

Impact of land cover types on soil aggregate stability and erodibility

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Received: 13 March 2018 / Accepted: 2 July 2018 / Published online: 16 August 2018
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Abstract Gökçeada is the biggest island, and it is also known as the organic island of Turkey. Approximately 65% of the Gökçeada lands have slope > 12%. Climate, topography, land cover, and soil characteristics are considered to be the main natural factors affecting soil erosion severity in the Gökçeada. Prevention of soil degradation, hence the preservation or improvement of the overall quality of the soil, is directly related to the presence of stable soil aggregates. In addition, the resistance to weathering and replacement of soil particles are also relevant aspects in terms of sustainability. Aggregate stability (AS) and erodibility of land (K_{fac}) are related to soil properties. However, this relationship can vary under different circumstances. In this study, 248 surface soil samples have been taken from forest and semi-natural areas (FSNA) and agricultural areas (AGRA) according to CORINE 2006. Eleven selected soil properties were measured, and their impacts on AS and K_{fac} (RUSLE-K) were determined by using the CRT (classification and regression tree) in Gökçeada. Results showed that the relations among soil characteristics changed according to the land cover classes. Total organic carbon is much more associated with AS in AGRA, while total carbon is associated with AS in FSNA. The effect of calcium carbonate on K_{fac} was

higher than other soil properties when the land cover type was ignored. On the other hand, in AGRA, the effect of between clay content on K_{fac} was greater than those of FSNA.

Keywords Gökçeada · Land cover class · Soil erodibility · Aggregate stability · K_{fac} (RUSLE-K)

Introduction

Gökçeada has a high potential for organic agriculture in terms of its location and nature. As a part of Gökçeada Agricultural Development and Settlement project, the Organic Project, initiated in 2002, aims to increase organic production and encourage organic farming by providing new subsidies to organic farmers (Anonymous 1993). On the other hand, Gökçeada has also high potential risk of soil erosion especially when considering the slope and terrain. Its topographical and geological conditions, rainfall, vegetation, soil properties, and soil erodibility (K_{fac}) have important role in terms of conservation and sustainability of land resources. Land use changes affect soil properties and K_{fac} (Bayramin et al. 2008; Başaran et al. 2008; Saygın et al. 2011). A number of factors play a role in the differentiation of soil properties. The parent material, topography, erosion, vegetation, and climate influence directly on the soil properties, and these effects can be changed by the interventions of the living organisms. Soil erosion, soil contamination, decline in soil organic carbon, biodiversity, soil compaction, salinization, and

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sealing are the major threats faced by soils (De la Rosa and Sobral 2008) following land-use change. Land-use changes, such as cultivation and tillage of deforested land, can diminish soil quality. Soil aggregate stability (AS) is one of the most important physical indicator of soil quality (Kavdir et al. 2006) and is used to classify soil structure (Six et al. 2000). The higher the stability of soil aggregate, the greater is to resist soil compaction and erosion (Beare and Bruce 1993). It was reported that soil AS increased with increasing soil organic carbon. In addition, pasture soils AS were ten times greater than those of agricultural soils (Kavdir et al. 2004). Aggregate breakdown is mainly affected by environmental and management factors, such as soil organisms, soil chemical and physical properties, temperature, nutrient availability, and soil moisture (Christensen 2001). Conservation tillage, plant carbon inputs, and complexity of the agricultural system improve soil aggregation and soil organic carbon contents of soils (Bronick and Lal 2005). Soil erosion can cause disruption and loss of topsoil; deterioration of soil structure, decrease in soil organic matter, soil depth, and nutrients; and reduce productivity of agricultural lands (Morgan 2005). The soil erodibility factor (K_{fac}) is a quantitative description of the inherent erodibility of a particular soil. K_{fac} and AS, which are related with many soil properties, are also important indicators of soil sustainability. Therefore, establishing their relationships and functions under differing circumstances is important in terms of soil sustainability. Evaluation of relationships and interactions among variables in an understandable way is very important in scientific research. CRT (classification and regression tree) is a non-parametric statistical techniques, continuous or categorical variables can be modeled. CRT method is a suitable alternative to linear regression in elucidating potentially complex interactions (Breiman et al. 1984). Flexibility is one of the most distinctive characteristic of classification trees (CTs). CT have the ability of to examine the effects of the predictor variables one by one at a time, rather than just all at once and on multiple occasions, and ability to allow identifying major variables and interactive effects between variables (Hill and Lewicki 2006; Lim et al. 2000). The flexibility of CRT makes them an attractive option of analysis. This method is used in many fields such as medicine, industry, botany, and engineering. The main advantage of CRT is that it does not require prerequisites like many other parametric tests. In the case of a categorical dependent variable, it is called as

CT; for continuous variables, it is called as regression tree (RT) (Chang and Wang 2006). CTs are being displayed graphically, helping to make them easier to interpret.

The aim of this research was to evaluate the effects of different soil parameters on soil erodibility factor (K_{fac}) in forest-semi-natural areas (FSNA) and agricultural areas (AGRA) by using CRT model in Gökçeada.

Materials and methods

Study area

This study was conducted in the Gökçeada, which is the largest island of Turkey. Gökçeada is located in Northern Aegean sea between 25° 40' 06"–26° 01' 05" eastern longitudes and 40° 05' 12"–40° 14' 18" northern latitudes (Fig. 1). East-west and north-south lengths of island are 29.5 and 13 km, respectively. The coastal line is about 95 km, and its surface area was approximately 286 km² (Öner 2001). Gökçeada is very rich in terms of fresh water resources. Gökçeada has hilly landscape and 64.72% of lands have more than 12% slopes, while 13.63% of the lands have flat or slightly flat slope. While the island is composed of sedimentary and volcanic formations, Yıldız Bay consists of sandstone shale alternation (Kesgin and Varol 2003). Çamlıca metamorphics are present in northwest of Gökçeada. Andesites are observed on a large area in the east part of Gökçeada. Conglomerate, sandstone, siltstone, and marl crop out in narrow regions at east, southeast, and south of Gökçeada. The north, south, and the center of the island consisted on claystone, sandstone, siltstone, and marl. Western part of Gökçeada is mainly rhyolitic tuffs (Sarı et al. 2015).

The most common vegetation is forests, pastures, and olive orchards. The mean annual rainfall is 722 mm (1982–2012) and annual mean temperature is 15 °C.

Soil sampling

Soil samples were taken from 0- to 20-cm depths (mainly in A horizons) in 248 different locations of Island (Fig. 2). Soil samples have been taken from surface layers, since results would be used in RUSLE equation. Composite samples were obtained by mixing subsamples from three points taken 40–60-m apart at each location. All plant litter and cover were removed from

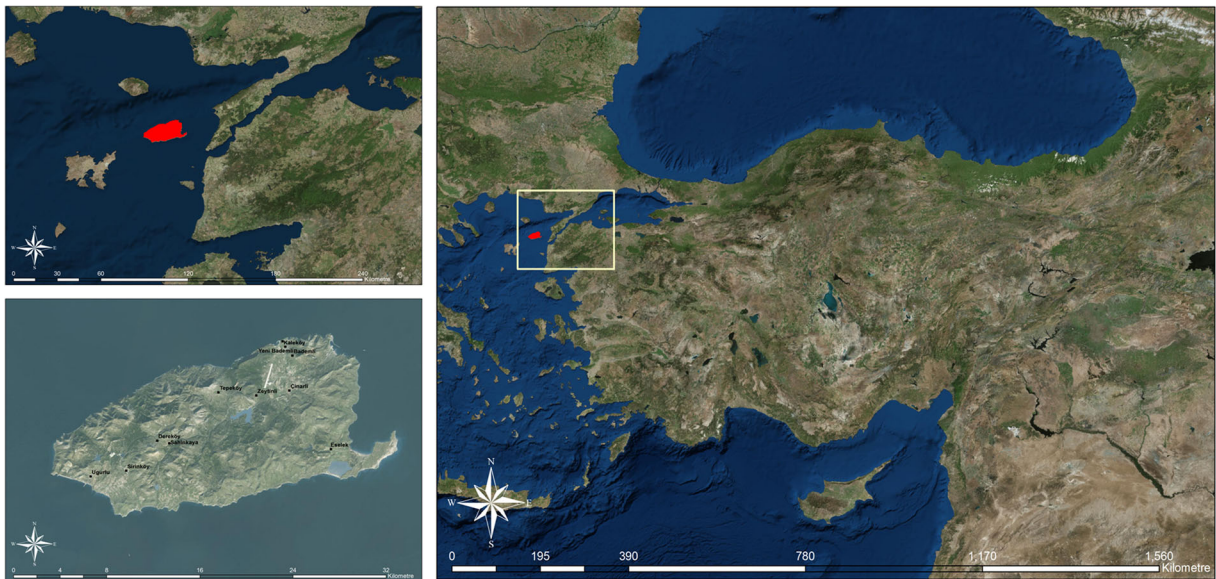


Fig. 1 Geographical position of Gökçeada

the soil surface before soil samples were collected using a shovel and placed in a plastic bag. Almost 82% of the land classified as FSNA, 15% as AGRA, and 3% as other areas (Corine 2006). A total of 65 soil samples were taken from AGRA and 183 from FSNA. Soil sampling points are presented on Fig. 2.

Physical and chemical soil analysis

Soil samples were air-dried, grounded, and sieved through a 2-mm sieve opening and the visible leaf, stubble, and roots were removed. Soil moisture content was measured gravimetrically by drying the soil samples at 105 °C in an oven until it reached a constant weight. The electrical conductivity of the soil was determined by an electrical conductivity meter using saturation extract (Richards 1954). Soil pH was measured after shaking a soil and water (1:2.5 w/v) suspension for 30 min (Grewelling and Peech 1960). The Scheibler calcimeter method was used to measure the CaCO₃ content of the soil (Schlichting and Blume 1966). Hydrometer analysis was used to determine soil particle size distribution (Bouyoucos 1951). Before the analysis, chemical (CaCO₃ and organic matter removal) and mechanical dispersion procedures were performed. The bulk density (dB) of the soils (g/cm³) was measured using the clod method (Blake 1965), and results were converted by using equations described by VanRemortel

and Shields (1993). Stabilities of 1–2-mm size of soil aggregates were determined using the wet-sieving method (Kemper and Rosenau 1986). Soil structure types were determined at the field by visual observations. Soils were dried, finely ground with mortar and pestle, and analyzed for total C using a LECO Truspec CN analyzer. Total organic carbon (TOC) was calculated using the following equation.

$$TOC = TC - (IC / 8.33) \tag{1}$$

where

- TOC total organic carbon (%)
- TC total carbon (%)
- IC inorganic carbon (%)

Saturated soil pastes were prepared by adding deionized water to 100 g of soil according to the method described by Rhoades et al. (1996). Mixtures were placed to laboratory for 5 h to equilibrate. Aliquot of the soil saturation extract was diluted with deionized water before ion analysis. Ions (Na⁺, K⁺, Mg²⁺, Ca²⁺, NH₄⁺, Cl⁻, NO₂⁻, NO₃⁻, and SO₄²⁻) were measured in these diluted extracts within 1 day of extract collection, after solutions had been filtered through 0.45-µm (Millipore brand) pore filters to remove the particulate material. Ion contents of soils were measured by Dionex 1100 Ion Chromatography (Scanlon et al. 2009).

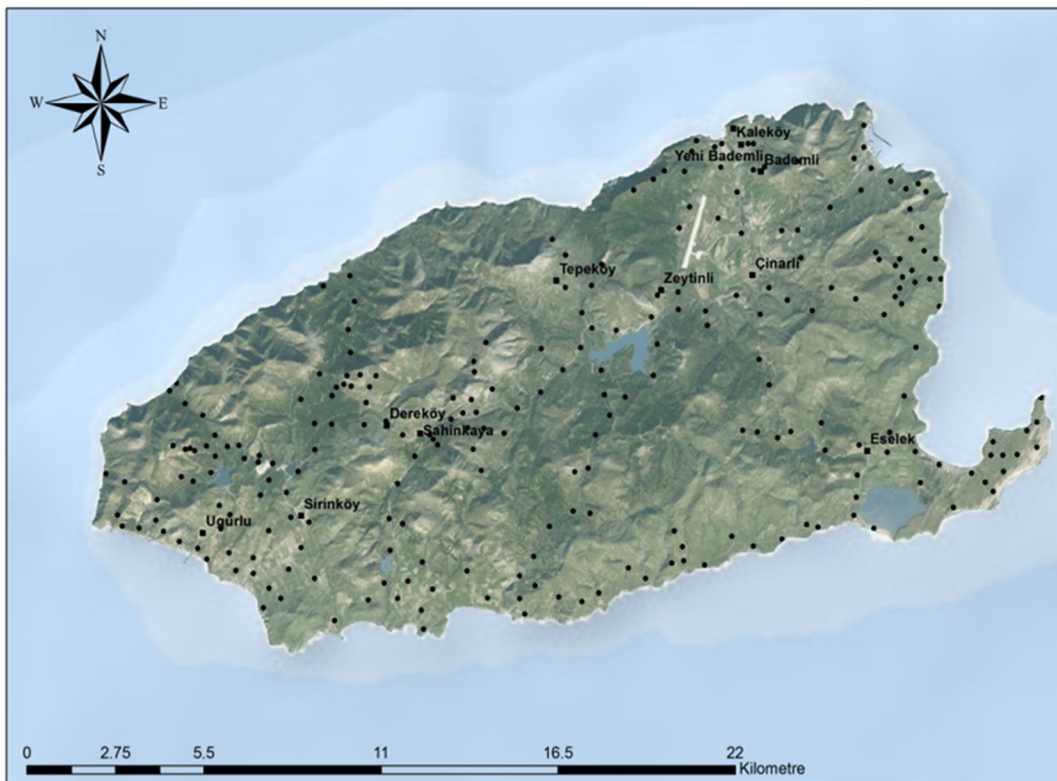


Fig. 2 Distributions of soil sampling points

Kfac (RUSLE-K) was calculated mathematically by using silt, very fine sand, clay, organic matter contents, surface soil structure, and permeability (Wischmeier and Smith 1978).

$$K = [2.1m^{1.14}(10^{-4})(12-a) + 3.25(b-2) + 2.5(c-3)]/100 \text{ (U.S.)} \quad (2)$$

where;

- m* is the grain size factor (silt (%) + very fine sands (%))(100 – clay (%))
- a* is the organic matter content expressed in %
- b* is the class index of top soil structure, which depends on its particle size
- c* is class index of soil profile permeability, which depends on its textural class

Statistical analysis

A *t* test was conducted to verify to test whether the differences between the physical and chemical properties determined in the soil under two different land covers were significant. SPSS 17.0 package program

was used to perform descriptive statistics and CRT analyzes (Breiman et al. 1984). Maximum tree depth selected as 5 and modeled using cross validation. AS and Kfac were selected as dependent variable, while pH, EC, C, Si, S, TC, TOC, CaCO₃, DB, Tanion, and Tcation were used as independent variables in the model.

Results

General evaluation regardless of land use and cover

Descriptive statistics of physical and chemical soil parameters are presented in Table 1. The soil pH is classified as strongly acidic to strongly alkaline, with a mean value of 7.18 (neutral). Soil EC values were between 269.25 and 4977.50 μS cm⁻¹ with a mean value of 940.84 μS cm⁻¹, which was classified as non-saline to slightly saline (Schoeneberger 2002). Island soils have generally high sand content, ranging from 11.44 to 92.79%, with a mean of 47.66%, while mean values of clay and silt were 22.94 and 29.40%, respectively. TOC

content ranges from 0.9 to 6.3% with a mean value of 2.11%, while total carbon (TC) content ranges from 1.19 to 9.24% with a mean value of 2.47%. Soil CaCO₃ contents range from 0 to 33.50%, which is non-calcareous to extremely calcareous with a mean value of 2.99% (moderately calcareous). AS values ranged from 26.65 to 96.41% with a mean of 70.52%. Average Kfac (RUSLE-K) value is 0.25, and values range from 0 to 0.65. The mean dB value was 1.42 varying between 0.97 and 1.91 g cm⁻³.

Soil properties in forest-semi-natural areas and agricultural areas

Descriptive statistics of soil analysis results and their statistical significance levels are presented in Table 2. Silt and sand contents, pH, EC, TOC, CaCO₃, Kfac, AS, dB, and Tcation values of soils differed significantly across land cover types (*p* < 0.05 in all cases), while clay content, TC, and Tanion values did not vary significantly across the land covers (*p* > 0.05 in all cases) (Table 2).

Parent material can influence the soil pH directly. However, even the pH values of the soil formed on the same parent material can vary considerably from one another. The mean pH of the FSNA soil was 7.02 and

ranging from 5.34 to 8.67, while the pH of the AGRA soils ranged from 6.18 to 8.33 and the mean was 7.65. Therefore, the mean pH in FSNA was lower than the pH of AGRA soils. Results were supported by previous studies that pH values were lower in FSNA than AGRA (Falkengren-Grerup et al. 2006; Khresat et al. 2008). Effects of land cover types on soil pH were statistically significant (*p* < 0.05). The fact that the AGRA's are located at lower slopes and that the surrounding land is covered with more inclined FSNA may cause leaching of basic elements from the slope areas and accumulate in the AGRAs. Differences of pH may be due to the removal of soil organic material by erosion and agricultural activities, as well as the leaching of the resulting bases in the forests where the rainwater can infiltrate better into the soil. SOM-induced acidification is another cause of decrease in pH value in forest soils. Aluminum release is strongly influenced by organic matter mineralization, since it naturally bound into organic complexes and that increases soil acidity (Borůvka et al. 2007).

Agricultural soils have higher EC values than those of the forest soils. EC values were between 475 and 4977.5 μS cm⁻¹ in AGRA and between 269.25 and 2917.50 μS cm⁻¹ in the FSNA. The difference between the mean EC values of soils under two different land covers was statistically significant (*p* < 0.05).

Clay content was not statistically different between land cover classes, while sand and silt contents differed significantly (*p* < 0.05 in all cases) regardless of parent material. Agricultural and cultivated soils had lower silt and clay contents than the adjacent FSNA soils, most likely as a result of preferential removal of silt by water erosion and surface runoff as it was also indicated by Islam and Weil (2000). Forest lands are covered by vegetation and have higher biomass than AGRA lands throughout the year; therefore, land surface is well-covered and directly protected from soil erosion. In addition, better plant root development, high soil moisture, and organic carbon content which enhance microbial population and chemical weathering can also cause the differentiation of textural dimensions in FSNA.

Despite the fact that most of the AGRA's are located on the alluvial and the colluvial parent materials, the unprotected nature of the lands and continuous tillage and planting activities can cause silt and clay content reduction in these areas. AGRA soils had presumably less microbial biomass activity due to plowing and field works (Zhao et al. 2005), resulting in accelerated

Table 1 Average values and standard errors (SE) of measured soil physical and chemical parameters (*n* = 248)

Parameter	Minimum	Maximum	Mean standard error
pH	5.34	8.67	7.18 ± 0.04
EC (μS cm ⁻¹)	269.25	4977.50	940.84 ± 34.78
Clay (%)	3.23	64.00	22.94 ± 0.64
Silt (%)	1.28	75.72	29.40 ± 0.93
Sand (%)	11.44	92.79	47.66 ± 0.97
TC (%)	1.19	9.24	2.47 ± 0.06
TOC (%)	0.90	6.32	2.11 ± 0.05
CaCO ₃ (%)	0.00	33.50	2.99 ± 0.35
AS* (%)	26.65	96.41	70.52 ± 0.84
dB (g/cm ³)	0.97	1.91	1.42 ± 0.01
Kfac (RUSLE-K)	0.00	0.65	0.25 ± 0.01
Total anion (ppm)	38.95	1631.66	184.17 ± 10.72
Total cation (ppm)	36.19	665.35	165.30 ± 5.91

EC: electrical conductivity, TC: total carbon, TOC: total organic carbon, AS: aggregate stability, dB: bulk density, RUSLE-K: soil erodibility factor, ±: SE

**n* = 246

Table 2 The mean, standard error values, and *t* test results of the parameters determined in soil samples according to land cover

Parameters	Land cover	Minimum	Maximum	Mean standard error	<i>t</i>	<i>p</i>
pH	FSNA	5.34	8.67	7.02 ± 0.05	-7.90	0.00
	AGRA	6.18	8.33	7.65 ± 0.06		
EC (µS/cm)	FSNA	269.25	2917.50	883.77 ± 30.59	-2.10	0.04
	AGRA	475.00	4977.50	1101.52 ± 98.84		
Clay (%)	FSNA	4.48	64.00	23.40 ± 0.75	1.22	0.22
	AGRA	3.23	43.97	21.63 ± 1.24		
Silt (%)	FSNA	1.28	72.22	26.96 ± 1.01	-4.58	0.00
	AGRA	12.18	75.72	36.29 ± 1.91		
Sand (%)	FSNA	13.45	92.79	49.64 ± 1.16	3.49	0.00
	AGRA	11.44	66.73	42.08 ± 1.60		
TC (%)	FSNA	1.19	9.24	2.51 ± 0.08	1.45	0.15
	AGRA	1.29	5.76	2.35 ± 0.08		
TOC (%)	FSNA	0.90	6.32	2.22 ± 0.06	3.92	0.00
	AGRA	1.05	3.38	1.82 ± 0.06		
CaCO ₃ (%)	FSNA	0.00	33.50	2.49 ± 0.43	-2.39	0.02
	AGRA	0.00	19.84	4.38 ± 0.55		
AS (%)	FSNA**	26.65	96.41	71.75 ± 0.91	2.26	0.03
	AGRA	36.71	95.90	67.08 ± 1.86		
dB (g/cm ³)	FSNA	0.97	1.91	1.40 ± 0.01	-2.55	0.01
	AGRA	1.07	1.90	1.45 ± 0.02		
RUSLE-K	FSNA	0.00	0.65	0.22 ± 0.01	-5.16	0.00
	AGRA	0.13	0.60	0.31 ± 0.02		
Total anion (ppm)	FSNA	38.95	750.29	176.87 ± 9.51	-0.86	0.39
	AGRA	42.52	1631.66	204.73 ± 30.98		
Total cation (ppm)	FSNA	36.19	610.95	156.60 ± 6.04	-2.12	0.04
	AGRA	61.13	665.35	189.81 ± 14.45		

EC: electrical conductivity, TC: total carbon, TOC: total organic carbon, AS: aggregate stability, dB: bulk density, RUSLE-K: soil erodibility factor, FSNA: semi-natural areas AGRA: agricultural areas

±: standard error FSNA (*n* = 183, ** *n* = 181) AGRA: (*n* = 65)

erosion and loss of fine mineral fractions. Seed bed preparation and tillage also caused clay and silt allocation to deeper soil depths. Poepflau and Don (2015) reported that clay content of soil was significantly higher at a depth of 20–30 cm than at depths of 0–10 and 10–20 cm. This can be due to repeated shallow tillage activity for monoculture for a long time. Clay and silt size soil particles move down with water and slowly fill up the soil interstices.

Average TC value was greater in FSNA (2.51%) than AGRA (2.35%), but the difference was not statistically significant; on the other hand, TOC and CaCO₃ contents differed significantly between land-use types (*p* ≤ 0.05, Table 2). AGRA soils contained

approximately twice (4.38%) as much CaCO₃ than FSNA soils. İlay (2016) reported that CaCO₃ content of soil was considerably high in the west, south-west, and north coastal parts of the island. Approximately half of the areas classified as AGRA are located in this region which explains the reason of high CaCO₃ in AGRAs compared to FSNAs.

Average TOC values were 2.22 and 1.82% in FSNA and AGRA, respectively. The lower levels of TOC in AGRA soils may have resulted from a lower carbon inputs and greater carbon losses because of aggregate disruption, increased aeration by tillage, crop residue burning, and accelerated water erosion (Girma 1998; Kavdir et al. 2004).

AS, bulk density, and erodibility (Kfac) values varied significantly across the land cover ($p < 0.05$) types. Enhanced AS of FSNA soils is consistent with greater clay and organic carbon content of FSNA. AGRA soils had lower AS than FSNA. Better aggregation probably accounts for the lower bulk density and increased porosity under forest soils when compared with agricultural soils.

Likewise, total anion and cation contents varied between forest and agricultural soils. Cultivated and agricultural lands had greater anion and cation concentrations than forest soils. Fertilization, cultivation, irrigation, and precipitation can affect ion solubility, movement, or accumulation, which directly affects results in AGRA soils (İlay and Kavdır 2017).

Relationships between soil aggregate stability and other soil parameters in FSNA

Relationships between AS and other parameters were classified with CRT model generated by the data obtained from the soils sampled in FSNA (Fig. 3). AS was the primary splitting node: average was 71.75%. At the second level in the hierarchy, the splitting criterion was TC contents. Higher level structure of Fig. 3 indicates that TC was the dominant variables influencing AS in FSNA. According to the model, relationships between other soil parameters and AS vary when TC value is above or below 2.05%. Approximately 37% of soil TC contents were below 2.05%, but majority (63%) of the samples was above 2.05% in forest soils. If TC is above 2.05, it is the most dominant factor influencing soil AS. On the other hand, if TC is below 2.05, sand content and pH value were also affected on soil AS (Fig. 3).

Figure 4 shows the dependent variable description of the non-dependent variable or the level of association between them. According to Fig. 4, the most important factor on AS value is TC and followed by TOC and sand content, respectively. It can be said that these three

independent variables are the most related parameter with AS in FSNA. However, the association of AS with other parameters remained limited.

Relationships between soil aggregate stability and other soil parameters in AGRA

The RT model for soil AS as a function of other soil variables in AGRA is shown in Fig. 5. According to this model, TOC ($n = 65$) was the most important variable determining AS variability and followed by clay ($n = 21$) and EC ($n = 7$). It is seen that the most important classifiable factor related to AS is TOC.

There were 44 locations with SOC less than 1.92%, and average soil AS of soils was 60.24%. On the other hand, 21 locations had SOC > 1.92% and average AS value was 81.41% (Fig. 5). Clay content (C) was the second most important variable and significantly impacted only those lands with high SOC. AS of soils with both SOC greater than 1.92% and clay content > 22.97% averaged 76.16%.

EC was the least important variable affecting AGRA lands with low SOC contents. If soil SOC was < 1.32% and EC was < 978.75 $\mu\text{S cm}^{-1}$, the mean AS value was 57.28% ($n = 3$); whereas, if EC was > 978.75 $\mu\text{S cm}^{-1}$, AS value was 42.78% ($n = 4$).

The levels of the relationships between the independent variables and the dependent variable (AS) are shown in Fig. 6. As a result, among the independent variables considered, the most important parameter effect on AS appears to be TOC. Although the effects of TC and TOC on the AS are very close to each other under FSNA, it is clear that the effect of the TOC on the AS is obviously much higher in AGRA. Additionally, TC and dB were also effective parameters on AS in AGRA. Soil pH and CaCO_3 have almost the same effect, whereas the decisive effect of the soil texture on

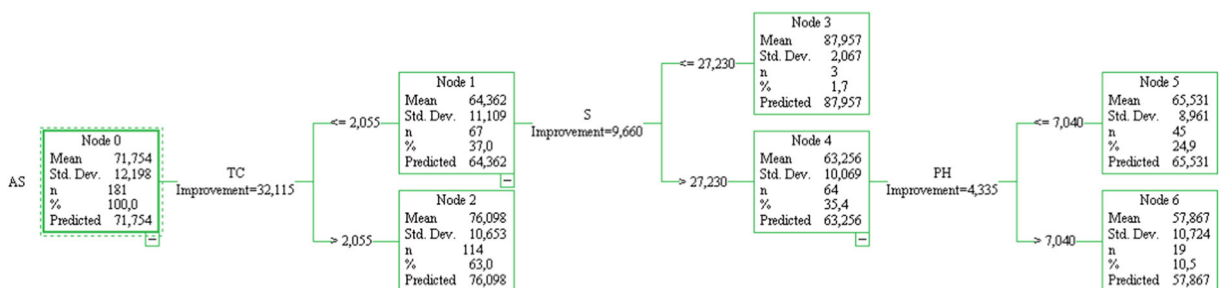
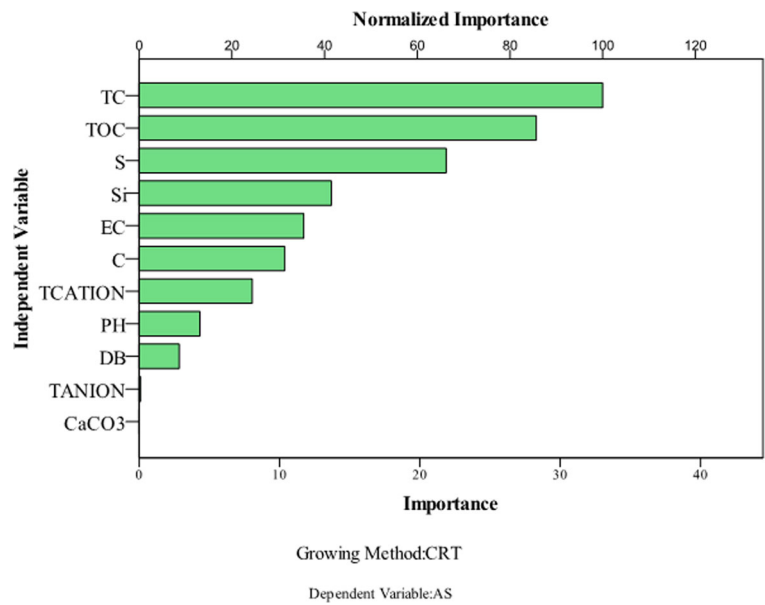


Fig. 3 Regression tree predicting AS from soil parameters sampled from FSNA. AS: aggregate stability; TC: total carbon; S: sand

Fig. 4 Relation levels of soil parameters in FSNA with AS. TC: total carbon; TOC: total organic carbon; S: sand; Si: silt; C: clay; DB: bulk density; AS: aggregate stability



AS is limited. Silt content had the lowest effect on soil AS in AGRA.

Relationships between Kfac and other soil parameters in FSNA

Relations among Kfac and other parameters are classified by using CRT model in FSNA (Fig. 7). The dependent variable was selected as Kfac in the model, then the

relation among Kfac with other 11 independent variables was evaluated.

It appears that silt was the most effective independent variable on Kfac. Different subclasses were formed in relation to Kfac depending on silt content of soils. Accordingly, when the silt content was below 35.73%, a subclass has emerged where Si can be splitted as above and below 7.07%. Kfac of soils with both silt content greater than 7.07% and organic carbon >2.11% averaged 0.176. When the content of silt is > 35.73%,

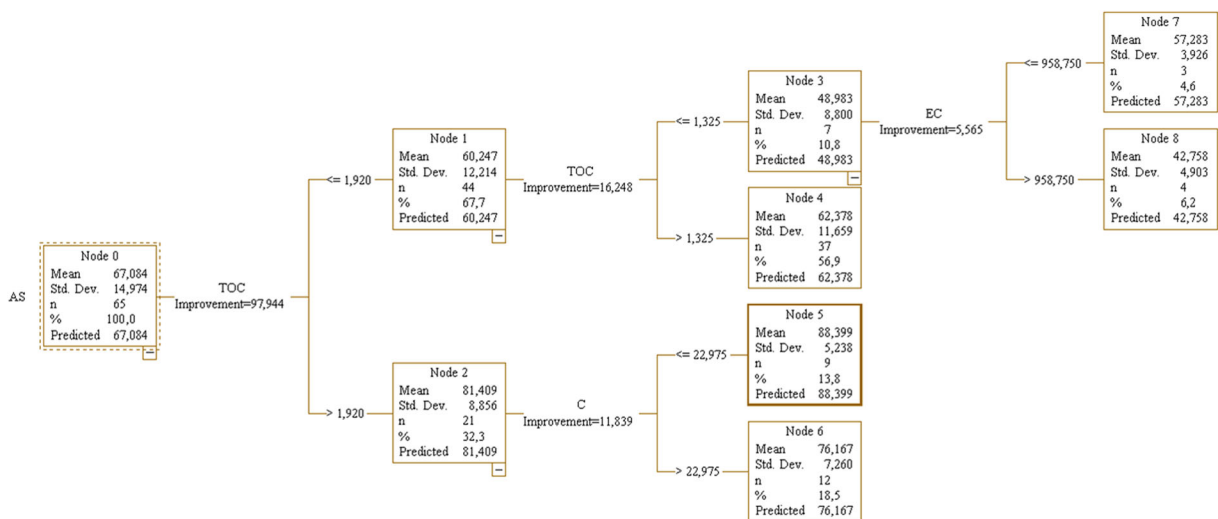
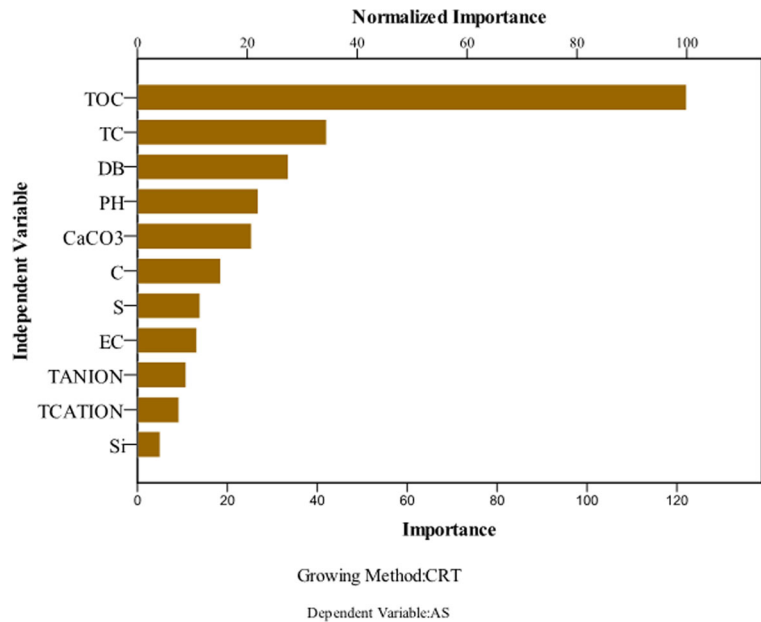


Fig. 5 Regression tree predicting AS from soil parameters sampled AGRA. AS: aggregate stability; TOC: total organic carbon; C: clay; EC: electrical conductivity

Fig. 6 Relation levels of soil parameters in AGRA with AS. TOC: total organic carbon; TC: total carbon; DB: bulk density; S: sand; Si: Silt; C: clay; EC: electrical conductivity



CaCO₃ appears to be an effective classifiable factor on Kfac (Fig. 7).

Kfac of soils with CaCO₃ content greater than 3.84% averaged 0.43, while CaCO₃ content < 3.84% averaged 0.248 (Fig. 7). The significant trend of lowest silt content and lowest Kfac value in FSNA soils suggests that erosion may preferentially remove silt from soils. Kfac was 0.185 and 0.368

when the silt content is below and above 35.73%, respectively (Fig. 7).

The effects of soil properties on Kfac in FSNA are shown in Fig. 8. The silt and CaCO₃ factors appeared to be the most important variables in defining Kfac. Subsequently, sand, clay, pH, and TOC were effective on Kfac, respectively. Tanion, Tcation, and EC were the least effective soil parameters among the factors studied.

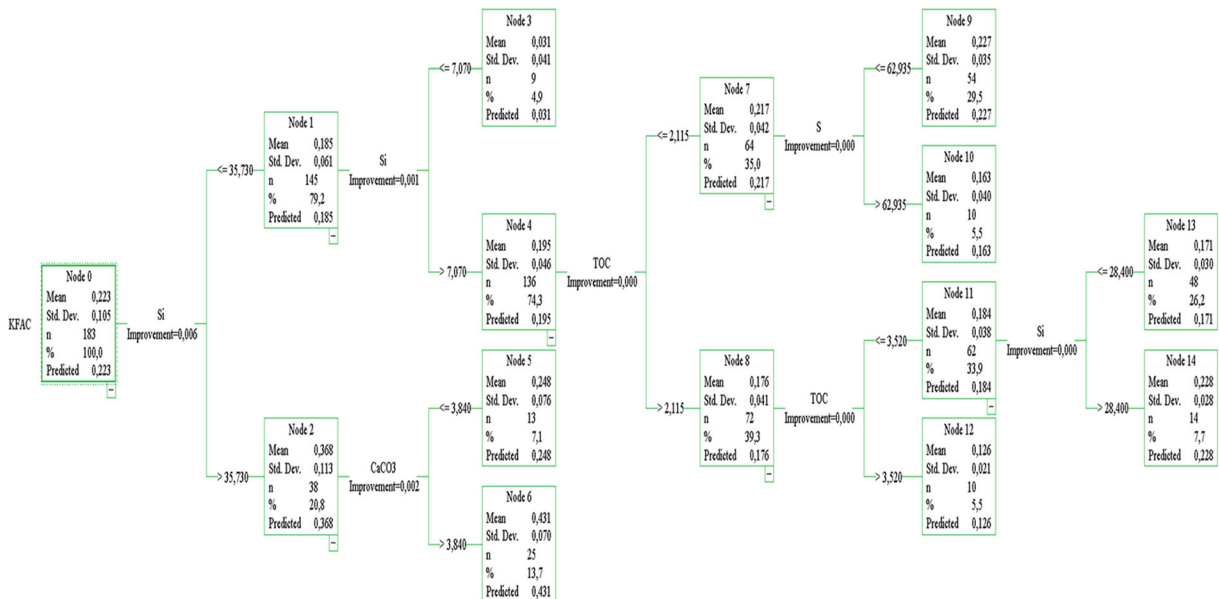
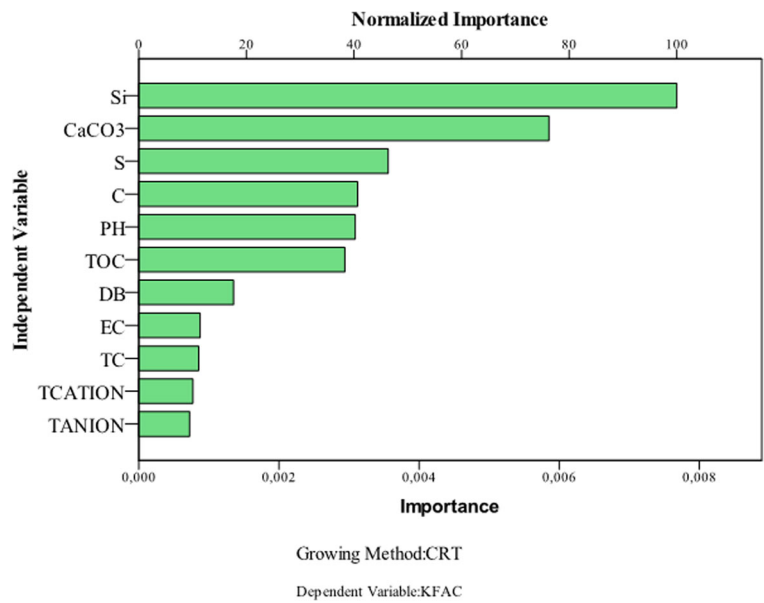


Fig. 7 Regression tree predicting Kfac from soil parameters sampled FSNA. KFAC: soil erodibility factor; Si: silt; TOC: total organic carbon; S: sand

Fig. 8 Relation levels of soil parameters in FSNA with KFac. KFac: soil erodibility factor; TOC: total organic carbon; TC: total carbon; DB: bulk density; S: sand; Si: silt; C: clay; EC: electrical conductivity



Relationships between Kfac and other soil parameters in AGRA

Relations among Kfac and other parameters are classified by using CRT model in AGRA (Fig. 9). Dependent variable was selected as Kfac, and the relation of Kfac with 11 independent variables was evaluated in the model. Classes of model created by CRT analysis are presented in Fig. 9. Accordingly, silt was the most important independent variable at the classifiable level on Kfac in agricultural lands, as it was also observed in

forest areas. There were different subclasses based on Si value. While the value of silt is below 39.17%, effects of pH and Tcation parameters on Kfac are increasing. If soil silt content was < 39.175% and pH was < 7.72, the mean Kfac value was 0.2 (n = 20). Additionally, if Tcation was < 172.175 ppm, Kfac was 0.167. Whereas, if pH was > 7.72, Kfac value was 0.268 (n = 16).

Figure 10 showed the importance of the results of soil properties on explaining Kfac in AGRA. Although the effect levels of the first three variables are very close to each other, silt has the most effective level of

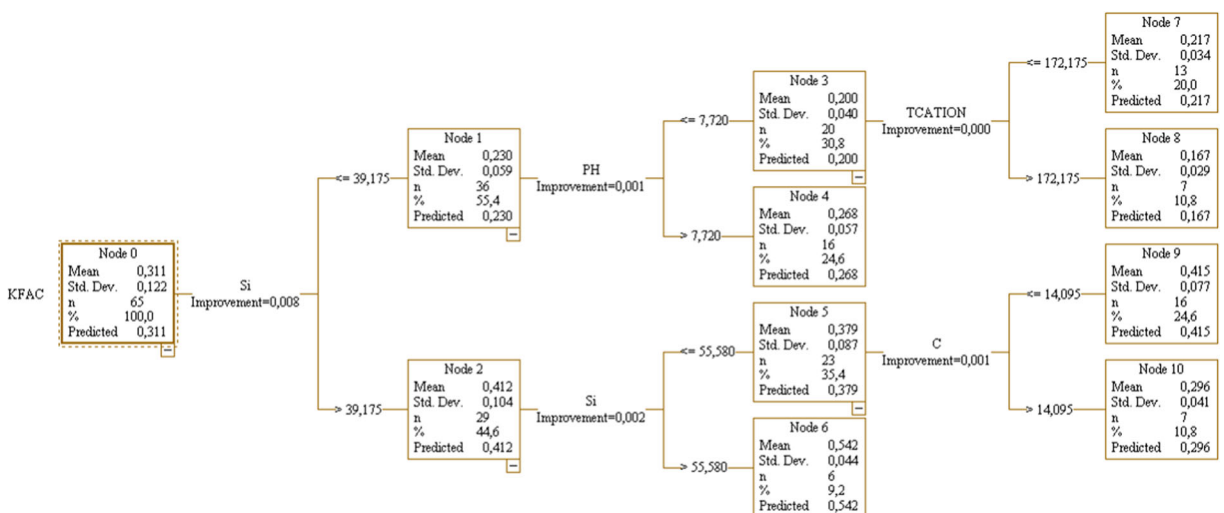


Fig. 9 Regression tree predicting Kfac from soil parameters sampled AGRA. KFac: soil erodibility factor; Si: silt; C: clay; Teation: total cation

relationship with Kfac and it was followed by CaCO₃ and clay, respectively. Tanion, Tcation, and EC have the least influence on the factors examined.

Discussion

The results of soil parameters under different land covers/land uses in Gökçeada are presented in Table 2. According to the results, there are statistically significant and not significant differences in soil parameters due to land cover. pH, EC, silt, sand, TOC, CaCO₃, AS, dB, Kfac, and Tcation values were statistically significant in terms of land cover difference.

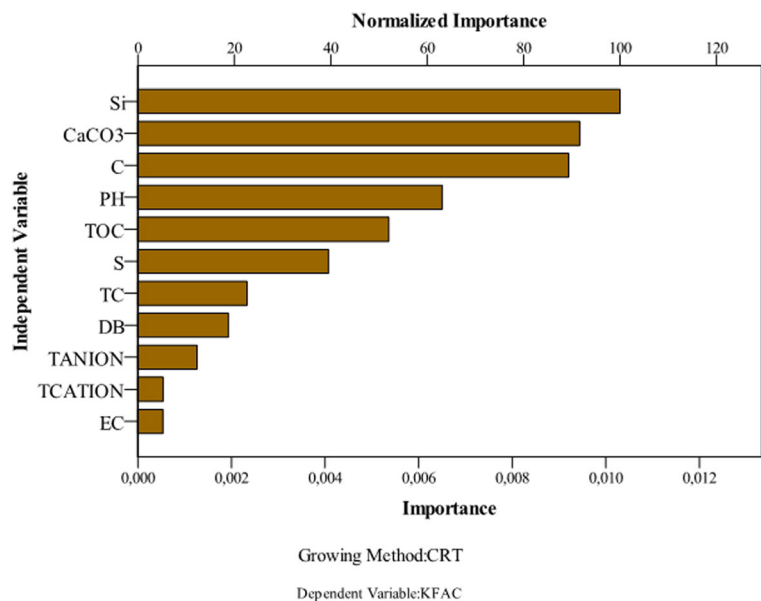
Soil aggregate stability and other parameters

According to results, it was found that TC has the most important effect in the explanation of AS in the FSNA, while TOC is more effective in AGRA. Agricultural lands are exposed to external influences more than other lands. Climatic factors and agricultural activities directly or indirectly affect many properties of soils. Soil management, land diversity, weather conditions, soil deposition/erosion, and environmental changes can affect soil carbon. Organic carbon is the most important indicator of soil quality, because it is responsible for improvement of biological activity, beneficial plant nutrients, and soil structure functions as well as properties, such as high AS and low volume weight (Acosta-

martinez et al. 2003; Pritchett et al. 2011; Arshad and Martin 2002). Depending on the topography and uncovered bare soil, it is inevitable to lose the organic carbon by leaching. Fertilization and cultivation processes in AGRA cause variability of the TOC in agricultural lands compared to forest areas. Changes of TOC contents also affect AS values in AGRA. With the conversion of natural forests and forests to arable land, there was an average decrease of 42 and 59% in organic carbon stocks, respectively (Guo and Gifford 2002). The presence of high amounts of TOC, depending on the vegetation density and the limited change of TOC contents due to external factors, caused TC and AS to become more relevant in FSNA. Soil aeration, weathering, disruption of soil aggregates, soil erosion, changes in microbial communities and vegetative production, and removal of plant biomass can lead to initial losses of TOC (Cusack Daniela et al. 2013). These losses can also affect the interaction of TC and TOC with other factors. It has been found that TC and TOC are more related to AS in the FSNA and AGRA. Following TC and TOC, sand is the most related in FSNA and bulk density (dB) in AGRA. It was found that the difference between the mean values of these two parameters changes according to the land cover and this change was statistically significant. Despite AGRA soils had higher CaCO₃, which derived from mostly parent material than FSNA, TOC is much effective on soil AS in AGRA.

Many studies have reported that the TOC is the most effective soil property on the soil bulk density. Da Silva

Fig. 10 Relation levels of soil parameters with Kfac in AGRA. KFAC: soil erodibility factor; TOC: total organic carbon; TC: total carbon; DB: bulk density; S: sand; Si: silt; C: clay; EC: electrical conductivity



et al. (1997) reported that interactions among organic material, clay, tillage, and location were related to bulk density. High correlations were also found between bulk density and TOC contents in different soil types (Curtis and Post 1964; Alexander 1989; Perie and Ouimet 2008; Pribyl 2010). TOC content in AGRA is lower than FSNA (Table 2), which has a direct effect on dB. Therefore, in AGRA, dB is more related to stability, while the level of the relationship between AS and dB is not strong in forest and semi-natural areas (FSNA) because of the variation in the factors that may affect the dB is more limited (Figs. 4–6). It is seen that there is a classifiable effect of both organic carbon and clay on AS (Fig. 4) in AGRA. There is a higher level of association between sand and AS in FSNA (Fig. 4). Many studies have shown strong correlations between increased soil organic matter levels and improvements in soil physical properties such as aggregation, water infiltration, hydraulic conductivity, and compaction (Whitbread et al. 2000; Blair et al. 2006a, b).

Kfac and other parameters

Kfac values were in the range between 0 and 0.65 in FSNA, and average was 0.22. In AGRA, the mean Kfac value was 0.31 and it changed from 0.13 to 0.60. The average Kfac was significantly higher in AGRA than that of in FSNA and therefore, the erosion risk could be higher in AGRA (Table 2).

CRT analysis was carried out on measured parameters of soil sampled from FSNA and agricultural AGRA. According to CRT analysis model where the dependent variable was selected as Kfac, it was seen that the most effective independent variable with classifiable presets on Kfac was silt regardless of the land cover. It appears that the second most effective parameter associated with Kfac is CaCO_3 in FSNA. A similar pattern was observed in AGRA, but it was found that clay was also effective on Kfac as silt and CaCO_3 . Clay was more effective on Kfac in AGRA than FSNA. Studies that were conducted to estimate the erodibility of calcareous soils reported that K factor was related to the soil properties affecting the structure and permeability (Gupta 2002; Hoyos 2005; Summer 1982). Some studies have shown that soil particles, organic matter, exchangeable potassium, and iron oxides have a direct effect on the soil erodibility (Kfac) (Veihe 2002; Santos et al. 2003; Zhang et al. 2004; Evrendilek et al. 2004; Rodriguez et al. 2006; Auerswald et al. 1996; Rhoton et al. 1998).

Conclusion

In this study, soil erodibility factor (Kfac) which is one of the most used models for predicting the stability of aggregates (AS) and soil erosion, which depends on physical-chemical factors in the soil, was evaluated in relation to other soil parameters depending on the land cover. The CRT method, which has been used recently in natural and environmental sciences, has been chosen for the evaluation of relations. It does not require much precondition, such as other statistical analysis methods, and it allows comfortable interpretation depending on the visual sense. Results showed that the relations among soil characteristics change according to the land cover types. TOC is much more associated with AS in AGRA than FSNA. The relationship between CaCO_3 and Kfac was found to be higher than the other parameters in both land cover types. However, in AGRA, the relation between clay and Kfac was found to be higher than the FSNA.

Funding information This study was supported by the COMU-BAP Project 2012/17.

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