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Soil pollution

ERODIBILITY CHARACTERISTICS OF SOILS FORMED FROM DIFFERENT UNITS OF OPHIOLITE IN EASTERN MEDITERRANEAN REGION OF TURKIYE

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Abstract. Although ophiolites cover approximately 1% of the total terrestrial land in the world, they have gained great importance due to their spread by wind and water erosion in addition to the high heavy metal (Ni, Cr, Mn, Co) contents. Ophiolitic units are common in Kahramanmaras and have different geochemical and petrographic features. In this study, it was aimed to determine the susceptibility of the ophiolitic assemblage to erosion of soils consisting of different units in Kahramanmaras site the Eastern mediterranean region. Accordingly, 29 samples of rocks and 46 samples of soils, of which these rocks are the parent material, were taken in the study area. Some physico-chemical analyses of the soil samples were carried out with commonly used analytical methods. When the physical characteristics of the soils taken from the research area were examined, it has been determined that soils formed from different units of the ophiolitic suite (metamorphic sole, tectonites and oceanic crust) have high dispersion and erosion rates, and low aggregate stability and structural stability index values. As a result of the tests, when the soils developed on all units of the ophiolite were correlated with the normal soils. It was observed that they did not exhibit a stable structure and their erodability was high. From an environmental point of view, there is a need for management practices that provide soil quality against water and wind erosion of soils, as soils in such areas have high heavy metal content.

Keywords: erodibility, ophiolite, environmental pollution, human health.

AIMS AND BACKGROUND

Ophiolitic units are defined as remnants of oceanic crust that formed on mid-oceanic ridges[1,2] or on an in-oceanic subduction zone[3,4] that are now emplaced on continental crust. Metamorphic sole rocks are located at the lowest part of the ophiolitic units. This unit is the section that is formed as a result of metamorphism at the bottom of the oceanic crust during the emplacement of the oceanic crust on the continental crust and generally presents an inverted metamorphic zoning. In

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the ophiolite sequence, the mantle part is represented by peridotitic rocks called tectonites such as harzburgite, lerzolite and verlite, while the oceanic crust consists of mafic-ultramafic cumulates, isotropic gabbros, sheeted dyke complex (usually diabase) and volcanic rocks. The extent to which the soils on these sections are located are affected by soil formation factors (climate, time, topography, organism activities and parent material) also differs from region to region, and this has a direct effect on the physico-chemical properties of the soil formed[5]. Especially in arid and semi-arid regions where the influence of climate and vegetation is insufficient, soil formation is almost controlled by the parent material, so it is clearly seen that there is a close relationship between soil properties and parent material. Soils composed of these units in general have coarse texture, poor structural structure, high hydraulic conductivity, low water holding capacity, low organic matter, low concentrations of macro and micro nutrients (Ca, N, P, K, Zn) and low Ca/Mg ratio[6–8]. However, the soils formed in these units draw attention with their high heavy metal concentrations. One of the most important problems of agricultural lands is heavy metal pollution, which can be sourced by humans (agricultural pesticides, fertilisation, urban wastes, industrial liquid and solid wastes, treatment sludge, etc.) or parent materials. Heavy metal pollution of soils composed of ophiolites is not of human origin, but of parent material[9].

The heavy metal contents of the soils formed from the mantle part of the ophiolites have been the subject of many studies. Although the lithologies of the mantle section are predominantly composed of peridotites (dunite-harzburgite-lerzolite-verlite), it is observed that these rocks are largely affected by ocean floor metamorphism and present an alteration in the form of serpentinisation. Therefore, the mantle section rocks were affected by the serpantinisation processes before the soil formation processes, and finally they are represented by the rocks called serpentinite. Aslaner[10] stated that soils of serpentinite origin contain high amounts of cobalt (Co), nickel (Ni) and chromium (Cr). While Aslaner (1973) stated that serpentinite origin soils contain high amounts of cobalt (Co), nickel (Ni) and chromium (Cr), Stueber and Goles[11] emphasised that the total Cr content in these soils can reach up to 10 000 μg/g. Kabata-Pendias and Mukherjee[12] stated that the total Ni contents of the soils are highly variable and generally vary between 13–37 μg/g, however, the total Ni contents of serpentinite soils vary between 1400–2000 μg/g. They stated that the average of the soils in cobalt concentration is 10 μg/g and this value varies between 10–520 μg/g in serpentinite origin soils. Soils made up of these units can have negative effects on ecological, agricultural and human health through the heavy metals (Ni, Cr, Co) leave to environmental areas and groundwater[13]. Heavy metals such as Fe, Zn, Cu, Mn in the soil are necessary for plant growth, their presence in high amounts creates a toxic effect. Since such soils contain heavy metals (Ni, Cr, Co), these areas are becoming more problematic soils day by day. When the ions of these metals are activated in the form of air, water and dust, they have the potential to adversely affect the environment and human health[14–16].

Although the soils composed of ophiolitic rocks cover approximately 1% of the total terrestrial area in the world, their spread as particulate matter by wind and water and also carried to surface and underground waters, they attract attention by causing enrichment of these waters in terms of heavy metals such as Ni, Cr, Mn, Co (Ref. 13). Due to the high heavy metal concentrations of the soils formed in different units of the ophiolitic sequence, it is of great importance to determine the erodibility parameters of agricultural soils consisting of these units.

Ophiolitic units, which have a large distribution in our country, are also widely found in Kahramanmaras[17,18]. In this context, it is aimed to determine the susceptibility of soils consisting of different units of the ophiolitic succession to erosion in Kahramanmaras and some of its districts (Turkoglu, Elbistan, Afsin, Goksun, Andırın and Ekinozu) in the Eastern Mediterranean region of Turkiye.

EXPERIMENTAL

Within the scope of the study, a total of 29 samples from the ophiolitic rocks outcropping around Afsin, Elbistan, Goksun and Ekinozu in the north of Kahramanmaras in the Southeastern Anatolian ophiolite belt and around Kahramanmaras, Turkoglu and Andırın in Peri-Arabian ophiolite belt and 46 samples representing the different soils formed on these rocks were collected according to the random sampling method by using GPS device and analytical studies were carried out on these samples (Fig. 1). Soil samples were dried under suitable conditions for analysis. The rocks belonging to which levels of the ophiolite in the seven different regions studied and the samples taken from the soils formed from these rocks are shown in Fig. 2.

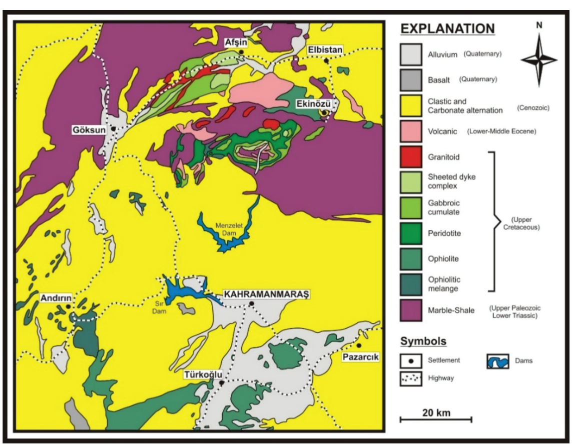

Fig. 1. Geological map of the study area (modified by[19])

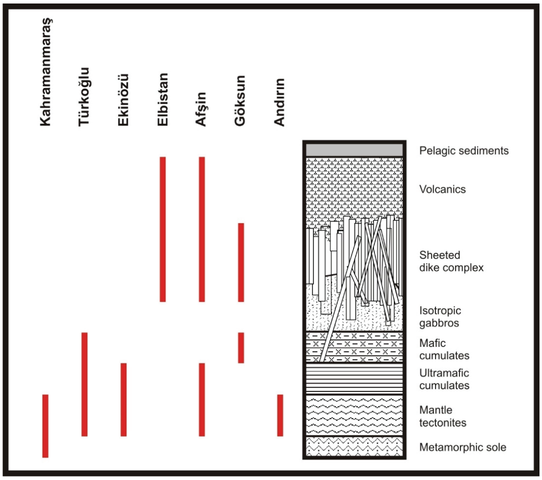

Fig. 2. An ideal ophiolitic sequence, the region and levels where the samples collected

PHYSICAL AND CHEMICAL ANALYSES OF SOIL SAMPLES

The texture analysis of the soils was determined according to the bouyoucus hydrometer method[20]. The dispersion ratio was based on the Bryan method[21]. The structure stable index was calculated using the % clay+silt ratio obtained in the 40 s hydrometer reading of the texture analysis and the % clay + silt ratio obtained in the dispersion analysis[22]. Aggregate stability was determined according to the wet sieving method[23]. The erosion rate of the soils (ER) was calculated as stated below[24].

$$ER = DR \times (c/d),$$

where c is the moisture equivalent of soil (moisture content at pF 2) (%); d – the Clay value (%) measured in mechanical analysis; DR – the Dispersion Ratio.

Clay ratio of the soils (CR) was determined based on the formula determined by[24]:

$$CR = (100 - d)/d,$$

where d is the % clay measured in mechanical analysis.

Soil reactions of the prepared saturation paste were made with a pH meter[25]. The total lime content of the soils was determined according to the method developed[26]. The organic matter contents of the soils were determined according to the Walkley-Black method[27].

STATISTICAL EVALUATION

Multivariate statistical method (PCA) was used to evaluate the variability among the data. In addition, the relationship between soil erosion parameters and some soil properties was determined by using correlation analysis. SPSS package program was used to perform these analyses (SPSS Package program).

RESULTS AND DISCUSSION

An ideal ophiolite sequence starts with the metomorphic sole rocks, which were formed during the ophiolite obduction at the base and show reverse metamorphic zoning due to the conditions brought by this formation, and this unit is overlain by tectonites, which are represented by peridotitic rocks with ultramafic character and exhibit excessive deformation. On these two units, there are crustal rocks that present various textural and mineralogical differences such as ultramafic cumulates, mafic cumulates, plate dyke complex and volcanics, according to the petrological moho-based distinction (Fig. 2).

Petrographically, metamorphic sole rocks generally consist of two different rocks, amphibolite and amphibole-schist, and amphibolites show granoblastic texture (Fig. 3a), while amphibole-schists show nematoblastic texture (Fig. 3b). Mineralogical compositions of both rock groups are seen to be composed of amphibole group minerals (hornblende, tremolite, actinolite), plagioclase, quartz and epidote. These rocks also present alterations in the form of epidotisation and iron oxide formations in ferromagnesian minerals. The tectonites in the study area generally present a mesh texture and are represented by serpentinite type rocks formed as a result of ocean floor metamorphism of rocks such as harzburgite, lerzolite and dunite (Figs 3c, d). Partially serpentinised rocks such as serpentinised lerzolite are also observed in places. The general mineralogical compositions of the rocks consist of olivine, clinopyroxene, orthopyroxene, serpentine group minerals (chrysotile, lizardite, antigorite, bastite) and opaque minerals (chromite, magnetite). Alterations in the form of talc formation are observed in these rocks. Ultramafic cumulates are represented by fresh pyroxenites together with serpentinised pyroxenites and verlites. Texturally, holocrystalline granular and mesh textures are dominant (Figs 3e, f). Pyroxenites are predominantly represented by ortho and clinopyroxene in their mineralogical composition, as well as a small amount of olivine, while the amount of olivine in serpentinised werlites increases. Opaque minerals such as magnetite and chromite are observed in all rocks. Talc, silica, serpentine and iron oxide formations are common alterations observed in rocks. The mafic cumulates are represented by olivine gabbros and draw attention by presenting cumulate texture both at field size and at microscopic scale (Fig. 3g). They also exhibit holocrystalline granular and poikilitic textures at microscopic scale. Their general mineralogical composition is composed of plagioclase, olivine and pyroxene, and they present alterations in the form of iddingsitisation, chloritisation and serpentinisation. Since isotropic gabbros are observed in a very narrow area in the region, neither soil nor rock samples were taken from this group. Sheeted dykes are represented by diabases with subophytic texture and are composed of plagioclase, pyroxene, olivine and secondary alteration minerals such as chlorite, calcite and epidote. It has been determined that they are affected by a wide spectrum of alterations such as chloritisation, calcitisation, carbonation, silicification, uralitisation and iron oxide formation (Fig. 3h). The last of the ophiolitic rocks collected from the study area are the volcanic rocks representing the highest level of the succession. This group of rocks consists of all compositions ranging from basic to acidic at the maturity stage in the formation of the ophiolite on the intraoceanic subduction zone. In addition to an extremely acidic rock such as rhyodacite, the rocks collected from Afsin and Elbistan regions also contain alkali basalt, spilitic basalt and basalt, which are representative of basic rocks (Figs 3i, j). Intersertal, hyalopilitic, amygdaloidal and porphyritic textures are observed in these rocks. Rhyodacites have the main mineral compositions such as quartz, K feldspar, plagioclase and biotite, while the main minerals such as Plagioclase, pyroxene and olivine are observed in the basaltic group. Secondary mineral formations such as calcite, epidote, chlorite and zeolite are observed in this group. In addition, both primary and secondary opaque mineral formations are observed. Alterations, on the other hand, show the results of very different processes such as chloritisation, epidotisation, opacitisation, zeolisation, silicification, carbonation, spilitisation, argillisation, and sossuritisation.

The descriptive statistical results of the soils formed on the metamorphic sole, tectonite and oceanic crustal rocks are given in Table 1. The average pH of the soils formed on these units was determined as 7.09, 7.26 and 7.20, respectively. The average pH of these soils is in the neutral soil class according to the classification system proposed[28]. The average organic matter content of the soils was determined as 1.36, 1.88 and 1.61%, respectively. According to this, the average organic matter content of the soils is in the class of soils with low organic matter content according to the classification system proposed[28].

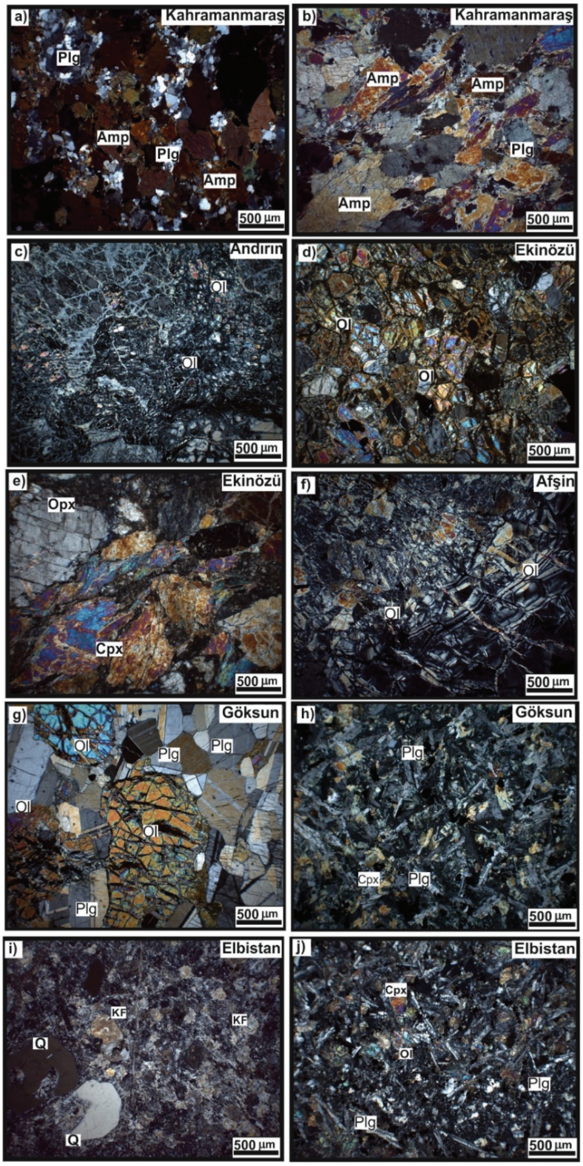

Fig. 3. Granoblastic – a; nematoblastic texture, in tectonites – b; sieve texture, in ultramafic cumulates c, d; cumulate texture – e; sieve texture in cumulate gabbros – f; cumulate texture in sheeted dykes – g; subophytic texture, in rhyodacites from volcanic rocks – h; corroded texture – i; intersertal texture – j (Crossed Polarized light, Amp: amphibole Plg: Plagioclase, Ol: Olivine, Opx: Orthopyroxene, Cpx: Clinopyroxene, KF: K Feldspar, Q:Quartz)

Table 1. Descriptive statistics results of soils composed of metamorphic sole, mantle tectonic and oceanic crust rocks

Soil properties	Unit	Metamorphic sole				Mantle tectonites				Oceanic crust			
		Min.	Max.	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
pH		6.43	7.50	7.09	0.44	6.55	8.03	7.26	0.42	6.34	7.91	7.20	0.43
OM	%	0.80	2.29	1.36	0.53	0.46	3.48	1.88	0.70	0.63	2.72	1.61	0.58
EC	dS/m	0.59	3.40	1.58	0.98	0.50	2.54	1.65	0.65	0.59	5.23	1.98	1.02
$CaCO_3$	%	0.40	3.59	1.12	1.22	0.20	17.53	1.99	3.98	0.60	7.17	1.91	2.25
Clay	%	7.03	25.70	15.55	7.10	6.82	56.63	23.23	12.90	4.62	45.90	20.64	10.45
Sand	%	43.60	85.34	63.84	13.66	27.33	89.42	59.64	17.05	29.50	86.19	61.30	16.04
Silt	%	7.64	30.70	20.61	7.45	3.16	25.40	17.13	6.53	6.17	27.59	18.06	6.40
AS	%	32.00	61.00	43.00	10.55	29.00	86.00	54.16	15.12	29.64	77.51	53.77	15.64
DR	%	40.00	71.00	58.50	11.24	9.00	84.46	42.73	22.80	12.52	77.00	43.29	23.13
SSI	%	6.55	30.70	15.83	8.71	1.64	57.27	25.76	15.51	4.16	59.90	25.66	16.56
ER	%	45.16	87.09	67.93	16.63	7.19	95.00	46.36	27.64	10.90	90.70	49.04	28.83
CR		2.89	13.23	6.75	3.77	0.77	13.66	5.06	4.05	1.18	20.64	5.86	4.96

SD – Standard deviation; OM – Organic matter; EC – Electrical conductivity; AS – Aggregate stability; DR – Dispersion ratio; SSI – Structure stable index; ER – Erosion rate; CR – Clay ratio.

While the average soil clay contents composed of the units of the ophiolitic suite (metamorphic sole, mantle tectonites and crust) were 15.55, 23.23 and 20.64%, respectively, the average sand contents were determined as 63.84, 59.64 and 61.30%. Considering the AS of the soils, the highest value was seen in the soils (54%) developed on the tectonitic main material, while the lowest AS value was observed in the soils formed on the metamorphic sole rocks (43%) (Table 1). The fact that the soils developed on the tectonite parent material exhibit a more stable structure compared to other units can be associated with higher clay and lower sand content. AS which is one of the erodibility parameters, showed a positive correlation with the % clay content from the soil properties and a negative correlation with the % sand content (Table 2).

Since the crustal rocks are in the basic igneous rock group and do not contain organic material specific to sedimentary rocks in their formation, physico-chemical weathering processes are more dominant by nature. The fact that the main mineral of peridotites is olivine, an nesosilicate, can be considered as one of the main reasons for this situation. Since nesosilicates are composed of independent SiO_4 tetraeders, these minerals can be easily altered due to isomorphism taking place in their cycle. Therefore, it is a natural result that the clays resulting from the weathering of rocks rich in these minerals are also abundantly observed in the final soils. It was observed that the results obtained from both the organic matter content and the clay content tests were at the lowest level in the metamorphic sole rocks in the three groups of rocks evaluated (Table 1). As stated above, this situation is basically related to the silicate structure, and the structure of the components of the metamorphic sole rocks is decisive. The main components of metamorphic slice rocks are amphbolites, and in these rocks, plagioclases together with amphibole group minerals are the main minerals of the rock. Since amphiboles are in the group of double-chain silicates (inosilicates) and plagioclases are in the group of lattice silicates (tectosilicates), the sensitivity of these minerals to alteration is lower than mantle tectonites. In this context, these rocks provide sand-size weathering products rather than clay.

The dispersion rates (DR) of soils composed of different units of ophiolite (metamorphic sole, mantle tectonites and oceanic crust) were determined as 58, 42 and 43%, respectively. As a result of the studies carried out by some researchers, it was stated that the DR of the soils is above 15%, the soils can be easily eroded, and when it is below 15%, it is resistant to erosion[24,29,30]. As can be seen in Table 1, the soils composed of these units have high erosive properties and this is associated with lower clay and organic matter contents compared to other soils. In addition, the DR of the soils consisting of these units showed a negative relationship with the clay content at the 1% significance level and a positive correlation with the sand content at the 1% significance level (Table 2).

Table 2. Correlation analysis results between soil erodibility parameters and some soil properties

Soil properties	Metamorphic sole					Mantle tectonites					Oceanic crust				
	AS	DR	SSI	ER	CR	AS	DR	SSI	ER	CR	AS	DR	SSI	ER	CR
pH	0.427	–0.492	0.490	–0.564	–0.327	–0.603**	0.611**	–0.650**	0.661**	0.832**	0.058	0.046	0.013	0.014	–0.084
OM	0.710	–0.698	0.714	–0.529	–0.572	–0.036	0.050	–0.190	0.083	0.023	0.320	–0.484*	0.503*	–0.400	–0.413
EC	–0.240	0.251	–0.235	0.340	0.626	0.485*	–0.603**	0.482*	–0.606**	–0.614**	0.692**	–0.638**	0.729**	–0.654**	–0.574**
$CaCO_3$	–0.309	0.300	–0.299	0.274	0.155	–0.476*	0.512*	–0.401	0.525*	0.639**	–0.165	0.235	–0.238	0.182	0.099
Clay	0.967**	–0.968**	0.973**	–0.986**	–0.921**	0.915**	–0.799**	0.949**	–0.835**	–0.826**	0.905**	–0.897**	0.952**	–0.922**	–0.840**
Sand	–0.929**	0.934**	–0.937**	0.914*	0.942**	–0.860**	0.796**	–0.924**	0.841**	0.924**	–0.882**	0.880**	–0.939**	0.915**	0.865**
Silt	0.781	–0.789	0.790	–0.735	–0.849*	0.439	–0.500*	0.538*	–0.547*	–0.780**	0.734**	–0.740**	0.798**	–0.788**	–0.796**

**OM – Organic matter; EC – Electrical conductivity; AS – Aggregate stability; DR – Dispersion ratio; SSI – Structure stable index; ER – Erosion rate; CR – Clay ratio.

The structure stable index (SSI) values of the soils were obtained the highest in the soils developed on the tectonite main material (25.76%), and the lowest in the soils formed on the metamorphic main material (15.83%). Leo[22] has stated that soils with an SSI value below 40% are highly susceptible to erosion. As the SSI values of the soils increase, their tendency to erode decreases. Accordingly, it was determined that the erosion tendency of soils developed on the metamorphic sole parent material was higher than the soils formed on other units of the ophiolite. This situation was associated with the higher sand content of soils composed of metamorphic sole rocks. As seen in Table 2, the SSI of the soils showed a positive relationship with clay and a negative relationship with sand.

Considering the soil erosion rates (ER) of the soils of the study area, the highest value was observed in the soils formed on the metamorphic sole parent material (67.93%), while the lowest value was observed in the soils developed on the tectonite parent material (43.36%) (Table 1). As the ER values of the soils decrease, their erosion tendency decreases. Lal[24] stated that soils are resistant to erosion if the ER is less than 10%. Although the soils developed on the tectonitic parent material are seen as the soils with the lowest erosion tendency, it has been determined that the soils formed from these units have low resistance to erosion.

Clay ratios (CR) of soils formed on different units of ophiolite are given in Table 1. The highest CR was observed in the soils formed on the metamorphic sole parent material (6.75), while the lowest CR was detected in the soils developed on the tectonitic parent material (5.06). Bryan[21] took the CR value as a basis and revealed that this ratio was below 2 in erosion-resistant soils. Since the CR of the soils of the study area are above 2, they are classified as unstable soils. The CR, which is one of the erodibility parameters, showed a negative correlation with clay content at 1% significance level and a positive correlation with sand at 1% importance level (Table 2).

The principle component analysis results of the soils developed in the metamorphic sole parent material of the ophiolitic sequence are given in Table 3a. Accordingly, a 2-factor result was obtained with the eigen value of the soils greater than ≥ 1. It explains 72.919% of the variance in the first of the determined factors and 15.5% in the second. These two factors explained 88.42% of the total variance (Table 3a). PC-1, which can explain 72.9% of the variance in soil properties; clay gave positive charge values with SSI, AS and OM, and negative charge values with DR, ER, CR and sand. PC-2, which explaining 15.5% of the variance, showed a positive charge with soil properties pH and lime (Table 3a). The low number of factors and the high variance values of the obtained components reflect the fact that the relevant variables are measured close to the truth. Kalayci[31] stated that the variables with a strong correlation between parameters were included in the same factor and the aim of principal component analysis was to obtain very few components that represented the relationships between parameters at the highest level.

The principle component analysis results of the soils formed from the mantle part of the ophiolite are given in Table 3b. According to the Tablo 3b, a 2-factor result with an eigen value ≥1 was obtained. It explained 69.08% variance in the first of the determined factors and 13.5% in the second. PC-1, which can explain 69.08% of the variance in soil properties; positive loading with sand-CR, ER, DR and pH. It showed negative loading with SSI, clay, AS and silt. PC-2, which can explain 13.5% of the variance showed positive charge with lime and negative charge with organic matter (Table 3b). It is seen in Table 3b that the aggregate stability of the soils developed on the mantle parent material and SSI show a stronger relationship with the % clay content.

Table 3. Principal component analysis (PCA) of soils formed from a metamorphic, mantle and oceanic crustal section

Soil Properties	Metamorphic sole		Mantle tectonites		Oceanic crust	
	PC-1	PC-2	PC-1	PC-2	PC-1	PC-2
SSI	0.991	–	–0.961	–	0.964	–
DR	–0.988	–	0.905	–	–0.938	–
Clay	0.985	–	–0.932	–	0.968	–
AS	0.978	–	–0.907	–	0.927	–
ER	–0.965	–	0.936	–	–0.957	–
Sand	–0.961	–	0.972	–	–0.983	–
CR	–0.919	–	0.950	–	–0.871	–
Silt	0.822	–	–0.697	–	0.882	–
OM	0.703	–	–	–0.910	0.507	–
$CaCO_3$	–	0.943	0.507	0.745	–	0.889
pH	–	0.659	0.807	–	–	0.788
Eigen values	8.021	1.705	7.599	1.489	7.89	1.610
Contribution rate (%)	72.919	15.500	69.082	13.53	65.72	13.36
Cumulative Contribution rate (%)	72.919	88.420	69.082	82.62	65.72	79.08

*Indicate strong loading (> 0.50).

High clay content in soils is one of the most important factors in aggregation. Some researchers have reported that the amount of clay is more effective than the type of clay in aggregation in soils[32]. It has been reported that there are significant positive relationships between the clay content of soils and aggregate stability[33–39]. The organic matter content of the soils did not show as strong a relationship as the % clay content and took place in PC-2.

The principal component analysis of the soils formed by the oceanic crustal section is given in Table 3. According to Table 3, 2-component result with an eigenvalue ≥1 was reached. The variance of 65.72% in the first component and 13.36% in the second component is explained. These two components explained 79.09%

of the total variance (Table 3). PC-1, which determined 65.72% of the variance as a result of factor analysis; clay, OM, AS and SSI showed positive loading, sand, CR, ER and DR showed negative loading. PC-2, which defined 13.36% of the variance; gave positive charge values with lime and pH (Table 3). OM and % clay showed a strong relationship on AS and SSI of soils (Table 3). Many researchers have reported that the organic matter and clay amount of the soils are effective in aggregation, and the aggregation increases due to the increase in the organic matter and clay content in the soil[40–46]. In addition, the % sand content of the soils; showed significant relationships with ER, DR and CR (Table 3).

CONCLUSIONS

In this study, the erodibility parameters of the soils developed on the units of the ophiolitic suite (metamorphic sole, mantle tectonites and oceanic crust) in the Eastern Mediterranean region were investigated.

Soils formed by the units of the ophiolitic sequence have high dispersion rates, low aggregate stability and low structure stable index values, which are among the erodibility parameters. It has been observed that the soils developed on all units of the ophiolite do not exhibit a stable structure and are sensitive to erosion. The main reason for this situation is that the degree of resistance to alteration varies between the forms of silicates that form the ophiolitic rocks. Due to the sensitivity of the soils formed on these units to water and wind erosion, they have the potential to be easily transported with the specified agents. The transportation of soils containing heavy metals (Ni, Cr, Co) and their turning into dust after drying can be considered a risk for the people living in the region. For this reason, special management measures are needed for agricultural use of soils containing heavy metals formed on different parent materials.

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