

The effects of land use and land cover changes (LULCC) in Kuseyr plateau of Turkey on erosion

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Abstract: Erosion is one of the important problems in degradation of agricultural lands and other natural lands. The most dynamic factor in controlling erosion is land cover, and this factor has been anthropogenically manipulated for ages. This study investigates the effect of land use and land cover changes (LULCC) on erosion at Kuseyr Plateau, which is situated in the southernmost part of the eastern Mediterranean basin, Turkey. A geographical information systems-based method using the revised universal soil loss equation (3D) was employed to identify the amount of annual soil loss, erosion risk classes, and distribution generated by LULCC. Landsat satellite images were used to analyze LULCC from 1987 to 2010. The implementations of both land cover and management factors were made possible by satellite image analysis performed throughout the years. The results obtained from the study show that there is a rather severe erosion risk covering as much as 30% of the land within the scope of the study for 1987; this rate corresponds to 22% in 2010. Maximum annual soil loss in the plateau was as high as 59.81 t ha⁻¹ per year in 1987 and 48.33 t ha⁻¹ per year in 2010. The average soil losses in the plateau were 6.19 and 5.00 t ha⁻¹ per year for 1987 and 2010, respectively. The related processes causing erosion from the past to present have slowed down, and reclamation of the land cover (with the intended purpose of decreasing erosion sensitivity) has always been the key factor in this regard. Despite a considerable decrease in severe erosion, as much as 22% of the study area still requires immediate measures in order to reduce soil loss.

Key words: Soil loss, erosion, RUSLE (3D), geographic information system (GIS), remote sensing (RS), Kuseyr plateau

1. Introduction

Soil degradation caused by erosion is ranked as the second most important environmental problem in the world after rapid population increase (Pimentel, 2006; Pradhan et al., 2011; Nikkani, 2012). Due to incorrect and extensive usage of agricultural lands and the resulting degradation of the natural balance, the problem has become quite serious (Williams, 1991; Tağil, 2007; Kiassari et al., 2012).

Soil erosion caused by land degradation is the main reason for the loss of fertile agricultural soils in Turkey, which is estimated to be around 500×10^6 t of soil per year; as much as 83.21% of agricultural lands are currently under risk of severe water erosion. The hilly topography, soil conditions that facilitate water erosion (i.e. fine texture, low organic matter, poor plant coverage due to semiarid climate), inappropriate agricultural practices (e.g. excessive soil tillage and cultivation of steep lands), and forest fires are the main causes for intensified erosion in Turkey (Irvem et al., 2007). Turkish soils have also been under agricultural usage for centuries, which eventually resulted in the degradation of lands and surface coverage

of soils. Even in the last decades, in order to reclaim new agricultural areas, significant amounts of steep rugged lands, meadows, forests, and shallow lakes in the region have been converted into agricultural lands (Ministry of Agriculture and Rural Affairs, 2003). On the other hand, an increasing population has increased the pressure on the lands used for both agricultural and nonagricultural reasons. Thus, this widespread problem threatens the sustainability of agricultural productivity and the ecological balance in the Mediterranean region, where diverse, economically important crops and many endemic plants are grown (Atalay, 2008; Efe, 2010). Evaluation of erosion generated by the changes in surface coverage is very important for improving the endangered areas and determining the type of conservation measures to be taken (Karami et al., 2012).

The Mediterranean basin has been under very strong human influence for centuries (Irshad et al., 2007; Efe and Tağil, 2007; Korkmaz et al., 2010). Thus, soil erosion has reached serious levels as a result of anthropogenic changes in the land cover (Grauso et al., 2010; Kefi et

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al., 2010; Conforti et al., 2011). In order to understand the role of erosion in the region, several erosion models have been tested (Cürebal and Ekinci, 2006; Ekinci, 2007; Irvem et al., 2007; Efe et al., 2008a, 2008b). The revised universal soil loss equation (RUSLE) is the most frequently used method for estimating the magnitude of erosion. Geographical information system (GIS)-based use of this method has been getting more common in the last decade (Shrestha, 2000; Yang et al., 2003; Efe et al., 2008b; Özşahin, 2011). By using GIS, it is possible to get precise information about the changing land situation, such as land use type, type and quality of surface coverage, and other soil-based information. Slope and slope length can easily be calculated from GIS-based information as well (Lin et al., 2002; Ekinci, 2007).

It is apparent that changes related to land use and land cover during the years have affected erosion (Sharma et al., 2011). Changes in all the factors that have an effect on erosion take a long time; however, land use and land cover can change rapidly due to anthropogenic influences, especially recently. Hence, the present study focuses on discussing the influence of changes observed in land cover on erosion. This study examines erosion risk through the use of a GIS-based and remote sensing (RS)-supported RUSLE (3D) method at Kuseyr Plateau by focusing on the influences caused by land cover and management (C), based on satellite image analysis results and data related to the years 1987–2010.

2. Materials and method

2.1. Study area

Kuseyr Plateau is situated in the eastern Mediterranean basin, on the Syrian borders of Hatay, Turkey. It is located at 35°48'–36°6'N and 35°55'–36°24'E (UTM Zone 37N–WGS84). It is surrounded by the Amik Plains to the north, the Asi (Orontes) River and the Mediterranean to the west, and Syria to the south and the east (Figure 1). This geomorphological unit between the Asi River and the Syrian border covers an area of 1000 km².

East of the plateau field, which features horst characteristics, there is the Asi Rift Valley, which also harbors the Asi River, with an elevation of 100–250 m and a width of 8–13 km. In the west, there is the Hatay Rift Valley, with an elevation of 0–80 m and a width of 10–20 km (Boulton and Robertson, 2008). The Asi River flows through this rift valley and reaches the Mediterranean Sea. The plateau field took its current shape after being separated by the Asi River and its tributaries. The plateau is characterized by tectono-karstic rift areas and hills, and has an elevation between 150 and 1000 m (Korkmaz and Fakı, 2009). According to the data obtained from Yayladağı and Altınözü meteorological stations between 1975 and 2009, the annual average temperature at the plateau and

its surrounding areas changes between 15.1 and 18.9 °C, and the annual average total rainfall is between 776.9 and 1120.3 mm. The monthly average total rainfall is the highest in winter months and reaches its lowest values in summer months. The plateau and its surrounding areas are under the influence of the Mediterranean climate (Csa, according to the Koeppen classification method) with hot and dry summers and warm and rainy winters (Korkmaz and Fakı, 2009). According to old American soil taxonomy (Soil Survey Staff, 1960), there are 6 different great soil groups at Kuseyr Plateau (General Directorate of Rural Services, 1998). The largest area consists of the brown forest and noncalcareous brown forest great soil groups, which show a tendency to spread towards the tertiary aged geological formations. Other groups, such as the red Mediterranean and red-brown great soil groups, are mostly seen on the Mesozoic formations. Alluvial and colluvial great soil groups can be observed on the youngest geological formations (General Directorate of Rural Services, 1998). Agriculture and animal husbandry are common economic activities in the study area. The effects of sheep and goat farming upon the quality of natural plant coverage are also common in the marquis shrublands. Water shortage is the main problem for the majority of the Kuseyr Plateau due to karstic reasons (Türkmen, 1937). Hence, it is preferable to grow tobacco, wheat, barley, lentils, and chickpeas on the plateau (Ministry of Agriculture and Rural Affairs, 2003).

2.2. Methods

Many different models can be used for estimating soil loss. In conjunction with GIS, the universal soil loss equation (USLE) (Wischmeier and Smith, 1978) or the RUSLE (Renard et al., 1997; Van de Knijff et al., 1999; Lufafaa et al., 2003; Sivertun and Prange, 2003) are often used to predict rainfall erosion in landscapes.

In this study, the RUSLE (3D) was employed, since it provides more plausible results and, with the help of information technology, can be used for detailed evaluation of the factors affecting erosion. Modeling soil erosion by RUSLE, a functional model derived from the analysis of intensive soil erosion data, has been widely applied in long-term water erosion predictions (Renard et al., 1997).

The integrated usage of RUSLE and GIS allows the estimation of potential soil loss from sheet and rill erosion for both rangelands and agricultural lands. The RUSLE equation estimating potential erosion (A) is as follows:

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

A: Average soil loss (t ha⁻¹ per year)

R: Rainfall erosivity factor (MJ ha⁻¹ per year)

K: Soil erodibility factor

LS: Slope length and slope steepness factor

C: Land cover and management factor

P: Support practice factor

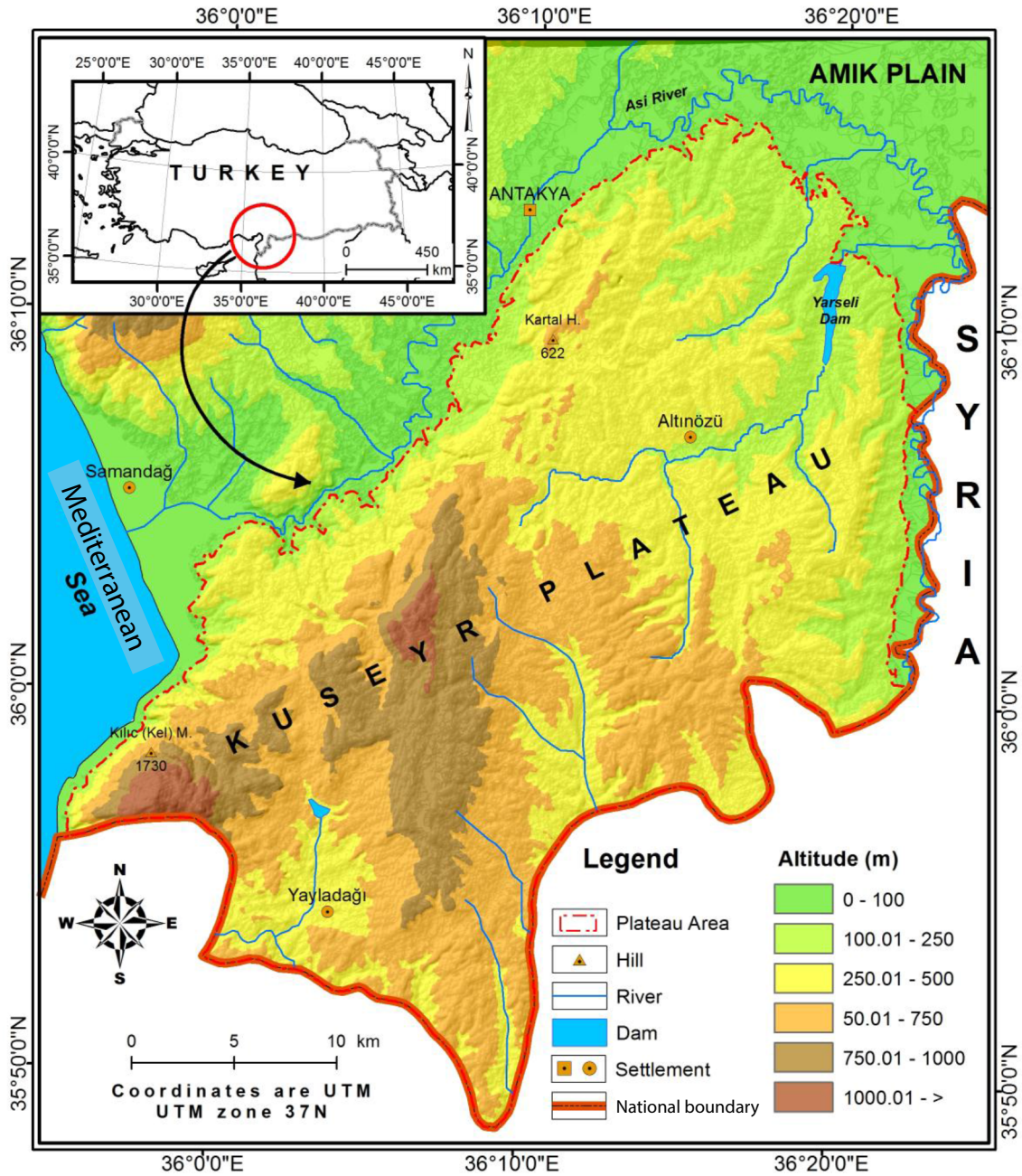


Figure 1. Location of Kuseyr Plateau.

The GIS data required during the implementation phase of the model are rainfall, soil characteristics, elevation, and land use/land cover. In this context, the 10-m grid was obtained from 1:25,000 topographical maps of the study area. The long-term (from 1975 to 2009) rainfall and the other required climatic data were taken from Korkmaz and Fakı (2009) and the Yayladağı and Altınözü meteorology stations of the Turkish Republic General Directorate of Meteorology. Data about soil characteristics were obtained

from 1:25,000 scaled digital soil maps provided by the Ministry of Food, Agriculture, and Livestock. In order to evaluate the effect of land cover changes on erosion, Landsat satellite images of the same period (summer) and dated 01/10/1987 and 29/08/2010 were utilized to eliminate the errors due to solar azimuth angles and diversity in the flora. These images were analyzed through RS methods and techniques with the Erdas Imagine 2011 program. The image assessment was made by means of the

hybrid supervised-unsupervised classification technique (Tağlı, 2006). Within this context, land use and land cover classifications were generated for each year. Then, the model was reimplemented by interchanging the C and P factors with annual satellite image results while the other factors were kept constant.

The data were used to generate sensitivity classifications based on their ratio to affect erosion. All the effective factors were then utilized in the framework of a grid-based method (Hickey, 2000; Van Remortel et al., 2004; Okalp, 2005) by producing 10 × 10 m resolution grid maps. These grid maps were then combined by connecting C and P factors, generated from C according to a formula that allows changes for the specified years, to create 2 independent erosion maps. Five different types of erosion risk classes (low, slight, medium, severe, and very severe) were identified in these maps on a yearly basis. The areas and distribution of these risk classifications were evaluated from a geological point of view. In addition, the total annual soil loss for the specified years was calculated for the study area and the outcomes were compared with each other to understand the reasons behind time-dependent changes and their future implications.

3. Results

3.1. Rainfall erosivity

This factor is critical for the calculation of total soil loss (Wischmeier and Smith, 1978); it should be obtained in RUSLE by multiplying the total kinetic energy of rainfall by a 30 min maximum intensity. The identification of Kuseyr Plateau's rainfall erosion factor was based on the modified Fournier index (MFI) obtained from long-term monthly precipitation (Arnoldous, 1977; Williams and Sheridan, 1991; Bayramin et al., 2006):

$$MFI = \sum_{i=1}^{12} \frac{pi^2}{P}$$

$$R = (4.17 MFI) - 152$$

where MFI represents the Fournier index (mm), pi is the average monthly precipitation (mm), and P represents the average annual rainfall (mm).

For the implementation phase of this process, long-term rainfall data obtained from Yayladağı (450 m) and Altınözü (350 m) meteorology stations, with varying elevation levels, were utilized. The rainfall distribution is not even in the plateau because of hilly topography. Thus, Schreiber's method was applied for calculating elevation-induced precipitation changes. Schreiber's equation is as follows;

$$Ph = Po + 4.5 \times h \text{ (Ardel et al., 1969).}$$

where Ph is the average monthly precipitation (mm), Po is the amount of average monthly rainfall (mm) at a chosen meteorological station, and h is the elevation (m) of the place for which the precipitation will be calculated (Ardel et al., 1969).

R and rainfall intensity data are difficult to collect and summarize. We, therefore, used the MFI (Fournier, 1960) which has been well correlated to Arnoldous's linear R (Arnoldous, 1980) within this region. In addition to this, when F is over 55 mm, r² must be at least 0.75 (Arnoldous, 1977, 1980; Renard and Freimund, 1994; Bayramin et al., 2006). In our case, for minimum and maximum elevations the R values were 309.73–370.52 and 613.72–674.52 MJ ha⁻¹ per year, respectively (Table 1).

R calculated according to levels of elevation by considering data from both meteorology stations was applied to the whole area using the interpolation method and the R values obtained are presented in Table 1. When the related overall aspects are taken into account, it is apparent that most of the R factors were generated by the class between 370.52 and 431.32 MJ ha⁻¹ per year with an area of 319.35 km² and a rate of 32.77%. The smallest distribution was seen in the class between 431.32 and 492.12 MJ ha⁻¹ per year, representing 90.48 km² and only 9.28% of the study area. R increased from the northeast to the southwest. The highest value was obtained for Mount Kılıç (Kel) and its vicinity, whereas the lowest values were around the Amik Plain.

3.2. Slope length and slope steepness factor

LS determines the dimensions and severity of erosion. It represents the portion of soil erosion due to combinations of slope length and steepness relative to a standard unit plot. LS was generated from a digital elevation model (DEM) within a GIS. The 2 factors of LS are cumulative slope length and slope steepness. To incorporate the impact of flow convergence, the hill slope length factor was replaced by upslope contributing area (Moore and Burch, 1986a, 1986b; Desmet and Govers, 1996; Mitsova et al., 1996). The modified equation for computation of LS in GIS in finite difference form for erosion in a grid cell representing a hill slope segment was derived (Desmet and Govers, 1996). A simpler, continuous form of equation for

Table 1. Areal distribution of rainfall erosivity (R) factor values.

R Factor (MJ ha ⁻¹ per year)	Area	
	ha	%
309.73–370.52	31,122.00	31.93
370.52–431.32	31,935.00	32.77
431.32–492.12	5321.00	5.46
492.12–552.92	5363.00	5.50
552.92–613.72	14,667.00	15.05
613.72–674.52	9048.00	9.28

the computation of LS at a point $r = (x, y)$ on a hill slope (Mitasova et al., 1996; Efe et al., 2008a, 2008b) is as follows:

$$LS(r) = (m + 1) [A(r)/a_0]^m \times [\sin b(r)/b_0]^n$$

where $A(r)$ is upslope contributing area per unit contour width, b [degree] is the slope, m and n are parameters, $a_0 = 22.1$ m is the length, and $b_0 = 0.09$ [m/m] degree is the slope of the standard RUSLE plot.

The basic input data for the LS map are a DEM (1:25,000 scaled topographical maps) produced by the General Command of Mapping, Turkey. The map of slope gradients was derived from a DEM. The DEM was imported to the ArcInfo grid format, since a model of this sort is the most suitable system for demonstrating the continuously changing topographic surface of the earth. In addition, the model is a general source of data for terrain analyses and other 3D applications (Verstraeten, 2006; Bahadır and Özdemir, 2011). In this study, the DEM data of a 10 m grid format were used. The technique for estimating the RUSLE 3D LS factor applied in this study was proposed by Mitas and Mitasova (1999). LS is calculated by using the ArcInfo hydrological extension and by producing flow accumulation

grid from 10 m DEM (Desmet and Govers, 1996; Sivertun and Prange, 2003; Cürebal and Ekinci, 2006).

3.3. Soil erodibility (K) factor

K values in this study were generated by combining the data obtained from 1:25,000 scaled digital soil maps provided by the Ministry of Food, Agriculture, and Livestock with those obtained from some other studies (Irvem et al., 2007; Karabulut and Küçükönder, 2008). K values for various soil types in the study area are presented in Table 2.

3.4. Land cover and management (C) factor

The effect of C is important for the comparison of the dimensions of erosion in recent years. This comparison was made possible by reimplementing the model on land use land cover maps generated through analyses concluded from satellite images of different years by keeping other factors constant. According to the results, land use/land cover analysis shows 6 different C factor classifications for 1987 and 2010 (Table 3). These classifications are provided in Table 4 with RUSLE 3D values assigned in the context of related literature from neighboring regions (Doğan et al., 2000; Irvem et al., 2007; Karabulut and Küçükönder, 2008).

Table 2. Areal distribution of soil erodibility (K) factor values.

Factor	Soil groups	Areas		RUSLE (3D) K values
		ha	%	
Soil (K) (MJ ha ⁻¹ per unit)	Alluvial	0.09	0.00	0.065
	Colluvial	9408.72	9.71	0.039
	Brown forest	47,876.11	49.42	0.015
	Noncalic brown forest	8076.56	8.34	0.048
	Red Mediterranean	30,989.21	31.99	0.033
	Red brown	117.54	0.12	0.055
	Rocky areas	414.17	0.43	0.001

Table 3. Areal distribution of land cover and management (C) factor values.

Factors	Classification	Areas (ha)		RUSLE (3D) C values
		1987	2010	
Land cover (C) (dimensionless)	Forest lands	9975.39	4217.16	0.05
	Scrublands	33,174.73	9435.09	0.09
	Agriculture	20,936.33	59,264.45	0.38
	Barren	32,971.70	20,317.62	1.00
	Settlements	618.81	4160.92	1.00
	Water bodies	83.75	365.47	1.00

In light of these findings, we can argue that important changes were experienced in the plateau from 1987 to 2010. Areas of settlements and agricultural crops increased to a great extent. The highest increase within this period was seen at agricultural areas corresponding to 38,328.12 ha. The highest decrease was seen in shrub areas with 23,739.64 ha in the same period.

3.5. Support practice (P) factor

An overall P factor was computed as a product of P factors for individual support practices that are used in combination to reduce erosion (Genovese, 1998). Information on P values in the plateau (e.g., contour intervals, terracing) was collected during fieldwork. Parameter P was identified from the related studies (Irvem et al., 2007; Tağıl, 2007). This parameter refers to any practices serving to control erosion, mainly by reducing surface runoff (e.g., terracing, buffer strips, and tillage methods). According to the RUSLE handbook (Renard et al., 1997), the only RUSLE support practice applicable to conditions in study area is contour tillage (Ekinci, 2007; Efe et al., 2008a, 2008b). Table 4 summarizes the P factor classifications generated in the framework of land cover analysis for the years 1987 and 2010 to apply RUSLE 3D in the Kuseyr Plateau.

Field examination of the land use land cover mapping units revealed that the only form of erosion control experienced in the plateau is related to the temporary commercial type of mapping unit on the cultivated land. The rest of the Kuseyr Plateau was assigned a P value of 1, indicating no physical evidence of erosion control in these areas.

4. Discussion

According to the results obtained by RUSLE 3D, it was concluded that C in the Kuseyr Plateau had changed over the years from 1987 to 2010. However, the assessment of other factors that affect erosion helped to identify erosion risk values, distribution, and soil loss quantity for the respective years. In this study, 5 different erosion risk classifications proposed by Efe et al. (2008a, 2008b) were identified in the study area. Erosion severity was found to change according to the year in question; however, in 1987 erosion severity was identified to be so severe that it corresponded to a soil loss of over 10 t ha⁻¹ per year, representing 30% of the plateau. This rate decreased to 22% in 2010 on account of differences in practice and land cover rate and quality. However, 2010 was found to be a year with low and very low rates of erosion, at a rate of 63%. This rate was 53% in 1987 (Table 5).

Table 4. Areal distribution of support practice (P) factor values.

Factors	Classification	Areas (ha)		RUSLE (3D) P values
		1987	2010	
Support Practice (P) (dimensionless)	Forest lands	9975.39	4217.16	1.00
	Scrublands	33,174.73	9435.09	1.00
	Agriculture	20,936.33	59,264.45	0.19
	Barren	32,971.70	20,317.62	1.00
	Settlements	618.81	4160.92	0.00
	Water bodies	83.64	365.47	0.00

Table 5. Areal distribution of mean annual soil loss quantity (t ha⁻¹ per year) and rate (%).

Soil Loss (t ha ⁻¹ per year)	Erosion Risk	1987		2010	
		Area (ha)	Rate (%)	Area (ha)	Rate (%)
<5	Low	40,156	42	49,473	51
5–10	Slight	11,076	11	11,872	12
10–25	Moderate	15,715	16	14,249	15
25–50	High	11,049	11	8395	9
>50	Severe	18,631	19	12,638	13

Although distribution of erosion varies in the Kuseyr Plateau by year, the southeast parts of the study area were found to be prone to severe and very severe erosion. Despite the lack of C and P factor sensitivity to erosion in these areas, the high values of LS can increase erosion. When the erosion maps are compared, it can be clearly seen that severe and very severe erosion are decreasing (Figures 2 and 3).

Annual soil loss in the plateau area is an important indicator of the magnitude of erosion between years.

According to annual soil loss quantity results, 1987 was the year with the highest soil loss quantity, with 59.81 t ha⁻¹ per year. In the following phases, this rate showed an accelerated decrease and reached 48.33 t ha⁻¹ per year in 2010. The average soil losses were 6.19 and 5.00 t ha⁻¹ per year for 1987 and 2010, respectively. Irvem et al. (2007) reported a similar average soil loss (16.38 t ha⁻¹ per year) for the neighboring Seyhan River basin.

As a result, it was observed that locations with high and very high erosion occurrences were observed on bare

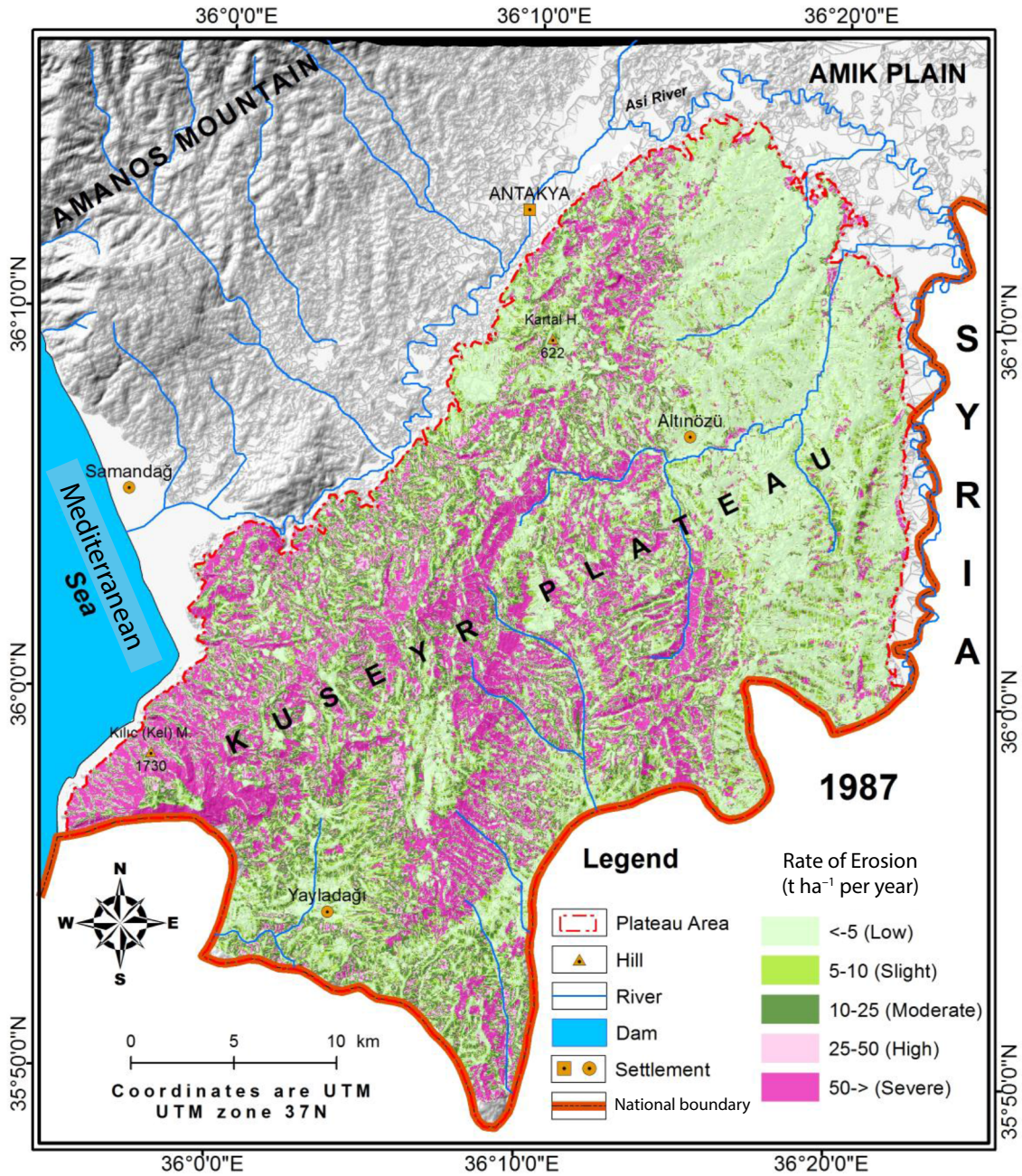


Figure 2. The classified mean annual soil loss distribution map in 1987.

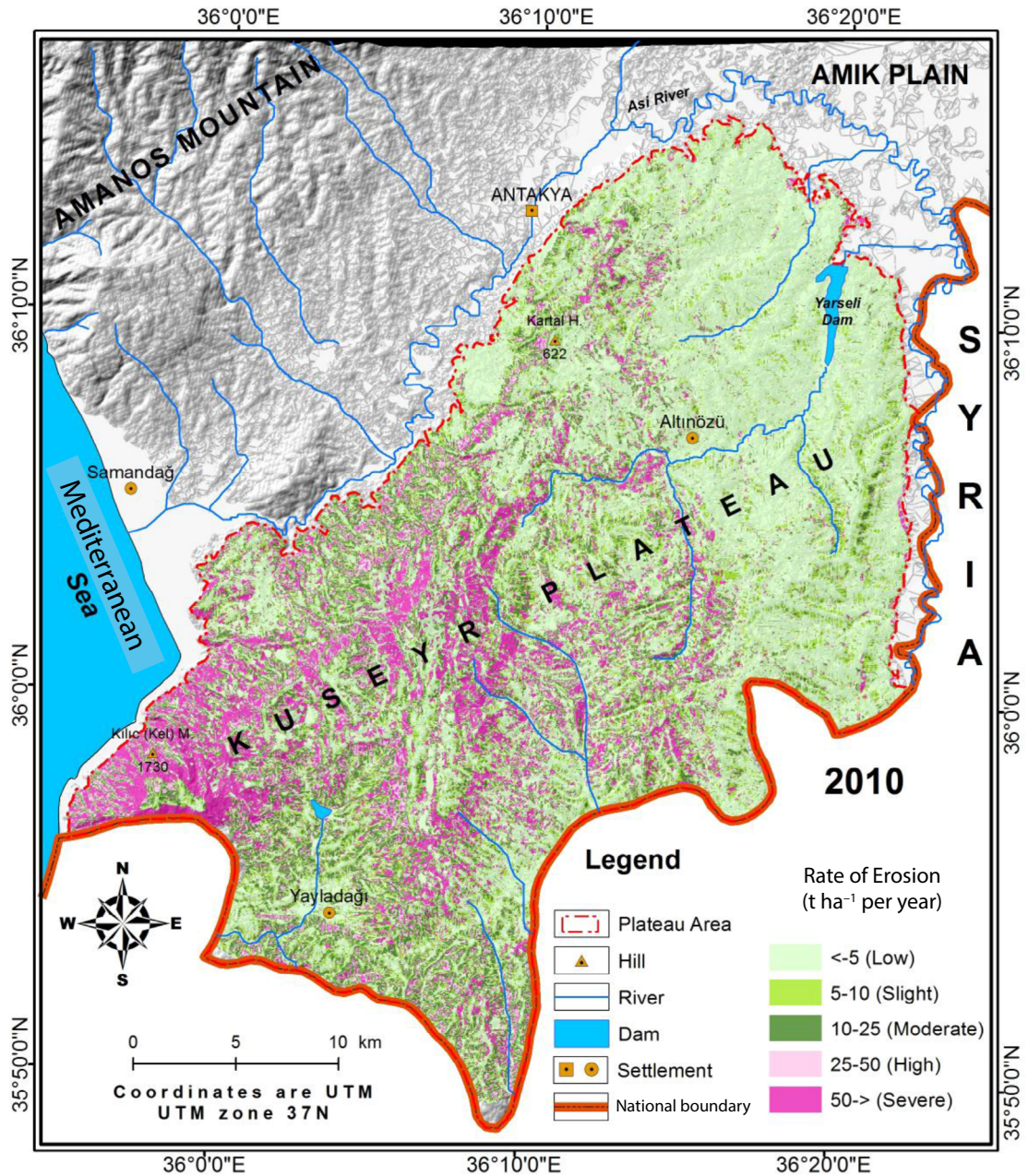


Figure 3. The classified mean annual soil loss distribution map in 2010.

soil with no cover, parts with steep slope, and fine-textured soil that can be easily transferred. Thus, in such areas the quantity of the transported soil was very high. It was also found that, based on the changes and improvements in land use and land cover, erosion density and quantity of annual soil loss had decreased.

In particular, the change occurring within the settlements in the flora and the agricultural areas has caused a recent decrease in erosion. Notably, growing wheat as a crop in agricultural areas is the main reason for reduced erosion. Indeed, during the past 20 years, wheat

has taken the first place among the crops grown region-wide (Ministry of Food, Agriculture, and Livestock, 2013). That said, the prevalence and popularity of wheat cultivation has, perhaps, been the greatest factor in the preservation of land against erosion. Hence, during the studies conducted in the samples of Whitman County, Washington (Kaiser, 1967), the west-central Great Plains (Meyer et al., 1999), and northeastern Oregon (Williams et al., 2009), wheat was reported to prevent erosion and to reduce the rate of erosion. The same is true for the Kuseyr Plateau.

At the time interval assessed during the study, there was an increase in settlements and water surfaces. The expansion in settlements occurred, in the course of time, due to population growth; on the other hand, the increase in water surfaces occurred due to the new water reserves built in the region (dams and ponds). These changes also played an effective role in the decrease of erosion. Even though this study was conducted in the eastern Mediterranean water basin, the change taking place due to socio-economic reasons shows parallelism with the other parts of the Mediterranean basin as well (Giourga, 1999; Marathianou et al., 2000; Tağıl, 2007).

The RUSLE method, employed together with GIS and RS data, was found to produce more accurate results and thus it was preferred for these areas due to its applicability and convenience. It is especially useful for changing factors such as support practice and land cover factors. There was severe and very severe erosion risk at 30% and 22% of the Kuseyr Plateau. Therefore, the soil loss in the study area is extremely high and threatens soil degradation. Immediate measures should be taken to maintain natural and agricultural sustainability. It was also proven that the anthropogenic influences on land are very distinctive in the severity of the soil erosion.

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