J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., Vol. 14 (8): 223 - 233 , 2023

Journal of Soil Sciences and Agricultural Engineering

Journal homepage & Available online at: www.jssae.journals.ekb.eg

Soil Quality Assessment of Certain Lands in Khor Sarah area, Aswan Governorate, Egypt

Elcossy, S. A. E.[1] and A. A. Elwan[2*]

[1]Soil Conservation Dept., Water Resources and Desert Soils Division, Desert Research Center (DRC), Cairo
[2]Pedology Dept., Water Resources and Desert Soils Division, Desert Research Center (DRC)

ABSTRACT

The goals of this study were to (i) determine the land capability classification of 111000 Faddan in southwestern Khor Sarah, Aswan, Upper Egypt, (ii) develop an effective and accurate soil quality indices and (iii) to evaluate the impact of converting barren land (BL) to three land use categories (PN, Peanut; ZM, Zea mays; WT, Wheat) on soil quality (SQ). Twenty-three soil pedons were investigated in order to represent the study area's six landforms. The data show that moderately capable lands account for 56.5% of Khor Sarah soils, while low capable lands account for 27.3% of the entire area. For SQ evaluation, twenty-six soil characteristics were measured as preliminary indicators. Eight physical-morphological characteristics, seven chemical factors, and eleven fertility-biological criteria were all measured at different depths of selected soil pedons as potential SQ indicators. Under all types of land uses, the SQI value under PN was the highest, followed by that under BL, ZM, and WT. PN with good management improved soil quality, whereas other land use types with poor management damaged soil quality. The statistical results showed that elected soil properties were significantly influenced by land-use changes and farm management. Combined the soil indicators of root-restrictive layer depth (R-RLD) and macro-aggregate associated organic carbon (Ma-SOC) may have a better prediction performance for SQ. Four soil quality indices based on R-RLD, ECe, Fe_2O_3, Ma-SOC, and WHC were developed in this work and can be successfully used to forecast SQ in desert soils of Upper Egypt and other similar regions.

***Keywords*: Land capability, Soil quality, Root-restrictive layer, Minimum data set, Management.**

INTRODUCTION

Egypt intends to expand its agricultural sector in order to address issues like as food security, population growth, and encroachment on agricultural fields in order to boost national income through increased product exports. The Egypt Vision 2030 Sustainable Development Strategy (SDS) focuses on the difficulties that Egypt's development processes face (MCIT, 2020). Egypt is an extremely arid country, with annual rainfall of less than 200 mm around the coast and rapidly dropping inland to zero in Upper Egypt (Egyptian Meteorological Authority, 2022). Evaporation losses in the massive Aswan Dam Reservoir are over 15 BCM per year. In the meantime, water usage is increasing due to rapid population growth. In some Aswan dry soils, intensive farming has led to severe rock desertification and soil erosion, posing a serious threat to the region's long-term development (Marion *et al*., 2022). Cultivation has been advocated as a cost-effective method of restoring degraded land all over the world (Zhang *et al*., 2021). The impact of agriculture on soil quality (SQ) in Aswan's dry areas, Southwest Egypt, is still unknown.

Observing the impact of cultivating on SQ is basic for tending to long-term land-use maintainability challenges in dry environments (Raiesi and Beheshti, 2022). However, due to the complexity of SQ and the absence of widely used methods for assessing it (Mamehpour *et al*., 2021), adequate evaluation of SQ remains difficult when examining the effects of soil practises and farm management on soil quality (Guo *et al*., 2021; Gura *et al*., 2022). For the effective evaluation of SQ from plot to national scales, an accurate method of SQ is required (Amorim *et al*., 2021). The incorporation of several soil qualities into a single value is simple to implement and quantitatively adaptable at many locations and scales to assess soil quality index (SQI) (Guo *et al*., 2021).

Despite the fact that different soil quality indices (SQIs) have been effectively constructed for certain lands in previous works, SQI construction as a global index remains a promising issue (Marion *et al*., 2022). Indicator selection process is the first problem in developing an optimum SQI. Principal component analysis (PCA) is a statistical method and characterized by objectivity and flexibility for selecting a suitable soil criteria for measuring SQI (Mamehpour *et al*., 2021). High loading values of soil indicators are eventually picked to calculate SQI in the PCA method, while other relevant indicators linked to soil functioning are omitted (Roy *et al*., 2022). For example, Yinga *et al*. (2022) shown that in northeast India, five chemical and only four physical variables were chosen for PCA. Soil quality reflects changes in soils and can be monitored by combining biological, chemical, and physical aspects of the soil under study. Furthermore, the absence of critical soil property elements may result in imprecise SQI for soil function evaluation (Zhang *et al*., 2021). As a result, more research is required before implementing an optimal SQI in each area worldwide (Davari *et al*., 2020). In the indicators selection procedure, each indicator is translated and normalised into unitless scores for SQ calculation (Cardoso *et al*., 2013). To calculate the

---

*** Corresponding author.**
E-mail address: dr.elwan@drc.gov.eg
DOI: 10.21608/jssae.2023.228977.1178

requisite SQI, these indicator scores should be combined together using an appropriate additive method (Amorim *et al*., 2021; Raiesi and Beheshti, 2022). The weighted additive and simple additive approaches are the two most commonly used mathematical methods for calculating SQI (Santos- Francés *et al*., 2019; Amorim *et al*., 2021).

The right identification of essential indicators of soil function is an important component in assessing soil quality. There is no uniform or universal model for evaluating soil quality. Furthermore, addressing solely SQ changes in topsoil is a fundamental drawback of the SQI model since it provides insufficient and inaccurate information for SQ after land use change (Mamehpour *et al*., 2021). Consequently, this study aimed to achieve three main objectives: firstly, to ascertain the morphological, physical, and fertility-biological attributes of soils across various layers and horizons within selected pedons, encompassing both surface and subsurface soils. Secondly, the goal was to formulate Soil Quality Indices (SQIs) for distinct land uses within the study region, employing two distinct indicator selection methodologies (minimum dataset and revised minimum dataset), combined with two weighted additive techniques (variance and communality weighted). Lastly, the study aimed to evaluate the influence of alterations in land use on Soil Quality (SQ) within the context of Khor Sarah, located in Upper Egypt.

MATERIALS AND METHODS

Study area

The Khor Sarah area is part of the Aswan Governorate in Upper Egypt (Fig. 1). The study area encompasses 111000 Faddan in total. The experimental plots were set up within the study area's alluvial plain.

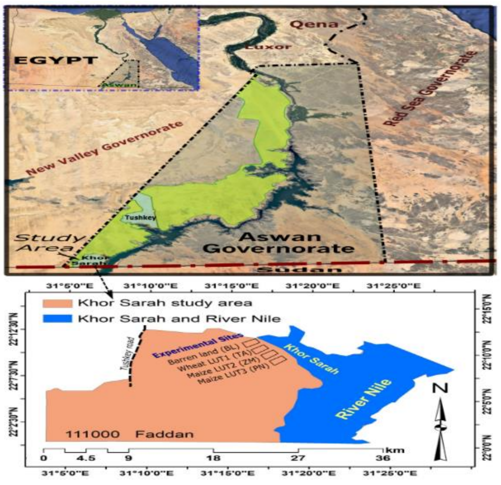

Fig. 1. The Location of the Khor Sarah study area, which includes the experimental sites for assessing SQ, in the Aswan Governorate of Upper Egypt.

The study location has a hypird environment with minimal rainfall (<1 mm yr^{-1}) and high temperatures (44.1°C). The area of study is characterized by a hot summer season, with average high temperatures ranging between 42.3°C and 44.1°C. The winter season, on the other hand, is moderate, with average temperatures ranging between 9.2°C and 10.6°C. The maximum temperature variation occurs in December, ranging from 24.3°C to 44.1°C (Egyptian Meteorological Authority, 2022). The lowest average temperatures are recorded in December and January, while the highest average temperatures are recorded in August. The study area is characterized by a high number of hours of sunshine. The average number of hours of sunshine ranges from 8 hours in December and increases to an average of 12.6 hours in June (Table 1) (Egyptian Meteorological Authority, 2022).

Table 1. Climate conditions of Khor Sarah area.

Month	Temperature		RH (%)	Wind speed (m/s)	Sunshine (h)	Rainfall (mm)
	Max.	Min.				
January	24.6	9.2	37	2.5	8	0.01
Febuary	27.7	10.6	27	2.7	8.5	0.0
March	32.9	15	19	3.0	10	0.0
April	35.9	18	17	3.1	10.4	0.0
May	39.4	21.9	15	3.0	10.9	0.0
June	42.4	24.5	14	2.4	12.6	0.0
July	42.3	24.6	16	2.3	12.1	0.0
August	44.1	25.3	17	2.7	10.1	0.0
September	40.3	23.7	20	2.5	8.7	0.0
October	34.6	19.4	23	2.6	8.4	0.0
November	29.5	14.3	36	2.5	8.1	0.0
December	24.3	9.7	38	2.7	8	0.1

The monthly average values of relative humidity (RH) in the study area range between 17% and 38%. The highest levels of RH were recorded in the winter season, reaching 38% in December and 37% in January. The lowest values of RH were 14% in June and 15% in May. The average wind speed in the study area ranges between 2.3 m/s in July and 3.1 m/s in April. The spring season is characterized by the highest wind speeds, with a maximum value of 3.1 m/s recorded in April. On the other hand, the summer season is characterized by the lowest wind speeds, with a maximum value of 2.7 m/s recorded in August (Table 1). The values of evapotranspiration ranged between 4.13 mm/day in December and 10.41 mm/day in June (Egyptian Meteorological Authority, 2022).

Field sampling

Using ArcGIS technology, six landforms were identified and delineated across the study region. Annual flood plain, almost flat terraces, alluvial plain, gently undulating old terraces, undulating old terraces, rock outcrops, and isolated hills are all of them (Fig. 2). These units collectively cover an area of 111000 Faddan. Twenty-three pedons were randomly dispersed over only four landforms (e.g., almost flat terraces, alluvial plain, gently undulating old terraces, and undulating old terraces) in the Khor Sarah research area to illustrate site variations (Fig. 2).

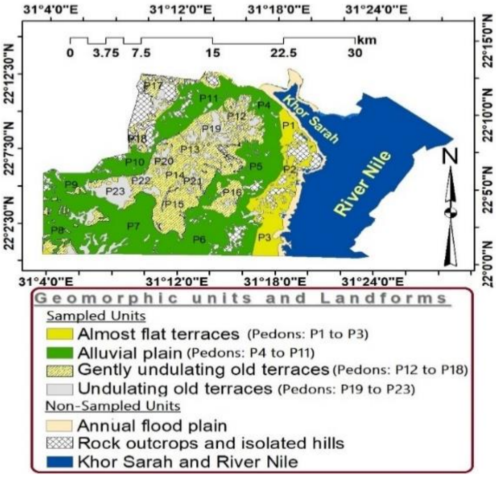

Fig. 2. Pedon locations on major geomorphic units of Khor Sarah study area.

The number of sampled pedons was roughly proportionate to the landform's map area. P1, P2, and P3 pedons sampled the almost flat terraces. Because the alluvial plain comprises the majority of the study area's landforms, it is represented by eight pedons (Pedons P4 to P11). Pedons ranging in number from 12 to 18 were dispersed across the landform of gently undulating old terraces. Finally, five pedons (P19 to P23) were occupied on undulating old terraces (Fig. 2).The land capability classification (LCC) was utilized in this study (Klingebiel and Montigomery, 1961; Gad, 2015). As physical land features, the classification was purely based on effective soil depth, topsoil texture, permeability, erosion risk, and slope (Thomas,2010). According to Gad (2015), the soils of Khor Sarah were classified into various classes. The most limiting factor determined which class a soil belonged to.

Experimental sites for SQ assessment

Land management practises and environmental factors were discovered following an in-depth consultation with local farmers and investors. To carry out the investigation, four different types of land use treatments were chosen. They are one desert barren land (BL) without any management as a control and three agricultural lands with different management practices, were established in this study: one wheat (*Triticum aestivum,* TA) as land utilization type 1 (LUT1(with not sufficient management, one maize (*Zea mays*) (ZM) as LUT2 with not sufficient management, and one peanut (*Arachis Hypogaea*) (PN) as LUT3 with suitable management (Fig. 1). The three selected agricultural lands occupied on alluvial plain that has moderately capable land of class-III (Figs. 2 and 4). They were uniform in soil type prior to cultivation, and their farming practices were identical. All experimental sites were irrigated by River Nile water under same climate conditions (Table 1).

The soils formed from limestone, and the soil depth was often greater than 100 cm for all selected sites. The elevation of the four study sites spans from 170 to 179 m above sea level, and they are all on the same slopeThe selected treatment sites also had similar environmental settings and pedomorphological parameters. Four standard plots (10 m × 10 m) were randomly established inside each experimental site for statistically independent sampling. To avoid the occurrence of pseudoreplication, the intervals between standard plots in each site exceeded 50 m. In the current investigation, there were 16 sampling plots (four experimental locations × four duplicated plots). The soil samples at varying depths of representative soil pedons were obtained in each replicated sampling plot in 2021-2022 with a soil core sampler. All soil samples were transported to the laboratory for various examinations.

Selected soil indicators and analyses

In this study, 26 soil indicators were employed to assess SQ, which included eight physical-morphological aspects, seven chemical qualities, and eleven fertility-biological parameters. Bulk density, BD; soil water holding capacity, WHC; hydraulic conductivity, HC; clay fraction, silt, sand; root-restrictive depth, R-RLD; and total porosity, TP are the physical-morphological parameters. Hydrogen potential, pH; electrical conductivity, ECe; lime, $CaCO_3$, gypsum, $CaSO_4.2H_2O$; iron oxide, Fe_2O_3; exchangeable sodium percentage, ESP; and cation exchangeable capacity, CEC are the chemical parameters chosen. Soil organic matter, SOM; macro-aggregate associated organic carbon, M-SOC; available nitrogen, AN; available phosphorus, AP; available potassium, AK; C:N ratio of soil organic carbon to total nitrogen, available iron, Fe; available zinc, Zn, available copper, Cu, available manganese, Mn) and microbial biomass carbon, MBC are the fertility-biological criteria. All of these characteristics were assessed in soil samples from each pedon in order to establish SQIs and assess the impact of cultivation management on soil function in the several selected locations (Table 3). These criteria were chosen because of their importance in soil health and crop production.

Wheat, maize, and peanut were extensively grown in the surrounding areas around Khor Sarah Lake (Fig. 1). The soil pedons were investigated pedomorphologically, physically, chemically, and for fertility-biological criteria. Soil samples were gathered from each layer/horizon of studied pedons.

In the laboratory, soil samples from each plot were air dried and sieved through a 2 mm diameter sieve. The fine earth fraction was examined for several soil qualities. Soil Survey Staff (2014) standard techniques were used to estimate pH, EC_e, Fe_2O_3, and particle size distribution (sand, silt, and clay). A Calcimeter was used to estimate $CaCO_3$ % as described by Allison and Moodie (1965). To determine soil organic matter (SOM), a modified Walkey-Black method was utilised (Black, 1965). The available macronutrients of phosphorous, potassium, and nitogen were determined as described by FAO (1970) and Thomas (1982). The accessible micronutrients Fe, Zn, Cu, and Mn were measured using the diethylenetriaminepentaacetic acid (DTPA) technique (Lindsay and Norvell, 1978).

The BD was measured using the core cutter method, while the WHC was measured using the gravimetric method (Lu, 2000). The standard methodologies of FAO (2006) and Landon (1991) were used to measure the total porosity. SOM and Ma-SOC were measured using the wet oxidation method, and the C:N was calculated using the molar ratio of SOC to total nitrogen (Yu *et al*., 2022).

Soil indicators selection and developing SQIs

In the current work, the guidelines of da Luza *et al.* (2019), Gura and Mnkeni (2019), and Marion *et al*., (2022) were used to construct SQI. The SQ indicators proposed in this study could depict soil management dynamics without requiring a time series method for comparison (Marion *et al*., 2022). The effects of cultivation on the 26 measured soil properties were tested using one-way analysis of variance to better compare the differences in SQ among different land-use treatments. The soil indicators that differed significantly among the tested land uses were selected as members of the total dataset (TDS) to develop and suggest the SQIs.

Two selection approaches for soil indicators were used to identify appropriate soil indicators in this study. They are the minimum dataset (MDS) and the revised minimum dataset (RMDS). To ensure a comprehensive SQ assessment, the selected soil indicators should reoresent at least one indicator for physical-mprohological, chemical and fertility-biological properties (da Luza *et al*., 2019; Gura and Mnkeni , 2019). A principal component analysis (PCA) of the TDS was used to pick significant soil indicators for the MDS. Whereas selected soil indicators were done individually in the RMDS based on the entire soil characteristics sectors (physical-morphological, chemical, and fertility-biological). According to the conventional procedures of Zhang *et al.* (2021), Marion *et al.*

(2022), and Raiesi and Beheshti (2022), the Pearson correlation analysis and eigenvalues were utilized to determine the PCA results and indicator selection.Both MDS and RMDS viewed higher eigenvalues (>1) in the principal components (PCs) to be relevant. To represent this PC, the loading value of soil indicators in each PC was kept. When more than one soil indication was retained in a PC, Pearson's correlation analysis was utilised to discover the redundant soil indicator. Only the indication with the highest loading factor was preserved for the MDS or RMDS, and the soil indicators that were retained were highly associated with each other. Otherwise, all of the preserved soil indicators were chosen.

Scoring the selected soil indicators

In this study, the nonlinear scoring function was employed as shown in Fig (3) to score soil indicators from 0 to 1 by normalizing and transforming them in both MDS and RMDS (Raiesi and Beheshti, 2022) . For each soil indictor, the minimum value denotes the lowest SQ value, while the maximum value represents the highest SQ value. The "more is better" nonlinear scoring curve was applied to the best soil indicator, while the "less is better" scoring function was applied to the poorest soil indicator to soil function (Table 3; Fig. 3). The scoring functions for each soil indicator were determined based the following equation (Marion *et al*., 2022).

$$\mathbf{S} = \frac{\mathbf{a}}{\mathbf{1} + \left(\frac{\mathbf{x}}{\mathbf{x_{ov}}}\right)^{\mathbf{b}}}$$

Where

S is the indicator score based on the nonlinear curve function, an is the highest indicator score (1), x is the soil indicator, x_{ov} is the indicator optimum value, and b is the slope (-2.5 for "+ is better"; 2.5 for "- is better").

Incorporating soil indicators into a soil quality index

The scored soil indicators were integrated into the MDS or RMDS using the weighted additive model (Mamehpour *et al*., 2021). Weights of selected soil indicators were assigned separately in the MDS using the variance or communality methods, whereas in the RMDS, each soil propertis sector was given an equal weight of 0.33, emphasising the equal importance of the three sectors to soil function (Davari *et al*., 2020). The soil quality index (SQI) was determined using the score and weight of each soil indicator as follows (Raiesi and Salek- Gilant, 2020):

$$\mathbf{SQI} = \sum_{\mathbf{i=1}}^{\mathbf{n}} (\mathbf{S_i} \times \mathbf{W_i})$$

Where

Si denotes the indicator score, n the number of selected soil indicators via MDS or RMDS, and Wi the indicator weight.

The current study developed four soil quality indices (SQ1, SQ2, SQ3, and SQ4) based on indicator selection and weighted additive approaches. SQ1 and SQ2 in the MDS were developed using communality-weighted and variance-weighted approaches, respectively. The created SQ3 and SQ4 in the RMDS were weighted by communality and variance, respectively. Soil quality index was categorized as follws: grade I: very high (SQ >0.55), grade II: high ($0.45 < SQ \leq 0.55$), grade III: medium ($0.35 < SQI \leq 0.45$), grade IV: low ($0.25 < SQI \leq 0.35$), and grade V: very low ($SQI \leq 0.25$) (Zeraatpisheh *et al*., 2020; Huang *et al*., 2021).

Statistical analysis

Mean standard deviation was used for descriptive statistics. The SPSS 16.0 programme was used to perform the statistical analyses. All datasets were evaluated to confirm that they met the underlying assumptions of normality and equal variance of the statistical analysis. At the P <0.05 significance level, one-way analysis of variance and Fisher's least-significant difference test (LSD) were used to evaluate and compare the mean differences in the 26 soil parameters and soil quality indices among treated sites (Marion *et al*., 2022). PCA and correlation matrices among the measured soil indicators were used at P <0.05, P <0.01, and P <0.001 to eliminate redundant soil indicators (Gotelli and Ellison 2013; Marion *et al*., 2022).

RESULTS AND DISCUSSION

Results

Land capability of Khor Sarah study area

Soil charcterstics and land capability sesults of study area are shown in Table 2 and Fig. 3. As per the guidelines of LCC, lands of the study area ranged from class III to V, being limited mainly by shallowness of soil depth, coarse texture, erosion, and high permeability. The majority of almost flat terraces and alluvial plain units were classed as arable classe-III (62715 Faddan), with sheet and moderate constraints and associated quick permeability. Surface soil depth was used as a criterion to determine evidence of soil erosion. The majority of soils from old terraces covering 30303 Faddan (27.3% of total research area) were placed in low capable land of class-IV. Other soils (10212 Faddan; 9.2%) were found on very low capable lands of class-V. The remainder of the land was not considered soils, but rather rock outcrops and isolated hills covering an area of 7770 Faddan (Fig. 4). The key land constraints for Class IV were moderate soil depth, high permeability, and moderate erosion, whereas the main constraints for Class V were sloping surface, severe erosion, and soil depth not exceeding 25 cm.

Table 2. Some soil characters and their capability classification of Khor Sarah area

Class Soil property	Class-III	Class-IV	Class-V
Pedon depth, cm	100-150	<100	<25
Horizons/layers No.	3-4	2-3	2
Roch fragments, %	10-13	15-35	>35
Topsoil texture	Silt loam to sandy loam	Loamy sand	Coarse sand
Permeability	Moderate	Rapid	Very rapid
Erosion	Slight	moderate	severe
Slope	Nearly level	Gently slping	Sloping
Experimental sites for SQ assessment	√	×	×
Land form	Almost flat terraces and alluvial plain	Gently undulating old terraces	Undulating old terraces
Area	62715 Faddan	30303 Faddan	10212 Faddan

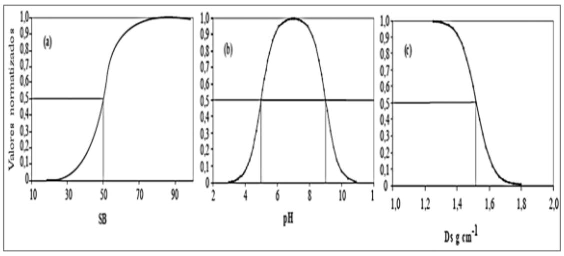

Fig. 3. The nonlinear scoring curves used in the current study. (a) indicates the nonlinear curve of "more is better", (b) referes to "optimal point", and (c) curve denotes to "less is better" for each soil indicator.

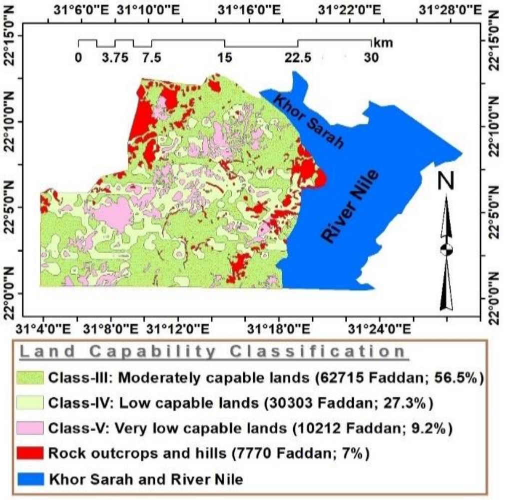

Fig. 4. Land capability of Khor Sarah area, Upper Egypt.

Soil indicators selection

In the current study, twenty-six soil variables associated with diverse soil functions were measured as preliminary indicators of SQ evaluation (Table 4). The findings revealed that soil management practices in different treated sites had a significant impact on the significant 15 soil properties. These parameters include four soil physical-morphological properties (BD, WHC, R-RLD, and TP), four chemical properties (pH, EC_e, Fe_2O_3, and ESP), and seven fertility-biological properties (SOM, Ma-SOC, AN, AP, C:N ratio, Fe, and Zn). These indicators were considered TDS members for assessing soil quality indices. They vary according to land use and management (Tables 2 & 4). The criterion WHC, HC, clay, and TP under PN had significantly greater values than those under BL, ZM, and WT. The R-RLD was not present in the soil pedon layers of non-agricultural areas under barren land (BL). This compacted layer was discovered at various depths in all land uses (105, 81, and 50 for PN, ZM, and WT, respectively). This reflects the management quality across all land uses. The presence of hard/cemented pans throughout the soil pedon was caused by the abundance of Fe_2O_3 and lime as cementing agents. The chemical criteria of pH, EC_e, $CaCO_3$, iron oxide, and ESP were significantly lower under PN than under BL, ZM, and WT. SOM, Ma-SOC, and accessible macro and micro nutrients were considerably higher in PN than in BL, ZM, and WT. Table 5 shows that three principal components (PC1, PC2, and PC3) with eigenvalues greater than one (8.39 for PC1, 5.49 for PC2, and 3.59 for PC3) were extracted for the MDS. The first PC accounts for 55.93% of the overall variability in the MDS. As high loading values for PC1, three soil indicators were obtained: pH, Fe_2O_3, and R-RLD. Because of the considerable correlations between these indicators in Table 6, pH, Fe2O3, and R-RLD, only the R-RLD obtained the greatest loading value (-0.92) as shown in Table 5, hence it was chosen as a representative indication for PC1. Similary for PC2, the soil indicators of EC_e and Ma-SOC had high loading values of -0.94 and 0.87, respectively. The correlation analysis results in Table 6 demonstrated that Ma-SOC was irrelevant to EC_e, hence these indicators represented the PC2.

In addition, BD and Ma-SOC are considered the highly loaded soil indicators in PC3, and the correlation analysis in Table 6 showed that BD was correlated to Ma-SOC (0.65). Therefore, PC3 was represented by only BD, which has a high loading value (-0.81) (Table 5). Finally, the BD, R-RLD, EC_e and Ma-SOC are elected to be the key soil indicators for developing the MDS (Table 5).

Based on the statistical analysis of PCA, certain soil indicators were chosen in the RMDS to reflect each of the physical-morphological, chemical, and fertility-biological qualities independently. Based on PC eigenvalues (Table 5) and Pearson correlation analysis (Table 6), the RMDS was represented by four high loaded values of WHC for physical-morphological qualities, ECe and Fe_2O_3 for chemical properties, and Ma-SOC for fertility-biological aspects.

Design soil quality indices

Table 7 presents the weights of the finalized four soil indicators for both MDS and RMDS using scoring curves ("more is better" and "less is better"), variance, and communality methods. The weights of the selected soil indicators of WHC, R-RLD, EC_e, and Fe_2O_3 in the MDS ranged from 0.24 for WHC and ECe to 0.27 for R-RLD using the communality methodology and from 0.13 for Fe2O3 to 0.39 for R-RLD using the variance method. The soil indicator R- RLD was found to have the highest weight in MDS due to its importance to soil health and agricultural output.

WHC, EC_e, Fe_2O_3, and Ma-SOC, on the other hand, were chosen as typical soils indicators for RMDS. By the communality method, the weights for these indicators are 0.33 for WHC, 0.19 for EC_e, 0.15 for Fe_2O_3, and 0.33 for Ma-SOC. In the RMDS, equal weights (0.33) were given by communality for each soil properties sector, because the physical-morphological indicator (WHC) contributed 0.33, chemical properties indicators (EC_e, 0.19, and Fe_2O_3, 0.15) contributed 0.33, and fertility-biological indicator (Ma-SOC) contributed 0.33 (Table 7). However, by variance, these indicators only had differing weights for chemical indicators, which are 0.23 for EC_e and 0.11 for Fe_2O_3, whereas the other property sectors each had 0.33.

As a result, four integrated soil quality indices (SQ1, SQ2, SQ3, and SQ4) were established using a weighted method and an indicator selection methodology (MDS and RMDS). SQ1 and SQ2 are MDS indices produced from communality and variance techniques, respectively, whereas SQ3 and SQ4 are RMDS indices developed from communality and variance weighted methods, respectively. The indexes developed are as follows:

$$\mathbf{SQ1 = (0.24 \times Score\ of\ WHC) + (0.27 \times Score\ of\ R\text{-}RLD) + (0.24 \times Score\ of\ EC_e) + (0.25 \times Score\ of\ Fe_2O_3),}$$

$$\mathbf{SQ2 = (0.14 \times Score\ of\ WHC) + (0.39 \times Score\ of\ R\text{-}RLD) + (0.34 \times Score\ of\ EC_e) + (0.13 \times Score\ of\ Fe_2O_3),}$$

$$\mathbf{SQ3 = (0.33 \times Score\ of\ WHC) + (0.19 \times Score\ of\ EC_e) + (0.15 \times Score\ of\ Fe_2O_3) + (0.33 \times Score\ of\ Ma\text{-}SOC),}$$

$$\mathbf{SQ4 = (0.33 \times Score\ of\ WHC) + (0.23 \times Score\ of\ EC_e) + (0.11 \times Score\ of\ Fe_2O_3) + (0.33 \times Score\ of\ Ma\text{-}SOC).}$$

In the current study, the values of SQ1 of the MDS using communality approach were 0.28, 0.39, 0.15, and 0.13 for the BL, PN, ZM, and WT land uses, respectively (Table 8). SQ2 values of MDS by variance method varied from 0.13 (Very low) in WT to 0.39 (Medium) in treated PN plot . SQ1 data revealed that the difference in SQIs between ZM and WT land uses was not significant, although it was much smaller than that between PN and BL (Table 8). The PN had the highest SQI values among all treated plaots of SQ1, SQ2, SQ3, and SQ4, whereas the the lowest SQ values were registered for WT plot (0.13 for MDS plots and 0.14 & 0.15 for RMDS plots). SQ2, SQ3, and SQ4 all received the same rating (0.39; medium SQ) for PN land use (Table 8). All SQI values were considerably higher under BL and PN than under ZM and WT. Significant values for SQI were found to be greater under PN for the four land uses than under BL > ZM > WT for the four land uses (Table 8).

Table 3. Transform of standard scoring functions on a weight scale (0-1) one for quantitative soil parameters in SQI.

Soil indicator	Abbrv.	Unit	LTV	Scoring Curve	UTV	Scoring Curve	OV	Scoring Curve
1) Physical-morphological characteristics								
Bulk density	BD	g cm^{-3}	1.2	“- ´e B”	1.8	“- ´e B”	<1.2	“O”
Water holding capacity	WHC	%	15	“+ ´e B”	35	“O”	≥35	“O”
Hydraulic conductivity	HC	cm hr^{-1}	3	“- ´e B”	12	“- ´e B”	1-2	“O”
Clay fraction	Clay	%	1	“+ ´e B”	50	“- ´e B”	27-40	“O”
Silt fraction	Silt	%	5	“+ ´e B”	30	“O”	15-50	“O”
Sand fraction	Sand	%	25	“O”	50	“- ´e B”	20-45	“O”
Root-restrictive layer depth (Throughout the soil pedon)	R-RLD	cm	10	“+ ´e B”	150	“+ ´e B”	≥150 or None	“O”
Total porosity	TP	%	2	“+ ´e B”	40	“O”	≥40	“O”
$\sum$ Weights of physical − morphological characteristics = 0.33 (for RMDS)								
2) Chemical characteristics								
Hydrogen potential	pH	unitless	6	“+ ´e B”	9.5	“- ´e B”	6.5-7.3	“O”
Soil electrical conductivity	EC_e	dS m^{-1}	2	“- ´e B”	16	“- ´e B”	<2	“O”
Lime ($CaCO_3$)	$CaCO_3$	g kg^{-1}	10	“- ´e B”	250	“- ´e B”	5-20	“O”
Gypsum ($CaSO_4.2H_2O$)	Gypsum	g kg^{-1}	10	“- ´e B”	500	“- ´e B”	5-50	“O”
Iron oxides (Fe_2O_3)	Fe_2O_3	%	1	“- ´e B”	10	“- ´e B”	<1	“O”
Exchangeable sodium percentage	ESP	%	10	“O”	50	“- ´e B”	≤10	“O”
Cation exchange capacity	CEC	cmol kg^{-1}	6	“+ ´e B”	40	“O”	30-40	“O”
$\sum$ Weights of chemical characteristics = 0.33 (for RMDS)								
3) Fertility-biological characteristics								
Soil organic matter	SOM	g kg^{-1}	1	“+ ´e B”	50	“O”	≥50	“O”
Macro-aggregate associated organic carbon	Ma-SOC	g kg^{-1}	5	“+ ´e B”	30	“+ ´e B”	>30	“O”
Available nitrogen	AN	mg kg^{-1}	30	“+ ´e B”	120	“+ ´e B”	>120	“O”
Available phosphorus	AP	mg kg^{-1}	2	“+ ´e B”	>20	“- ´e B”	10-15	“O”
Available potassium	AK	mg kg^{-1}	10	“+ ´e B”	180	“O”	≥180	“O”
Ratio of soil organic carbon and total nitrogen	C:N	unitless	20	“- ´e B”	24	“- ´e B”	<20	“O”
Available iron	Fe	mg kg^{-1}	0		>5	“- ´e B”	5	“O”
Available zinc	Zn	mg kg^{-1}	0	“+ ´e B”	>1.5	“- ´e B”	1.5	“O”
Available copper	Cu	mg kg^{-1}	0	“+ ´e B”	>0.5	“- ´e B”	0.5	“O”
Available manganese	Mn	mg kg^{-1}	0	“+ ´e B”	>1	“- ´e B”	1	“O”
Microbial biomass carbon	MBC	mg kg^{-1}	50	“+ ´e B”	1100	“- ´e B”	550	“O”
$\sum$ Weights of soil fertility − biological characteristics = 0.33 (for RMDS)								

Explanations:Soil quality classes and their abbreviations were given as per the methodologies of FAO (2006), Soil Science Division Staff (2017), Elwan and Khalil (2018), Abuzaid *et al*., (2021), and Gozukara *et al*. (2022); Abbrv. (abbreviation); LTV (lower threshold value), UTV (upper threshold value), OV (optimum value), “O”=optimum point; “+ ´e B” (more is better), “- ´e B” (less is better).

Table 4. Selected 26 soil indicators measured as potential indicators of soil quality across different land uses.

Soil indictors	BL	PN	ZM	WT	ANOVA	
					F	P
1) Physical-morphological characteristics						
BD (g cm^{-3})	1.22 ± 0.04^{b}	1.02 ± 0.02^{c}	1.57 ± 0.01^{a}	1.69 ± 0.03^{a}	1.62	0.019^{**}
WHC (%)	18.33 ± 1.01^{a}	27.9 ± 2.74^{b}	22.25 ± 1.11^{a}	21.2 ± 0.71^{ab}	4.82	0.028^{*}
HC (cm hr^{-1})	11.32 ± 1.01^{a}	13.02 ± 1.21^{a}	12.32 ± 0.95^{a}	10.03 ± 1.01^{a}	3.09	0.124^{NS}
Clay (%)	13.21 ± 0.51^{b}	22.35 ± 0.95^{c}	14.05 ± 0.27^{a}	11.74 ± 0.31^{b}	19.17	0.409^{NS}
Silt (%)	57.01 ± 2.19^{b}	54.47 ± 1.33^{c}	69.01 ± 1.02^{a}	61.21 ± 1.99^{b}	30.43	0.512^{NS}
Sand (%)	29.78 ± 2.01^{b}	23.18 ± 1.47^{a}	16.94 ± 1.11^{C}	27.05 ± 1.20^{b}	42.13	0.223^{NS}
R-RLD (cm)	None	105 ± 1.37^{b}	80 ± 1.37^{b}	50 ± 1.37^{b}	12.36	0.056^{**}
TP (%)	15 ± 1.37^{b}	45 ± 1.37^{c}	23 ± 1.37^{b}	9 ± 1.37^{b}	15.24	0.065^{**}
2) Chemical characteristics						
pH	7.89 ± 0.12^{a}	7.72 ± 0.12^{b}	8.23 ± 0.27^{a}	8.37 ± 0.12^{a}	1.61	0.021^{*}
EC_e (dS m^{-1})	2.2 ± 0.31^{a}	1.51 ± 0.19^{c}	3.7 ± 0.13^{b}	3.1 ± 0.14^{b}	4.92	0.019^{*}
$CaCO_3$ (g kg^{-1})	102 ± 0.01^{a}	75.1 ± 0.01^{a}	109.07 ± 0.01^{a}	120 ± 0.02^{a}	65.99	0.015^{NS}
Gypsum (g kg^{-1})	45.05 ± 2.35^{a}	49.35 ± 4.47^{a}	35.45 ± 2.29^{a}	45.05 ± 3.08^{a}	33.15	0.021^{NS}
Iron oxides (Fe_2O_3)	3.11 ± 0.37^{a}	1.04 ± 0.41^{a}	5.12 ± 0.35^{a}	7.05 ± 2.35^{a}	3.88	0.021^{*}
ESP (%)	11.26 ± 0.14^{a}	9.35 ± 0.31^{a}	20.05 ± 0.82^{b}	17.06 ± 0.04^{b}	5.00	0.018^{*}
CEC (cmol kg^{-1})	12.35 ± 0.11^{b}	13.24 ± 0.14^{a}	12.06 ± 0.07^{b}	13.45 ± 0.03^{b}	3.15	0.123^{NS}
3) Fertility-biological characteristics						
SOM (g kg^{-1})	7.11 ± 0.08^{b}	17.3 ± 0.33^{a}	11.5 ± 0.17^{a}	12.3 ± 0.16^{a}	10.12	0.013^{**}
Ma-SOC (g kg^{-1})	9.12 ± 0.41^{a}	23.6 ± 0.14^{b}	12.34 ± 1.26^{a}	10.21 ± 0.22^{a}	8.12	0.009^{***}
AN (mg kg^{-1})	50.3 ± 1.9^{b}	95.1 ± 2.77^{a}	56.2 ± 1.01^{b}	59.1 ± 1.07^{b}	7.02	$0.0.44^{*}$
AP (mg kg^{-1})	7.88 ± 1.18^{c}	34.21 ± 9.55^{b}	48.16 ± 13.27^{ab}	59.25 ± 17.64^{a}	65.33	$< 0.001^{***}$
TK (g kg^{-1})	122.1 ± 3.12^{a}	130.2 ± 6.99^{a}	125.3 ± 9.01^{a}	136.2 ± 5.12^{a}	9.65	0.321^{NS}
C:N ratio	17.9 ± 0.27^{b}	10.7 ± 0.69^{c}	21.3 ± 1.49^{a}	25.7 ± 0.51^{a}	1.55	0.217^{**}
Fe (mg kg^{-1})	6.41 ± 0.44^{a}	9.01 ± 0.21^{a}	6.65 ± 0.12^{ab}	8.32 ± 0.51^{b}	3.96	0.009^{***}
Zn (mg kg^{-1})	0.9 ± 0.03^{c}	1.3 ± 0.04^{b}	1.1 ± 0.02^{ab}	0.99 ± 0.01^{a}	0.98	$<0.001^{***}$
Cu (mg kg^{-1})	0.50 ± 0.03^{a}	0.56 ± 0.01^{a}	0.49 ± 0.02^{a}	0.48 ± 0.01^{a}	0.27	0.324^{NS}
Mn (mg kg^{-1})	0.51 ± 0.04^{a}	0.53 ± 0.05^{a}	0.51 ± 0.07^{a}	0.52 ± 0.07^{a}	3.59	0.209^{NS}
MBC (mg kg^{-1})	103 ± 4.01^{a}	107 ± 3.13^{a}	101 ± 3.28^{a}	104 ± 1.99^{a}	1.02	0.346^{NS}

See Table 3 for the abbreviations of soil indicators; Results of each indicator parameter were calculated for each pedon as weighted mean value. They are shown as the mean (±SD). Values with the same uppercase letters within rows (land use types) are not significant different at $P < 0.05$. BL (barren desert land); PN (Pea nut); ZM (Maize; Zea mays); WT (Wheat). ***$P < 0.001$, **$P < 0.01$, *$P < 0.05$, NS (Not significant).

Table 5. The analysis results of correlation, variable and communality of selected soil indicators for each principal component

Indicators (Significant values)	Minimum Data Set (MDS)							Revised minimum Data Set (RMDS)										
								Physical-morphological			Chemical					Fertility-biological		
	PC1		PC2		PC3		Com.	PC1		Com.	PC1		PC2		Com.	PC1		Com.
	Corr.	Var.	Corr.	Var.	Corr.	Var.		Corr.	Var.		Corr.	Var.	Corr.	Var.		Corr.	Var.	
BD ($g\ cm^{-3}$)	-0.85	0.72	0.53	0.28	-0.81	0.66	1.66	0.48	0.23	0.23	--	--	--	--	--	--	--	--
WHC (%)	-0.73	0.53	-0.70	0.49	-0.21	0.04	1.07	0.95	0.90	0.90	--	--	--	--	--	--	--	--
R-RLD (cm)	-0.92	0.85	-0.71	0.50	0.74	0.55	1.90	0.87	0.76	0.76	--	--	--	--	--	--	--	--
TP (%)	0.78	0.61	0.45	0.20	-0.42	0.18	0.99	-0.91	0.83	0.83	--	--	--	--	--	--	--	--
pH	0.88	0.77	0.29	0.08	-0.18	0.03	0.89	--	--	--	-0.78	0.61	-0.69	0.48	1.08	--	--	--
EC_e ($dS\ m^{-1}$)	0.72	0.52	-0.94	0.88	0.51	0.26	1.66	--	--	--	0.74	0.55	-0.82	0.67	1.22	--	--	--
Fe_2O_3	-0.91	0.83	0.87	0.76	0.69	0.48	2.06	--	--	--	0.93	0.86	0.79	0.62	1.49	--	--	--
ESP (%)	0.79	0.62	-0.61	0.37	0.29	0.08	1.08	--	--	--	0.64	0.41	0.41	0.17	0.58	--	--	--
SOM ($g\ kg^{-1}$)	0.56	0.31	-0.57	0.32	0.31	0.10	0.73	--	--	--	--	--	--	--	--	-0.79	0.62	0.62
Ma-SOC($g\ kg^{-1}$)	0.61	0.37	0.87	0.76	0.78	0.61	1.74	--	--	--	--	--	--	--	--	0.95	0.90	0.90
AN ($mg\ kg^{-1}$)	0.58	0.34	0.64	0.41	-0.17	0.03	0.77	--	--	--	--	--	--	--	--	0.69	0.48	0.48
AP ($mg\ kg^{-1}$)	-0.46	0.21	0.37	0.14	0.37	0.14	0.49	--	--	--	--	--	--	--	--	0.24	0.06	0.06
C:N ratio	-0.69	0.48	0.46	0.21	0.51	0.26	0.95	--	--	--	--	--	--	--	--	0.88	0.77	0.77
Fe ($mg\ kg^{-1}$)	0.84	0.71	-0.17	0.03	-0.31	0.10	0.83	--	--	--	--	--	--	--	--	-0.57	0.32	0.32
Zn ($mg\ kg^{-1}$)	-0.72	0.52	0.21	0.04	0.29	0.08	0.65	--	--	--	--	--	--	--	--	0.61	0.37	0.37
Eigenvalue		8.39		5.49		3.59			2.72			2.43		1.94			3.53	3.53
Variance (%)		55.93		36.58		23.92			67.95			60.76		48.52			50.45	50.45

Explanations:PC (principal component); Corr. (Correlation); Var. (Variable); Com. (Communality).The highly weighted indicators are given by underlined loading values.

Table 6. The correlation matrix of the 15 elected soil indicators.

Indicators	BD ($g\ cm^{-3}$)	WHC (%)	R-RLD (cm)	TP (%)	pH	EC_e ($dS\ m^{-1}$)	Fe_2O_3 (%)	ESP (%)	SOM ($g\ kg^{-1}$)	Ma-SOC ($g\ kg^{-1}$)	AN ($mg\ kg^{-1}$)	AP ($mg\ kg^{-1}$)	C:N ratio	Fe ($mg\ kg^{-1}$)	Zn ($mg\ kg^{-1}$)
BD ($g\ cm^{-3}$)	1														
WHC (%)	0.35^{NS}	1													
R-RLD (cm)	0.43^{*}	0.89^{***}	1												
TP (%)	-0.56^{*}	-0.94^{***}	-0.99^{***}	1											
pH	-0.38^{NS}	-0.24^{NS}	-0.72^{**}	0.82^{**}	1										
EC_e ($dS\ m^{-1}$)	0.71^{**}	-0.33^{NS}	-0.22^{NS}	0.15^{NS}	0.54^{*}	1									
Fe_2O_3 (%)	0.47^{**}	0.18^{NS}	0.71^{***}	0.51^{**}	-0.59^{**}	0.27^{NS}	1								
ESP (%)	0.80^{***}	-0.62^{**}	0.55^{*}	-0.58^{**}	0.83^{***}	0.61^{**}	0.71^{**}	1							
SOM ($g\ kg^{-1}$)	-0.75^{**}	0.85^{**}	0.71^{*}	0.82^{***}	-0.71^{**}	0.19^{NS}	0.23^{NS}	-0.56^{**}	1						
Ma-SOC($g\ kg^{-1}$)	-0.65^{*}	-0.35^{**}	-0.71^{**}	0.65^{**}	-0.58^{**}	-0.59^{**}	0.07^{NS}	-0.53^{**}	0.87^{*}	1					
AN ($mg\ kg^{-1}$)	-0.22^{NS}	-0.19^{NS}	0.08^{NS}	0.11^{NS}	-0.71^{**}	0.31^{NS}	0.21^{NS}	-0.19^{NS}	0.67^{**}	0.78^{**}	1				
AP ($mg\ kg^{-1}$)	0.38^{NS}	-0.03^{NS}	0.04^{NS}	-0.07^{NS}	-0.92^{*}	-0.34^{NS}	-0.82^{*}	–027NS	0.58^{**}	0.69^{*}	0.71^{*}	1			
C:N ratio	0.57^{*}	-0.59^{**}	-0.51^{*}	-0.87^{***}	0.47^{*}	-0.57^{*}	0.57^{*}	-0.53^{*}	-0.91^{**}	-0.77^{*}	-0.89^{**}	0.59^{**}	1		
Fe ($mg\ kg^{-1}$)	0.28^{NS}	0.28^{NS}	-0.48^{*}	0.52^{*}	0.60^{**}	0.64^{**}	0.49^{**}	-0.74^{**}	0.50^{*}	0.72^{***}	0.93^{**}	0.62^{*}	0.79^{**}	1	
Zn ($mg\ kg^{-1}$)	0.28^{NS}	0.35^{NS}	0.34^{NS}	-0.35^{NS}	-0.56^{*}	-0.58^{**}	0.14^{NS}	-0.55^{*}	0.56^{*}	0.83^{**}	0.77^{***}	0.58^{*}	0.72^{**}	−0.61*	1

Abbreviations of the studied indicators are given in Table 3. *($P < 0.001$), ** ($P < 0.01$), * ($P < 0.05$), NS (Not significant)**

Table 7. Type of scoring curves, the parameters of non-linear equations and the weights for the soil indicators in minimum data set and the revised minimum data set.

Indicators	Scoring curve	Parameters for non-linear scoring method			Weight for minimum data set (MDS)		Weight for revised minimum data set (RMDS)	
		Mean	OV	Slope	Communality	Variance	Communality	Variance
WHC (%)	"+ ′e B"	22.42	35	− 2.5	0.24	0.14	0.33	0.33
R-RLD (cm)	"+ ′e B" or None	73.3	None />150	− 2.5	0.27	0.39	--	--
EC_e ($dS\ m^{-1}$)	"- ′e B"	2.63	1.5	2.5	0.24	0.34	0.19	0.23
Fe_2O_3 (%)	"- ′e B"	14.43	0.9	2.5	0.25	0.13	0.15	0.11
Ma-SOC ($g\ kg^{-1}$)	"+ ′e B"	13.82	31	− 2.5	--	--	0.33	0.33

See Table 3 for abbreviations; OV (Optimum value).

SQ1 = (0.24 × Score of WHC) + (0.27 × Score of R-RLD) + (0.24 × Score of ECe) + (0.25 × Score of Fe2O3), (MDS – Communality method)
SQ2 = (0.14 × Score of WHC) + (0.39 × Score of R-RLD) + (0.34 × Score of ECe) + (0.13 × Score of Fe2O3), (MDS –Variance method)
SQ3 = (0.33 × Score of WHC) + (0.19 × Score of ECe) + (0.15 × Score of Fe2O3) + (0.33 × Score of Ma-SOC), (RMDS – Communality method)
SQ4 = (0.33 × Score of WHC) + (0.23 × Score of ECe) + (0.11 × Score of Fe2O3) + (0.33 × Score of Ma-SOC), (RMDS – Variance method)

Table 8. Soil quality indices calculation based on elected parameters and scoring function and under different land uses.

Indicator / land uses	WHC (%)		R-RLD (cm)	EC_e ($dS\ m^{-1}$)		Fe_2O_3 (%)		Ma-SOC ($g\ kg^{-1}$)		SQ index	
	Wi	Si	Wi	Si	Wi	Si	Wi	Si	Wi	Si	
				MDS – Communality method						SQ1	
BL	0.24	0.17	0.27	0.50	0.24	0.41	0.25	0.04	--	--	0.28
PN	0.24	0.36	0.27	0.29	0.24	0.50	0.25	0.41	--	--	0.39
ZM	0.24	0.24	0.27	0.17	0.24	0.16	0.25	0.01	--	--	0.15
WT	0.24	0.22	0.27	0.06	0.24	0.23	0.25	0.01	--	--	0.13
				MDS – Variance method						SQ2	
BL	0.14	0.17	0.39	0.50	0.34	0.41	0.13	0.04	--	--	0.36
PN	0.14	0.36	0.39	0.29	0.34	0.50	0.13	0.41	--	--	0.39
ZM	0.14	0.24	0.39	0.17	0.34	0.16	0.13	0.01	--	--	0.16
WT	0.14	0.22	0.39	0.06	0.34	0.23	0.13	0.01	--	--	0.13
				RMDS – Communality method						SQ3	
BL	0.33	0.17	--	--	0.19	0.41	0.15	0.04	0.33	0.04	0.15
PN	0.33	0.36	--	--	0.19	0.50	0.15	0.41	0.33	0.34	0.39
ZM	0.33	0.24	--	--	0.19	0.16	0.15	0.01	0.33	0.09	0.14
WT	0.33	0.22	--	--	0.19	0.23	0.15	0.01	0.33	0.06	0.14
				RMDS – Variance method						SQ4	
BL	0.33	0.17	--	--	0.23	0.41	0.11	0.04	0.33	0.04	0.17
PN	0.33	0.36	--	--	0.23	0.50	0.11	0.41	0.33	0.34	0.39
ZM	0.33	0.24	--	--	0.23	0.16	0.11	0.01	0.33	0.09	0.15
WT	0.33	0.22	--	--	0.23	0.23	0.11	0.01	0.33	0.06	0.15

Explanations: Wi (Weight of soil indicatore); Si (Score of indicator); BL (Barren land); PN (Peanut experimental site); ZM (Maize experimental site); WT (Wheat experimental site)

Discussion

In the current study, 26 soil parameters affecting soil quality in Khor Sarah area were chosen. Only 15 of them were elected after doing several statistical analyses, finaly only four indicators were employed to construct four indices in the current study. To improve soil quality in the study region, the water content of any treated land use must be supplied at the appropriate time throughout crop season. However, organic matter is derived from plant and animal leftovers, and because vegetation coverage in Khor Sarah is minimal, SOM concentration is low. This rendered SOM content of BL infertile and much lower than that of farmed land of PN. The current study found that the highest WHC content under PN among the four land uses was mostly owing to greater clay (22.35%) and SOM (17.3 g kg^{-1}) levels (Table 4). The current soil organic matter (SOM) concentration ranged from 7.11 g kg^{-1} in newly developed land of BL farms to 17.3 g kg^{-1} under PN land use (Table 4). Because of the dry high temperatures that cause dead organic matter in the soil to breakdown more quickly, releasing and losing nutrients more quickly, the natural desert soils of the current study location have comparatively low SOM values when compared to other natural environments around the world. Phosphorus (P) and nitrogen (N) are necessary elements for plant growth and are a major component of agricultural fertilizers. Peanut has the ability to fix free nitrogen from the atmosphere through symbiotic nitrogen-fixing bacteria in the root nodules, which can increase soil nitrogen content after years of cultivation. Phosphorus is essential for Peanut growth and development, especially during the seedling stage when it absorbs phosphorus quickly.

Soil aggregate stability is critical for soil nutrient and water content conservation, as well as soil erosion resistance (Deng *et al*., 2018). The higher soil aggregate stability under PN land use compared to BL in the current study substantiated the importance of soil structure and SOM, which significantly improved soil aggregate stability. boosted inputs of Peanut biomass from vegetation to soil as a result of farming boosted the creation of macro-aggregates, hence increasing soil aggregate stability (Yu *et al*., 2022).

Cultivation in land utilization type of PN enhanced carbon sequestration in soils throughout SOM and Ma-SOC in Khor Sarah, Aswan (Tables 3, 5 & 6). Several studies have indicated that agricultural revegetation greatly increases overall SOM content (Qin *et al*., 2022). Significant inputs of plant litter and little soil erosion in surface soil with sufficient SOM concentration were the key causes for the increases in total SOC following cultivation. To get large yields, farmers often lightened the soils and removed heavy weeds with ZM and WT. These diverse management practises reduced the major development in SOM contents and resulted in the smallest SOM content differences between ZM and WT farmed fields in Khor Sarah soils. The lack of a significant change in the C:N ratio between BL, ZM, and WT was mostly owing to modest differences in SOM and TN contents. The C:N ratio can be used to evaluate soil coupling processes and nutrient status. In comparison to the well-constrained C:N (12.1, molar ratio) ratio in the world's arid and hyper-arid zones (Tian *et al*., 2010), the lower C:N (10.7) ratio in PN land use revealed that soil management was superior compared to BL, ZM, and WT land uses. Plant growth is influenced by the quantity and relative supply of nutrients in soils. PN had much higher AN and TK contents than the other land uses. The significantly decreased AP concentration in the study area under the ZM and WT compared to PN was mostly due to differences in fertilization and irrigation management for varied land uses. In comparison to BL, cultivation increased the concentration of SOM, Ma-SOC, AN, AP, and micronutrients (Tables 3 and 6).

Based on the PCA results, four appropriate indicators (WHC, R-RLD, EC_e, and Fe_2O_3) relevant to physical and chemical qualities were chosen to construct the soil quality indices based on MDS (Table 7). Soil quality is an excellent technique for evaluating the status or fluctuations of soils since it is a combination of morphological, physical, chemical, fertility, and biological elements of soils (Marion *et al*., 2022). Inadequate or incorrect information for soil health may come from the absence of morphological, physical, and biological aspects in SQ evaluation models (Bunemann *et al*., 2018; Amorim *et al*., 2021; Marion *et al*., 2022). In addition to the potential indicators identified in the MDS, one fertility-biological indicator (Ma-SOC) was identified as a key indicator in the RMDS (Table 4) (Bunemann *et al*., 2018; Raiesi and Beheshti, 2022; Roy *et al*., 2022). Improvements in Ma-SOC or absence of R-RLD within soil pedon layers indicate that all soil qualities relating to physical, chemical, and fertility criteria have improved. As a result, choosing this criteria is a good indicator of soil function and quality in Khor Sarah Soils. The RMDS or MDS indicator selection approaches may improve the accuracy and comprehensiveness of SQ evaluation.

Different soil indicators have varying contributions to soil functions and quality (Marion *et al*., 2022). As a result, weighted additive approaches were commonly used when the scores of the selected soil indicators were merged into a SQI (Zhang *et al*., 2021). When compared to the variance weighted technique, the communality weighted method increased the contribution of Fe_2O_3 in the MDS while decreasing it in the RMDS. Using the weighted additive approach, the contributions of R-RLD in the MDS and Ma-SOC in the RMDS improved SQI discrimination. Given the excellent performance of the MDS and RMDS approaches in SQ evaluation using the variance-weighted method, the four established SQIs in the current study based on these methods were similar and considered the most accurate and sensitive techniques for SQ assessment following land-use changes in Khor Sarah, Upper Egypt, and were thus recommended as an effective framework for SQ evaluation in other desert regions under similar conditions.

Land use change has a considerable ($P > 0.001$) impact on soil quality in Aswan's Khor Sarah region. Higher SQI values (0.39) in all PN plots compared to BL revealed that converting from BL to PN significantly improved soil quality, which was consistent with prior study (Zhang *et al*., 2021). The highest SQI value under PN was mostly due to increased WHC, Ma-SOC, and decreased ECe and Fe2O3 in the absence of any rooting-zone limitation due to hard pan or cemented layers (R-RLD) throughout the soil pedon of the research region (Tables 3 and 7). Cultivation increased plant biomass inputs into soils in the absence of soil erosion in the study area, increasing labile carbon content and improving soil nutrients. inadequate soil quality in the WT and PT was mostly driven by inadequate farm management practises, and as a result of continuous wheat or maize production (increased nutrient absorption from soils), soil quality is degrading.

Wheat grown on WT land collected a much of nutrients from the soil but didn't give back enough, leading soil quality to decline. Unlike BL, crops require frequent fertilisation to compensate for crop loss of soil nutrients. The small difference in SQI values between ZM and WT was primarily due to Fe_2O_3 score similarities. The Fe_2O_3 level increased considerably after conversion from BL to ZM (Table 4). The fundamental cause of R-RLD or any cemented layers in the pedon horizons is due to an increase in Fe_2O_3. Thes results agreed with those of Zethof *et al.* (2019) and Guo *et al.* (2021).

The current study's findings may first imply that a SQI should rely on the integration of all soil qualities to be the best indicators for evaluating SQ under various land uses (Tables 2 and 6). The SQ indicators produced using both MDS and RMDS approaches were sensitive to management-induced changes in Khor Sarah soils, and they could assist local farmers and policymakers in identifying appropriate desert soil management practises. As a result, the developed SQI models based on the MDS or RMDS might be used as a realistic, one-of-a-kind framework for evaluating SQ accuracy in Upper Egypt and other parts of the world (Tables 6 and 7). Land use change has been shown to have a significant impact on soil characteristics in the surface soil and subsurface (Deng *et al*., 2018). This study emphasised the importance of topsoil and subsoil indicators in establishing soil quality indices, particularly the R-RLD within the pedon layers and horizons studied.

CONCLUSION

To accomplish sustainable agricultural development in Upper Egypt, it is required to integrate soil morphological, physical, chemical, fertility, and biological features. Arable land made up 83.8% of Khor Sarah soils. The rest of Khor Sarah area has been excluded from agricultural development. Four experimental plots on arable lands of alluvial plain with similar features were chosen for SQ assessment. The SQIs developed in the current study using different indicator selection approaches (MDS and RMDS) based on communality and variancel weighted additive methods indicated that farming on barren land greatly affected soil quality in the Khor Sarah area of Upper Egypt. The highest SQI readings under PN suggested that converting from BL to BN improved soil quality significantly. As a result, PN may be an appropriate strategy for improving soil quality in Upper Egypt and other similar places. The much higher SI values of SQ1 than SQ2, SQ3, and SQ4 among the four developed SQIs demonstrated that the selected soil indicators had the potential to identify soil quality utilizing the MDS. The MDS's choice of physical-morphological (R-RLD) was the key basis for SQ2's good performance. The calculated values by communality and the determined weights by variance resulted in some changing trends of SQ2 values among the four land uses. Given the improvement in discrimination and accuracy of soil criteria selection in both MDS and RMDS, the four established soilquality indices were recommended as powerful tool for evaluating soil quality under different land uses in Upper Egypt and other desert ecosystems.

This study revealed that converting natural barren land (BL) to agriculture resulted in increased soil quality if effective soil and crop selection management was implemented. WHC, R-RLD, ECe, Fe_2O_3, and Ma-SOC may also be more effective and consistent indicators of soil quality changes produced by the conversion of natural land to agricultural land use regimes. The computed soil quality index could be used to set a threshold value for management action in agricultural desert habitats to prevent further degradation of soil quality indicators. Soil quality index analysis, according to the findings, could be a valuable approach for measuring soil health. As a result, the current study provides an early warning of environmental degradation caused by changes in land use. To our knowledge, this is the first time in soil quality assessment that the R-RLD value has been used as the optimum value of morphological criteria Furthermore, this study will help policymakers and land use planners understand the current state of the Upper Egypt soil ecosystem for sustainable agricultural land management. Furthermore, restorative, long-term, and land utilisation practises should be emphasised in sustainable ecological and land management methods to restore soil health and biological processes in arid and hyper-arid ecosystems' desert soils.

REFERENCES

Abuzaid, A.S., Abdellatif, A.D., and Fadl, M.E. (2021). Modeling soil quality in Dakahlia Governorate, Egypt using GIS techniques. The Egyptian Journal of Remote Sensing and Space Sciences 24, 255–264

Allison, L.E. and Moodie, C.D. (1965). Carbonate. Agronomy monograph, methods of soil analysis. Part 2. In: Chemical and Microbiological Properties, Agronomy. 9.2 American Society of Agronomy, Wisconsin, pp. 1379–1396.

Amorim, H.C.S., Ashworth, A.J., Brey, K.R., Wienhold, B.J., Savin, M.C., Owens, P.R., and Silva, S.H.G. (2021). Soil quality indices as affected by long-term burning, irrigation, tillage and fertility management. Soil Sci. Soc. Am. J. 85, 379–395.

Black, C.A. (1965). Methods of Soil Analysis. Part: 2. Amer. Soc. of Agronomy Inc., Publisher Madison, Wisconsin, USA, pp. 1372–1376.

Bunemann, E.K., Bongiorno, G., Bai, Z.G., Greamer, R.E., Deyn, G.D., Goede, R., Fleskens, L., Geissen, V., Kuyper, T.W., Mader, P., Pulleman, M., Sukkel, W., and Groenigen, J.W., Brussaard, L. (2018). Soil quality – A critical review. Soil Biol. Biochem. 120, 105–125.

Cardoso, E.J.B.N., Vasconcellos, R.L.F., Bini, D., Miyauchi, M.Y.H., Santos, C.A.D., Alves, P.R.L., Paula, A.M.D., Nakatani, A.S., Pereira, J.D.M., and Nogueira, M.A. (2013). Soil health: looking for suitable indicators. What should be considered to assess the effects of use and management on soil health? Scientia agricola 70 (4), 274–289. https://doi.org/10.1590/S0103-90162013000400009.

da Luza, F.B., da Silvaa, V. R., Mallmannb, F. J. K., Piresc, C.A.B., Debiasid, H., Franchinid, J. C., Cherubine, M.R. (2019). Monitoring soil quality changes in diversified agricultural cropping systems by the Soil Management Assessment Framework (SMAF) in southern Brazil. Agriculture, Ecosystems and Environment, 281, 100–110.

Davari, M., Gholami, L., Nabiollahi, K., Homaee, M., and Jafari, H.J. (2020). Deforestation and cultivation of sparse forest impacts on soil quality (case study: West Iran, Baneh). Soil Tillage Res. 198, 104504.

Deng, L., Kim, D.G., Peng, C., and Shangguan, Z. (2018). Controls of soil and aggregate- associated organic carbon variations following natural vegetation restoration on the Loess Plateau in China. Land Degrad. Dev. 29, 3974–3984.

Egyptian Meteorological Authority. (2022). Climatic Atlas of Egypt, Cairo, Egypt.

Elwan, A.A. and Khalil, M.M.N. (2018). Quantitative assessment of desertification in Bahariya Oasis environment, Western Desert, Egypt. J. Product. & Dev., 23(3): 505- 532.

FAO. (1970). Physical and Chemical Methods of Soil and Water Analysis. Soils Bulletin. No. 10, FAO, Rome .

FAO. (2006). Guidelines for Soil Description. 4th Edition. Food and Agriculture Organization of the United Nations, Rome, Italy.

Gad, A. (2015). Land capability classification of some western desert Oases, Egypt, using remote sensing and GIS. The Egyptian Journal of Remote Sensing and Space Sciences, 18, S9–S18.

Gotelli, N.J. and Ellison, A.M., 2013. *A primer of ecological statistics*, 2nd. Sunderland: Sinauer Associates.

Gozukara, G. M. Acar, E. Ozlu, O. Dengiz, A.E. and Hartemink, Y. Z. (2022). A soil quality index using Vis-NIR and pXRF spectra of a soil profile. Catena 211, 105954.

Guo, Y., Abdalla, M., Espenberg, M., Hastings, A., Hallett, P., and Smith, P. (2021). A systematic analysis and review of the impacts of afforestation on soil quality indicators as modified by climate zone, forest type and age. Sci. Total Environ. 757, 143824.

Gura, I. and Mnkeni , P.N.S. (2019). Dataset on the use of the Soil Management Assessment Framework (SMAF) in evaluating the impact of conservation agriculture strategies on soil quality. Data inBrief, 22, 578–582.

Gura, I., Mnkeni and P.N.S., Preez, C.C.D., and Barnard, J.H. (2022). Short-term effects of conservation agriculture strategies on the soil quality of a Haplic Plinthosol in Eastern Cape, South Africa. Soil Tillage Res. 220, 105378.

Huang, W., Zong, M., Fan, Z., Feng, Y., Li, S., Duan, C., and Li, H. (2021). Determining the impacts of deforestation and corn cultivation on soil quality in tropical acidic red soils using a soil quality index. Ecol. Ind. 125, 107580 https://doi.org/10.1016/j.ecolind.2021.107580.

Klingebiel, A.A., and Montgomery, P.H. (1961). Land capability classification. USDA Agricultural Handbook 210. US Government Printing Office, Washington, D.C, p. 310.

Landon, J.R. (1991). Booker Tropical Soil Manual. A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and sub Tropics. Longman Scientific & Technical Publ., Harlon.

Lindsay, W.L. and Norvell, W.A. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. 42, 421–428.

Lu, R.K. (2000). Analytical Methods of Agricultural Chemistry in Soil. China Agricultural Scientech Press, Beijing, China.

Mamehpour, N., Rezapour, S., and Ghaemian, N. (2021). Quantitative assessment of soil quality indices for urban croplands in a calcareous semi-arid ecosystem. Geoderma 382, 114781.

Marion, L.F., Schneider, R. Cherubin, M.R. Colares, G.S. Wiesel, P.G. Costa, A.B., and Lobo, E.A. (2022). Development of a soil quality index to evaluate agricultural cropping systems in southern Brazil. Soil & Tillage Research, 218, 105293.

MCIT. (2020). Retrieved from Egypt Vision 2030: http://mcit.gov.eg/Publication/Publication_Summary/1020./

Qin, C.Q., Li, S.L., Yu, G.H., Bass, A.M., Yue, F.J., and Xu, S. (2022). Vertical variations of soil carbon under different land uses in a karst critical zone observatory (CZO), SW China. Geoderma 412, 115741.

Raiesi, F. and Beheshti, A. (2022). Evaluating forest soil quality after deforestation and loss of ecosystem services using network analysis and factor analysis techniques. Catena 208, 105778.

Raiesi, F. and Salek-Gilant, S. (2020). Development of a soil quality index for characterizing effects of land-use changes on degradation and ecological restoration of rangeland soils in a semi-arid ecosystem. Land Degrad. Dev. 31, 1533–1544.

Roy, D., Datta, A., Jat, H.S., Choudhary, M., Sharma, P.C., Singh, P.K., and Jat, M.L. (2022). Impact of long term conservation agriculture on soil quality under cereal based systems of North West India. Geoderma 405, 115391.

Santos- Franc´es, F., Martínez-Grana, A., Avila-Zarza, C., Criado, M., and S´anchez, Y. (2019). Comparison of methods for evaluating soil quality of semiarid ecosystem and evaluation of the effects of physico-chemical properties and factor soil erodibility (Northern Plateau, Spain). Geoderma 354, 113872.

Soil Science Division Staff. (2017). Soil survey manual. United States Department of Agriculture (USDA), Agriculture Handbook No. 18. Natural Resources Conservation Service, Washington, D.C.

Soil Survey Staff. (2014). Kellogg Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42, Version 5.0. R. Burt and Soil Survey Staff (Ed.), Lincoln NE: U.S. Department of Agriculture, Natural Resources Conservation Service .

Thomas, C.G. (2010). Land Husbandry and Watershed Management. Kalyani Publishers, New Delhi, p. 716.

Thomas, G.W. (1982). Exchangeable Cations. In: Page, A.L., Ed. Methods of Soil Analysis: Part 2-Chemical and Microbiological Properties, SSSA Book Madison (WI): ASA and SSSA, pp. 159–165.

Tian, H.Q., Chen, G.S., Zhang, C., Melillo, J.M., and Hall, C.A.S. (2010). Patterns and variation of C:N: P ratios in China’s soils: a synthesis of observational data. Biogeochemistry 98, 139–151.

Yinga, O.E., Kumar, D.S., Chowlani, M., Tripathi, S.K., Khandurl, V.P., and Singh, S.K. (2022). Influence of land-use pattern on soil quality in a steeply sloped tropical mountainous regions, India. Arch. Agron. Soil Sci. 68, 852–872.

Yu, P.J., Li, Y.X., Liu, S.W., Liu, J.L., Ding, Z., Ma, M.G., and Tang, X.G. (2022). Afforestation influences soil organic carbon and its fractions associated with aggregates in a karst region of Southwest China. Sci. Total Environ. 814, 152710.

Zeraatpisheh, M., Bakhshandeh, E., Hosseini, M., and Alavi, S.M. (2020). Assessing the effects of deforestation and intensive agriculture on the soil quality through digital soil mapping. Geoderma 363, 114139.https://doi.org/10.1016/j.geoderma.2019.114139.

Zethof, J.H.T., Cammeraat, E.L.H., and Nadal-Romero, E. (2019). The enhancing effect of afforestation over secondary succession on soil quality under semiarid climate conditions. Sci. Total Environ. 652, 1090–1101 .

Zhang, J., Chen, H.S., Fu, Z.Y., and Wang, K.L. (2021). Effects of vegetation restoration on soil properties along an elevation gradient in the karst region of southwest China. Agric. Ecosyst. Environ. 320, 107572.

تقييم جودة التربة لبعض أراضي منطقة خور سارة، محافظة أسوان، مصر

صلاح عبدالنبي الشحات القوسي[1] و عادل عبدالحميد علوان خليل[2]

[1]قسم صيانة الأراضي، شعبة مصادر المياه والأراضي الصحراوية، مركز بحوث الصحراء، القاهرة
[2]قسم البيدولوجي، شعبة مصادر المياه والأراضي الصحراوية، مركز بحوث الصحراء، القاهرة

الملخص

تقييم جودة التربة Soil quality (SQ) يمكن أن يساهم في رصد أكثر دقة وكفاءة لتغيرات جودة التربة تحت ممارسات الإدارة المختلفة. أهداف هذه الدراسة هي (i) تحديد قدرة الأرض الإنتاجية لمساحة تصل لـ 111000 فدان في جنوب غرب خور سارة، أسوان، صعيد مصر (ii) تصميم أدلة فعالة ودقيقة لجودة التربة (SQI) بالمنطقة تحت الدراسة باستخدام مجموعة بيانات (Minimum data set; MDS) ، ومجموعة بيانات (Revised minimum data set; RMDS) و (iii) تقييم تأثير تحويل الأراضي الصحراوية القاحلة (Barren desert land; BL) إلى أراضي مزروعة على جودة الترب؛ وذلك من خلال ثلاث مواقع تجارب من إستخدام الأراضي Land utilization types (LUTs) وهي: موقع الفول السوداني (Peanut; PN)، موقع الذرة (Maize, ZM)، وموقع القمح (Wheat, WT) حيث تطابق كافة هذه المواقع في صفات التربة المختلفة مع موقع BL قبل الزراعة. أظهرت نتائج الدراسة أن حوالي 56,5% من إجمالي المساحة المدروسة ذات قدرة إنتاجية متوسطة Moderately capable lands، بينما تشكل الأراضي ذات القدرة المنخفضة 27,3٪ من المساحة الكلية. بالاضافة إلى أنه تم إستبعاد المساحة المتبقية من التنمية الزراعية كونها صخور او بقايا تلال. ولتصميم أدلة تقييم جودة التربة بمنطقة خور سارة عبر المعاملات تجريبية المختلفة (BL, TA, ZM, and PN)؛ تم إختيار مواقع هذه المعاملات على أراضي السهل الرسوبي (أفضل أنواع الأراضي بمنطقة الدراسة) والتي تحمل صفات واحدة لكافة المعاملات قبل الزراعة، ومن ثم تم قياس ستة وعشرون خاصية كمؤشرات اولية محتملة لجودة التربة، وهم كالتالي: ثمانية مؤشرات تتعلق بالصفات الفيزيائية والموروفولوجية: Bulk density (BD)، Water holding capacity (WHC)، Hydraulic conductivity (HC)، Clay, silt, sand fractions، Root-restrictive layer depth (R-RLD)، و Total porosity (TP). وسبعة عوامل كيميائية: pH, EC_e, lime, gypsum, Fe_2O_3, ESP, CEC، وأحد عشر معيارًا تتعلق بالصفات الخصوبية والبيولوجية: Soil organic matter (SOM) و Macro-aggregate associated organic carbon (Ma-SOC) و Available N, P, K, Fe, Zn, Cu, M, و Microbial biomass carbon (MBS). ومن خلال المرور بالعديد من التحليلات الاحصائية المختلفة تم تصميم أربعة ادلة مختلفة بإستخدام خمس مؤشرات ذات فعالية عالية (WHC، Ma-SOC، Fe_2O_3، EC_e، R-RLD) والتي تعكس أغلب صفات التربة الأخرى. كما أكدت الدراسة أن هذه هي المرة الأولى في تقييم جودة التربة التي يتم فيها استخدام قيمة R-RLD كؤشر بيدومورفولوچي لتقييم جودة التربة، كما اوصت الدراسة بأن موقع المعاملة PN هو من أفضل المعاملات بالمقارنة بالمعاملات الـأخرى، حيث زراعة الفول البلدي تحت إدارة مُستدامة أدت إلى تحسين صفات التربة بشكل كبير سواء على مستوى صفات التربة الطبيعية حيث عدم وجود طبقات صماء R-RLD خلال قطاعات التربة ، أو زيادة تركيزات النيتيروجين الميسر بالتربة من خلال تثبيت من الهواء الجوي وزيادة كفاءة النشاط الحيوي بها، وظهر ذلك من خلال زيادة تركيز المؤشر Ma-SOC وقلة المؤشرات الأخرى Fe_2O_3 و EC_e والتي تؤثر بالسلب على صفات التربة المختلفة.