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The Impact of Land Use/Cover Change (2000-2018) on Soil Erosion in the Acısu Basin (Sivas/TÜRKİYE)

Acısu Havzası'nda (Sivas/TÜRKİYE) Arazi Kullanımı/Örtüsü Değişiminin (2000-2018) Toprak Erozyonu Üzerindeki Etkisi

Aytaç Murat Marangoz[1], Faruk Aylar[2], Halil İbrahim Zeybek[3]

Abstract

This study was conducted to determine the erosion risk caused by the change in land use/cover in Acısu Basin between 2000-2018. In the study where the RUSLE model was preferred, other parameters were kept constant, but the model was applied to the model twice separately with the land cover/use data of the relevant years and two independent erosion maps were created. With the study, how much soil is lost in Acısu Basin during the year, which regions are more exposed to erosion, and their distribution was classified and revealed. During the study, the data obtained from satellite images, topographic maps, and field observations were analyzed by GIS and IA techniques. Kappa statistical test was used for the accuracy of the findings. It was determined that the most change in the direction of growth in the basin in 18 years from 2000 to 2018 was 17.08 km² (3.35%) in grassland and pasture areas. On the other hand, it was determined that the highest change in the direction of the decrease occurred in plant change areas with a value of -23.05 km² (4.49%). It is seen that the change in the surface cover of the study area in this time interval caused the expansion of very light, light, and moderate erosion areas. Due to this change in the land surface of Acısu Basin covering 18 years, it was determined that there was an increase in the annual total of 197 t ha^{-1} y^{-1} and an increase in the average soil loss amount of 49 t ha^{-1} y^{-1}.

Keywords: *Erosion, RUSLE, Kappa test, Land use/cover, Sivas.*

Öz

Bu çalışma, Acısu Havzası'nda 2000-2018 yılları arasında arazi kullanımı/örtüsündeki değişimin neden olduğu erozyon riskini belirlemek amacıyla yapılmıştır. RUSLE modelinin tercih edildiği çalışmada diğer parametreler sabit tutulmuş ancak ilgili yıllara ait arazi örtüsü/kullanımı verileri ile model iki kez ayrı ayrı uygulanarak birbirinden bağımsız iki erozyon haritası oluşturulmuştur. Çalışma ile Acısu Havzası'nda yıl içerisinde ne kadar toprak kaybedildiği, hangi bölgelerin erozyona daha fazla maruz kaldığı ve bunların dağılımı sınıflandırılarak ortaya konuldu. Çalışma sırasında uydu görüntüleri, topografik haritalar ve saha gözlemlerinden elde edilen veriler CBS ve UA teknikleri ile analiz edildi. Bulguların doğruluğu için Kappa istatistik testi kullanılmıştır. 2000-2018 yılları arasındaki 18 yıllık dönemde havzada büyüme yönünde en fazla değişimin 17,08 km2 (%3,35) ile çayır ve mera alanlarında olduğu tespit edildi. Öte yandan azalma yönünde en fazla değişimin -23,05 km² (%4,49) değeri ile bitki değişim alanlarında gerçekleştiği tespit edilmiştir. Bu zaman aralığında çalışma alanının yüzey örtüsündeki değişimin çok hafif, hafif ve orta derecede erozyon alanlarının genişlemesine neden olduğu görülmektedir. Acısu Havzası'nın arazi yüzeyinde 18 yılı kapsayan bu değişime bağlı olarak yıllık toplam 197 t ha^{-1} y^{-1}. ve ortalama toprak kaybı miktarında 49 t ha^{-1} y^{-1} artış olduğu tespit edilmiştir.

Anahtar Kelimeler: *Erozyon, RUSLE, Kappa testi, Arazi kullanımı/örtüsü, Sivas.*

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[1] Student, Ondokuz Mayıs University Graduate School of Education, Samsun, Türkiye, Orcid: http://orcid.org/0000-0003-4067-8804
[2] Associate Professor,Ondokuz Mayıs University, Samsun, Türkiye, farukaylar@gmail.com, Orcid: http://orcid.org/0000-0003-4439-9079
[3] Professor, Ondokuz Mayıs University, Samsun, Türkiye, zeybekhi@gmail.com, Orcid: http://orcid.org/0000-0002-4097-9079

Introduction

Soil erosion is defined as the process by which the surface of a mature soil is removed from the environment and transported to other areas under the influence of water and wind (Morgan 2005; Jahun, 2015; Jafari et al., 2022). Erosion is a process that occurs when soil is left unprotected for various reasons. In this case, raindrops hit the exposed soil with great energy and easily remove soil particles from the surface (Mater, 2004; Ekinci, 2005; Morgan, 2005; Özşahin, 2011; Jahun et al., 2015; Zeybek, 2002; Erinç, 2021; Jafari et al., 2022). Soil erosion occurs in three stages including weathering, transport and deposition. The severity of erosion increases especially where the topographic slope values increase. In such locations, factors such as soil texture, structure, slope ratio, and surface cover are important parameters that determine the amount of erosion (Merritt et al., 2003). Soil erosion, which occurs for various reasons, is one of the most important environmental problems today. According to the World Health Organization, the structure of about 10 million hectares of agricultural land in the world is degraded by erosion and converted into non-agricultural land, and this situation causes a decrease in agricultural production needed to feed about 3.7 billion people (Pimentel et al., 2009). Approximately 85% of the negative impact on the Earth's land cover is caused by soil erosion, which has led to a 17% decline in agricultural crop productivity since 1945 (Angima et al., 2003).

Soil erosion has become an important problem in areas such as Turkey, where drought is experienced for long periods of the year due to intense rainfall falling on steep slopes with loose soil structure and causing significant erosion (Onori et al., 2006; Jahun et al., 2015; URL-1, 2023). Some studies have found that soils transported by erosion carry many substances used in agricultural activities and mixed with soil to surface and groundwater, causing pollution of these waters (Gallaher and Hewf, 1997). In addition, it has been shown that the productivity of soils in eroded areas decreases and that these soils, whose structure changes during agricultural activities, cause air pollution (Renard et al., 1997; Zachar, 1982). As can be seen, these studies show the importance of identifying and controlling erosion risk in countries such as Turkey, which has a rugged land structure and high slope values. However, depending on the local factors, it is very important to accurately determine the erosion characteristics of this area and take measures accordingly before determining a protection strategy in any region (Jahun, 2015).

Numerous studies have been conducted at different scales to determine how soil erosion occurs and to quantify it (Desmet and Govers, 1996; Renard et al, 1997; Knijft et al., 1999; Sivertun and Prange, 2003; Cürebal and Ekinci, 2006; Ekinci, 2007; Tağıl, 2007; Efe et al., 2008; Jahun et al., Ganasri and Ramesh, 2016; Koirala et al., 2019; Kumar et al., 2022; Şen et al., 2022; Xu et al., 2022; Majoro et al., 2023). As a result of these studies, soil erosion prediction models have been developed based on different land uses. These can be classified as empirical, conceptual, and physically based models (Merritt et al., 2003; Jahun et al., 2015). However, the different data sets required for the application of all these models and the difficulty in their application lead to the application of different models in different regions (Merritt et al., 2003).

USLE (Wischmeier and Smith, 1978), which is one of the models produced for predicting the amount of erosion, is preferred by many researchers due to the ease of data supply and parameterization (Wilson and Lorang, 1999; Eisenberg and Muvundja, 2020; Romero et al., 2023). USLE is an important model that predicts the future annual erosion rate of the land by determining precipitation characteristics, soil structure, morphological appearance, surface closure status, and measures taken (Kouli et al., 2009). However, in light of the data obtained from new studies, this model was revised and started to be applied as the RUSLE model (Renard et al., 1997; Jahun et al., 2015; Şen et al., 2022). In addition, the use of RUSLE integrated with remote sensing (RS) and geographic information system (GIS) techniques is one of the advantages of the model. The results of many studies using this model show that it is effective and accurate in estimating the magnitude and spatial distribution of erosion in an area. In addition to such studies that attempt to estimate the amount of erosion directly, there have been many studies that investigate the relationship between land use/land cover, which is one of the important factors causing erosion. Most of these studies show that changes in land use/cover due to anthropogenic impacts have a significant impact on erosion (Sharma et al., 2011; Alkharabsheh et al., 2013; Özşahin et al., 2018).

This study covers the Acısu Basin located in the eastern part of the Sivas Basin, one of the most important gypsum fields in Turkey. The change in land use due to intensive human activities in the basin and its presentation reveals the importance of this study. Based on this situation, the study aims to discuss the effect of human activities on soil erosion of land use/land cover change in the Acısu Basin. Based on this idea, does the change in land use/cover affect the formation of erosion or the expansion of erosion areas in the basin formed by the Acısu stream, which is one of the important tributaries in the upper course of Kızılırmak, the longest river of Turkey? This question constitutes the research problem. To find the answer to this question, erosion risk and annual soil loss in this basin were calculated with the Geographic Information Systems (GIS) based and Remote Sensing (RUSLE) model considering fixed and variable parameters. In the RUSLE model, (R) and (K) parameters that affect erosion are fixed variables while (LS), (C), and (P) parameters are controllable variables (Renard et al., 1997; Jemai et al., 2021; Majaro et al., 2023; Romero et al., 2023). Therefore, in this study, the controllable parameter C in the RUSLE model was calculated separately for the years 2000 and 2018, while other parameters were kept constant.

1. Study Area

The Acısu basin, which is the study area, is located in the Upper Kızılırmak region of Central Anatolia. The study area, which is the drainage basin of Acısu, one of the tributaries of Kızılırmak River, the longest river in Turkey, is approximately 513 km^2. According to the geographical coordinate system, the basin is located between 39º 52' 38" - 39º 41' 35" north latitude and 37º 44' 18" - 38º 11' 48" east longitude (Figure 1). Acısu Stream, which originates from the northeastern slopes of Tecer Mountains, flows westward by taking many tributaries from here and joins Kızılırmak in the southwest of Zara District.

Acısu Stream flows for about 68 km from its source to the vicinity of Zara District where it joins Kızılırmak. The lowest point of the basin formed by Acısu Stream is the confluence of the stream with Kızılırmak in the southeast of Zara with an elevation of 1320 m On the other hand, the highest point of the basin is Üçlerbaba Hill, which is located on the Tecer Mountains in the south and has an elevation of approximately 2355 m Accordingly, while the elevation difference of the basin is 1035 m, the general average elevation of the basin is determined to be 1655 m.

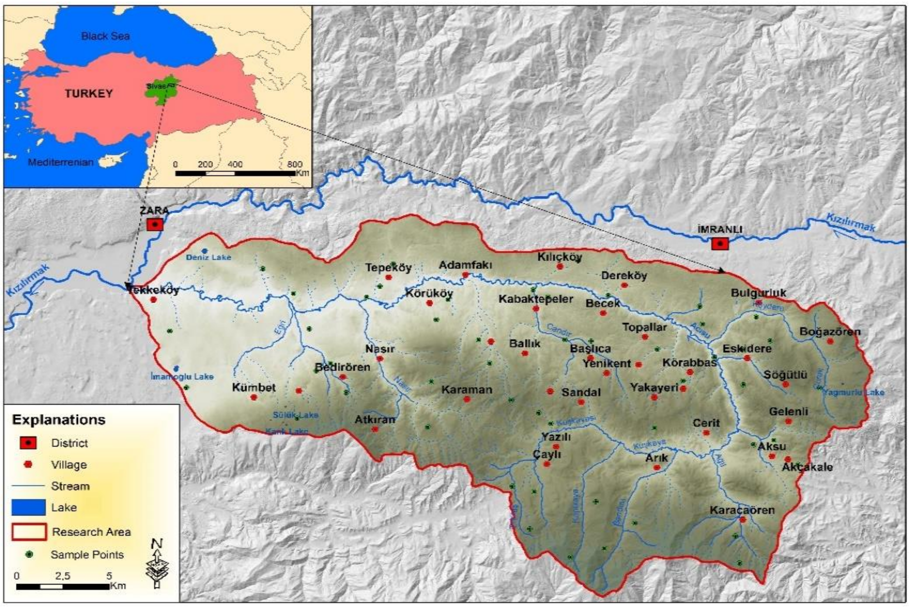

Figure 1. Location map of the study area.

While the Acısu Stream flows through the Upper Oligocene-Lower Miocene rocks such as sandstone, mudstone, and limestone in the southeast of the study area, it flows through the Middle-Upper Miocene gypsiferous terrain from the village of Eskidere in the east to its confluence with Kızılırmak (Fig. 2). In addition, Quaternary units are observed on the valley floor, especially in the lower course of the river (Figure 3; Figure 4). While the western lower reaches of the Acısu Basin, which has a typical hydrological basin character, have a simpler topography, the middle and upper reaches have a highly faulted and fragmented topographic appearance (Figure 5).

The Acısu Basin is in the typical continental climate zone of the mid-latitudes with cold and wet winters and warm and dry summers, indicated by the letters "Dsb" in the Köppen-Geiger climate classification (Öztürk et al., 2017). According to the data (1965-2020) of the Zara meteorological station (1338 m) located in the west of the basin, the average annual temperature is 8.6 °C and the average annual precipitation is 536.0 mm.The average temperatures of the winter months (December, January, February) are below 0 °C and the average temperatures of the summer months are below 20.0 °C (MGM, 2022). The coldest month is January (-3.6 °C) and the hottest month is August (19.6 °C). However, a decrease in average temperature and an increase in precipitation is expected with increasing elevation towards the east of the basin.

Figure 2. Polygonal karst topography formed on the gypsum terrain west of Eskidere village. This area is also among the areas where soil erosion is effective in the study area

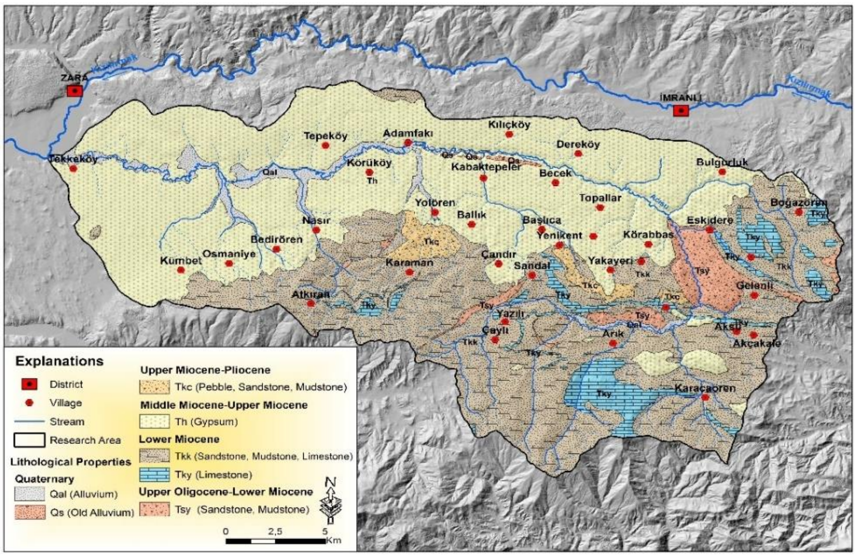

Figure 3. Geological map of the study area

Figure 4. The Quaternary alluvial deposits formed by Acısu Stream in the lower course of the basin. Tekkeköy village is in the background

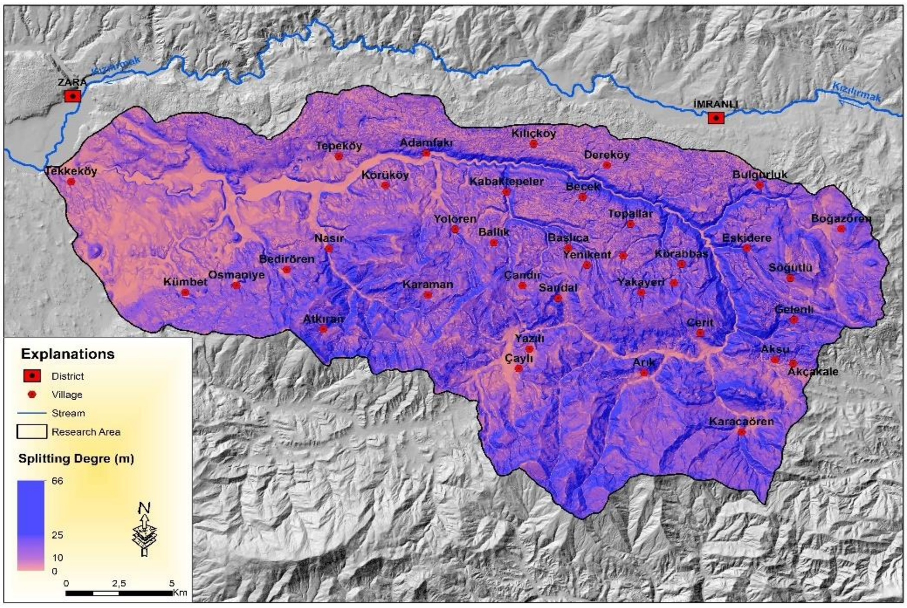

Figure 5. Splitting degree map of the study area

Acısu Stream, which drains the waters of the study area, is one of the most important tributaries of Kızılırmak. While Kuşkayası stream, the most important tributary of this stream in the south, flows from west to east, depending on local differences, it starts to flow towards the north after merging with Ağıl stream in the north of Cerit village. Acısu, which is strengthened with the participation of Köyderesi in the west of Eskidere, starts to flow westwards from here and merges with Kızılırmak in the southwest of Zara district. The winter season in the basin is cold and snowy and the snow cover remains on the ground for a long time. Snow melts and spring rains caused by the increase in temperatures cause the flow rate of the Acısu Stream to increase. In the summer months, the snow cover disappears completely, and monthly precipitation averages decrease. This causes the flow of the stream to decrease. However, the short-term downpours in the summer months quickly pass into surface runoff due to the thin soil cover and sparse vegetation cover, causing soil erosion to increase. Brown forest soils are the most widely distributed soil group in Acısu Basin. These soils, which are distributed in approximately 70% of the basin, have a wide distribution in the southern, central, and northern parts of the basin. However, brown soils are distributed between Boğazören-Söğütlü-Bulgurluk villages in the east of the basin, while reddish-brown soils have a wide distribution between Tekkeköy-Nasır villages in the west of the basin.

The most common land use/cover class in Acısu Basin is grassland and pasture areas (59.16% in 2018). In this respect, large parts of the basin are particularly suitable for ovine breeding (Figure 6). Depending on the climatic characteristics, steppe-characterized plants that flourish in spring turn yellow in early summer. Therefore, this characteristic of the area does not have suitable conditions for cattle breeding (pasture animal husbandry). While agricultural areas cover large areas, especially in the west of the basin, they have a fragmented appearance in other parts. Dry agricultural activities are more common in agricultural areas covering 15.49% (2018) of the total area of the basin. It is observed that irrigated agriculture is practiced only in a limited area on the banks of the river in the lower part of the basin. In a significant part of the Acısu Basin (20.84%), there are agricultural areas with natural vegetation. This is especially evident at the bases of the dolines, which are widespread in the northern part of the basin due to lithological features (Figure 7). Some fodder crops, mainly wheat and barley, are grown in agricultural areas, and sugar beet production is carried out in places where irrigation is possible. In the basin where forested areas cover a very small area (3.30%), forests are located on the slopes of mountainous areas and have a fragmented appearance.

Figure 6. Intensive animal husbandry activities are carried out in the pastures within the basin. South of Söğütlü village

Figure 7. View of agricultural fields at the base of the doline east of Bulgurluk village

3. Materials and Methods

In this study, a 5 m resolution Digital Elevation Model (DEM) obtained from the General Directorate of Mapping was used as the base material and this DEM was used as a base for other maps. The "Regulated Universal Soil Loss Equation" (RUSLE) model (Wischmeier, 1978; Desmet and Govers, 1996; Özşahin, 2014; Jahun et al., 2015; Şen et al., 2022) reported by various researchers was used to determine the potential erosion risk areas of Acısu Basin and to classify these areas (1).

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

According to this formula forming the model; A: Estimated annual soil loss amount (ha^{-1}/y^{-1}), R: Rainfall erosion factor ($MJ/ ha^{-1}/y^{-1}$), K: Soil erosion factor, LS: Slope slope length and slope steepness factor, C: Land cover and management factor, P: Erosion control (preventive) factor. In the erosion risk map obtained as a result of the application of this formula, the erosion potential risk categories determined by Bergsma et al. (1996) and frequently applied in the literature were used (Özşahin, 2023). These are; Very Light (< - 5 t/ha^{-1} $/year^{-1}$), Light (5-12 t/ha^{-1} $/year^{-1}$), Medium (12-35 t/ha^{-1} $/year^{-1}$), Strong (35-60 t/ha^{-1} $/year^{-1}$), Severe (60-150 t/ha^{-1} $/year^{-1}$) and Very Severe (150 > t/ha^{-1} $/year^{-1}$).

In the calculation of the "Rainfall Erosion (R) Factor" in the formula, the "Erosion Index" value is obtained by multiplying the kinetic energies of precipitation by their maximum intensities for 30 minutes, which is applied at many different points and data sets of many years, has an important place in the calculation of soil loss caused by precipitation (Cürebal and

Ekinci, 2006; Efe et al., 2008; Nearing et al., 2017). For the calculation of this factor, the long-term precipitation data of Zara Meteorological Station (1965-2021), which is located just west of the Acisu Basin, were used. This factor was calculated using the formula "Modified Fournier Index (MFI)" (2) (Williams and Sheridan, 1991; Bayramin et al., 2006), which takes into account annual and monthly rainfall averages.

$$MFI = \sum_{i=1}^{12} \frac{p_i^2}{P} \qquad (2)$$

In this formula, pi is the monthly precipitation (mm) and P is the average annual precipitation (mm). The "Precipitation Erosive Factor" required for the application of the RUSLE model is calculated by applying the result of the above formula to the equation "(4.17 - MFI)-152". However, as an example for other studies, if there is not more than one meteorological station in the study area, the long-term precipitation data of these meteorological stations at different elevations should be calculated with the help of the formula "Ph=Po+4,5h" developed by taking into account the principle of 54 mm of precipitation increase per 100 m proposed by Schreiber (Cürebal and Ekinci, 2006; Efe et al., 2008). In this formula, Ph is the average monthly precipitation (mm), Po is the monthly precipitation (mm) of the station with known elevation and h is the elevation value. Precipitation data obtained from local units can be used in the calculation of precipitation erosivity, and there are institutions such as the European Soil Data Centre (ESDAC) where precipitation erosivity data can be obtained on a global scale (Şen, 2022).

The Soil Erosion (K) Factor usually examines the relationship between soil properties and erodibility to determine the K value (Kebede et al., 2021). Erosion refers to the transport of soil from one place to another (Blanco-Canqui and Lal, 2008). As a result of erosion occurring due to different reasons, the material transported is usually soil formed over a very long time. Therefore, the determination of soil resistance to erosion has an important place in such studies. Factors such as soil texture and structure, profile, grain size, water holding capacity, and permeability are the main soil properties that affect erosion (Renard et al., 1997; Mater, 1998; Atalay, 2011; Mutlu and Soykan, 2018). While creating the K factor map, it was checked from the 1/25.000 scale digital soil maps obtained from the Ministry of Agriculture and Forestry and the TAD Portal (Non-Agricultural Authorisation and Soil Survey Portal) data provided by the ministry to users on the web.

The slope Length and Slope Steepness (LS) Factor is one the important parameters in the RUSLE model. The velocity and flow of water causing erosion are closely related to the slope. There is a directly proportional relationship between slope and erosion (Hoşgören, 2004; Ekinci, 2005). While creating the LS map, DEM data obtained from the General Directorate of Mapping was utilized. The flow direction (slope length and elevation classes) characteristics of the catchment area were determined by considering the following equation (3).

*"Flow accumulation * Flow direction * (elevation)"* *(3)*

The (LS) factor of the catchment was calculated according to the following equation (4) considering the above equation (Ekinci, 2007; Tağıl, 2007; Pradhan et al., 2011).

*"LS = 1.6 * Pow (([current accumulation] * resolution) / 22.1, 0.6) *Pow (Sin([slope] *0.01745) / 0.09, 1.3)"* *(4)*

Land Cover and Management (C) Factor, CORINE LULC data for the years 2000 and 2018 were utilized from Copernicus Europe's Eyes on Earth website for the years 2000 and 2018 (Özşahin and Atasoy, 2014) . CORINE LULC data for 2000 was obtained from Landsat-7 satellite and the time interval is 2000 +/- 1 year. The geometric accuracy of the satellite data is ≤ 25 meters. Produced for 4 years, these data are provided free of charge to users as standard metadata. On the other hand, CORINE land cover data for 2018 was obtained from Sentinel-2 and Landsat-8 satellites and the time interval covers the years 2017-2018. The geometric accuracy of the satellite data for this year is ≤ 10 meters and the thematic accuracy is ≤ 85%. Produced for 1.5 years, these data are presented as standard metadata. To check the accuracy of CORINE land cover data, which constitutes the main data of the study, free satellite images of July of the relevant years were obtained from the United States Geological Survey (USGS) website. This is important for eliminating errors due to differences in sun angle and vegetation cover (Tağıl, 2007; Özşahin, 2016).

In the evaluation of the images, a supervised classification technique was used with the maximum likelihood approach. Tağıl (2007) and Özşahin (2016) state that supervised classification would be more appropriate for the construction of land use/cover maps. In addition, during the determination and control of land use/cover classes, existing GPS data and location points determined and coordinated during field studies were also utilized. After correlating all the data, the kappa statistical test was applied to determine the accuracy rate of the land use/cover classes determined as a result of the analysis. Used for the first time in 1960 by Cohen, this method is a statistical method that measures the reliability of the agreement in two or more data sets (Cohen, 1960; Jensen, 1996; Kılıç, 2015). "Cohen's Kappa Coefficient" only deals with the agreement between two data sets. Since the data set (variable) in which the agreement is evaluated is a categorical (nominal) variable, the applied statistic is a non-parametric statistic type. Since Cohen's (1960) kappa test also takes into account that the agreement between data sets (variables) may be by chance, it is accepted that it gives a stronger result than the agreement found as a percentage proportion between two data sets (Cohen, 1960; Fleiss, 1971; Kılıç, 2015).

When calculating the Kappa coefficient, a calculation is made by considering two different probabilities. These are expressed as Pr(a) and Pr(e). Pr(a) is the total proportion of the observed agreement for two data sets (variables), while Pr(e) is the probability of this agreement occurring due to chance. The formula (5) to be used to compare the data sets over these two probabilities is given below (Kılıç, 2015).

$$\kappa = \frac{\Pr(a) - \Pr(e)}{1 - \Pr(e)} \quad (5)$$

To interpret the κ value obtained from this calculation, Landis and Koch (1977) proposed the following table (Table 1).

Table 1. Interpretation of the κ value obtained from Cohen's Kappa Statistical Test (Landis and Koch, 1977)

κ Value	Comment
< 0	Worse compliance than that which might be due to chance
0.01-0.20	Insignificant level of compliance
0.21-0.40	Weak level of harmonization
0.41-0.60	Moderate level of harmonization
0.61-0.80	Good level of harmonization
0.81-1.00	Very good level of harmonization

On the other hand, in the classification made by Fleiss (1971), the Kappa value of 0.75 and above is considered excellent, with 0.40-0.75 as medium-good and below 0.40 as poor compatibility (Kılıç, 2015). As a result of all these analyses, 6 different land use/cover classes with an overall accuracy of 80% and kappa coefficients above 0.75 were identified. The C factor values of the relevant classes were compiled from different sources (Jordan et al., 2005).

The erosion Control (Prevention) (P) Factor refers to the techniques used to prevent, control, or reduce erosion in the RUSLE model (Lane et al., 1992; Renard et al., 1997). Increasing the density of vegetation cover, terracing on steep slopes, and draining water by opening artificial channels are some of the techniques used in this regard (Mutlu and Soykan, 2018; Ghosal and Bhattacharya, 2020). The P factor should be evaluated between 0 and 1. It is expressed as 0 for areas where there is no erosion risk and 1 for areas with high risk (Zeng et al., 2017). This factor is used as 1 in cases where no detection is made during field studies and the value is ignored in the equation.

After the factors constituting all parameters were produced according to the RUSLE method, the soil loss of Acısu Basin for the years 2000 and 2018 was calculated by combining them with the help of the raster calculator tool of the ArcGIS program within the framework of the grid-based method and erosion risk maps with a resolution of 30x30 m were created. Some statistical analyses were also performed to make the findings obtained as a result of the study more meaningful. Within the scope of these analyses, 50 sampling points determined by random sampling method within the basin were determined (Figure 1) and the information on land use/cover changes and soil loss at each point was determined using the "correlated tabulation method" (Özşahin, 2016). Then, the relationship between the data was subjected to a one-way analysis of variance (One-way ANOVA). The results of the analysis were evaluated at a 0.05 significance level. In addition, the image analyses of the study were performed with ArcGIS 10.5 and Erdas 9.2, and statistical analyses were performed with SPSS 20 (Statistical Package for Social Sciences) software.

4. Result

Determining land use/cover at local and regional scales and monitoring the changes over time provides important information on planning, development, and sustainable management of natural resources. Such studies also contribute to the interpretation of information on LULC changes, and social and economic trends (Başyiğit et al., 2013; Özşahin, 2016). Sivas region is one of the most important settlement centers of Anatolia with thousands of years of historical past. This situation has enabled the land use/land cover to be used in different ways in the region where the study area is located for a long time. The unconscious, unplanned, and inappropriate use of the local people, the ambition of the people to gain new lands, and the rapid destruction of existing forests, especially for the need for fuel, construction, timber and to open agricultural land, have led to negative consequences on land use/cover. For this purpose, monitoring and accurate evaluation of anthropogenic changes in the Acısu Basin with scientific methods are of great importance in terms of making inferences for the future. Therefore, in this study, like many similar studies, aerial photographs and satellite images were used extensively to assess the field with a holistic perspective as well as field studies (Verstappen and Zuidam, 1970; William et al., 1999).

Different parameters are effective in soil erosion (Gobin et al., 2004; Walstra et al., 2007). The degree of influence of these parameters in the basin can also change the type and extent of erosion. To reveal the effect of erosion due to land use/land cover in Acısu Basin, firstly, the model of the parameters affecting soil erosion according to the method content will be applied and then the effect of land use/land cover will be discussed in the light of the findings obtained within the framework of the analysis.

4.1. Implementation of the Model

To determine the rainfall erosion (R) factor in the RUSLE model, the total kinetic energy of the rainfall throughout the basin should be multiplied by the maximum intensity of this rainfall for 30 minutes. This calculated value has a decisive effect on soil loss (Cürebal and Ekinci, 2006; Özşahin, 2014). For this reason, the rainfall erosion factor for Acısu Basin was calculated as described in the method section (Table 2). Accordingly, the areas where the (R) factor is more effective are the mountainous areas in the south of the site. Especially in the south of Atkıran and Karacaören villages, the effect is higher. On the other hand, the effect of this factor is less in the area where Tekkeköy village is in the west of the basin (Figure 8).

Table 2. Areal distribution of the Rainfall Erosion (R) factor.

R Factor (MJ ha^{-1} y^{-1})	Area	
	km^2	%
531-600	85	16.58
600-700	162	31.57
700-800	187	36.45
800-900	63	12.28
900 >	16	3.12
TOTAL	513	100.00

Soil has effects such as providing the material necessary for the realization of the erosion event, retaining the rainwater causing erosion, and resisting the erosive forces passing to the surface flow. This resistance to weathering and transport depending on the physical properties of the soil is known as the soil erosion (E) factor (Kebede et al., 2021). The main factors determining this factor are grain size, aggregation, water retention ability, water holding capacity, and profile characteristics (Blanco-Canqui and Lal, 2008; Mutlu and Soykan, 2018). However, the effect of this factor varies in different soil types. For this purpose, the K factor value can be calculated using different methods (Wischmeier and Smith, 1978; Goldman et al., 1986; Rosewell and Loch, 2002). In this study, soil erosion (K) factor values in Acısu Basin were assigned as a result of the correlation of local samples taken from the field with the values used in similar studies conducted throughout Turkey (Hammad et al. 2004), as in many studies using the RUSLE model (Table 3; Figure 9).

Table 3. Areal distribution of soil erosion (K) factor.

Factor	Soil Group	Area		RUSLE K Value
		Km^2	%	
Soil (K) (Tons per unit hectare)	Alluvial Soils	14.2	2.76	0.24
	Colluvial Soils	16.1	3.15	0.21
	Brown Soils	36.1	7.05	0.18
	Brown Forest Soils	383.4	74.73	0.16
	Reddish Brown Soils	63.2	12.31	0.14
TOTAL		**513.0**	**100.00**	

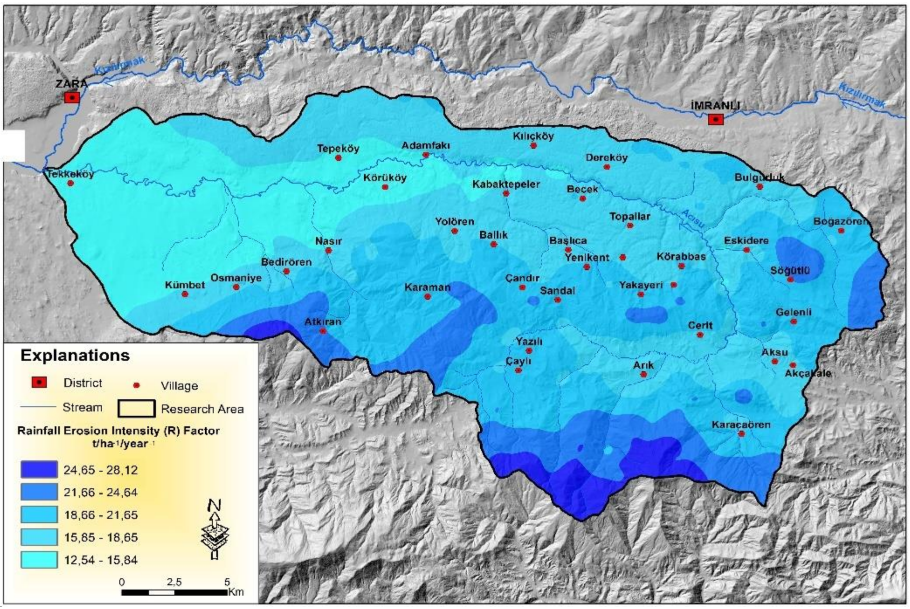

Figure 8. (R) factor map of the study area

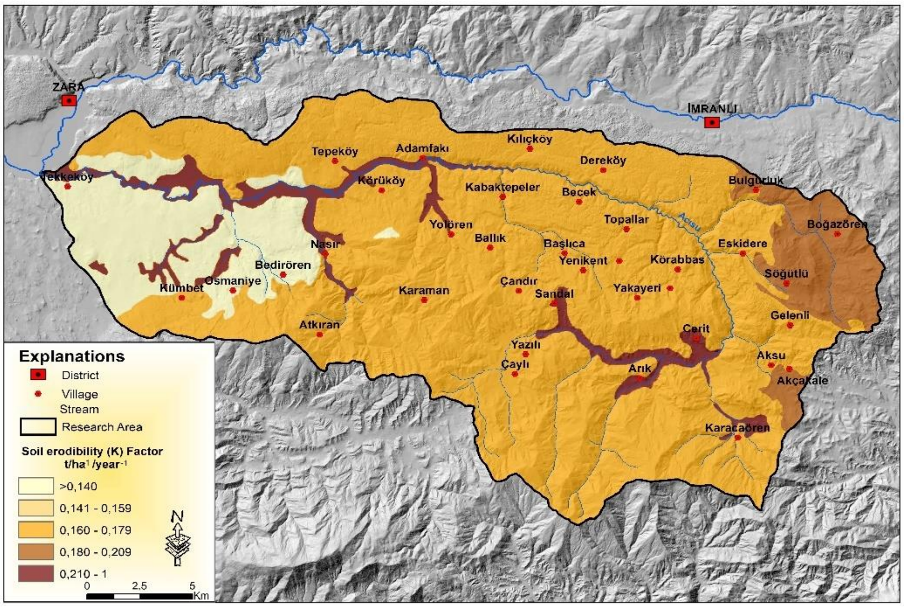

Figure 9. (K) factor map of the study area

The LS factor expresses the effect of slope length (L) and slope steepness (S) on soil erosion (Wischmeier and Smith, 1978). These two factors are the most important topographic parameters affecting soil susceptibility to erosion (Datta and Schack-Kirchner, 2010). These two factors are usually calculated as one factor. This is because these two factors are related to topography, unlike other factors that represent different elements (Kaffas et al., 2021). Naturally, soil erosion occurs more on steep slopes due to increased soil transport by water (Nanna, 1996). However, this erosion caused by water is also directly proportional to the increase in the length of the slope, which has an increasing effect on the collection of surface water (Hoşgören, 2004; Özşahin, 2014; Mutlu and Soykan, 2018). Accordingly, the slope values in Acısu Basin were analyzed in five groups considering the slope classes determined for soil erosion (Table 4).

Table 4. Areal distribution of slope

Slope	Area	
	Km2	%
Very little slope (0-3%)	46.10	9.16

Slightly sloping (3-10%)	61.20	11.89
Moderate slope (10-20%)	119.70	23.19
Steep slope (20-30%)	111.90	21.83
Very steep slope (30%->)	174.10	33.93
TOTAL	**513.00**	**100.00**

The values of this factor (LS) are high on the slopes of the river valleys in the study area and on the slopes of the mountainous area in the south. On the other hand, the values are partly lower in the alluvial area in the west of the basin and in the area with dolines in the north (Figure 10).

The Land Cover and Management (C) factor, which constitutes another parameter of the RUSLE model, is determined depending on the relationship between precipitation, infiltration, and runoff. Because these factors were developed based on the idea that the natural land cover of the land surface and the alteration of this natural land cover as a result of human activities will be effective in different ways (Özşahin, 2014). For this reason, it is important to compare the dimensions of the C factor effect in the Acısu Basin from the recent past to the present. To make this comparison, the land use/cover maps created because of the analyses made on satellite images of different years (2000 and 2018) were obtained as a result of applying the model to both years, provided that other factors remain constant.

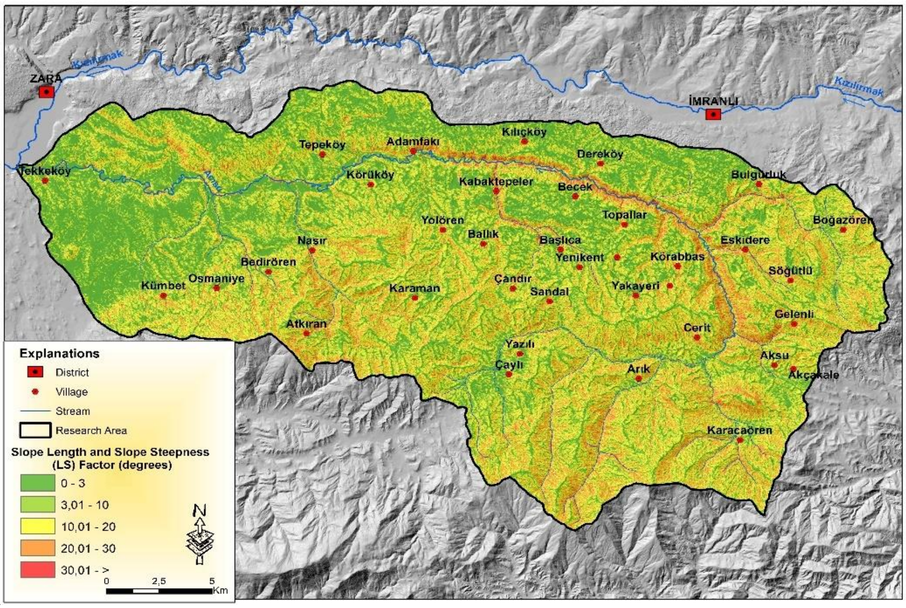

Figure 10. (LS) factor map of the study area

Accordingly, after the land use/cover classification process of Acısu Basin for the years 2000 and 2018, the classified areas were subjected to accuracy analysis in comparison with satellite images. During this analysis, reference points taken from the field and classified satellite images were compared. For this comparison, the "Kappa Statistical Test" described in the method section was applied. This test measures the reliability of the agreement between two or more data sets. The results of this test are given in Table 5.

Table 5. Accuracy analysis results of the controlled classification process for the years 2000 and 2018

Years	Kappa Value	Accuracy Percentage
2000	0.8928	93.21%
2018	0.9051	94.13%

As a result of this classification for Acısu Basin, the Kappa value of the satellite image of 2000 is 0.8928 and the accuracy is 93.21%, while the Kappa value of the satellite image of 2018 is 0.9051 and the accuracy is 94.13%. The data obtained reveal that the accuracy between the data sets is "very good" according to the classification of Landis and Koch (1977), while it is considered "Excellent" compatibility according to the classification made by Fleiss (1971). Taking this analysis into account, six different classes with an accuracy rate of approximately 90% were obtained for land use/cover for the years 2000 and 2018 (Table 6; Figures 11 and 12).

Table 6. Areal change in land use/land cover between 2000-2018

Land Use/Cover	2000		2018		Change	
	Area		Area		Area	
	km²	%	km²	%	km²	%
Agriculture areas	70.23	13.69	79.50	15.49	9.27	1.80
Forest areas	22.68	4.42	16.98	3.30	-5.70	-1.12
Natural grassland and Pastures	285.92	55.81	303.40	59.16	17.08	3.35
Land principally occupied by agriculture, with significant areas of natural vegetation	129.98	25.33	106.93	20.84	-23.05	-4.49
Bare rocks	2.78	0.57	5.53	1.07	2.57	0.50
Inland wetlands	0.83	0.18	0.66	0.14	-0.17	-0.04
TOTAL	**513.00**	**100.00**	**513.00**	**100.00**		

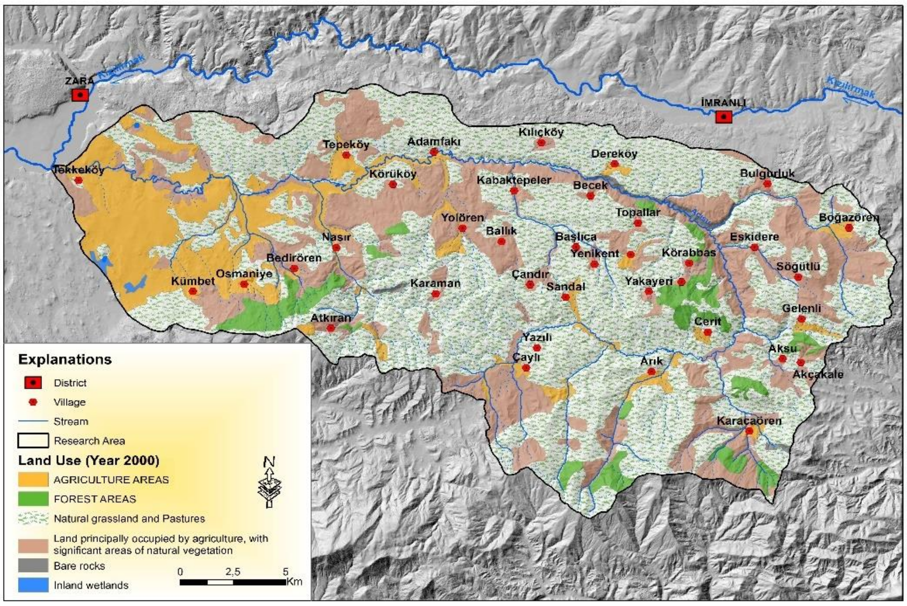

Figure 11. Land use/cover map of the study area (2000)

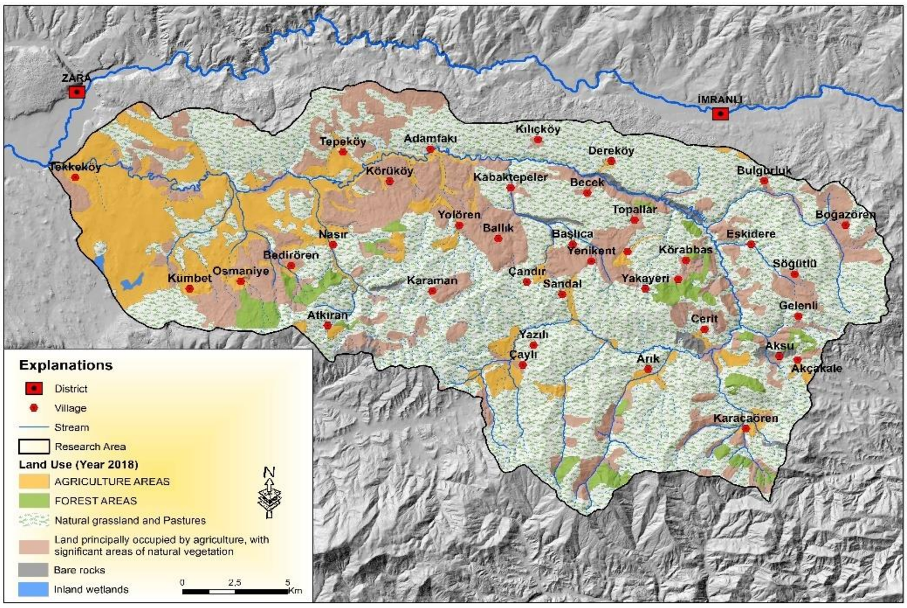

Figure 12. Land use/cover map of the study area (2018)

Accordingly, the highest areal change in the Acısu Basin 18 years from 2000 to 2018 in the direction of growth was 17.08 km^2 (3.35%) in grassland and pasture areas, and in the direction of decrease -23.05 km^2 (-4.49%) in plant change areas. Field observations and information received from local people also confirm this situation. Accordingly, from 2000 to 2018, the destruction of forested and scrub areas in the basin and the abandonment of agricultural areas caused the expansion of grassland and pasture areas (Figure 13 and 14). Accordingly, from 2000 to 2018, the destruction of forested and shrubland areas in the basin and the abandonment of agricultural areas led to the expansion of grassland and pasture areas (Photographs 5, 6). In interviews with local people, it was stated that until the 1970s, forested and scrub areas were intensively destroyed to gain agricultural land. However, in the following period, the migration of the peasant population for different reasons, especially economic reasons, led to the abandonment of these opened agricultural lands over time. In the process, these abandoned agricultural lands were covered with weeds and turned into natural pastures and grasslands. During the field studies, it was observed that herds brought from nearby provinces were grazing in these areas.

Figure 13. In the north of Kılıçköy, abandoned former agricultural lands are now used for animal husbandry

Figure 14. The base of the doline in the east of Topallar village, where agriculture used to be practiced, is now abandoned

The erosion Control (Prevention) (P) Factor refers to the techniques used to prevent, control, or reduce erosion (Lane et al., 1992; Renard et al., 1997). Increasing the density of vegetation cover, terracing on steep slopes, and drainage of water by opening artificial forts are some of the techniques used in this regard (Milward and Mersey, 1999). The P factor should be evaluated between 0 and 1. It is expressed as 0 for areas where there is no erosion risk and 1 for areas with high risk (Zeng et al., 2017). During the field studies carried out in the Acısu Basin, no erosion preventive measures of the type given above were identified. Therefore, the effect of this factor is taken as 1 in the RUSLE model.

4.2. Erosion Analysis

Land cover and management (C) factors for the years 2000 and 2018 were calculated using the RUSLE model in Acısu Basin, keeping other factors constant. The erosion risk occurring in the basin was classified into erosion potential risk categories used for the first time by Bergsma et al. (1996). According to these categories, the erosion susceptibility of the basin and the amount of soil loss and total area were determined separately for the relevant years using the data obtained (Table 7; Figures 15 and 16).

Table 7. Areal distribution and change of erosion rates of the study area in 2000 and 2018

Erosion rate (t ha^{-1} y^{-1})	2000		2018		Change	
	Area		Area		Area	
	km²	%	km²	%	km²	%
Very Light (Risk 1, < - 5)	281.95	54.96	296.15	57.72	14.20	2.76
Light (Risk 2, 5 - 12)	112.05	21.84	116.23	22.65	4.18	0.81
Medium (Risk 3, 12 - 35)	97.45	18.99	82.78	16.13	-14.67	-2.86
Strong (Risk 4, 35 - 60)	16.25	3.16	10.66	2.09	-5.59	-1.07
Severe (Risk 5, 60 - 150)	3.22	0.64	4.41	0.87	1.19	0.23
Very severe (Risk 6, 150 - >)	2.08	0.41	2.77	0.54	0.69	0.13
TOTAL	**513.00**	**100.00**	**513.00**	**100.00**		

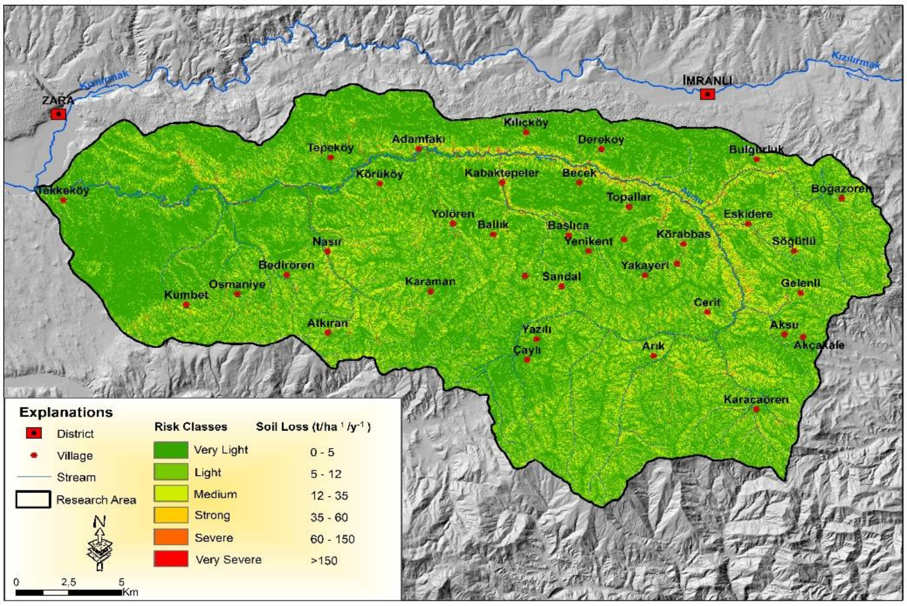

Figure 15. Erosion map of the study area (2000)

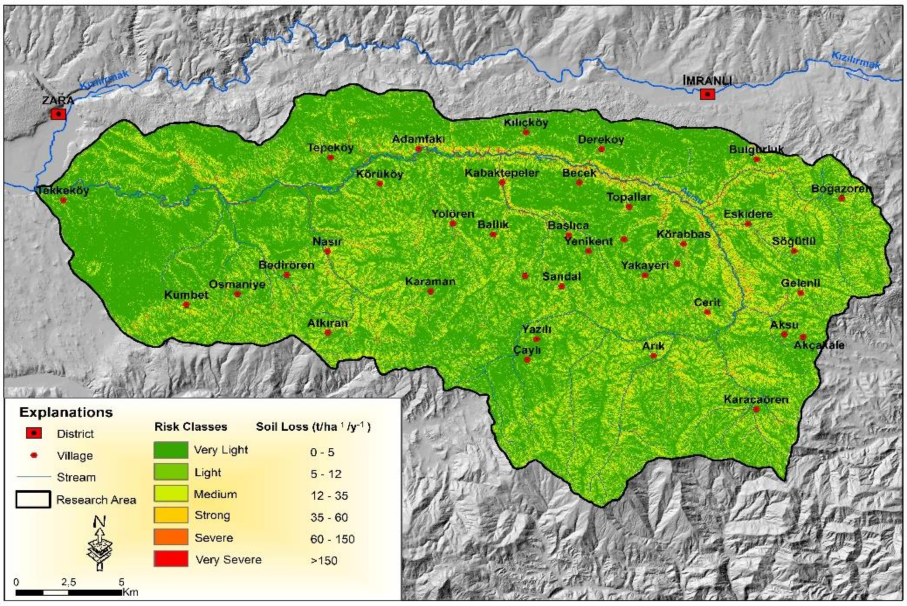

Figure 16. Erosion map of the study area (2018)

The erosion status of Acısu Basin is divided into six classes within the scope of erosion potential risk categories created by Bergsma et al. (1996). In this context, when an evaluation is made according to the risk classes, the severity of erosion in the basin varies according to years. From 2000 to 2018, there has been an areal increase in classes 1, 2, 5, and 6 in the basin (Table 7; Figures 14 and 15). In 2000, very light erosion was effective on 281.95 km^2 (54.96%) of the basin, while the area in the very light class increased to 296.15 km^2 in 2018. Likewise, the light class of erosion severity, which was effective at 112.05 km^2 (21.84%) in 2000, increased to 116.23 km^2 (22.65%) in 2018. However, a slight regression was detected in the areas where medium and strong erosion occurred. Medium erosion, which was effective on an area of 97.45 km^2 (18.99%) in 2000, decreased to 82.78 km^2 (16.13%) in 2018. Again, erosion in the strong class, which was effective on an area of 16.25 km^2 (3.16%) in 2000, decreased to 10.66 km^2 (2.09%) in 2018. During the field studies, it is thought that this situation is related to the abandonment of agricultural lands in rural areas, especially on slope lands, and the re-development of natural vegetation in these areas, albeit sparse.

However, the spatial distribution of erosion in the related years has also significantly differentiated. The areas where erosion is observed intensively in both periods are the slope lands with high slope values (Figure 17). Very severe erosion is observed in areas with high relative elevation, especially in the upper and middle parts of the Acısu Stream valley. However, between 2000 and 2018, there has been a significant change in the erosion areas on the valley slopes and the mountainous area in the south because of the destruction of the local people, especially to meet their fuel needs (Figure 18).

Figure 17. In the south of Boğazören village, high slope values and sparse vegetation cover increase erosion

Figure 18. View of the slope lands south of Arık village where erosion has increased due to the destruction of vegetation

The negative change in land use/land cover in the relevant years also manifests itself in the annual total and average soil loss amounts. In 2000, the annual total soil loss in Acısu Basin was 3.128 t ha^{-1} $y^{-1}$and the annual average soil loss was 537 t ha^{-1} y^{-1}. On the other hand, in 2018, it was determined that the annual total soil loss amount was 3.325 t ha^{-1} y^{-1} and the annual average soil loss amount was 586 t ha^{-1} y^{-1}. This situation shows that there has been an increase in the annual total soil loss of 197 t ha^{-1} y^{-1} and the average soil loss of 49 t ha^{-1} y^{-1} in the 18 years. The probable reason for these changes is the destruction of forest areas and the opening of the slope lands, especially in the lower slope of the basin, to agriculture.

Conclusion

According to the data of the model applied in Acısu Basin, the amount of soil loss as a result of erosion has increased in the period between 2000-2018. The fact that the LS factor, one of the parameters of the model, has high values in areas where the slope increases, such as the slopes of river valleys, has led to extreme soil loss results in these areas. While these extreme values in the severe and very severe class corresponded to approximately 1.05 percent of the basin in 2000, they increased to 1.41 percent in 2018. On the other hand, the areas with very light, light, and moderate erosion risk corresponded to 95.79% of the total area of the basin in 2000, while it corresponded to 96.50% in 2018. This situation shows that the areas with low and moderate erosion generally indicate that water-based soil loss in the basin is not very severe.

Considering the spatial distribution of soil loss risk in the basin, the sloping slopes of the relatively high mountainous areas surrounding the basin floor, areas with sparse vegetation cover, and the sloping valley slopes of the Acısu Stream, especially in the middle and upper reaches, are the places where the risk is high. These areas correspond to areas where erosion risk is strong, severe, and very severe. However, the LS factor has a significant effect on increasing the erosion risk in these areas (Figure 19 and 20). Especially in the mountainous areas in the south of the basin where the erosion risk is high, K and C factors also affect increasing the risk. In this area, the shallow cover of brown forest soils and sparse vegetation cover increases the risk (Figure 21 and 22).

According to the RUSLE model, the amount of soil loss due to water in the Acisu Basin increased between 2000 and 2018. The fact that the LS factor, one of the parameters of the model, has high values in areas where the slope increases, such as the slopes of river valleys, has led to extreme soil loss results in these areas. While these extreme values in the severe and very severe class corresponded to approximately 1.05% of the basin in 200, they increased to 1.41% in 2018. On the other hand, the areas with very light, light and medium erosion risk corresponded to 95.79% of the total area of the basin in 2000 and 96.50% in 2018. This situation shows that the areas with low and moderate erosion generally indicate that water-based soil loss in the basin is not very severe.

Figure 19. In the central part of the basin west of Körabbas-Eskidere villages, increasing LS values in the Acısu Stream valley increase the risk of erosion

Figure 20. The sparse vegetation cover and low soil thickness in the upper avalanche of the basin increase the risk of erosion. South of Çaylı village

Figure 21. Erosion areas east of Atkıran Village where the vegetation cover is sparse, and the soil cover is shallow.

Figure 22. Increasing slope and structural features increase the severity of erosion in the south of Arık village

When the distribution of the areas with high erosion potential in the Acısu Basin is compared with the land use/cover characteristics, the risk increases in areas with high slope values and lack of vegetation cover or shallow soil cover. However, there is an increase in the amount of soil loss when moving from forested and shrubland areas with high vegetation density to pasture and grassland areas where vegetation cover becomes sparse. When the land use/cover characteristics and erosion risk are compared for the basin in general, it can be said that the erosion risk increases in agricultural areas, pasture, and grassland areas, while the erosion risk decreases in scrub and forested areas. However, it should not be ignored that land tolerance is not known in the basin and the analyses performed are only for the determination of soil loss due to water.

As long as there is no change in land use characteristics, it is not possible to eliminate the soil erosion potential in absolute terms (Ellis and Mellor, 1995; Danacıoğlu and Tağıl, 2017). However, the amount of erosion can be kept below an acceptable tolerance limit by soil conservation methods in areas with high erosion potential (Danacıoğlu and Tağıl, 2017). For this reason, the process of determining the soil loss potential with the RUSLE model can also form the basis for how the land should be used and the planning to be made to protect the soil. After obtaining the amount of erosion that will occur on land under certain conditions with the RUSLE model, it can be tried to achieve equality in the equation by changing some of the parameters in the model (such as C and P).

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