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Soil Quality Assessment and Sustainable Management for Nutritional Security

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ABSTRACT: Soil, apart from providing a number of ecosystem services, strongly influence human health by producing safe and nutritious food and providing pollution free environment. None of the soil services will go right until it itself is healthful. Human health is directly related to the soil quality because soil is the ultimate source of human nutrition. Enhanced reliance on inorganic inputs for intensive cultivation and poor management practices have led to widespread degradation in soil quality. Negligence of on-going degradation processes like soil erosion, compaction, loss of organic matter can lead to major catastrophes. Therefore soil quality assessment and its management through sustainable tool is very important for nutritional security. Maintenance of soil quality is a very complex process due to interactive involvement of many factors (Climate, humans, soil *etc.*) but can be achieved through sustainable use of resources following the 4R's of nutrient stewardship. This article is aimed to raise the concern for soil quality for nutritional security and to bring the methods for its assessment and remedies for its sustainable management on single page.

Keywords: Soil Quality, Assessment, Sustainable management, Nutritional security.

INTRODUCTION

Soil is a major provider, supporter and regulator of ecosystem services like biomass production, buffering, filtering, water and nutrient cycling, carbon sequestration, bioremediation, climate change mitigation *etc.* (Karlen *et al*., 2001). It has complex entanglement on human health (Zornoza *et al*., 2015), being the ultimate source of safe, nutritious food. All the functions and services provided by soil will go right only when it itself is salubrious. The various physical, chemical and biological characteristics of soil are the indicators of its quality/health. Assessment of soil quality of farm is needed to demonstrate the positive impacts of agricultural management practices on soil properties and crop production. To make the concept of soil quality more clear and understandable for farming community, soil quality should be displayed by assigning scores for diversified soil parameters. Scores are given on the basis of physical, chemical and biological data that is responsible for variability in its quality and will facilitate the growers for better soil management.

India has achieved the goal of food security to a great extent but hidden hunger still continues to be one of the major challenges as nutrient deficiencies in soils are directly impacting the food quality. Worldwide two billion people are in the grip of malnutrition, particularly in developing countries due to their reliance on low-cost staples and monotonous diet (Grebmer *et al*., 2014). Impact of hidden hunger is clearly visible on COVID-19 patients as Ali *et al*. (2021) observed a positive correlation between the high prevalence of zinc deficiency and the COVID-19 cases per million populations in Asian countries. Moreover, it is convincing that low baseline zinc levels in COVID-19 patients were associated with more complications, leading to prolonged hospitalization and increased mortality (Jothimani *et al*., 2020). Ascorbic acid, Fe, Zn, vitamin D are some of the most important supplements being given to COVID-19 patients due to their deficiency in humans. Therefore, there is an urgent need to assess the soil quality so as to fix the nutritional quality of food stuff.

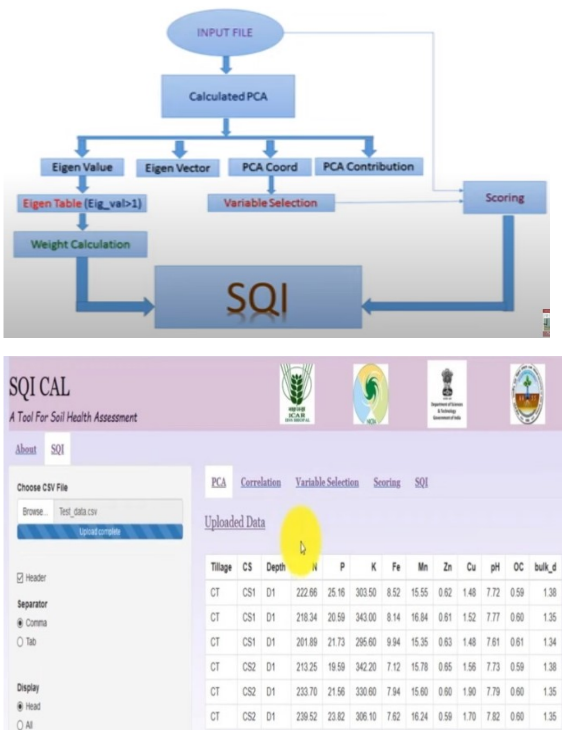
SOIL QUALITY ASSESSMENT

Soil quality assessment is the process of assigning the scores to the soils on the basis of certain indicators that are specific soil properties and processes. Single indicator is not enough to assess soil quality as univariate approach is unable to provide comprehensive judgement on soil nutrients' status. In contrast, increasing the number of indicators may complicate the process by increasing collinearity or provide conflicting results (Armenise *et al*., 2013). Therefore, a minimum data set (MDS) is a prerequisite to capture a holistic image of soil quality. After selecting MDS, it is normalized (*i.e.* all the indicators are scored between the range 0-1) so as to make the values comparable, *e.g.* pH is not comparable with the nitrogen content of soil as long as it is not normalised between the range of 0-1. After normalising the data, scores are integrated to construct the final index (Stellacci *et al*., 2021). Various software programmes and procedures are available for calculating the soil quality index. Some of these are discussed below:

(a) Soil Conditioning Index (SCI): It is a quick way to characterize organic matter dynamics of a farming system. It predicts the soil quality on the basis of amount of organic material (OM) returned to the soil after a crop harvest, effects of tillage and field operations (FO) on soil organic matter decomposition and the effect of predicted erosion (ER) associated with the management system on organic carbon. SCI score for a cropland must be greater than 0.0. It is calculated using the formula (Hubbs *et al*., 2002):

$$SCI = 0.4 \times OM + 0.4 \times FO + 0.2 \times ER$$

(b) Principal Component Analysis (PCA): Principal component analysis (PCA) is a widespread procedure designed to summarize large datasets of correlated variables into a reduced number of components bearing the greatest part of the original information (Stellacci *et al*., 2021). Variable weights or loadings of the retained components are useful to identify the variables that contribute most to each selected principal components and investigate their relationships. SQI Cal software (Fig. 1) designed by IARI, New Delhi to work out the soil quality index through PCA.



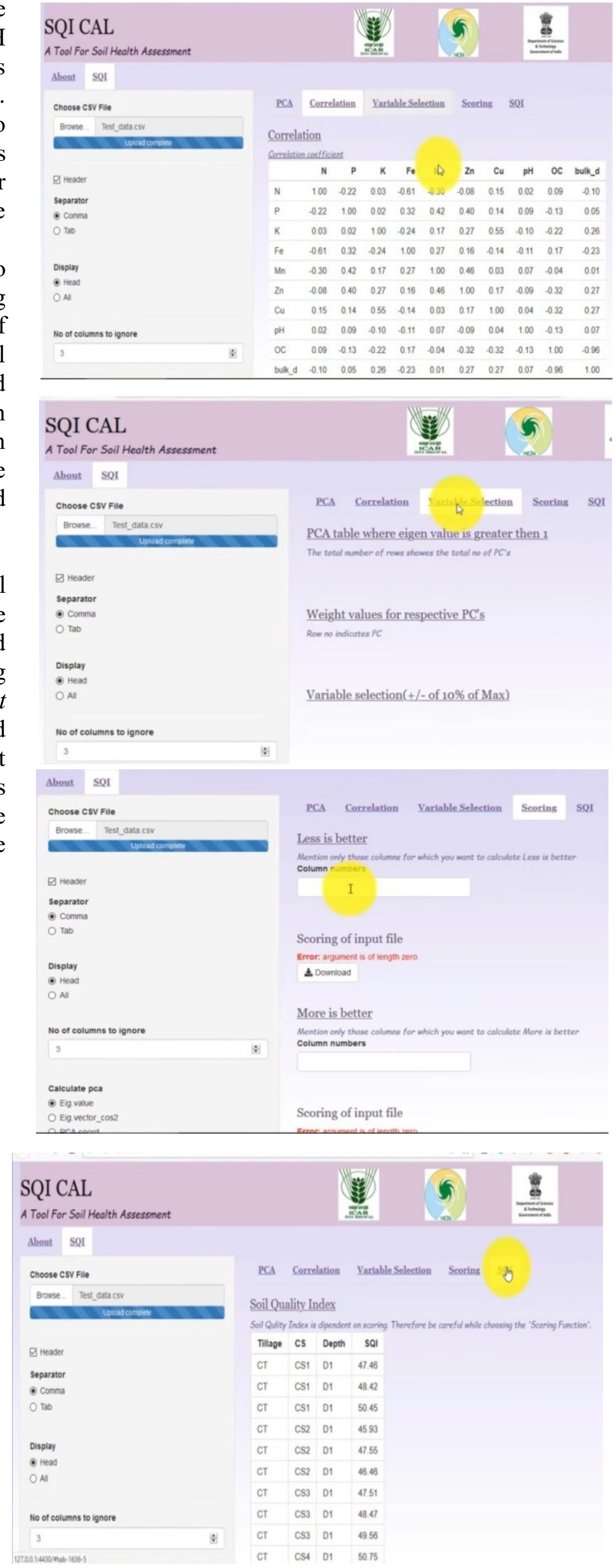
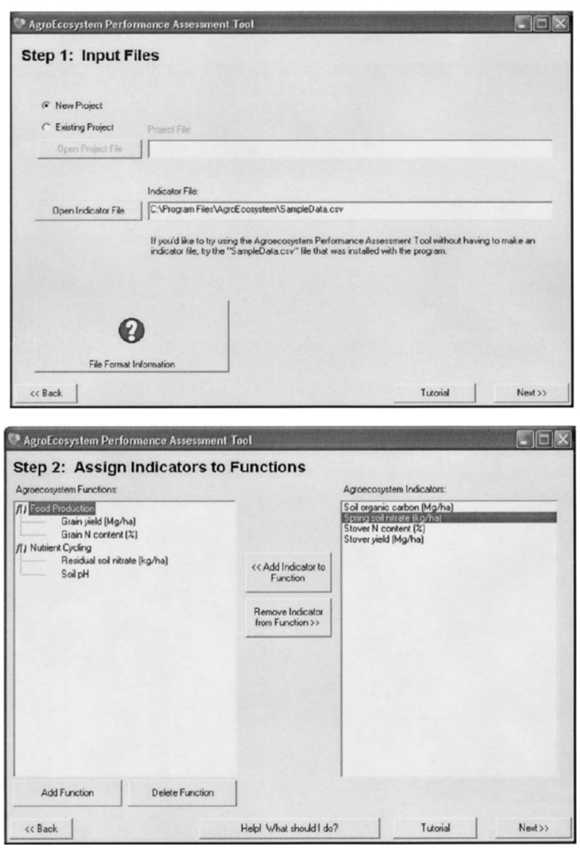


Fig. 1. Steps involved in soil quality indexing through SQI Cal software.

(c) Soil Management Assessment Framework (SMAF): The SMAF includes three steps: indicator selection, indicator interpretation, and integration into a soil quality index (Gura *et al*., 2022). The indicator selection step uses an expert system of decision rules to recommend indicators for inclusion in the assessment based on the user's stated management goals, location and current practice. In the indicator interpretation step, observed indicator data is transformed into a unitless score based on clearly defined, site-specific relationships to soil function. The integration steps allows for the individual indicator scores to be combined into a single index value. This can be done with equal or differential weighting for the various indicators depending upon the relative importance of the soil functions for which they are measured.

(d) Agro-Ecosystem Performance Assessment Tool (AEPAT): It is a computer program used to evaluate the agronomic and environmental performance of management practices in long-term agro-ecosystem experiments (Liebig *et al*., 2004). The program employs a simple scoring method to quantify the performance of management practices using indicators grouped within agro-ecosystem functions. Management practices are evaluated on a relative basis using AEPAT, thereby comparisons are made. It evaluates the effects of cropping system on soil quality and assesses agronomic and environmental functioning of soil. The working of the software is presented in Fig. 2.



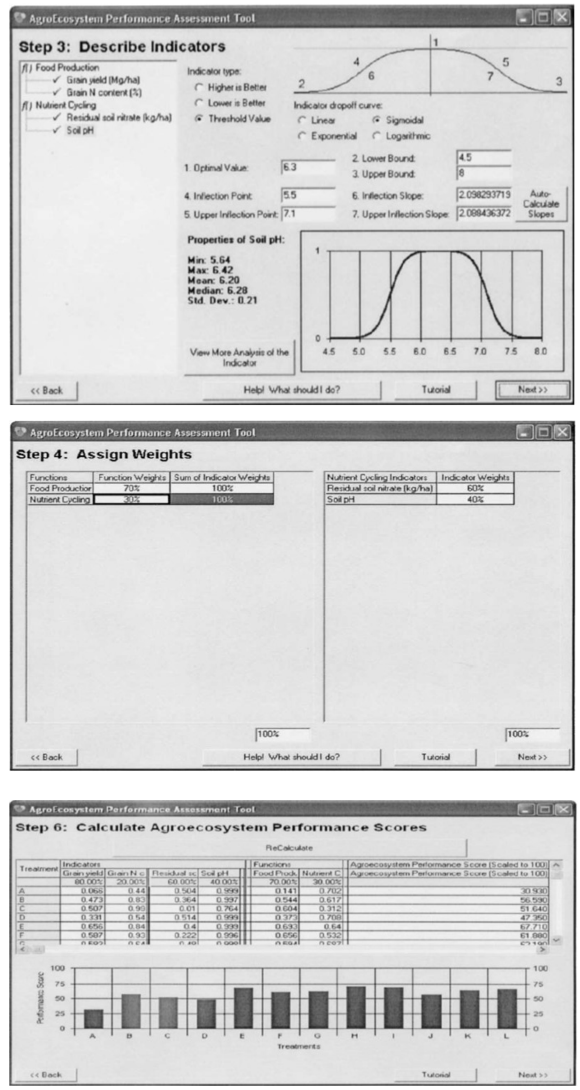


Fig. 2. Working of AEPAT software.

(e) Cornell Soil Health Test (CSHT): It considers 17 indicators which include soil texture, four soil physical indicators (Wet Aggregate Stability, Available Water Capacity, Penetration Resistance 0-15cm and Penetration Resistance 15-45cm), seven chemical indicators (pH, Phosphorus, Potassium, Magnesium, Iron, Manganese, and Zinc), five biological indicators (Organic Matter Content, Active Carbon, Autoclaved-Citrate Extractable Protein, Soil Respiration, Root Health Rating) (Idowu *et al*., 2009). These indicators are assessed, scored and converted to a single value soil quality index.

SUSTAINABLE SOIL MANAGEMENT FOR NUTRITIONAL SECURITY

COVID-19 has shown the mirrors to the scientific community highlighting the fact that the diet we are consuming is poor in nutrition. The principle reason behind the under-nourished food is its source (soil) that itself is a victim of nutrient imbalance. Maintaining soil nutrition and quality at desirable level is a very complex issue due to interactive involvement of climatic, soil, plant, and human factors. However, proper and timely diagnosis and adoption of sustainable practices can clear up this issue. Agronomic biofortification (nutrient enrichment of crops) with the use of 4 R's (Right source, Right rate, Right method and Right time) can serve the purpose.

(a) Right Source: Combination of organic and inorganic sources i.e. integrated nutrient management approach can take us one step closer to better nutrition. For instance, Manzeke *et al.* (2014) reported better nutritional quality in maize and improved soil quality with the integrated use of inorganic N, P, Zn and cattle manure or leaf litter compost. After the harvest of wheat, Bangre *et al.* (2021) noticed improvement in soil physical properties with the integrated application of 100% NPK and FYM in a Vertisol of central India.

(b) Right rate: Adding the fertilizers precisely according to the need of the crop can eliminate the problem of environmental pollution and can improve the nutrient uptake and content in the crops. It will contribute in better soil quality. Precision agriculture tools like site specific nutrient management, variable rate technology, etc. can be used for better results. Morari *et al*. (2021) supplied variable nitrogen rates using normalised difference vegetation index (NDVI) in different fertility zones (High, Medium and Low fertility zones) and got statistically coequal yields, protein content and nitrogen use efficiency in all the zones.

(c) Right time: Supplementation of fertilizer at right stage of the crop is as important as its rate. Foliar sprays can be done as and when required by the crop. Besides increasing the production, it decreases the losses and improves the soil quality. Zn application at 50 DAS reported best nutritional quality of wheat among the treatments containing Zn spray at 0, 30, 35, 40, 45 and 50 DAS at all rates of Zn application (AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, Annual report 2019-20).

(d) Right method: Some crops responds well to soil application of fertilizers while others to foliar. Similarly some fertilizers work efficiently when supplied through soil while others responds well to foliar applications. So, fertilizer must be applied through right methods. Thakur *et al*. (2021) noticed better maize yield and soil quality with the foliar application of boron at recommended rate (0.034%) as compared to soil application (2 kg ha^{-1}).

CONCLUSION

Soil performs various ecosystem functions and their performance depends on its quality. Soil management systems affect the soil quality and therefore its assessment is an important step for maintaining its quality. There are a number of tools available for determining the soil quality index. On the basis of soil quality index, fertilizer scheduling can be done precisely by using right source with right rate through right method at right time.

FUTURE THRUST

1. Farmers can be motivated to maintain/improve the soil quality by providing annual soil score cards. The farmers with best soil scores should be awarded by agri-inputs or cash prizes.
2. Proper recommendations should be given to the farmers with low soil quality index.
3. Use of precision technology should be popularised by running awareness campaigns among farmers.

Conflict of Interest. The authors declare that there is no conflict of interest.

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