced lower soil loss estimates, while coarser DEMs overestimated erosion rates. This finding is particularly relevant for large-scale erosion studies, where the use of freely available, coarse-resolution DEMs may lead to inflated soil loss values. The sensitivity of the model to DEM resolution underscores the importance of multi-resolution analysis in soil erosion studies, as it provides insights into the reliability and potential biases of different datasets.

Moreover, the impact of the P factor on erosion estimates was assessed by recalculating soil loss without considering conservation practices. The results showed a substantial increase in erosion predictions, particularly for the Wischmeier and Smith method, which exceeded the 52.85 million tons per year reported by the Ministry of Agriculture and Forestry. This highlights the critical role of conservation practices in controlling erosion and suggests that neglecting the P factor in RUSLE

applications can lead to significant overestimations. The comparison with official erosion statistics further underscores the importance of parameter selection in model calibration, as different methodological choices can lead to divergent results.

Uncertainties resulting from a variety of sources, such as model parameters, input datasets, and methodological decisions, are inherent in soil erosion modeling. Because of its empirical formulation and flexibility, the Revised Universal Soil Loss Equation (RUSLE) is still one of the most used models for estimating long-term soil erosion rates. RUSLE is extremely sensitive to input parameters like rainfall erosivity (R), soil erodibility (K), topographic variables (LS), land cover management (C), and conservation strategies (P), despite its wide range of applications. Among these, the accuracy and dependability of model predictions are significantly influenced by the LS factor and the resolution of the Digital Elevation Model (DEM) that was used to derive it. The selection of different LS formulations and DEM sources introduces inherent uncertainties in erosion estimates, necessitating a careful examination of their impact on the final results. The analysis in this study confirms that the accurate way to determine model parameters decreases the uncertainties in the results and verifies the accuracy of the method of calculation of erosion form the study area.

In addition to the methodological uncertainties discussed above, it is also important to consider that climate change may influence reservoir sediment yield by changing rainfall regimes and the frequency of extreme events. Here, the critical link is the rainfall erosivity and the frequency of high-intensity storms, because these events can dominate runoff production and sediment transportation. Even if long-term mean precipitation has limited change, increased occurrence of high-intensity short-duration events may increase erosion and transport capacity, resulting in

increased sediment load delivered to river networks (Nearing et al., 2004; Walling, 1994). Such behavior has practical implications for reservoir sedimentation such that even small number of extreme events may result in substantial sediment load transportation.

Recent RUSLE applications further suggest that basin mean erosion rates may not change significantly, while erosion characteristics can shift spatially, especially due to projected changes in rainfall erosivity (R factor) and its variability within the basin (Gezici et al., 2025). This is important for reservoir sedimentation because sediment yield depends on hillslope erosion as well as how efficiently sediment is transported to the river network. As a result, local increases in sediment yield may occur even if basin mean erosion stays constant. In practice, this indicates the need to focus on sub-basins where the erosivity-related risk is likely to increase and to support the model findings with observations (e.g., periodic bathymetry measurements or satellite-based storage loss tracking) (Yao et al., 2023).

## 7. Conclusion

A study was made to determine accurate erosion predictions and reservoir sediment yield in GIS environment considering the bathymetric field surveys of two dams Muratlı and Borçka Dams, and RUSLE. This study also investigated uncertainties associated with soil erosion estimation using the RUSLE model, specifically the impact of four different resolutions of Digital Elevation Models (DEMs) of the basin, and LS factor formulations. In the study area, the findings revealed that erosion calculations are extremely sensitive to DEM resolution, with finer-resolution datasets (DSI 5 m and 12 m) generating lower soil loss projections than coarser-resolution DEMs (SRTM 30 m and ALOS 30 m).

The choice of LS factor formulation further contributed to variations in erosion predictions. The Wischmeier and Smith method yielded consistently higher soil loss estimates than the Moore and

Burch approach, emphasizing the role of slope representation in erosion modeling. The study underscores the necessity for multi-resolution analysis and uncertainty assessment in soil erosion modeling. Differences in DEM sources, LS factor formulations, and parameter assumptions can lead to substantial variability in soil loss estimates, affecting the reliability of erosion risk assessments. It was shown in the study area that the More and Burch approach is more appropriate for erosion modeling.

Since the RUSLE calculation for estimating erosion depends on several variables such as calculation of LS factor and data quality, its validation is crucial for erosion prediction. To achieve this goal, reservoir sediment yield calculations based on bathymetric field surveys are considered for validation. The Borçka Dam deposits $SY_{RS}$=7.312 t/ha/yr sediment in the reservoir considering the reservoir bathymetric survey while $SY_{RS}$=19.119 t/ha/yr sediment is deposited in the Muratlı Dam reservoir. To relate RUSLE results with reservoir sediment yield, it is necessary to calculate SDR. The SDR of the reservoirs are calculated by using Vanoni (1975) and USDR-SCS (1971) methods to relate RUSLE results with those reservoirs sediment yields. The analysis of the results showed that considering sediment yield of reservoir surveys ($SY_{RS}$) of the Muratlı and Borçka Dams, Moore and Burch equation using the DEM obtained from TerraSAR5m (DSI 5m) satellite for the basin, predicts RUSLE LS parameter more accurately. The analysis of the results showed that when ESDAC K-factor is considered the percent differences between reservoir field survey ($SY_{rs}$) for Muratlı and Borçka Dams and calculated sediment yield by RUSLE are 2% for Borçka Dam and 23% for Muratlı Dam, whereas when EPIC K-factor is considered those percent differences are 10.7% for Borçka Dam and 7.8% for Muratlı Dam. This analysis clearly documents that accurate prediction of erosion from the basin using RUSLE methods relies on accurate

determination of the RUSLE parameters as well as validation of results with the field measurements.

The findings of this study are valid for the area of interest. However, findings related to the data resolution and calculation methods can be generalized for various regions. Most of the time, validation of the results cannot be possible due to the lack of validation data. However, results of this study suggest that RUSLE is still beneficial tool for predicting erosion.

Ultimately, knowing these uncertainties is critical for effective sediment management, erosion control, and long-term watershed planning. Recognizing the limits of RUSLE and incorporating high-quality datasets allows decision-makers to build more reliable soil conservation policies that reduce erosion risks and ensure long-term environmental sustainability.

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