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Assessment of Soil Quality in the Varamin Region

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Abstract: This study was conducted in the Varamin region, Iran to study a set of inexpensive and agronomically meaningful indicators of soil quality (SQ), i.e. aggregate stability, available water capacity, organic matter content, active carbon content, pH, available phosphorus and available potassium. For each SQ indicator, the measured value was reported as well as the associated rating score from its scoring curve. Results of the study indicated very favorable results for chemical indicators, with high rating scores for pH, available phosphorous and available potassium (88, 100 and 100, respectively). The remaining indicators, i.e. the physical and biological indicators of SQ, had unfavorable or very unfavorable results and consequently showed evidence of low physical and biological SQ. Low rating scores for aggregate stability, available water content and organic matter content (20, 44 and 3, respectively) were evidences of soil degradation from long-term intensive tillage and lacking use of soil-building crops or organic matter additions. Also, very low rating score for active carbon content (4) indicated that the soil of site was biologically degraded and unbalanced.

Key words: Soil · Quality · Quality indicators · Varamin · Iran

INTRODUCTION

Soil quality (SQ) includes an inherent and a dynamic component. The former is an expression of the soil forming factors, documented by soil surveys as expressed by land capability classification. Dynamic SQ, however, refers to the condition of soil that is changeable in a short period of time (Fig. 1) largely due to human impact and management [1-4]. The SQ concept encompasses the chemical, physical and biological soil characteristics (Fig. 2) needed to maintain environmental quality and agricultural sustainability [4-8]. With farmer and lay audiences, the term “soil health” is often preferred when referring to this dynamic SQ concept as it suggests a holistic approach to soil management [9].

SQ can not be measured directly, but soil properties that are sensitive to changes in management can be used as SQ indicators [4, 10]. Methods for measuring individual SQ indicators or minimum data set (Fig. 3) for calculating indices from groups of SQ indicators (Fig. 4) are being developed for SQ monitoring over time and for evaluating the integrated sustainability of agricultural management practices [2, 6, 11-13]. In a more holistic SQ paradigm, integrative assessment of the three SQ domains (chemical, physical and biological) would be accomplished by SQ indicators that represent soil processes relevant to soil functions and provide information that is useful for practical soil management [4, 9]. However, measuring of SQ indicators must be inexpensive and dependent on minimal infrastructure if they are to be widely adopted beyond the research domain and especially in the developing countries such as Iran. SQ indicator suitability can be judged by several criteria, such as relevance, accessibility to users and measurability [14].

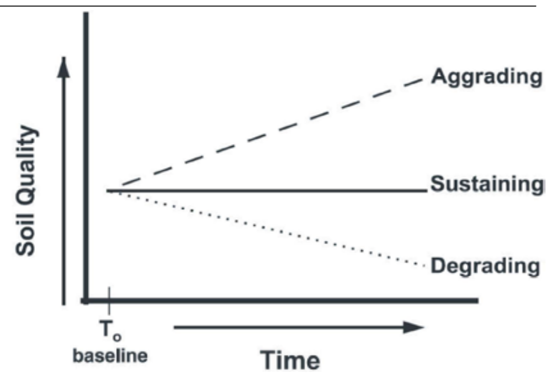

Fig. 1: Dynamic component of SQ, adapted from Karlen *et al.* [2]

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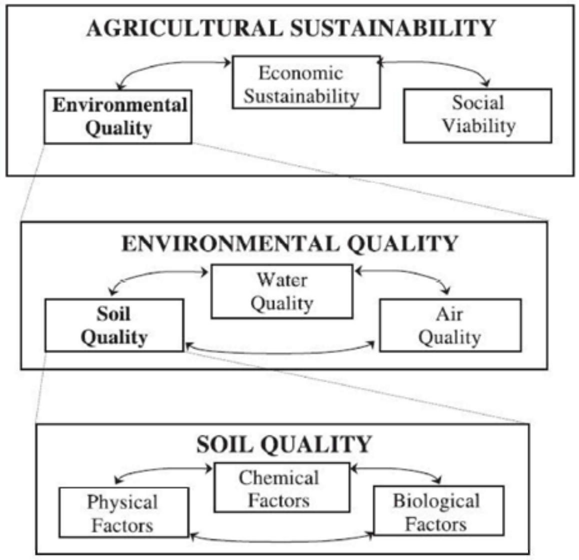

Fig. 2: Hierarchical relationship of SQ to environmental quality and agricultural sustainability, adapted from Andrews [6]

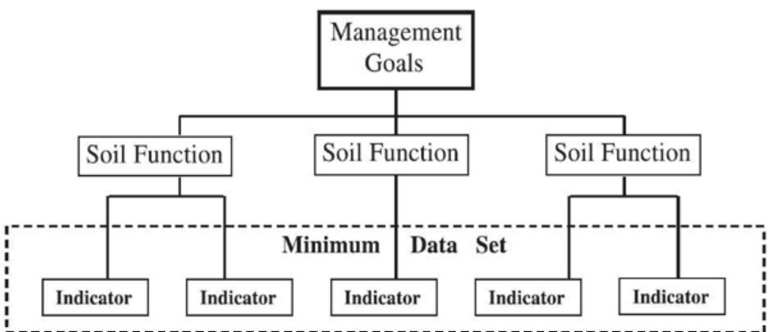

Fig. 3: A framework for selecting SQ indicators for a minimum data set, adapted from Karlen *et al.* [2]

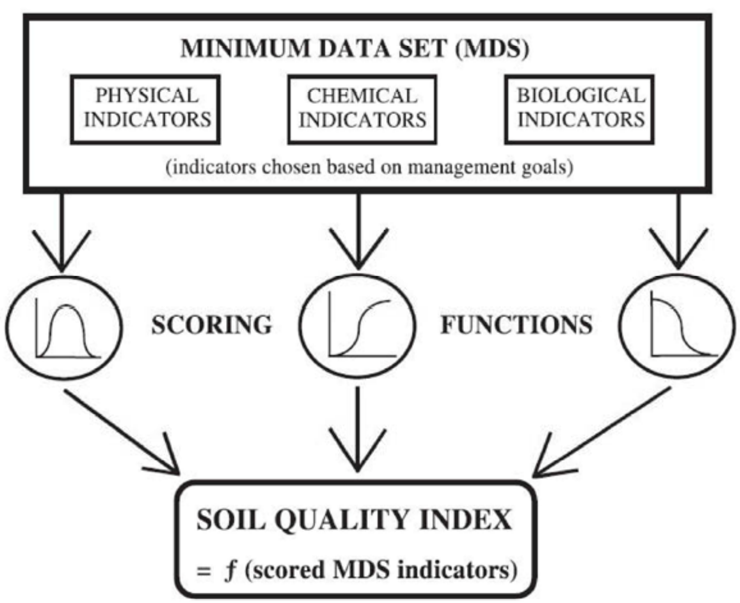

Fig. 4: Conceptual model for converting minimum data set indicators to SQ index values, adapted from Andrews [6]

The objective of this work was to study a set of inexpensive and agronomically meaningful indicators of SQ in the Varamin region, Iran.

MATERIALS AND METHODS

Study Site: The site is located in a production area of Varamin region, Tehran Province, Iran, at latitude of 35° 19' N and longitude of 51° 39' E and is 1000 m above mean sea level, in semi-arid climate, where the summers are dry and hot, while the winters are cool. The selected site had approximately 15 ha (300 m × 500 m) and the soil was a fine, mixed, thermic, Typic Haplocambids loam soil (USDA Soil Taxonomy). The mean monthly rainfall and temperature data of the study site during the years 2008-2009 are given in Fig. 5.

SQ Indicators Selection: The general criteria used for SQ indicators in this study included: 1) sensitivity to management, 2) precision of measurement method, 3) relevance to important functional soil processes, 4) ease and cost of sampling and analysis [15]. Based on the mentioned criteria, many soil physical properties were rejected as suitable indicators due to the requirement for undisturbed samples, or due to high variability. For example, although bulk density is widely regarded as an important physical indicator [16], it was not included, because of the impractical need for undisturbed core samples and generally strong correlations with other physical indicators in the test [17]. Also, many soil biological indicators were rejected due to the high cost of analysis, often associated with labor intensity [4]. Furthermore, the soil chemical indicators adopted in this study are part of well-established standard soil nutrient analysis tests that are widely used at reasonable cost in Iran [18-24].

Selected SQ Indicators: Table 1 shows the physical (aggregate stability and available water capacity), biological (organic matter content and active carbon content) and chemical (pH, available phosphorous and available potassium) indicators that have been selected as a set of inexpensive and agronomically meaningful indicators of SQ. These are indicators of critical soil processes such as aeration, infiltration, water and nutrient retention, toxicity prevention, nutrient availability, etc., which in turn relate to soil functions such as plant production, landscape water partitioning and filtration and habitat support [9]. All of the selected indicators can be measured using a composite soil sample, which it is recommended to be obtained from at least two locations nested within five sampling plots on a site [25]. Most indicators were shown to have significant within-season variability [3] and soil management practices can be a confounding influence for soil physical and biological indicators. Thus, samples should be collected at an appropriate and consistent time to be established regionally [4]. In Iran, like many countries in the world, early spring sampling prior to tillage is the best, due to favorable soil water conditions (near field capacity) and relatively uniform biological conditions following over-wintering.

Soil Sampling: Within research site, 24 sampling points were selected. Around these points, circular plots with a 10 m radius (314 m^2) were delimited and five random discrete soil samples taken from each one of them. Soil samples were collected from the 0-10 cm depth using trowels. Soil depth of 10 cm is the average depth for expansion of roots, i.e. active crop root zone [25-27]. After collection, all samples were placed in airtight polyethylene bags and transported back to the Laboratory.

Soil Processing and Analyses: Upon their arrival to the laboratory, samples were split in two portions. One was sieved through a 2-mm mesh screen at field moist and used for biological analyses. These filed moist samples were kept at 4°C until the analyses were carried out, which took no longer than two days after sampling. The remaining was air-dried and further split in tow other portions. One was sieved through a 4-mm mesh for physical analyses and other sieved through a 2-mm mesh for chemical analyses. Soil texture was determined as an integrative property and provided the basis for result interpretation through scoring curves. Clay was separated from sand and silt through successive dispersion and gravity sedimentation following the principles of Stoke's Law [28]. Aggregate stability was measured using a rain simulation sprinkler that steadily rained on a sieve containing a known weight of soil aggregates between 0.5 mm and 2.0 mm. The unstable aggregates slaked (fell apart) and passed through the sieve. The fraction of soil that remained on the sieve determined the percent aggregate stability [25]. Available water content was measured using pressure chambers to determine the difference between water stored at field capacity and the permanent wilting point [3, 25]. Organic matter content was determined by loss on ignition, based on the change in weight after a soil sample was exposed to approximately

Table 1: Physical, chemical and biological soil quality indicators included in this study and associated processes.

Soil quality domain	Soil quality indicator	Soil process
Physical	Aggregate stability	Aeration, infiltration, shallow rooting, crusting
	Available water capacity	Water retention
Biological	Organic matter content	Energy storage, water and nutrient retention
	Active carbon content	Organic material to support biological functions
Chemical	pH	Toxicity, nutrient availability
	Available phosphorous	P availability, environmental loss potential
	Available potassium	K availability

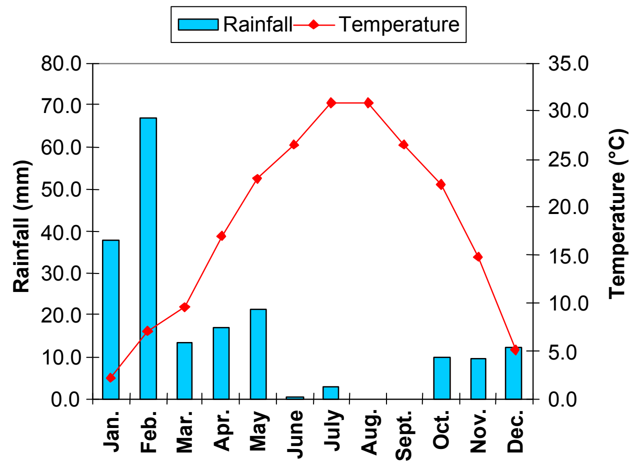

Fig. 5: Mean monthly rainfall and temperature data of the study site during the years 2008-2009

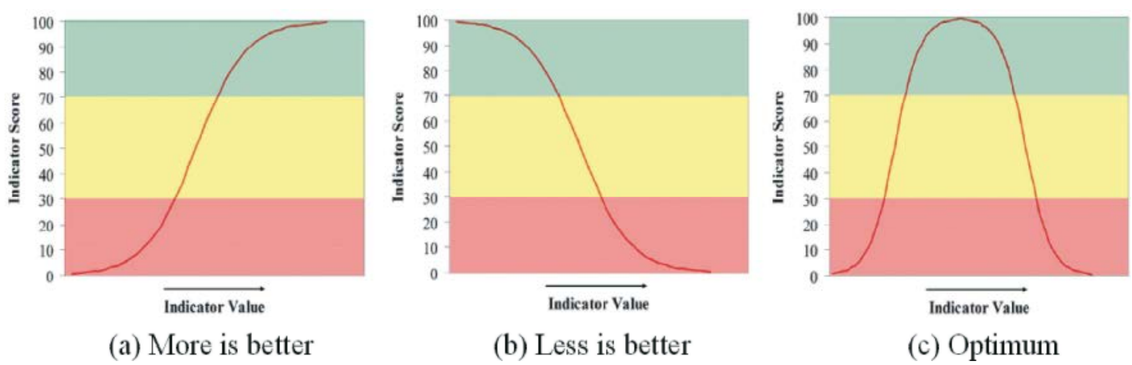

Fig. 6: Three types of scoring curves used for the interpretation of measured values of SQ indicators; (a) More is better, (b) Less is better and (c) Optimum, adapted from Gugino *et al.* [25]

500°C in a furnace for two hours [25]. To determine active carbon content the soil sample was mixed with potassium permanganate (deep purple in color) and as it oxidized the active carbon, the color changed (became less purple), which could be observed visually, but was measured very accurately using a spectrophotometer as discussed in Weil *et al.* [29]. The pH of a suspension of one part water to one part soil was determined using a standard pH meter with glass electrodes. Available phosphorous was determined by the Bray No II method. Available potassium was first extracted with ammonium acetate (1 N NH4OAc) and the content of K^+ was determined by the Atomic Absorption Emission Spectrophotometer.

Data Interpretation and Scoring Curves: Effective use of SQ test results requires the development of an interpretive framework for the measured data. The general approach of Andrews *et al.* [11] was applied for this purpose and the three types of scoring curves (Fig. 6), i.e. "more is better", "less is better" and "optimum" reported by Gugino *et al.* [25] for the three main soil textural classes, i.e. coarse-textured (sand, loamy sand, sandy loam), medium-textured (loam, silt loam, silt, sandy clay loam) and fine-textured (clay loam, silty clay loam, sandy clay, silty clay, clay) were used for all the selected SQ indicators to rate test results. Also, the critical high and low cutoff values of some selected SQ indicators were modified based on the frequency distribution of data throughout the study site as discussed in Arshad and Martin [17].

SQ Test Report: A standard SQ test report designed by Moebius *et al.* [4] was also used to facilitate SQ indicators assessment and detection of soil constraints. This was accomplished through the combined use of quantitative data and color coding. The physical, biological and chemical indicators were grouped by blue, green and yellow colors, respectively. For each SQ indicator, the measured value was reported as well as the associated rating score from its scoring curve. In addition, the indicators were rated with color codes depending on their scores. Generally, a score of less than 30 was regarded as low and received a red color code. A score from 30 to 70 was considered medium and was color coded yellow. A score value higher than 70 was regarded as high and color coded green. This provided for an intuitive overview of the test report. If the rating of a particular indicator was poor/low (red color code), the respective soil constraints were additionally listed. This was a very useful toll for identifying areas to target their management efforts. An overall SQ score was computed from the individual indicators. This score was further rated as follows: less than 40% is regarded as very low, 40-55% was low, 55-70% was medium, 70-85% was high and greater than 85% was regarded as very high. The highest possible score was 100 and the least was 0. Thus, it was a relative overall SQ status indicator [4, 9, 25].

RESULTS AND DISCUSSION

Fig. 7 shows the standard SQ test report for the Varamin region, Iran. This site has been used for production of wheat, canola and different vegetables such as watermelon, melon, cantaloupe, tomato, eggplant, bell pepper and garlic using intensive conventional tillage (moldboard plow + two passes of disk harrow), without manure application.

The SQ test report shows generally very favorable results for chemical indicators, with high rating scores for pH, available phosphorous and available potassium (88, 100 and 100, respectively). These results are in agreement with those of Karlen *et al.* [2], Moebius *et al.* [4], Idowu *et al.* [9] and Gugino *et al.* [25] who concluded that based on traditional soil testing methodology, i.e. testing the chemical indicators of SQ, almost all soils may appear to be of good or acceptable quality. This may be commonly the case, as most farmers are diligent about

Indicators		Value	Score	Constraint
PHYSICAL	Aggregate Stability (%)	19.0	20	aeration, infiltration, rooting
	Available Water Capacity (m/m)	0.15	44	
BOLOGICAL	Organic Matter Content (%)	1.03	3	energy storage, C sequestration, water retention
	Active Carbon Content (ppm)	275	4	soil biological activity
CHEMICAL	pH	7.30	88	
	Available Phosphorous (ppm)	14.7	100	
	Available Potassium (ppm)	345	100	
OVERALL QUALITY SCORE (OUT OF 100)			51.3	Low
Measured Soil Textural Class: Loam	SAND (%): 33	SILT (%): 45		CLAY (%): 22
Location (GPS):	Latitude: 35° 19' N	Longitude: 51° 39' E		

Fig. 7: The standard SQ test report for the Varamin region, Iran

submitting soil samples for nutrient analysis and subsequently correcting the deficiencies. Chemical constraints can be readily remedied by application inorganic chemicals, which generally provide instant results.

The remaining indicators, i.e. the physical and biological indicators of SQ, have unfavorable or adverse results and consequently show evidence of low physical and biological SQ. Low rating scores for aggregate stability, available water content and organic matter content (20, 44 and 3, respectively) are evidences of soil degradation from long-term intensive tillage and lacking use of soil-building crops or organic matter additions. Moreover, very low rating score for active carbon content (4) indicates that the soil is biologically degraded and unbalanced. These results are in agreement with those of Carter [1], Moebius *et al.* [4], Idowu *et al.* [9] and rews [11] and Gugino *et al.* [25] who concluded that the lack of routine tests for physical and biological indicators of SQ has resulted in inadequate attention to these aspects of the SQ.

The overall score of 51.3 (low) also signifies considerable opportunity for targeted improvement. However, enhancing the physical and biological quality of soils generally requires a long-term commitment to soil management through practices such as conservation tillage, improved rotations, cover cropping and organic amendments, as discussed in Carter [1], Karlen *et al.* [2], Moebius *et al.* [3, 4], Idowu *et al.* [9], Andrews [11], Santanna *et al.* [13] and Gugino *et al.* [25]. Long-term conservation tillage management maintains soil organic matter, because less physical disturbance which reduces the short-term rapid decomposition in tilled soils, leading to aggregate stabilization and improved soil structure [3, 30].

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