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SOIL QUALITY OF VARIOUS CROPPING SYSTEMS IN RAHAT MICROWATERSHED OF VIDARBHA

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ABSTRACT

Soils of the Rahat watershed in Nagpur district were studied for Physical, chemical and biological parameters and minimum data set was selected to assess the soil quality for making better soil specific management decisions. The soil properties of the Vertisols, Inceptisols and Entisols under various cropping system had shown multivariations. The AWC ranged between 12.34 to 25.72 per cent and bulk density ranged from 1.2 to 1.6 Mg m^{-3}. The saturated hydraulic conductivity of soils was ranged from 1.45 to 3.65 cm hr^{-1} indicating moderately to well drain. The mean weight diameter indicating soil aggregation ranged between 0.54 to 0.76 mm. The soils were slight to moderately alkaline in reaction (pH 7.2 to 8.2) and under safe limit of electrical conductivity and calcium carbonate content (0.10 to 0.23 dSm^{-1} and 2.5 to 7.8%). The soils were low to medium in organic carbon, available nitrogen and phosphorus whereas medium to very high in available potassium. DTPA extracted Fe, Mn and Cu were well above the critical limits however, Zn content in some soils was at the point of critical levels.

Based on significance of multiple regression and expert opinion the seven parameters were selected as minimum data set for principal component analysis. The contribution of these parameters were dehydrogenase activity- 22.84%, bulk density-16.36%, organic carbon-15%, available P- 13.18%, available K-12.30%, Zn- 11.7% and AWC-7.34%. The soil quality index (SQI) of Vertisols for different cropping system ranged between 0.71 to 0.81, Inceptisols 0.61 to 0.77 and Entisols 0.61 to 0.65 respectively. Cotton-pigeonpea intercropping system recorded higher soil quality index in both the soils i.e Vertisols and Inceptisols and attributed to higher rating in dehydrogenage activity and bulk density of soils. The low soil quality index in Entisols was due to less rating of these soils in SOC content. Low soil quality index indicates poor soil health and requires interventions of management practices for increasing production.

(**Key words***:* AWC, MWD, MDS, PCA, DHA, SMBC, SMBN, soil quality index)

INTRODUCTION

Soil quality assessment is necessary for making management interventions in the watershed. The principal soil properties most affected by soil degradation process are the key attributes for soil quality. Soil quality is defined as the capacity of soil to function within the ecosystem boundaries to sustain biological productivity, maintaining environmental quality and promote plant and animal health (Doran and Parkin, 1996). Quantitatively soil quality can assess by developing an integrated or relative soil quality index. A valid SQI would help to interpret data from soil measurements and show the land use and present managements are having the desired results for productivity, environmental protection and health. Soil quality assessment provides a basic means to evaluate the sustainability of quality that is basically defined by stable, natural and inherent features related to soil forming factors and dynamic changes induced by soil management (Larson and Pierce, 1994). Soil organic matter and nutrient levels, drainage, moisture availability, are the prime indicators of soil quality which readily decline when soils are taken under cultivation. Soils respond differently to management interventions depending upon the inherent properties of the soil and surrounding landscape. Soil is a key natural resource and soil quality is the integrated effect of management on most soil properties that determine crop productivity and sustainability.

Good soil quality not only produces good crop yield, but also maintains environmental quality and consequently plant, animal and human health. The 80.90 per cent area of the Rahat watershed is under cultivation. Single crop occurs on very gentle slope and occupies an area of 168.02 ha. Double crop mainly occurs on very gently sloping alluvial plain and occupies an area of 125.77 ha. The various cropping system occurring on three soils were

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chosen for the present study to understand the soil quality.

MATERIALS A ND METHODS

The study area falls in the toposheet of 55K/12 and lies between 78^o 33' to 78^o 36' E and 21^o 4' to 21^o 6' N covering an area of 363.02 ha. The soils of the watershed are developed form basaltic alluvium and clayey in texture. The climate of the area is subtropical semi-arid with summer (March to May) rainy season (June to October) and winter (November to February). The mean annual temperature is 26.9^{o}C and mean annual precipitation is about 1050 mm of which 90 per cent rain is received during monsoon. Total 40 surface samples (0-20 cm depth) were collected from three soils, *viz.*, Vertisols, Inceptisols and Entisols under various cropping systems of Rahat watershed. These cropping systems were consecutively adopted by the farmers. Samples of 4 to 5 field mixed and combine together for making a representative sample for laboratory analysis. Bulk density of soils was determined by core method (Blake and Hartge, 1986). Saturated hydraulic conductivity of the soils was determined by using constant head method (Richard's, 1954). Available water capacity was determined by using pressure plate technique (Richard's, 1954). Aggregate stability was determined by using Yodder's apparatus (Kemper and Rosenau, 1986) and mean weight diameter was calculated as an index of aggregation (Van Bavel, 1949). The soil reaction (pH) and electrical conductivity (EC) were determined in 1:2.5 (soil:water) suspension (Jackson, 1973). Organic carbon content was determined by wet oxidation method (Walkey and Black, 1934). Available Nitrogen (Subbiah and Asija, 1956) available P (Olsen *et al*., 1954), available potassium (Jackson, 1973), The DTPA extract soil micronutrients (Zn, Fe, Mn, and Cu) were determined by Lindsay and Norvell method (1978). The dehydrogenase activity was determined by method as suggested by Casida *et al*. (1964). Microbial biomass carbon and nitrogen was determined by fumigation – extraction method (Vance *et al*., 1987). Assessment of soil quality was done by statistically analysis of data (regression equations, scoring functions, PCA) by using SPSS window version 17.00 programme.

RESULTS AND DISCUSSION

Variation in physical parameters of soils

These soils were derived from basaltic alluvium and clayey textured. Clay per cent varied between 40 to 61 per cent. The bulk density of soils in Vertisols was slightly lower (1.24-1.50 Mg m^{-3}) than the Entisols (1.36-1.63 Mg m^{-1}) and Inceptisols region (1.32-1.52 Mg m^{-3}) (Table 1) which might be due to variation in clay content resulting in greater compaction of swelling clay soils (Ahuja *et al*., 1988). The AWC showed that in soils of Vertisols ranged between 16.53 to 18.86 per cent whereas in Entisols region varied between 12.34 to 18.47 per cent and in Inceptisols it ranged between 13.50 to 18.98 per cent (Table 1). The low AWC in Entisols region might be due to shallow depth of the soils occurring on moderate slope condition, whereas, the higher AWC on the Vertisols might be due to higher moisture retention by the clayey soils. Drainage has importance in arable cropping the hydraulic conductivity of Entisols observed lower (1.67-1.89 cm hr^{-1}) than the soils of Inceptisols (1.71-2.54 cm hr^{-1}) and Vertisols (2.56-3.61 cm hr^{-1}) (Table 1). The reduction in hydraulic conductivity indicates impairment in physical condition (Balpande *et al*., 1996; Pal *et al*., 2000; Meena *et al*.,2011). Aggregate stability decreases with increasing pH. Higher clay content results in greater aggregate stability (Kemper *et al*., 1987), indicating that clay provides more contact points between the larger soil particles and helps to bind the soil particles together resulting into the better structure. The mean weight diameter (MWD) is considered as an index of aggregation of soil (Dongare, 2010). The MWD of soils on Vertisols, Inceptisols and Entisols varied between 0.54 to 0.73, 0.65-0.74 and 0.54-0.74 mm respectively (Table 1).

Variation in chemical parameters of soils

The soils of the study areas were slight to moderately alkaline in reaction. pH of soils in Vertisols ranged from 7.62 to 8.20, in Inseptisols varied from 7.30-8.14 and in Entisols varied from 7.32-8.20 (Table 2). The total soluble salt content was very low as indicated by electrical conductivity values. The organic carbon content of soils in Vertisols varied from 4.6-7.1 g kg^{-1}, in Inceptisols it varied from 7.0-7.6 g kg^{-1} and in Entisols region varied from 5.1-6.9 g kg^{-1} (Table 2). The result showed the lowest value of organic carbon in cotton sole cropping and highest in soybean – wheat cropping systems in Vertisols, low in cotton-pigeonpea and highest in cotton sole cropping in Inceptisols. Similarly in Entisols organic carbon was low in pigeonpea sole and highest in soybean wheat cropping system. From the result in all soils soybean-wheat cropping pattern contributed more organic carbon followed by soybean-gram cropping system in soil. This indicates that double cropping system added more organic carbon in soil than mono cropping systems. Similar findings were reported by Bhattacharyya *et al*. (2015). The free lime content ranged between 3.8-7.4, 2.5-7.8 and 4.1-7.8 per cent in soils of Vertisols, Inceptisols and in Entisols region respectively, (Table 2). The available N varied from 201.6-307.5 kg ha^{-1} in Vertisols, 257.4-347.8 kg ha^{-1} in Inceptisols region and 147.5-297.1 kg ha^{-1} in Entisols region in watershed area. The available P varied from 14.34-24.09 kg ha^{-1} in Vertisols, 21.76-27.10 kg ha^{-1} in Inceptisols region and 17.32-24.85 kg ha^{-1} in Entisols region (Table 2) whereas, available K status varied from 356.7-459.8 kg ha^{-1} in Vertisols, 244.4-468.9 kg ha^{-1} in Inceptisols and in Entisols region it varied from 120.9-300.6 kg ha^{-1}. The NPK status in soils showed wide variation due to farmer's level of management and adoption of different cropping systems.

The DTPA extractable micronutrient status of soils (Table 3) indicated that the Fe content ranged between 3.5-11.2, 5.617.2 and 6.6-15.3 mg kg^{-1} in Vertisols, Inceptisols and Entisols respectively, and found to be higher than the critical limit of 4.5 mg kg^{-1}. The Cu content varied from 6.3-7.2, 2.5-13.8 and 4.8-9.3 mg kg^{-1} in Vertisols, Inceptisols and Entisols respectively, in study area and found much higher than its critical level of 0.2 mg kg^{-1}. The Zn content ranged between 0.94-1.10, 0.40-1.30 and 0.53-0.79 mg kg^{-1} in Vertisols, Inceptisols and Entisols respectively, whereas some soils showed Zn deficiency as the level below the critical limit of 0.6 mg kg^{-1}. The Mn content was sufficient in all the soils vary from 9.3-16.8, 11.1-19.8 and 13.1-16.6 mg kg^{-1} in Vertisols, Inceptisols and Entisols respectively, in Rahat watershed. The critical limits of the micronutrients were suggested by Lindsey and Norvell (1978) as deficit Cu <0.2, Fe <4.5 and Mn <2.5 mg kg^{-1}.

Variation in biological parameters of soils

Dehydrogenase activity (DHA) is an index of the microbial activity of the soil. It reflects the physiological efficiency of the soil micro-organism. More DHA activity produced higher nutrient available to the crops. It ranged between 41.1-49.9 ug TPF g^{-1} 24^{-1hr} in Vertisols, 32.5-48.1 ug TPF g^{-1} 24^{-1hr} in Inceptisols and in Entisols it varied from 42.8-44.5 ug TPF g^{-1} 24^{-1hr} (Table 3). The highest DHA observed in soybean-wheat cropping system of Vertisols, whereas the lowest DHA recorded under cotton- sole cropping in Inceptisols soil. The DHA activity found higher in cultivated double cropping systems than single cropping and waste lands (Lakdan *et al*., 2015). The soil microbial biomass carbon ranged from 226.5-248.1 ug g^{-1} in Vertisols, 138.3-247.3 to 226.5-248.1 ug g^{-1} in Ineptisols region and in Entisols region it varied from 204.9-237.6 to 226.5-248.1 ug g^{-1} of the soil (Table 3). The soil microbial biomass nitrogen was ranged from 14.8-18.2 to 226.5-248.1 ug g^{-1} in Vertisols, 8.4-17.7 to 226.5-248.1 ug g^{-1} in Inceptisols region and 15.8-16.8 to 226.5-248.1 ug g^{-1} in Entisols region. The highest SMBC was observed in soils of soybean – wheat cropping at Vertisols, whereas lowest was observed in cotton sole cropping in Inceptisols. Similar results were recorded of the soil microbial biomass nitrogen (SMBN). These biological indicators are very effective indicators of soil quality for assessing long term soil and crop management effects (Karlen *et al*., 1997).

Soil quality

The multivariate data sets due to their multidimensionality are difficult to interpret, in such circumstance; the use of principle component analysis is very useful. Principal component analysis (PCA) was performed to reduce multidimensionality of data followed by scoring by homothetic transformation of the selected indicators. The entire data set was subjected to PCA to identify the critical soil parameters under different land uses that can be considered as soil indicators. Among eighteen soil parameters seven parameters were selected as Minimum data set (MDS) based on significance of multiple regression and expert opinion which had more correlation with each other and had more impact on soil quality (Andrews *et al*., 2004). These seven parameters were retaining on different PCs.

The choice among well correlated variables could also be based on the practicability of the variables. Hence, one could use the option to retain or drop the variables from the final MDS considering the ease of sampling, cost of estimation and logic and sampling, cost of estimation and logic and interpretability. Considering these, options were utilized to retain or eliminate the variables from the MDS (Dala and Melony, 2000).

The contribution of these parameters in soil quality were dehydrogenase activity- 22.84%, bulk density-16.36%, organic carbon-15%, available P- 13.18%, available K-12.30%, Zn- 11.7% and AWC-7.34%. The soil quality index (SQI) of the crop land under Vertisols ranged between 0.72 to 0.83, Inceptisols 0.64 to 0.77 and Entisols 0.61 to 0.69 respectively (Fig. 1). In cropping systems of the Vertisols the highest SQI (0.83) was assess in soybean-gram and lowest (0.71) was observed in cotton sole. In Inceptisols the SQI was highest in cotton-pigeonpea and lowest in soybean-wheat. In Entisols region the SQI was highest in soybean- fallow and lowest in sorghum- fallow.

Cotton-pigeonpea intercropping system recorded higher soil quality index in both the soils i.e Vertisols and Inceptisols and attributed to higher rating in dehydrogenage activity and bulk density of soils. Soil profile when correlated with yield it was observed that vertisol were best for cotton growing (Agarkar *et al*., 2012).The low soil quality index in Entisols was due to less rating of these soils in SOC content. Low soil quality index indicates poor soil health and requires interventions of management practices for increasing production.

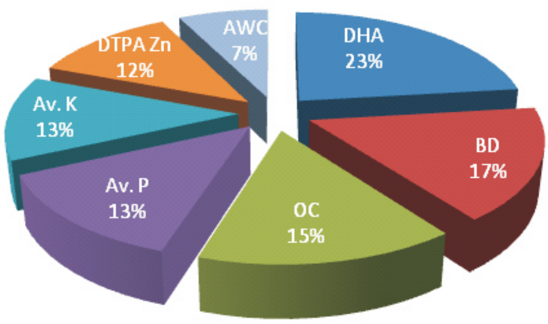

Fig. 1. Per cent contribution of various soil parameters in soil quality index

Table 1. Physical properties of soil in Rahat micro-watershed

Cropping systems	Bulk density (Mg m^{-3})	Avail. Water Capacity (%)	Satu. Hydraulic Conductivity (cm hr^{-1})	Mean Wet Diameter (mm)
Typic Haplusterts				
Soybean- Gram	1.24	16.53	1.89	0.64
Cotton sole	1.43	17.73	1.67	0.56
Cotton- Pigeonpea	1.32	18.86	1.70	0.54
Soybean-Wheat	1.50	17.63	1.79	0.73
Vertic Ustocrepts				
Soybean- Gram	1.43	13.60	2.54	0.67
Cotton sole	1.34	18.38	2.27	0.69
Cotton - Pigeon pea	1.40	17.47	2.34	0.65
Soybean- Wheat	1.52	13.50	1.71	0.74
Pigeonpea sole	1.32	18.98	1.73	0.72
Vertic Ustorthents				
Soybean- Gram	1.63	17.36	2.56	0.74
Pigeonpea - sole	1.36	12.34	3.09	0.58
Soybean-Wheat	1.62	18.47	3.61	0.72
Sorghum-Fallow	1.52	17.72	2.86	0.54

Table 2. Chemical properties of soils in Rahat micro-watershed

Cropping pattern	pH	EC	O.C.	$CaCO_3$	Available Nutrient (kg ha^{-1})		
	(1 :2.5)	(d Sm^{-1})	(g kg^{-1})	(%)	N	P	K
Typic Haplusterts							
Soybean- Gram	8.2	0.13	6.6	7.2	235.1	14.34	379.2
Cotton sole	7.6	0.10	4.6	3.8	201.6	16.13	356.7
Cotton-Tur	7.9	0.12	6.8	4.2	282.0	23.30	459.8
Soybean-Wheat	8.2	0.16	7.1	7.4	307.5	24.09	424.1
Vertic Ustocrepts							
Soybean- Gram	7.2	0.13	7.4	5.4	347.8	24.19	390.4
Cotton sole	7.3	0.10	7.6	2.5	264.5	25.57	246.8
Cotton - Pigeonpea	7.6	0.11	7.0	2.6	267.4	21.76	468.9
Soybean- Wheat	7.4	0.23	7.2	6.2	257.4	24.40	244.4
Pigeonpea sole	8.1	0.17	7.2	7.8	268.9	27.10	244.4
Vertic Ustorthents							
Soybean- Gram	8.1	0.10	5.8	5.2	232.0	24.85	300.6
Pigeonpea sole	7.5	0.10	5.1	4.6	247.1	22.57	120.9
Soybean-Wheat	8.2	0.17	6.9	7.8	297.1	17.32	175.1
Sorghum-Fallow	7.3	0.10	4.6	4.1	147.5	14.34	114.9

Table 3. Available micronutient status and biological properties of soil of Rahat Micro-watershed

Cropping pattern	DHA	SMBC	SMBN	Micronutrient ,mg kg^{-1}			
	ugTPF g^{-1}	ug g^{-1}	ug g^{-1}	Fe	Mn	Cu	Zn
Typic Haplusterts							
Soybean- Gram	44.4	231.5	15.5	11.2	12.6	6.9	0.96
Cotton sole	41.1	226.5	14.8	3.5	9.3	6.3	1.10
Cotton- Pigeonpea	43.9	232.3	16.3	4.8	10.0	7.2	0.93
Soybean-Wheat	49.9	248.1	18.2	8.5	16.8	7.1	0.94
Vertic Ustocrepts							
Soybean- Gram	39.0	154.0	9.2	5.6	11.1	2.5	0.40
Cotton sole	28.4	138.3	8.4	7.2	15.1	7.9	0.82
Cotton - Pigeonpea	32.5	158.3	10.2	13.1	16.2	8.3	1.30
Soybean- Wheat	40.3	246.8	14.9	17.2	15.4	8.6	1.00
Pigeonpea sole	48.1	247.3	17.7	16.9	19.8	13.8	0.74
Vertic Ustorthents							
Soybean- Gram	42.8	204.9	16.8	15.3	12.4	7.4	0.76
Pigeonpea sole	44.5	207.9	16.6	8.9	14.3	4.8	0.63
Soybean-Wheat	42.9	205.6	15.8	14.3	16.6	9.3	0.79
Sorghum-Fallow	43.6	237.6	15.8	6.6	13.1	6.5	0.53

Table 4. Soil quality index of cropland in Rahat Micro-watershed

Cropping pattern	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	Total
	DH	BD	OC	P	K	Zn	AWC	SQI
Typic Haplusterts								
Soybean- Gram	0.16	0.11	0.14	0.10	0.06	0.10	0.05	0.72
Cotton sole	0.16	0.11	0.10	0.10	0.12	0.07	0.05	0.71
Cotton-Pigeonpea	o.19	0.14	0.12	0.11	0.11	0.09	0.05	0.81
Soybean-Wheat	0.17	0.12	0.11	0.12	0.07	0.09	0.05	0.73
Vertic Ustocrepts								
Soybean- Gram	0.18	0.13	0.14	0.12	0.07	0.04	0.05	0.72
Cotton sole	0.19	0.14	0.12	0.12	0.04	0.08	0.05	0.75
Cotton - Pigeonpea	0.18	0.13	0.11	0.11	0.08	0.12	0.05	0.77
Soybean- Wheat	0.17	o.12	0.15	0.13	0.03	0.10	0.05	0.74
Pigeonpea sole	o.18	0.13	0.08	0.11	0.02	0.06	0.04	0.61
Vertic Ustorthents								
Soybean- Gram	0.16	0.11	0.09	0.12	0.05	0.07	0.05	0.65
Pigeonpea sole	o.18	0.13	0.08	0.11	0.02	0.06	0.04	0.61
Soybean-Wheat	0.14	0.11	0.14	0.08	0.03	0.07	0.05	0.63
Sorghum-Fallow	0.17	0.12	0.07	0.07	0.02	0.05	0.05	0.55

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