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EFFECTS OF LAND USE AND LAND COVER CHANGES ON SOIL EROSION IN SEMI-ARID REGIONS OF TURKEY; A CASE STUDY IN ALMUS LAKE WATERSHED

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Abstract: Land use and land cover (LULC) changes, which are the major causes of soil erosion in watersheds are important processes of land degradation in the world. Erosion models are useful to investigate temporal changes in the past and estimate the future soil losses that might threat the sustainability of crop production. In this study, temporal changes (between 1990 and 2018) of soil loss under different LULC were investigated in a small watershed located in Almus, Turkey. Universal soil loss equation (USLE) was used to model soil loss in the watershed at a fine spatial resolution using geographic information techniques. Rainfall (R), soil erodibility (K), slope length and steepness (LS) and supporting and conservation practices (P) factors of USLE model were kept constant, while cover and management factor (C) was determined by based on LULC types in 1990 and 2018. Spatial and temporal changes in erosion risk were mapped. The maps obtained indicated that LULC change has have both reducing and increasing effects on erosion risk. The average soil loss in 1990 decreased from 0.312 to 0.308 t ha^{-1} $year^{-1}$ in 2018. Coverage of low-risk class areas in the basin increased by 20.19 km^2 between 1990 and 2018. The increase in mixed forest cover caused a significant decrease in erosion risk. The results demonstrated that LULC is the driving factor for increasing or decreasing in soil erosion at the watershed. Conversion of forests to agricultural lands disturbed the surface cover and increased the erosion risk. The results revealed the significant impacts of LULC changes on soil erosion potential in the Almus Lake Watershed.

Keywords: Soil Erosion, Land use Land Cover Change, GIS, USLE, Almus Lake Watershed

1. INTRODUCTION

Soil is an indispensable natural resource for the conservation of terrestrial ecosystems and the presence of humanity (Jazouli et al., 2019). Soil erosion, a prevalent form of land degradation, is one of the most serious threats to the sustainability of delivering ecosystem services (Yan et al., 2018; Pimentel et al., 1995). The soil erosion causes a significant decrease in the production function of soils and quality of agricultural products (Pimentel & Kounang, 1998) by deteriorating soil structure, decreasing infiltration and retention of water in soil and covering the surface of fertile soils with new sediments. In addition, the lakes and dams are filled with the sediments, water quality decreases, and biodiversity is adversely affected (Houghton, 1994; Turner et al., 1995; Pimentel, 2006; Alkharabsheh et al., 2013; Simonneaux et al., 2015). Human being have not been experienced with the current natural disasters occurring in all over the world. Therefore, the researchers suggested the call this period as Anthropocene, especially due to the noticeable global climate change occurring due to the activities of human being (Steffen et al., 2011; Waters et al., 2016). Changes in land cover and land use type result in substantial impact on physical and biological characteristics of ecosystems. Land use is a dynamic and anthropogenic factor controlling the effects of soil erosion. Many studies carried out in all over the world have demonstrated that the changes in land-use have prominent effects on soil erosion (Wynants et al., 2018; Chen et al., 2019; Diyabalanage et al., 2017; Zhang et al., 2017; Sharma et al., 2011; Ferreira et al., 2015; Häring et al., 2014)

Expanding agricultural areas, establishment of new settlements, overgrazing of pastures destroyed the natural vegetation and consequently, increased soil erosion in Turkey (Efe et al., 2008; Zeybek, 2011). Determining the distribution of soil erosion potentialin a basin enables sustainable management and protection of natural resources (Morgan, 2005; Buttafuoco et al., 2012). The amount of soil erosion in a region provides information to prepare effective soil conservation plans (Bagarello et al., 2012). Many predictive and experimental models were used to determine the soil erosion. Universal soil loss equation (USLE) is a widely used numerical model to predict soil loss from a cultivated area and to select the plant, soil and land management practices (Wischmeier & Smith., 1978). The USLE estimates the amount of soil erosion in a given area employing the data on climate, topography, soil, land cover and human activities.

Soil erosion models are widely adopted to determine and estimate soil losses using the data gathered from the field, remote sensing devices and geographic information system (GIS) (Chen et al., 2019). The GIS is a useful technique in integrating numerous datasets to interpret complicated data on dynamic processes such as soil erosion (Krivtsov, 2004). The USLE model has been successfully integrated into GIS to determine soil erosion due to factor-based, fast and easy preparation of the required data. Temporal LULC changes in small watersheds can be determined using remotely sensed data. Scientists have investigated the impacts of changes in land cover on soil losses using remotely sensed data and reported significant impacts of land cover changes on soil losses (Pruski & Nearing, 2002; Ito, 2007; Jordan et al., 2005; Devátý et al., 2019).

Changes in socio-economic environment of Almus watershed caused a significant regional change in land use pattern. Inappropriate land use practices increased the susceptibility of basin to soil erosion. This study was carried out to determine the effects of long-term LULC changes in Almus lake basin on soil erosion potential using USLE model integrated in GIS and remote sensing techniques.

2. MATERIAL AND METHODS

2.1. Study Area

The study area composed of agricultural lands, forests, pasture lands and urban areas; thus was selected to investigate the impacts of land use and land cover (LULC) changes on soil erosion risk in a semi-arid regions of Turkey. The study area is an upland and located in the headwaters (36˚40ˈ- 37˚50ˈ E and 40˚10ˈ - 40˚20ˈ N) of the Yesilırmak River basin (2364 km^2) within the border of Almus district in Turkey (Fig. 1). According to the Köppen-Geiger classification, the climate of the watersed is Mediterranean with an annual average temperature of 10.7 C˚and total annual rainfall of 481 mm of which the highest precipitation occurs in April (60 mm). Eutric Cambisols dominated the area, followed by Calcic Cambisols, Lithosols, Calcaric Regosols, and Calcic Xerosols (FAO, 1990).

Agricultural lands and urban areas are mostly located on lower part of the watershed. The study area is mostly covered by forests which includes Scotch pine (*Pinus Sylvestris*), Eastern Beech (*Fagus orientalis*), Eastern hornbeam (*Carpinus orientalis*), Oak (*Quercus*) and Juniper (*Juniperus communis*) tree species.

2.2. Methods

The USLE model that estimates soil losses caused by impacts of raindrop and surface runoff, in ArcGIS 10.5 environment module was used to calculate the soil erosion index for Almus Dam watershed. The equation of the USLE model is shown in equation 1;

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

In the equation; A denotes the annual average soil loss (ton ha^{-1} year^{-1}), R is the erosivity factor for rainfall and runoff (MJ ha^{-1} per year), L is the slope length factor (unitless), S is the slope steepness factor (unitless), K is the soil erodibility factor, (t ha h ha^{-1} MJ^{-1} mm^{-1}), C is the cover and management factor (unitless), and P is the supporting and conservation practices factor (unitless). The R factor is a function of precipitation time, intensity, diameter of raindrops, mass and rate of raindrops. The increase in annual rainfall increases the erosive effect of the R factor. The R factor is calculated using the total kinetic energy of precipitation and the maximum rain intensity values in 30 minutes (Renard et al., 1997). Modified Fournier Index (MFI) (2) was used to calculate the R factor due to the lack of precipitation intensity and duration data for the Almus Lake watershed (Arnoldous, 1977). Monthly average precipitation data between 1970 and 1994 for the MFI were obtained from the meteorology general directorate of Tokat province.

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

In the equation, Pi denotes the total rainfall (mm) occurred in the ith month, and P denotes the annual average rainfall (mm).

The altitude of the basin varies between 774 and 2703 m, which has significant influence on precipitation. Therefore, the precipitation at different altitudes was calculated using the Schreiber's method

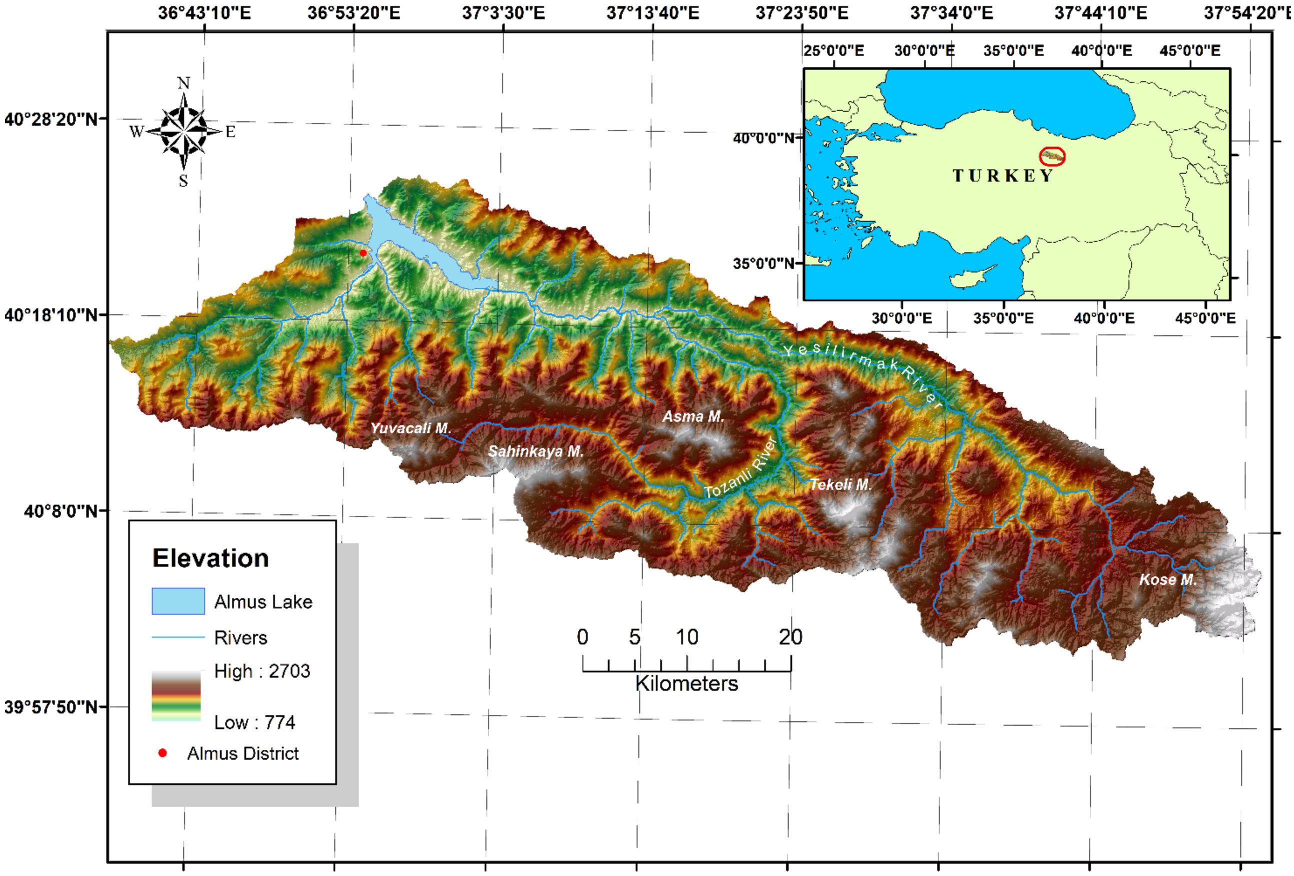

Figure 1. Location of Almus Dam Watershed

(Equation 3). Spatial distribution of precipitation erosivity map for the Almus Dam basin was created by IDW interpolation method using calculated R values.

$$Ph = Po + 4.5 \times h \quad (3)$$

Where, Ph represents the monthly average precipitation (mm), Po represents the monthly average rainfall (mm) of a predetermined meteorological station. The h denotes the elevation (m) of a location that the precipitation was calculated (Özşahin & Uygur, 2014)

The K, soil erodibility factor, refers to susceptibility of soils to erosion and is closely related to the structure, texture and composition of soils. The K factor was calculated using the characteristics of 66 geo-referenced soil samples collected from Almus Dam basin. Soil samples were collected by stratified random sampling style. Organic matter, texture and very fine sand content of soil samples were determined. Organic matter content was determined using the Walkley-Black method (Nelson & Sommers, 1982), soil texture was determined using the Hydrometer method (Bouyoucos, 1951). Very fine sand content of soil samples was measured using the wet sieving method. Soil permeability was estimated using SPAW software (Saxton & Willey, 2004). The K factor values of sampling points were calculated using the laboratory data (Equation 4). (Wischmeier & Smith, 1978; Panagos et al., 2014). Spatial distribution of K factor was prepared in raster format using the K factor values of the sample points by ordinary kriging interpolation method.

$$K = [(2.1 \times 10^{-4} (12 - OM) M^{1.14} + 3.25(s - 2) + 2.5(p - 3)) / 100] \times 0.1317 \quad (4)$$

In the equation, K represents the soil erodibility factor, OM represents the organic matter content (%), M indicates the fractions of particle sizes ((% modified silt or the 0.002-0.1 mm size fraction) * (% silt + % sand)), s is the structure type code, and p is the permeability values.

Slope length (L) and degree (S) are two complementary elements that have significant effects on soil erosion. The L and S factors are evaluated together as the topographic factor (LS). The LS factor is equal to 1.0 in a land with 9% homogeneous slope and 22.1 m slope length. The severity of erosion increases with the increase in degree and length of slope. Digital elevation model (DEM) was created using the ASTER satellite data with a resolution of 30 m to calculate the LS factor values. The LS factor was calculated by equation 5 using slope and flow accumulation maps created from Aster DEM (Moore and Burch 1986).

$$LS = \left[\frac{A}{22.13}\right]^{0.4} \times \left[\frac{Sin\ Q}{0.0896}\right]^{1.3} \qquad (5)$$

Where, L is the slope length and S is slope steepness factor; A is the product of flow accumulation and cell size; and Q is the slope in degrees.

The C factor indicates the deviation from soil loss occurring under continuous vegetation compared to a fallow plot that is constantly cultivated. In addition, the C factor reflects the integrated impacts of variations in land cover and management. The CORINE 3rd level land cover maps were used to determine the effect of LULC changes on soil erosion. The C factor values of land cover types for 1990 and 2018 were determined from the reports of similar studies (Lastoria et al., 2008; Bakker et al., 2008; Vijith et al., 2017). Separate C factor map was created for 1990 and 2018.

The P factor reflects the effects of conservation practices and is defined as the ratio of soil loss occurring under a certain soil conservation measure to soil loss occurring on a bare field plowed along the slope. There were no erosion control practices in the Almus Lake Watershed, therefore, the P factor was accepted as 1.0.

Raster map layers using 30x30 m grid size were prepared for each of the computed R, K, LS, C and P factors. Employing the map calculation functions in ArcGIS software, raster maps of soil loss for 1990 and 2018 were prepared by multiplying all the map layers with each other. All factors except the C factor were kept constant and soil losses of two different years were calculated. Thus, the USLE soil loss maps of two different years were obtained and the effect of LULC change on soil loss was determined.

3. RESULTS

3.1. Land Use Land Cover (LULC) Dynamics

The results indicated significant changes in LULC between 1990 and 2018, and the changes in LULC caused a negative and positive impacts on soil erosion. The third level classification system was preferred to obtain more sensitive results. The maps obtained from CORINE database of 1990 and 2018 were shown in Figure 2. The map indicated the presence of same land use types in the region both in 1990 and 2018. The results did not show any changes or a new land use type emerged in the basin. Fifteen LULC types determined in the region and the spatial distribution of LULC were given in Table 1.

The coverage of pastures, complex cultivation patterns, mixed lands (agriculture and natural vegetation), broad-leaved forest, coniferous forest, meadow and sparse vegetation in the watershed was decreased. In contrast, the area of discontinuous urban fabric, non-irrigated arable land, permanently irrigated land, mixed forest, transitional woodland-shrub, bare rocks and water bodies was increased. The most widely distributed LULC type in both years was natural grasslands, which covered 546.36 km^2 land in 1990, and 528.10 km^2 in 2018. The second most common LULC was the transitional woodland-shrub type which covered an area of 367.08 km^2 in 1990, and 381.13 km^2 in 2018.

Table 1. The LULC classes determined by CORINE Land Cover (CLC)

LULC Cover Corine: 3rd Level	Corine Code	1990 (km^2)	2018 (km^2)	Change (km^2)	C Factor Values
Discontinuous urban fabric	112	2.80	2.97	0.17	0
Non-irrigated arable land	211	19.79	21.56	1.77	0.45
Permanently irrigated land	212	35.87	36.21	0.34	0.003
Pastures	231	3.37	3.36	-0.02	0.05
Complex cultivation patterns	242	152.57	147.76	-4.81	0.12
Mixed lands with agriculture and natural vegetation	243	258.76	234.67	-24.09	0.12
Broad-leaf forest	311	323.12	313.07	-10.05	0.004
Coniferous forest	312	53.72	47.56	-6.15	0.004
Mixed forest	313	274.80	325.31	50.51	0.004
Natural grassland	321	546.36	528.11	-18.26	0.02
Transitional woodland/shrub	324	367.08	381.13	14.05	0.007
Bare rock	332	10.89	12.40	1.51	1
Sparsely vegetated areas	333	281.28	275.64	-5.64	0.3
Water courses	511	2.15	2.15	0	0
Water bodies	512	32.25	32.93	0.68	0
Discontinuous urban fabric	112	2.80	2.97	0.17	0

The highest total increase was recorded in the mixed forest lands (50.51 km^2). Statistics shared by the Ministry of Forest indicated that forest land in the country increased approximately 2 million ha since 1975 (Anonymous, 2017), which is in accordance with the increase in Almus Dam basin. Transitional woodland-shrub (20.77 km^2) and natural grassland (5.40 km^2) LULC types have been transformed into the mixed forest type. The transitional woodland-shrub type was the second LULC class increased the most in 2018 with an area of 14.05 km^2. The mixed lands of agriculture and natural vegetation decreased by 24.09 km^2 of which 15.79 km^2 land become natural grassland, 4.59 km^2 land transformed into complex cultivation, and 0.02 km^2 used as settlement. The results revealed the effect of anthropogenic factors on spatial distribution of land principally occupied by agriculture, with significant areas of natural vegetation LULC. In contrast to conversion of the mixed lands of agriculture and natural grassland, total area of natural grassland in the study area decreased by 18.26 km^2. Vast majority of natural grassland turned into a transitional woodland-shrub use due to the afforestation studies concentrated in these areas. The increase in bare rock areas within the watershed draws attention. The transitional woodland-shrub (approximately 150 ha) was destroyed and turned into a bare land. Total of 277 ha land converted to agricultural lands due to anthropogenic factors, which increased the soil loss.

3.2. Estimation of soil erosion potential

The dynamics of LULC change showed that the basin is under intensive management and local anthropogenic activities, which have a direct impact on acceleration of erosion. The values of R factor in the basin ranged from 133.75 to 92.52 MJ mm ha^{-1} h^{-1} $year^{-1}$ (Fig. 2). The values of R factor decreased from north to south of the basin. The increase of R factor values towards the north may be associated with the proximity to the Black Sea region. In contrast, the R values factor were lower in the west part of the basin.

The K factor values in the basin ranged from 0.0034 to 0.0324 t ha h MJ^{-1} ha^{-1} mm^{-1} (Fig. 2). The L and S factors in the USLE model reflect the effects of topography on erosion. Digital elevation model (DEM) of the Almus Lake watershed was prepared using the ASTER satellite data with a 30 m resolution. The LS values in the basin were between 0 and 46.54 (Fig. 2), while the mean LS factor value was 0. The P factor reflects the erosion control and conservation efforts within the watershed boundary. The information on P value can be easily obtained in small scale studies. Erosion control or conversion studies have not been carried out within the Almus Lake watershed. In similar studies, the P value was used as 1.0 for the whole study area to eliminate the effect of P factor (Ganasri & Ramesh, 2016).

The potential human impact on erosion was investigated by determining the LULC types in 1990 and 2018 from CORINE maps (Table 1). Soil cover decreases the erosive effect of the raindrops. Therefore, C factor values were low in densely vegetated areas, while it was high in places where vegetation density was low or the surface was bare. The C factor values varied between 0 and 1 in both years, and spatial distribution varied due to changes in LULC (Fig. 2). The USLE soil loss for both years was calculated by multiplying all factors in the USLE model. Soil loss in 1990 varied between 0 and 65.75 tons ha^{-1} $year^{-1}$ with an average soil loss of 0.312 tons ha^{-1} $year^{-1}$. Soil loss in 2018 ranged from 0 to 90.04 tons ha^{-1} $year^{-1}$ with an average soil loss of 0.308 tons ha^{-1} $year^{-1}$ (Fig. 3). The severity of erosion was divided into five classes according to the EOINET European erosion map (Panagos et al. 2014). The erosion classes in 1990 and 2018 and their distributions were given in Table 2. The erosion intensity between 0 and 0.5 tons ha^{-1} $year^{-1}$ covered 2037.34 km^2 land in 1990, the intensity between 0.5 and 1 tons ha^{-1} $year^{-1}$ covered 146.32 km^2, 1-2 tons ha^{-1} $year^{-1}$ class was 98.98 km^2, 2-5 tons ha^{-1} $year^{-1}$ class was 61.81 km^2, and 5> tons ha^{-1} $year^{-1}$ class occupied an area of 19.55 km^2. Erosion classification in 2018 revealed that total area with the erosion intensity between 0 and 0.5 tons ha^{-1} $year^{-1}$ was 2057.53 km^2. Deforestration due to the pasture and urban settlement increased the erosion risk from 65.75 to 90.04 tons ha^{-1} $year^{-1}$.

Table 2. Erosion classes and spatial distribution of soil losses predicted by USLE model in 1990 and 2018

Erosion Intensity ($t\ ha^{-1}\ year^{-1}$)		1990		2018		Area change (km^2)
		Percent Area (%)	Area (km^2)	Percent Area (%)	Area (km^2)	
Low	(0 - 0.5)	86.18	2037.34	87.04	2057.53	20.19
Slight	(0.5 – 1)	6.19	146.32	5.56	131.43	-14.89
Moderate	(1 – 2)	4.19	98.98	4.01	94.83	-4.16
High	(2 – 5)	2.61	61.81	2.57	60.71	-1.10
Severe	(5 >)	0.83	19.55	0.83	19.51	-0.04

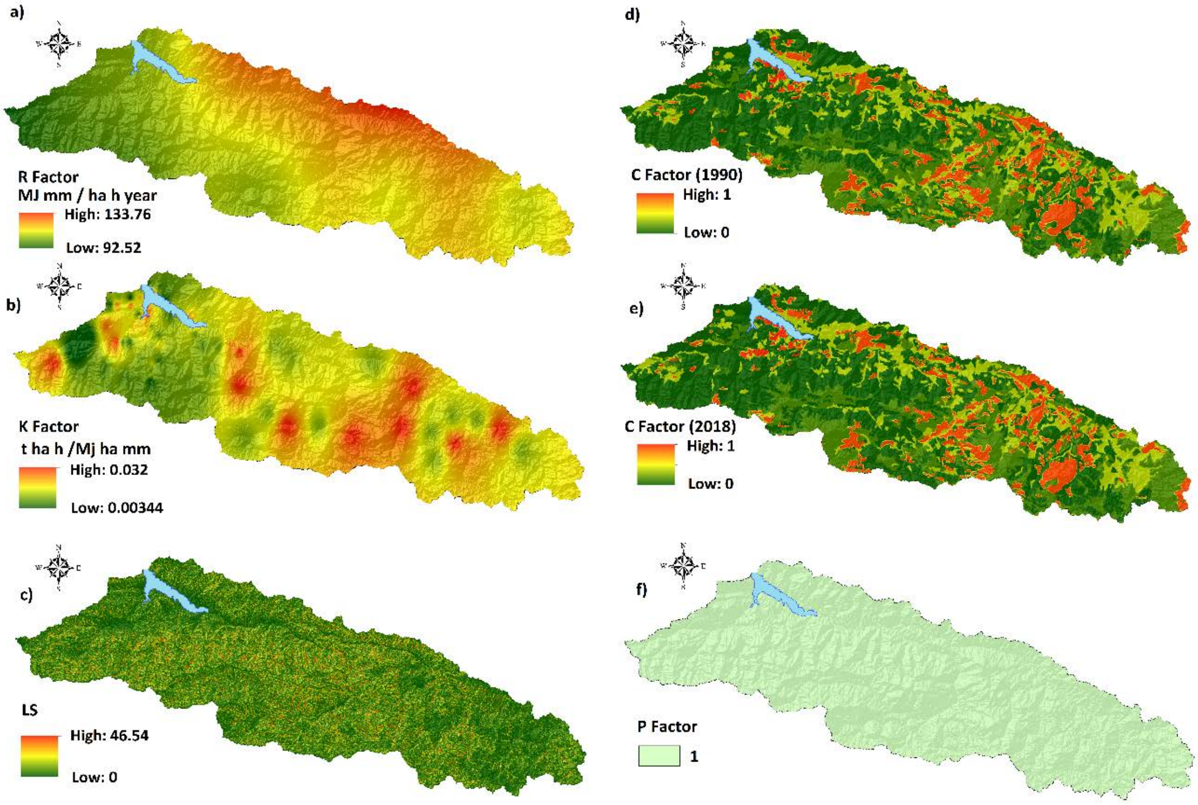

Figure 2. Distribution of USLE Factors in the Study Area; a) R factor (MJ ha^{-1} per year), b) K factor (t ha h ha^{-1} MJ^{-1} mm^{-1}) c) LS factor, d) C factor 1990, e) C factor 2018, f) P factor

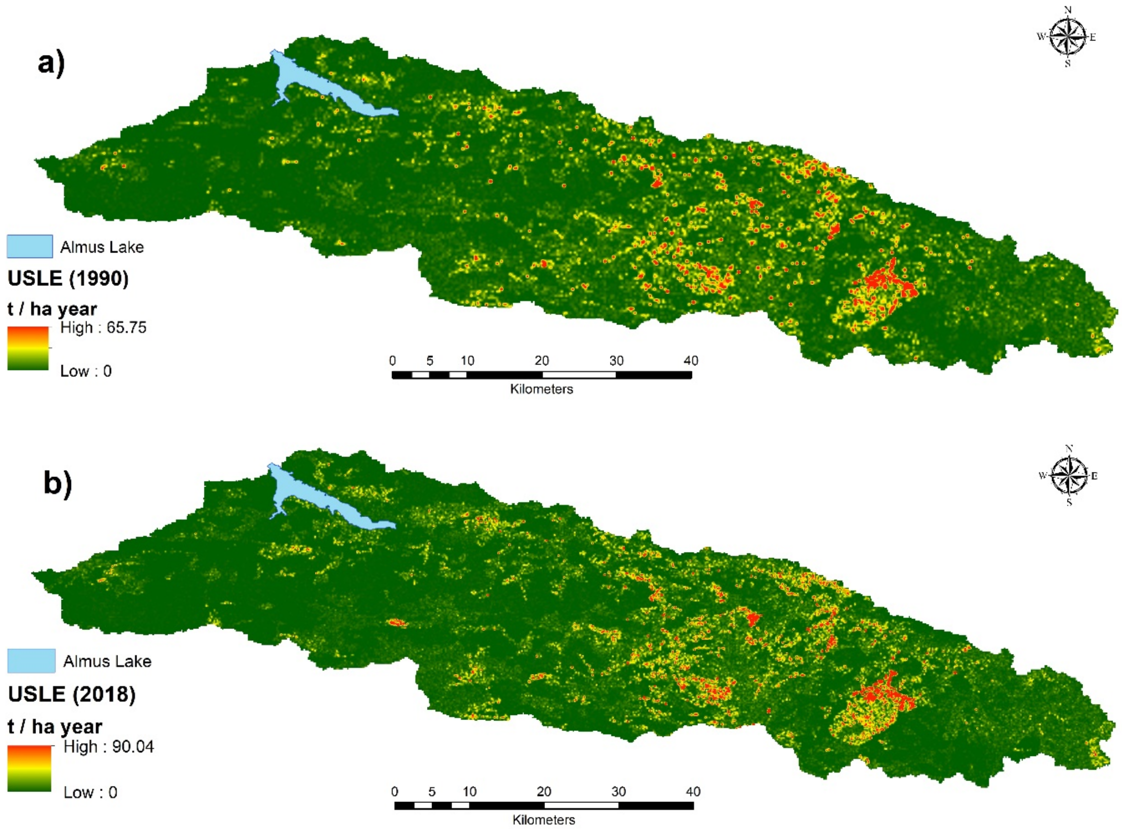

Figure 3. Distribution of Soil Losses predicted by USLE model.

4. DISCUSSION

Soil erosion has been frequently attributed to the intensity and type of land use (Mutu et al., 2006; Sun et al., 2014). Patchy or fragmented LULC in the study area demonstrated the intensive management and various local anthropogenic activities in the watershed. The patchy structure of the LULC is also an indication that producers are engaged in agricultural production on very small fields. In contrast to the higher erosion risks in some areas compared to 1990 and locally increased anthropogenic activities, overall erosion risk in the watershed tended to decrease in 2018.

In particular, low erosion intensity class was increased by 20.19 km^2 that may be related to the 50.51 km^2 increase of mixed forest cover in the basin. The Mixed Forest cover in the basin significantly increased from 1990 to 2018. Land surface was covered even with a more protective cover over the time; thus, the C factor values decreased further and the mean soil loss decreased from 0.312 to 0.308 tons ha^{-1} $year^{-1}$. Sharma et al., (2011) also indicated that the increase in forestland within an agricultural basin decreased the erosion potential. The results in this study also revealed the importance of aforestration to conserve soils. Similar to our findings, Mancino et al., (2016) reported that changes in LULC reduced soil erosion due to the conservative effects of vegetation cover preventing from raindrop impact and increasing organic matter and consequently water holding capacity of soils. The results reported by Erpul et al., (2018) are in agreement with our finding and the previous studies. The researchers estimated soil losses in the Yeşilırmak basin using the RUSLE method and reported the effects of vegetation cover to soil erosion in the basin as 46.23%. The results obtained in the Almus Lake Basin located at the upper part of the Yeşilırmak basin showed that soil losses could be significantly reduced by maintaining vegetation cover on soil surface. Similar to our findings, Zuo et al., (2016) who carried out a study on the loess plateau in China reported a significant decreases in sediment yield with the increase in forest coverage by 14.7%.

Insufficient vegetation on the surfaces of pasture lands causes raindrops to break up the soil aggregates and increases the susceptibility of the soil to erosion (Sun et al., 2014). Therefore, the areas with moderate, high and serious erosion classes with high erosion potential were located mostly on bare areas and some in the sparsely vegetated lands.

Erosion potential of the flat areas, close to the dam, was higher due to the conversion of natural grasslands to agricultural fields. Conventional tillage practices, which are commonly used in seedbed preparation, in agricultural fields disturbs soil aggregates (Çelik et al., 2020) and decrease the resistance of soils to erosion. Therefore, soil erosion due to water and tillage are considered the major causes of fertile topsoil losses, and therefore productive lands in Europe (Luetzenburg et al., 2020). Similar result was encountered with the conversion of pasture lands into agricultural fields.

The erosion risk in the watershed increased from 65.75 to 90.04 tons ha^{-1} $year^{-1}$. The result is related to disturbance of forest lands on the high sloppy areas in the south-western part of the watershed. In general, deforestation and an increase in agricultural activities in the basin are the most detrimental land changes and caused an increase in soil erosion. However, the increase in forest lands reduced the average erosion risk after 28 years despite the intensive anthropogenic activities in the watershed.

5. CONCLUSION

This study investigated the potential of GIS and remote sensing for the assessment of LULC and the effects of LULC on soil erosion potential in Almus Lake watershed between 1990 and 2018. The results revealed that human-induced activities in the basin caused a considerable land use changes which had positive and negative effects on soil erosion potential in 28 years. Deforestation to create new agricultural lands and degradation of natural grassland and pastures increased the soil erosion risk potential in some parts of the Almus Lake watershed. In contrast, the erosion potential reduced with the increase in mixed forest areas in a large part of the basin. The mean erosion potential in the watershed slightly decreased from 0.312 t ha^{-1} $year^{-1}$ in 1990 to 0.308 t ha^{-1} $year^{-1}$ in 2018. The results indicated that forest lands are a very effective to decrease soil erosion risk. The main purpose of soil and water conservation planning should be to increase the conservative soil cultivation to minimize soil losses from agricultural fields. In addition, erosion potential can be reduced by ensuring the quality and protection of the vegetation cover in the basin. This study provided the first basic data of the basin for erosion models based on future projections. The results also demonstrated the effectiveness of spatial analysis tools in mapping the spatial distribution of soil erosion potential. The GIS-based USLE model will assist decision-makers in effective planning for erosion control studies on risky areas, thanks to fast and effective mapping in the spatial estimation of watershed-based soil erosion risk.

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