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Evaluation of Soil Erosion and Sustainable Land Use Management in the Sarısu Basin

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A B S T R A C T

Land use management requires controlling natural resources for sustainability. Soil erosion related to improper land use is a major issue around the world. Land degradation may harm the health of ecosystems. Defining the soil loss in a basin is the starting point in the restoration of soil quality for crop production. Reducing soil losses to a tolerable rate is one of the primary objectives for sustainability and soil conservation. Central Anatolia is under considerable risk due to an increase in the cultivation of marginal lands for food production. Cultivated lands have already been reached the final limits throughout the last 50 years. Moreover, forests and considerable areas of pasture have recently been converted to ploughed fields due to agricultural expansion. This study was conducted in the Sarısu basin to evaluate soil losses and land use management for sustainability. The Universal Soil Loss Equation model and Geographic Information System techniques were used to estimate the soil losses. The mean potential soil loss of the basin was calculated to be 1.88 t ha^{-1} per year with the Universal Soil Loss Equation model. These results are comparatively small when compared to the average value for Turkey of 13 t ha^{-1} yearly. Our calculated results are closer to the value for the Sakarya river basin, which is approximately 2.77 t ha^{-1} y^{-1}. In this study, land usages in the Sarısu basin were evaluated in terms of soil losses, tolerable soil loss rates and soil conservation precautions.

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Introduction

Soil degradation refers to a decline in a soil's productivity through deterioration of physical, chemical and biological soil properties (Öztaş, 1997). Degradation related to the soil's physical properties is known as physical degradation. Physical degradation of the soil is a result of processes such as sticking, hard setting, cream binding, long-term saturation/drought and accelerated erosion (Logan, 1989). Accelerated erosion is one of the main components of land and soil degradation and can be caused by human activities such as farming, construction, logging, and mining. These activities radically alter the balance between natural resources, including soil and water. Erosion can be minimized through land use planning and by implementing proper control measures.

Erosion causes land degradation by removing the soil from where it originates and by depositing the sediment on other productive land. Erosion limits plant growth by decreasing the effective root depth, available plant nutrients and organic matter content (Öztaş, 1997). The rapidly changing of process in the world leads to not only the demolition of nature but also the destruction of ecological balance, as well as the pollution of air, water and soil (Mutlu et al., 2016; Sevik et al., 2015; Kulac and Yildiz, 2016; Kurnaz et al., 2016). Soil erosion has begun to increasingly influenced both agricultural and natural environments and is one of the foremost environmental issues. Soil erosion affects both sites where the soil is detached and where the eroded soil is deposited. High productivity can be achieved without degrading of the soil structure by preventing soil erosion, increasing biological activity, and restoring the deteriorated nutrient balance (Lal and Stewart, 1990a).

The primary on-site effect of soil erosion is the decline in soil quality due to the loss of the nutrient-rich soil layers and the lower water-holding capability. The on-site effects of water erosion in agricultural soils can be mitigated by increasing the use of artificial fertilizers. The on-site effects of erosion on agricultural yields are well known in the developing countries of Asia and Africa. Water erosion is regionally severe in certain parts of the USA, New Zealand, Australia, and Southern and Eastern Europe. Plant productivity can be sustained over the short to medium term by increasing the use of fertilizers in erosion-prone areas in the more affluent countries. Therefore, the effects of erosion are seldom recognized by farmers in richer countries. This strategy is inappropriate in developing countries. In addition to its, erosion leads to increase both on-site and of-site problems by replacing soils.

Soil erosion results from environmental conditions that are exasperated by both improper land use and fertilizer management (Bhattacharyya et al, 2015; Gomiero, 2016) and by socioeconomic constraints (Steiner, 1996; Mueller-Saemann, 1998 et al.; Sariyildiz et al., 2013; Aydin, 2009).). Soil degradation involves structural changes in the soil (Lal, 2004), and soil erosion can cause the loss of cover vegetation, especially in developing countries such as Turkey, where populations are large and agricultural practices are often insufficient to preserve soil. Additionally, the burning of crop residues increases the soil's sensitivity to erosion. For instance, in China and 90% of Bangladesh, approximately 60% of crop residues are customarily collected from the land and burned as fuel. In areas where biomass and wood are insufficient, shrubs and the roots of grass are burned as fuel. These practices leave the soil bare and exposed to rain and wind, which drive erosion (Pimentel, 2006).

The Mediterranean region is especially at risk of water erosion because of its climate, topography and soil characteristics. Serious erosion is irreversible (Ioannis et al., 2009).

Turkey has long dry periods followed by heavy storms with erosive rainfall. The main causes of soil erosion are inappropriate agricultural practices, overgrazing, deforestation, and construction activities (Yassoglou et al., 1998). The current geography, climate, and topography of Turkey can increase land/soil degradation and the drought sensitivity of the country. Human activities are the number one cause of erosion in Turkey. The geography, topography, and atmospheric conditions of Turkey contribute to the impact of erosion and make combating erosion difficult. The majority of Turkey, i.e., approximately 59% of agricultural fields, 54% of forest land, and 64% of pasture, is under the threat of erosion. The quantity of transported sediment was nearly 500 million tons year^{-1} in the mid-1990s in Turkey. The amount of soil removed by erosion in Turkey has decreased as a result of erosion control, reforestation efforts, and the improvement of degraded forest and rangeland areas. Improving the irrigation technology in agricultural areas reduced the soil erosion to approximately 220 million tons yearly (2.82 t ha^{-1} y^{-1}) in the beginning the 2010's. In Turkey, studies have focused on reforestation, erosion control, improvement of degraded forests and forest-pasture reclamation works that was carried out in 6.75×10^{4} hectares by the end of 2011. In these studies, 8.7×10^{4} hectares of area were received under the erosion control measures. The aim of this study is to determine the amount of potential soil loss and to evaluate the erosion-susceptible areas in terms of land use and tolerable soil losses in the Sarisu basin (Karaş et al. 1995).

Materials and Methods

Study Area

Sarısu, with a drainage area of 66.470 ha, is a sub-basin of Porsuk and is located on the western side of Eskişehir (Figure 1). The primary fluvial system is known as Sarısu creek and has a length of 66 kilometres.

Climate

The basin's climate reflects all aspects of Central Anatolia's characteristics. It has an arid and semi-arid climate with hot dry summers and cold winters. This region generally receives little precipitation throughout the year. In this study, we use meteorological data from Agricultural Research Institute, on the eastern side of the Sarisu basin. The mean annual precipitation is 343 mm, and the mean annual temperature is 10.6 ºC. The area experiences approximately 85-100 rainy days throughout the year, with daily precipitation totals of generally less than 10 mm. Annual evaporation from a Class A pan is almost 950 mm between April and October (Karaş et al., 2009)

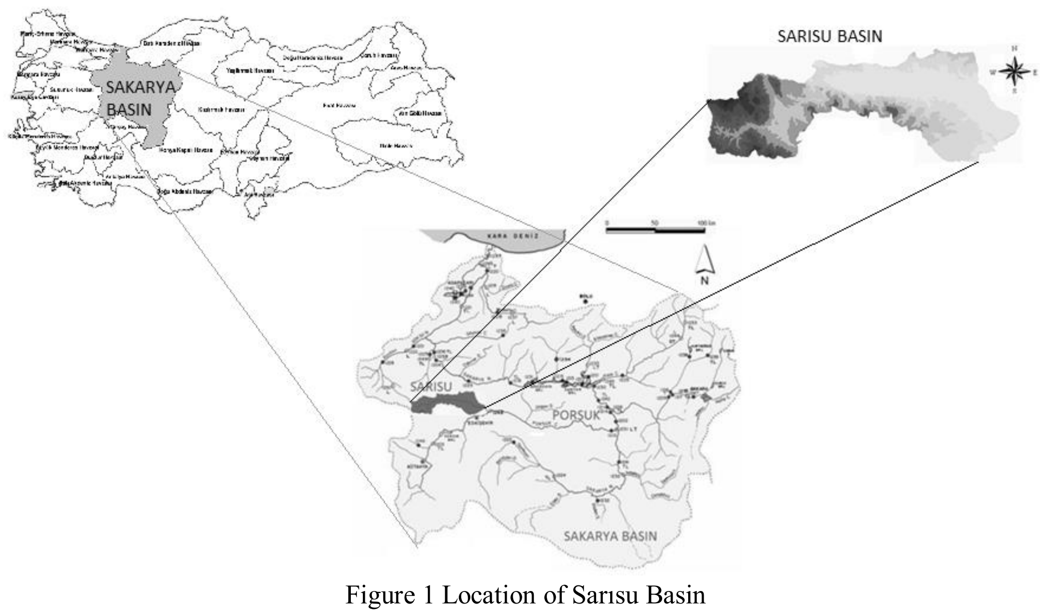

Figure 1 Location of Sarısu Basin

Soil Properties

Soils in the basin were primarily mapped by the General Directorate Soil and Water in the 1980s at the 1/25.000 scale. The most common soil groups in the basin are Brown Forest (56.22%), Brown (15.07%), Alluvial (11.44%) and Non-Calcareous Brown Forest (7.18%) (Table 1 and Figure 2). Most of these soil groups have a loamy texture, except alluvial soils, which predominantly have a clay texture. The basin's soils commonly have a fine to medium granular structure (Karaş et al., 2009)

Table 1 Distribution of soil groups in Sarısu basin

Soil groups	Area	
	(Ha)	(%)
Brown Forest soils	37367.64	56.22
Brown soils	10019.60	15.07
Alluvial soils	7607.18	11.44
Non-calcareous brown forest soils	4774.73	7.18
Non-calcareous forest soils	3268.71	4.92
Bare rock	2161.54	3.25
Kolluvial soils	246.49	0.37
Water surface	331.57	0.50
Residential area	693.36	1.04
Total	66470.82	100.00

Table 2 Land use distribution of Sarisu basin

Land Use	Area	
	(Ha)	(%)
Agricultural	29617.65	44.56
Forest	28592.10	43.01
Pasture	6345.83	9.55
Brush land	1579.72	2.38
Water surface	331.57	0.50
Total	66470.82	100.00

Table 3 Implication of soil loss tolerance

Rooting depth	Soil loss tolerance (ton $ha^{-1}y^{-1}$)	
cm	Renewable soil	Nonrenewable soil
0-25	2.2	2.2
25-50	4.5	2.3
50-100	6.7	4.5
100-150	9.0	6.7
>150	11.2	11.2

In this study, 171 soil samples were taken from the topsoil to determine whether the soils were disturbed, undisturbed, or coordinated (Figure 3). The organic matter, texture, saturated hydraulic conductivity, and mulch factor of the samples were analysed in the laboratory. Soil structure was obtained through field measurements and classified according to the USDA (1993) as fine to medium granular at all sites. The particle size distribution was measured using the hydrometer method to determine the textural characteristics (Tüzüner, 1990). The saturated hydraulic conductivity of undisturbed soil samples was determined by using the constant-head conductivity test with a permeameter cylinder under laboratory conditions according to Klute (1969).

Land Use

The Sarısu basin principally contains agriculture (44.56%), forest (43.01%), pasture (9.55%), and brush land uses (2.38%). Land use in the basin is 95% row-crop agriculture. The main crops are wheat (*Triticum aestivum)*, barley (*Hordeum vulgare*), chickpea (*Cicer arietinum*), sugar beet (*Beta vulgaris*), sunflower (*Helianthus annuus*) and minor amounts of alfalfa (*Medicago sativa*). Forest land within the basin is mostly located in the south-western portion of the basin. Yellow pine, black pine, cedar and oak are the dominant tree species, and the percentage of forest cover is generally moderate. Pasture land use is not concentrated in a particular part of the basin. Pastures are a common type of land use in the basin, and the overall vegetation conditions are moderate to weak (Figure 2 and Table 2).

Geology and Hydrogeology

The basin's geology primarily features the Palaeozoic, Mesozoic- and Cenozoic-aged units. The Palaeozoic rocks are metamorphic units. Metamorphic lower and upper Mesozoic ophiolites within the system are dominated by carbonate and carbonate rock formations. The Cenozoic system features primarily fine-grained sedimentary units. Additionally, carbonate units and volcanic units are also present. These units, which crop out in river valleys and on plains and hillsides, are covered with recent deposits. Additionally, granitic intrusions, volcanic lava and pyroclastic flows associated with different phases of magmatic activity in the region are also observed. The hydrological and hydrogeological features of the Sarısu basin are primarily associated with the area's metamorphic rocks, such as gneiss, schist and marble. These metamorphic rocks generally form impervious or less permeable areas (Yuce et al., 2006).

Soil Loss Tolerance

Soil loss tolerance is defined as the maximum rate of soil erosion from an area that will still permit a high level of productivity to be maintained. The tolerance level varies depending on depth and the type of soil. Soils with a high tolerance limit generally have deep, uniform, and stone free topsoil material and have not been previously eroded. Shallow soils generally have low tolerance limits for erosion, usually in the range of 2.2-11.2 t ha^{-1} y^{-1}. A shallow soil over hard rock will have a lower tolerance than a deep soil or one formed from unconsolidated parent materials. In fact, such limits are often not achieved (Young, 1990 this reference is exist in text but your isn't reference.). Soil loss tolerance values, adapted from McCormack et al. (1982) according to rooting depth, were categorized into five classes in Table 3.

Soil Erosion Modelling

A model-based approach was used to assess soil erosion risk for this study. The Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978) was used because it is one of the least data-demanding erosion models that have been developed and it has been applied widely at different scales. The model is designed to estimate long-term annual erosion rates in agricultural fields. The USLE model, as described in Equation 1, was used to predict the erosion of each 100 m^2 cell in this study.

A=RxKxLSxCxP (1)

where A is annual soil loss (in ton ha^{-1} $year^{-1}$); R is the rainfall erosivity factor (MJ mm ha^{-1} h^{-1}); K is the soil erodibility factor (t ha h ha^{-1} MJ^{-1} mm^{-1}); LS is the slope steepness and length factor (dimensionless); C is the cover management factor (dimensionless) and P is the supporting practice factor (dimensionless) (Wishmeier and Smith, 1978).

The factors were derived from the database. The vector-based information was converted into a 10×10 m grid using Arcview.

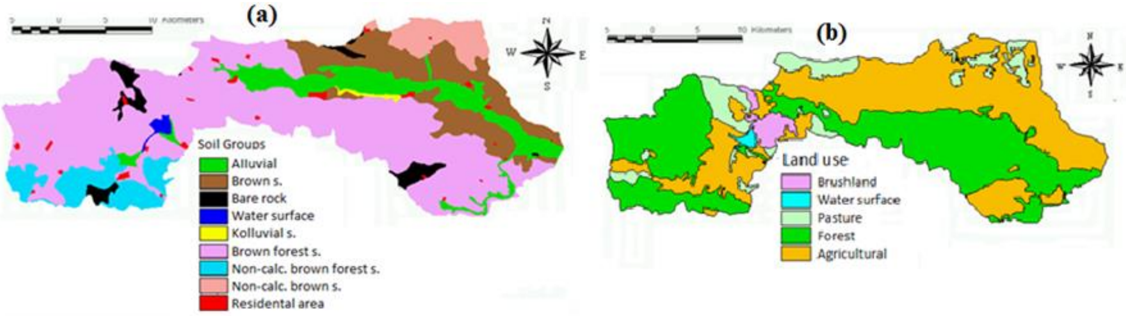

Figure 2 Soil groups (a), Land use (b) of Sakarya basin

Figure 3 Soil sampling locations in the basin

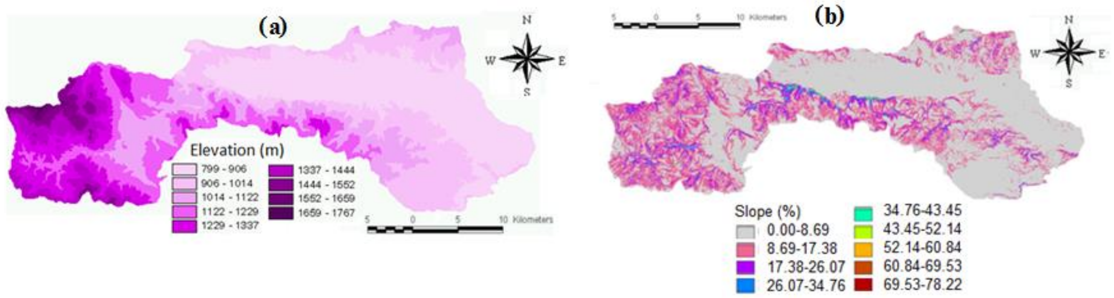

Figure 4 Digital elevation model (a) and Slope (b) of the basin

Results and Discussion

The rainfall-runoff (R) factor for the basin was used a single value (R=41.89), obtained from USLE trials in Soil and Water Resources Research Institute performed during 1973-1982 (Ayday, 1996). Some of the studies are using by GIS such as forestry, agriculture, landscape, protecting area (Aricak, 2015; Aricak et al., 2016; Cetin and Sevik, 2016; Kaya et al., 2009). But until now, GIS can't be used for erosion control. In this study, soil and land use maps were also digitized in a GIS environment, and then converted to dgn format. Analyses were performed by using ArcGIS software. Basin topography was extracted from a digital elevation model (DEM), which is shown in Figure 4.

The K factor map was prepared in a GIS environment by using interpolation. The Kriging technique, a geostatistical analysis method, was used to obtain a K factor map for areal transformation of the 171 soils sampling points within the basin. With these results, the spatial distribution of the K factor was computed in a GIS environment at a resolution of 10 meters, as shown in Figure 5 (a). The majority of the study area has a K factor between 0.15 and 0.28.

The C factor was derived using research results and the USLE guide and is given in Table 4. According to these results, a C factor map of the study area was generated and is shown in Figure 5 (b).

The LS factor was calculated using GIS via the method proposed by Moore and Burch (1986). The slope was calculated using a 10-meter-resolution digital elevation model (DEM). The basin slope lengths (L) ranged from 15.09 to 121.95 meters. The mean slope length was determined to be 46 m, and the slope length factors vary between 0 and 2.15. Basin slopes (Figure 7) have a range of 0-78%, and the slope steepness factor has a range of 0-22.07, which mostly varies between 0 and 2.45. The LS factor was calculated by multiplying the L and S factor values attained for each 10×10 m grid cell. The basin's LS factors range between 0 and 43.55, with an average of 2.235. Furthermore, most of the values are between 0 and 4.439 (Figure 5 (c)).

The P values range between 0 and 1. Because of a lack of information on conservation tillage practices, we adopt P = 1 over the study area.

The factor layers R, LS, K, and C were computed and attained previously by using of GIS functions and then combined to obtain a layer for the soil loss rate (Figure 5 (d)). Areal and percentage distribution of potential soil loss values for the basin are listed in Table 5.

An average of 1.88 t ha^{-1} y^{-1} of potential soil erosion in the catchment was obtained. Soil erosion rates vary between 0 and 179.9 t ha^{-1} y^{-1}. Soil losses within the agricultural, brush, pasture and forest land uses were found to be 3.25, 1.18, 0.33 and 0.04 t ha^{-1} y^{-1}, respectively (Table 6).

Generally, 79.22% of the study area had an erosion rate of less than 2.2 t ha^{-1} y^{-1}, and this area contributed 9.41% of the total soil loss. This portion of the basin includes 57.27% of the agricultural land use, 99.97% of the forest, 99.67% of the pasture and 28.52% of the brush land use. The portion of the basin with less than 11.2 t ha^{-1} y^{-1} of soil loss contributed 56.12% of the total soil loss. The portion of the basin with soil loss rates greater than 11.2 t ha^{-1} y^{-1} represented only 4.25% of the basin area but produced 43.79% of the total soil loss. Agricultural and brush land are the main sources of soil loss, contributing 97.44% of the total soil loss (Table 7).

Agricultural use resulted in 3.72 ton ha^{-1} of soil loss yearly. Although agricultural use represented 44.56% of the basin, it produced 88.44% of the total soil losses. For the agricultural areas, 56.00% experienced soil losses of less than 11.2 t ha^{-1} y^{-1}, which has been accepted as the maximum sustainable value for soil loss tolerance by many researchers, such as Li et al. (2009), Du et al. (2013), Di Stefano and Ferro (2016). Approximately 8.32% of the agricultural areas produces 44.00% of the total soil loss. Therefore, these areas should be protected via cultural applications, such as contour farming and strip cropping; physical structures, such as terracing; or land use changes and conversion to natural land uses.

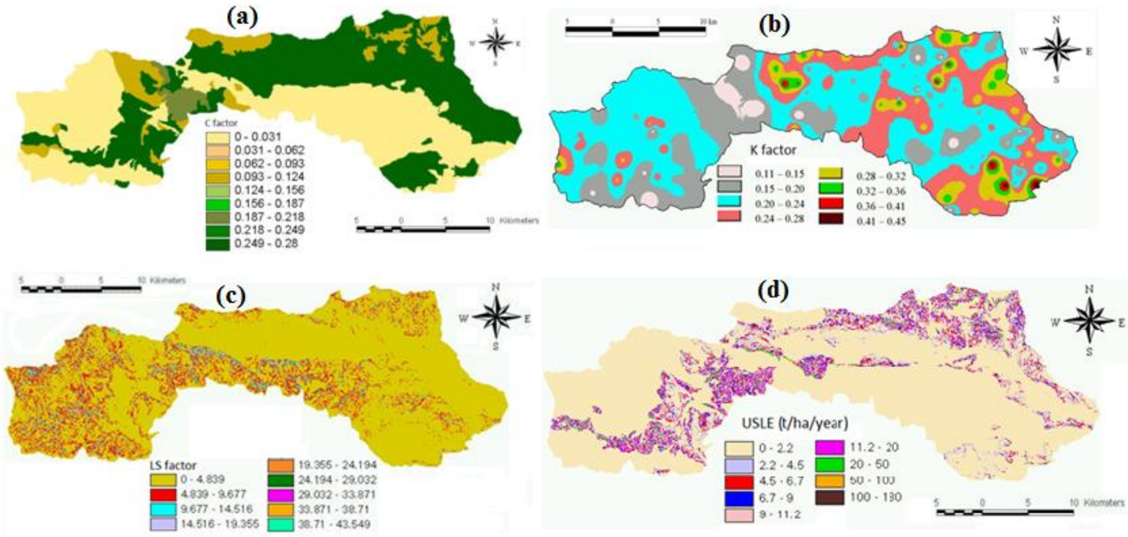

Figure 5 C factor (a), K factor (b), LS factor (c) and Potential soil loss (d) in the study area

Table 4 C factors used in this study for land use and its conditions

Land use	Variation	Application condition	C factor
Agricultural	0.10 – 0.40	Continuously wheat-fallow.	0.28
Forest	0.001 – 0.005	50% covered and weak quality	0.005
Brush land (intensive shrub)	0.038 – 0.081	50% covered, shrub crops decayed on top soil and surface, minimum cover depth is 5 cm	0.050
Pasture	0.01 – 0.10	50% covered, grass yield with middle and weak quality	0.05
Water surface	0.00		0.00

Table 5 Areal and percentage distribution of potential soil loss for the entire basin

Potential soil loss, (ton $ha^{-1}y^{-1}$)	Area (Ha)	Area (%)
0.0 – 2.2	52658.78	79.22
2.2 – 4.5	5149.75	7.75
4.5 – 6.7	2865.29	4.31
6.7 – 9.0	1828.39	2.75
9.0 – 11.2	1142.47	1.72
11.2 – 20.0	1991.30	3.00
20.0 – 50.0	770.21	1.16
50.0 – 100.0	64.63	0.10
> 100.0	3.95	0.01
Total	66470.82	100.00

Table 6 Potential soil losses, according to land use types

Land Use	Area		Potential Soil Loss (t $ha^{-1}y^{-1}$)		Total Soil loss	
	Ha	%	Intervals	Mean	ton	%
Agricultural	29617.65	44.56	0 – 179.9	3.72	110222.10	88.44
Forest	28592.10	43.01	0 – 82.0	0.04	1091.61	0.88
Pasture	6345.83	9.55	0 – 61.6	0.33	2093.36	1.68
Brush land	1579.72	2.38	0 – 13.20	1.18	11221.37	9.00
Water surface	331.57	0.50	0.00	0.00	0.00	0.00
Total	66470.82	100.00	0 – 179.9	1.88	124628.44	100.00

Table 7 Potential soil losses and distribution of land use groups in Sarısu basin

Soil loss (t $ha^{-1}y^{-1}$)	Land use, total soil loss (ton) and %									
	Agricultural		Forest		Pasture		Brush land		General	
	Soil loss	%	Soil loss	%	Soil loss	%	Soil loss	%	Soil loss	%
0.0 – 2.2	8540.48	7.75	988.84	90.59	1954.54	93.37	204.11	1.82	11689.32	9.41
2.2 – 4.5	15874.67	14.40	7.84	0.72	34.17	1.63	785.45	7.00	16677.39	13.43
4.5 – 6.7	14562.27	13.21	6.59	0.60	11.48	0.55	1208.84	10.77	15790.85	12.72
6.7 – 9.0	12672.58	11.50	9.52	0.87	12.48	0.60	1485.07	13.23	14180.14	11.42
9.0 – 11.2	10078.63	9.14	7.95	0.73	11.84	0.57	1364.43	12.16	11463.59	9.23
11.2 – 20.0	24957.93	22.64	32.05	2.94	37.77	1.80	4028.00	35.90	29057.50	23.40
20.0 – 50.0	18902.04	17.15	38.00	3.48	30.02	1.43	2167.33	19.31	21137.40	17.02
50.0 – 100	4184.54	3.80	0.82	0.08	1.66	0.08	5.14	0.05	4192.17	3.38
> 100	448.96	0.41	-	-	-	-	-	-	448.96	0.36
Total (t)	110222.10	100.00	1091.61	100.00	2093.36	100.00	11221.37	100.00	124188.44	100.00
Mean	3.72		0.04		0.33		7.10		1.88	

Brush land use, representing 2.38% of the total basin area, accounted for 9.00% of the total soil losses. Soil losses within this land use ranged from 0 to 13.20 t ha^{-1} y^{-1}. These areas are on steep slopes (Figures 4 and 8). Soil depths of the brush are generally shallow, approximately 20-50 cm. Soil loss tolerances for these depths is 4.5 and 2.3 t ha^{-1} y^{-1} for renewable and non-renewable soils, respectively. If we accept 4.5 t ha^{-1} y^{-1} as a reference value, only 8.82% of the total brush area falls below this value. Therefore, 91.18% of brush area experiences high soil loss rates, and soil conservation should be applied.

Pasture land with a soil loss rate of 0.33 t ha^{-1} y^{-1} accounts for 9.55% of the total area and produces 1.68% of the total soil losses. For this land use type, 93.37% of the soil loss occurs at rates of less than 2.2 t ha^{-1} y^{-1} (Tables 6 and 7). Soil depths in this land use type are generally between 0 and 20 centimetres. Investigations have shown that the pasture crops in this basin have relatively weak quality (Anonymous, 2011). This shallow depth has relatively low soil moisture holding capacity. Consequently, when soil moisture levels do not meet crop evapotranspiration rates, the pasture crops start to desiccate at the beginning of June, and crops do not grow significantly due to insufficient rainfall and water holding capacities. Overgrazing in pasture areas leaves the soils partially bare and exposed to heavy rainstorms. The soil loss tolerance for 25-cm depths is 2.2 t ha^{-1} y^{-1} for both renewable and nonrenewable soils (McCormack et al., 1981). In this land use type, soil losses are between 0 and 61.6 t ha^{-1} y^{-1}, and the soil loss values that are larger than the soil loss tolerance limits should be reduced to minimize soil erosion. Although the soil loss quantities are relatively small, soil conservation practices, such as cultural methods (e.g., fertilization or controlled grazing) or more advanced precautions (e.g., terracing, contour strips, or installation of the trench and holes) should be enacted in degraded areas.

Forest land has the lowest soil loss rates with 0.88 t ha^{-1} y^{-1}. Although the forests represent 43.01% of the area, it contributes only 0.04% of the total soil loss. Soil losses within this area vary between 0 and 82 t ha^{-1} y^{-1}. The soil depths in this area are shallow and generally 0-20 or 20-50 cm. In the study area, 90.59% of the total soil loss is sourced from 99.97% of the total area with loss rates of 2.2 t ha^{-1} y^{-1}. The highest soil losses for forest land use are between 11.2-20.0 and 20.0-50.0 t ha^{-1} y^{-1}, and these areas require conservation measures, such as agroforestry, proper forest management, reforestation/afforestation, controlled cutting or terracing.

In this study, it revealed that the soil losses in the basin are chiefly related to human activities. The high values of soil loss are the result of the combination of steep slopes, low water holding capacity and bare soils due to human activities, such as agriculture, overgrazing of pasture, and expansion of brush land as a result of forest clearing in the most sensitive areas. The agricultural and brush land use types are the primary contributors to soil loss.

The P factor was taken as 1 because no soil conservation practices, such as strip cropping or contour farming techniques, were present in the study area. However, in the studied basin, the field parcels are generally small, approximately 2.5 ha. Field borders serve to shorten the slope lengths. This pattern results in an effect similar to the strip cropping down the slope. USLE only incorporates unique and undivided areas as completely agricultural, and the other land uses do not consider this positive effect on the reduction of soil loss.

Although it is a research result, a single value was used for the R factor due to the insufficiency of information in this study. Precipitation is the spatial data, which can be variable along the slope. Therefore, the soil loss can be change spatially throughout the slope (Karaş et al., 1995)

Soil formation is a dynamic process and is a slower process than soil degradation, especially at the present rate. Soil is accepted as a nonrenewable resource, and once it is destroyed, it is gone forever. Soil can be thought of as a living organism that includes the biological diversity and ensures agricultural productivity. Soil erosion is a deterioration of a soil's productivity via decreases in the biological diversity. Soil erosion is a continuous process and is impossible to remove completely. Soil erosion can be decreased or retarded by taking certain physical or cultural precautions. Comparisons can be made between the natural rates of soil formation and tolerable rates of the soil erosion. The tolerable soil erosion rate defines the maximum level of soil erosion that will permit a high level of agricultural productivity to be sustained economically and indefinitely. The World Resource Institute (1989) estimated the mean rate of erosion on Earth to be 0.9 t ha^{-1} yearly. Considering many published reports, European soil formation rates can be set at approximately 1 ton ha^{-1} yearly (Verheijena et al. 2009). These two values are similar. When soil is tilled, actual soil erosion rates exceed the predicted level. Soil formation is affected by changes in the amount of rainfall, temperature, cover type, infiltration rate and other environmental factors. Studies such as Owens and Watson (1979) and Wakastsuki and Rasyidin (1992) revealed that soil formation rates range from 0.004 mm y^{-1} up to 0.011 mm y^{-1}. Miklos (1992) obtained soil formation rates of approximately 0.5 mm y^{-1} for Alfisols and Oxisols due to biological activity in Brazil. Friend (1992) found soil formation rates of 0.01 mm y^{-1} to 8.5 mm y^{-1} and considered values between 0.12 mm y^{-1} and 0.25 mm y^{-1} to be normal. Sparovek and Van Lier (1997) indicated that the soil erosion should be kept at a tolerable rate in order to maintain sustainability throughout its using. These authors also stated that soil depth increases and target erosion rates maintain the soil depth through time. Liu et al. (2009) documented soil formation rates of 800-1200 mg km^{-2} y^{-1} in China based on a) the soil type and parent materials or bedrock, b) vegetation and c) soil depth. According to Fujisaka (1994), due to excessive reductions in soil depth, sustainable agriculture cannot be maintained in the distant future. Alewell et al. (2014) evaluated the soil erosion rates of the Urseren Valley in Switzerland using the USLE model plus soil loss due to landslides. These calculations yielded soil losses of 1.80 ton ha^{-1} $year^{-1}$, which considerably exceeds the production rates of the soils. When we calculate the soil formation, even the smallest amount of erosion can result in extremely high rates in a short time. The time required to remove 1 mm of soil with a medium structure (assuming a soil bulk density of 1.4 g/cm^3) in association with erosion rates of 1 ton ha^{-1} in the Sarısu basin is approximately 140 years. In the 1950s, the U.S. Department of Agriculture (USDA) established soil-loss tolerance values to evaluate "acceptable" rates of soil erosion. Generally, the T values are between 5-12 ton ha^{-1} y^{-1} in soil conservation programs. These rates are equal to approximately 0.4-1 mm of erosion per year assuming a soil bulk density of 1.2 g cm^{-3}. Based on the USDA's acceptance criteria, the soil erosion rates in the Sarısu basin are mainly below the limits. However, a significant amount of information is not available on the rates of soil formation. Due to the large number of the soil formation factors, such as time, climate, rock weathering, landscape position (such as upland, depression, terrace, flood plain), slope characteristics, decomposition, parent material, depth, and vegetation. One or more factors likely has more significant effects than the others in a given region or basin. Whichever factors contribute most significantly to soil formation, each of the factors is a dependent variable. Thus, a universal equation cannot be applied to every catchment. Because each catchment is unique in terms of soil formation, the soils present reflect the basin's special and natural properties.

Conclusion

In this study, soil losses are investigated according to land use types at the basin scale. Areal and percentage distributions of potential soil loss for the basin are examined separately. The forest and the pasture land use types produced the lowest soil losses, and over the 90% of the soil lost from these areas occurred at rates of 0-2.2 ton ha^{-1} per year. Agricultural and brush lands are the most prone to soil loss and contributed 97.44% of the total soil losses. Nearly half of the total soil losses from these areas occurred at rates of 11.2 t ha^{-1} per year. In general, 96% of the basin produced only 56% of the total soil losses, and the remaining 4% of the basin area produced 44% of the total soil losses at rates of over 11.2 t ha^{-1} per year. Therefore, if land use renders the ground susceptible to the effects of heavy rainfall, even small areas can produce significant soil losses. GIS is a convenient tool for determining critical areas, such as erosion prone areas.

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