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Effect of Integrated Soil Management Practices (ISMP) on Soil Properties and Soil Quality Indices in Hot Moist Semi-Arid Red Alfisol Soils of Bangalore Region

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ABSTRACT : Alfisol soils encounter diversity of constraints on account of physical, chemical, and biological soil properties because of climatic and management factors leading to low productivity. This paper summarizes the effect of integrated soil management practices (ISMP) on soil properties and yield of finger millet cropping system in hot moist Alfisol soils. The experiment site is located in Deccan (Karnataka) plateau of Central Eastern Ghats, Bengaluru which was initiated in 1998 in deep sandy Alfisols. Changes in soil properties were assessed after thirteen years using 19 soil physical, chemical and biological parameters. The treatments include 3 main treatments *viz.*, Conventional Tillage (M1), Reduced Tillage (M2), Minimum tillage (M3) and 3 sub-plot treatments *viz.*, 100% N through organic source (F1), 50% N through organic source + 50% N through inorganic source (F2) and 100% N through inorganic source (F3) laid out in a split plot design. The results revealed that ISMP's had a significant effect on soil chemical and biological properties *viz.*, OC , N, P, K, MBC and LC. Among the set of nine ISMP's, the combination of MT + 100% organic N, MT + 100% inorganic N and MT + 50% organic N + 50% inorganic N were found most promising in improving the majority of soil properties. Among integrated soil management practices (ISMP), the combinations of minimum tillage + 100% organic N resulted in significantly higher SQI of 1.54. The average percent contribution of key indicators towards soil quality indices was: pH (8%), available N (12%), available P (33%), available K (7%), available Ca (28%), labile carbon (12%). A significant correlation between yield of finger millet crop and soil quality confirmed the importance of soil quality indicators and indices for achieving sustainable yields in these Alfisol soils.

Key words: Alfisols, finger millet, integrated soil management, soil properties, soil quality indices

Introduction

Geographically, Alfisol soils are extensively spread in Southern Asia, Western and Central Africa, and many parts of the South America, particularly northeastern Brazil. Predominantly, these soils are shallow, with a compacted subsurface layer which restricts root development and water infiltration. The loamy sand texture of the topsoil and predominance of kaolinite among the clay minerals make them structurally inert. Structurally being unstable, these soils are susceptible to crusting and hard setting whenever there is dry spell. As these soils are mostly found in tropical environment, these are low in organic carbon content (5.0 g/kg) and consequently poor in fertility. The reasons behind low organic carbon could be to (i) loss of topsoil and associated fractions of organic matter and nutrients due to water erosion; (ii) no return of the crop residues back to the soil because of competing demand to animal fodder and domestic fuel; and (iii) fast oxidation of organic matter entrapped in soil micro aggregates owing to higher temperature in summers and frequent inversion tillage. Consequently, because of climatic and management factors, these Alfisol soils encounter diversity of constraints on account of physical, chemical, and biological properties (Lal, 1998), (Sharma *et al.*, 2005) and lead to low productivity. Research reports of International Crop Research Institute for Semi Arid Tropics (ICRISAT), revealed that Alfisols of semi-arid tropical regions of the world have been degraded in terms of soil properties primarily due to loss of topsoil by wind and water erosion, depletion of organic carbon, and it has been emphasized that tillage is a major factor determining the loss of soil organic matter. In order to maintain a high level of soil organic matter to enhance soil tilth, fertility, and productivity, there has been increasing awareness among researchers to identify suitable soil management practices depending upon climatic and edaphic conditions. These management practices may ensure the protection of soil from erosion, reduction in the loss of nutrients through runoff, improvement in soil fertility, sustainability in production, and maintenance of overall soil quality in the tropics. In most of the long-term experiments initiated world-wide to identify suitable soil-management treatments, the main research focus until the end of the 20th century was to assess the increase in yields and individual changes in predominant soil parameters. It is now well established fact that soil quality cannot be measured directly, but must be inferred from measuring changes in its attributes or attributes of the ecosystem, referred to as indicators. These indicators may help in directly monitoring the soil, or monitor the outcomes that are affected by the soil, such as increases in biomass, improved water use efficiency, and aeration. According to (Dalal and Moloney, 2000) the indicators which directly monitor soil quality can be categorized as visual, chemical, physical, and biological indicators. (Nortcliff, 2002) stated that there are potentially many soil properties which might serve as indicators of soil quality, and research is required to identify the most suitable one. He also emphasized that the methods used in determining these indicators must be fully defined, otherwise the comparison of different sets of data may be of little value. While giving a comprehensive check list of soil quality indicators, (Parr *et al.,* 1992) suggested that increased infiltration, aeration, macropores, aggregate distribution and their stability, and soil organic matter, and decreased bulk density, soil resistance, erosion, and nutrient runoff are some of the important indicators for improved soil quality. Further, (Chaudhury *et al.,* 2005) identified total soil N, available P, dehydrogenase activity and mean weight diameter (MWD) of aggregates as the key indicators for Alluvial soils. (Karlen *et al.,* 1992) suggested biological measurements, viz. microbial biomass, respiration, and ergosterol concentrations, as very effective indicators for assessing long-term soil and crop management effects on soil quality. Assessment of soil-test properties from time to time has also been emphasized for evaluating the chemical aspects of soil quality. The indicators used are selected by different researchers in different regions may not be the same because soil quality assessment is purpose- and site-specific. However, when selecting indicators, it is important to ensure that they: (i) correlate well with natural processes in the ecosystem (this also increases their utility in process-oriented modelling); (ii) integrate soil physical, chemical, and biological properties and processes, and serve as basic inputs needed for estimation of soil properties or functions which are more difficult to measure directly; (iii) be relatively easy to use under field conditions, so that both specialists and producers can use them to assess soil quality; (iv) be sensitive to variations in management and climate; and (v) be components of existing soil databases wherever possible (Doran and Parkin, 1996; Doran *et al.,* 1996; Chen, 1998). Interpreting soil quality merely by monitoring changes in individual soil quality indicators may not give complete information about soil quality. The recent approach in assessing soil quality includes normalization of the data from measurements and conversion to a numeric value that is more than a static descriptor, called a ‘soil quality index’ (SQI), which can be used to compare various management practices or to assess management-induced changes over time. Therefore, combining them in a meaningful way to a single index may assess soil quality more precisely. With the intensification in agriculture, most of the systematic research efforts on the assessment of soil quality have been in temperate regions (Hussain *et al.,* 1999), (Andrews *et al.,* 2002a). Information is much more limited in the fragile agro-ecosystems of the tropics which suffer more in terms of climatic and edaphic constraints and soil quality degradation. Some research initiatives have been made on systematic assessment of soil quality on the Indian subcontinent in (i) a semi-arid tropical Alfisol (Sharma *et al.,* 2005) (ii) irrigated Inceptisols (Masto *et al.,* 2007) (iii) an irrigated rice–wheat system on Vertisols and (iv) the lowlands of Assam under a rice-based system. In most of these studies, a wide spectrum of methodologies and varying sets of indicators have been used under irrigated conditions with high cropping intensities and higher levels of management.

In the report on global strategy for the *ex situ* conservation of finger millet**,** it has been clearly brought out that millets are the most important cereals of the semi-arid zones of the world. For millions of people in Africa and Asia millets are staple crops. Among millet crops, finger millet figures prominently; it ranks fourth in importance after sorghum, pearl millet and foxtail millet. It has been reported that finger millet cultivation is more widespread in terms of its geographical adaptation compared to other millets. It has the ability to withstand varied conditions of heat, drought, humidity and tropical weather. It is an important staple in many parts of eastern and southern Africa, as well as in South Asia. The global annual planting area of finger millet is estimated at around 4-4.5 million hectares, with a total production of 5 million tons of grains, of which India alone produces about 2.2 million tons and Africa about 2 million tons. The rest comes from other countries in South Asia. The important finger millet growing countries in eastern and southern Africa have been especially the sub humid regions of Ethiopia, Kenya, Malawi, Tanzania, Uganda, Zaire, Zambia and Zimbabwe. Similarly in South Asia the crop is largely grown in India, Nepal and, to some extent, in Bhutan and Sri Lanka. Finger millet is reported to be grown in both China and Japan to a limited extent. Among the major food grains, finger millet is one of the most nutritious crops for protein, minerals (calcium and iron) and amino acids (methionine, an amino acid lacking in the diets of hundreds of millions of the poor who live on starchy foods such as cassava, plantain, polished rice, and maize meal); and provides 8-10 times more calcium than wheat or rice. Finally, the crop is productive in a wide range of environments and growing conditions, from southern Karnataka state in India to the foothills of the Himalayas in Nepal, and throughout the middle-elevation areas of Eastern and Southern Africa. In the major finger millet growing region of Bangalore, the predominant climatic and edaphic problems include i) occurrence of drought once in five years, moderate water erosion leading to terrain deformation, affecting 26-50% area and loss of topsoil. Climatic effects and poor management practices have severely affected the quality of these soils and ultimately the productivity of finger millet. Keeping in view the importance of finger millets and production constraints, the present long term study was conducted with the specific objectives: i) To monitor the effect of long term integrated soil management practices on physical , chemical and biological soil properties in red Alfisol soils representing hot moist semiarid climate, ii) to identify the key soil quality indicators for these soils and iii) to study the long term influence on relative soil quality indices (RSQI) with finger millet as the test crop.

Materials and Methods

This long term experiment was initiated during 1998 at Bangalore Centre of All India Coordinated Research Project for Dryland Agriculture (AICRPDA). This centre is located in Deccan (Karnataka) plateau of Central Eastern Ghats situated in the latitude ranging from 12^0 46` to $12^0$ 47` North and longitude 77^0 11` East at an elevation of 810 m mean sea level (MSL) (AESR 8.2). The climate of the region is hot moist semi-arid. Annual average rainfall of the region is 926 mm and the annual potential evapotranspiration is 503 mm. Length of growing period varies from 120-150 days. The probability of occurrence of drought in the region is once in five years. The soils of experimental site are deep sandy Alfisols. The other important crops of the region are groundnut, pulses etc. The experiment was conducted in a split plot design using integrated soil management practices comprising of 3 main treatments *viz.* Conventional Tillage (M1), Reduced Tillage (M2), Minimum tillage (M3) and 3 sub-plot treatments *viz.* 100% N through organic source (F1), 50% N through organic source + 50% N through inorganic source (F2) and 100% N through inorganic source (F3) with three replications and fingermillet (*Eleusine coracana* L.) as the test crop. In all, a set of 9 treatments comprising of integrated soil management practices were evaluated for soil properties and its quality.

Soil sampling and analysis

After the completion of thirteen years of the experiment during the year 2010, surface soil samples were collected from plough layer (0.0-0.15 m depth). These samples were grind, partitioned and passed through standard prescribed sieves for further use in different kind of analysis. Soil samples passed through 8 mm sieve and retained on the 4.75 mm sieve were used for aggregate analysis, while the sample passed through 0.2 mm sieve was used for estimating organic carbon as well as labile carbon. For the rest of the soil parameters *viz.*, chemical and biological parameters, soil samples passed through 2 mm sieves were used. Soil pH was measured in 1:2 soil water suspensions where 10 gm of soil was taken and stirred intermittently for 30 min with 20 ml water and measured with pH meter (Mclean, 1982). The electrical conductivity was measured in 1:2 soil water suspension using conductivity meter (Rhoades, 1982). Organic carbon was determined by the modified Walkley-Black wet digestion method (Walkley and Black, 1934). Available nitrogen was estimated by alkaline- $KMnO_4$ method (Subbaiah and Asija, 1956). Bicarbonate-extractable P was extracted with 0.5 M sodium bicarbonate (pH of 8.5) and was determined colorimetrically (Olsen *et al.*, 1954). Available K was extracted with neutral normal ammonium acetate solution and the extract was analyzed for potassium on inductively coupled plasma spectrophotometer (ICP-OES, GBC, Australian Model). Exchangeable Ca and Mg were also determined by using 1N ammonium acetate solution as extractant and using atomic absorption spectrophotometer (GBC 906, Australian Model). Sulphur was extracted with 0.15% $CaCl_2$ reagent (Williams and Steinbergs, 1959) and was estimated turbidimetrically with a colorimeter using blue filter in spectrophotometer at 340 nm. The micronutrients *viz.*, Zinc, Iron, Copper, and Manganese were estimated using the method suggested by (Lindsay and Norvell, 1978) with Inductively Coupled Plasma Spectrophotometer (ICP), (model ICP-OES simultaneous system, GBC-Australia) while, boron was estimated using DTPA-Sorbitol extraction method (Miller *et al.*, 2001).

Bulk density was measured by Keen box method. The distribution of water stable aggregates was determined by wet sieving technique using sieves of 4750 um, 2000 um, 1000 um, 500 um, 250 um and 100 um sizes (Yoder, 1936) and mean weight diameter (MWD) was computed after oven drying (Van Bevel, 1949). Dehydrogenase activity (DHA) in the soils was measured by triphenyl tetrazolium chloride method (TTC) (Lenhard, 1956). The results were expressed as mg TPF formed per hour per gm soil. MBC was determined using the chloroform fumigation incubation technique (Jenkinson and Powlson, 1976). Immediately after collection, the portion of the 2 mm sieved samples was preserved in a horizontal refrigerator at 4-5^o C. Before analyzing MBC, these samples were taken out of the refrigerator and primed in bio - oxygen demand (BOD) incubator at field capacity (15% w/w) moisture regime for 10 days at $25^0C \pm 1^0C$ temperature. MBC was calculated using the following relationship

$$MBC\ (\mu g/g\ of\ soil) = (EC_F - EC_{UF}) / K_{EC}$$

Where EC_F is the total weight of extractable carbon in fumigated sample, EC_{UF} is the total weight of the extractable carbon in unfumigated samples and K_{EC} = 0.25 ±0.05 represents the efficiency of extraction of microbial biomass carbon. Labile carbon, which is also considered as one of the important biological soil quality indicators, was estimated using the method suggested by (Weil *et al.*, 2003) with slight modification. In this method, moist fresh air dried soil was equilibrated with 20 ml 0.01 M $KMnO_4$ solution for 15 minutes. The soil-solution suspension was centrifuged at 3000 rpm for 5 min. The absorbance was measured at 550 nm using Mini Spectrophotometer (Model SL 171 of Elico Ltd.).

Soil quality indices computation

The rigorous data set obtained for all the 19 soil quality parameters was statistically analysed for their level of significance using split plot design. After the statistical analysis, the parameters which were found significant were subjected to principal component analysis (PCA) using SPSS software (Version 12.0). The principal components (PC) which received eigen values ≥ 1 (Brejda *et al.,* 2000a, b) and explained at least 5% of the variation in the data and variables which had high factor loading were considered as the best representative of system attributes. Within each PC, only highly weighted factors (having absolute values within 10% of the highest factor loading) were retained for the minimum data set (MDS). The final MDS variables were regressed with the ragi yield as management goals. The variables qualified under these series of steps were termed as the 'key indicators' and were considered for computation of SQI after suitable transformation and scoring.

All the observations of each identified key MDS indicators were transformed using linear scoring technique (Andrews *et al.,* 2002a). To assign the scores, indicators were arranged in order depending on whether a higher value was considered "good" or "bad" in terms of soil function. In case of 'more is better' indicators, each observation was divided by the highest observed value such that the highest observed value received a score of 1. For 'less is better' indicators, the lowest observed value (in the numerator) was divided by each observation (in the denominator) such that the lowest observed value received a score of 1. After transformation using linear scoring, the MDS indicators for each observation were weighted using the PCA results. Each PC explained a certain amount (%) of the variation in the total data set. This percentage when divided by the total percentage of variation explained by all PCs with eigenvectors > 1, gave the weighted factors for indicators chosen under a given PC. After performing these steps, to obtain SQI, the weighted MDS indicator scores for each observation were summed up using the following function:

$$SQI = \sum_{i=1}^{n} (Wi \times Si)$$

where, Si is the score for the subscripted variable and Wi is the weighing factor obtained from the PCA. Here the assumption is that, higher index scores meant better soil quality or greater performance of soil function. For better understanding and relative comparison of the long-term performance of the nutrient treatments, the SQI values were reduced to a scale of 0-1 by dividing all the SQI values with the highest SQI value. The numerical values thus obtained, clearly reflect the relative performance of the management treatments, and hence were termed as the 'relative soil quality indices'. Further, the percent contributions of each final key indicator towards SQI were also calculated and plotted in a pie chart.

Statistical analysis

Analysis of variance (ANOVA) was performed using 'Drysoft' design package. Split –Plot design was used for the experiment and the differences were compared by Least Significant Difference (LSD) test at a significance level of $p < 0.05$ (Snedecor *et al.,* 1989). Principal component analysis was performed using SPSS 12 version. In order to establish quantitative predictive relationship between crop yield and soil quality, simple regression function was computed by using finger millet crop yields and relative soil quality indices.

Results and Discussion

Effect on soil properties

Results revealed that the among the integrated soil management practices, tillage did not significantly influence the pH and electrical conductivity of soils. However, the pH in these soils ranged from 4.54 to 5.58 and exhibited acidic soil reaction. The electrical conductivity of these soils ranged from 0.10 to 0.16 dS/m. Organic carbon content in these soils as influenced by the soil management treatments varied from 1.81 to 3.77 g/kg. Both, the tillage and nutrient treatments significantly influenced the organic carbon content in soils. Significantly highest organic carbon content (2.95 g/kg) was recorded with minimum tillage (average over nutrient treatments) which was on par with reduced tillage treatments (2.77 g/kg) followed by conventional tillage (2.15 g/kg) which was attributed to reduced mineralization due to lower soil aeration in minimum tillage systems. Hence, some authors attribute the potential of C sequestration to no-till or reduced tillage systems.

Among the ISMP, application of 100% N through organic sources recorded the highest organic carbon content. Interaction effect of tillage and nutrient treatments was found to be significant on organic carbon content. Of all the treatments, higher organic carbon content of 3.77 g/kg was recorded in Minimum Tillage (MT) + 100% organic N followed by Reduced Tillage (RT) + 100% organic N (3.24 g/kg) (Table 1). Available nitrogen ($KMnO_4$ oxidizable N) in these soils was significantly influenced by tillage as well as conjunctive nutrient treatments. Among the tillage treatments, available nitrogen was highest (215.83 kg/ha) in MT + 100% inorganic N followed by MT + 50% organic N + 50 % inorganic N (205.46 kg/ha). (Malecka *et al.,* 2012) observed increase in nitrogen content in reduced and no tillage systems compared to conventional tillage. In the present study, the tillage treatments alone showed significant influence on the available phosphorus in soils. Highest phosphorus content 22.63 kg/ha was observed in MT + 100% inorganic N followed by RT + 100% organic N (19.90 kg/ha). Within the same tillage treatment, the nutrient treatments did not significantly influence the available phosphorus in soils. However, the available phosphorus in these soils varied from 16.6 to 22.6 kg/ha across all the treatments. Available Potassium in the experimental plots ranged from 125.93 to 150.19 kg/ha in these soils. The tillage treatments significantly influenced the available potassium in soils and was recorded highest (150.19 kg/ha) in MT + 100% organic N followed by RT + 100% inorganic N (137.12 kg/ha) (Table 1).

Table 1 : Effect of integrated soil management practices (ISMP) on soil physico-chemical and chemical characteristics in red Alfisol soils

Treatment	pH	EC dS/m	OC (g/kg)	N	P	K
				(kg/ha)		
CT + 100% organic N	4.54	0.15	2.24	163.69	17.01	132.46
CT + 50% organic N + 50% inorganic N	4.96	0.14	2.40	174.73	16.97	131.37
CT + 100% inorganic N	5.11	0.14	1.81	183.47	16.61	125.93
RT + 100% organic N	4.80	0.16	3.21	184.96	19.90	143.08
RT + 50% organic N + 50% inorganic N	5.58	0.12	2.86	187.27	19.66	144.67
RT + 100% inorganic N	4.56	0.10	2.23	194.41	18.94	137.12
MT + 100% organic N	4.68	0.12	3.77	202.01	20.62	150.19
MT + 50% organic N + 50% inorganic N	4.72	0.12	2.48	205.46	20.23	147.98
MT + 100% inorganic N	4.84	0.14	2.59	215.83	22.63	143.62
LSD (P= 0.05)						
Between two tillage means	NS	NS	0.33*	3.80*	1.47*	12.37*
Between two source of N means	0.28*	NS	0.29*	6.49*	NS	NS
Between two source of means at the same tillage	0.49*	NS	0.51*	NS	1.57*	NS
Between two tillage means at the same or two different source of N treatments	0.45*	NS	0.49*	NS	1.73*	NS

*indicates significance at p=0.05; NS, non significant; CT, conventional tillage; RT, reduced tillage; MT, minimum tillage; EC, electrical conductivity; OC, organic carbon.

The tillage treatments significantly influenced the exchangeable calcium and magnesium in these soils. Exchangeable calcium in these soils ranged from 2.10 to 3.68 c mol/kg and it was recorded higher (3.68 c mol/kg) in MT + 100% organic N followed by RT + 100% organic N (2.97 c mol/kg). The nutrient treatments did not significantly influence the exchangeable Calcium and Magnesium. The exchangeable magnesium in these soils ranged from 1.0 to 1.56 c mol/kg. Tillage treatments had a significant effect on the exchangeable magnesium content in these soils while no significant influence was observed with the nutrient treatments. Highest exchangeable magnesium (1.56 c mol/kg) content was recorded in case of MT + 100% organic N followed by RT + 100% organic N (1.44 c mol/kg) (Table 2). The tillage and nutrient management treatments did not show any significant effect on the availability of sulphur as well as micronutrients (except manganese) in these soils. However, the available sulphur in these soils ranged from 22.45 to 32.30 kg/ha (Table 2).

Table 2 : Effect of integrated soil management practices (ISMP) on secondary and micronutrients content in red Alfisol soils

Treatment	Ca	Mg	S	Zn	Fe	Cu	Mn	B
	(c mol/kg)		(kg/ha)			µg/g		
CT + 100% organic N	2.13	1.19	25.2	0.82	12.75	1.33	36.48	0.29
CT + 50% organic N + 50% inorganic N	2.10	1.13	22.4	0.73	11.51	1.15	31.33	0.31
CT + 100% inorganic N	2.10	1.00	23.8	0.70	9.68	1.02	30.90	0.27
RT + 100% organic N	2.97	1.44	29.4	0.92	12.02	0.85	29.19	0.32
RT + 50% organic N + 50% inorganic N	2.92	1.41	28.8	0.83	10.56	0.92	27.00	0.30
RT + 100% inorganic N	2.37	1.38	25.1	0.73	13.28	0.95	26.46	0.33
MT + 100% organic N	3.68	1.56	32.3	1.17	12.76	0.93	23.14	0.36
MT + 50% organic N + 50% inorganic N	3.02	1.46	26.2	1.00	13.16	0.98	24.13	0.32
MT + 100% inorganic N	3.16	1.39	26.3	0.80	10.88	0.86	23.82	0.34
LSD (P= 0.05)								
Between two tillage means	0.33*	0.16*	NS	NS	NS	NS	2.15*	NS
Between two source of N means	NS	NS	NS	NS	NS	NS	NS	NS

* indicates significance at p=0.05; NS, non significant; CT, conventional tillage; RT, reduced tillage; MT, minimum tillage

The DHA in these soils ranged from 1.33 to 4.0 mg TPF/hr/g. Tillage had no significant influence on the microbial biomass carbon, while significant effect was observed with the nutrient management treatments. Integrated use of chemical fertilizers with organic sources increased the concentration of MBC in soil compared to chemical fertilizer alone. Relatively, higher MBC (254.14 mg/g) was observed in case of MT + 100% organic N which was on par with MT + 50% organic N + 50%

inorganic N (244.89 mg/g) (Table 3). Higher levels of MBC in compost treated soil could be due to greater amounts of biogenic materials like mineralizable nitrogen, water soluble carbon and carbohydrates. Labile carbon content in these soils ranged from 236.81 to 300.83 mg/kg. The tillage and nutrient treatments showed significant effect on the labile carbon content of the soils. Highest labile carbon content (300.83 mg/kg) was recorded with MT + 100% organic N followed by RT + 100% organic N (284.45 mg/kg) whereas, their interaction effects did not show any significant influence on labile carbon.

Both the tillage and nutrient treatments showed significant effect on the bulk density. The bulk density in these soils ranged from 1.19 to 1.58 Mg/m^3. Highest bulk density was recorded (1.58 Mg m^{-3}) with RT + 100% organic N followed by Conventional Tillage (CT) + 50% organic N + 50 % inorganic N (1.36 Mg/m^3). No significant effect of tillage and nutrient treatments, as well as their interaction was observed on mean weight diameter of soil aggregates. However, the MWD of soil aggregates as influenced by the management treatments in these soils varied from 0.24 to 0.37 mm (Table 3).

Table 3 : Effect of integrated soil management practices (ISMP) on soil physical and biological properties in red Alfisols

Treatment	DHA mg TPF/ Hr/g	MBC mg/g	LC Mg/kg	BD Mg/m^3	MWD mm
CT + 100% organic N	1.33	232.20	275.69	1.31	0.26
CT + 50% organic N + 50% inorganic N	2.50	223.84	253.59	1.36	0.28
CT + 100% inorganic N	1.81	173.84	236.81	1.36	0.24
RT + 100% organic N	1.99	235.70	284.45	1.58	0.34
RT + 50% organic N + 50% inorganic N	4.00	240.12	267.15	1.28	0.31
RT + 100% inorganic N	1.25	205.97	256.79	1.32	0.29
MT + 100% organic N	1.57	254.14	300.83	1.19	0.37
MT + 50% organic N + 50% inorganic N	1.53	244.89	271.80	1.26	0.35
MT + 100% inorganic N	2.59	232.57	263.71	1.33	0.31
LSD (P=0.05)					
Between two tillage means	NS	NS	13.22*	0.04**	NS
Between two source of N means	NS	25.83*	13.19*	0.05*	NS
Between two source of means at the same tillage	1.53*	NS	NS	NS	NS
Between two tillage means at the same or two different source of N treatments	1.53*	NS	NS	NS	NS

* indicates significance at p=0.05; NS, non significant; CT, conventional tillage; RT, reduced tillage; MT, minimum tillage; DHA, dehydrogenase activity; MBC, microbial biomass carbon; LC, labile carbon; BD, bulk density; MWD, mean weight diameter.

Principal component analysis (PCA)

Data pertaining to the influence of integrated soil management practices in Alfisols of Bangalore on 19 soil quality indices was statistically analyzed. It was observed that out of 19 soil quality parameters, 8 parameters *viz.*, EC, available S, available Zn, Fe, Cu, B, DHA, MWD were non significant, and hence, were dropped from further PCA analysis. In the PCA of 11 variables, only two principal component (PCs) had eigen values >1 and explained 83.4% variance in the data set (Table 4).

Table 4 : Principal component analysis of soil quality parameters as influenced by integrated soil management practices (ISMP) in red Alfisol soils

Parameters	PC1	PC2	PC3	PC4
Total eigen values	5.369	1.681	1.12	1.012
% of variance	48.808	15.285	10.186	9.198
Cumulative %	48.808	64.092	74.278	83.476
Eigen vectors				
pH	-0.110	-0.486	0.762	-0.275
OC	0.728	0.232	0.125	-0.529
N	0.713	-0.592	-0.185	0.215
P	0.816	-0.149	0.003	0.058
K	0.713	0.180	0.106	0.506
Ca	0.880	-0.179	0.152	-0.198
Mg	0.753	0.114	0.164	-0.008
Mn	-0.713	0.461	0.329	-0.046
LC	0.699	0.599	-0.090	-0.066
BD	-0.708	-0.256	0.261	0.351
MBC	0.551	0.387	0.494	0.426

PC: Principal component

In PC1 Ca and P were highly weighted variables. In PC2, LC and N were the highly weighted variables. In PC3 and PC4, only one variable each *viz.*, pH and K was the highly weighted variable. The correlation analysis run between the variables qualified under PC1, (Ca and P) (Table 5) showed significant correlation between the highly weighted variables.

Table 5 : Correlation matrix for highly weighted variables under PC's with high factor loading under integrated soil management practices (ISMP)

PC 1 variables	Calcium	Phosphorus
Calcium	1	0.789**
Phosphorus	0.789**	1
PC 2 variables	N	LC
N	1	0.143** 0.477*
LC	0.143** 0.477*	1

** Correlation indicates significant difference at P = 0.01 (2 tailed)

Soil quality indices (SQI)

Soil quality indices were computed using six soil quality indicators *viz.*, pH, N, P, K, Ca and labile carbon (Figure 1).

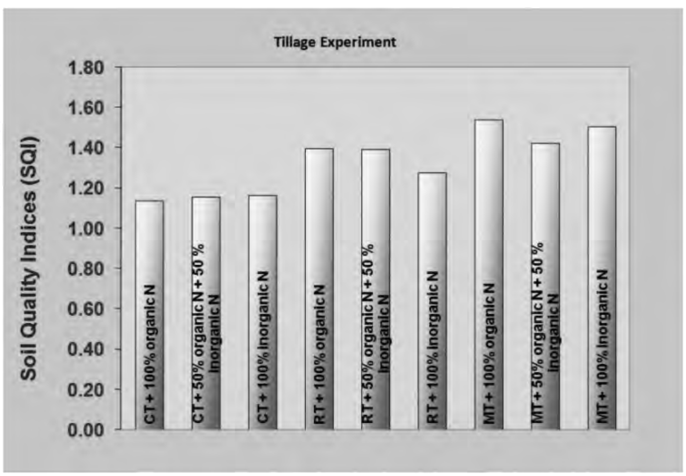

Fig. 1 : Soil quality indices as influenced by integrated soil management treatments in red Alfisol

The soil quality indices varied from 1.14 to 1.54 across the tillage and nutrient management treatments. The soil quality indices, when reduced to a scale of one, termed as 'relative soil quality indices', varied between 0.70 to 0.95. From the data, it was clearly observed that tillage and nutrient management treatments played significant role in maintaining soil quality. The interactive effects of tillage and nutrient management treatments were also significant. Among the tillage methods, minimum tillage maintained significantly higher SQI of 1.48 followed by reduced tillage (1.35). Across all the tillage and nutrient treatments, practice, minimum tillage + 100% organic N resulted in significantly higher SQI of 1.54 followed by the other two tillage methods. The average percent contribution of key indicators towards soil quality indices was: pH (8%), available N (12%), available P (33%), available K (7%), available Ca (28%), labile carbon (12%) (Table 6, Figure 2).

Table 6 : Key soil quality indicators, soil quality indices and the best performing integrated soil management practices (ISMP) in red Alfisol soils

Key soil quality indicators and their % contribution	SQI	RSQI	Best management practices with higher SQI
pH (8%)	1.14-1.54	0.70 – 0.95	MT + 100% organic
Available N (12%)			N
Available P (33%)			MT + 50% organic
Available K (7%)			N + 50% inorganic
Available Ca (28%)			N
Labile carbon (12%)			MT + 100% inorganic N

SQI: soil quality indices; RSQI: relative soil quality indices

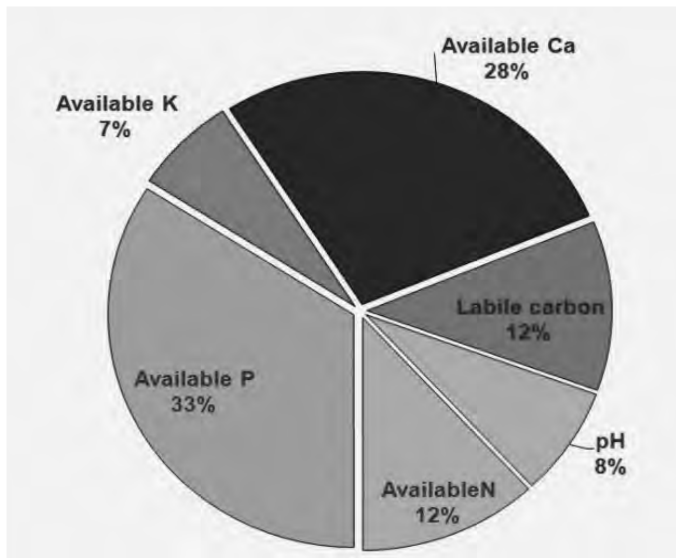

Fig. 2 : Percent contribution of soil quality indices as influenced by integrated soil management treatments in red Alfisol

Linear predictive function between crop yield and relative soil quality indices (RSQI)

Simple quantitative relationships were also worked out between finger millet yield vs RSQI over a set of treatments. The linear regression coefficient (R^2) of this relationship was 0.423. From this simple function, fingermillet yield could be quantitatively related to soil quality and it was expressed as

$Y_{fingermillet}$ = -2230.62 + 5865.72 (RSQI)....................R^2 = 0.423

Where Y = Finger millet yield in kg/ha, RSQI= Relative soil quality Index

This linear regression equation can be used to predict average yield on the basis of RSQI values of hot moist semi arid Alfisols of Bangalore region.

Conclusion

This study evaluated the effect of integrated soil management practices (ISMP) on soil properties and fingermillet crop yield. These practices had a significant effect on soil chemical and biological properties *viz.,* OC, N, P, K, MBC and LC. Further, a significant positive relationship between finger millet crop yield and relative soil quality index was observed, and can be a good predictor of crop yield in hot moist semi arid red Alfisols. Hence, it was concluded that integrated soil management practices (ISMP) improved soil properties, overall soil quality indices and crop productivity.

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