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Soil Quality Assessment for Cotton Growing Environs of Nilona Micro-Watershed in Yavatmal District, Maharashtra, India

Y.S. Pawar*, S. Chatterji, S. Chattraj, T.K. Sen, M.V. Venugopalan, S.K. Singh and S.R. Kadam

National Bureau of Soil Survey and Land Use Planning, Nagpur, Central Institute for Cotton Research, Nagpur, Dr. Panjabrao Deshmukh Krushi Vidyapith, Akola, India

**Corresponding author*

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A B S T R A C T

The study was conducted to assess soil quality in cotton growing environs of Nilona micro-watershed in Yavatmal district, Maharashtra, covering mainly cotton growing areas. One hundred eighteen surface soil samples were identified for determining physical and chemical indicators of soils. A minimum dataset was developed using expert knowledge for identifying soil quality indicators. Soil quality was determined using concept of relative soil quality index (RSQI). The RSQI was computed for each samples based on the four soil attributes, which are known to exact influence crop productivity in the region. The highest Relative Soil Quality Index (RSQI) was obtained for 86.3% area whereas the lowest was found for 33.8 % area with a mean value of 48.8% area. The results indicate that the conventional approach namely relative soil quality index (RSQI) was positively correlated with average yield values.

Introduction

The concern for agricultural sustainability and food security that started growing in the twentieth century has assumed serious proportions in the 21st century.

It has been due to, among other factors, the continually and rapidly limiting arable land resources as a result of their degradation, a major global issue, rapidly increasing world population especially in developing countries of tropics and subtropics, (mis) use of agricultural land for non-agricultural purposes, persisting hunger and malnutrition in several regions of the world.

Nothing new is being said when one appreciates that soil resources are precious in terms of their ability to address food security (quality and quantity), environmental quality and biodiversity and last but not the least human health and welfare.

Understandably, the concept of soil quality (SQ) and its significance have been recognised since ancient times. Soil quality has been defined as the capacity of soil to function within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality and promote plant, animal and human health (Carter *et al.*, 1997; Karlen *et al.*, 1998). In context of agriculture, SQ is a measure of soil's fitness to support crop growth without becoming degraded or otherwise harming the environment (Acton and Gregorich, 1995).

Soil quality assessment typically includes development of minimum dataset (MDS) of SQ indicators and their quantification (Saybold *et al.,* 1998) which reflects the capacity of any soil to function and is derived from educational studies or general quantitative observations of soil. A minimum dataset identifies locally relevant and mutually exclusive soil indicators and evaluates the link between selected indicators and significant soil and plant properties. This dataset should consist of a number of indicators describing the quality health of the soil. Conventionally, a MDS of SQ indicators is developed based on expert knowledge of local soil conditions and soil-crop response. A conventional method using the concept of relative soil quality index (RSQI) has been applied in the present study.

The major states growing cotton in 2016 in order of hectarage were Maharashtra (38.06 lakh ha) representing almost half of the total area growing cotton, or 40%, of all cotton area in India in 2012, followed by Gujarat (2.36 m ha or 20%), Andhra Pradesh (2.14 m ha or 16%), Northern Zone (1.56 m ha or 15%), Madhya Pradesh (608,000 ha or 8%), and the rest in Karnataka, Tamil Nadu and other states. The production and productivity of Maharashtra, during 2016-17 was 89.0 lakh bales and 398 kg/ha respectively (CCI, 2016). Vidarbha is an important cotton growing region in Maharashtra, where a continuous increase in area under cotton crop area under cotton is 13.60 lakh ha with a production of 24 lakh bales with productivity of 310 kg lint ha^{-1} (Anonymous, 2018).

The major district of interest in the present investigation is Yavatmal district is located in the south west part of Vidarbha region of Maharashtra state. It is one of the important districts of the Vidarbha region. Yavatmal is a major cotton growing area. The district has a geographical area of 13582 sq km (4.41% of the state) with population of 20,77,144 (2.63% of the state) and with 43 per cent of rural families living below poverty line. The land holding of 2-5 ha constitutes 40.12% of entire district followed by 28.26% of 5-10 ha holding. The total cultivated land is 8.84 lakh ha with double cropped area of 9475 ha and a cropping intensity of 101%. The cotton growers are facing severe economic crisis that is resulting in their committing suicide. Yavatmal district accounts for 32 per cent of suicides in Vidharbha region suggesting that Yavatmal seems to be epicenter of the recent spate of farmers' suicides (NBSS and LUP, 2015). This region is a hotspot for critical analysis of land use activity where economic dependence of farmers is solely on cotton and where, more than 50 per cent of the total net sown area has been under single crop over years. The poor agriculture productivity and low level of food grain outputs resulting from the low level introduction of agriculture crop technologies, poor rural infrastructure, and high vulnerability of crop production to natural disasters such as droughts and high rates of unemployment and poverty, are some of the reasons for the high degree of food insecurity in some parts of the district (Bhaskar *et al.*, 2014).

Materials and Methods

Study area

The Nilona micro-watershed is located between 20^o 15' 43" to 20^o 17' 39" N latitude and 77^o 38' 41" to 77^o 41' 10" E longitude, covering an area of 1297.35 ha in Darwha tehsil of Yavatmal district, Maharashtra. The elevation of the area ranges from 360 to 467 m above MSL. The study area falls under North Deccan (Maharashtra) Plateau and is agroclimatically placed under hot moist to semi-arid eco-sub-region. The climate of the area is subtropical, dry sub-humid with well-expressed summer (March-May), rainy season (June-October) and winter season (November-February). The mean maximum temperature varies from 33 ^{o}C to 46 ^{o}C in summer season; mean daily minimum temperature is 13 ^{o}C to 15 ^{o}C with a mean annual temperature of 29 ^{o}C. The average annual rainfall of the district is 930 mm some of the area is under cultivation and mostly under cotton, soybean, pigeon pea, gram and vegetables. The mean monthly climatic parameters like rainfall, maximum and minimum temperature of the study area.

Information was collected from farmers on crop yield data (Fig. 1) and the yield considered for correlating it with soil quality index was average of five year (2011-12, 2012-13, 2013-14, 2014-15, 2015-16 year) yield data were collected from farmers' fields. Horizon-wise soil samples were collected for determining physical and chemical properties surface samples (0-20 cm) were taken freshly. A minimum dataset (MDS) comprising physical parameters (saturated hydraulic conductivity and clay), chemical (exchangeable sodium percent and OC) parameters were developed for SQ assessment. Soil samples were analyzed for these physical and chemical properties following standard procedures.

Particle-size distribution (sand, silt and clay) was determined as per international pipette method (Jackson, 1979); saturated hydraulic conductivity (sHC) was determined by constant head methods as per Richards (1954); exchangeable sodium percentage (ESP) was determined by formula as the ratio of exchangeable Na with CEC by Jackson (1967) and OC content of the soil was determined by Walkley and Black method (Nelson and Sommers, 1982).

Soil quality assessment

Selection of attributes: Selection of the attributes for developing MDS comprising physical and chemical properties of soils that best represent soil functions is made using expert knowledge (Sys, 1985; NBSS and LUP, 1994; Chatterji, 2000; Chatterji *et al.,* 2002; Kadu *et al.*, 2003; Naidu *et al.*, 2006 and Venugopalan *et al.*, 2009, Pabale *et al.*, 2016).

For minimum datasets, 4 soils attributes comprising 2 physical (clay and sHC), 2 chemical (ESP and OC) properties of soils were selected.

Clay and hydraulic conductivity offer reflection on the suitability of cotton as it has deep root system and prefers a relatively heavy soil. ESP influences mainly water retention which affects physical and chemical properties of the soils. OC is an indicator of soil fertility. The organic fraction in soils is formed from the microbial decomposition of organic residues. In addition to this, it also improves soil structure, infiltration rate, water and nutrient storage capacity and reduces soil erosion (Smith and Elliot, 1990).

All these factors have, therefore, been used to reflect the various aspects of soil quality in relation to plant growth. The MDS of attributes developed through expert knowledge were used for assessing SQ by using a conventional method through development of Relative Soil Quality Index (RSQI).

The following five steps were followed to assess soil quality using this method.

Assignment of weightages: Weightages to each attribute was based on available knowledge about its relative role in influencing crop yield and also on the basis of soil conditions, cropping pattern and agroclimatic conditions of study area have also done by Davidson *et al.,* (1994). Weightages are given (Table 1) on 0 to 100 scale and sum of all the weights was normalized to 100 %. Depth is known to contribute more to influence cotton yield, it was, therefore, assigned the highest weight of 40, saturated hydraulic conductivity was next important property so it had a weight of 30, whereas clay, ESP and SMBC had a weight of 10 each. The sum of all the weights was normalized to 100 %.

Scoring of attributes: The status of the each attribute was categorized according to four classes namely Class – I (very good), Class – II (good), Class – III (poor) and Class – IV (very poor) with assigned score of 4, 3, 2 and 1 respectively (Table 1).

The range of each class is shown in table 2. Score varied from 1 to 4, so the theoretical range of SQI was 100 to 400 i.e. the minimum value of SQI was 100 and maximum value of SQI 400 (Wang and Gong, 1998).

Computation of SQI as per the method described by Karlen and Stott (1994) and Kundu *et al.,* (2012).

$$SQI = \sum Wi\ Mi$$

Where, Wi = weight of i^{th} indicator and Mi = marks of i^{th} indicator class

Relative soil quality index (RSQI) was determined using the following relationship for judging the SQI value of any site against maximum theoretical value.

Categorisation of the RSQI: Soils with RSQI values of less than 50% were identified as poor quality soil, those with RSQI values of 50-70% as medium quality soil and those with RSQI values of more than 70% % were categorized as good quality soil.

Correlation study: Correlation of the values of RSQI with average yield for validation.

Results and Discussion

Properties of MDS parameters

The SQI and RSQI values of soils were calculated (Table 2). The SQI was calculated separately by multiplying weight of the indicator and mark allotted to each class, which has been discussed in the methodology section.

Higher soil quality index of 345 was observed. The lowest SQI of 135 was observed with a mean value of soil quality index was 195. The highest Relative Soil Quality Index (RSQI) was obtained for 86.3 % whereas the lowest was found for 33.8 % with a mean value of 48.8 %.

The results indicate that the conventional approach namely relative soil quality index (RSQI) was positively correlated with average yield.

The linear regression lines were also drawn using RSQI values (x) with average yield (y) and their mathematical expressions were y = 0.0074 x + 0.2881 (R^2= 0.63**) i.e. significant at 5% level) for the soils (Fig. 2).

Based on relative soil quality index (RSQI) values, the surface soils were classified into three categories (Fig. 3). The soils with a RSQI value less than 50% were rated as poor in quality. The soils having RSQI values ranging from 50-70% were rated as medium in quality and the soils having RSQI values more than 70% were rated as good in quality. In the selected micro-watershed, out of 118 soil samples, 31 samples were medium in soil quality whereas 16 samples were good in soil quality and 71 samples were poor in soil quality.

Table.1 Soil quality indicators, their weights and classes

Soil quality indicator	weights	class I with score 4	class II with score 3	class III with score 2	class IV with score 1
sHC (cm hr^{-1})	45	>5.5	5.5-2.5	2.5-1.5	<1.5
Clay (%)	35	35-50	<35	50-60	>60
ESP (%)	10	>1.5	1.5-2.5	2.5-4.5	>4.5
OC (%)	10	>1	0.75-1	0.50-0.75	<0.50

Table.2 Grouping of soils into different categories based on Relative Soil Quality Index (RSQI)

Sample No.	RSQI	Quality rating	Sample No.	RSQI	Quality rating
0	47.5	Poor	**59**	36.3	Poor
1	45.0	Poor	**60**	43.8	Poor
2	41.3	Poor	**61**	41.3	Poor
3	43.8	Poor	**62**	55.0	Medium
4	38.8	Poor	**63**	86.3	Good
5	38.8	Poor	**64**	52.5	Medium
6	45.0	Poor	**65**	43.8	Poor
7	47.5	Poor	**66**	43.8	Poor
8	47.5	Poor	**67**	52.5	Medium
9	50.0	Medium	**68**	52.5	Medium
10	43.8	Poor	**69**	43.8	Poor
11	50.0	Medium	**70**	36.3	Poor
12	75.0	Good	**71**	38.8	Poor
13	50.0	Medium	**72**	36.3	Poor
14	41.3	Poor	**73**	36.3	Poor
15	43.8	Poor	**74**	86.3	Good
16	43.8	Poor	**75**	72.5	Good
17	43.8	Poor	**76**	50.0	Medium
18	52.5	Medium	**77**	52.5	Medium
19	41.3	Poor	**78**	36.3	Poor
20	55.0	Medium	**79**	61.3	Medium
21	43.8	Poor	**80**	47.5	Poor
22	50.0	Medium	**81**	36.3	Poor
23	38.8	Poor	**82**	43.8	Poor
24	43.8	Poor	**83**	36.3	Poor

25	41.3	Poor	**84**	36.3	Poor
26	41.3	Poor	**85**	58.8	Medium
27	36.3	Poor	**86**	33.8	Poor
28	46.3	Poor	**87**	38.8	Poor
29	38.8	Poor	**88**	36.3	Poor
30	38.8	Poor	**89**	50.0	Medium
31	47.5	Poor	**90**	50.0	Medium
32	41.3	Poor	**91**	38.8	Poor
33	43.8	Poor	**92**	52.5	Good
34	38.8	Poor	**93**	38.8	Poor
35	83.8	Good	**94**	66.3	Medium
36	47.5	Poor	**95**	58.8	Medium
37	50.0	Medium	**96**	72.5	Good
38	45.0	Poor	**97**	61.3	Medium
39	50.0	Medium	**98**	36.3	Poor
40	72.5	Good	**99**	33.8	Poor
41	67.5	Medium	**100**	77.5	Good
42	41.3	Poor	**101**	50.0	Medium
43	36.3	Poor	**102**	72.5	Good
44	36.3	Poor	**103**	52.5	Medium
45	46.3	Poor	**104**	36.3	Poor
46	45.0	Poor	**105**	38.8	Poor
47	33.8	Poor	**106**	47.5	Poor
48	36.3	Poor	**107**	36.3	Poor
49	70.0	Good	**108**	72.5	Good
50	33.8	Poor	**109**	50.0	Medium
51	50.0	Medium	**110**	72.5	Good
52	86.3	Good	**111**	52.5	Medium
53	33.8	Poor	**112**	55.0	Medium
54	36.3	Poor	**113**	47.5	Poor
55	38.8	Poor	**114**	75.0	Good
56	38.8	Poor	**115**	52.5	Medium
57	67.5	Medium	**116**	72.5	Good
58	43.8	Poor	**117**	52.5	Medium

Fig.1 Location map of Nilona micro-watershed, Darwha block, Yavatmal district

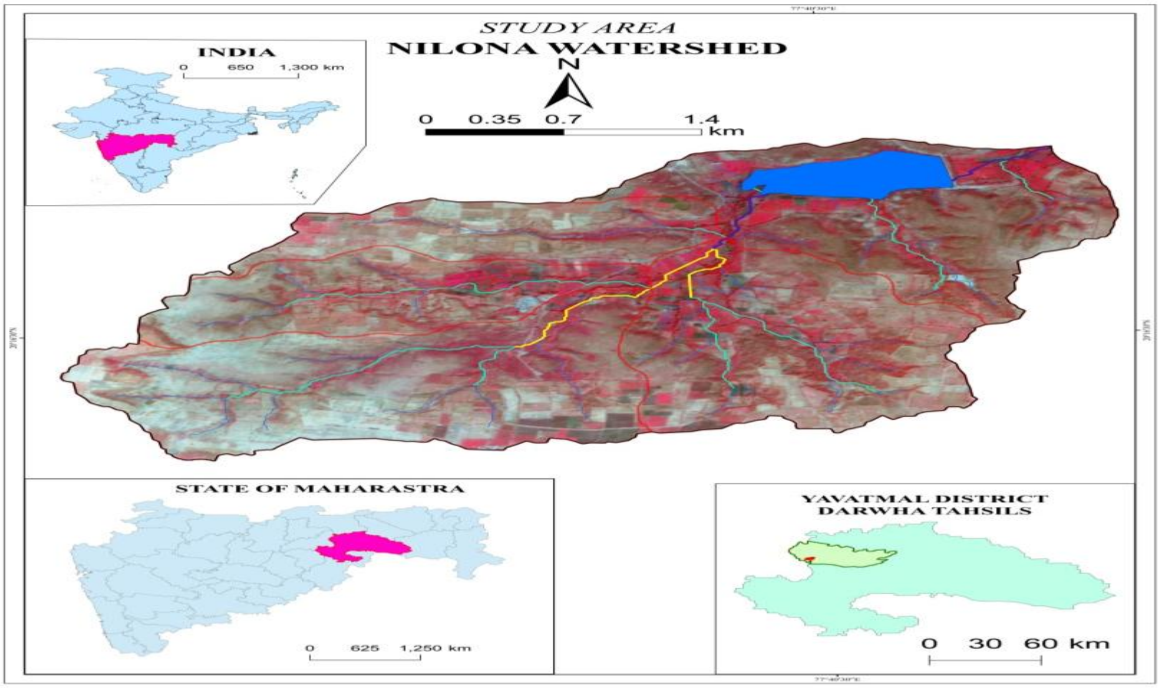


Fig.2 Relationship between SQI by RSQI method and SYI

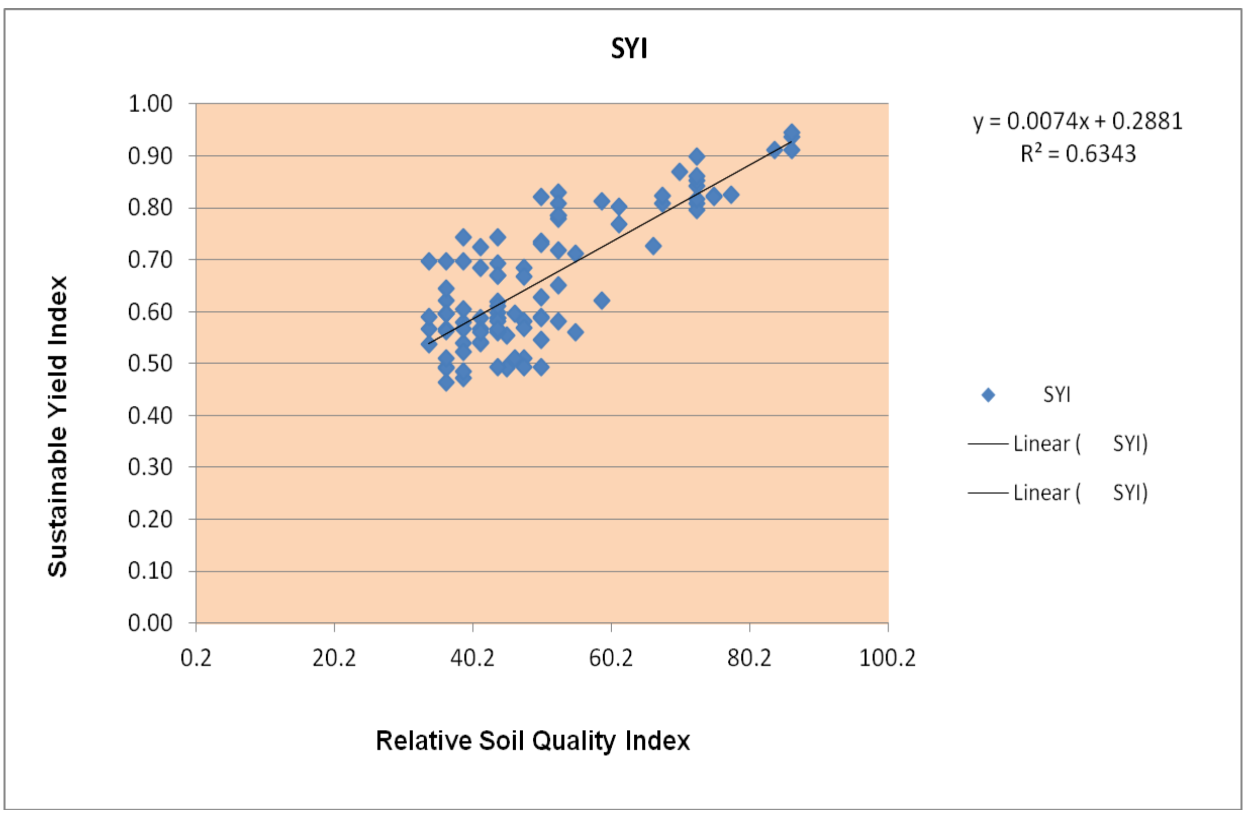
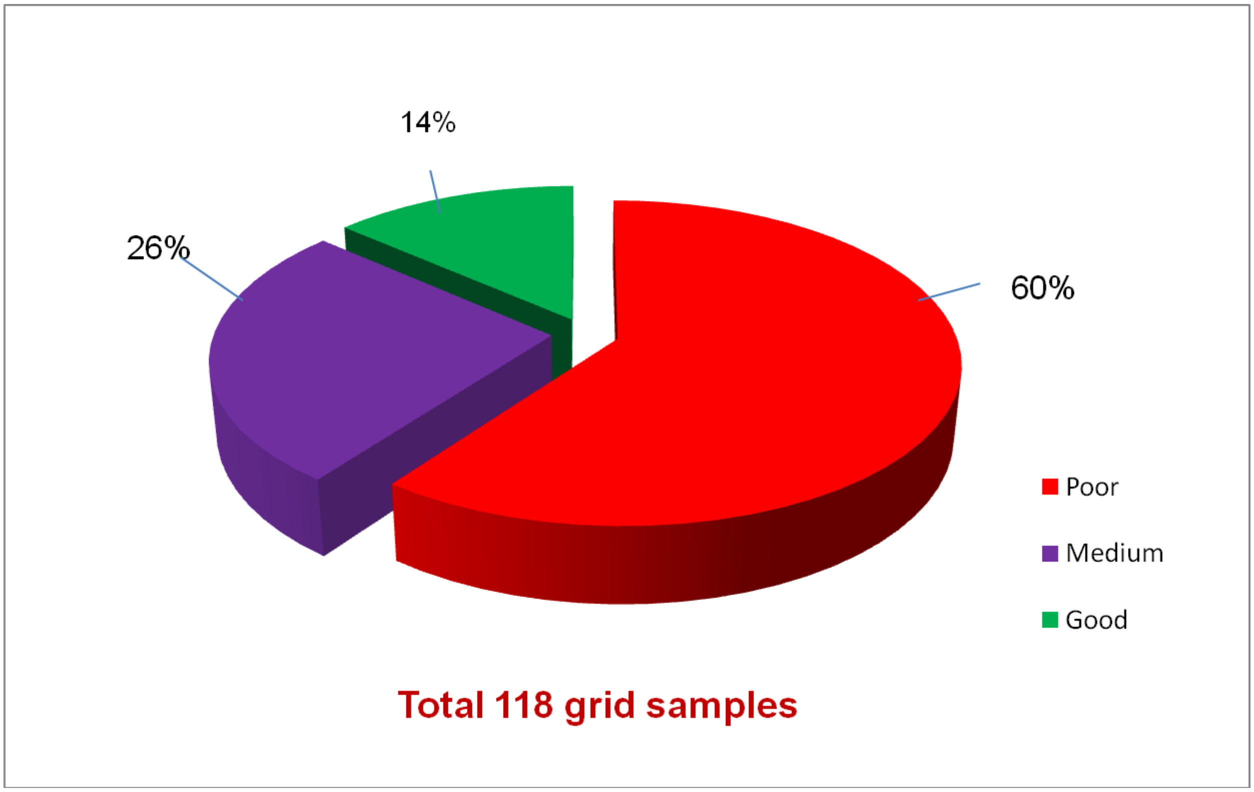


Fig.3 Relative Soil Qality Index (RSQI) category of Nilona micro-watershed



Relative soil quality index method was used by Kundu *et al.,* (2012) for assessing soil quality in soils of AESR 10.1 who calculated the relative soil quality index based on 15 soil attributes which were known to exert significant influence on the productivity of wheat and chickpea in winter season and soybean and rice in rainy season.

The soils with RSQI values less than 50 % were rated as poor quality soils, 50-70 % as medium and more than 70% as good soil quality soils.

They observed that about 4, 78 and 18 percent soil samples of Sehore district and 16, 78 and 66 percent soil samples of Vidisha district, Madhya Pradesh belonged to poor, medium and good quality categories respectively.

They concluded that the proposed methodology appears to be very simple and can be easily adopted by soil testing laboratories.

The successful application of this method provides us to suggest that whenever we have such datasets (as used in the present investigation), we could use this method for reliably assessing and monitoring soil quality for similar agroecological setups. Having mentioned this, more studies will, however, need to be conducted before this method could be recommended as a standard method of soil quality assessment.

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