Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 120 (2014) 730 – 739

Procedia
Social and Behavioral Sciences

The 3rd International Geography Symposium - GEOMED2013

# Soil erosion estimation in lower Asi river catchment using GIS

Emre Özşahin[a]*, Ahmet Atasoy[b]

[a]*Namık Kemal University, Science and Art Faculty, Department of Geography, 59030, Tekirdağ, Turkey*
[a]*Mustafa Kemal University, Science and Art Faculty, Department of Geography, 31040, Antakya, Hatay, Turkey*

**Abstract**

Different methods are used to calculate the amount of erosion. Assessment of erosion factors through the use of spatial data integration is the most common method. Generally, RUSLE (3D) erosion model is preferred in the implementation of this method. Current study identified the erosion risk levels and distribution along with annual soil loss according to RUSLE (3D) erosion model in Lower Asi River Basin sample. Geographical Information Systems (GIS) and Remote Sensing (RS) methods and techniques were used in implementing the RUSLE model. Results of analysis show that the basin area experiences low (< - 5 t $ha^{-1}$ $y^{-1}$) levels of erosion the most (1787.40 $km^2$ - 41.40 %) and very severe (150 - > t $ha^{-1}$ $y^{-1}$) levels of erosion the least (154.75 $km^2$ - 3.58 %). Areas with high levels of erosion are the slope areas with high declivity. Total annual soil loss in the basin area was calculated to be 50.66 t $ha^{-1}$ $y^{-1}$ and average annual soil loss in the basin area was calculated to be 10.74 t $ha^{-1}$ $y^{-1}$. These values are lower than those of neighboring (Seyhan River) basin.



*Keywords*: Geographical Information Systems (GIS); *Erosion; Lower Asi River Basin..*

## 1. Introduction

Soil erosion, which is a complex phenomenon, is assessed with three different approaches in general. The first approach is related to measuring erosion in different locations by using some measurement devices and erosion plot regions (Loughran, 1989; Hudson, 1993). However, measurements obtained this way can only be undertaken standard equipment that requires time and money in general (Stroosnijder, 2005). Measurement results may show

* Corresponding author. Tel.: +90 282 250 26 00; fax: +90 282 250 99 25
*E-mail address*:ozsahine@hotmail.com


doi:10.1016/j.sbspro.2014.02.156

significant variations under similar conditions as well (Nearing, Govers, & Norton, 1999).

The second approach is related to the implementation of areal erosion studies that cover the characteristics which identify the formations in the forms of surface or flood rivulets developed as a result of erosion (Herweg, 1996). Although quantitative information is obtained in this approach, classification of erosion ratio is undertaken qualitatively at the end of the research. Also this type of approach requires that the study is completed in a specific time frame since various management implementations are not available throughout the year. The studies conducted using this approach are large scale rather than small scale studies (Vigiak, Okoba, Sterk, & Groenenberg, 2005)

The third and most common method that is used is based on assessing the erosion factors through the use of spatial data integration. RUSLE (3D) erosion model is generally preferred in this approach (Vrieling, 2007). Current study identified the erosion risk levels and distribution along with annual soil loss according to RUSLE (3D) erosion model in Lower Asi River Basin sample. These values were assessed by taking neighboring river basins and the whole of Asi River Basin into consideration. The values of erosion in Asi River with the status of trans boundary waters were provided in Turkey scale. The research sought answers to questions regarding the distribution of erosion risk classes in Asi River Basin, total annual soil loss in the basin and the extent of changes in annual soil loss in relation to both neighboring river basins and to the countries in the whole basin.

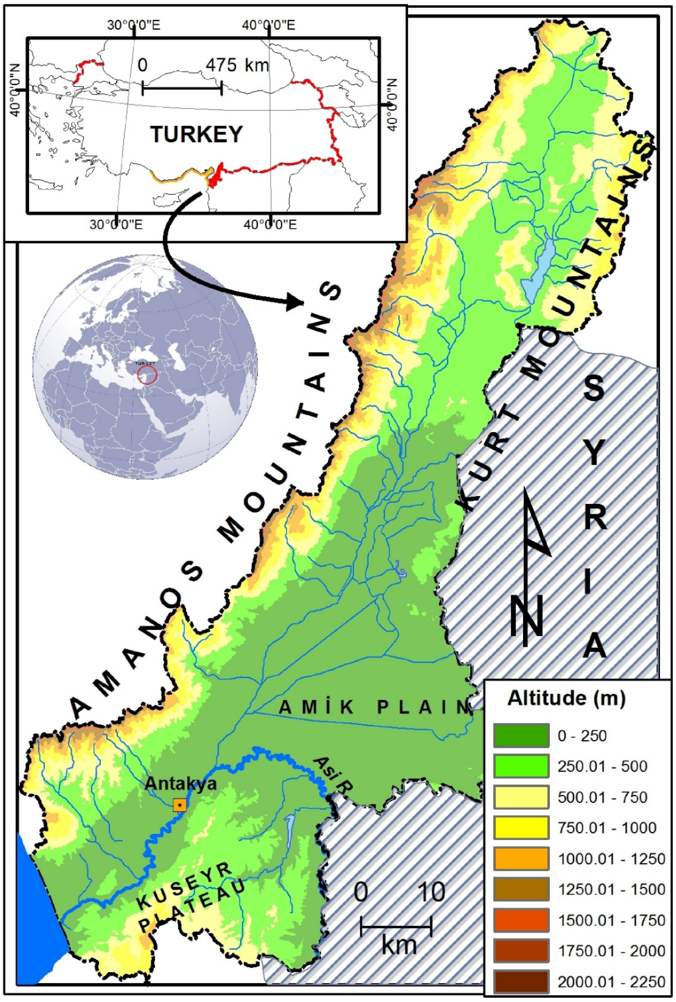


Fig. 1. Location map

## 2. Materials and Method

Asi River Basin is situated in Eastern Mediterranean Sea Basin, an area where the continents of Asia, Europe and Africa are the closest to each other (Fig. 1). Asi River which reaches Mediterranean Sea by flowing along 556 km in the countries of Lebanon, Syria and Turkey has a basin area of 1582 km². 1.582 km² (7 %) of this surface area is located in Lebanon, 14.613 km² (67 %) in Syria and 5.548 km² (26 %) is in Turkey borders (Korkmaz & Karataş, 2009).

The area defined as Lower Asi River Basin (Fig. 1) is located in Turkey. However some of the branches in this basin are born in Turkey and connects with Asi River after flowing through different countries. Since this situation contributes to the erosion rate from the soils of various countries, the final border in the current study was set by taking the branches of Asi River that are only located in Turkey (Fig. 1). The surface area of the basin is rather smaller compared to whole basin. The study area is located in the eastern most of the Mediterranean Sea region, in Adana section. In administrative terms, it is located in Hatay, Gaziantep, Kilis, Osmaniye and Kahramanmaras provinces (Fig. 1). According to geographical coordinate system, it is situated between 35° 51' 04"-36° 54' 44" eastern longitudes and 35° 59' 45" – 37° 12' 34" northern latitudes (Fig. 1). Basin area has a perimeter of 586.23 km with a surface area of 4317.00 km².

The study undertaken in the light of related literature made use of topography maps scaled 1/25.000 were utilized in the study as materials. Elevation and hydrograph layers of these sheets were obtained digitally in DVD format following UTM projection, WGS-84 datum and ArcInfo Covarage formats from General Command of Mapping. These data were later converted to vector format. Other data used in the study were generated by transforming the data to vector data format by using digitized topography maps transferred to computer environment. All the obtained data were processed and enriched in line with the purpose of use to generate the other thematic maps. Climate data for the study field were obtained from the long term climate data of Antakya, Samandag, Altınozu, Reyhanlı, Kumlu, Kırıkhan, Hassa and Islahiye Meteorology Stations of T.R. General Directorate of Meteorology. The data related to soil characteristics were generated by compiling topography maps scaled 1/25.000 obtained from T.R. Ministry of Food, Agriculture and Livestock with some studies (Kılıç et al., 2008). Vegetation and other ground related characteristics were obtained from Landsat satellite images. In this context, data received from Landsat satellite images dated 29.08.2010 and 03.10.2011 and that contained 7-band with topographic resolution of 30 m and thermal band with 120 m resolution images were used. These images were processed with the help of Erdas Imagine 2011 program according to the most preferred controlled classification method to represent the current land cover characteristics of the basin. In this stage, 1/25.000 scaled land use maps obtained from Ministry of Food, Agriculture and Livestock and 1/25.000 scaled forestry development maps prepared by Ministry of Forestry and Water Affairs General Directorate of Forestry were used. The maps obtained from all the sources cited above were reorganized in ArcInfo/ArcMap 10.0 program by utilizing Geographical Information Systems (GIS) methods and techniques according to the renowned “Revised Universal Soil Loss Equation” (RUSLE) method. In this stage, the characteristics that are effective in shaping erosion were examined to generate susceptibility classes according to their effect levels. As a result, 10x10 m grid maps regarding all effective factors were produced in line with the grid based method. These grid maps were combined according to the formula, erosion risk level map was created and annual soil loss was calculated.

## 3. Result and Discussion

As we all know, soil erosion takes place as a result of various factors (Lee, 2004; Gobin, Kirkby, & Govers, 2004; Jain & Das, 2010; Sharma, Tiwari, & Bhadoria, 2011). The effect levels of these factors may change the type and dimension of erosion. In this section, the factors that affect soil erosion is assessed with the help of RUSLE (3D) equation according to the formula below:

$$\mathbf{A = R \times K \times LS \times C \times P}$$

Here; A = estimated average soil loss in tons per acre per year (ton / hectare / year); R = rainfall-runoff erosivity factor (MJ $ha^{-1}$ $year^{-1}$); K = the soil erodibility factor (to hectare per unit); LS = slope length factor length and slope steepness factor (L= slope length; S= slope steepness); C = cover-management factor (without dimension); P =

support practice factor (preventive) (without dimension).

### *3.1. Rainfall Erosivity*

Rainfall erosivity factor (R) is obtained with the help of RUSLE by multiplying total kinetic energy of precipitation and 30 minute maximum density of precipitation. This value is predictive in calculating total soil loss (Cürebal & Ekinci, 2006; Ekinci, 2007). "Modified Fournier Index (MFI)" (Cürebal & Ekinci, 2006; Ekinci, 2007; Özşahin, 2011) formula was used which takes the average of annual and monthly precipitation into account. Accordingly, rainfall erosivity factor (R) of the basin was calculated for the 7 meteorology stations located in different elevation steps by using the formula of "Ph=Po+4.5xh" (Cürebal & Ekinci, 2006; Efe, Ekinci, & Cürebal, 2008a; 2008b) which takes Schreiber's principle that precipitation increases 54 mm at each 100 m. According to this formula, "Ph" is the monthly average precipitation amount (mm) and "Po" is the monthly average precipitation amount (mm) of the specific point whose elevation is known. Rainfall erosivity factor (R) values and the affected areas obtained according to the result of the formula are provided below (Table 1).

Table1. Areal distribution of rainfall erosivity (R) factor values

| R Factor (MJ $ha^{-1}$ $year^{-1}$) | Area | |
|---|---|---|
| | km² | % |
| 164.5 | 513.70 | 11.90 |
| 200.0 | 1659.80 | 38.45 |
| 300.0 | 1413.20 | 32.74 |
| 400.0 | 532.40 | 12.33 |
| 500.0 | 189.70 | 4.39 |
| 600.0 | 8.30 | 0.19 |
| **TOTAL** | **4317.00** | **100.00** |

According to this finding, the areas with the highest rainfall erosivity factor (R) are the South Amanos Mountains and the sections closest to the watershed of Kuseyr Plateau. The areas with the lowest rainfall erosivity factor are the northeast of Amik Plain and the areas between Islahiye-Katrancı.

### *3.2. Soil Erodibility (K) Factor*

Soil is rather important since it provides the necessary material for the event of erosion to take place and it can absorb the precipitation, an important factor that causes erosion, and it can resist erosive powers such as precipitation. This resistance towards being broken down and carried away according to its physical properties is identified as soil erodibility (K) factor (Karabulut & Küçükönder, 2008). The important elements that identify the soil erodibility (K) factor are the structural properties such as the size of the grains that make up of the land cover, the ability to hold water, capacity and soil profile [19; 20; 22; 23]. Soil susceptibility to erosion is defined as the unit erosion index in a standard land unit with 9 % slope and 22.1 m slope length with no vegetation and plowed parallel to the slope and it is reflected as the ton of soil lost form the hectare (Doğan & Güçer, 1976; Altınbaş et al., 2008). In the case that all factors effect in erosion are fixed, the physical properties of soils and their related erosion levels may still be different (Tülücü, 2002). In the current study, soil erodibility (K) factor values in the basin area were assigned by taking the values used in sample studies undertaken in Turkey in general (Doğan et al., 2000) and in the vicinity (İrvem et al., 2007; Karabulut & Küçükönder, 2008) into consideration (Table 2).

### *3.3. Slope Length and Slope Steepness Factor*

Slope length and slope steepness factor (LS) regarded as the common parameter (Petter, 1992) used in erosion modeling is one of the most important factors that identify the dimension and severity of erosion. The increase or decrease in these factors plays a significant role in erosion identification (Desmet & Govers, 1996; Cürebal &

Ekinci, 2006; Efe, Ekinci, & Cürebal, 2008a; 2008b). Soil erosion is naturally more common in steep land due to the increase in the amount of soil that is carried with water (Nanna, 1996). Similarly, soil erosion is directly proportional to the increase in slope length that plays an important role in collecting surface waters (Özsoy, 2007; Karabulut & Küçükönder, 2008).

Slope length and slope steepness factor (LS) regarded as the common parameter (Petter, 1992) used in erosion modeling is one of the most important factors that identify the dimension and severity of erosion. The increase or decrease in these factors plays a significant role in erosion identification (Desmet & Govers, 1996; Cürebal & Ekinci, 2006; Efe et al., 2008a; 2008b). Soil erosion is naturally more common in steep land due to the increase in the amount of soil that is carried with water (Nanna, 1996). Similarly, soil erosion is directly proportional to the increase in slope length that plays an important role in collecting surface waters (Özsoy, 2007; Karabulut & Küçükönder, 2008).

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

| Factor | Soil groups | Areas | | RUSLE (3D) |
|---|---|---|---|---|
| | | km² | % | K values |
| **Soil (K)** (MJ $ha^{-1}$ per unit) | Alluvial | 951.07 | 22.03 | 0.15 |
| | Hydromorphic alluvial | 1.81 | 0.04 | 0.18 |
| | Colluvial | 599.16 | 13.88 | 0.18 |
| | Basaltic | 342.88 | 7.94 | 0.10 |
| | Non calcic brown | 1.06 | 0.02 | 0.20 |
| | Brown forest | 773.72 | 17.92 | 0.20 |
| | Non calcic brown forest | 1062.50 | 24.61 | 0.15 |
| | Red mediterranean | 390.95 | 9.06 | 0.011 |
| | Red brownmediterranean | 40.04 | 0.93 | 0.15 |
| | Organic | 23.65 | 0.55 | 0.15 |

Although soil and vegetation properties change according to the area, slope level is the main factor for erosion control (Koulouri & Giourga, 2007). According to this, the slope levels in the basin area were examined in 5 groups. Slope classes identified for soil erosion were taken into consideration in classification. While slope levels were found to be lower in valley and prairie floors, a significant increase was observed in the higher areas around the basin. The highest values are observed around the slopes of Amanos Mountains.

Slope length (L) factor is identified as the ratio of soil loss to the loss generated in a standard land unit with 22.1 m slope in any slope length with similar soil characteristics (Altınbaş et al., 2008). Slope steepness (S) factor is defined as the ratio of soil loss to the loss generated in a standard land unit with 22.1 m slope with 9 % slope with similar soil characteristics (Altınbaş et al., 2008). LS factor was created by using digital elevation model (DEM) of the basin. DEM was used to generate slope (º) map and ArcHydrotool was used to calculate flow accumulation (Fac) and flow direction (Desmet & Govers, 1996; Mitasova et al., 1996).

Flow direction characteristics for the basin (slope length and elevation classes) were defined by taking the equation below into consideration. The map created using this equation has parallels with the identified valley networks.

**"FlowAccumulation * (FlowDirection * ((elevation))"**

Slope length and slope steepness factor (LS) was calculated according to the equation below (Cürebal & Ekinci, 2006; Ekinci, 2007; Karabulut & Küçükönder, 2008; Pradhan, Chaudhari, Adinarayana, & Buchroithner, 2011)..

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

According to this assessment LS values increase in areas that correspond to river valleys in the basin area and mountain areas with higher slope values. These values decrease in alluvial areas in the basin floor where slope values are low.

### 3.4. Land Cover and Management (C) Factor

Land cover and management (C) factor that shapes the relationship among precipitation, penetration and flow was developed with the idea that soil loss increases in areas where land cover that decreases the kinetic energy of rain drops do not exist or the existing land cover do not have a high ratio of covering the ground (Ekinci, 2007; Karabulut & Küçükönder, 2008). This factor has varying values according to current land use/land cover properties obtained from previous studies mainly undertaken in Turkey (Doğan & Güçer, 1976; Cürebal & Ekinci, 2006; Ekinci, 2007; Efe, Ekinci, & Cürebal, 2008a; 2008b; Karabulut & Küçükönder, 2008). Values of 0.05-0.2 in the land cover and management (C) factor developed accordingly in the basin are more common. These values are followed by factor values between 0.2-0.4 (Table 3).

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

| Factors | Classification | Areas | | RUSLE (3D) |
|---|---|---|---|---|
| | | km² | % | C values |
| Land cover (C) (dimensionless) | Forest lands | 831.34 | 19.26 | 0.05 |
| | Scrublands | 333.05 | 7.71 | 0.09 |
| | Grassland | 589.45 | 13.65 | 0.09 |
| | Vineyard | 109.84 | 2.54 | 0.09 |
| | Garden | 0.74 | 0.02 | 0.05 |
| | Olive | 220.45 | 5.11 | 0.09 |
| | Irrigated agriculture | 1230.38 | 28.50 | 0.28 |
| | Dry Agriculture (fallowless) | 783.35 | 18.15 | 0.07 |
| | Dry Agriculture (fallowing) | 84.04 | 1.95 | 0.38 |
| | Settlements | 132.56 | 3.07 | 1 |
| | Barren | 1.81 | 0.04 | 1 |
| | **TOTAL** | **4317.00** | **100.00** | |

### 3.5. Support Practice (P) Factor

Support practice (P) factor is regarded as the soil loss ratio under soil support processes to the soil loss observed in fallow pasture (Doğan & Güçer, 1976; Karabulut & Küçükönder, 2008). It includes all properties that aim to minimize the effect of water that set the opportunity to erode and carry the soil by absorbing or canalizing it. Plant cover intensification, terracing, canalizing the existing water with the help of artificial channels can be regarded in this respect. There is an inverse relationship between these factors and amount of soil loss (Cürebal & Ekinci, 2006). Preventive measures of this sort in Lower Asi Basin are not sufficient. Therefore the effect of this factor was not fully identified. Value of 1 is used when the factor cannot be identified (Renard, Foster, Weeies, & Porter, 1991). Hence this factor was set at 1 for the basin and disregarded in the equation.

Table 4. Areal distribution of mean annual soil loss quantity (t $ha^{-1}$ $y^{-1}$) and rate (%)

| Soil Loss (t $ha^{-1}$ $y^{-1}$) | Erosion Risk | Area | |
|---|---|---|---|
| | | km² | % |
| < - 5 | Very low | 1787.40 | 41.40 |
| 5 - 12 | Low | 678.79 | 15.72 |
| 12 - 35 | Moderate | 910.43 | 21.09 |
| 35 - 60 | High | 380.83 | 8.82 |
| 60 - 150 | Very high | 404.80 | 9.38 |
| 150 - > | Extremely high | 154.75 | 3.58 |
| **TOTAL** | | **4317.00** | **100.00** |

### 3.6. General Evaluation of the Erosion

Erosion risk levels, distribution and amount of annual soil loss were identified as a result of assessing the basic factors that affect erosion in this section where erosion analysis was undertaken with RUSLE (3D) method. Potential erosion risk classes determined by Bergsma et al., 1996) was taken into consideration in erosion risk classification. These classes are; Very Light (< - 5 t ha-¹ y-¹), Light (5 - 12 t ha-¹ y-¹), Medium (12 - 35 t ha-¹ y-¹), Strong (35 - 60 t ha-¹ y-¹), Severe (60 - 150 t ha-¹ y-¹), Very Severe (150 - > t ha-¹ y-¹).

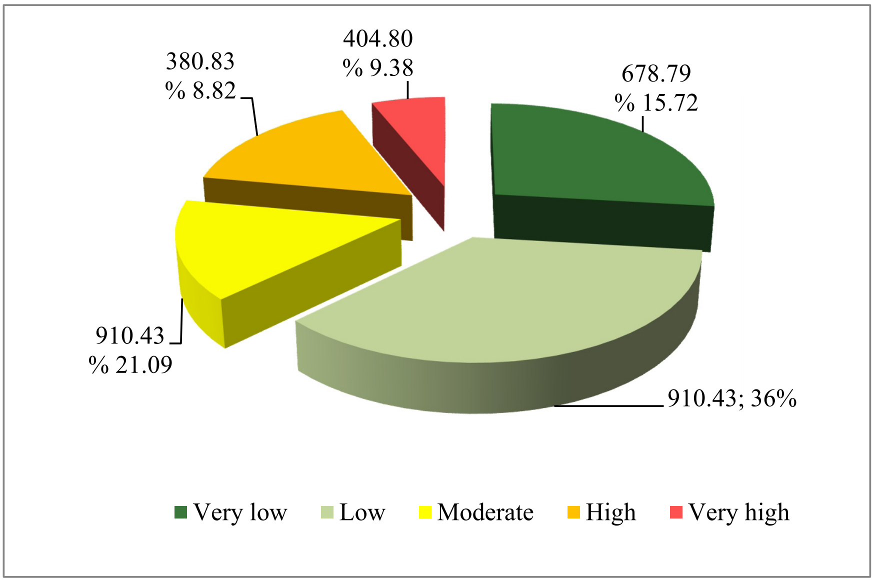


Fig. 2. Distribution of mean annual soil loss (t $ha^{-1}$ $y^{-1}$) and rate (%)

Fig. 3. Erosion in the basin area (Kuseyr Plateau)

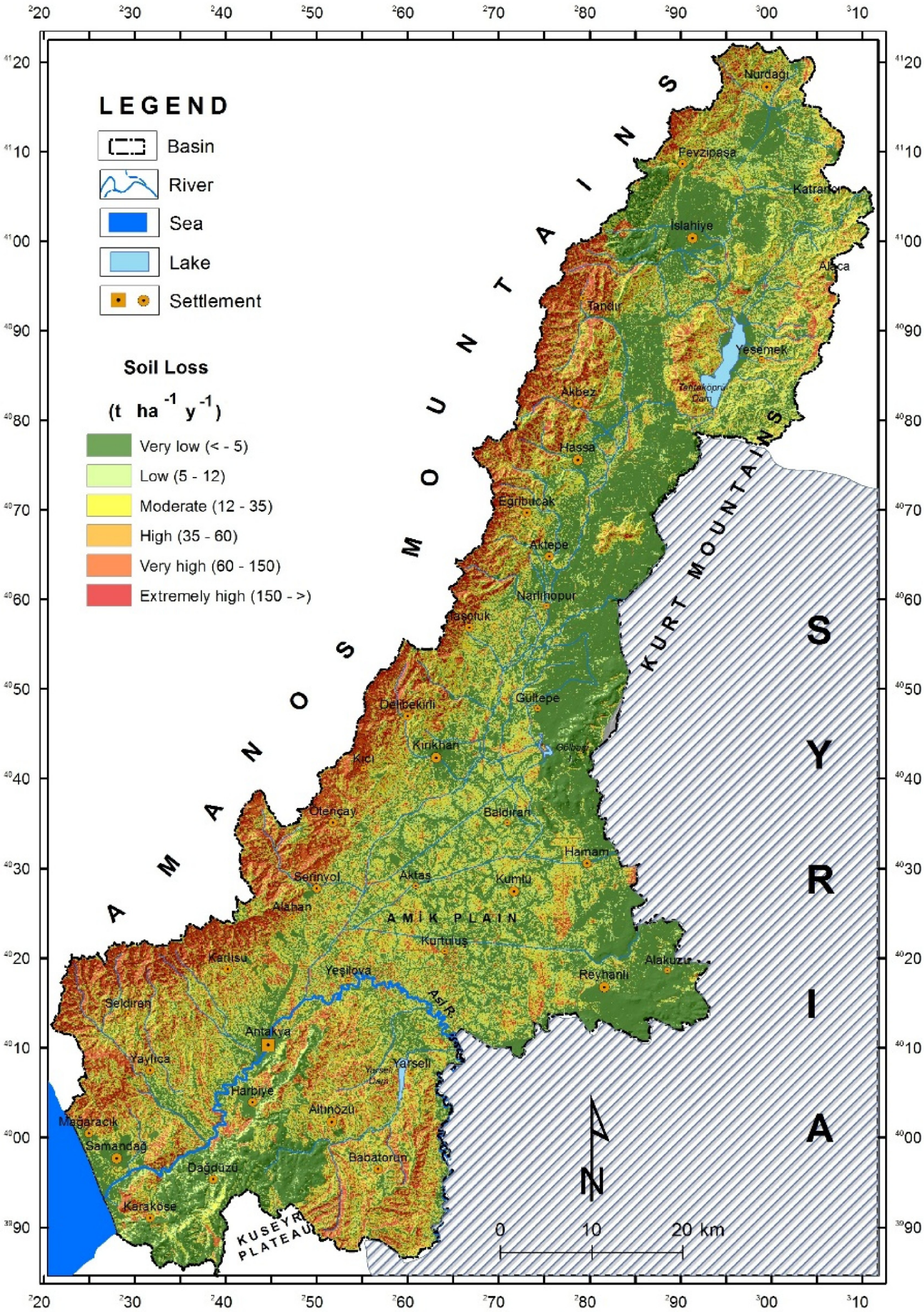


Fig. 4. The classified mean annual soil loss distribution map

According to the results of analysis the basin has light (< - 5 t ha-¹ y-¹) erosion ratio the most (1787.40 km² - 41.40 %) and very severe (150 - > t ha-¹ y-¹) erosion ratio the least (154.75 km² - 3.58 %) (Table 4; Fig. 2). The areas with the densest erosion values are the areas with high slope values. Very severe erosion is experienced especially in the slopes of Amanos Mountains, the north and northeast of Kuseyr Plateau and northern sections of Kurt Mountains (Fig. 3, 4). Light and very light erosion risk is observed in areas with low slope such as the east and north of Amik Plain, in the vicinity of Islahiye and the midlands of Kuseyr Plateau (Fig. 3). In addition, low sloped land where transitions between mountain and plateau areas and valley floors in the basin have medium level erosion (Fig. 3).

Total annual soil loss in the basin is 50.66 t ha-¹ y-¹ and average annual soil loss is 10.74 t ha-¹ y-¹. When these values were compared with the results of annual soil loss amount in a similar study undertaken in Seyhan River (21.000 km²) neighboring river basin (İrvem et al., 2007) (16.38 t ha-¹ y-¹), it was seen that the erosion in the basin is less.

Similarly, the comparison of total annual soil loss amount with that of Asi River in general displays an interesting point. The amount of sediment carried by Asi River is 1.773.453 ton/year (Çalışkan, 2002). When this value was compared with the identified total annual soil loss amount, it was seen that a sediment intake of 1.722.793 ton/year war resourced from the other countries located in the Asi River basin. The calculations undertaken by taking the basin areas in other countries [8] into consideration show that the most erosion with the ration of 156.63 t ha-¹ y-¹ is caused in Syrian. This ratio is followed by Turkey with 50.66 t ha-¹ y-¹ ratio and by Lebanon with 15.63 t ha-¹ y-¹ ratio.

## 4. Conclusion

As a result, the locations where erosion has high or very high ratios correspond to the open land where there is no land cover, the sections where valley density and slope values are high and the areas where fine grained and easily carried soil is located. Therefore the amount of soil that is carried is also high in these areas. On the other hand, the average annual soil loss amount was found to be less than that of neighboring river basin and to be medium when compared with the countries in the basin in general. It was also concluded that RUSLE (3D) method can be preferred to be used in these areas since it provides correct results and is easily applicable.

## Acknowledgements

This study was supported by Mustafa Kemal University, Scientific Research Projects Unit (BAP) as project coded 1201M0112.

## References

Altınbaş, Ü.; Çengel, M.; Uysal, H.; Okur, B.; Okur, N.; Kurucu, Y.; Delibacak, S. (2008). *Toprak Bilimi.* Ege Üniversitesi Ziraat Fakültesi Yayınları No: 557, İzmir.

Bergsma, E.; Charman, P.; Gibbons, F.; Hurni, H.; Moldenhauer, W.C.; Panichapong, S. (1996). *Terminology for Soil Erosion and Conservation*. International Society of Soil Science. Grafisch Service Centrom,Wageningen.

Çalışkan, V. (2002). Amik Ovası'nın Beşerî ve İktisadî Coğrafyası. Yayınlanmamış Doktora Tezi, İstanbul Üniversitesi Sosyal Bilimler Enstitüsü Beşerî ve İktisadî Coğrafya Anabilim Dalı, İstanbul.

Cürebal, İ.; Ekinci, D. (2006). Kızılkeçili Deresi Havzasında CBS Tabanlı RUSLE (3D) Yöntemiyle Erozyon Analizi. *Türk Coğrafya Dergisi*, 47: 115–130.

Desmet, P.J.J.; Govers, G.A (1996). GIS-procedure for automatically calculating the USLE LS-factor on topographically complex landscape units. *Journal of Soil and Water Conservation,* 51 (5): 427-433.

Doğan, O.; Güçer, C. (1976). *Su Erozyonunun Nedenleri, Oluşumu ve Üniversal Denklem İle Toprak Kayıplarının Saptanması*. Merkez TOPRAKSU Araştırma Enstitüsü Müdürlüğü Yayınları, Genel Yayın No: 41, Teknik Yayın No: 224, Ankara.

Doğan, O.; Küçükçakar, N.; Cebel, H.; Akgül, S. (2000). *Türkiye Büyük Toprakları "K" Faktörleri*. Köy Hizmetleri Genel Müdürlüğü Ankara Araştırma Enstitüsü Müdürlüğü Yayınları, Ankara.

Efe, R.; Ekinci, D.; Cürebal, İ. (2008a). Erosion Analysis of Şahin Creek Watershed (NW of Turkey) Using GIS Based on RUSLE (3D) Method. *Journal of Applied Science*, 8 (1): 49-58.
Efe, R.; Ekinci, D.; Cürebal, İ. (2008b). Erosion Analysis of Fındıklı Creek Catchment (NW of Turkey) Using GIS Based on RUSLE (3D) Method. *Fresenius Environmental Bulletin* 17 (5): 568-576.
Ekinci, D. (2007). Estimating of Soil Erosion in Lake Durusu Basin Using Revised USLE 3D with GIS. Çantay Press, İstanbul.
Gobin, A.; Kirkby, M.; Govers, G. (2004). Pan-European soil risk assessment. In R. Francaviglia (Ed.), Agricultural impacts on soil erosion and soil biodiversity: Developingindicatorsforpolicyanalysis, pp.: 1–15, Proceedings from an OECD Expert Meeting, Rome, Italy.
Herweg, K. (1996). *Field Manual for Assessment of Current Erosion Damage*. SCRP Ethiopia and Centre for Development and Environment, University of Berne, Switzerland.
Hudson, N.W. (1993). Field measurement of soil erosion and runoff. *FAO Soils Bulletin*, 68, Food and Agriculture Organization, Rome, Italy.
İrvem, A.; Topaloğlu, F.; Uygur, V. (2007). Estimating spatial distribution of soil loss over Seyhan River Basin in Turkey. *Journal of Hydrology*, 336: 30– 37.
Jain, M.K.; Das, D. (2010). Estimation of sediment yield and areas of soil erosion and deposition for watershed prioritization using GIS and Remote sensing. *Water Resource Management*, 24: 2091–2112.
Karabulut, M.; Küçükönder, M. (2008). Kahramanmaraş Ovası ve Çevresinde CBS Kullanılarak Erozyon Alanlarının Tespiti. *KSÜ Fen ve Mühendislik Dergisi*, 11(2): 14-22.
Kılıç, Ş.; Ağca, N.; Karanlık, S.; Şenol, S.; Aydın, M.; Yalçın, M.; Çelik, İ.; Evrendilek, F.; Uygur, V.; Doğan, K.; Aslan, S.; Çullu, M.A. (2008). *Amik Ovasının Detaylı Toprak Etütleri, Verimlilik Çalışması ve Arazi Kullanım Planlaması*. Mustafa Kemal Üniversitesi Bilimsel Araştırma Projeleri, Proje No: DPT2002K120480, Hatay.
Korkmaz, H.; Karataş, A. (2009). Asi Nehrin'de Su Yönetimi ve Ortaya Çıkan Sorunlar. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 6 (12): 18-40.
Koulouri, M.; Giourga, Chr. (2007). Land aband on mentand slope gradient as key factors of soil erosion in Mediterranean terraced lands. *Catena*, 69: 274-281.
Lee, S. (2004). Soil erosion assessment and its verification using the universal soil loss equation and geographic information system: A casestudy at Boun, Korea. *Environmental Geology*, 45: 457–465.
Loughran, R.J. (1989). The measurement of soil erosion. *Progress in Physical Geography*, 13 (2): 216-233.
Mitasova, H.; Hofierka, J.; Zlocha, M.; Iverson, L.R. (1996). Modelling topographic potential for erosion and deposition using GIS. *International Journal of Geographical Information Systems*, 10: 629–641.
Nanna, S.A. (1996). *Geo-information Theoretical Approach to Inductive Erosion Modelling Based on Terrain Mapping Units*. PhD Thesis, Wageningen Agricultural University, Wageningen.
Nearing, M.A.; Govers, G.; Norton, L.D. (1999). Variability in soil erosion data from replicated plots. *Soil Science Society of America Journal*, 63 (6): 1829-1835.
Özşahin, E. (2011). Zeytinli Çayı Havzasının (Balıkesir) Erozyon Analizi. *E-Journal of New World Sciences Academy*, 6 (1): 42-56.
Özsoy, G. (2007). *Uzaktan Algılama (UA) ve Coğrafi Bilgi Sistemi (CBS) Teknikleri Kullanılarak Erozyon Riskinin Belirlenmesi*. Basılmamış Doktora Tezi, Uludağ Üniversitesi Fen Bilimleri Enstitüsü Toprak Anabilim Dalı, Bursa; 2007.
Petter, P. (1992). GIS *and Remote Sensing for Soil Erosion Studies in Semi-arid Environments*. PhD Thesis, University of Lund, Lund.
Pradhan, B.; Chaudhari, A.; Adinarayana, J.; Buchroithner, M.F. (2011). Soil erosion assessment and its correlation with landslide events using remote sensing data and GIS: a case study at Penang Island, Malaysia. *Environmental Monitoring and Assessment*, 184 (2): 80-85.
Renard, K.G.; Foster, G.R.; Weeies, G.A.; Porter, J.P. (1991). RUSLE: revised universal soil loss equation. *Journal of Soil and Water Conservation*, 46: 30-33.
Sharma, A.;Tiwari, K.N.; Bhadoria, P.B.S. (2011). Effect of landuse landcover change on soil erosion potential in an agricultural watershed. *Environmental Monitoring and Assessment*, 173: 789–801.
Stroosnijder, L. (2005). Measurement of erosion: is it possible?. *Catena*, 64 (2-3): 162-173.
Tülücü, K. (2002). *Su Kaynaklarının Planlanması*. Ç.Ü. Ziraat Fakültesi Genel Yayın No:175, Ders Kitapları Yayın No: 53, Ç.Ü. Yayınları No:169, Ç.Ü. Ziraat Fakültesi Ofset Atölyesi, Adana.
Vigiak, O.; Okoba, B.O.; Sterk, G.; Groenenberg, S. (2005). Modelling catchment-scale erosion patterns in the East African highlands. *Earth Surface Processes and Landforms*, 30 (2): 183-196.
Vrieling, A. (2007). *Mapping Erosion from Space*. Tropical Resources Management Papers, No: 90, TheNetherlands.