



# Soil quality assessment for olive groves areas of Menderes District, Izmir-Turkey

Belgin Doğan <sup>a</sup>, Coşkun Gülser <sup>b,\*</sup>

<sup>a</sup> Menderes Rural Directorate of Agriculture, Izmir, Turkey

<sup>b</sup> Ondokuz Mayıs University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Samsun, Turkey

## Abstract

This study was carried out to determine assessment of soil quality for olive groves areas of Akçaköy, Çatalca, Efemçukuru, Görece and Yeniköy villages in Menderes district of Izmir-Turkey. The surface soil samples (0-20 cm) were taken from 19 olive groves areas of Menderes District. Soil physical and chemical quality indicators were analyzed and classified in 4 suitability classes for olive production. In olive groves areas, soil reaction (pH) gave positive correlations with clay, exch. Ca, CaCO<sub>3</sub> contents, and significant negative correlations with sand, available Fe, Mn and Zn contents. Soil organic matter (OM) content showed significant positive correlations with EC, P, exch. Ca and a significant negative correlation with bulk density. Electrical conductivity (EC) values gave significant positive correlations with clay, OM, exch. Ca contents. Soil quality index values for the olive groves areas ranged between 0.44 and 0.77 with a mean of 0.60. The olive groves areas at Akçaköy and Çatalca villages of Menderes District were generally suitable for olive production. According to the soil quality index (SQI) values, only one of the 19 olive groves areas was found in very suitable (S1:1.00-0.75) class, the other areas were classified as 8 in suitable (S2:0.75-0.60), 6 in marginal suitable (S3:0.60-0.50) and 4 in non-suitable (N:<0.50) for olive growth. The most restricting soil factors for olive growth generally became low OM, low nutrient contents and high clay and sand contents than that of suggested levels. The SQI values had significant positive relations with silt content of the soils while they gave negative correlations with clay and sand contents. It indicates that moderate or loamy soil textural classes are important for high olive production. The SQI values also gave a significant positive correlation with olive yields. Evaluation of soil physical and chemical properties with a SQI value is important for assessment of olive groves areas in sustainable soil management system.

**Keywords:** Soil quality, olive, yield, soil properties.

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## Introduction

Soil quality plays a great role in plant growth and production with biological transformations, degradation of organic matter, hydrological cycle and chemical reactions in soil. Soil quality covers the functions of sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation within natural or managed ecosystem boundaries (Karlen et al., 1997). Sustainable soil management practices for a specific crop production can be controlled by chemical, physical, and biological soil properties and their interactions (Sofu et al., 2010; Fountas et al., 2011; Palese et al. 2014; Calabrese et al., 2015).

Although olive trees can grow up several soil types, they grow and produce well in moderate or coarse textured soils within a wide range of pH from moderately acid (5.6) to moderately alkaline (8.5) and well drained calcareous soils (El-Kholy, 2010). Fountas et al. (2010) studied on site-specific management in an

Belgin Doğan  
\* Coşkun Gülser



✉ : [blgndgn@hotmail.com](mailto:blgndgn@hotmail.com)  
✉ : [cgulser@omu.edu.tr](mailto:cgulser@omu.edu.tr)



id : --  
id : 0000-0002-6332-4876 (Corresponding author)

olive tree plantation area in Greece with measuring the penetration resistance, soil texture, soil organic matter, pH, phosphorus, nitrate N, potassium, Mg, Zn, Mn, Fe, B and Ca contents in surface soil samples (0-30 cm) taken a 30-m systematic sampling grid. They found that organic matter content was 22% greater and penetration resistance was 26% less under no-tillage areas, and there was a considerable spatial variation in yield and soil properties. López-Granados et al. (2004) investigated soil variation and site-specific fertilization of nutrients in olive groves farms in southern Spain depending on the spatial variation of leaf nutrients. Calabrese et al. (2015) studied the short-term effects of the grassing on biodiversity and soil quality of Mediterranean ancient olive orchards. They found that few soil quality indicators had responsiveness in indicating the effects of management systems and of the grassing on biodiversity and soil properties. They concluded that there was a clear positive influence of the organic management systems on some soil quality parameters and on biodiversity. Sofo et al. (2010) compared to effects of sustainable and conventional practices on the composition, functional and metabolic diversity of soil microbial communities in a Mediterranean olive orchard. They found that sustainable agricultural practices stimulated soil microorganism activity and improved olive yield and fruit quality. Palese et al. (2014) studied the effect of soil management on soil physical characteristics and water storage in a mature rainfed olive orchard. They found that sustainable soil management techniques, such as cover cropping and pruning recycling, had higher autumn–winter rainwater storage in the soil than the conventional technique based on tillage.

Most soil properties show interaction each other generally related with land use, land characteristics and management practices (Ekberli and Kerimova, 2005; Karaca and Gülser, 2015; Karaca et al., 2018; Kars and Ekberli, 2020). Many studies related to land suitability for crop cultivation have been conducted in different areas (Mandal et al. 2002; Lake et al. 2009; Khormali et al, 2012). Lake et al. (2009) studied land suitability for olive production using simple limitation method. They found that the most limiting factors of land characteristics for olive production were topography, coarse fragmentation, shallow soil depth, salinity and alkalinity. Similarly Khormali et al. (2009) studied the effects of some soil and topographic characteristics on tea production. They found that solum thickness, thickness of the epipedons, clay content, organic carbon, total nitrogen, carbonate, and exchangeable magnesium were significantly different on different slope positions in the near surface layers, but the differences were not reflected in the tea yield.

Olives are cultivated on 864.000 ha area which comprises 2.3% of agricultural land and 22% of horticultural land in Turkey (Anonymous, 2018). Mediterranean and Aegean regions are the main regions for olive production in Turkey. Most of olive groves areas with 75% are on mountainous land and only 8% of total olive production is under irrigation. While the mean olive production in Turkey between 2010 and 2019 was 1.698.446 ton/year, total olive productions for tables and oil were 415.000 and 1.110.000 tons in 2019, respectively (TUIK 2020). According to these values, the annual mean total olive production in Turkey can be estimated as 1.96 ton/ha year. Chatzistathis et al. (2009) determined that soil types impacted on nutrient uptake and utilization efficiency by olive trees. Álvarez et al. (2007) reported that differences in some soil properties and management effect on specific soil properties varied between soil types. They suggest that farm and soil type should be taken a careful consideration in any attempt to evaluate soil condition in olive groves. There is not much study about soil quality evaluation for a specific crop production. Recently Doğan and Gülser (2019) studied the assessment of soil quality for vineyard fields in western Anatolia. The objective of this study was to determine assessment of soil quality for olive groves areas located in some villages of Menderes District, Izmir-Turkey.

## Material and Methods

The village names and locations of 19 olive groves areas of Menderes District of Izmir-Turkey are given in Table 1. In the study, 19 surface soil samples (0-20 cm) were taken from Akçaköy (3), Çatalca (4), Görece (5), Efemçukuru (2) and Yeniköy (5) villages located on the elevations between 138 and 617 m above sea level. After the harvest season completed in 2011, the olive yield (ton/ha) was also recorded for each field.

Some properties of the soil samples were determined using the following methods: particle size distribution by the hydrometer method (Day, 1965); bulk density (BD) by soil core method (Demiralay, 1993), soil reaction (pH) in 1:1 (w:v) soil water suspension by pH meter; electrical conductivity (EC<sub>25</sub><sup>°C</sup>) in the same suspension by EC meter; and exchangeable cations (Ca, Mg, K, Na) by ammonium acetate extraction (Kacar, 1994), available phosphorus by Olsen's method (Olsen et al., 1954), DTPA extractable Fe, Mn, Zn, Cu according to Lindsay and Norvell (1978). The soil organic matter content was determined by the modified Walkley-Black method (Kacar, 1994). The lime content was determined by Scheibler Calcimeter (Nelson, 1982). Exchangeable Ca, Mg, K and Na (ECaP, EMgP, EKP, ENaP) were calculated with dividing an exch. cation by the sum of exch. cations.

Table 1. Villages and locations of olive groves areas in Menderes District, Izmir-Turkey

Location	Coordinates		Elevation (m)	Location	Coordinates		Elevation (m)
	North 'N'	East 'E'			North 'N'	East 'E'	
Akçaköy-1	38°14.675'	27°05.628'	154	Çatalca-1	38°15.875'	27°04.509'	201
Akçaköy-2	38°15.108'	27°05.873'	145	Çatalca-2	38°15.274'	27°04.485'	179
Akçaköy-3	38°15.616'	27°06.121'	145	Çatalca-3	38°15.838'	27°04.489'	195
Efemçukuru-1	38°16.740'	26°57.939'	617	Çatalca-4	38°15.283'	27°04.774'	189
Efemçukuru-2	38°16.787'	26°57.872'	615	Görece-1	38°16.486'	27°07.721'	138
Yeniköy-1	38°12.271'	27°01.835'	216	Görece-2	38°16.179'	27°07.242'	145
Yeniköy-2	38°12.787'	27°02.497'	202	Görece-3	38°16.352'	27°07.579'	143
Yeniköy-3	38°14.793'	27°03.508'	202	Görece-4	38°16.805'	27°07.870'	174
Yeniköy-4	38°12.351'	27°01.512'	192	Görece-5	38°16.793'	27°07.559'	148
Yeniköy-5	38°12.317'	27°01.782'	219				

To determine the soil quality index values for each olive groves area, the following geometric mean equation was used

$$SQI = \sqrt[n]{a_1 \cdot a_2 \cdot a_3 \dots a_n}$$

where; SQI: soil quality index; a: score of each soil parameter between 1.0 and 0.2 given in Table 2, n is number of soil parameter.

SQI values for olive groves areas were classified as; S<sub>1</sub>: between 1.00 – 0.75 as very suitable S<sub>2</sub>: between 0.75 – 0.60 as suitable S<sub>3</sub>: between 0.60 – 0.50 as marginal suitable and N: < 0.50 as non-suitable for vineyard growth.

The correlations among the research data were performed using the SPSS 17 software package programme.

## Results and Discussion

### Soil Properties of Some Olive Groves Areas in Menderes District

According to the descriptive statistics of research data given in Table 2, clay content of the areas varied between 10.18% and 41.23% with a mean of 22.13%. While only one area had clay (C) soil textural class, the soil textural classes of the other areas were sandy loam (SL) in 9, sandy clay loam (SCL) in 5, clay loam (CL) in 2, sandy clay (SC) and loam (L). Olive trees generally grow well in moderate to coarse textural and well drained soils (Tombesi and Tombesi, 2007; Chatzistathis et al. 2010; El-Kholy, 2010). Álvarez et al. (2007) reported that soil textural classes in organic and natural olive groves areas in southern Spain were loam or sandy loam. In this study, the soils of olive groves areas have generally coarse or moderate textural classes. The bulk density (Db) values of the soils varied between 1.05 g/cm<sup>3</sup> and 1.64 g/cm<sup>3</sup>. Palese et al. (2014) reported that bulk density values of surface soils (0-20 cm) under sustainable and conventional management in a rainfed olive orchard varied between 1.23 g/cm<sup>3</sup> and 1.52 g/cm<sup>3</sup>. An ideal bulk density to root growth based on sandy loams and loams textural soils should be lower than 1.40 g/cm<sup>3</sup> (Leake 2001; Soil Qual. Ins. Staff, 1999). If the bulk density value of these textural soils is higher than 1.63 g/cm<sup>3</sup>, it may affect plant root growth (Soil Qual. Ins. Staff, 1999). While the Db values of 9 olive groves areas were lower than 1.40 g/cm<sup>3</sup>, the Db values of 9 areas were between 1.40 g/cm<sup>3</sup> and 1.63 g/cm<sup>3</sup>.

The soil pH values ranged from 5.90 to 7.95 were classified as neutral in 8, slightly acid in 4, moderately acid in 3, slightly alkaline in 1 and moderately alkaline in 3 olive groves areas. An ideal soil pH level for olive growth should be between 6.0 and 7.0 (Leake, 2001). The most suitable soil pH in terms of olive growth is neutral, 10 soil samples were found to be in the ideal pH range. The electrical conductivity of the soils varied between 0.15 dS/m and 0.73 dS/m. According to the classification of Soil Quality Ins. Staff (1999), all of the soils were found in non-saline class. The lime contents of the soils ranged between 0.04% and 54.03%. Ferreira Llamas (1984), reported that lime content range in soil for ideal olive growth should be between 9% and 19%, but olive also grows in the lime content higher than these values in soil. In this study only for soil had lime content values greater than 19%. Gálvez et al. (2004) found that there is a negative correlation between lime content in 0-30 cm soil depth and olive canopy development, the canopy growth restricted when the lime content in soil increased to 58-68 % levels. In this study, there is not much lime content in soils to restrict olive growth.

Table 2. Descriptive statistics for some soil properties, soil quality index values and olive yields (n=19).

	Minimum	Maximum	Mean	Std. Dev.	Skewness	Kurtosis
Clay, %	10.18	41.23	22.13	9.13	0.714	-0.451
Silt, %	14.36	39.95	22.89	7.03	0.891	0.478
Sand, %	26.13	72.55	54.97	12.67	-1.29	1.11
Bulk density, g/cm <sup>3</sup>	1.05	1.64	1.38	0.17	-0.35	-1.03
pH (1:1)	5.90	7.95	6.84	0.65	0.140	-1.064
EC, dS/m	0.15	0.73	0.35	0.16	0.798	0.144
CaCO <sub>3</sub> , %	0.04	54.03	8.84	15.15	1.905	3.266
Organic Matter, %	0.20	2.88	1.55	0.72	0.114	-0.617
Av. P, mg/kg	1.98	94.15	24.16	24.29	1.760	2.874
K, cmol/kg	0.11	0.74	0.33	0.17	0.812	0.222
Ca, cmol/kg	4.06	27.68	12.75	7.60	0.360	-1.150
Mg, cmol/kg	1.01	8.87	3.45	2.13	1.279	0.940
Na, cmol/kg	0.23	0.50	0.31	0.07	1.477	1.936
Exch. K (EKP), %	0.47	8.95	2.73	2.46	1.542	1.523
Exch. Ca (ECaP), %	57.13	90.40	72.87	10.49	0.122	-1.348
Exch. Mg (EMgP), %	7.69	37.36	22.07	8.57	0.027	-1.048
Exch. Na (ENaP), %	0.86	4.84	2.33	1.14	0.639	-0.434
Fe, mg/kg	3.50	23.40	11.24	7.44	0.574	-1.295
Cu, mg/kg	0.50	2.52	1.38	0.62	0.460	-0.776
Mn, mg/kg	7.60	155.76	36.95	41.32	2.268	4.598
Zn, mg/kg	4.78	392.20	59.18	88.04	3.307	12.402
Soil quality index (SQI)	0.44	0.77	0.60	0.10	-0.108	-0.860
Olive yield, ton/ha	1.50	5.00	1.87	1.49	1.040	0.212

The organic matter contents of the soils ranged from 0.20% to 2.88% (Table 2). [Ferreira Llamas \(1984\)](#) reported that soil organic matter content should be at least 1.0% level for olive growth. The organic matter content level of surface soil should be around 3.0% for ideal olive growth ([Leake, 2001](#)). While the organic matter contents of 5 soil samples in this study were lower than 1.0%, organic matter contents of 11 soil samples were between 1.0% and 2.5%. The organic matter content of 3 soil samples were only found as suitable for olive growth. The available phosphorus contents were between 1.98 mg/kg and 94.15 mg/kg with a mean of 24.16 mg/kg. [Leake \(2001\)](#) reported that available phosphorus content in soil should be higher than 20 mg/kg, and it should be around 50 mg/kg for ideal olive growth. In this study, available P contents of 12 soil samples were lower than 20 mg/kg and classified as deficient.

The K content and exch. K percentage (EKP) of the soil samples were between 0.11 and 0.74 cmol/kg, and 0.47% and 8.955, respectively. Researchers reported that the K content of soils should be at least 0.26 cmol/kg for good quality olive production and exch. K percentage in soil should be between 3% - 10% for ideal olive growth ([Ferreira Llamas 1984; Leake 2001](#)). While the exch. K percentages of 5 soils were more than 3%, the others were lower than this value and classified as K deficient for olive growth. The Ca contents and exch. Ca percentages (ECaP) of the soils were found as between 4.06 cmol/kg and 27.68 cmol/kg, and between 57.13% and 90.40%, respectively (Table 2). The Mg contents and exch. Mg percentages (ECaP) of the soils were between 1.01 cmol/kg and 8.87 cmol/kg, and between 7.69% and 37.36%, respectively. The ECaP and EMgP of olive groves soils should be between 65-75% and between 12-15% ([Leake 2001; Du Preez 2005](#)). The ECaP values of 6 soil samples were found less than 65% and the others were higher than this critical value. While the EMgP values of 2 soil samples were found to be less than 12%, 5 of them were between 12-150% and 9 of them were higher than 15%. The Na contents and exch. Na percentages (ENaP) of the soils were found as between 0.23 cmol/kg and 0.50 cmol/kg, and between 0.86% and 4.84%, respectively. The ideal range of ENaP for olive growth was suggested as less than 7.0% ([Leake 2001](#)). In this study all olive groves areas had lower ENaP than this critical value. The mean values of available Fe, Cu, Mn, and Zn contents of the soils were 11.24, 1.38, 36.95 and 59.18 mg/kg, respectively (Table 2). [Fernández-Escobar \(2010\)](#) reported that the critical values of DTPA extractable Fe, Cu, Mn and Zn in soil for olive growth are 3 mg/kg, 0.2 mg/kg, 1.4 mg/kg and 0.8 mg/kg, respectively. According to micronutrients, soil requirements for olive growth were suggested as 5-8 mg Mn/kg, 3-5 mg Cu/kg and 10 mg Zn/kg ([Du Preez, 2005](#)).

## Soil Quality Classification for Olive Groves Areas

The selected soil quality indicators were classified between 1.00 (ideal) and 0.20 (poor) according to the soil requirements of olive plant in the literatures (Ferreira Llamas 1984; Soil Qual. Ins. Staff, 1999; Leake, 2001; Du Preez 2005; Álvarez et al. 2007; Tombesi and Tombesi, 2007; Fernández-Escobar 2010; Chatzistathis et al. 2010; El-Kholy, 2010; Palese et al. 2014) and given in Table 3.

Table 3. Suitable classes of some soil properties for olive growth.

Suitable classes	Ideal	Good	Moderate	Poor
Score	1.0	0.8	0.5	0.2
Soil texture*	L, SCL	CL, SiCL, SiL	C, SiC	others
Bulk density, g/cm <sup>3</sup>	<1.2	1.2-1.4	1.4-1.6	>1.6
pH (1:1)	6.8-7.3	6.0-6.8 or 7.3-8.0	6.0-5.0 or 8.0-8.5	<5.0 or >8.5
EC dS/m	<2.7	2.7-3.8	3.8-6.0	>6.0
Organic matter, %	>2.5	2.5-2	2-1	<1
Phosphorus, mg/kg	50-20	20-10	10-5	<5
Ca, cmol/kg	>12	12-10	10-8	<8
Mg, cmol/kg	>2	2-1.6	1.6-1.2	<1.2
K, cmol/kg	>0.60	0.60-0.40	0.40-0.20	<0.20
CaCO <sub>3</sub> , %	9-19	7-9 or 19-22	7-5 or 22-25	<5 or >25
Zn, mg/kg	>15	15-10	10-5	<5
Mn, mg/kg	>8	8-5	5-2	<2
Cu, mg/kg	>5	5-3	3-1	<1
Fe, mg/kg	>5	5-2	2-1	>1

\*L: loam, Si: silt, C: clay, S: sand

The soil quality index values calculated for the olive groves areas varied between 0.44 and 0.77 with a mean of 0.60 (Table 2). The olive groves areas at Akçaköy and Çatalca villages were generally found to be suitable for olive production (Figure 1A). The 4 olive groves areas at Efemçukuru, Görece and Yeniköy villages were found to be non-suitable for olive growth and classified in N class. According to the frequency distribution of soil quality classes given in Figure 1B, only one (5.3%) of the 19 olive groves areas was determined as very suitable (S1) class, and the other areas were classified as; 8 areas (42%) in suitable (S2), 6 areas (31.6%) in marginal suitable (S3) and 4 areas (21%) in non-suitable (N) class for olive growth.

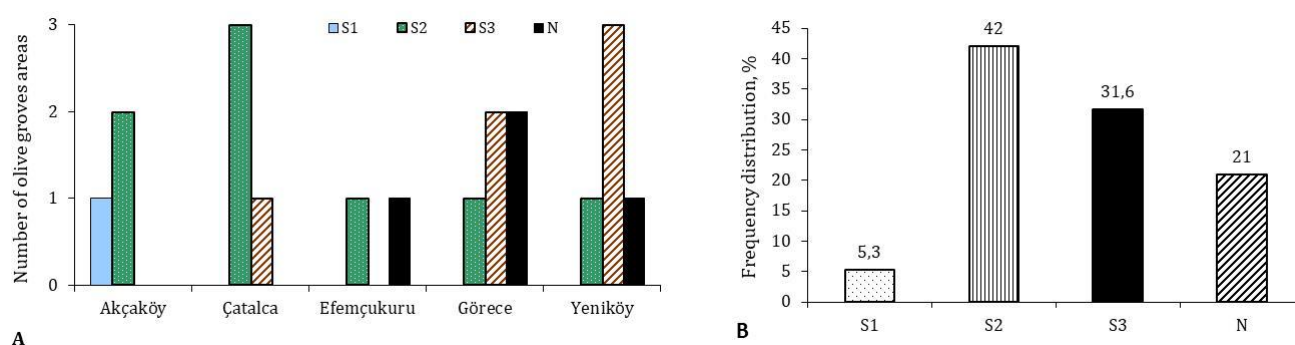


Figure 1. A) Soil quality classification of olive groves areas at different locations; B) Frequency distribution of soil quality classes (S<sub>1</sub>:very suitable S<sub>2</sub>: suitable, S<sub>3</sub>:marginal suitable, N:non-suitable).

Restricting soil factors for olive growth in the areas classified as S<sub>2</sub> generally became lower OM, exch. K and CaCO<sub>3</sub> contents than that of the suggested levels. Non suitable soil texture, lower OM, exch. Ca, exch. K, CaCO<sub>3</sub> and available Cu contents were the restricting soil factors for olive groves areas classified as S<sub>3</sub>. Except EC, available Zn, Mn and Fe contents, all physical and chemical soil properties of the olive groves areas classified as non-suitable (N) were lower than that of the suggested levels. Lake et al. (2009) determined that the most important restricting factors for olive production were coarse fragment, shallow soil depth, salinity and alkalinity. Leake (2001) indicated that most soils in the areas of interest to olive growers can suffer the some productivity problems such as; low organic matter content. Low to very low soil fertility, a strong texture contrast between surface and sub horizons, acidity and sodicity. Doğan and Gülser (2019) reported that the restricting soil factors for vine growth fields classified as suitable (S<sub>2</sub>) and marginally suitable (S<sub>3</sub>) classes generally became low pH, lower organic matter, P, Fe, Mn, Cu, Mg and K contents than that of suggested levels.

The correlation matrix among the soil properties are given in Table 4. Soil reaction (pH) had positive relations with clay, exch. Ca, CaCO<sub>3</sub> contents, significant negative relations with sand, available Fe, Mn and Zn contents. Organic matter (OM) content had significant positive correlations with EC, P, exch. Ca and a significant negative correlation with Db. Electrical conductivity (EC) values had significant positive correlations with clay, OM, exch. Ca contents. There were also significant positive correlations among DTPA extractable micro nutrient contents of soils. Gülser et al. (2015) reported that compost and organic residue applications to soil in a hazelnut orchard increased plant available nutrient contents of the soil and OM content had significant positive relations with EC, exch. Ca, and sum of exch. cations. In another study, Candemir and Gülser (2011) determined that soil bulk density decreased with organic waste addition, and bulk density had generally significant negative relations with OM and other soil properties. They reported that the soil quality indicators of clay and loamy sand soils improved by different agricultural waste applications.

Table 4. Correlation matrix among the soil properties of vineyard fields.

	Si	S	Db	pH	EC	OM	P	K	Ca	Mg	Na	CaCO <sub>3</sub>	Fe	Cu	Mn	Zn
C	0.22	<b>-0.84**</b>	-0.45	<b>0.60**</b>	<b>0.48*</b>	0.27	-0.11	0.02	<b>0.68**</b>	<b>0.51*</b>	<b>0.51*</b>	<b>0.66**</b>	<b>-0.62**</b>	-0.23	-0.36	-0.25
Si		<b>-0.71**</b>	0.06	0.27	0.05	0.13	0.09	-0.21	0.20	-0.38	-0.10	0.29	-0.08	-0.23	-0.08	-0.12
S				<b>-0.58**</b>	-0.37	-0.27	0.03	0.10	<b>-0.60**</b>	-0.16	-0.31	<b>-0.64**</b>	<b>0.49*</b>	0.29	0.31	0.25
Db				-0.04	-0.43	<b>-0.56*</b>	0.05	-0.21	<b>-0.73**</b>	<b>-0.61**</b>	-0.20	-0.16	0.19	0.11	-0.18	-0.12
pH					0.18	-0.01	-0.07	-0.28	<b>0.54*</b>	0.14	0.19	<b>0.61**</b>	<b>-0.78**</b>	-0.26	<b>-0.64**</b>	<b>-0.52*</b>
EC						<b>0.57**</b>	0.23	0.09	<b>0.51*</b>	0.32	0.36	0.20	-0.18	0.41	0.14	0.41
OM							<b>0.49*</b>	0.44	<b>0.54*</b>	0.01	-0.04	0.08	0.03	0.25	0.10	0.23
P								<b>0.54*</b>	0.08	-0.10	0.31	-0.16	0.21	0.30	-0.15	-0.08
K									-0.06	0.23	0.19	-0.16	0.32	0.08	-0.14	-0.12
Ca										<b>0.47*</b>	0.27	0.41	<b>-0.66**</b>	-0.11	-0.32	-0.20
Mg											<b>0.61**</b>	0.23	-0.40	-0.18	-0.19	-0.22
Na												0.09	-0.32	-0.13	-0.18	-0.14
CaCO <sub>3</sub>													-0.43	-0.33	-0.33	-0.29
Fe														0.40	<b>0.69**</b>	<b>0.57*</b>
Cu															0.33	<b>0.58**</b>
Mn																<b>0.88**</b>

\*\* significant at 0.01 level, \*significant at 0.05 level.

According to the correlation matrix among the SQI, olive yield and soil properties, the SQI values had a significant positive correlation with silt content while SQI values gave negative correlations with clay and sand contents of soils (Table 5). It indicates that olive trees grow very well in well drained moderate textural soils. Soil quality index values of the olive groves areas had also a significant positive correlation with olive yields at 5% level (Figure 2). The olive yields had positive correlations with Si, Db, OM, P, exch. K, available Fe, Cu and Zn contents of the soils and negative correlations with clay, sand, pH, exch. Ca, Mg Na, CaCO<sub>3</sub> and available Mn contents (Table 5).

Table 5. Relationships among the soil quality index (SQI) values, grape yield and soil properties.

	O. Yield	C	Si	S	Db	pH	EC	OM	P
SQI	0.458*	-0.159	0.574*	-0.204	0.151	0.068	-0.024	0.098	0.243
Olive Yield	1	-0.174	0.300	-0.040	0.192	-0.069	0.228	0.375	0.187
	K	Ca	Mg	Na	CaCO <sub>3</sub>	Fe	Cu	Mn	Zn
SQI	0.077	-0.025	-0.181	-0.173	0.093	-0.003	-0.361	-0.230	-0.356
Olive Yield	0.136	-0.024	-0.269	-0.352	-0.098	0.054	0.341	-0.048	0.062

In this study, soil OM contents generally were lower than 3.5%, which is a major threshold for soil OM level, and a potentially serious decline in soil quality occurs below this value (Loveland and Webb, 2003). Generally increasing soil OM content increased soil nutrient contents, olive yield and SQI values and reduced bulk density values. Soil organic matter improves soil structure and soil physical quality by increasing porosity and reducing bulk density (Gülser, 2004; Gülser 2006; Candemir and Gülser 2011). There are functional relationships between plant nutrition, fertility and soil properties (Ekberli and Kerimova, 2008; Bayram and Gülser, 2018). Demir and Gülser (2015) reported that the compost application improved soil quality with increasing the water holding capacity, EC, OM content, exch. Mg, K and available P contents and decreasing Db, pH, Na and Ca contents, and increased tomato yield under greenhouse condition. In this

study, the olive yields increased with increasing SQI values due to moderate textural class, high OM, nutrient contents.

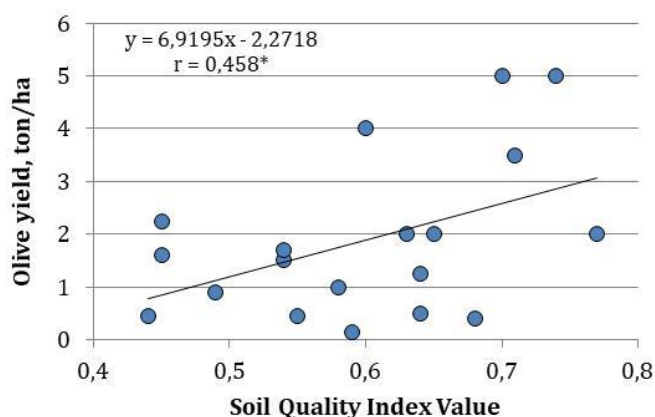


Figure 2. Relationship between soil quality index values and olive yields

## Conclusion

In this study, soil quality of 19 different olive groves areas located in Menderes district of İzmir-Turkey were assessed according to soil quality indicators. While the most of olive groves areas (47.3%) classified in very suitable ( $S_1$ ) and suitable ( $S_2$ ) classes, the other areas were classified as marginal suitable (31.6%  $S_3$ ) and non-suitable (21% N) classes for olive growth. Restricting soil factors for olive growth were generally low soil OM, lime and nutrient contents. Generally low OM and exch. K and Ca contents, high clay and sand contents of the soils reduced soil quality for olive growth. The moderate or loamy textural classes are important for olive production. The olive yields of the areas had a significant positive correlation with SQI values which increased by increasing the suitable soil physical and chemical characteristics of the olive groves areas. It can be concluded that soil quality of the olive groves areas plays an important role for high olive production and it should be considered in sustainable soil management systems.

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