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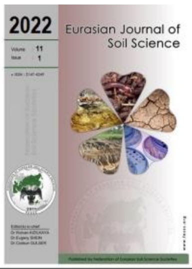

Estimation and spatial distribution of some soil erodibility parameters in soils of Ilgaz National Park

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Abstract

The aim of this research was to determine some erodibility factors, aggregate stability, structure stability and crust formation, in soils located at Ilgaz National Park and to generate their spatial distribution maps using fifteen different interpolation models in GIS medium. For this aim, total 151 soil samples were collected from surface (0-20 cm) soil depth. According to analysis results, it was determined that most part of the investigated soils has high erodibility value. In addition, correlation analysis was performed between erodibility factors and some soil physical and chemical properties. According to analysis results, it was found that a significantly positive relationship was found between AS and EC (0.460**) and OM (0.603**) at the 1% importance level whereas, a negative relationship was found between BD (-0.544**) at the 1% importance level. A positive relationship was also found between SSI values and EC (0.418**) and OM (0.565**) at a 1% significance level, and a negative relationship was found at a 1% significance level with BD (-0.542**). Moreover, a positive relationship was found between CF and EC (0.523**), OM (0.894**) and sand (0.345**) at a 1% importance level, and a negative relationship was found at a 1% importance level with clay (-0.376**) and BD (-0.811**).

Keywords: Aggregate stability, structure stability, crust formation, GIS, Ilgaz national park.

Introduction

Given its ecological differences, Turkey has favourable conditions for erosion, especially due to climate, topographic conditions, and land use pressures (Kanar and Dengiz, 2015). Erosion is generally defined as transport and accumulation of soil from where it is located by various factors such as water, wind and gravity. Although soil erosion is a natural event that occurs on the surface of the earth, it is accelerated as a result of human effects and can lead to serious environmental problems. As a result of erosion, problems such as decreased nutrient content in the soil, acidification of the soil, formation of poor drainage conditions, deterioration of water balance in the root zone, loss of soil productivity, accumulation of sediment in water channels, increased amounts of floods, contamination of water resources are caused (Singer and Warkentin, 1996; Li and Fang, 2016; Wang et al., 2017). From these negative effects of erosion, soil and water resources, which are our most important natural resources, need to be protected. Effective and sustainable use of these two important natural resources is very important both in terms of the continuity of the terrestrial ecosystem and in terms of food security, given the rapid increase in population (Saygın et al., 2019). Because of this, soil erosion studies are critical in creating successful land use and management planning and in developing appropriate conservation practices at different scales (Breetzke et al., 2013). It is well known that many factors influence the severity of soil erosion. These factors such as the characteristic and erosivity of rainfall, the degree and length of slope, vegetation cover and land management can be more effective than the natural properties of the soil. On the other hand, even if all these factors are the same, some soils are

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more easily eroded or sensitive for erosion. This difference, caused by the soil's own properties, is called soil erodibility (Wischmeier and Smith, 1978; Kanar and Dengiz, 2015). In this case, in order estimate soil loss and understand the functioning of soil erosion, it is necessary to evaluate soil erodibility. However, since soil erosion studies are often expensive and time-consuming, some soil characteristics that are closely related to erosion are identified and soil erodibility is estimated (Carlos and Odette, 2012; Stanchi et al., 2013).

Aggregate stability, one of the physical properties of the soil, is a measure of the ability of the soil to maintain its structure when the soil is under mechanical stress or subjected to destructive forces. Shi et al. (2010) noted that soil aggregate structure is an appropriate indicator of soil sensitivity to erosion, while Igwe and Obalum (2013) reported the importance of micro aggregate stability as an indicator of soil erodibility. After precipitation, a crust is formed on the surface following the breakdown of aggregates on the soil surface, and as a result, water infiltration into the soil decreases and surface flow occurs. Many studies have been carried out examining the relationship of crust formation with infiltration rate and erodibility of soils (Le Bissonnais, 1996; Issa et al., 2004; Darboux and Le Bissonnais, 2007). In addition, the crust formation is an indicator of the physical deterioration in the structure when the soil is wet, and a decrease in this ratio means an increase in resistance to erosion. In order to eliminate these adverse conditions, it is necessary to improve the physical properties of soils and increase their structural stability. For that reason, some studies are also conducted in which the relationship between the dispersion ratio and structural stability indexes of soils and their erodibility is evaluated (Mbagwu et al., 1999; Özdemir et al., 2005).

The aims of this study are to determine some erosion sensitivity parameters such as aggregate stability, structure stability index and crust formation of soils distributed within Ilgaz National Park area in Turkey and to map their spatial distributions using different interpolation methods using geographical information techniques.

Material and Methods

Ilgaz Mountain National Park is located in the Western Black Sea region of the Black Sea region of Turkey and within the borders of Kastamonu and Çankırı provinces. The study area is located between 558759 - 4548060 East longitudes and 563823-4544347 North latitudes (WGS84- Zone 36, UTM m) (Figure 1).

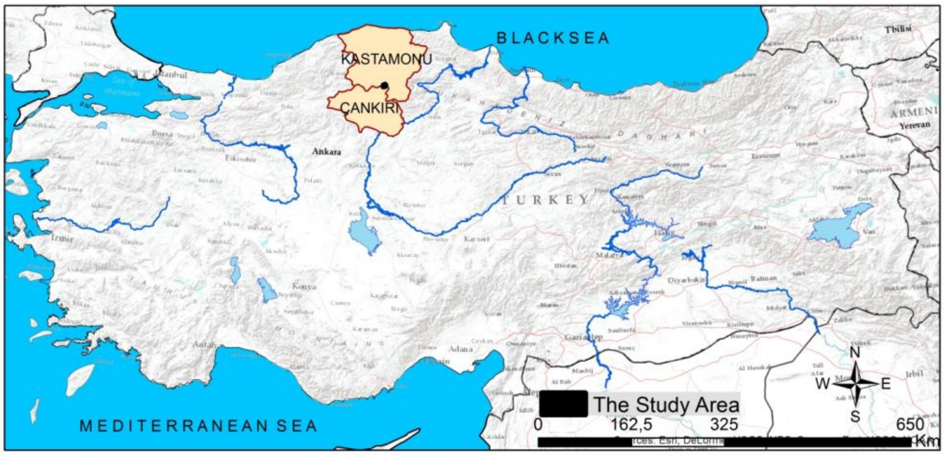

Figure 1. Location of the study area

The National park has an area of 1117.54 ha, 778.93 ha of the study area is within the borders of Kastamonu province, while 337.75 ha of the area is within the borders of Çankırı province. Kozançal Tepe (2070 m), Karakeçilik Tepe (1999 m), Hemdir Tepe (1931 m), Şadımın Tepe (1843 m), Haydarın Ridge and Arpasekisi Ridge are important hills and ridges within the borders of the National Park (Anonymous, 2009). The National Park has an undulating and mountainous topography and is located between 1519m and 2072m above sea level (Celilov and Dengiz, 2019) (Figure 2).

For long years (2009-2017) meteorological station located about 885m from sea level data was used in the Çankırı Ilgaz District in the research area. According to the Thorthwaite climate classification, it was coded as “B2C2sb2”; subhumid, microthermal climate, moderate water deficiency in summer, 2. decree shows marine characteristics. The average annual rainfall in the research area is 680.5 mm and the temperature is 5.1 ^{o}C. According to the Newhall simulation model (Van Wambeke, 2000), the soil moisture of the working area soils was classified as Udic and in the sub classification as Dry Tempudic. According to soil taxonomy (Soil Survey Staff, 1999), the majority of the study area soils are still at the beginning of pedological development and can be characterized as young because they do not have any sub-surface diagnostic horizons. Soils have formed on sloping land and have shallow depth. There are no diagnostic horizons except for a lithic contact within 50 cm depth under the surface of these soils. Soils are classified in the orthent suborder due to their location on hillside shallow depth and classified as Cryorthent great group due to soil temperature regime. In addition, they were classified as Lithic Cryorthent in subgroup level due to reaching bedrock at depths of 50 cm. The type of bedrock distributed within the study area is sandstone-mudstone, limestone in the north-eastern parts, while in the south-eastern parts there are mostly flints. In addition, in the cross-section located in the northeast-southwest direction of the study area, there are lime stones (Celilov and Dengiz, 2019).

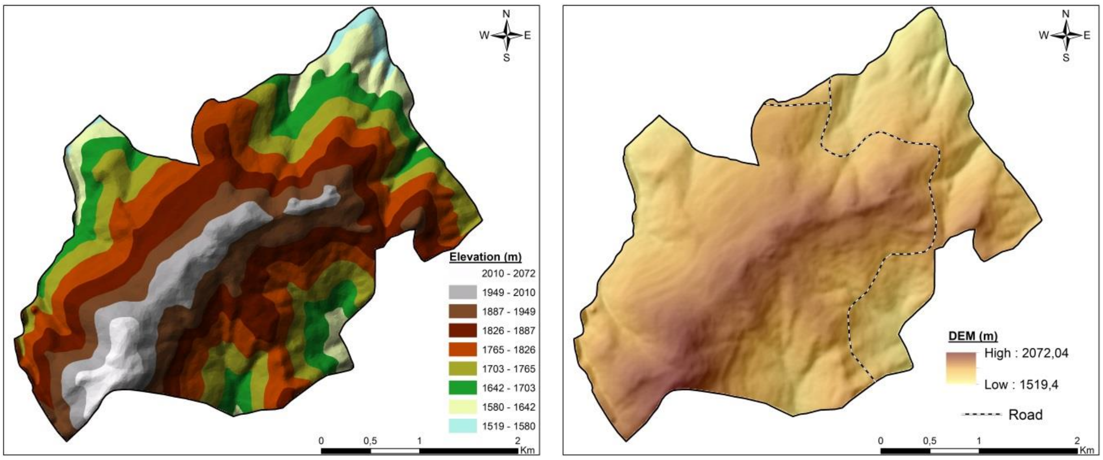

Figure 2. DEM and elevation maps of the study area

Soil sampling and analysis

A total of 151 soil samples were collected from a depth of 0-20 cm within the study area (Figure 3).

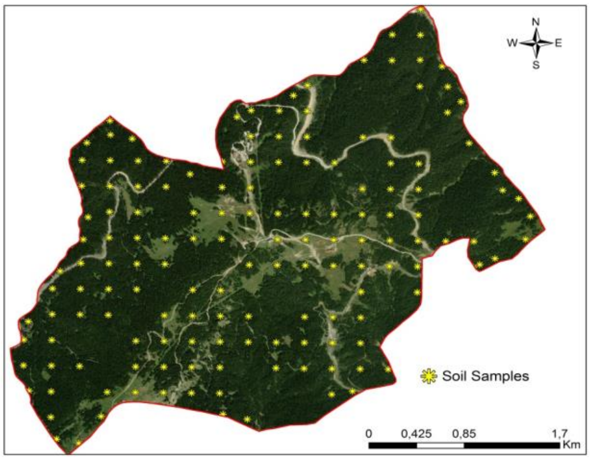

Figure 3. Soil samples patter of the study area

Collected soil samples brought from the field to the laboratory separated from stone and gravel after air dry and they were made ready for analysis by sieving with 2 mm sieve and some physical and chemical analyses were performed. Sand, silt and clay percentages of soils were determined by Bouyoucos hydrometer method (Bouyoucos, 1962), and bulk density was determined with the help of cylinders with a volume of 100 cm^3 in undisturbed soil samples. Hydraulic conductivity was measured using a hydraulic permeable set (Klute and Dirksen, 1986). The electrical conductivity (EC) and pH of soils were determined in 1:1 soil-water suspensions. Lime ($CaCO_3$) content was calculated with volumetric calcimeter method (Soil Survey Staff, 1992), and organic matter (OM) was calculated using the modified Walkley-Black method (Soil Survey Field and Laboratory Methods Manual, 2014).

Soil erodibility parameters

Aggregate Stability Index (ASI): Aggregate stability index was determined according to wet sieving method using Yoder type sieving set (Kemper and Rosenau, 1986).

$$\text{ASI (\%)} = \frac{(\text{Weight of soil} + \text{sand}) - (\text{Weight of sand})}{\text{weight of sample}} \times 100 \qquad (1)$$

Structural stability index (SSI): It was calculated by subtracting total silt + clay value measured in suspension without being dispersed from the total silt + clay value measured by mechanical analysis (Eq. 2). Soils with a SSI value less than 40% are considered susceptible to erosion. As the SSI values of soils increase, their erodibility decreases (Lal and Elliot, 1994).

$$SSI\ (\%) = \Sigma b - \Sigma a \quad (2)$$

Where; a: silt plus clay content measured in suspension with no calgon agent (%), b: silt plus clay content measured by mechanical analysis with calgon agent (%)

Crust Formation Index (CFI):

$$CFI = \text{Organic matter } (\%) \times 100 / \text{Clay } (\%) + \text{Silt } (\%) \quad (3)$$

Another important indicator of physical degradation of soils, the soil crust index, a state of sensitivity to crust formation, was determined by the following Formula (Eq. 3) (Pieri, 1989). It was given class of CFI in Table 1.

Table 1. Class of the Crust Formation Index

Class	Values	Description
1	CFI < 5	High physical degradation
2	5< CFI <7	Moderate physical degradation
3	7< CFI < 9	Low physical degradation
4	CFI > 9	No physical degradation

Interpolation analyses and descriptive statistic

In this study, different interpolation methods (Inverse Distance Weighing-IDW with the weights of 1, 2, 3 and radial basis function-RBF with thin plate spline (TPS), simple kriging (OK) with spherical, exponential and gaussian variograms, ordinary kriging (OK) with spherical, exponential and gaussian variograms, universal kriging (OK) with spherical, exponential and gaussian variograms) were applied for predicting the spatial distribution of soil quality index criteria with ArcGIS 10.2.2.

In the present study, root mean square error (RMSE) was used to assess and figure out the most suitable interpolation model. That's why, the lowest RMSE indicates the most accurate prediction. Estimates are determined by using the following formula (Eq. 4):

$$RMSE = \sqrt{\frac{\sum (z_{i^*} - z_i)^2}{n}} \quad (4)$$

where; RMSE: root mean square error, Z_i is the predicted value, Z_{i^*} is the observed value, and n is the number of observations. Descriptive statistics as minimum, maximum, mean, standard deviation, skewness, kurtosis coefficient and coefficients of variation of physico-chemical properties of surface soil samples were calculated.

Results and Discussion

Soil physico-chemical properties and correlation analysis

The sensitivity of soils to erosion is due to differences of their physical and chemical properties which affect soil erosion. In many studies conducted by some researchers, it has been reported that the texture, structure, hydraulic conductivity, organic matter content are the most important soil properties which affects soil erodibility (Imani et al., 2014; Yakupoğlu et al., 2017; Celilov and Dengiz, 2019). A total of 151 soil samples were taken at the research site. In these samples, twelve different physical and chemical properties were examined. The Normal distribution is a symmetric distribution. The degree of distortion of symmetry in the Normal distribution is called skewness. The distribution is called right (positive) skewness if it is long-tailed to the right and left (negative) skewness if it is long-tailed to the left. The degree of tapering or roundness of the normal distribution curve is called kurtosis (Yıldız et al., 1999; Saygın et al., 2019). Results of some descriptive statistics features of soils are given in Table 2. In Table 2, the skewness values of clay, silt, sand, BD, SSI and pH showed normal distribution, while other properties were determined to be far from normal distribution. ASI that is away from the Normal distribution has a negative (left) skewness, while other properties that showed non normal distribution are a positive (right) skewness.

Many researchers accept coefficient of variability as an important indicator to explain changes of soil properties and classify it as low (<15%), medium (15-35%) and high (>35%) according to the values it receives (Wilding, 1985; Mallants et al., 1996; Çelik and Dengiz, 2018; Aydın and Dengiz, 2019). In this case, clay, silt, sand, ASI, SSI and CFI have high variability in soil samples taken from the research area, OM and $CaCO_3$ have medium variability, and other soil characteristics have low variability. Similar results were obtained as a result of research conducted by Özyazici et al. (2016). According to the their study, it was reported that all physical and chemical soil properties except for (pH and silt content) have high variability, and the most variable soil property is $CaCO_3$. The amount of organic matter in soils varies between 0.37% and 21.42 %. According to the classification reported by Ülgen and Yurtsever (1995), it was determined that soils contain an amount of organic matter ranging from less to more. In addition, it was determined that the $CaCO_3$ content of soil samples taken from the research area had the highest coefficient of variability in chemical properties. It was determined that the lime content of soils ranged between 0.8% and 44.1 %. According to Ülgen and Yurtsever (1995) classification, soils are distributed between less calcareous and more calcareous in terms of their lime content. EC values of research soils vary between 0.047 and 0.118 dS m^{-1} and there is no any salinity problem in the study area while the pH values of soils range from 4.09 to 7.38 which can be called ranging from strong acid to slightly alkaline soil.

Table 2. Descriptive statistics of some erodibility factors and phsico-chemical properties of soil sample.

Criteria	Mean	SD	CV	Variance	Min.	Max.	Skewness	Kurtosis
Clay (%)	20,62	8,59	41,37	73,88	4,08	45,45	0,35	-0,09
Silt (%)	25,76	6,04	37,69	36,53	8,69	46,38	0,43	0,38
Sand (%)	53,33	12,28	64,81	150,82	14,59	79,40	-0,14	-0,34
pH	5,72	0,77	3,29	0,60	4,09	7,38	-0,07	-0,74
EC (dS/m)	0,27	0,18	1,14	0,03	0,05	1,19	1,60	3,71
$CaCO_3$ (%)	2,14	4,76	33,99	22,73	0,11	34,10	5,40	31,00
OM	6,04	3,35	21,05	11,26	0,37	21,42	1,06	2,32
BD	1,28	0,14	0,60	0,02	0,99	1,59	0,10	-1,00
HC	3,59	2,88	14,75	8,33	0,18	14,93	1,54	2,69
ASI	57,57	14,40	66,22	207,41	16,52	82,74	-0,61	-0,27
SSI	27,48	8,54	41,10	73,03	8,47	49,57	0,18	-0,34
CFI	13,55	7,95	35,50	63,30	1,48	36,98	1,01	0,79

OM: Organic matter, EC: Electrical Conductivity, HC: Hydraulic Conductivity, AS: Aggregate Stability, SSI: Structure stability index,, CF: Crust Formation, SD: standard deviation, CV: coefficient of variation, Min: Minimum, Max: Maximum

As for the changing in physical properties of soils, it was determined that sand, clay and silt content of soils of the study area varied between 14.59-79.40%, 4.08-45.45% and 8.69-46.38%, respectively. Texture classes of soil samples were generally determined as clay, clay loam, loam, loamy sand, sandy clay loam and sandy loam. Besides, bulk density values of soils range from 0.99-1.59 gr cm^{-3}. This high variation of bulk density resulted from textural changing and organic matter content. Finally, when looking at the changing of the soil erodibility factors which are ASI, SSI and CFI, it was found that values of ASI, SSI and CFI are 16.52-82.74%, 8.47-49.57% and 1.48-36.98%, respectively. Stanchi et al. (2015) stated that a relationship between soil erodibility and aggregation should therefore be expected. However, erosion may limit the development of soil structure; hence aggregates should not only be related to erodibility but also partially mirror soil erosion rates. Therefore, it can be said that the higher the aggregate ratio of soils, the more resistant the soil is to erosion.

Interpolation models and distribution maps of erosion sensitivity parameters

Determining the spatial changing pattern of any soil property using interpolation models allows to estimate the value of the studied soil property at any point in the study area with minimal errors. Thus, distribution maps obtained as a result of interpolation analysis of soil characteristics allow the most appropriate planning and management decisions related to land management to be taken and implemented for the study area (Arslan, 2014; Özyazıcı et al., 2015; Gülser et al., 2016; Alaboz et al., 2020). RMSE values of 15 interpolation models were obtained in order to create distribution maps of the selected soil erodibility parameters and their values have been given in Table 6. IDW-2 with the lowest RMSE value for SSI (7.9195) was determined as the most appropriate model in terms of distribution mapping, while IDW-1 model for ASI with a RMSE value (12.7548) was determined to be the most suitable model. In addition, the Gaussian model of simple Kriging with the lowest RMSE value (7.3754) for CFI has been determined to be the most appropriate model in terms of distribution map creation.

In planning for soil and water conservation, it is necessary to know the resistance of the soil to changing the structural continuity of the soil and its tendency to erosion. Many erosion sensitivity indices have been developed for this purpose. One of these erosion sensitivity indices is the aggregate stability index.

Aggregate distributions and stability measurements of soils are considered a quality indicator of soils (Six et al. 2000), as well as aggregate stability measurements are considered as an important indicator in determining the resistance of soil aggregates to environmental factors that cause degradation (Hillel, 1982). Aggregate stability values were found to be between 16.52% and 82.74% in soil samples taken from study area. The mean aggregate stability value of the research area was found 57.57 %. Furthermore, when the aggregate stability values of soil samples of the study area were examined, it was determined that almost half of soil samples had more than 60% aggregates stability value. Considering the frequency distribution and statistical information of values in the creation of distribution maps for aggregate and stock stability, it was evaluated in 10 (ASI) and 5 (SSI) classes using the Natural Breaks (Jenks) method by means of GIS. This methodologic approach is used in cases where data is not evenly distributed, there are large differences between values, and differences between classes should be given prominently. Aggregate stability distribution map was given in Figure 4. According to Figure 4, particularly centre and south west part of the study area has more than 56% aggregate stability values whereas aggregate stability values is increasing in south east part of the study area. The use of aggregate stability to estimate soil sensitivity to erosion has been proposed by various researchers (Le Bissonnais et al., 1989; Barthès and Roose, 2002; Stanchi et al. 2015). Kanar and Dengiz (2015) carried out a research to the determination of the relationship between land use/land cover and some erodibility indices in Madendere Watershed soils after taking from surface (0-20 cm) soil samples based on grit system. They reported that small part of the study area has less than 20% aggregate stability index value which was generally located on agriculture lands. On the other hand, the highest aggregate stability index value was determined under forest lands. Another of the erosion sensitivity parameters is the structure stability index of soils, and there is no limit value for this ratio. Structural stability index (SSI) by the sum of the difference between mechanical and aggregate analyses of silt plus clay fractions was introduced as a rapid technique for estimating structural stability of soils (Leo, 1963; Özdemir and Gülser, 2017). In general, as the SSI value decreases, the degree of erosion resistance of soils also decreases. When looking at the Figure 4, distribution map of the SSI pattern shows parallel trend with map of ASI. İmamoğlu and Dengiz (2020) performed a research to determination of relationship between situation of soil erosion sensitivity using SSI and land use/land cover in two adjacent micro catchments called Ilıcak and Kum Çay located in Gediz Basin soils. In this study, it was determined that the lowest SSI of the study area was found on agriculture lands whereas the highest SSI values located on the pasture and forest land in the Basin. As for crust formation, Öztürk and Özdemir (2006) stated that some practices to take under control the crusting, increase the seedling emergence, improve the aggregation, increase the resistance of soil aggregate, and control the erosion are these; soil organic matter management, use of soil surface covers, the application of amendments and improve the irrigation management. In addition, İmamoğlu et al. (2018) reported that crust layer formation is not only related to the structure, but also the dispersion rate and aggregate stability values of factors that accelerate erosion also affect crust formation. According to CFI class in Table 1, less than 5 and between 5 and 7 values of CFI mean highly and moderately physical degradation and this case was also found at the same areas which located on south-east part of the study area, when compared SSI and ASI maps. On the other hand, most part of the study area has low or no physical degradation.

Table 6. Cross validation according to different interpolation models

Interpolation Models	Semivariogram models		Soil erodibility parameters		
			SSI	ASI	CFI
Inverse Distance Weighing-IDW	IDW -1		7,9854	12,7548	7,4008
	IDW -2		7,9195	12,7648	7,5227
	IDW -3		8,0102	12,9599	7,7297
Radial Basis Function-RBF	TPS		9,1378	15,4610	9,2049
	CRS		7,9605	12,7989	7,5152
	SWT		7,9575	12,7752	7,4768
Kriging	Ordinary	Gaussian	7,9755	12,7915	7,3970
		Exponential	7,9305	12,8217	7,5114
		Spherical	8,0014	12,7920	7,4438
	Simple	Gaussian	8,0146	12,8227	7,3754
		Exponential	7,9853	12,8719	7,4911
		Spherical	7,9722	12,8299	7,4228
	Universal	Gaussian	7,9755	12,7915	7,3970
		Exponential	7,9305	12,8217	7,5114
		Spherical	8,0014	12,7920	7,4438

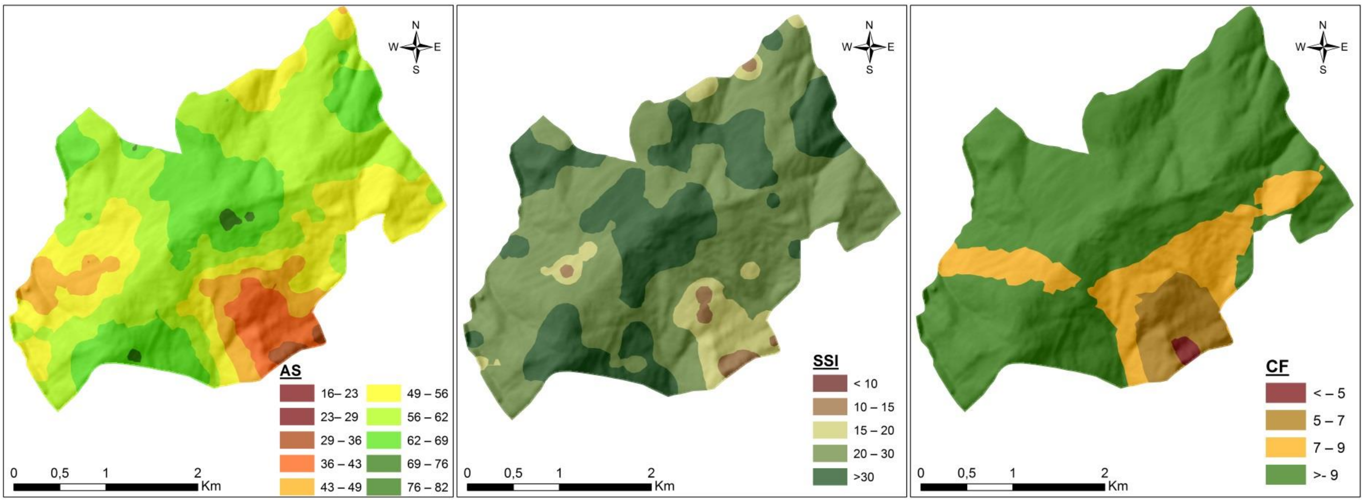

Figure 4. Distribution maps of the AS, SSI and CF in the study area

Correlation analysis between erosion sensitivity parameters and soil properties

Kolmogorov-Smirnov (K-S) test was applied to determine whether soil parameters showed normal distribution. As a result of the K-S test, it was found that not all parameters showed normal distribution. For this reason, Spearman correlation was applied to reveal the correlation relationship of the data. As a result of the study, 18 correlation pairs were found as statistically significant ($p<0.05$; $p<0.01$) and results were given in Table 7. A positive relationship was found between AS and EC (0.460**) and OM (0.603**) at the 1% importance level whereas, a negative relationship was found between BD (-0.544**) at the 1% importance level. There are many studies in the literature on this subject that show change in OM level due to change in land use (Chan, 2001; Neufeldt et al., 2002; Dengiz, 2007) and increasing soil erosion due to diminishing OM content (Celik, 2005; Cerda and Doerr, 2007; Yilmaz et al., 2008). On the other hand, effect of total OM on aggregation was defined in many studies, but in some cases, the origin of organic matter and dominant clay mineralogy rather than total quantity play a role in aggregation. A positive relationship was also found between SSI values and EC (0.418**) and OM (0.565**) at a 1% significance level, and a negative relationship was found at a 1% significance level with BD (-0.542**). Moreover, a positive relationship was found between CF and EC (0.523**), OM (0.894**) and sand (0.345**) at a 1% importance level, and a negative relationship was found at a 1% importance level with clay (-0.376**) and BD (-0.811**).

Table 7. Analysis results of correlation between erosion sensitivity parameters and some physical and chemical properties of soils

Soil parameters	Erodibility factors		
	ASI	SSI	CFI
pH	0,057	-0,015	-0,001
EC (dS/m)	0,460**	0,418**	0,523**
OM (%)	0,603**	0,565**	0,894**
$CaCO_3$ (%)	0,147	0,053	0,132
Clay (%)	0,144	0,121	-0,376**
Silt (%)	0,159	0,137	-0,146
Sand (%)	-0,139	-0,123	0,345**
BD (gr/cm^3)	-0,544**	-0,542**	-0,811**
HC mm/h	0,131	0,141	0,679**

*: p<0,05; **: p<0,01

Conclusion

In this present study, the determination of some erodability factors such as ASI, SSI and CFI of soils distributed within the Ilgaz National Park area and its relationship with some other soil properties were examined. In addition, the distribution maps of the sensitivity some factors were produced using different spatial distribution interpolation models. In this case, IDW-2, IDW-1 and Gaussian model of simple Kriging were determined the most semivariogram model for SSI, ASI and CFI, respectively. According to three erodobility factors, it was found that some south east part of the study area has sensitive for erosion risk and physical degradation. Therefore, this side of the study area should be taken some measurement to protect from soil erosion and physical degradation. In addition to being possible by taking measures to increase the scope of organic matter and hydraulic permeability of the soil and improve its structure, the vegetation on it is not destroyed.

References

Alaboz, P., Demir, S., Dengiz, O., 2020. Determination of spatial distribution of soil moisture constant using different interpolation model case study, Isparta Atabey Plain. *Journal of Tekirdag Agricultural Faculty* 17(3); 432- 444.

Anonymous, 2009. Ilgaz Dağı Milli Parkı Ölçekli Uzun Devreli Gelişme Planı. Çevre ve Orman Bakanlığı Doğa Koruma ve Milli Parklar Genel Müdürlüğü Milli Parklar Dairesi Başkanlığı. [in Turkish].

Arslan, H., 2014. Estimation of spatial distrubition of groundwater level and risky areas of seawater intrusion on the coastal region in Çarşamba Plain, Turkey, using different interpolation methods. *Environmental Monitoring and Assessment* 186(8): 5123-5134.

Aydın, A., Dengiz, O., 2019. Determination of some pysico-chemical properties of the soils formed under semihumid ecological condition and their classification and mapping in series level. *Toprak Su Dergisi* 8(2): 68-80. [in Turkish].

Barthès, B., Roose, E., 2002. Aggregate stability as an indicator of soil susceptibility to runoff and erosion; validation at several levels. *Catena* 47: 133-149.

Bouyoucos, G.J., 1962. Hydrometer method improved for making particle size analyses of soils. *Agronomy Journal* 54: 464-465.

Breetzke, G.D., Koomen, E., Critchley, W.R.S., 2013. GIS-assisted modelling of soil erosion in a South African catchment: Evaluating the USLE and SLEMSA approach. In: Water resources planning, development and management. Wurbs, R., (Ed.). InTech, Rijeka, Croatia. pp. 53–71.

Carlos, A.B., Odette, I.J., 2012. Soil erodibility mapping and its correlation with soil properties in Central Chile. *Geoderma* 189–190:116–123.

Celik, I., 2005. Land-use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. *Soil and Tillage Research 83*(2): 270-277.

Çelik, P., Dengiz, O. 2018. Determination of basic soil properties and nutrient element states of agricultural soils of Akselendi plain and formation of distribution maps. *Türkiye Tarımsal Araştırmalar Dergisi* 5: 9-18. [in Turkish].

Celilov, C., Dengiz, O., 2019. Determination of the spatial distribution for erodibility parameters using different interpolation methods: Ilgaz National Park Soils, Turkey. *Türkiye Tarımsal Araştırmalar Dergisi* 6(3): 242-256. [in Turkish].

Cerdà, A., Doerr, S.H., 2007. Soil wettability, runoff and erodibility of major dry-Mediterranean land use types on calcareous soils. *Hydrological Processes* 21(17) 2325-2336.

Chan, K.Y., 2001. Soil particulate organic carbon under different land use and management. *Soil Use and Management* 17(4): 217-221.

Darboux, F., Le Bissonnais, Y., 2007. Changes in structural stability with soil surface crusting: consequences for erodibility estimation. *European Journal of Soil Science* 58(5): 1107-1114.

Dengiz, O., 2007. Assessment of soil productivity and erosion status for the Ankara-Sogulca catchment using GIS. *International Journal of Soil Science* 2 (1): 15-28.

Gülser, C., Ekberli, I., Candemir, F., 2016. Spatial variability of soil physical properties in a cultivated field. *Eurasian Journal of Soil Science 5*(3): 192-200.

Hillel, D., 1982. Introduction to soil physics. Academic Press, New York, USA. 392p.

Igwe, C.A., Obalum, S. E., 2013. Microaggregate stability of tropical soils and its roles on soil erosion hazard prediction. In: Advances in Agrophysical Research, Grundas, S. (Ed.). InTech, Rijeka, Croatia. pp. 175-192.

İmamoğlu, A., Dengiz O. 2020. Determination of relationship between situation of soil erosion sensitivity indexes and land use/land cover in two adjacent micro catchments. *Toprak Bilimi ve Bitki Besleme Dergisi* 8(1): 53-60. [in Turkish].

İmamoğlu, A., Eraslan, S., Coşkun, A., Saygın, F., Dengiz, O., 2018. Soil crust formation depent on different soil characteristics. *Türk Coğrafya Dergisi* 71: 47-52. [in Turkish].

Imani, R., Ghasemien, H., Mirzavand, M., 2014. Determining and mapping soil erodibility factor (Case study: Yamchi watershed in Northwest of Iran). *Open Journal of Soil Science* 4(5): 168-173.

Issa, O.M.,, Cousin, I., Le Bissonnais, Y., Quétin, P., 2004. Dynamic evolution of the unsaturated hydraulic conductivity of a developing crust. *Earth Surface Processes and Landforms* 29(9): 1131–1142.

Kanar, E., Dengiz, O., 2015. Determination of potential soil erosion using two different parametric models and making of risk maps in Madendere Watershed. *Türkiye Tarımsal Araştırmalar Dergisi* 2(2): 123-134. [in Turkish].

Kemper, W.D., Rosenau, R.C., 1986. Aggregate stability and size distribution. In: Methods of soil analysis Part 1 Physical and mineralocigal methods. Klute, A. (Ed.). 2nd Ed., SSSA Book Series No: 5, ASA- SSSA, Madison, Wisconsin, USA. pp. 425-442.

Klute, A., Dirksen, C., 1986. Hydraulic conductivity and diffusivity: Laboratory methods. In: Methods of soil analysis Part 1 Physical and mineralocigal methods. Klute, A. (Ed.). 2nd Ed., SSSA Book Series No: 5, ASA- SSSA, Madison, Wisconsin, USA. pp. 687-734.

Lal, R., Elliot, W., 1994. Erodibility and erosivity. In: Soil erosion research methods. Lal, R., (Ed.). 2nd Edition, St. Lucie Press, Delray Beach, pp. 181-210.

Le Bissonnais, Y., 1996. Aggregate stability and assessment of soil crustability and erodibility: I. Theory and methodology. *European Journal of Soil Science* 47(4): 425–437.

Le Bissonnais, Y., Bruand, A., Jamagne, M., 1989. Laboratory experimental study of soil crusting: Relation between aggregate breakdown mechanisms and crust stucture. *Catena* 16(4-5): 377-392. doi:

Leo, W.M., 1963. A rapid method for estimating structural stability of soils. *Soil Science* 96: 342-346.

Li, Z.Y., Fang, H.Y., 2016. Impacts of climate change on water erosion: a review. *Earth-Science Reviews* 163: 94-117.

Mallants, D., Mohanty, B.P., Jacques, D., Feyen, J., 1996. Spatial variability of hydraulic properties in a multi-layered soil profile. *Soil Science* 161(3): 167-181.

Mbagwu, J.S.C., Auerswald, K., 1999. Relationship of percolation stability of soil aggregates to land use, selected properties, structural indices and simulated rainfall erosion. *Soil and Tillage Research* 50(3-4): 197-206.

Neufeldt, H., Resck, D.V., Ayarza, M.A., 2002. Texture and land-use effects on soil organic matter in Cerrado Oxisols, Central Brazil. *Geoderma* 107(3-4): 151-164.

Özdemir, N., Gülser, C., 2017. Clay activity index as an indicator of soil erodibility. *Eurasian Journal of Soil Science 6*(4): 307-311.

Özdemir, N., Gülser, C., Ekberli, İ., Özkaptan, S., 2005. Effects of soil conditioners on structural stability of an acid soil. *Atatürk Üniversitesi Ziraat Fakültesi Dergisi 36*(2): 151-156. [in Turkish].

Öztürk, E., Özdemir, N., 2006. Formation, types and preventing of crust in soils. *OMÜ Ziraat Fakültesi Dergisi* 21(2):275-282. [in Turkish].

Özyazıcı, M.A., Dengiz, O., Aydoğan, M., Bayraklı, B., Kesim, E., Urla, Ö., Yıldız, H., Ünal, E., 2016. Levels of basic fertility and the spatial distribution of agricultural soils in Central and Eastern Black Sea Region. *Anadolu Tarım Bilimleri Dergisi* 31(1): 136-148. [in Turkish].

Pieri, C., 1989. Fertilité des terres de savanes. Bilan de trente ans de recherche et de développement agricoles au Sud du Sahara. Montpellier : CIRAD-IRAT, Paris, France. 444 p. [in French].

Saygın, F., Dengiz, O., İç, S., İmamoğlu, A., 2019. Assessment of the relationship between some physico-chemical properties of soil and some erodibility parameters in micro basin scale. *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi 20*(1): 82-91. [in Turkish].

Shi, Z.H., Yan, F.L., Li, L., Li, Z.X., Cai, C.F., 2010. Interrill erosion from disturbed and undisturbed samples in relation to topsoil aggregate stability in red soils from subtropical China. *Catena* 81(3): 240–248.

Singer, M.J., Warkentin, B.P., 1996. Soils in an environmental context: an American perspective. *Catena* 27(3-4): 179-189.

Six, J., Elliott, E.T., Paustian, K., 2000. Soil structure and soil organic matter II. A Normalized stability index and the effect of mineralogy. *Soil Science Society of America Journal* 64(3): 1042-1049.

Soil Survey Field and Laboratory Methods Manual, 2014. Soil Survey Investigations Report No. 51 Version 2. USDA-NRCS. National Soil Survey Center, Kellog Soil Survey Laboratory. Available at [Access date: 12.03.2021]: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1244466.pdf

Soil Survey Staff, 1992. Procedures for collecting soil samples and methods of analysis for soil survey. Soil Survey Investigations Reports U.S. Govermentan Print Office, Washington D.C., USA.

Soil Survey Staff, 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd Edition. Agriculture Handbook Vol. 435. USDA, NRCS. US Government Printing Office, Washington DC, USA.

Stanchi, S., Falsone, G., Bonifacio, E., 2015. Soil aggregation, erodibility, and erosion rates in mountain soils (NW Alps, Italy). *Solid Earth* 6: 403–414, 2015.

Stanchi, S., Freppaz, M., Godone, D., Zanini, E., 2013. Assessing the susceptibility of alpine soils to erosion using soil physical and site indicators. *Soil Use and Management* 29(4): 586–596.

Ülgen, N., Yurtsever, N., 1995. Türkiye Gübre ve Gübreleme Rehberi (4. Baskı). T.C. Başbakanlık Köy Hizmetleri Genel Müdürlüğü Toprak ve Gübre Araştırma Enstitüsü Müdürlüğü Yayınları, Genel Yayın No: 209, Teknik Yayınlar No: T.66, Ankara. [in Turkish].

Van Wambeke, A.R., 2000. The Newhall Simulation Model for estimating soil moisture & temperature regimes. Department of Crop and Soil Sciences. Cornell University, Ithaca, New York, USA. Available at [Access date: 12.03.2021]: http://www.css.cornell.edu/faculty/dgr2/research/nsm/nsmt.pdf

Wang, H., Zhang, G.H., Liu, F., Geng, R., Wang, L.J., 2017. Effects of biological crust coverage on soil hydraulic properties for the Loess Plateau of China. *Hydrological Processes* 31(19): 3396-3406.

Wilding, L.P., 1985. Spatial variability: its documentation, accomodation and implication to soil surveys. In: Soil Spatial Variability Proceedings of a Workshop of the ISSS and the SSA, Las Vegas PUDOC, Wageningen. Nielsen, D.R., Bouma, J., (Eds.). 30 November-1 December 1984. pp. 166-187.

Wischmeier, W.H., Smith, D.D., 1978. Predicting rainfall erosion loses a guide to conservation planning. United States Department of Agronomy, Agriculture Handbook No:557, Washington, USA. 163p.

Yakupoğlu, T., Gundogan, R., Dindaroğlu, T., Kara, Z., 2017. Effects of land conversion from native shrub to pistachio orchard on soil erodibility in an arid region. *Environmental Monitoring and Assessment* 189: 588.

Yıldız, N., Akbulut, Ö., Bircan, H., 1999. İstatistiğe Giriş. Aktif Yayınevi, Erzurum. [in Turkish].

Yilmaz, M., Yilmaz, F., Karagul, R., Altun, L., 2008. Changes in erodibility indices and some soil properties according to parent materials and land use regimes in erfelek dam creek watershed (Sinop, Turkey). *Fresenius Environmental Bulletin* 17(12): 2083-2090.