Emirates Journal of Food and Agriculture. 2018. 30(12): 1042-1050
doi: 10.9755/ejfa.2018.v30.i12.1886
http://www.ejfa.me/

REGULAR ARTICLE

An Assessment of the Soil Quality Index in a Mediterranean Agro Ecosystem

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ABSTRACT

Soil quality is a complex functional concept, which cannot be measured directly but only be inferred from both soil characteristics and cultivation practices. Among different approaches used, Soil Quality Index (SQI) is considered to be the most appropriate for quantitative assessment of soil quality. Since, there is no standard method for SQI estimation, the aim of this study is to identify soil quality parameters that could be used for the development of reliable SQI which could be effectively applied in Mediterranean ecosystems. Three different methods resulting in different SQIs were evaluated regarding their ability to monitor changes in agricultural soil properties over time. Overall, a set of soil's parameters was used as soil health indicators (pH, $CaCO_3$, EC, NO_3-N, P, K, Mg, Cu, B, Zn, Fe, Mn, Silt, Clay, Sand and SOC) derived from 605 soil samples used to calculate the above SQIs. The most reliable SQI to distinguish the effect of the examined parameters was the weighted additive approach. These 16 soil indicators can be used as decision support tool for soil management practices, as well as indirect measures of soil function, serving to assess soil health for a sustainable Mediterranean agro-environment.

Keywords: Soil health; Soil quality index; Principal component analysis; Soil texture; Sustainability

INTRODUCTION

The cultivated soils are a limited and predominantly non-renewable resource (Blum 2006). The function of productivity is related to the most usual definition of soil quality as "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen et al., 1997). According to this definition, good soil quality is reflected to the soil type and geographic region. Soil quality Indexes (SQIs) comprise of indicators sensitive to regional scale (Brejda and Moorman, 2001). When management goals focus on sustainability rather than simply crop yield, a soil quality index (SQI) can be also viewed as one component within a nested agroecosystem sustainability hierarchy (Andrews et al., 2002).

Soil quality depend on a variety of factors, including soil type, management practices and environmental influences such as climate and inherent soil characteristics (Hammac et al., 2016; Stott et al., 2013). Consequently, a holistic dataset of soil health indicators should include physical, chemical and biological properties (Doran and Zeiss, 2000; Dick, 1994). Takoutsing et al. (2016) focused on chemical properties because they were considered as the most important factors that have been reported to be affected by land management while they have a great impact on crop productivity.

Despite the fact that there are a variety of possible indexing techniques, little research has been done comparing the different methods in complex Mediterranean agroecosystems like the one found in the prefecture of Aitoloakarnania – Western Greece. Nevertheless, in order to determine the sustainability of agricultural land prevalent in the examined region, quantitative assessment of soil quality on regional scale is needed. Thus, in this study, three different SQIs were evaluated for the region of

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Received: 21 October 2018 **Accepted:** 12 December 2018

Aitoloakarnania that integrate 16 soil chemical properties. The main hypothesis was that a soil quality assessment using 605 soil samples with a minimum dataset of specific soil quality indicators in a three-year sampling period, would be sensitive enough to describe the quality of lowland area in relation to different textural classes of Mediterranean soils. This study is considered as the first effort to express the soil quality with an Index, which integrates basic chemical properties of soil in correlation with different textural classes in the Mediterranean area with an emphasis on the agro-environment sustainability.

METHODS AND MATERIALS

The study area is located in Aitoloakarnania prefecture, located in the western part of Greece, extending between 38°42' latitude to North and 21°15' and 21°37' longitude to East, and covering an area of about 43.000 ha. The climate is typically Mediterranean, with a mean annual temperature of 18°C. The amount of precipitation is very high, the annual rainfall ranges from 800mm to 1000mm. In Aitoloakarnania there are two main typological soil units such as Calcaric Fluvisol (FLca) and Chromic Luvisol (LVcr) (Yassoglou 2004).

Soil sampling took place in winter season and during a three-year period (2012-2014). Because soils are inherently variable in their distribution of plant nutrients, an individual soil sample should be a composite of several subsamples for the same crop field. Each composite sample was consisted of 15-30 subsamples and they were mixed. From this well-mixed soil, a pint of soil was analyzed. In total 605 composite soil samples were taken to a depth of 0 to 30 cm. Laboratory determinations were performed according to the methods usually used for soil characterization (Page et al., 1982). Particle size distribution was carried out using the Bouyoucos method (1962). Electrical conductivity (EC) and pH of saturated pastes were measured for each sample using conductivity (HandyLab LF1) and pH (Crison GLP21) meters, respectively (Rhoades, 1982). The $CaCO_3$ equivalent was determined by treatment with diluted acid and the volume of released carbon dioxide (CO_2) using a Bernard calcimeter (Müller and Gastner, 1971). Soil organic matter was determined by the Walkley–Black method (Nelson and Sommers, 1982). The exchangeable K, and Mg were determined following extraction by 1 N ammonium acetate at pH 7.0 (Chapman and Pratt, 1962) and the available P was measured by the method of Olsen et al. (1954). Available Mn, Fe, Cu and Zn were determined by DTPA extraction (Lindsay and Norvell, 1978), the concentrations were determined using a flame atomic absorption spectrometry (AAS) Analyst 700 by Perkin Elmer. Soil B was extracted with boiling water using the azomethine-H method (Bingham, 1982). Determination of NO_3-N was performed in 1:10 water extracts using Dionex-1500 Ionic Chromatography (Kosma et al., 2009). Soil textural classes determined based on the USDA particle-size classification (Soil Science Division Staff, 2017).

In order to assess trends in Aitoloakarnania agricultural soil quality for different soil types (Table 1), three (3) different indices were calculated. There are three main steps involved in soil quality indexing: first, selecting appropriate indicators; second, transforming indicators to scores; and third, combining the scores into index (Andrews et al., 2002). Scoring of indicators can be done using linear and nonlinear scoring methods (Andrews et al., 2002) and, finally, using multiplicative (Singh et al., 1992), simple additive (Andrews and Carroll, 2001), or weighted additive (Karlen et al., 1998) methods, then scores can be integrated into the final SQI. Indicators' selection can be made using expert opinion or statistical techniques like principal component analysis (PCA) (Andrews et al., 2002; Sharma et al., 2005) and factor analysis (Brejda et al., 2000).

All the SQI methods involved a set of 605 soil samples and a number of soil quality parameters. The 16 parameters used for developing SQIs were pH, Soil Organic Carbon (SOC), $CaCO_3$, EC, NO_3-N, P, K, Mg, Cu, Zn, Mn, Fe, B and the texture indicators (sand/silt/clay). Soil quality index values and associated soil property threshold values with interpretations were estimated mainly according to Amacher et al. (2007). Texture indicators were included in this study as they have been reported to be a component of soil quality indices in many previous studies (Brejda and Moorman, 2001; Singh, 2014; Takoutsing et al., 2016).

Firstly, a simple additive SQI (SQI-1) was estimated according to Mukherjee and Lal (2014). Then, the individual values were summed up to obtain a total SQI for each sample. The SQI-1 index was computed with the eq.1:

$$\text{SQI-1} = \left(\sum SQI - SQImin\right) / \left(SQImax - SQImin\right) \quad (1)$$

Table 1: Soil textural classes based on the USDA particle-size classification of soils and them percentage (%) in the study area

Soil textural classes/no. of samples	Loamy soils						Clayey soils	
	Moderately coarse	Medium		Moderately fine			Fine	
	SL	L	SiL	CL	SCL	SiCL	SiC	C
Aitoloakarnania prefecture (n=605)	13.0%	28.2%	3.8%	20.3%	9.0%	7.3%	4.7%	13.7%

Where: SQI min =Minimum value of SQI, and SQI max = Maximum value of SQI from the whole dataset.

A second - weighted additive - SQ index (SQI-2) was calculated with the following approach (Mukherjee and Lal, 2014). Each soil parameter was assigned with a unit less score ranging from 0 to 1. Soil parameters were divided into groups based on three mathematical algorithm functions: (a): "more is better" (e.g., SOC, NO_3-N, K, Mg, Fe, P, B) (b) "less is better" (e.g., EC), and (c) "optimum" (e.g., pH, $CaCO_3$, Cu, Mn, Zn).

For "more is better" parameters, each observation was divided by the highest observed value of the entire dataset so that the highest observed value would have a score of 1; for "less is better" parameters, the lowest observed value in the entire dataset was divided by each observation so that the lowest observed value received a score of 1; and "optimum" parameters were scored up to a threshold value as "more is better", and thereafter above the threshold values were scored as "less is better" For example (Table 2), pH with values less than 5.5 were scored as "more is better" and pHs more than 7.2 were scored as "less is better" (Mukherjee and Lal, 2014).

A statistics-based model was used to estimate the third SQI (SQI-3) by using principal component analysis (PCA). PCA is a data reduction tool used to select the most appropriate indicator(s) to represent and estimate SQI. Thus, PCA was used to create a minimum data set (MDS) to reduce the indicator load in the model and avoid data redundancy. Principal components (PC) for a data set are defined as linear combinations of the variables that account for maximum variance within the set by describing vectors of closest fit to the n observations in p-dimensional space, subject to being orthogonal to one another.

This study uses the approach described by Andrews et al. (2002). The PCs with high eigenvalues and variables with high factor loading were assumed to be variables that best represented system attributes. Therefore, the PCs with eigenvalues >1 and those that explained at least 5 % of the variation in the data were selected and subjected to varimax rotation to maximize correlation between PCs and the measured attributes (Singh et al., 2014). Within each PC, each variable is given a weight or factor loading that represents the contribution of that variable to the composition of that specific PC. Usually, only the highly weighted variables are retained from each PC for the MDS. Table 3 presents the variables used to calculate the SQI – 3.

After selecting the variables composing the MDS all selected observations were transformed with a similar approach as in SQI-2 by using the three linear score functions (less is better, more is better and optimum). Afterwards, the selected observations were transformed in numerical scores (ranged 0–1) and a weighted additive approach was used to integrate them into indices for each soil sample. In order to get a certain weightage value for each PC the variance explained by each PC was divided by the maximum total variation of the all PCs created with the PCA (Table 3).

For example, the % variance of the first PC (19.68) was divided by total cumulative variance (71.725) to obtain the weight value of 0.27 for PC-1. Thereafter, the weighted additive SQI was computed using eq. 2:

$$\text{SQI-3} = \sum \text{Principal Component Weight} * \text{Individual soil parameter score} \quad (2)$$

The use of PCA in order to derive a SQI has the potential to integrate soil biological, chemical, and physical data for ecological management application where such integration has often been lacking (Mandal et al., 2008). All values are presented as means ± standard deviations. PCA and ANOVA were performed with SPSS ver. 22 and Microsoft Excel was used to calculate the three SQ indices.

RESULTS AND DISCUSSION

Composite soils samples (n=605) were classified based on the USDA particle-size classification of soils, in order to assess in Aitoloakarnania agricultural soil quality for different soil types (Table 1). Soil particle size and texture relates to factors that have a major impact on productivity and affect management strategies. In the study area soils characterized loamy or clayey in the percentage 81.6% and 18.4% respectively (Table 1). To quantitative assessment of soil quality sixteen soil indicators selected and transformed to index values. These index values used to calculate score for SQI. In Table 2 showed the index values and associated soil property threshold values with their interpretations.

The different calculations for the SQIs in the Aitoloakarnania region provide different results (Table 4). Moreover, the Kruskal-Wallis H for SQI-2 showed that there are statistically significant differences in mean rank scores of SQI-2 (Table 4). Having in mind the above results it can be concluded that SQI – 2 could be more useful to evaluate the soil quality for the region of Aitoloakarnania. In particular, the comparison of 3 different SQIs calculations indicates that only SQI-2 could be used to discriminate the different soil textural classes among the examined samples (Table 5).

The weighted additive index (SQI – 2) was able to discriminate (statistically significant) differences in soil characteristics for soil textural classes (Table 6). The highest

Table 2: Soil quality index values and associated soil property threshold values and interpretations

Parameter	Level	Interpetation	Index
Soil pH	<3.0	Severely acid-almost no plants can grow in this environment	0
	3.01 to 4.0	Strongly acid - only the most acid tolerant plants can grow in this pH range and then only if organic matter levels are high enough to mitigate high levels of extractable Al and other metals.	
	4.01 to 5.5	Moderately acid – growth of acid intolerant plants is affected depending on levels of extractable Al and other metals.	
	5.51 to 6.8	Slightly acid – optimum for many plant species, particularly more acid tolerant species	1
	6.81 to 7.2	Near neutral – optimum for many plant species expect those that prefer acid soils	
	7.21 to 7.5	Slightly alkaline – optimum for many plant species except those that prefer acid soils, possible deficiencies of available P and some metals (for example, Zn)	
	7.51 to 8.5	Moderately alkaline – preferred by plants adapted to this pH range, possible P and metal deficiencies	
	>8.5 to 9.5	Strongly alkaline – preferred by plants adapted to this pH range, possible B and other oxyanion toxicities	
	>9.5	Severely alkaline-almost no plants can grow in this environment	0
SOC (%)	>5	High - excellent buildup of organic C with all associated benefits	1
	1 to 5	Moderate – adequate levels	
	<1	Low – could indicate possible loss of organic C from erosion or other processes	0
K (mg/kg)	500 to 700	High – excellent reserve	1
	100 to 500	Moderate – adequate levels for most plants	
	<100	Low – possible deficiencies	0
Mg (mg/Kg)	300 to 500	High – excellent reserve	1
	50 to 300	Moderate – adequate levels for most plants	
	<50	Low – possible deficiencies	
	<10	Very low – severe Ca depletion, adverse effects more likely	0
Mn (mg/kg)	>100	High – possible adverse effects to Mn sensitive plants	0
	11 to 100	Moderate – adverse effects or deficiencies less likely	1
	1 to 10	Low - adverse effects unlikely, possible deficiencies	
	<1	Very low – deficiencies more likely	0
Fe (mg/kg)	>10	High – effects unknown	1
	0.1 to 10	Moderate – effects unknown	
	<0.1	Low – possible deficiencies, possibly calcareous soil	0
Cu (mg/kg)	>1	High – possible toxicity to Cu sensitive plants, may indicate mining areas or industrial sources of Cu	0
	0.1 to 1	Moderate – effects unknown, but adverse effects unlikely	1
	<0.1	Low – possible deficiencies in organic, calcareous, or sandy soils	0
Zn (mg/kg)	>10	High – possible toxicity to Zn sensitive plants	0
	1 to 10	Moderate – effects unknown, but adverse effects unlikely	1
	<1	Low – possible deficiencies in calcareous or sandy soils	0
EC (ms/cm in 25^{0}C)	<4	Normally	1
	4 to 8	slightly saline	
	8 to 16	Moderataly saline	
	16 to 40	strongly saline	0
	>40	Very strongly saline	
P (Olsen method)(mg/kg)	25.1 to 40	High – excellent reserve of available P for plants in acid to alkaline soils.	1
	15.1 to 25	sufficient	
	5.1 to 15	inadequate	
	<5	Very poor	0
Total $CaCO_3$ (%)	<0.5	poorly	0
	0.5 to 3.0	Moderate	1
	3.0 to 20	Rich	
	20 to 40	loam soils	
	>40	calcareous	0
B (mg/kg)	1.3 to 2	High	1
	0.8 to 1.2	Moderate	
	<0.7	Low	0

(Contd...)

Table 2: *(Continued)*

Parameter	Level	Interpetation					Index
Textural classes of soils based on the USDA particle-size classification	**Common names of soils (General texture)**	**Sand**	**Silt**	**Clay**	**Textural class**		
	Sandy soils (Coarse texture)	86-100	0-14	0-10	Sand	S	0
		70-86	0-30	0-15	Loamy sand	LS	
	Loamy soils (Moderately coarse texture)	50-70	0-50	0-20	Sandy loam	SL	
	Loamy soils (Medium texture)	23-52	28-50	7-27	Loam	L	1
		20-50	74-88	0-27	Silty loam	SiL	
		0-20	88-100	0-12	Silt	Si	
	Loamy soils (Moderately fine texture)	20-45	15-52	27-40	Clay loam	CL	
		45-80	0-28	20-35	Sandy clay loam	SCL	
		0-20	40-73	27-40	Silty clay loam	SiCL	
	Clayey soils (Fine texture)	45-65	0-20	35-55	Sandy clay	SC	
		0-20	40-60	40-60	Silty clay	SiC	
		0-45	0-40	40-100	Clay	C	0
NO_3-N (mg/kg)	20.1 to 40	High – adequate levels					1
	10.1 to 20	Moderate					
	3.1-10	inadequate					
	<3	Low – could indicate loss of organic N					0

Table 3: Results of the Principal Component analysis of the Soil Quality indicators

	Rotated component matrix						
	PC #1	**PC #2**	**PC #3**	**PC #4**	**PC #5**	**PC #6**	**PC #7**
Eigenvalue	3.150	2.389	1.510	1.289	1.125	1.048	0.966
% of variance	19.685	14.928	9.438	8.055	7.032	6.547	6.039
Cumulative %	19.685	34.613	44.051	52.106	59.139	65.686	71.725
PC weight*	0.27	0.20	0.13	0.11	0.09	0.09	0.08
Variables	**Factor loadings**						
pH	–0.839	0.134	0.173				
$CaCO_3$	–0.602	–0.198	0.400		0.136		
EC	–0.144		0.197		0.740		0.389
Mg	0.120	0.752				–0.259	0.164
NO_3-N					0.886		–0.165
P	0.347			0.689		–0.151	
K		0.211		0.682		0.177	
Cu	0.133	–0.171		0.172		0.816	
Zn							0.946
Mn	0.731					0.338	
Fe	0.734						
B				0.696		0.173	
sand	0.160	–0.624	–0.736				
silt			0.910			–0.144	
clay	–0.157	0.835	0.224			0.151	
SOC		0.447	–0.209	0.185	0.183	0.563	

*% of variance to total variance explained 1: Underlined variables have been used to calculate SQI – 3, 2: PC principal Component, Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

values were observed in loamy soils with moderately coarse and medium texture in contrast to the lowest values that were observed in clayey and loamy soils with fine texture. Takoutsing et al. (2016) showed that the main factors that explain most of the variability observed in soil health were soil texture and nutrient concentrations in maize crops. Additionally, soil properties such as EC, pH, SOC and soil texture were reported to accurately describe soil quality in previous studies (Liu et al., 2014; Yao et al., 2013).

Table 4: Mean SQI rank scores for soil texture in the examined area

Soil texture	N	SQI-1	SQI-2	SQI-3
		Mean rank	Mean rank	Mean rank
C	82	291.85	203.99	318.60
SCL	55	291.61	171.84	287.74
SL	79	297.13	423.74	345.27
L	170	313.85	414.28	301.64
SiL	24	261.85	371.63	248.20
SiCL	44	313.61	235.36	304.03
SiC	29	322.25	248.86	276.18
CL	122	291.48	207.84	277.94
Total	605			
			Kruskal wallis test	
Chi-Square (df)		3.545 (7)	214.825 (7)	11.126 (7)
Asymp. Sig.		0.830	0.000	0.133

In our results, statistical significant differences in pH, SOC, $CaCO_3$, EC, Mg and K between different textural soil classes, were observed (Table 6). In particular, the highest values of SOC, were observed in clayey soils in comparison to loamy soils (Table 6). This is in agreement with Dexter (2004), who showed that organic matter content is positively correlated with soil clay content, (Table 7). As far as the electrical conductivity of soils is concerned, previous studies (Williams and Hoey, 1987; Grisso et al., 2005) showed that its value varies according to the amount of moisture held by soil particles (sands, silts and clay have low, medium and high EC respectively). This is consistent with our results which indicated that in clayey soils were observed the highest EC mean values comparing to loamy soils (Table 6). Also, in clayey soils were observed the highest mean values for exchangeable K and Mg soil concentrations compared to loamy soils (Table 6). Previous studies showed that the highest K values are often found in clayey soils in temperate regions, but depending on the

Table 5: Anova analysis for soil texture and SQIs

ANOVA Results for soil characteristics					
	Sum of squares	df	Mean square	F	Sig.
SQI_1					
Between groups	0.041	7	0.006	0.386	0.911
Within groups	8.952	598	0.015		
Total	8.993	605			
SQI_2					
Between groups	0.687	7	0.098	37.699	0.000
Within groups	1.541	598	0.003		
Total	2.228	605			
SQI_3					
Between groups	0.157	7	0.022	0.962	0.458
Within groups	13.832	598	0.023		
Total	13.989	605			

Table 6: Selected Indicators in soil quality and SQI-2. Their behavior in different textural classes of Mediterranean soils

Selected indicators of soil quality	Units	Loamy soils						Clayey soils	
		Moderately coarse texture	Medium texture		Moderately fine texture			Fine texture	
		SL (79)	L (170)	SiL (24)	CL (122)	SCL (55)	SiCL (44)	SiC (29)	C (82)
pH	-	$7.03±0.11^{a.b}$	$7.25±0.07^{b.c}$	$7.62±0.17^{d}$	$7.39±0.08^{c.d}$	$6.88±0.13^{a}$	$7.66±0.09^{d}$	$7.73±0.1^{d}$	$7.43±0.08^{c.d}$
SOC	%	$1.23±0.07^{b}$	$1.10±0.04^{a.b}$	$0.91±0.07^{a}$	$1.33±0.06^{b.c}$	$1.27±0.09^{b}$	$1.22±0.06^{b}$	$1.55±0.11^{c.d}$	$1.74±0.09^{d}$
$CaCO_3$	%	$6.39±0.92^{a.b}$	$6.17±0.60^{a.b}$	$10.2±2.06^{b}$	$8.58±0.96^{b}$	$3.13±0.79^{a}$	$10.1±1.34^{b}$	$9.18±1.15^{b}$	$8.75±1.28^{b}$
EC	mS/cm	$0.73±0.1^{a.b}$	$0.80±0.06^{a.b}$	$0.91±0.14^{a.b}$	$0.88±0.08^{a.b}$	$0.61±0.07^{a}$	$1.09±0.15^{b}$	$1.58±0.26^{c}$	$1.11±0.11^{b}$
Mg	mg/kg	$123±6.93^{a}$	$163±8.81^{a.b}$	$154±18.9^{a.b}$	$203±12.0^{b}$	$142±8.44^{a}$	$172±8.86^{a.b}$	$259±32.7^{c}$	$250±18.7^{c}$
NO_3-N	mg/kg	21.5±7.22	13.5±1.95	11.6±3.39	14.2±1.93	9.91±2.39	29.1±9.16	20.31±5.51	26.7±9.35
P	mg/kg	33.9±4.92	34.9±3.16	26.3±7.74	36.5±3.79	34.3±5.34	19.9±3.91	17.71±2.57	28.9±3.76
K	mg/kg	$210±20.2^{a}$	$236±14.30^{a.b}$	$209±26.2^{a}$	$247±14.8^{a.b}$	$233±23.1^{a.b}$	$206±21.5^{a}$	$266±32.6^{a.b}$	$293±15.4^{b}$
Cu	mg/kg	5.40±0.75	4.50±0.42	3.01±0.64	4.59±0.42	6.03±0.97	3.94±0.44	4.55±0.63	4.05±0.43
Zn	mg/kg	1.56±0.17	2.31±0.58	0.67±0.08	1.57±0.14	2.89±0.59	1.15±0.29	3.03±1.59	1.49±0.24
Mn	mg/kg	14.7±1.88	13.8±1.10	11.2±1.50	13.8±1.40	16.3±2.20	12.0±1.97	13.1±2.2	13.8±1.34
Fe	mg/kg	43.5±5.90	32.5±2.88	33.5±5.45	32.1±3.51	30.9±4.00	31.2±5.51	23.3±2.24	25.3±2.09
B	mg/kg	0.64±0.05	0.65±0.02	0.57±0.05	0.71±0.05	0.55±0.04	0.63±0.04	0.66±0.06	0.67±0.04
SQI-2		0.35 ± 0.04	0.35 ± 0.05	0.33 ± 0.09	0.28 ± 0.05	0.27 ± 0.05	0.29 ± 0.05	0.29 ± 0.06	0.28 ± 0.04

* Different letters indicate significant differences at significance level $P<0.05$ between values in rows for each parameter. There are statistical significant differences between textural classes of soils for SQI-2, and for the following indicators: pH, SOC, Total $CaCO_3$, EC, Mg and K.

Table 7: Pearson correlations among soil properties of the study area (n=605)

	pH	SOM	$CaCO_3$	sand	silt	clay	EC	Mg	K	NO_3-N	P	Cu	Zn	Mn	Fe	B
pH	1															
SOM	0,112**	1														
$CaCO_3$	0,480**	0,054	1													
sand	–0,212**	–0,160**	–0,173**	1												
silt	0,188**	–0,107*	0,180**	–0,717**	1											
clay	0,114**	0,339**	0,073	–0,685**	-0,004	1										
EC	0,084	0,178**	0,124**	–0,201**	0,153**	0,146**	1									
Mg	–0,060	0,146**	–0,166**	–0,228**	0,043	0,297**	0,183**	1								
K	–0,047	0,270**	–0,064	–0,075	–0,056	0,180**	0,222**	0,231**	1							
NO_3-N	–0,065	0,032	0,017	–0,090*	0,066	0,060	0,623**	0,055	0,085*	1						
P	–0,430**	0,014	–0,309**	0,099*	–0,127**	–0,013	0,116**	0,145**	0,388**	0,179**	1					
Cu	–0,178**	0,034	–0,109*	0,090	–0,116*	–0,009	–0,036	0,014	0,089	0,066	0,125**	1				
Zn	–0,074	0,084	–0,102*	0,075	–0,087*	–0,016	0,090*	0,146**	0,187**	0,080	0,227**	0,008	1			
Mn	–0,406**	0,083	–0,311**	0,055	–0,098*	0,028	0,037	0,181**	0,122**	–0,001	0,156**	0,004	0,167**	1		
Fe	–0,531**	0,026	-0,243**	0,069	–0,008	–0,088*	0,038	0,075	0,032	0,032	0,381**	0,059	0,054	0,255**	1	
B	–0,097	–0,053	–0,043	-0,064	–0,055	0,111*	0,098	0,122*	0,173**	0,212**	0,254**	0,131*	0,041	0,091	0,044	1

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

mineralogy, a high K content may also be found in sandy soils (Øgaard et al., 2002; Wakeel et al., 2013). The existence of magnesium in soil is related to several factors, including type of rock, pH, nature of drainage water, clay content, cation exchange capacity, climatic conditions, geographic location, and type of plant grown (Jodral-Segado et al., 2006), particularly according to Dontsova and Norton (1999) high Mg concentration in soil solution can be nature of dolomitic limestone. In the study area alkaline pH values were observed and related to the presence of calcareous sediments and (limestone) basic rocks (Yassoglou, 2004) also, two main typological soil units exists, such as Calcaric Fluvisol (FLca) and Chromic Luvisol (LVcr). Jodral-Segado et al., (2006) observed similar results in calcareous fluvisols and they noted the high capacity of this soil type to retain several minerals, specifically calcium and magnesium when compared to concentrations found by other studies.

Pearson correlations showed that nitrates soil concentrations (NO_3-N) significantly correlated ($p < 0.01$) with EC (Table 7). Previous studies (Patriquin et al., 1993; Gali et al., 2012) observed that there were strong linear relationships between nitrate concentrations and EC for soil samples and reported that EC values give the same type of information as nitrate values. Moreover, higher significant correlation ($p < 0.01$) observed among soil pH with $CaCO_3$ content and Fe concentrations than other properties (Table 7), showed the high influence of pH on the availability of Fe concentrations, and the high correlation between pH and total $CaCO_3$% content, which is in accordance with Sillanpää (1982), all correlations among soil health indicators showed in Table 7.

The rank score according to the textural classes of soil had the following ranking from best to worst SL>L>SiL>SiC>SiCL>CL>C>SCL (Table 4). Between mean rank scores of soils texture the highest mean score was observed at SL textural class (423.74) while in contrast the lowest mean score was observed at SCL textural class (171.84); the difference between them was 251.9. loamy soils with moderately coarse and medium texture presented best rank score compared to loamy soils with moderately fine texture and the clayey soils.

CONCLUSION

Sixteen (pH, $CaCO_3$, EC, NO_3-N, P, K, Mg, Cu, B, Zn, Fe, Mn, Silt, Clay, Sand and SOC) soil's parameters were used as a dataset of soil health indicators. These indicators were used to develop different soil quality indexes. Among these different SQIs, the most reliable SQI able to distinguish the effect of the examined parameters was the weighted additive approach (SQI-2). The analyses and correlations according to textural classes of soil can provide evidence relevant to their impact on soil quality in Mediterranean agro-environment. Such a soil quality index can be used by policymakers, researchers, extension agents and farmers as a decision support tool for cost-effective soil management practices, as well as indirect measures of soil function, serving to assess soil health. In addition, a further research should include biological and other physicochemical soil properties in order to expand soil quality index efficiency and consequently improve soil management and the agroecosystem sustainability.

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