Determination of Soil Quality Index in Areas with High Erosion Risk and Usability in Watershed Rehabilitation Applications

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Abstract

Erosion is an important environmental issue threatening natural resources and ecosystems, especially soil and water. Soil losses occur in many parts of the world due to erosion at different degrees, and various rehabilitation plans have been carried out to reduce these losses. However, soil protection applications are generally carried out by considering only the essential characteristics of the soil. This may decrease the chance of success of rehabilitation applications. The present study aimed to determine the soil quality index (SQI) by weighting the soil quality parameters according to the Analytical Hierarchy Process (AHP) in the Çapakçur microcatchment (Bingöl, Türkiye) where soil loss is high. Accordingly, 428 soil samples were taken from the study area and analyzed. The soil losses in the Çapakçur watershed were calculated employing the Revised Universal Soil Loss Equation (RUSLE). To determine the soil quality index, a total of 20 indicators were used, including (i) physical soil properties, (ii) chemical soil properties, and (iii) soil nutrient content. Soil quality index results are divided into classes between 1 and 5. As a result of the study, the annual total amount of soil lost from the microcatchment was calculated as 96 915.20 tons, and the yearly average amount of soil lost from the unit area was calculated as 10.14 tons.ha-1. According to SQI, the largest area in the micro-catchment was Class-2 (weak), with 39.49%, whereas the smallest area was 1.4% (the most suitable). However, it was determined that there was a significant negative relationship between SQI and soil erodibility. Considering the SQI distribution of the area in the planning of soil protection and erosion prevention practices in watershed rehabilitation studies may increase success.

1. Introduction

Soil erosion is an important environmental threat as it destroys the fertile topsoil layer, pollutes water resources, and negatively affects many cycles (water, carbon, nitrogen, etc.) in the ecosystem. To minimize the damages caused by this threat, soil erosion control has attracted significant attention worldwide, and soil erosion management has been carried out at different spatial scales in various countries (Meatens et al., 2012; Poesen, 2018; Wen & Zhen, 2020, Demir 2020; Ahmad et al., 2020). As is the case in the whole world, erosion control applications have been carried out successfully in Turkey for the last 50 years. Practices aiming to stop erosion by afforestation, cover development, grazing, pasture improvement, reclamation of dry stream beds, and afforestation when necessary to establish vegetation or improve existing vegetation by authorized institutions are currently being carried out successfully. However, a total of 642 million tons of soil is displaced annually in Turkey due to water erosion (Erpul et al., 2020). This necessitates the implementation of erosion control and soil protection management practices more effectively.

For sustainable soil management in lands with high erosion risk, it is necessary to have sufficient data on many properties of soils. Today, in erosion control engineering studies, many applications vary according to soil's physical and chemical properties and topographic factors. At the beginning of these applications, methods such as terracing, gully control, planting-mulching, afforestation, and water diversion are adopted (Morgan, 2009). Also, soil cover materials (such as geotextiles and wire netting) made using natural and artificial materials have been used in erosion control studies in recent years (Bhattacharyya, 2011; Artidteang et al., 2015; Demir, 2020).

In general, erosion control studies and applications to be made are based on the evaluation of individual soil parameters. For instance, while the parameters of the physical properties of the soils (FES, 2008; Chen et al., 2017) and the topography and climate are effective in terrace applications, data on chemical soil properties may be needed in addition to the physical soil parameters for applications such as afforestation and grazing. Because, in the planning of the area to be afforested, the chemical properties of the soils such as pH, lime, and organic matter content (FGM, 2020) have an essential effect on the selection of the plant species. Knowing the soil quality parameters of the area where erosion control applications will be made and reducing these parameters to an evaluable index value can increase the chance of success in the planning. The soil quality index (SQI) enables the assessment of soil quality of a given area or ecosystem and comparisons between areas of various scales (land, field, or watershed) under different land use and management practices. Soil quality indicators can not only assess the condition or condition of the soil but also help shape soil and land use policies. Using indices instead of soil properties for measuring soil quality is useful because indices represent the total effect of soil properties by giving a weighted score to each property according to its role in soil quality (Singh & Khera, 2009). The present study determined a soil quality index of a microcatchment with high erosion risk and an index distribution map. The results obtained were correlated by considering the soil loss classes of the microcatchment. The Çapakçur microcatchment, the study area, is an area with high erosion risk (Yüksel & Avcı, 2015; Meral & Eroğlu, 2021), and the annual soil loss is above the Turkey average (Demir, 2020; Demir & Mirici, 2020). Therefore, best soil management and soil conservation management practices are carried out to be implemented in many watersheds, such as the Çapakçur microcatchment in Turkey. Rehabilitation and soil protection work carried out by the Ministry of Agriculture and Forestry in many watersheds has made it essential to carry out soil quality index (SQI) studies in the watersheds.

2. Method And Material

2.1. Study Area

This study was carried out in the 10626.9-h-wide Çapakçur microcatchment (611203–628133 E; 4296160–4306130 N/ UTM, 37 Zone m) located in the Upper Euphrates Basin of the Eastern Anatolia Region (Fig. 1).

The altitude of the microcatchment is between 1150 and 2500, with an average of 1650 m. Approximately half of the study area has a more than 40% slope, with only 6.8% of the area in the 0–12% slope range. In the Çapakçur microcatchment, most areas are located in the north (24.63%) and the least in the southwest (5.97%). In the land use distribution of the microcatchment, the highest rate consists of bare and rocky areas. (Fig. 2).

Cold continental climate conditions prevail in the study area. Summers are hot, and winters are very cold. According to the region's meteorological data covering the years 1961–2021, the annual average temperature, precipitation, and evaporation values are 12.2 C, 944.6 mm, and 1202 mm, respectively (MGM, 2021).

2.2. Soil Sampling and scoring of indicators

According to the grid (500 m x 500 m) soil sampling method from the study area, 428 soil samples were taken from 0-30-cm-depth (Fig. 3). These samples were transported to the laboratory and made ready for analysis after drying, grinding, and sieving processes. A total of 20 soil quality indicators were determined to determine the soil quality index values of the study area. To determine the quality indicators, the topographical features of the study area, land use status and erosion susceptibility, and literature studies were taken into consideration (Arshad et al., 1997; Ratta & Lal, 1998; R Zheng-An et al., 2010; Herrick et al., 2018; Dengiz, 2020; Demir, 2020; Demir & Mirici, 2020). Accordingşly, the quality indicators determined were grouped into three criteria and included in the Soil Quality Index (SQI) model. These are criterion-1, physical properties of soil (clay percentage-C, silt percentage-Si, sand percentage-S, aggregate stability - AS, dispersion ratio - DR, bulk density- Db, field capacity-FC, wilting point-WP, hydraulic conductivity-Ks), criterion-2- chemical properties of soil (soil reaction - pH, electrical conductivity - EC, organic matter - OM, lime content - $CaCO_3$ and cation exchange capacity, CEC), criterion-3, macronutrients (total nitrogen) - TN, available phosphorus - AvP, exchangeable potassium - exK, exchangeable calcium - exCa, exchangeable magnesium - exMg and sulfur - S). The methods in Table 1 were used to analyze the soil properties selected as the indicator.

Table 1
Protocol measurements for indicators selected in the study

Soil parameters	Unit	Method	Reference
Texture (Clay, Silt and Sand)	%	hydrometer method	Bouyoucos (1951)
Dispersion ratio (DR)	%	DR= (a/b)* 100	Lal & Elliot (1994)
Aggregate stability (AS)	%	Wet sieving	Lal & Elliot (1994)
Bulk density (Db)	$g.cm^{-3}$	Gravimetric	Blake (1965)
Feld Capacity (FC)	%	1 kPa with tension tables	Tinslesy (1967)
Wilting point (WP)	%	1500 kPa with tension tables	Tinslesy (1967)
Hydrualic Conductivity (Ks)	$cm.h^{-1}$	Permeameter	Jackson (1972)
pH		Saturated soil	Soil Survey Laboratory (1992)
Electrical conductivity (EC)	µS/cm	Saturated soil	Soil Survey Laboratory (1992)
Organic matter (OM)	%	Walkley-Black wet digestion)	Nelson & Sommers (1982
Lime ($CaCO_3$)	%	Scheibler calcimeter	Soil Survey Staff (1993)
Cation exchange capacity (CEC)	%	Ammonium acetate	Lavkulich (1981)
Total N	%	Kjeldahl	Bremner & Mulvaney (1982)
Avaliable Phosporus (NaHCO3-P)	$mg\ kg^{-1}$	Sodium cicarbonate extraction	Olsen et al., (1954)
Exchange cations (K, Ca, Mg)	$mg\ kg^{-1}$	Ammonium acetate extraction	Lavkulich (1981)
Ex Sulphur (S)	$mg\ kg^{-1}$	Monocalcium phosphate	Jones (2001)

Analysis results of soil properties selected as indicators in this study were scored between 0 and 1 using the standard scoring function (SSF) (Andrews et al., 2002). Thus, the differences between units are normalized. Soil properties (excluding pH) used as an indicator are divided into two indicators "more is better (MB)" or "Low is better (LB)," taking soil conservation practices (Liebig et al. 2001) into consideration. The pH analysis results were scored as "1" in the 6.5–7.5 (neutral) range. Values with pH less than 6.5 and more significant than 7.5 were scored in a linearly decreasing direction. The indicators to which they are assigned and the standard scoring functions with which they are calculated are given in Table 2.

Table 2 Standard scoring functions (SSF) and parameters for soil indicators

Parametres	*FT**	*L*	*U*	*SSF Equation***
DR	LB	0,870	18,720	$f\,(x) = \begin{cases} 0.1 & x \le L \\ 1 - 0.9\ \times \dfrac{x-L}{U-L} + 0.1 & L \le x \le U \\ 1 & x \ge U \end{cases}$
Db	LB	1,17	1,62	
S	LB	18,6	81,5	
Si	LB	8	64	
EC	LB	41	1600	
$CaCO_3$	MB	0,1	35,34	$f\,(x) = \begin{cases} 0.1 & x \le L \\ 0.9\ \times \dfrac{x-L}{U-L} + 0.1 & L \le x \le U \\ 1 & x \ge U \end{cases}$
Clay	MB	6,8	33,4	
FC	MB	17,37	39	
WP	MB	9,2	22,7	
Ks	MB	0,366	8,012	
AS	MB	2,3	90,9	
OM	MB	0,1	11,76	
Av.P	MB	0	45,77	
TN	MB	0,02	0,29	
Ex Ca	MB	10,6	511,7	
Ex.K	MB	2,3	317,1	
Ex Mg	MB	0,5	287,1	
Ex.S	MB	0	171,2	
KDK	MB	21,26	85,6	
pH	Log	6,23	8,66	$pH<7.5;\ 0.1<x<1$ pH 6.5 – 7.5; x = 1 $pH>7.5;\ 0.1<x<1$

MB means more is better; LB, means low is better; Log, means logical; in SSF two equations, x is the monitoring value of the indicator, f(x) is the score of indicators ranged between 0.1 and 1, and L and U are the lower and the upper threshold value, respectively

2.3. Weighting of soil quality indicators using Analytical Hierarchy Process (AHP)

All indicators used in the study were scored using the SSF in Table 2. The obtained values were then weighted with the Analytical Hierarchy Process (AHP) (Jiuquan et al., 2015). Due to its ability to handle heterogeneous factors at the multi-criteria decision level, AHP makes it possible to evaluate the contribution of specific criteria at lower levels to higher-level criteria (Dengiz et al., 2018). Accordingly, 20 soil quality indicators grouped under three criteria (physical, chemical, nutrient element) were logically designed as A, B, and C matrices for AHP (Fig. 4). To assign the weights of the criteria used in the study, the Analytical Hierarchy Process, according to Saaty (1980), was adopted due to its ability to handle heterogeneous factors at the multi-criteria decision level (Jiuquan et al. 2015). The hierarchical structure makes it possible to evaluate the contribution of specific criteria at lower levels to higher-level standards. However, AHP weighting uses a pairwise comparison matrix rather than directly considering expert opinions. In the study, indicator weights (Wi) were determined by evaluating the two criteria against each other and giving values between 9 and 1/9 from the scale, as defined by Saaty (1980). The scale values used in pairwise comparison in AHP weighting are shown in Table 3.

Table 3
The comparison scale in AHP

Numerical value	Description
1	Equal importance to element 1 and 2
3	Moderate importance of element 1 over element 2
5	Strong importance of element 1 over element 2
7	Very strong importance of element 1 over element 2
9	The extreme importance of element 1 over element 2
2,4,6,8	Intermediate values

A square matrix was constructed from pairwise comparisons of the normalized and weighted indicators. These are the weights obtained for the criteria based on our pairwise comparison. The weights obtained were based on the main eigenvector of the decision matrix. Then the matrix consistency was evaluated. Then, the consistency index (CI) was estimated with the help of the following formula (1).

$$CI = (\gamma_{max} - \mathrm{n})/(\mathrm{n} - 1)$$

1

Where; CI, means the consistency index; λmax, represents the highest principal eigenvalue of the matrix, and *n* indicates the order of the matrix. The consistency ratio was then calculated (2):

$$CR = CI/RI$$

2

Where; CR is the consistency ratio, and RI means the random index (the details were given in Saaty, 1980). The matrix is considered consistent if the CR value is 0.1 or less due to the calculation. After all, indicators were scored and weighted, soil quality indices were estimated for each soil sample using the formula (3) below. (Doran & Parkin, 1994);

$$SQI = \sum_{i=1}^{n} (W_i \mathrm{x} X_i)$$

3

Here, *SQIw* is the soil quality index for the study area; *Wi* is the weighting of indicator *i*, *Xi* is the score of indicator *i* obtained by SSF, and n is the number of indicators.

The soil quality index values calculated in the study were recorded in the ArcMap program and the SQI distribution map of the study area was obtained. SQI results are categorized into five classes according to the equal interval method. Thus, according to the calculated results, Çapakçur microcatchment was classified from 1 to 5.

2.4. Estimation of soil losses

The amount of soil lost from the Çapakçur microcatchment was determined using the RUSLE method. The RUSLE model is expressed by the following Eq. (4) (Renard et al., 1997);

$$A = RxKxLSxCxP$$

4

where:

A – average soil erosion per surface unit (t/ha•year). R is the precipitation factor, and it was calculated as stated in Wischmeier & Smith (1965) using the multi-year data of the Bingöl Meteorological Station. K is the soil erosion factor, and it was calculated as stated in Wischmeier & Smith (1965) using the soil properties of the study area. LS is the slope length and degree factor and was calculated as Moore & Burch (1985) described using the "flow direction" function of ArcGIS Pro software. It is the vegetation cover and crop management factor (C-factor) and was determined according to the procedure of Panagos et al. (2015). The P factor is determined by whether there is a study on erosion control and prevention, and it was determined as described by Demir et al. (2022).

2.5. Statistical Analysis

The descriptive statistical calculations and correlation analyses were calculated using the SPSS 18 package program.

3. Results And Discussion

3.1. General Soil Properties

Descriptive statistical values of soils in the study area are given in Table 4. In the table, the minimum values of some soil parameters (OM, CaCO3, etc.) are zero (0). The high level of soil loss that occurred in some regions in the Çapakçur microcatchment had a negative impact on soil fertility at these points. Çapakçur microcatchment is a region where different geographical structures (elevation, aspect, slope, etc.) show high variation (Demir & Mirici, 2020). Accordingly, a high level of variability was detected in dynamic soil properties. The lowest variation (%Cv) was found in pH, and the highest variation in CaCo3 content. According to Table 4, the soil's bulk density, PH, Ca, Ks, AS, and DR properties showed normal distribution. The results of other soil parameters showed a non-symmetrical distribution called skewness. In the grain size distribution of the soils, clay varied between 6.8% and 33.4%, silt between 8% and 64%, and sand between 18.6% and 81.5%. Land use status and geographical factors are effective on soil grain size distribution. Soil losses, primarily due to erosion, have the potential to change the grain size distribution (Qi et al., 2018). Changes in soil grain distribution are closely related to many soil properties. Soil fertility parameters such as soil water permeability, plant nutrient content, and biological activity are affected by grain size distribution (Kroetsch & Wang, 2008; Hu et al., 2011; Li et al., 2021). The pH varied between 6.23 and 6.66, EC between 41.0 and 1600.0 µS/cm, lime ($CaCO_3$) between 0% and 35.34%, and OM between 0.0% and 11.766% in the soils of the study area. These features directly or indirectly affect the soil's structural stability and direct the erosion severity positively or negatively. As OM and $CaCO_3$ increase soil structure stability, they reduce the severity of erosion (Guerra, 1994; Hassan, 2012; Kabelka et al., 2019; Demir, 2020). However, some physical properties of soils also affect the erosion process. Because the deterioration of the physical properties of the soil is manifested by interrelated infiltration, crusting, soil compaction, poor drainage, inhibited root growth, excessive runoff, and accelerated erosion (Lujan, 2006). Here, FC and WP amounts, which are closely related to many soil properties, especially soil stability, Ks value, which is an indicator of water transmission in the soil, and Db, which is connected to soil compaction, are essential soil properties that affect the severity of erosion in the Çapakçur microcatchment. Table 4 shows these soil properties had a wide variation.

Table 4
Descriptive statistical analysis of physical and chemical properties of soil samples

Statistic	n	Min	Max	Mean	Variance	SD	CV	Skewness	Kurtosis
Clay (%)	428	6,800	33,400	14,239	22,942	4,790	33,638	1,261	1,757
Silt (%)	428	8,000	64,000	19,242	44,076	6,639	34,502	0,925	3,640
Sand (%)	428	18,600	81,500	66,545	75,108	8,666	13,023	-0,785	1,909
Db (%)	428	1,170	1,620	1,348	0,008	0,088	6,559	0,428	-0,372
pH	428	6,230	8,660	7,495	0,225	0,475	6,333	-0,043	-0,247
EC (µS/cm)	428	41,000	1600,000	261,272	27601,088	166,136	63,587	1,817	9,775
$CaCO_3$ (%)	428	0,000	35,340	3,200	36,645	6,054	189,170	3,012	8,556
OM (%)	428	0,000	11,766	2,364	5,073	2,252	95,282	2,025	4,055
N (%)	428	0,015	0,292	0,102	0,002	0,046	45,691	0,660	0,715
Av.P (mg kg^{-1})	428	0,000	45,770	6,764	48,535	6,967	102,998	2,485	7,944
Ex.K (mg kg^{-1})	428	2,600	317,100	31,948	848,887	29,136	91,197	4,532	33,997
Ca (mg kg^{-1})	428	10,600	511,700	220,319	8666,959	93,097	42,255	0,491	-0,250
Mg (mg kg^{-1})	428	0,500	287,100	29,185	804,461	28,363	97,184	4,044	27,650
S (mg kg^{-1})	428	0,000	171,220	20,133	321,096	17,919	89,005	5,376	34,000
CEC (%)	428	21,265	85,610	39,077	84,616	9,199	23,540	1,003	2,229
FC (%)	428	17,376	39,000	25,810	31,479	5,611	21,738	0,517	-0,842
WP (%)	428	9,200	22,702	13,112	5,196	2,280	17,385	1,112	1,287
Ks (cm/h)	428	0,366	8,012	4,233	3,347	1,829	43,217	-0,059	-0,611
AS (%)	428	2,300	90,900	40,089	343,968	18,546	46,262	0,201	-0,564
DR (%)	428	0,870	18,720	8,657	19,787	4,448	51,385	0,302	-0,819

3.2. Calculation of Soil Quality Index for Çapakçur microcatchment

Indicator parameters used to determine the soil quality index (SQI) in the Çapakçur microcatchment were weighted with AHP. The contributions of these indicators are given in Table 5. The highest value of 0.6923 was in soil physical properties (hierarchy B1). Soil chemical properties (B2) and plant nutrients (B3) were determined to be 0.2308 and 0.0769, respectively. However, the highest indicator values for each hierarchy B1, B2, and B3, were calculated as AS (0.2927), OM (0.5851), and TN (0.4061), respectively.

Table 5
Contribution weight of soil indicators to soil quality calculated by the AHP (Consistency ratio was determined below the highest value at which the weighting could be called consistent, which is 0.1.)

Hiyerarcy A				
Hiyerarcy C	**Hiyerarcy B**			**Combined weight (∑ Bi x Ci)**
	B1	**B2**	**B3**	
0,6923	0,2308	0,0769		
Clay (%)	0,1277			**0,0884**
Silt (%)	0,0420			**0,0291**
Sand (%)	0,0455			**0,0315**
Db (%)	0,0550			**0,0381**
FC (%)	0,0641			**0,0444**
WP (%)	0,0529			**0,0366**
Ks (cm/h)	0,1284			**0,0889**
AS (%)	0,2927			**0,2026**
DR (%)	0,1916			**0,1326**
pH (Sat.)		0,0778		**0,0180**
EC /µS/cm)		0,0543		**0,0125**
$CaCO_3$ (%)		0,2211		**0,0510**
OM (%)		0,5851		**0,1350**
CEC (%)		0,0617		**0,0142**
N (%)			0,4061	**0,0312**
P (mg kg^{-1})			0,2567	**0,0197**
K (mg kg^{-1})			0,1482	**0,0114**
Ca (mg kg^{-1})			0,0800	**0,0062**
Mg (mg kg^{-1})			0,0587	**0,0045**
S (mg kg^{-1})			0,0503	**0,0039**
Total	**1**	**1**	**1**	**1**

Today, many methods such as ICONA, CORINE, LEAM, LUCC, RUSLE, RIVM, GLASOD, INRA, and PESERA are used to estimate soil losses. These methods generally estimate the amount of soil transported from a particular area and predict the degradation that will occur due to erosion (Lal, 1994; Salumbo, 2020). Besides topographic factors, soil physical properties are used as inputs in these methods. The most critical indicator in the deterioration of the structural structure of soils is the physical properties of those soils. Among these features, AS, particle size distribution, and infiltration rate are more prominent. In the weighting (∑ Bi x Ci) made with AHP in the soil physical properties discussed in the present study, the highest value was determined to be AS (0.2026). Aggregation and structural stability in the soil appear as two important features that affect the fertility potential of soils (Yılmaz et al., 2005). Also, the high amount of water-resistant aggregates prevents soil erosion, which is one of the main factors in soil degradation (Dinel et al., 1991). In the weighting (∑ Bi x Ci) made with AHP in the soil chemical properties discussed in the present study, the highest value was found to be OM (0,1350). Chemical properties of the soil play an important role in erosion due to their effects on aggregation and structural stability. However, unsuitable chemical properties can accelerate dispersion and reduce infiltration (Norton et al., 2018). In well-developed deep, fertile soil, the effects of erosion are minimal (Lal et al., 2018). Therefore, it is vital to know and monitor the chemical properties of soils in areas with high erosion risk in terms of soil management practices. The highest value was TN (0.0312) in the weighting (∑ Bi x Ci) made with AHP in the soil macronutrient properties discussed in the present study. The plant nutrient content of soils is an important criterion for soil quality and fertility. These elements are necessary for soil biological activity and for plants to sustain their life cycles (Donahue et al., 1990; Osman, 2013). However, these elements can be easily washed away from the soil by water erosion (Bertol et al., 2003; Zhang et al., 2004; Meena et al., 2017).

The SQI values calculated for the Çapakçur microcatchment and the classes corresponding to these value ranges are given in Table 6. The lowest SQI was 0.3556, whereas the highest SQI was 0.7628 in the Çapakçur microcatchment. The highest SQI value was obtained at soil sampling point 259, whereas the lowest SQI value was obtained at soil sampling point 242. Accordingly, Class-2 soils occupy the most space in the microcatchment with 4196.563 Ha (39.49%). These lands are described as "weak lands." On the other hand, at least Class-5 soils occupy 148.7766 Ha (1.4%) in the microcatchment. These soils are also described as “The most suitable soils” (Fig. 5).

Table 6
Spatial and proportional distribution of soil quality index classes in Çapakçur microcatchment

SQI Class	SQI Value Range		(%)	Area (Ha)	Definition
1	0,3556	0,4371	14,25	1514,333	Poor
2	0,4372	0,5185	39,49	4196,563	Weak
3	0,5186	0,5999	32,01	3401,671	Moderate
4	0,6000	0,6814	12,85	1365,557	Suitable
5	0,6815	0,7628	1,4	148,7766	The most suitable
Total			100	10626,9	

At points 259 and 242, where the highest and lowest SQI values were calculated, it was determined that the direction was north and southeast, the slope was 58% and 88.4%, and the elevation was 1777 m and 1720 m. The AS, OM, and TN features with the highest scores in AHP weighting were compared. Soil samples 259 and 242 had AS values of 61.8% and 10.8%, OM values of 11.31% and 0.39%, and TN values of 0.11% and 0.03%, respectively. There are significant quality differences between these two soils. The annual amount of soil loss due to erosion in the Çapakçur microcatchment was calculated (Fig. 6).

The total yearly amount of soil lost from the microcatchment was calculated as 96 915.20 tons, and the average annual amount of soil lost from the unit area was 10.14 tons.ha^{-1}. According to the soil loss distribution map in

Fig. 6, it is seen that the resulting soil loss is more than 5–12 $tons.ha^{-1}.yr^{-1}$ of the soil loss at the soil sampling point 259 (SQI: 0.7628), more than 60 $tons.ha^{-1}.yr^{-1}$at the soil sampling point no 242 (SQI: 0.3556). Therefore, it can be mentioned that there is a negative relationship between SQI and the amount of soil lost per unit area. In the correlation between SQI and soil erodibility (K factor), it was found that there was a significant negative ($P < 0.05$) relationship between the two variable groups (Fig. 7).

Soil conservation measures used by Agricultural and Environmental experts and public and private organizations are tightly linked to soil quality management. In other words, implementing soil conservation practices also aim to improve soil quality indicators (Friedman et al., 2001). Soil quality can affect the rate of soil erosion and vice versa, and soil erosion can affect soil quality (Sing & Khera, 2009). Today, numerous methods are used to estimate soil erosion. In the use of these methods, the physical properties of the soils and the topographic and meteorological factors of the region are used as inputs (Morgan, 2009; Loughran, 1989; Batista et al., 2019; Nearing et al., 2017). However, these inputs alone may not be sufficient in erosion control, soil protection, and management studies. Soil properties such as soil pH, salinity, organic carbon, and nutrient content are essential for sustainable management practices. It is necessary to protect and improve these soil quality parameters in soil management practices (Bhat et al., 2019; Demir, 2020). Masoodi et al., (2017) reported that some chemical properties of soils, such as salinity, can be used as primary indicators for maintaining soil quality in erosion sites. However, many studies have shown that soil properties such as SOC and salinity are important parameters that affect structural stability (Whitbread, 1995; Shepherd et al., 2002; Tang et al., 2020; Göçük & Demir, 2021). Therefore, considering SQI in erosion control and soil protection studies in areas with high erosion risk will increase the chances of success. However, SQI helps assess the soil quality of a particular site or ecosystem and enables comparisons between areas under different land uses and management practices (Gelaw et al., 2015). Nosrati & Collins (2019) reported that the soil quality index could be used to evaluate the degradation under land use and soil erosion categories.

The use of soil quality indices based on knowledge-based decision support systems (AHP) in evaluating and managing degraded soils, such as erosion, soil compaction, salinity, and infertility, is vital for sustainable management (De La Rosa, 2019). Göl & Yel (2016) reported that there are significant relationships between the physical, chemical, and morphological properties of soils and the morphological properties of seedlings. The suitability of the soil's physical, chemical, and nutritional element properties is closely related to the seeds' germination and the seedlings' excellent development. In such a case, the soil quality index has an important role (Ürgenç & Çepel, 2001). Of the Çapakçur microcatchment, 53.74% of the area has Weak (class 2) and poor (class 2) SQI. Soils in these areas are inadequate in terms of physical and chemical properties and nutrient content. Special soil management practices are needed here.

4. Conclusion

The information on the measurable properties of soils in erosion control and soil conservation studies facilitates the planning of best management practices. Reducing the obtained multiple and complex soil quality parameters (SQI) to a single evaluable parameter can increase the success of watershed rehabilitation applications. In this study, the soil quality index of a watershed with high erosion risk was determined and mapped by using 20 criteria consisting of physical, chemical, and nutrient content properties of soils. Thus, it will be possible to plan rehabilitation works by using both the erosion risk degree and soil quality index of an area. In line with the planning, it can be decided based on more realistic data which areas to afforestation, terracing, grazing, fencing, or mulching for soil protection and erosion prevention.

Declarations

Authors Contribution

Yasin DEMIR and Azize DOGAN DEMIR designed the work. Soil sampling and laboratory analyzes were carried out by Yasin DEMİR, Azize DOĞAN DEMİR and Alperen MERAL. Alaaddin YÜKSEL and Alperen MERAL mapped the analysis results. Yasin DEMİR and Azize DOĞAN DEMİR did the statistical analysis and calculations. All authors contributed equally to the evaluation of the results.

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Financial interests

The authors declare they have no financial interests.

Conflict of Interest Statement

All authors have no conflicts of interest.

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Figures

Figure 1

Study area location map

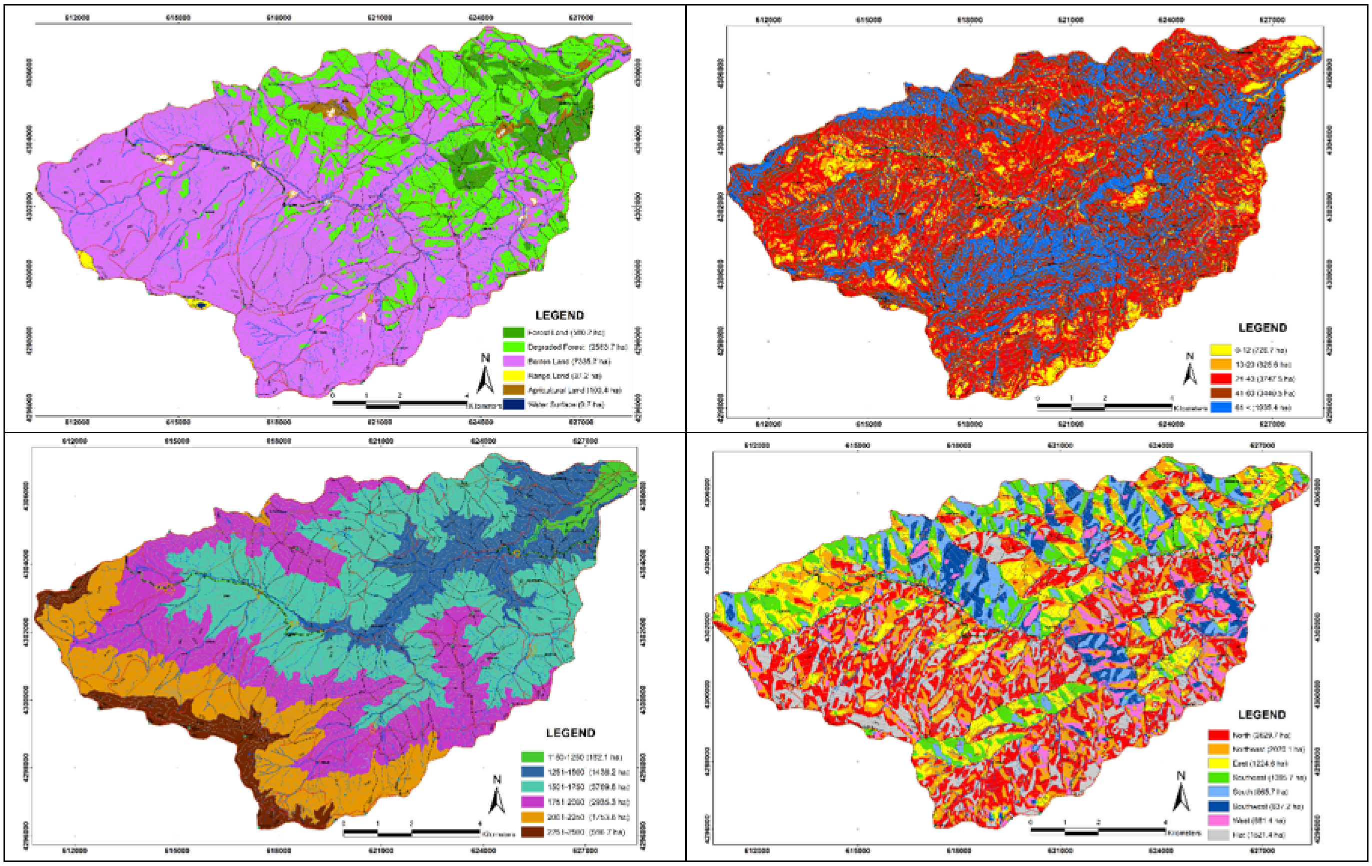

Figure 2

Land use, slope, elevation, and aspect maps of Çapakçur microcatchment

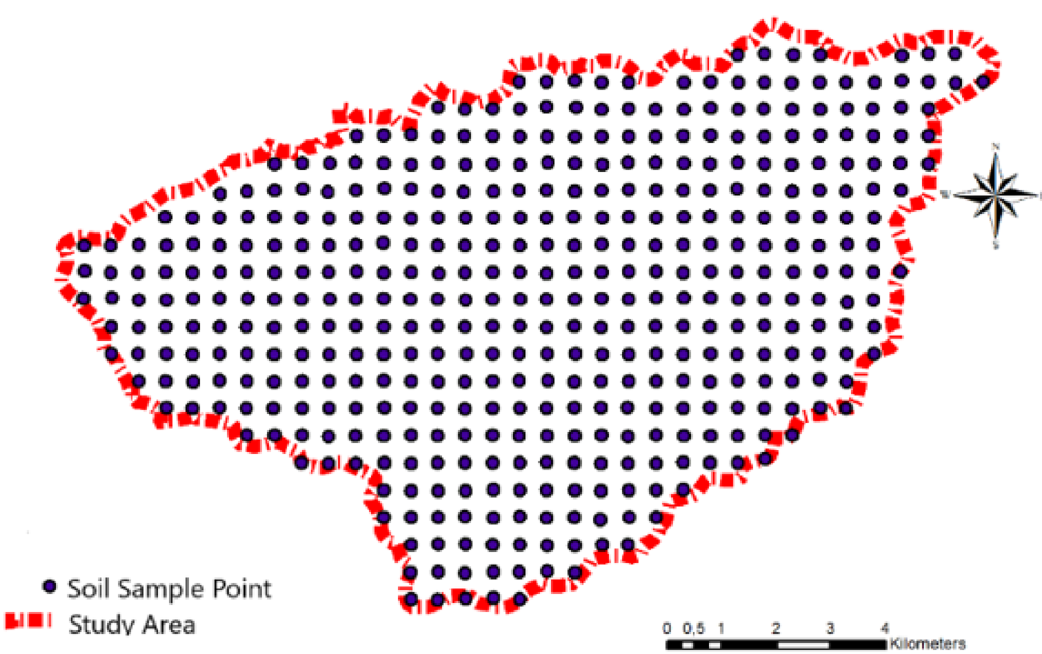

Figure 3

Soil sampling points in the study area

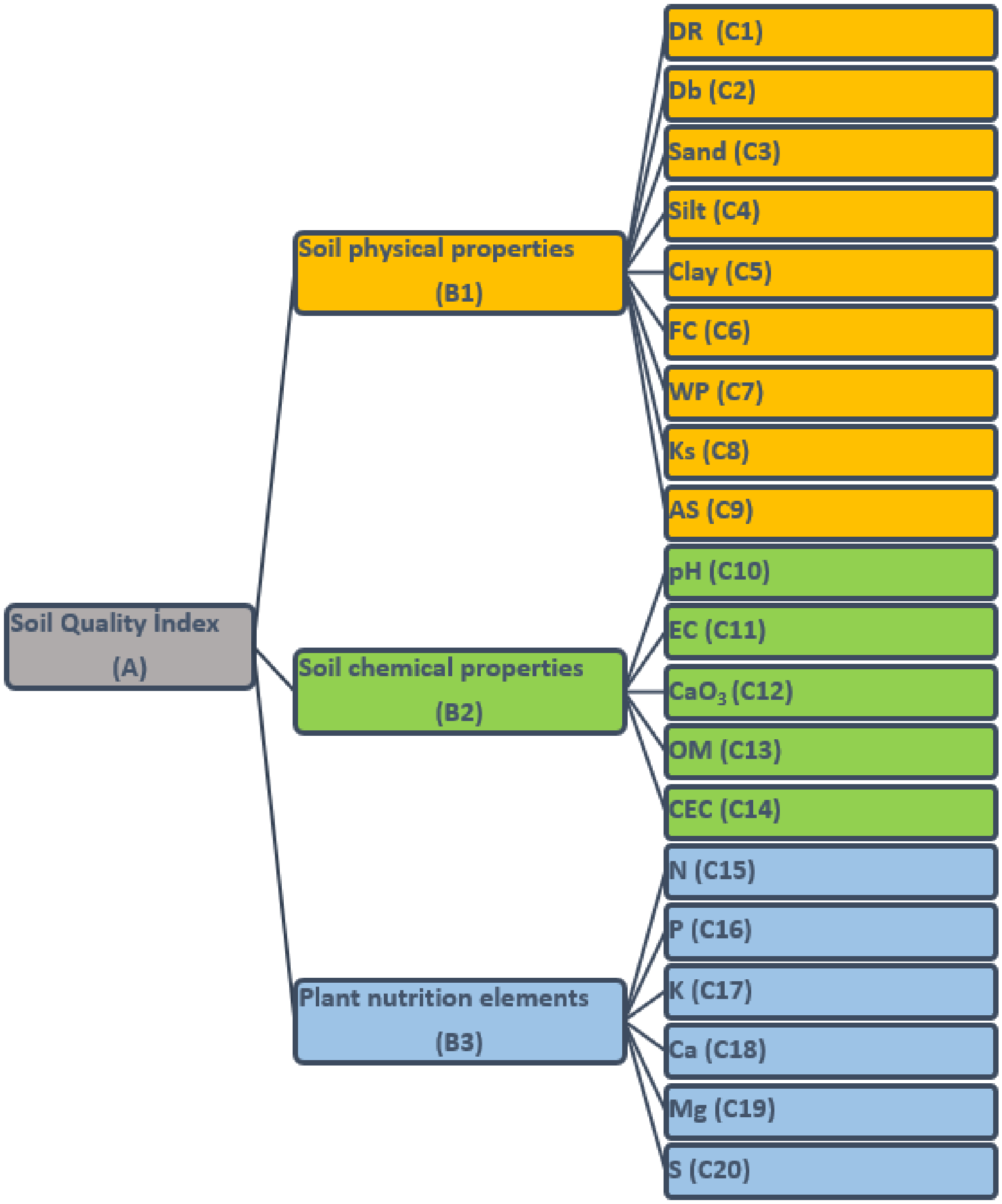

Figure 4

Hierarchical structure for the parameters’ weight assignments

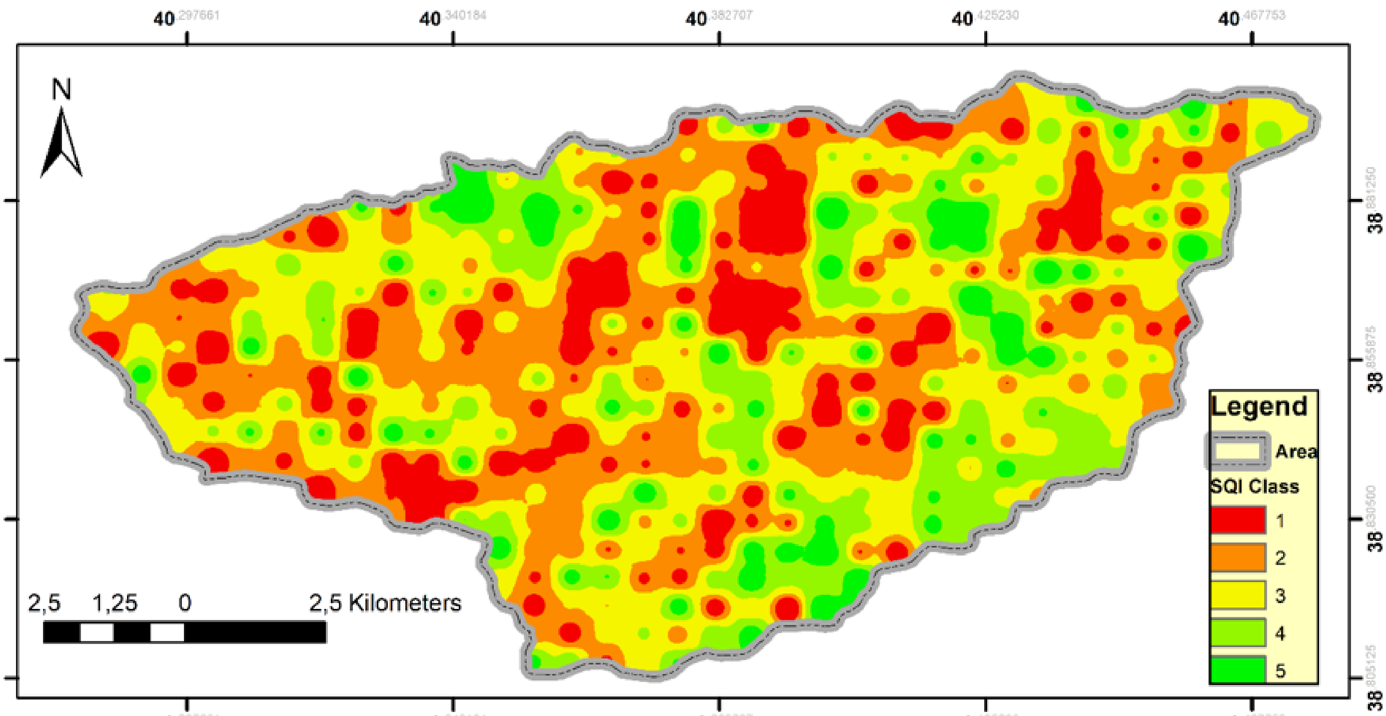

Figure 5

Çapakçur microcatchment soil quality index distribution map

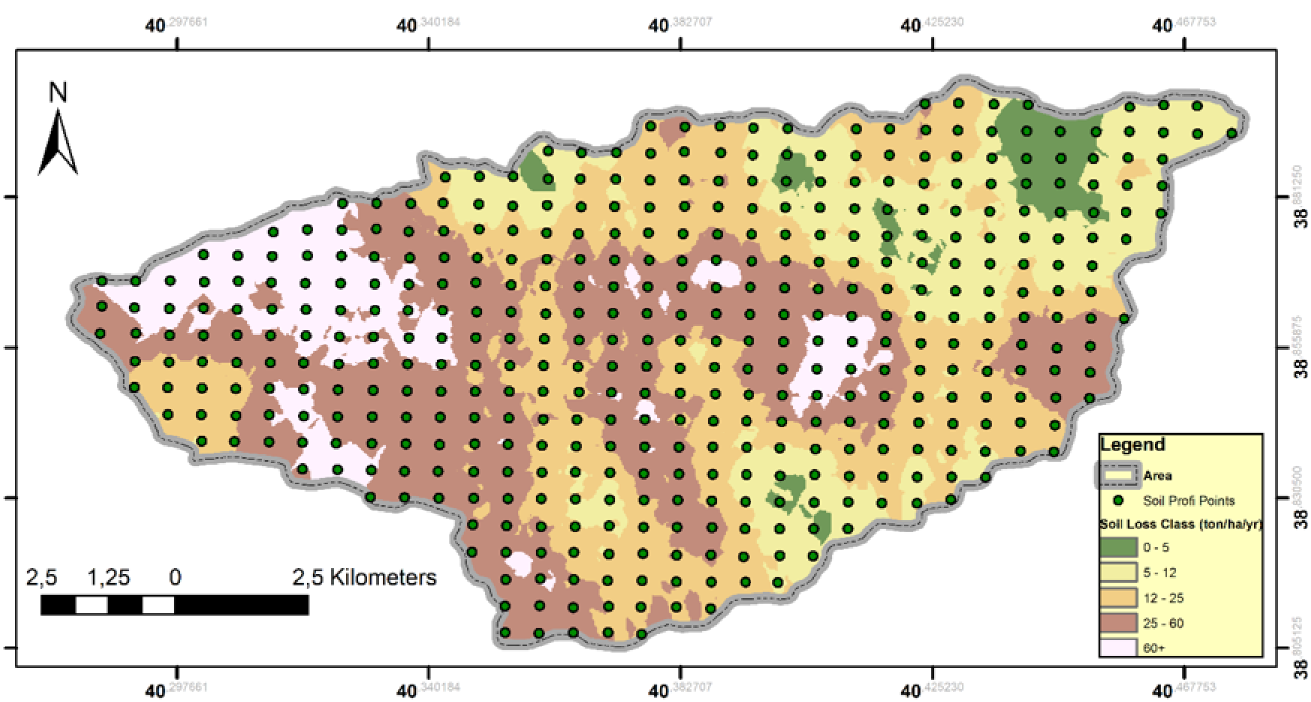

Figure 6

Erosion severity and soil loss map of Çapakçur watershed

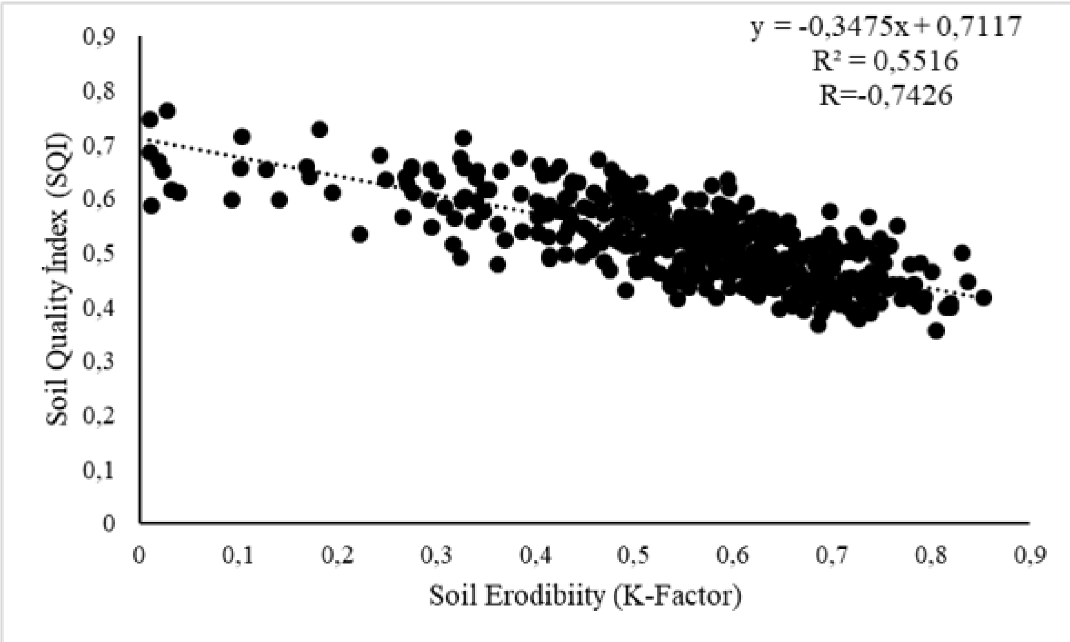

Figure 7

Correlation coefficients (R) between soil quality index and erodibility factor.