Identification of Regional Soil Quality Factors and Indicators: An Alluvial Plain From Central Anatolia

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Abstract

Açıklama [hn1]: In the abstract, the abbreviations should be eliminated.

Sustainable agriculture largely depends on soil quality. The evaluation of agricultural soil quality is essential for economic success and environmental stability in rapidly developing regions. A wide variety of methods are currently used to evaluate soil quality using vastly different indicators.

This study was conducted in one of the most important irrigated agriculture areas of Konya in central Anatolia, Turkey, to analyze the soil quality indicators of Çumra County in combination with an indicator selection method, the minimum data set. A total of 38 soil parameters were used to select the most suitable indicators with the minimum data set method. We therefore determined a minimum data set with principle component analysis to assess soil quality in the study area and soil quality was evaluated on the basis of a scoring function.

Field capacity, bulk density, aggregate stability and permanent wilting point from physical soil properties, and electrical conductivity, Mn, total nitrogen, available phosphorus, pH and NO_3-N from chemical soil properties, and urease enzyme activity, root health value, organic carbon, respiration and potentially mineralized nitrogen from biological properties were chosen as a Minimum data set from total data sets to assessment of soil quality by principle component, correlation analysis and expert opinion.

According the results, chosen properties were found as the most sensitive indicators of soil quality and they can be used as indicators for evaluating and monitoring soil quality at a regional scale.

Keywords: Soil quality, Çumra plain, indicators, minimum data set,

1. Introduction

Soil is an important non-renewable natural resource on which humanity and all flora and fauna are dependent (Doran and Zeiss, 2000). The ever increasing growth of the human population has brought about a global food safety problem, and it has become an urgent necessity to obtain greater efficiency per unit area (Doran, 2002). In developing countries, the intense use of land on the grounds of progress through fast economic development has brought about serious limitations on the sustainable use of soils and created a major problem in soil quality (SQ) (Arshad and Martin, 2002). Furthermore, the negative effects of land degradation from various causes on agricultural productivity, the indirect effects on environmental and food safety and quality of life have also become global problems. Increasing the amount of agricultural lands may seem to be a solution to fulfill the food demand. On the other hand, the amount of agricultural land is already at a maximum level in most countries (Eswaran et al., 2001). Thus, for both the resolution of this problem and the sustainable use of soils, it is much more important to focus on improving the SQ rather than increasing the amount of arable land (Rasheed et al., 1996; Yemefack et al., 2006).

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SQ is defined as the capacity of the soil to sustain biological productivity and preserve the environmental quality and health of plants and animals within the boundaries of the ecosystem (Doran and Parkin, 1994). Karlen et al. (1997) defined SQ as the soil's ability to support sustainable plant and animal production, improve human and environmental health, enhance the quality of water and air as the function of the properties of each soil type, and they regarded it as the manifestation of the natural and dynamic properties of soils.

The efficient and sustainable usage of soils, which are among our most important natural resources, can be achieved by defining their properties through proper methods (Doran, 2002), determining the restrictions that affect their productivity and the properties that affect sustainability (Doran and Zeiss, 2000). Assessing and monitoring SQ can provide effective tools for determining the properties of degraded soil (Aronson et al., 1993; Bindraban et al., 2000), revealing sustainable land practices for land managers (Karlen et al., 2011; McGrath and Zhang, 2003) and defining the elements needed for plant nutrition (Yu-Dong et al., 2013). Thus, SQ has received great attention in the recent years (Sinha et al., 2014). In recent years the number of studies assessing SQ in different management and product systems has increased worldwide, and several methods and scoring models have been developed for the determination of SQ (Andrews et al., 2004; Brandt and Thornes, 1996; Doran et al., 1997; Doran and Jones, 1996; Doran et al., 1996; Doran and Zeiss, 2000; Gugino et al., 2009; Hueso- González et al., 2014; Karlen et al., 1997; Larson and Pierce, 1991; Muñoz-Rojas et al., 2016).

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Açıklama [hn8]: the reference was added

In the past, SQ was accepted as the natural capacity of soil that provides the main plant nutrients (El-Ramady et al., 2014). However, it is currently regarded as an immaterial property of soils due to its dependency on land usage and soil management practices, ecosystem and environmental interactions, socio-economic and political priorities and several other external factors (Doran and Jones, 1996). So, it is not possible to use a single soil property to digitize SQ. On the other hand, the combined assessment of several parameters formed by the combination of certain soil properties provides important indicators for monitoring and assessing SQ.

Açıklama [hn9]: 65-72 lines were revised.

Açıklama [hn10]: the reference was added

In general, SQ parameters are defined as the processes and properties of soil that are sensitive to the changes in soil functions (Aparicio and Costa, 2007; Doran and Jones, 1996). It is very important to establish simple, sensitive and practical methods for the assessment of SQ and to select indicators accordingly. The quality parameters to be selected must correlate well with the natural processes in the ecosystem (Özulu et al., 2006). They must also be related to the measurable soil functions (natural or human-based), be integrated with the physical, chemical

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Açıklama [hn12]: 77-81 lines were revised.

and biological properties and processes of soil, and they must be components of the current data bases (Aparicio and Costa, 2007; Chen, 1998; Doran and Parkin, 1994; Doran et al., 1996; Dumanski and Pieri, 2000; Herrick and Jones, 2002; Muñoz- Rojas et al., 2016).

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The following properties are reported to be suitable for use as SQ factors and indicators when studies on SQ are evaluated: a)Physical properties: texture, bulk density, water retention, aeration, compression, hydraulic properties, aggregation state, consistence properties, and surface crusting (Arshad and Coen, 1992; Burger and Kelting, 1998; Doran and Parkin, 1994; Kay[1] et al., 1996; Larson and Pierce, 1991; Powers et al., 1998); b)Chemical properties: pH, salt content, total organic carbon, total nitrogen, organic nitrogen, soluble carbon, mineral nitrogen, total phosphorus, extractable ammonium, nitrate, phosphor, potassium, calcium, magnesium, microelements, contaminants, cation change capacity (Doran and Parkin, 1994; Harris et al., 1996; Larson and Pierce, 1994; Reganold and Palmer, 1995); c)Biological properties: microbial carbon, microbial nitrogen, soil respiration, biological activity, enzyme activities, root development, germination and growth (Blair et al., 1995; Dick et al., 1996; Doran and Parkin, 1994; Fauci and Dick, 1994; Gregorich et al., 1994; Harris et al., 1996; Linden et al., 1994; Rice et al., 1996; Turco et al., 1992); Genetic properties: soil color, type of structure, the thickness and depth of the impermeable layer that is genetically formed, the thickness of horizon A and depth of the clay accumulation horizon (Brejda et al., 2000a; Brejda et al., 2000b; Doran and Parkin, 1994; Qi et al., 2009).

Açıklama [hn14]: Physical, chemical, biological and genetic characteristics starting from 82 lines were divided into a, b, c, d.

To digitize and reveal out SQ, it is necessary to determine and score the measurable SQ parameters (Andrews et al., 2002; Andrews et al., 2004; Gugino et al., 2009). Selection of the indicators to be used is very important for the determination of SQ. Several properties affect the SQ in varying degrees (Doran and Parkin, 1994; Harris et al., 1996). Many of the above-mentioned physical, chemical and biological parameters are reported to be suitable for use as indicators (Arshad and Coen, 1992; Brejda et al., 2000a; Doran and Parkin, 1994; Fernandes

Açıklama [hn15]: the reference was added

Açıklama [hn16]: the reference was added

Açıklama [hn17]: the reference was added et al., 2011; Karlen et al., 1997; Larson and Pierce, 1994; Lima et al., 2013). On the other hand, the concurrent use of all these properties as quality indicators is both impractical and contrary to the main principles of quality assessment parameters. Doran et al. (1996) advised that the number of indicators used to determine SQ should be as few as possible. In general, the greater the number of indicators, the more comprehensively the SQ can be determined (Nortcliff, 2002). However, when a high correlation exists among the indicators, significant effects may emerge as a problem (Doran and Parkin, 1994; Li and Lindstrom, 2001). Therefore, neglecting some indicators should be considered. On the other hand, if the indicators to be neglected are not well selected, non-realistic losses in SQ may emerge. Thus, it is necessary to select among the indicators to be used. Therefore, these authors recommended several approaches. The important thing here is that the parameters to be used as indicators should reflect the soil primarily in a simple and accurate way.

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They recommended some SQ indicator sets for the assessment of SQ based on the total data set (TDS) (Doran and Parkin, 1994; Karlen et al., 1997; Larson and Pierce, 1994). On the other hand, some studies proposed that instead of using all the properties, certain parameters such as the presence or absence of a correlation among the parameters and the measurement practicality could be considered. The MDS formed by representative indicators selected by various methods such as multiple-variant regression analysis (Doran and Parkin, 1994; Li and Lindstrom, 2001), principal components analysis, factor analysis (Brejda et al., 2000b; Shukla et al., 2004) and cluster analysis (Einax and Soldt, 1999) could be used for the determination of SQ (Andrews et al., 2002; Govaerts et al., 2006; Rezaei et al., 2006). Other authors stated that just as in the Delphi data set (DDS) (Zhang et al., 2004), SQ could be determined by using the indicators that are selected according to expert views (Herrick and Jones, 2002).

In the Middle Eastern Anatolia region in Turkey, sufficient data are lacking about the general SQ and the parameters that could be used to determine the SQ. The Çumra Plain is one of the most fluvial plains in Turkey. In this study, we aimed to select the parameters that could be used to establish regional quality indexes and to determine the variables that affect SQ.

Açıklama [hn20]: Line 127 has been corrected in line with the opinion of the referee.

2. MATERİALS AND METHODS

2.1. Site description

The study area (Çumra Plain) is a part of the Great Konya Basin in Konya Province, Turkey, is located in the Central Anatolian Plateau (X: 36 467296-36 473117 m; Y:41 60910-41 52356 m; UTM36N/ED50). The alluvial plains and fans comprise the sediments of several rivers debouching into the southern part of the basin. The alluvial fans or inland deltas consist of sediments ranging from coarse sand to a heavy clay texture (sand=17.00-61.00%, silt=11.00-40.00%, clay=18.00-60.00%). The climate is semi-arid with mild summers and very cold winters. The Konya meteorological station’s long-term records (1971-2014) show a mean annual precipitation of 296.8 mm, which mostly falls during winter and spring. The total evaporation is 996.6 mm year^{-1}, the mean annual temperature is 10.8°C, and the mean annual soil temperature at 50 cm depth is 13.1°C (MGM, 2014). The soil moisture and temperature regimes are xeric and mesic, respectively (Staff, 1999).

Açıklama [hn21]: texture percentages were added.

Açıklama [hn22]: 1971-2004 years indicated.

Açıklama [hn23]: Depth was added.

Detailed soil investigation reports and maps (1:15.000) were used to determine the research area (De Meester, 1970; Meester, 1971, 1970). When determining the study area on this detailed soil map that was prepared at series and phase levels, we considered the prevalence of the soil series. For this reason, the ***Alibey series,*** which covered the largest area in the region, was selected as the study area. This series consists of deep loamy-textured soils formed on the main alluvial fan of the May River. It covers an area of approximately 4.000 ha, which represents 6% of the Çumra Plain where irrigated farming (four rotation; corn-wheat-sugar beet-sun flower) is carried out, and is approximately 1.023 m above sea level.

Açıklama [hn24]: 15.000

Açıklama [hn25]: “Physiographically , the study area was a homogenous alluvial plain “ was removed.

Açıklama [hn26]: 4.000

Açıklama [hn27]: This information was added.

Açıklama [hn28]: 1.023

2.2 Soil Sampling and Analysis

Açıklama [hn29]: Soil Sampling and Analysis has been corrected in line with the opinion of the referee.

The map of the series, including the coordinate information, was created to determine the points where soil samples would be taken. Samplings and measurements were carried in two sampling period out on 108 parcels of land on which wheat and sugar beet were grown in the years 2013-2014 and the necessary following parameters were defined for total 108 samples. Disturbed soil samples were taken from different points in each parcel at depths of 0-20 and 20-40 cm and mixed samples were formed for each depth. Mixed samples taken from the surface to depths of 0-20 cm depth were divided into three subsamples, each of which weighed 1 kg (Gugino et al., 2009; Karlen et al., 2003). One of these subsamples was dried sieved and used for chemical and physical analyses. The second was kept in the cooler in +4 ^{0}C for biological analysis. The third subsample be used for the determination of aggregate stability. The soils textures were determined by Bouyoucos hydrometer methods (Gee and Bauder, 1986). The bulk density (*Pb*) was measured by core sampling method (Blake and Hartge, 1986). The pycnometer method (Blake and Hartge, 1986) was used to find the particle density (*Pk*) and bulk density and particle density were used to find porosity (*P*) (Danielson et al., 1986). The field capacity (*FC*), was determined at 10 kPa (FC_{10}) and 33 kPa (FC_{33}) by pressure plate methods (Klute, 1986). The permanent wilting point (*PWP*), was measured at 1500 kPa pressure (Klute, 1986), and to obtain the available water (*AW*), the wilting point was deducted from the field capacities (FC_{10} and FC_{33}). Aggregate stability (*AS*) was determined in a rain simulator (Gugino et al., 2009). Penetration resistance was measured using Eijkelkamp’s penetrologger, which is pushed under the soil by hand. Upper-layer penetration resistance (PR_{0-20}) was measured by taking the averages of the penetration resistance values at 0-20 cm depth, and lower-layer penetration resistance (PR_{20-40}) was measured by taking the averages of the penetration resistance values at 20-40 cm depth. pH measurement was made according to the CSHA manual procedure, so 1:1 soil:water ratio was used. Electrical conductivity (EC) was measured using an electrical conductivity device in a 1:1 soil and pure

Açıklama [hn30]: degraded was removed and disturbed was added.

Açıklama [hn31]: “In the laboratory”,”through a 2 mm sieve” were removed.

Açıklama [hn32]: “was carried to the laboratory in proper containers to” was removed.

Açıklama [hn33]: “This subsample was not ground or sieved and was air dried.” was removed.

water mixture (Kacar, 2009). Total nitrogen was measured using a LECO CN-2000 device with the Dumas dry combustion method (Wright and Bailey, 2001). Ammonium nitrogen ($NH_4^+ - N$) and nitrate nitrogen ($NO_3^- - N$) were measured using the Kjeldahl device (Keeney and Nelson, 1982). Available phosphorus (AP) was determined by the Olsen method (Olsen et al., 1982). Extractable Ca, Mg, Na and K, were extracted using 1 N ammonium acetate solution and available Fe, Cu, Mn and Zn were determined with atomic absorption spectrophotometry through Diethylenetriaminepentaacetic acid (DTPA) extraction (Kacar, 2009). Organic matter was determined by using a LECO CN-2000 device with Dumas dry combustion (Wright and Bailey, 2001). Active carbon was determined according to (Blair et al., 1995; Gugino et al., 2009). Potential mineralizable nitrogen (PMN) was measured by (Gugino et al., 2009). Roots of germinated bean plants were removed from the soil at the end of the blooming period to determine the root health value (RHV) (Gugino et al., 2009). The following activities were determined: urease enzyme activity (UA) (Hoffmann and Teicher, 1961), catalyzing enzyme activity (CA) (Beck, 1971), dehydrogenase enzyme activity (DA) (Thalmann, 1968), and soil respiration (R) (Isermeyer, 1952). Moreover, mycorrhizal fungi (MSN) were isolated and counted using 30×–40× enlarged microscopic images of the fungi in samples prepared by washing through 38 µm sieves (Gerdemann and Nicolson, 1963).

2.3 Indicators Selection

Various methods were used to assess SQ and other environmental data, such as multiple-variable regression analysis (Doran and Parkin, 1994; Li and Lindstrom, 2001), principal components and factor analysis (Brejda et al., 2000b; Shukla et al., 2004), discriminant analysis (Brejda et al., 2000a) and cluster analysis (Einax and Soldt, 1999).

First The KMO and Bartlett tests were conducted to check whether the data sets that were created based on these properties were in conformity with the principal components analysis.

Açıklama [hn34]: Statistical analysis???

Açıklama [hn35]: "Selection of the indicators to be used for the determination of soil quality is very important. Though it would be proper to assess all soil properties within the framework of soil quality, this is not practical. This is because several parameters are concerned with the assessment of soil quality, and assessing each of these would require both time and significant costs. Thus, it is necessary to select among the indicators to be used. The important thing here is that the parameters to be used as indicators should reflect the soil primarily in a simple and accurate way (Andrews *et al.*, 2004)." was removed.

In this study, we used principal components analysis among others to assess and monitor SQ. For this purpose, the total data set was divided into three groups first to create the minimum data set (MDS) from the total of 38 data sets obtained in the study. Physical properties were included in the first group, chemical properties in the second and biological properties in the third group. In the first stage, the Kaiser-Meyer-Olkin (KMO) and Bartlett test was conducted to verify whether the data included in each group were in conformity with the principal components analysis (Tatlidil, 2002). All properties had values above P>0.5 and passed the KMO and Bartlett test (Table 1). In the second stage, principal components analysis (PCA) was conducted for each of four data groups to create the MDS and correlation matrixes of the data sets were established (Minitab, 1995). To determine the parameters that may take part in the MDS, MDS recommendations were prepared for each series by considering the component loads determined through PCA, correlation load totals, inter-data correlations and analysis methods.

Açıklama [hn36]: P value was added.

3. RESULTS AND DISCUSSION

3.1. Indicator Selection and Creating the Minimum Data Set

The values concerning the physical, chemical and biological properties obtained at the end of the study are given in Table 2. The KMO and Bartlett test results are given in Table 1. The following percentages were obtained at the end of the KMO test: 63.4% for the physical properties (P value 0.634>0.5), 66.7% for the chemical properties (P value 0.667>0.50), 62.9% (P value 0.629>0.50) for the biological properties. The Bartlett test results were significant for all the data sets (P value 0.000<0.05). These results showed that the physical, chemical and biological properties were in conformity with the principal components analysis and showed a high correlation among the variables (Karagöz and Kösterelioğlu, 2015). When selecting the number of principal components, it is necessary to make selections such that the

Açıklama [hn37]: "The KMO and Bartlett tests were conducted to check whether the data sets that were created based on these properties were in conformity with the principal components analysis." was moved the materials and methods section.

minimum number of principal components can explain 2/3 (67%) of the total variance. This percentage can be increased up to 95%. On the other hand, as it is necessary to work with many principal components to increase the percentage after 67%, this ratio is kept limited and the number of principal components which meets 67% level is generally used. In the principal components test, we used the number of PC whose was eigenvalue > 1 and which explained 2/3 of the total variance. This is because one of the most commonly accepted rules is to select the number of PC that meets the number of R matrix or S matrix eigenvalues that are greater than 1 (Tatlidil, 2002). Therefore, the eigenvalues of the matrixes were found, and the same number of PC was selected as the number of eigenvalues with values greater than 1. For selecting the PC properties to be used to create the MDS as quality indicators, we accepted as candidates for the MDS those properties whose principal component value had the highest percentage in the components cluster for explaining the variance. Properties such as the principal component loads, correlation load totals, inter-data correlations, and analysis methods were considered when determining the MDS. When deciding which ones to choose among the properties that are highly correlated, we considered issues such as whether the property would be practical and inexpensive and whether a relationship existed between that property and the other properties.

The results of PC analysis for the physical properties of soils are given in Figure 1. A correlation matrix of the physical properties selected through the PC analysis is given in Table 3. According to that, the first PC explained 43.7%, the second PC 20.2%, the third PC 8.9% and the fourth PC 7.90% of the variance. As the four PCs explained 80.8% of the total variance and had an eigenvalue ≥1.1113, these four PCs were selected. The PC results of the physical properties are given in Figure 3. The properties that contributed most to the first PC were Sand (-0.381), Clay (0.294), FC_{10} (0.354), FC_{33} (0.379) and Silt (0.294); the properties contributing most to the second PC were Pb (-0.457) and P (0.457); those contributing most to the third PC were PWP (-0.564), AWC_{10} (0.359) and AWC_{33} (0.523); and the properties contributing most to the fourth PC were PR_{0-20} (-0.481) and PR_{20-40} (-0.662). From the order of PCs achieved by assessing the physical properties of soils, Sand, Clay, FC_{10}, FC_{33}, Silt, Pb, P, PWP_{1500}, AWC_{10}, AWC_{33}, PR_{0-20} and PR_{20-40} were qualified for selection as candidates for the MDS. However, as it is necessary to use the fewest data in determining SQ, we needed to select MDS by considering the component data loads, correlation load totals, inter-data correlations, analysis methods and applicability.

According to these criteria, the correlation load totals of the candidate data in PC1, Sand, Clay, FC_{10}, FC_{33} and Silt, were 4.352, 3.153, 3.897, 4.099 and 4.209, respectively. It is not possible to change the values of Sand and Clay in practice and they have no sensitivity against the periodic climate and land management changes. Therefore, these two properties were eliminated from the MDS. Among the other three properties, FC_{33} was the first physical soil property selected for inclusion in the MDS, as it had the highest correlation load (4.209), was extensively used and showed correlation with 11 of the physical properties of soil (Table 6). Furthermore, as the high values of FC_{33} would mean a greater accumulation of water in the soils, it will be a quality indicator, particularly for dry and semi-dry regions to show that plants are less affected from water stress. This will also be valid for the other regions considering the cost-effective and sustainable use of water. The candidate PB and P data for PC2 had inner total correlation loads of **1.994**. Because of a high negative correlation between these two candidate properties (R^2 = -0.994; $p<0.01$, Table 9) and P was measured from Pb, Pb was selected as the second physical property of soil for inclusion in the MDS. The total inner correlation loads of the candidate properties of PC3, PWP, AWC_{10} and AWC_{33}, were 1.200, 1.981 and 1.861, respectively. As PWP had the lowest total correlation load among these three properties and a high positive correlation existed between AWC_{10} and AWC_{33} (R^2 = 0.821; $p<0.000$; Table 9), AWC_{10} was included in the MDS for PC3. As the candidate data of PC4, PR_{0-20} and PR_{20-40} indicated the compression at different depths in the soil, both parameters were included in the MDS.

Summarizing, FC_{33}, Pb, AWC_{10}, PR_{0-20} and PR_{20-40} among the physical SQ parameters were included in the MDS, and among these selected properties Pb, AWC_{10}, PR_{0-20} and PR_{20-40} are present in common SQ assessment systems, such as the CSHA or SMAF (Gugino et al., 2009; Karlen et al., 1997). These selected physical properties are used in the CSHA and SMAF and they were also reported by many researchers as the quality indicators for parameters such as FC_{33} that are not included in the CSHA (Erkossa et al., 2007; Moncada et al., 2014; Rashidi et al., 2010; Sánchez-Navarro et al., 2015; Yang et al., 2010).

Açıklama [hn38]: In conclusion deleted.

At the end of the PC analysis, of the chemical properties of soils, are given in Figure 2, and the correlation matrix of the selected chemical properties is given in Table 4. According to this, the first PC explained 29%, the second PC 19.4%, the third PC 10.7% and the fourth PC 8.7% of the variance. As these four PCs explained 67.8% of the total variance and had an eigenvalue ≥1.3042, they were selected. The PC results of the chemical properties are given in Figure 2. The properties that contributed most to the first PC were EC (0.447), Lime (0.335) and Mg (0.375); the properties contributing most to the second PC were Ca (-0.484), Na (-0.342), K (-0.431), Cu (-0.359) and Mn (-0.417); the properties contributing most to the third PC were TN (-0.475), AP (-0.401) and Zn (-0.411); and the properties that contributed most to the fourth PC were pH (-0.359) and NO_3-N (0.381).From the order of the PCs obtained from assessing the chemical properties of soils, EC, Lime, Mg, Ca, Na, K, Cu, Mn, TN, AP, Zn, pH and NO_3-N qualified as candidates for the MDS. However, as it is necessary to use the fewest data in determining the SQ, MDS were selected. The total inner correlation loads of the candidate properties of PC1, EC, Lime and Mg, were 1.585, 1.839 and 1.962, respectively. Although the total EC correlation load was lower than the other two properties, as the PC load was higher, the region was located in a dry to semi-dry climate zone and significant salinization problems existed in certain areas, it was included in the minimum set together with Lime. However, as Mg was highly correlated with EC (R^2=0,623; p<0,01) and $Lime_{0-20}$ (R^2=0,608; p<0,01) (Table 6) and the Mg scopes of the soils subject to the study were above the sufficiency level in all samples, it was not included in the MDS.

The total inner correlation loads of the candidate properties of PC2, Ca, Na, K, Cu and Mn, were 3.019, 2.280, 2.891 and 2.131, respectively. As Ca had the highest total correlation load among these five properties and Mn remained below the level of sufficiency in certain samples (<14.0 mg Mn kg^{-1} (FAO, 1990)), it was included in the MDS. However, as the Cu and K contents of the soils were above the level of sufficiency in all samples (>0.2 mg Cu kg^{-1} (Follett, 1969); >110 mg K kg^{-1} (FAO, 1990)) and Na was not a nutrient element, it was not included in the MDS. The total inner correlation loads of the candidate properties of PC3, TN, AP and Zn, were 1.244, 1.543 and 1.443, respectively. No significant correlation existed among these three properties, Zn remained below the sufficiency level (>0.7 mg Zn kg^{-1} presence (FAO, 1990)), P was an important macro nutrient element and TN remained below the sufficiency level in most of the soils studied (<0.09% N); thus, they were included in the MDS for TN, AP and Zn. The total inner correlation load of the candidate properties of pH and NO_3-N was 1.425. Soil pH directly affects the usefulness of the nutrient elements. NO_3-N was lacking in our soils, and when it is excessive, it might cause environmental health problems, it was therefore included in the MDS. Similarly, pH, AP, Mn and Zn in CSHA and SMAF were also accepted as SQ parameters (Andrews et al., 2004; Gugino et al., 2009).). Summarizing, EC, Lime**,** Mg, Ca, Mn, TN, AP, Zn, pH and NO_3-N among the chemical SQ parameters were selected as the variables that could be included in MDS. Most of these selected properties are also used as quality criteria in the CSHA and SMAF. Several other researchers reported that Lime**,** Ca, TN and NO_3**-**N that are not used in these assessment systems could be used as quality indicators (Baridón and Casas, 2014; Benintende et al.,

Açıklama [hn39]: In conclusion deleted.

2015; Liu et al., 2014; Mojiri et al., 2011; Sánchez-Navarro et al., 2015; Shirani et al., 2015; Viana et al., 2014; Zdruli et al., 2014).

From the PC analysis, for the biological properties of soils, are given in Figure 3 and the correlation matrix for the selected biological properties is given in Table 5. The first PC explained 34%, the second PC 23.2% and the third PC 15.3% of the variance. As the three PCs explained 72.5% of the total variance and had an eigenvalue ≥1.3738, these three PCs were selected. The properties that contributed most to the first PC were the amounts of UA (0.486), DA (-0.412) and MSN (0.461); properties that contributed most to the second PC were OC (-0.410), AC (0.411) and R (-0.426); properties that contributed most to the third PC were PMN (0.584), RHV (-0.506) and CA (-0.380), and these became candidates for MDS. The total inner correlation loads of the candidate properties of PC1, the levels of UA, DA and MSN, were 2.248, 2.044 and 2.184, respectively. As urease had the highest total correlation load among these properties, UA was included in the MDS for PC1. Although dehydrogenase was the second property with the highest correlation total, due to the presence of significant correlations both between DA and UA and between DA and AC and the difficulty of determining the amount of MSN, the latter two properties were not included in the MDS. The properties that contributed the most to PC2 were OC, AC and R. The correlation load totals of these were 1.680, 1.043 and 1.671, respectively. Among these properties, R and OC, which had the highest PC coefficient, were included in the minimum set for PC2. Only PMN, RHV and CA were selected as candidates for the PC3 data set. The correlation load totals of PMN, RHV and CA were 1.269, 1.685 and 1.526, respectively. They were included in the MDS, as the highest correlation load total was in the RHV. According to the results obtained, OC and R were accepted as SQ parameters in the CSHA, and OC and R were accepted as SQ parameters in the SMAF (Andrews et al., 2004; Gugino et al., 2009; Moebius-Clune et al., 2011). Though urease activity among these selected properties is not listed in the CSHA or

SMAF, many other researchers reported that these could be used as quality indicators (Baridón and Casas, 2014; Benintende et al., 2015; Masto et al., 2007; Saviozzi et al., 2001).

4. CONCLUSIONS

This paper discusses the parameters that could be used to monitor the SQ in the Konya Çumra region, one of the most important agricultural lands in Turkey.

The study also revealed the physical, chemical and biological parameters that could be used to assess the SQ in the study area and in other areas. The MDS was created for the selection of indicators using the PC analysis for this purpose. FC_{33}, Pb, AW_{10}, PR_{0-20} and PR_{20-40}, among the physical properties; EC, Mg, lime, Ca, Mn, TN, AP, Zn, pH and NO_3-N among the chemical properties; and UA, OC, R and root health among the biological properties were selected as indicators that could be used in the assessment of SQ. Score functions for the properties that exist in the CSHA and SMAF among these parameters can be used in scoring. On the other hand, other parameters such as FC_{33}, lime, Ca, TN, NO_3-N and urease were also found to be suitable for use in assessing SQ. Consequently, scoring functions of these properties must be developed. In this study, the MDS method and principal components analysis were found to be appropriate statistical methods to select the quality indicators.

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REFERENCES

Andrews, S., Karlen, D., and Mitchell, J.: A comparison of soil quality indexing methods for vegetable production systems in Northern California, Agriculture, ecosystems & environment, 90, 25-45, 2002.

Andrews, S. S., Karlen, D. L., and Cambardella, C. A.: The soil management assessment framework, Soil Science Society of America Journal, 68, 1945-1962, 2004.

Aparicio, V. and Costa, J. L.: Soil quality indicators under continuous cropping systems in the Argentinean Pampas, Soil and Tillage Research, 96, 155-165, 2007.

Aronson, J., Floret, C., Floc'h, E., Ovalle, C., and Pontanier, R.: Restoration and Rehabilitation of Degraded Ecosystems in Arid and Semi- Arid Lands. I. A View from the South, Restoration ecology, 1, 8-17, 1993.

Arshad, M. and Coen, G.: Characterization of soil quality: physical and chemical criteria, American Journal of Alternative Agriculture, 7, 25-31, 1992.

Arshad, M. A. and Martin, S.: Identifying critical limits for soil quality indicators in agro-ecosystems, Agriculture, Ecosystems & Environment, 88, 153-160, 2002.

Baridón, J. E. and Casas, R. R.: Quality indicators in subtropical soils of Formosa, Argentina: Changes for agriculturization process, International Soil and Water Conservation Research, 2, 13-24, 2014.

Beck, T.: Die messung der katalaseaktivitaet von Böden, Zeitschrift für Pflanzenernährung und Bodenkunde, 130, 68-81, 1971.

Benintende, S., Benintende, M., Sterren, M., Saluzzio, M., and Barbagelata, P.: Biological variables as soil quality indicators: Effect of sampling time and ability to classify soils by their suitability, Ecological Indicators, 52, 147-152, 2015.

Bindraban, P., Stoorvogel, J., Jansen, D., Vlaming, J., and Groot, J.: Land quality indicators for sustainable land management: proposed method for yield gap and soil nutrient balance, Agriculture, Ecosystems & Environment, 81, 103-112, 2000.

Blair, G. J., Lefroy, R. D., and Lisle, L.: Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for agricultural systems, Crop and Pasture Science, 46, 1459-1466, 1995.

Blake, G. and Hartge, K.: Particle density, Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods, 1986. 377-382, 1986.

Brandt, C. J. and Thornes, J. B.: Mediterranean desertification and land use, John Wiley & Sons Ltd, 1996.

Brejda, J. J., Karlen, D. L., Smith, J. L., and Allan, D. L.: Identification of regional soil quality factors and indicators II. Northern Mississippi Loess Hills and Palouse Prairie, Soil Science Society of America Journal, 64, 2125-2135, 2000a.

Brejda, J. J., Moorman, T. B., Karlen, D. L., and Dao, T. H.: Identification of regional soil quality factors and indicators I. Central and Southern High Plains, Soil Science Society of America Journal, 64, 2115-2124, 2000b.

Burger, J. A. and Kelting, D. L.: Soil quality monitoring for assessing sustainable forest management, The contribution of soil science to the development of and implementation of criteria and indicators of sustainable forest management, 1998. 17-52, 1998.

Chen, Z.: Selecting the indicators to evaluate the soil quality of Taiwan soils and approaching the national level of sustainable soil management, 1998, 131-171.

Danielson, R., Sutherland, P., and Klute, A.: Porosity, Methods of soil analysis. Part 1. Physical and mineralogical methods, 1986. 443-461, 1986.

De Meester, T.: Soils of the Great Konya Basin, Turkey, Agric. Res. Rep, 740, 290, 1970.

Dick, R. P., Breakwell, D. P., Turco, R. F., Doran, J., and Jones, A.: Soil enzyme activities and biodiversity measurements as integrative microbiological indicators, Methods for assessing soil quality., 1996. 247-271, 1996.

Doran, J., Safley, M., Pankhurst, C., Doube, B., and Gupta, V.: Defining and assessing soil health and sustainable productivity, Biological indicators of soil health., 1997. 1-28, 1997.

Doran, J. W.: Soil health and global sustainability: translating science into practice, Agriculture, ecosystems & environment, 88, 119-127, 2002.

Doran, J. W. and Jones, A. J.: Methods for assessing soil quality, Soil Science Society of America Inc., 1996.

Doran, J. W. and Parkin, T. B.: Defining and assessing soil quality, Defining soil quality for a sustainable environment, 1994. 1-21, 1994.

Doran, J. W., Parkin, T. B., and Jones, A.: Quantitative indicators of soil quality: a minimum data set, Methods for assessing soil quality., 1996. 25-37, 1996.

Doran, J. W. and Zeiss, M. R.: Soil health and sustainability: managing the biotic component of soil quality, Applied soil ecology, 15, 3-11, 2000.

Dumanski, J. and Pieri, C.: Land quality indicators: research plan, Agriculture, Ecosystems & Environment, 81, 93-102, 2000.

Einax, J. and Soldt, U.: Geostatistical and multivariate statistical methods for the assessment of polluted soils—merits and limitations, Chemometrics and Intelligent Laboratory Systems, 46, 79-91, 1999.

El-Ramady, H. R., Alshaal, T., Amer, M., Domokos-Szabolcsy, É., Elhawat, N., Prokisch, J., and Fári, M.: Soil quality and plant nutrition. In: Sustainable Agriculture Reviews 14, Springer, 2014.

Erkossa, T., Itanna, F., and Stahr, K.: Indexing soil quality: a new paradigm in soil science research, Soil Research, 45, 129-137, 2007.

Eswaran, H., Lal, R., and Reich, P.: Land degradation: an overview, Responses to Land degradation, 2001. 20-35, 2001.

FAO: Micronutrient Assessment at The Country Level p 1-208, An international study (Ed., M. Sillanpa). FAO Soil Bulletin 63. Published by FAO, Rome, İtaly., 1990.

Fauci, M. F. and Dick, R. P.: Microbial biomass as an indicator of soil quality: Effects of long-term management and recent soil amendments, Defining soil quality for a sustainable environment, 1994. 229-234, 1994.

Fernandes, J. C., Gamero, C. A., Rodrigues, J. G. L., and Mirás-Avalos, J. M.: Determination of the quality index of a Paleudult under sunflower culture and different management systems, Soil and Tillage Research, 112, 167-174, 2011.

Follett, R. H.: Zn, Fe, Mn, and Cu in Colorado soils, 1969. 1969.

Gee, G. and Bauder, J.: Particle-size analysis In: Klute, A.(ed) Methods of soil analysis, Part 1. American society of Agronomy, Inc., Ma, 1986. 1986.

Gerdemann, J. and Nicolson, T. H.: Spores of mycorrhizal Endogone species extracted from soil by wet sieving and decanting, Transactions of the British Mycological society, 46, 235-244, 1963.

Govaerts, B., Sayre, K. D., and Deckers, J.: A minimum data set for soil quality assessment of wheat and maize cropping in the highlands of Mexico, Soil and Tillage Research, 87, 163-174, 2006.

Gregorich, E., Monreal, C., Carter, M., Angers, D., and Ellert, B.: Towards a minimum data set to assess soil organic matter quality in agricultural soils, Canadian journal of soil science, 74, 367-385, 1994.

Gugino, B. K., Abawi, G. S., Idowu, O. J., Schindelbeck, R. R., Smith, L. L., Thies, J. E., Wolfe, D. W., and Van Es, H. M.: Cornell soil health assessment training manual, Cornell University College of Agriculture and Life Sciences, 2009.

Harris, R. F., Karlen, D. L., Mulla, D. J., Doran, J., and Jones, A.: A conceptual framework for assessment and management of soil quality and health, Methods for assessing soil quality., 1996. 61-82, 1996.

Herrick, J. E. and Jones, T. L.: A dynamic cone penetrometer for measuring soil penetration resistance, Soil Science Society of America Journal, 66, 1320-1324, 2002.

Hoffmann, G. and Teicher, K.: Ein kolorimetrisches Verfahren zur Bestimmung der Ureaseaktivität in Böden, Zeitschrift für Pflanzenernährung, Düngung, Bodenkunde, 95, 55-63, 1961.

Hueso‐ González, P., Martínez‐ Murillo, J. F., and Ruiz‐ Sinoga, J. D.: The impact of organic amendments on forest soil properties under Mediterranean climatic conditions, Land Degradation & Development, 25, 604-612, 2014.

Isermeyer, H.: Eine einfache Methode zur Bestimmung der Bodenatmung und der Karbonate im Boden, Zeitschrift für Pflanzenernährung, Düngung, Bodenkunde, 56, 26-38, 1952.

Kacar, B.: Toprak analizleri, Nobel Yayın Dağıtım, 2009.

Karagöz, Y. and Kösterelioğlu, İ.: İletişim becerileri değerlendirme ölçeğinin faktör analizi metodu ile geliştirilmesi, Dumlupınar Üniversitesi Sosyal Bilimler Dergisi, 21, 2015.

Karlen, D., Mausbach, M., Doran, J., Cline, R., Harris, R., and Schuman, G.: Soil quality: a concept, definition, and framework for evaluation (a guest editorial), Soil Science Society of America Journal, 61, 4-10, 1997.

Karlen, D. L., Birell, S. J., and Hess, J. R.: A five-year assessment of corn stover harvest in central Iowa, USA, Soil and Tillage Research, 115, 47-55, 2011.

Karlen, D. L., Ditzler, C. A., and Andrews, S. S.: Soil quality: why and how?, Geoderma, 114, 145-156, 2003.

Kay[1], B., Grant, C., and Australia, S.: Structural aspects of soil quality, Soil Quality is in the Hands of the Land Manager, 1996. 37, 1996.

Keeney, D. R. and Nelson, D.: Nitrogen—inorganic forms, Methods of soil analysis. Part 2. Chemical and microbiological properties, 1982. 643-698, 1982.

Klute, A.: Water retention: laboratory methods, Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods, 1986. 635-662, 1986.

Larson, W. and Pierce, F.: Conservation and enhancement of soil quality, 1991.

Larson, W. E. and Pierce, F. J.: The dynamics of soil quality as a measure of sustainable management, Defining soil quality for a sustainable environment, 1994. 37-51, 1994.

Li, Y. and Lindstrom, M.: Evaluating soil quality–soil redistribution relationship on terraces and steep hillslope, Soil Science Society of America Journal, 65, 1500-1508, 2001.

Lima, A., Brussaard, L., Totola, M., Hoogmoed, W., and De Goede, R.: A functional evaluation of three indicator sets for assessing soil quality, Applied Soil Ecology, 64, 194-200, 2013.

Linden, D. R., Hendrix, P. F., Coleman, D. C., and van Vliet, P. C.: Faunal indicators of soil quality, Defining soil quality for a sustainable environment, 1994. 91-106, 1994.

Liu, Z., Zhou, W., Shen, J., Li, S., He, P., and Liang, G.: Soil quality assessment of Albic soils with different productivities for eastern China, Soil and Tillage Research, 140, 74-81, 2014.

Masto, R. E., Chhonkar, P. K., Singh, D., and Patra, A. K.: Soil quality response to long-term nutrient and crop management on a semi-arid Inceptisol, Agriculture, Ecosystems & Environment, 118, 130-142, 2007.

McGrath, D. and Zhang, C.: Spatial distribution of soil organic carbon concentrations in grassland of Ireland, Applied Geochemistry, 18, 1629-1639, 2003.

Meester, T. d.: Highly calcareous lacustrine soils in the Great Konya Basin, Turkey, Pudoc, Wageningen, The Netherlands, 1971. 1971.

Meester, T. d.: Soils of the Great Konya Basin, Turkiye, Wageningen: Pudoc, Centre for Agricultural Publishing and Documentation, 1970.

MGM: Müdürlüğü, Meteoroloji Genel İklim Verileri. Meteoroloji Genel Müdürlüğü, 2014.

Minitab: Minitab reference manual (Release 7.1). In: Minitab Inc., State Coll PA, 16801, USA, 1995.

Moebius-Clune, B., Idowu, O., Schindelbeck, R., Van Es, H., Wolfe, D., Abawi, G., and Gugino, B.: Developing standard protocols for soil quality monitoring and assessment. In: Innovations as key to the green revolution in Africa, Springer, 2011.

Mojiri, A., Kazemi, Z., and Amirossadat, Z.: Effects of land use changes and hillslope position on soil quality attributes (A case study: Fereydoonshahr, Iran), African journal of Agricultural research, 6, 1114-1119, 2011.

Moncada, M. P., Gabriels, D., and Cornelis, W. M.: Data-driven analysis of soil quality indicators using limited data, Geoderma, 235, 271-278, 2014.

Muñoz-Rojas, M., Erickson, T. E., Martini, D., Dixon, K. W., and Merritt, D. J.: Soil physicochemical and microbiological indicators of short, medium and long term post-fire recovery in semi-arid ecosystems, Ecological Indicators, 63, 14-22, 2016.

Muñoz- Rojas, M., Erickson, T. E., Dixon, K. W., and Merritt, D. J.: Soil quality indicators to assess functionality of restored soils in degraded semiarid ecosystems, Restoration Ecology, 2016. 2016.

Nortcliff, S.: Standardisation of soil quality attributes, Agriculture, Ecosystems & Environment, 88, 161-168, 2002.

Olsen, S., Sommers, L., and Page, A.: Methods of soil analysis. Part 2, Agron. Monogr, 9, 403-430, 1982.

Özulu, M., Özaytekin, H. H., and Uyanöz, R.: Toprak Kalitesinin Değerlendirilmesinde Farklı Yaklaşımlar, Selçuk Tarım Bilimleri Dergisi, 20, 1-8, 2006.

Powers, R. F., Tiarks, P., and Boyle, J. R.: Assessing soil quality: practicable standards for sustainable forest productivity in the United States, The contribution of soil science to the development of and implementation of criteria and indicators of sustainable forest management, 1998. 53-80, 1998.

Qi, Y., Darilek, J. L., Huang, B., Zhao, Y., Sun, W., and Gu, Z.: Evaluating soil quality indices in an agricultural region of Jiangsu Province, China, Geoderma, 149, 325-334, 2009.

Rasheed, S., Li, Z., Xu, D., and Kovacs, A.: Presence of cell-free human immunodeficiency virus in cervicovaginal secretions is independent of viral load in the blood of human immunodeficiency virus-infected women, American journal of obstetrics and gynecology, 175, 122-130, 1996.

Rashidi, M., Seilsepour, M., Ranjbar, I., Gholami, M., and Abbassi, S.: Evaluation of some soil quality indicators in the Varamin region, Iran, World Applied Sciences Journal, 9, 101-108, 2010.

Reganold, J. P. and Palmer, A. S.: Significance of gravimetric versus volumetric measurements of soil quality under biodynamic, conventional, and continuous grass management, Journal of Soil and Water Conservation, 50, 298-305, 1995.

Rezaei, S. A., Gilkes, R. J., and Andrews, S. S.: A minimum data set for assessing soil quality in rangelands, Geoderma, 136, 229-234, 2006.

Rice, C. W., Moorman, T. B., and Beare, M.: Role of microbial biomass carbon and nitrogen in soil quality, Methods for assessing soil quality, 1996. 203-215, 1996.

Sánchez-Navarro, A., Gil-Vázquez, J., Delgado-Iniesta, M., Marín-Sanleandro, P., Blanco-Bernardeau, A., and Ortiz-Silla, R.: Establishing an index and identification of limiting parameters for characterizing soil quality in Mediterranean ecosystems, Catena, 131, 35-45, 2015.

Saviozzi, A., Levi-Minzi, R., Cardelli, R., and Riffaldi, R.: A comparison of soil quality in adjacent cultivated, forest and native grassland soils, Plant and soil, 233, 251-259, 2001.

Shirani, H., Habibi, M., Besalatpour, A., and Esfandiarpour, I.: Determining the features influencing physical quality of calcareous soils in a semiarid region of Iran using a hybrid PSO-DT algorithm, Geoderma, 259, 1-11, 2015.

Shukla, M., Lal, R., and Ebinger, M.: Soıl qualıty ındıcators for the north Appalachian experimental watersheds ın Coshocton Ohio, Soil Science, 169, 195-205, 2004.

Sinha, N. K., Chopra, U. K., Singh, A. K., Mohanty, M., Somasundaram, J., and Chaudhary, R.: Soil Physical Quality as Affected by Management Practices Under Maize–Wheat System, National Academy Science Letters, 37, 13-18, 2014.

Staff, S. S.: Keys to soil taxonomy, Soil Conservation Service, 1999.

Tatlidil, H.: Uygulamali çok degiskenli istatistiksel analiz, Ankara: Cem Web Ofset Ltd. Sti, 2002. 424, 2002.

Thalmann, A.: Zur Methodik der bestimmung der dehydrogenaseaktivität im boden mittels triphenyltetrazoliumchlorid (TTC), Landwirtsch. Forsch, 21, 249-258, 1968.

Turco, R., Kennedy, A., and Jawson, M.: Microbial indicators of soil quality, Purdue Univ., Lafayette, IN (United States), 1992.

Viana, R. M., Ferraz, J. B., Neves, A. F., Vieira, G., and Pereira, B. F.: Soil quality indicators for different restoration stages on Amazon rainforest, Soil and Tillage Research, 140, 1-7, 2014.

Wright, A. F. and Bailey, J. S.: Organic carbon, total carbon, and total nitrogen determinations in soils of variable calcium carbonate contents using a Leco CN-2000 dry combustion analyzer, Communications in Soil Science and Plant Analysis, 32, 3243-3258, 2001.

Yang, J., Kim, S., Ok, Y., Lee, H., Kim, D., and Kim, K.: Determining minimum data set for soil quality assessment of organic farming system in Korea, 2010, 1-6.

Yemefack, M., Jetten, V. G., and Rossiter, D. G.: Developing a minimum data set for characterizing soil dynamics in shifting cultivation systems, Soil and Tillage Research, 86, 84-98, 2006.

Yu-Dong, C., Huo-Yan, W., Jian-Min, Z., Lu, X., Bai-Shu, Z., Yong-Cun, Z., and Xiao-Qin, C.: Minimum data set for assessing soil quality in farmland of northeast China, Pedosphere, 23, 564-576, 2013.

Zdruli, P., Calabrese, J., Ladisa, G., and Otekhile, A.: Impacts of land cover change on soil quality of manmade soils cultivated with table grapes in the Apulia Region of south-eastern Italy, Catena, 121, 13-21, 2014.

Zhang, B., Zhang, Y., Chen, D., White, R., and Li, Y.: A quantitative evaluation system of soil productivity for intensive agriculture in China, Geoderma, 123, 319-331, 2004.

Table 1. Physical, Chemical and Biological Data Sets Belonging to the KMO and Barlett Sphericity Test

	Physical Properties	Chemical Properties	Biological Properties
Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.634	0.667	0.629
Bartlett's Test of Sphericity Approx. Chi-Square	3967	977	453
Sphericity	91	105	36
Significance level	0.000	0.000	0.000

Table 2. Physical, Chemical and Biological Properties of Soil at Sampling Sites.

Parameters	Variable		Mean	%CV	Min.	Max.
Physical Properties	Sand	%	40.32	27.55	17.10	61.88
	Silt	%	25.17	24.03	11.60	40.00
	Clay	%	34.52	21.76	18.05	53.53
	Pb	g cm^{-3}	1.35	8.80	1.10	1.63
	Pk	g cm^{-3}	2.64	0.99	2.54	2.71
	P	%	48.85	9.22	38.38	58.00
	FC_{10}	g g^{-1}	0.32	16.55	0.22	0.46
	FC_{33}	g g^{-1}	0.24	17.17	0.17	0.38
	PWP	g g^{-1}	0.14	21.92	0.10	0.25
	AWC_{10}	g g^{-1}	0.18	21.61	0.09	0.29
	AWC_{33}	g g^{-1}	0.10	27.36	0.04	0.20
	AS	%	17.84	56.07	4.83	52.32
	$PR_{0\text{-}20}$	PSI	208.08	37.70	83.00	415.00
	$PR_{20\text{-}40}$	PSI	314.82	31.32	147.00	689.00
Chemical Properties	pH	-	8.03	1.98	7.34	8.29
	EC	µS m^{-1}	523.50	48.08	243.00	1748.00
	Lime	%	8.97	20.33	6.47	16.48
	TN	%	0.08	35.65	0.03	0.16
	NH_4-N	mg kg^{-1}	17.13	30.56	7.00	44.89
	NO_3-N	mg kg^{-1}	25.07	83.61	3.46	129.88
	AP	mg kg^{-1}	12.97	50.80	3.36	37.79
	Ca	mg kg^{-1}	5089	28.82	2622.00	8160.00
	Mg	mg kg^{-1}	818.90	53.54	220.00	1925.00
	Na	mg kg^{-1}	82.36	38.41	25.00	203.00
	K	mg kg^{-1}	577.50	33.95	307.00	1356.00
	Fe	mg kg^{-1}	7.52	33.53	3.65	14.38
	Cu	mg kg^{-1}	1.29	29.61	0.45	2.06
	Mn	mg kg^{-1}	15.82	38.81	5.45	25.97
	Zn	mg kg^{-1}	1.10	43.10	0.26	3.77
Biological Properties	OC	%	0.71	31.90	0.29	1.43
	AC	mg kg^{-1}	486.70	49.25	96.00	996.00
	PMN	µg g^{-1}w^{-1}	9.59	50.37	0.51	20.26
	RHV	-	3.90	40.29	1.00	8.00
	R	mg 100g^{-1} 24h^{-1}	25.56	23.42	11.37	39.27
	CA	mg 5g^{-1}	6.56	41.33	1.87	16.20
	UA	µg g^{-1}	189.20	90.49	17.80	581.00
	DA	µg g^{-1}	2.29	69.26	0.12	5.87
	MSN number	10g^{-1}	60.90	78.16	5.83	259.00

Pb, bulk density; Pk, particle density; P, porosity; FC_{10}, field capacity (10 kPa); FC_{33}, field capacity (33 kPa); PWP_{10}, permanent wilting percentage; AW_{10}, available water (10-1500 kPa); AW_{33}, available water (33-1500 kPa); AS, Aggregate stability; $PR_{0\text{-}20}$, penetration resistance (0-20 cm); $PR_{20\text{-}40}$, penetration resistance (20-40 cm); TN, total nitrogen; NH_4-N, ammonium nitrogen; NO_3-N, nitrate nitrogen; AP; available phosphorus; OC, organic carbon; AC, active carbon; PMN, potential mineralizable nitrogen; RHV, root health value; R, respiration; UA urease enzyme activity; CA, catalyzing enzyme activity; DA, dehydrogenase enzyme activity; MSN, mycorrhizal fungi; CV, coefficient of variation; Min, minimum; Max, maximum.

Table 3. Correlation Matrixes of the Selected Physical Properties in Principal Components Analysis (* Selected soil properties as a result of PCA)

PC1 variables	Sand	Silt	Clay	FC_{10}	FC_{33}
Sand		-0.770	-0.858	-0.843	-0.881
Silt	-0.770		0.334	0.485	0.564
Clay	-0.858	0.334		0.856	0.849
FC_{10}	-0.843	0.485	0.856		0.915
FC_{33}	-0.881	0.564	0.849	0.915	
Total	4.352	3.153	3.897	4.099	4.209*
PC2 variables	**Pb**	**P**			
Pb		-0.994			
P	-0.994				
Total	1.994*	1.994			
PC3 variables	**PWP**	**$AW_{10-1500}$**	**$AW_{33-1500}$**		
PWP		0.160	0.040		
AWC_{10}	0.160		0.821		
AWC_{33}	0.040	0.821			
Total	1.200	1.981*	1.861		
PC4 variables	**PR_{0-20}**	**PR_{20-40}**			
PR_{0-20}		0.788			
PR_{20-40}	0.788				
Total	1.788*	1.788*			

Table 4. Correlation Matrixes of the Selected Chemical Properties in Principal Components Analysis (* Selected soil properties as a result of PCA)

PC1 variables	EC	Lime	Mg		
EC		-0.231	-0.354		
Lime	-0.231		0.608		
Mg	-0.354	0.608			
Total	1.585*	1.839*	1.962*		
PC2 variables	Ca	Na	K	Cu	Mn
Ca		0.308	0.539	0.756	0.416
Na	0.308		0.415	0.243	0.314
K	0.539	0.415		0.566	0.371
Cu	0.756	0.243	0.566		0.030
Mn	0.416	0.314	0.371	0.030	
Total	3.019*	2.280	2.891	2.595	2.131*
PC3 variables	TN	AP	Zn		
TN		0.172	0.072		
AP	0.172		0.371		
Zn	0.072	0.371			
Total	1.244*	1.543*	1.443*		
PC4 variables	pH	NO_3-N			
pH		-0.425			
NO_3-N	-0.425				
Total	1.425*	1.425*			

Table 5. Correlation Matrixes of the Selected Biological Properties in Principal Components Analysis (* Selected soil properties as a result of PCA)

PC1 variables	UA	DA	MSN
UA		-0.554	0.694
DA	-0.554		-0.490
MSN	0.694	-0.490	
Total	2.248*	2.044	2.184
PC2 variables	OC	AC	R
OC		-0.026	0.654
AC	-0.026		0.017
R	0.654	0.017	
Total	1.680*	1.043*	1.671*
PC3 variables	PMN	RHV	CA
PMN		-0.214	-0.055
RHV	-0.214		0.471
CA	-0.055	0.471	
Total	1.269	1.685*	1.526

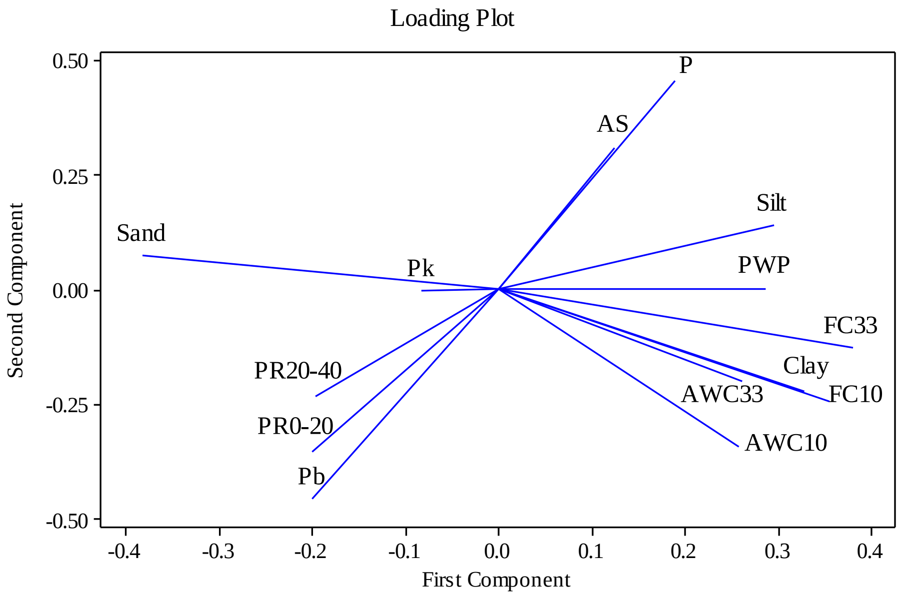
Table 6. Correlation matrix of physical, chemical and biological properties of soils (* P<0.05; ** P<0.01)

		Sand	Silt	Clay	Pb	Pk	P	FC_{10}	FC_{33}	PWP	AWC_{10}	AWC_{33}	PR_{0-20}	PR_{20-40}
Physical Properties	**Silt**	-0.770**												
	Clay	-0.858**	0.334**											
	Pb	0.375**	-0.547**											
	Pk													
	P	-0.353**	0.532**		-0.994**									
	FC_{10}	-0.843**	0.485**	0.856**										
	FC_{33}	-0.881**	0.564**	0.849**	-0.295**		0.277**	0.915**						
	PWP	-0.689**	0.374**	0.718**	-0.285**		0.268**	0.704**	0.763**					
	AWC_{10}	-0.602**	0.361**	0.599**				0.808**	0.644**					
	AWC_{33}	-0.574**	0.446**	0.489**				0.612**	0.664**		0,821**			
	AS		0.220*		-0.525**	-0.223*	0.499**							
	PR_{0-20}	0.334**	-0.416**		0.520**		-0.507**		-0.334**	-0.352**			-0,313**	
	PR_{20-40}	0.328**	-0.350**	-0.204*	0.333**		-0.316**	-0.252**	-0.349**	-0.296**		-0,219**	-0,199**	0,788**

		pH	EC	Lime	TN	NH_4-N	NO_3-N	AP	Ca	Mg	Na	K	Fe	Cu	Mn
Chemical Properties	**EC**	-0.604**													
	Lime	-0.231*	0.531**												
	TN			-0.226*											
	NH_4-N		0.221*	0.195*											
	NO_3-N	-0.425**	0.719**	0.371**		0.240*									
	AP	-0.230*	0.522**	0.259**			0.257**								
	Ca		0.235*				0.279**								
	Mg	-0.354**	0.623**	0.608**			0.307**	0.518**	-0.208**						
	Na				0.328**				0.308**						
	K		0.229*	0.277**	0.206*			0.209*	0.539**		0,415**				
	Fe	0.315**	-0.353**	-0.350**					0.258**	-0.418**					
	Cu	-0.233*	0.576**	0.434**		0.228*	0.444**		0.756**	0.306**	0,243*	0,566**			
	Mn	0.207*	-0.348**	-0.428**	0.458**	-0.218*	-0.164	-0.273**	0.416**	-0.749**	0,314**	0,371**	0,296**		
	Zn	-0.374*	0.518**				0.345**	0.371**		0.208*					

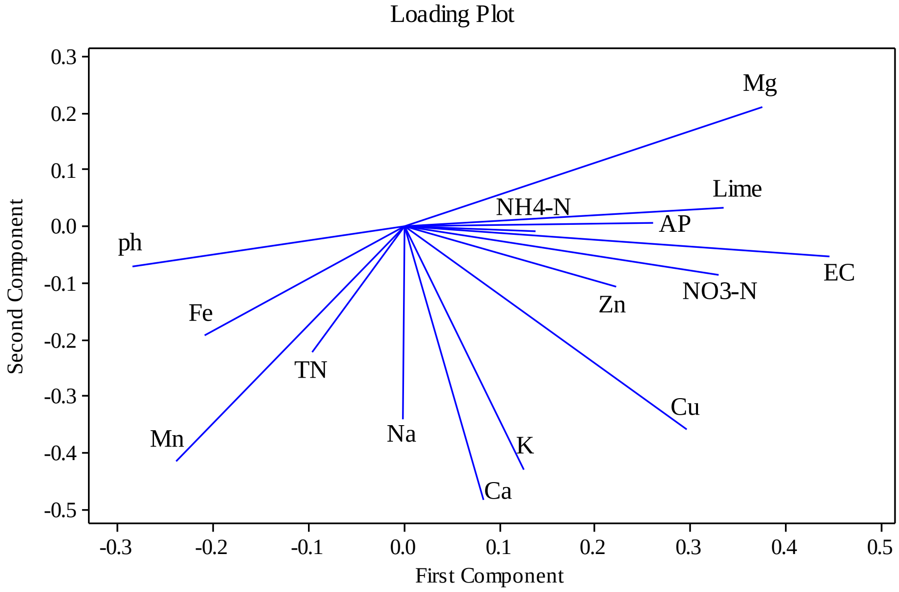
		OC	AC	PMN	RHV	R	CA	UA	DA
Biological Properties	**AC**								
	PMN		0.281**						
	RHV			-0.214*					
	R	0.654**			-0.255**				
	CA				0.471**	-0.343**			
	UA	0.363**	0.401**			0.526**			
	DA		-0.821**	-0.338**				-0.554**	
	MSN	0.298**	0.337**			0.482**		0.694**	-0.490**

Figure 1. Result of PCA with physical properties of soil



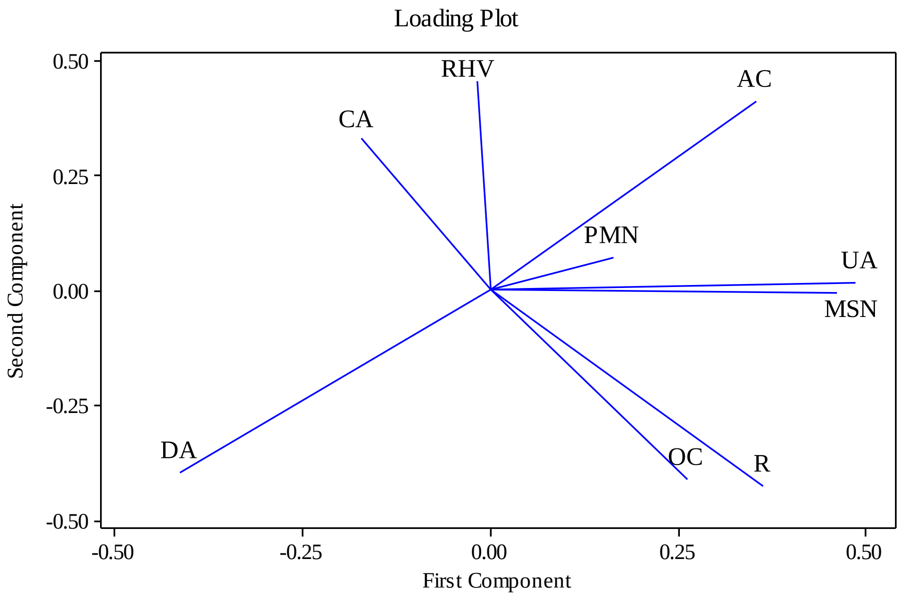
PCA, principle component analysis; Pb, bulk density; Pk, particle density; P, porosity; FC10, field capacity (10 kPa); FC33, field capacity (33 kPa); PWP10, permanent wilting percentage; AW10, available water (10-1500 kPa); AW33, available water (33-1500 kPa); AS, Aggregate stability; PR0-20, penetration resistance (0-20 cm); PR20-40, penetration resistance (20-40 cm).

Figure 2. Result of PCA with chemical properties of soil



PCA, principle component analysis; TN, total nitrogen; NH_4-N, Ammonium nitrogen; NO_3-N, nitrate nitrogen; AP; Available phosphorus.

Figure 3. Result of PCA with biological properties of soil



PCA, principle component analysis; OC, organic carbon; AC, active carbon; PMN, Potential mineralizable nitrogen; RHV, root health value; R, respiration; UA urease enzyme activity; CA, catalyzing enzyme activity; DA, dehydrogenase enzyme activity; MSN, mycorrhizal fungi.