Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; SP1: 378-382

Brajendra
ICAR-Indian Institute of Rice Research, Hyderabad, Telangana, India

K Surekha
ICAR-Indian Institute of Rice Research, Hyderabad, Telangana, India

MBB Prasad Babu
ICAR-Indian Institute of Rice Research, Hyderabad, Telangana, India

Mir Imran
ICAR-Indian Institute of Rice Research, Hyderabad, Telangana, India

N Sailaja
ICAR-Indian Institute of Rice Research, Hyderabad, Telangana, India

AK Vishwakarma
ICAR-Indian Institute of Soil Science, Bhopal, MP, India

Meghna Sarma
ICAR RC NEH Region, Umiam, Meghalaya, India

Correspondence
Brajendra
ICAR-Indian Institute of Rice Research, Hyderabad, Telangana, India

Developing a model rice soil health indicator- Methods and methodologies for assessment

Brajendra, K Surekha, MBB Prasad Babu, Mir Imran, N Sailaja, AK Vishwakarma and Meghna Sarma

Abstract
Fertility is an important indicator because nutrient levels directly influence crop productivity. So are the soil related constraints such as **s**alinity, sodicity and acidity which are equally very important indicators because high salinity inhibits crop growth, while high sodicity leads to loss of soil structure and acidity related infertility syndrome is quite common. As rice and rice based cropping systems contribute largely to the total food production, sustainability of this system is vital for food and nutritional security. Further, water shortage being experienced in the country is threatening the conventional rice cultivation system warranting a re-look into the current practices and design strategies for enhancing resource quality and water productivity. Measurement procedures and guideline optimum ranges for soil chemical, physical and biological properties are available and can be used to identify the most critical limiting soil factors in relation to their soil condition, plant type, climate and management practices. Emphasis to date has been largely on chemical and physical indicators of soil quality rather than on microbiological indicators, which are generally regarded as more difficult to measure, predict or quantify. Soil microorganisms are also very suitable and sensitive indicators that can also be used as predictive tools in soil quality monitoring. The indices for soil quality are considered to be of immense significance to manage soil health in order to sustain productivity of crop and to achieve an environment friendly crop production.

Keywords: Rice Soil, Indicator, Methods, Assessment

Introduction

Soil (Soul of Infinite Lives) is a dynamic, vital living resource. Perceptions of what constitutes a good soil vary. Soil quality or health integrates the physical, chemical and biological component of soil and their interactions. With nutrient removal through crop uptake far exceeding nutrient inputs in many intensive cropping systems, there is growing concern about sustaining such productivity demands under conditions of declining land and water availability, deteriorating soil quality and uncertainty in climate change impacts on agriculture. Efficient management of resources and inputs in such systems on a long-term basis becomes important for sustaining agricultural growth.

Given the large number of soil characteristics that can be measured as indices of the soil quality, a 'minimum data set (MDS)', i.e. a set of specific soil measurements considered as the basic requirement for assessing the soil quality (Doran *et al*., 1996) [5] needs to be selected. Some attributes for any indicators of MDS must be

(i) compatible with basic ecosystem processes in soil as well as physical or chemical indicators of soil health, (ii) sensitive to management in acceptable time frames, (iii) easy to assess or measure, (iv) composed of robust methodology with standardized sampling techniques, (v) cost-effective, and (vi) relevant to human goals, food security, agricultural production, sustainability and economic efficiency. Some of the commonest examples are

Aggregation-Aggregate stability is a measure of a soil's ability to remain aggregated despite stresses from tillage, raindrop impact, etc.

Soil Reaction (pH)- Soil pH is an important indicator because it regulates nutrient availability/toxicities.

Salinity and Sodicity- Salinity is an excess of soluble salts in the soil. Sodicity is an excess of sodium in sodic soils.

Organic Matter-Organic matter comprises all carbon-based constituents of the soil, including living organisms, decaying plant material, and humus.

The amount of organic matter in the soil is an important indicator because it is the storehouse for the energy and nutrients used by plants and soil organisms.

Soil Fertility- Measures the inherent capacity of the soil for supplying all the essential nutrients in balanced and proportionate amount.

Microbial activity- in the rhizosphere can also affect nutrient availability to the plant through complex of interactions. The effects of microbial interactions on nutrient availability has practical implications for improving the efficiency of use of fertilisers. The physical and chemical components of soil are important, but the organisms that live in the soil ensure that it remains fertile and productive in the long term (Roger *et al*., 1991) [10].

Biological Diversity-is the number of species in the soil or plant community, either at a particular time or over time. Most soils, except for highly disturbed or young soils, have inherent biological diversity. Diversity is an important indicator because biological composition of the soil can affect nutrient and pest cycles, disease suppression and pollutant degradation, as well as development of soil structure. Soils have redundancy for organisms responsible for organic matter decomposition and nutrient cycling.
Measuring soil health provides site-specific interpretations for indicator results.

The index framework involves three main steps

- **Indicator selection** to efficiently and effectively monitor the critical soil functions
- **Interpreting indicators** in terms of soil function (using expected ranges determined by the soil's inherent capability)
- **Combining indicator scores** into an integrated index of soil health.

Ideal Indicators should

- correlate well with ecosystem processes
- Perform the functions necessary for its intended use.
- integrate soil physical, chemical, and biological properties & processes
- be accessible to many users
- be sensitive to management & climate
- be interpretable

Indicator Categories -Typical soil tests only look at chemical indicators. Soil health attempts to integrate all three types of indicators. These categories do not neatly align with the various soil functions. Broadly indicator's categories are:

- **Physical indicators-** provide information about soil hydrologic characteristics such as water entry and retention which influences availability to plants. Some indicators are related to nutrient availability by their influence on rooting volume and aeration status.
- **Chemical indicators-** can give information about the equilibrium between soil solution and exchange sites, plant health, nutritional requirements of plant, levels of soil contaminants and their availability for uptake by plants.
- **Biological indicators-** can tell about the organisms that form the soil food web, which are responsible for decomposition of organic matter and nutrient cycling. Information about the numbers of organisms, both individuals and species, that perform similar jobs or niches, can indicate a soil's ability to function or bounce back after disturbance (resistance and resilience). The set of indicators used to determine soil health is also called a minimum data set. The table below shows the relationship between indicator type and soil function (Borromeo T.H. 2001) [3].

Background literatures /Methodologies
Combining indicators scores
Once scored, indicators can be combined in a variety of ways, such as additive (Andrews and Carroll, 2001) [2], weighted (Karlen *et al*, 1998), or multiplicative indexes (Doran and Parkin, 1996; Larsen and Pierce, 1991) [5, 9].

Evaluating soil health
1. When the dataset is few or less method given by Abassi, 1999 [1]. Selecting only five soil attributes, namely acidity (pH), OM, phosphorus, potassium, and EC can be combined to construct an index to represent the soil quality. The SQI constructed using the formula
SQI = (DpH + DOM + DP + DK + DEC)/5

where DpH = 1, if pH > 6.5 and 0 otherwise
DOM = 1, if OM > 2 and 0 otherwise, DP = 1, if P > 20 and 0 otherwise, DK = 1, if K > 80 and 0 otherwise, and DEC = 1, if EC < 2 and 0 otherwise, D = constant.
SQI is bounded between 0 to 1, and higher the SQI, better is the quality of the soil.
Based on the SQI values, the soil quality scale can be rated as very good (>0.5), good (0.6– 0.7), average (0.5–0.6), and poor (0.4–0.5)

2. Biochemical soil fertility index (Herrick, J. 2000) [7]
To compare the effect of a varied organic-and-mineral fertilization on the soil bioactivity in many-year fertilization experiments it can be useful to involve indices which would define the relationship between the activity and the soil fertility. Such indices prefer the use of enzymatic activity, contrary to defining the count of selected groups of microorganisms, since defining the activity of enzymes is more convenient and easier to carry out serial analyses. Based on the obtained values of the enzymatic activity and the content of N_{total} and C_{org} Biochemical Soil Fertility Index (B) is calculated as:
$B = C_{org} + N_{total} + DHA + F_{al} + Prot + Amyl$

where: C_{org}– OC%
N_{total} – total nitrogen content, %
DHA – dehydrogenases activity, $cm^3\ H_2 \cdot kg^{-1} \cdot 24h^{-1}$
F_{al} – alkaline phosphatase activity, mmol $PNP \cdot kg^{-1} \cdot h^{-1}$
Prot – proteases activity, mmol $N\text{-}NH_4^+ \cdot kg^{-1} \cdot h^{-1}$
Amyl – amylases activity, mg of decomposed $starch \cdot h^{-1}$
In order to classify the respective soil samples to evaluate soil fertility, the values of the biochemical fertility index can be divided into the following ranges:

- 3-4 – low fertility, 4-5 – average fertility, 5-6 – high fertility, 6-7 – very high fertility.

3. Biological index of fertility (BIF) (Doran JW, Zeiss MR 2000) [6]: Several indices have been proposed to assess soil quality which are mostly microbial in nature. They use a weighted average to calculate the
BIF = DA+KCA/2
Where DA and CA represent dehydrogenase and catalase

activity, respectively, and K is a proportionality coefficient.

4. Brejda *et al.*, 2000 [4] proposed an enzyme activity (EAN) as biological index based on 5 different enzymes given by the expression:
EAN= 0.2(TPF + catalase/10 + phenol/40 + amino-N/2+ amylase/20)

5. Sustainability index for soil quality- It is usually based on the area of triangle in which nutrient index, microbial index and crop index of soil represents the three vertices of a triangle. Nutrient index can be calculated from the analysis of different soil parameters. Microbial index can be calculated as soil microbial and biochemical activities and crop index by measuring of crop yield parameters (Mohotti, 2002) [11]. Different indicators can be assessed in order to compare the effect of different sources of nutrients such as green manure, fym, and chemical fertilizer on cropping systems/patterns. The nutrient index can be calculated by following the different chemical parameters. In calculating NI each parameter is divided by the respective threshold value (arithmetic mean value of treatments for a parameter in field experiment). Thus each parameter has five calculated threshold value and each field experiment is being considered as a separate systems with a difference equilibrium wrt to nutrient status, microbial activity and productivity. The index value of the treatment (Iji)) calculated by dividing the value by the respective threshold of a parameter is given as:
Iji= Aij/Thj
Where Iji is the index value for ith treatment corresponding to jth parameter in an experiment, Aji is the actual measured value for ith treatment and jth aparameter in an experiment and Thi is the threshold for jth parameter. The nutrient index after then is calculated as an average of index values (Iji) of all six parameters in an experiment.

$$NIj = 1/6\sum_{j=1}^{6} Iij$$

where NIi is the nutrient index for ith treatment and J is the number of parameters considered in deriving nutrient index.

Microbial index of soil (MIi)
Microbial index can be calculated as the nutrient index, the meaused microbial parameters as Microbial Biomass Carbon (MBC), Microbial Biomass Nitrogen (MBN), Potential Microbial Nitrogen (PMN), Soil Respiration (SR), Dehydrogenase activity (DA). The microbial index for each treatment can be calculated as an average of index values of all the parameters in each experiment.

$$MIj = 1/8\sum_{j=1}^{8} Iij$$

where MIi is the microbial index for ith treatment and J is the number of parameters considered in deriving microbial index.

Crop index (CIi)
Estimated as dry matter yield, N, P, K uptake by the crop. The crop index for each treatment is measured for each treatment as an average of index values for all the parameters in each experiment.

$$CIj = 1/4\sum_{j=1}^{4} Iij$$

where CIi is the crop index for ith treatment and J is the number of parameters considered in deriving crop index.

6. Soil quality evaluation by Larson and Pierce, 1991) [9] - They proposed more parameters for evaluating soil health parameters. It is suggested that changes in indicator values reflect the combined effects of land use. If the changes in quality are positive and higher, then it is of better quality. A brief methodology is as follows:

a) **Weights of the indicator-**The contribution of each indicator towards soil health is different and can be indicated by weighing coefficient. Several ways are there to assign weighing coefficient. This may include existing soil condition, cropping pattern, agro-climatic condition besides others. The sum of all weights is normalized to 100%. The indicators are subdivided based on their marks into Class I, Class II, ClassIII and Class IV. The Class I is the most suitable for plant growth, Class II is suitable for plant growth with slight limitations, Class III with more serious limitations than Class II and Class IV with severe limitation to plant growth. Marks of 4,3,2,1 are given to each class from I to IV.
b) **Quantitative evaluation of changes in soil quality-** (Karlen and Stott 1994) [8] introduced a concept of Relative Soil quality index RSQI. The equation is given as RSQI= (SQI/SQIm) x 100

Where, SQI = Soil quality index
SQIm = maximum value of SQI.
The maximum value of SQI for soil is 400 and the minimum value is 100.
SQI=∑ Wi Ii
Where, Wi= Weights of the indicators
Ii= the marks of the indicators classes
Then SQI of each indicator can be calculated separately by multiplying weights of indicators and marks allotted to each class. An optimized soil in any region will have a normalized RSQI score of 100, but actual soil readings will have a value of less than 100 which indicate their deviation from the optimum range. According to the RSQI values, soils can be classified into 5 classes from best to worst, represented as I, II, III, IV and V respectively.

Classes	RSQI value
I	90-100
II	80-90
III	70-80
IV	60-70
V	<60

By comparing RSQI values, soil health in different regions can be compared even if they are evaluated with different evaluation systems, weightings and classes. Similarly, the ∆RSQI will quantify changes in soil health in a comparable way between two places. Changes in soil health (∆RSQI) can be further grouped as

Change Classes	∆RSQI
Great change	>10
Moderate increase	10 - 5
Slight increase	5 – 0
Slight decrease	0 - 5
Moderate decrease	-5 - 10
Great decrease	<-10

∆RSQI can also be used to quantify small changes during a specified time period. The RSQI and ΔRSQI can provide useful tools for evaluating spatial or temporal changes in soil health. With this indexing, it is possible to quantify the degree and direction of soil health changes as affected by different land use and management and intrinsic quality of the original soil.

Model Rice Soil health Index Developed at ICAR-IIRR, Hyderabad

The unique system of flooding mostly followed for rice cultivation to facilitate rice roots to access plant nutrients, for effective weed control and to reduce percolation loss of water, has many beneficial effects of general amelioration of chemical fertility, increased availability of nutrients like N, P, K, Ca, Mn, Fe, Si, etc, preferential accumulation of organic matter and biological N fixation, reduced toxicity of Al and Mn, while availability of sulfur (S) may be reduced due sulfate reduction. Flooding soil is a great pH neutralizer. In problem soils this neutralizes acidity and alkalinity thereby influencing favorably to an extent in the release and availability of plant nutrients. On the contrary, the electro-chemical changes upon flooding could also lead to release of certain nutrients into toxic levels (Fe, H_2S toxicity), and deficiency of micronutrients like Zn, Cu etc while the physical changes could constrain establishment and nutrition of non rice crops in the cropping system. Some indicators are crop specific. For instance, the optimum score for soil pH depends on what crop is being grown. Most indicators are site-specific, including interpretation based on inherent soil properties.

Suggested Scoring system for developing Soil health Index

Parameter	Class	Scores and their index	Parameter	Class	Scores and their index
Texture	C1	Sand	Soil respiration	C1	No biological activity
	C2	Silt		C2	Little biological activity
	C3	Clay		C3	Moderate biological activity
	C4	Loam		C4	High biological activity
Bulk Density	C1	Respective texture		C5	Very High biological activity
	C2	Respective texture	All the essential micronutrients nutrients	C1	Very low
	C3	Respective texture		C2	Low
	C4	Respective texture		C3	Medium
Soil pH	C1	Respective scales		C4	High
EC	C2	Safe limits and their classes		C5	Very High
	C3	Safe limits and their classes	Avail N, P, K, Ca, Mg, S	C1	Very low
	C4	Safe limits and their classes		C2	Low
	C5	Safe limits and their classes		C3	Medium
				C4	High
				C5	Very High

Scoring and indexing system for RSQI

RSQI= ∑ (Sp + Sc+ Sf+ Sb)/18

RSQI=∑ [(Sp1+ Sp2) X Scores) + ∑ (Sc 1+ Sc 2……..+Scn X Scores) + (Sf1+Sf2…….Sfn X Scores) + (Sb1 X Scores)]/ 18

RSQI= Two Physical Parameters X Their Scores + Three Chemical Parameters X Their Scores + Twelve Fertility Parametes X Their Scores+One Biological Parameters X Their Score Divided By 18

Makes a five way soil health indexing and scoring system

Hypothesis: A rating of 100 per cent expresses most favourable conditions and lower per cent indicates less favourable conditions.

The index rating of 0.8-1.0 is assigned Grade 1 – excellent
0.60-0.79 is assigned Grade 2 –Very good
0.40-0.59 Grade 3 – Good
0.20-0.39 Grade 4 – poor
0.10-0.19 Grade 5 – very poor

The contribution of each indicator towards soil health is different and can be indicated by weighing coefficient. Scoring of indicators is necessary to interpret how each relates to the soil function of interest and to allow indicators to be integrated by eliminating unit differences. A common scoring method is the use of non-linear scoring functions. Scoring functions are used widely as utility functions, multi-objective decision making as decision functions and systems engineering as a tool for modeling. The three main scoring curves are self evident: more is better, less-is-better, and mid-point optimum and their optimal score would be given when an indicator value represented high function in the particular soil, i.e., if the indicator was non-limiting to related soil functions and processes such as filtering and buffering, nutrient cycling, or structural stability. Hence, the proposed rice soil indicator is being further validated in diverse rice ecosystems of India to determine the most suitable indicator and how they should be interpreted.

Conclusions

While physical and chemical properties are important determinants of soil quality, microorganisms which drive many soil processes respond quickly to natural perturbations and environmental stress due to their short generation time and their intimate relation with their surroundings, attributed to their higher surface to volume ratio. In some instances, changes in microbial populations or activity can precede detectable changes in soil physical and chemical properties, thereby providing an early sign of soil improvement or an early warning of soil degradation. This allows microbial analyses to discriminate soil quality status, and shifts in microbial population and activity could be used as an indicator of changes in soil quality. Currently, though several different indices for soil health assessment have been established, but it is very difficult to know which index is most suitable for a given situation.

References

1. Abassi SA. Water quality indices: State-of-the-art. J. IPHE, 1999; 21:22-25.
2. Andrews SS, Karlen DL, Mitchell JP. A comparison of soil quality indexing methods for vegetable production systems in Northern California. Agriculture, Ecosystems and Environment, 2001; 1760:1-21.

3. Borromeo TH. Biodiversity and the quest for sustainable rice production systems. Philipp J Crop Sci. 2001; 26(1):15-20.
4. Brejda JJ, Moorman TB, Smith JL, Karlen DL, Allan DL, Dao TH. Distribution and variability of surface soil properties at a regional scale. Soil Sci. Soc. Am. J. 2000; 64:974-982.
5. Doran JW, Parkin TB. Quantitative indicators of soil quality: a minimum data set. In J.W. Doran and A.J. Jones, eds. Methods for Assessing Soil Quality. SSSA, Inc., Madison, Wisconsin, USA, 1996.
6. Doran JW, Zeiss MR. Soil quality and sustainability: managing the biotic component of soil quality. Applied Soil Ecology. 2000; 15:3-11.
7. Herrick J. Soil quality: an indicator of sustainable land management. Applied Soil Ecology, 2000; 15:75-83.
8. Karlen DL, Stott DE. A framework for evaluating physical and chemical indicators of soil quality. In J. W. Doran, D. C. Coleman, D. F. Bezdicek and B. A. Stewart, eds. Defining Soil Quality for a Sustainable Environment. SSSA, Inc., Madison, Wisconsin, USA, 1994.
9. Larson WE, Pierce FJ. Conservation and enhancement of soil quality. In: J. Dumanski, E. Pushparajah, M. Latham, and R. Myers, eds. Evaluation for Sustainable Land Management in the Developing World. Technical Papers. Proc. Int. Workshop., Chiang Rai, Thailand. 15-21 Sept. 1991. Int. Board for Soil Res. and Management, Bangkok, Thailand, 1991, 2.
10. Roger PA, Heong KL, Teng PS. Biodiversity and Sustainability of Wetland Rice Production: Role and Potential of Microorganisms and Invertebrates. In (Eds.) D.L. Hawks worth, The Biodiversity of microorganisms and Invertebrates: Its Role in Sustainable Agriculture, CAB international, 1991, 117-136.
11. Mohotti, Keerthi. Soil Biodiversity Measurements as Potential Determinants in Organic Certification: Supportive Evidence from Sri Lanka in 1st RDA/ARNOA International Conference Development of Basic Standard for Organic Rice Cultivation 12-15 November, RDA and Dankook Univ. Korea, 2002.