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Assessment of soil quality and its relationship with crop yield in tribal areas of Madhya Pradesh

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ABSTRACT

Soil health management for sustaining crop productivity is a major challenge of recent years to meet the food demand and nutritional security of increasing population. For effective management of soil quality, assessment of soil health and periodic monitoring is foremost important step. In this connection, the soil quality status of the tribal areas of Madhya Pradesh was assessed and interrelated with crop productivity. The relative soil quality index (RSQI) was calculated by adopting expert opinion method. The results revealed the majority of the soils in the region had poor soil quality. The soil samples had poor soil quality based on RSQI were 66.3% in Jhabua and 84.8% in Alirajpur, respectively. Further crop yield of the study area was also found to be very low. The linear relationship between RSQI and relative yield was Y=1.613X-30.21 (R^2=0.464) in Jhabua and Y=1.358X-13.34 (R^2=0.489) in Alirajpur. The major soil quality indicators that constraint soil quality and crop productivity in the region were poor soil organic carbon, nutrients deficiency particularly N, S, P and Zn, and shallow soil depth and poor microbial activity (dehydrogenase activity, DHA). The developed soil quality assessment protocol is very simple and can be easily adoptable. Periodic monitoring and assessment of (at least once in five years) of soil quality status can be very useful for enhancing crop productivity and sustaining soil health of the region.

Keywords: Soil quality, crop productivity, tribal areas, relative soil quality index, soil management

INTRODUCTION

Soil quality deterioration is becoming major issues for declining crop productivity in the tribal areas of Madhya Pradesh. Nutrient present in the soils along with other physical properties, chemical process and biological activities governs the soil health and crop productivity. Further introduction of high yielding varieties and inadequate supply of fertilizer nutrients causes mining of nutrients from soil particularly potassium (Pathak *et al.*, 2010; AICRP-LTFE, 2013) and emergence of many numbers of nutrient deficiencies in soil specifically micronutrients (Zn, B, Fe, etc.) (Singh, 2006; Singh, 2009). Therefore periodic monitoring and management of soil health are inevitable to sustain the crop yield.To evaluate sustainability of agricultural practices, assessment of soil health using various indicators of soil quality is needed. Several farmer-participatory programs for managing soil quality and health have incorporated abiotic and simple biotic indicators (Doran and Zeiss, 2000). Furtherassessment tools for indexing soil quality at various scales are pursued to show the multiple functions (e.g. nutrient and water cycling, filtering and buffering of contaminants, decomposition of crop residues and other organic matter sources, and recycling of essential plant nutrients) that soils provide as the foundation for sustainable land management (Karlen *et al.*, 2003). However the challenge for the future is to develop sustainable management systems which are the vanguard of soil health; soil quality indicators are merely a means towards this end. Therefore development of simple and easily adoptable soil quality assessment protocol that can be widely adopted for this purpose is need of the hour.

In this connection, an attempt has been made to assess the soil quality status of the tribal areas of Madhya Pradesh. The available information showed that tribal predominant areas such as Alirajpur and Jhabua districts of Madhya Pradesh in India had very poor average crop yields that resulted into the low socio-economic status of the farmers in the region. This might be due to improper management and inadequate supply of nutrients, mono-cropping, soil erosion, low rainfall and poor water availability, low water holding capacity of soil, high BPL families and migration, etc. (Agricultural Statistics, 2012;

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NAAS, 2006). With this background, the current investigation was conceptualized to assess the soil quality status of these districts and to understand the linkages between soil quality and crop yield in the region for enhancing crop productivity and livelihood status through sustainable management of soil. Further this work focuses on major soil constraints that influence the crop yield for their meaningful management.

MATERIALS AND METHODS

The study area covers all the twelve administrative blocks in Jhabua (namely Jhabua, Meghnagar, Ranapur, Rama, Tandla and Petlawad) and Alirajpur (viz. Alirajpur, Jobat, Sondwa, Udaigarh, Kathiwada and Babhra) district. Alirajpur and Jhabua are tribal dominated (around 90% of the total population) and the most backward districts of Madhya Pradesh. Both the districts come under Central Plateau and Hills Agro-Climatic Region (Planning Commission) and Madhya Bharat plateau, western Malwa Plateau, eastern Gujarat plain Vindhya Satpura range and Narmada valley Agro-Ecological Region (ICAR), the terrain is hilly and undulating. Most of the rural population in the district are largely depends on agriculture for their livelihood. The total geographical area of Jhabua is 3600 km^2 and Alirajpur is3189 km^2. Average annual rainfall of the region is about 800 mm. Only 53.2% of total geographical area of Jhabua is under cultivation with 115% cropping intensity and area under irrigation is only 16.36% of cultivable area. In case of Alirajpur, 41% of total geographical area is under cultivation with 107% cropping intensity and area under irrigation is only 13.9% of cultivable area (Agriculture Statistics, 2012). The major crops grown in these districts are maize (both in *kharif* and*rabi*season), soybean, cotton and black gram in *kharif;* wheat and gram in *rabi*. Also green gram, groundnut, sorghum, pigeon pea, black gram, peas, paddy, etc. are some of the minor crops grown in this region. The soils are grouped under Entisols and more than 80% of the soils are shallow to medium deep soils (NBSS & LUP). The major issues/problems of the region are failure of rainfall and low water availability, soil erosion, undulating topography, low soil water retention capacity, fluoride contamination in ground water, highly drought-prone and degraded waste lands, severe land degradation, poor crop productivity, one crop per year and mono-cropping, low soil fertility, mostly landless labourers or marginal land holdings, agricultural indebtedness, more than 50% under BPL family/ poverty, migration, etc.

The geo-referenced composite surface (0-15 cm depth) soil samples (540 N) were collected from each Alirajpur and Jhabua district.

Table 1: Minimum data set of soil quality indicators and their classes with weight and score

Soil quality indicators	Weights	Class I	Class II	Class III	Class IV
Physical indicators					
Depth (m)	10	>2	2-1	1-0.5	<0.5
Texture	10	Loam	CL /SL	Clay/SC	Sand
Bulk Density (Mg m^{-3})	5	1.3-1.4	1.3-1.2/1.4-1.5	1.2-1.1/1.5-1.6	<1.1/>1.6
Biological indicators					
Organic carbon (%) DHA (µg	15	>1	1-0.75	0.75-0.5	<0.5
TPF g^{-1} 24 h^{-1})	10	>20	15-20	15-10	<10
Chemical indicators					
Soil pH	5	6.5-7.5	6.5- 6/7.5-8	6- 5.5/8-8.5	<5.5 />8.5
Avail. N (kg ha^{-1})	10	>560	560-420	420-280	<280
Avail. P (kg ha^{-1})	10	>25	15-25	15-10	<10
Avail. K (kg ha^{-1})	5	>280	280-200	200-120	<120
Avail. S (mg kg^{-1})	5	>25	25-15	15-10	<10
Avail. Zn (mg kg^{-1})	3	>2.0	2.0-1.0	1.0-0.5	<0.5
Avail. Fe (mg kg^{-1})	3	>10.0	10-5.5	5.5-2.5	<2.5
Avail. Mn (mg kg^{-1})	3	>10.0	10.0-4.0	4.0-2.0	<2.0
Avail. Cu (mg kg^{-1})	3	>2.0	2.0-0.5	0.5-0.2	<0.2
Avail. B (mg kg^{-1})	3	>1.5	1.5-0.7	0.7-0.3	<0.3
Score	100	4	3	2	1

Note: CL- Clay Loam; SL- Sandy Loam, SC-Sandy Clay

The samples were collected across the districts in a way that 15 representative villages were randomly selected in each block and about 6 samples were collected in each village. Soil samples were air dried and processed to pass through 2 mm sieve and analyzed. Soil depth was also measured by digging soil profile. The physico-chemical properties of collected soil samples were analyzed using standard procedures (Singh *et al.*, 2005). In order to make some comparative analysis of soils of these districts, the relative soil quality index was worked out using 15 important and known physical, biological and chemical indicators with uniform weight-age and scoring value (Table 1). Each of the indicators was divided into four classes namely, Class – I, Class – II, Class - III and Class - IV with an assigned score of 4, 3, 2 and 1, respectively.

The soil quality index (SQI) was calculated by the following equation as described by Wang and Gong (1998):

$$SQI = \Sigma (Wi \times Ii)$$

Where, Wi= the weight of the indicator and Ii = the marks/score of the indicators classes.

Thus, summing up of all the 15 indicators provided the SQI value for a particular soil of the farmer's field. As per Table 1, the maximum value of SQI is 400 (best quality) and minimum value is 100 (poor quality soil). In order to judge the SQI value of any site against the theoretical maximum value of SQI (i.e. 400), the concept of relative soil quality index (RSQI) was used and calculated as:

$$\text{Relative soil quality index (RSQI)} = (SQI_{sample} / SQI_{max}) \times 100$$

Where, SQI_{sample}= the SQI calculated and SQI_{max}= Maximum possible SQI value (in this case it is 400)

Based on RSQI value, soils were classified into different classes (Singh, 2007).

The yield data collected from each sampling point during survey and soil sampling activities used for relative yield calculations. As soil samples were collected from soybean, maize and wheat cultivated fields, the wheat equivalent yield was calculated for soybean and maize using following formulae.

$$\text{Wheat equivalent yield for soybean (kg ha}^{-1}) = \frac{\text{Yield of Soybean (kg ha}^{-1}) \text{ x Price of Soybean (Rs. kg}^{-1})}{\text{Price of Wheat (Rs. kg}^{-1})}$$

$$\text{Wheat equivalent yield for maize(kg ha}^{-1}) = \frac{\text{Yield of Maize (kg ha}^{-1}) \text{ x Price of Maize (Rs. kg}^{-1})}{\text{Price of Wheat (Rs. kg}^{-1})}$$

The following values were used for calculation:

Soybean: price Rs. 30 kg^{-1}; yield ranged from 7.5 – 18.5 q ha^{-1}
Wheat : price Rs. 18 kg^{-1}; yield ranged from 19.5 – 32.0 q ha^{-1}
Maize : price Rs. 15 kg^{-1}; yield ranged from 15.0 – 26.0 q ha^{-1}

From the wheat equivalent yields, relative yield was calculated from the following equation as below:

$$\text{Relative yield (\%)} = \frac{\text{Wheat equivalent yield of particular location(kg ha}^{-1})}{\text{Maximum yield (kg ha}^{-1})} \text{x10}$$

The obtained RSQI value of each location was correlated with relative crop yields of respective locations.

RESULTS AND DISCUSSION

The yield of soybean in the study area, from the data collected during field survey and soil sampling, ranged from 750-1850 kg ha^{-1}. Similarly, wheat and maize yield of the region ranged from 1950-3200 kg ha^{-1}and 1500-2600 kg ha^{-1}, respectively. The large variation in the crop yields might be the difference in management practices, variety, climatic and soil conditions, etc. The average yield of soybean, wheat and maize during the year 2010-11 in Jhabua district were 721 kg ha^{-1}, 1942 kg ha^{-1} and 1019 kg ha^{-1}, respectively. The corresponding values for Alirajpur district were 745 kg ha^{-1}, 1889 kg ha^{-1} and 900 kg ha^{-1} (Agricultural Statistics, 2012). The improper management, inadequate application of fertilizer, water scarcity and prolonged dry spell of rainfall during crop growth period and erratic weather condition might have resulted in low crop productivity in the region.

The RSQI estimated for the study area by following expert opinion method was presented in Table 2. The soil quality of the study area was largely under poor quality category followed by moderately poor and medium category. The soil samples under poor soil quality status were 66.3% in Jhabua and 84.8% in Alirajpur. In Jhabua, only poor to medium quality soils were found and no good and very good quality soils were found. Further none of the soils in these districts had very good quality soils. The major indicators that constraints soil quality in the region were found to be poor soil organic carbon, nutrients deficiency particularly N, S, P and Zn, and shallow soil depth and poor microbial activity (DHA). Soil organic carbon is considered as primary and significant parameter of soil quality and therefore maintenance of organic matter in the soil could sustain crop productivity and soil health (Manna *et al.*, 2007; Manna *et al.*, 2005). Further poor management practices like inadequate and imbalance fertilizer application resulted in deterioration of soil health and crop productivity (LTFE-AICRP, 2013). The average total fertilizer application in the study area was only 25-30 kg per ha (Agricultural Statistics, 2012). Moreover the majority of the soils in the region is poorly developed shallow to medium deep soils (more than 80%) and is conducive to erosion due to undulated rolling topography and poor forest cover. Moreover poor water holding capacity of the soil, mono-cropping, over grazing and weather anomaly led to loss of large quantity of soils in the region.

Table 2: Classes/category of soil quality based on RSQI and soil quality status of study area

RSQI (%)	Classes	Category	Jhabua (% of samples)	Alirajpur (% of samples)
90-100	I	Very Good	-	-
80-90	II	Good	-	0.37
70-80	III	Medium	4.07	4.63
60-70	IV	Moderately Poor	29.44	10.19
<60	V	Poor	66.29	84.81

The linear relationship was established between RSQI and relative yield in respective districts (Figure 1). In Jhabua, the relationship between RSQI and RY were y=1.613x-30.21 with R^2=0.464 under expert opinion method. Similarly in Alirajpur the relationship was y=1.358x-13.34 (R^2=0.489). This relationship showed that the selected parameters and index developed (RSQI) were very good indicators of soil quality indeed that governs the crop productivity of the region or production system (Singh, 2007).

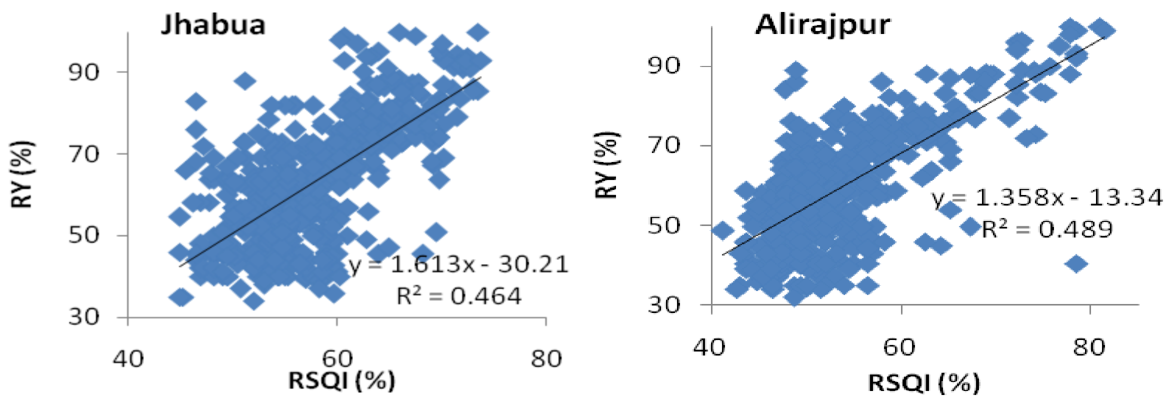

Fig. 1.Interrelationship between RSQI and relative yield

Summing up, the study area is tribal predominant and socio-economically backward region of the Madhya Pradesh State. The soil quality status of the region is found to be very poor and the crop productivity is also very low. The developed protocol for soil quality assessment for the region is very simple, systematic and easily adoptable. The major indicators that constraints soil quality in the region found to be poor soil organic carbon, nutrients deficiency particularly N, S, P and Zn (Rajendiran *et al.*, 2018), and shallow soil depth and poor microbial activity (DHA). Further periodic monitoring and assessment of soil quality status can be very useful for enhancing crop productivity and sustaining soil health of the region.

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