Long-Term Impact of Soil and Nutrient Management Practices on Soil Quality in Rainfed Alfisols at Anantapur in Andhra Pradesh

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Long-Term Impact of Soil and Nutrient Management Practices on Soil Quality in Rainfed Alfisols at Anantapur in Andhra Pradesh

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ABSTRACT : Impact of long-term use of soil and nutrient management treatments was studied at All India Coordinated Research Project for Dryland agriculture Anantapur in three on-going experiments. In experiment 1, the long-term integrated nutrient management treatments tested under groundnut system significantly influenced most of the soil quality parameters. The soil quality indices as influenced by different integrated nutrient management practices varied from 1.32 to 1.96 across the management treatments. The key soil quality indicators identified under this system along with their percent contributions were: EC (7%), OC (17%), available N (4%), available K (16%), exchangeable Ca (16%), exchangeable Mg (16%), DTPA- Fe (6%), DTPA-Zn (2%), and dehydrogenase activity (DHA) (16%). In experiment 2 comprising of tillage practices and nutrient management treatments using groundnut as test crop, the soil quality indices varied from 2.01 to 2.7. The parameters which emerged as key soil quality indicators were: pH, EC, exchangeable Ca, Mg, DTPA- Fe, available B, DHA and labile carbon (LC). Of all the indicators, LC played a major role in influencing or aggrading the quality of the soils followed by soil pH. Among the tillage practices, low tillage played a significant role in improving the soil quality (SQI 2.43) and proved superior, followed by conventional tillage practice (SQI 2.37). Among the nutrient treatments, sole 100% organic treatment (SQI 2.62) proved quite superior in improving the soil quality followed by conjunctive nutrient application viz., 50% organic + 50% inorganic (SQI 2.35). while the sole 100% inorganic nutrient application could maintain SQI value only up to 2.10. In experiment 3, where groundnut-castor was the crop rotation, soil quality indices varied from 0.85 to 1.73 across the treatments. The key soil quality indicators identified for groundnut-castor system along with their percent contributions were: EC (23%), available P (21%), available S (22%), available B (9%), LC (21%) and MWD (4%). Application of 100% N (inorganic) maintained significantly highest soil quality with SQI value of 1.73, followed by application of 50% N through gliricidia loppings + 50% N through inorganic source (SQI 1.52). This observation clearly indicated the proportionally equal and important role-played by EC, available P, available S and LC in influencing the quality of these Alfisols under castor-groundnut rotation.

Key words: Soil quality, key indicators, tillage, INM, Alfisol, groundnut, castor

Anantapur centre is located in Rayalaseema–Karnataka plateau, situated in between 20^{o}32’ to 20^{o}35’ north latitude and 77^{o}7’ to 77^{o}10’ east longitude with an altitude of 325 m above MSL (AESR 3) having arid climate. The decennial mean annual rainfall is 616 mm received in 36 days. In general, the soils of the region are red sandy loams with compact subsoil having 10-15 cm m^{-1} available water. Soils of this region suffer from serious crusting problem and high infiltration. Besides these, soils are also miserably low in organic matter and fertility. The preparatory cultivation practices which are normally done 2 to 3 times might be one of the reasons hindering the improvement in soil quality besides leaving the lands susceptible to erosion. Consequent to the above reasons, the crop yields are very low. It was opined that minimum tillage in general, might improve the soil structure, organic matter contents, intercept the rainwater and improve the quality of the crop land. On the other hand, in order to improve the crop yields, it was also felt essential to give emphasis on soil quality (physical, chemical and biological quality) improvement. Considering this, couple of experiments comprising of conjunctive nutrient use treatments (organic and inorganic sources of nutrients) and conventional and reduced tillage etc were experimented with different crops and cropping systems in Alfisol soil of Anantapur

Materials and Methods

Experiment 1 : The experiment on Integrated Nutrient Management (INM) for groundnut was initiated during the year 1985 in a randomized block design with three replications using groundnut as test crop. Out of the total set of treatments, only six most important treatments viz., T1: Control, T2: 20-40-40 NPK kg ha^{-1}, T3: FYM @ 4 t ha^{-1}, T4: 10-20-20- NPK kg ha^{-1} + FYM 4t ha^{-1}, T5: 20-40-40 NPK kg ha^{-1} + $ZnSO_4$ @ 50 kg ha^{-1} (once in 3 years) and T6: 20-40-40 NPK kg ha^{-1} + G. nutshells @ 4 t ha^{-1} were selected from this experiment for monitoring soil quality.

Experiment 2: Another experiment on tillage and nutrient management for resource conservation and soil quality improvement initiated at Anantapur was adopted under soil quality assessment programme to monitor the long-term impact of soil and nutrient management treatments. This experiment was initiated during the year 2000 in a split plot design with three main plot treatments and three sub-plot treatments in three replications using groundnut (TMV-2) as test crop. The main plot treatments comprised of three tillage levels viz. i) conventional Tillage (CT), ii) Low Tillage (LT), and iii) LT + herbicide. The sub-plot treatments comprised of three fertilizer levels viz i) 100% recommended dose of fertilizer (RDF) as organic source, ii) 50% RFD as organic + 50% RFD as inorganic, and iii) 100 % RFD as inorganic source. All the 9 treatment combinations with 3 replicates were chosen for soil quality assessment study from this experiment. The soil quality assessment study in this experiment was taken up after 6th year of experimentation.

Experiment 3 : The third experiment, which was selected for soil quality assessment study at Anantapur was initiated during 1998. This experiment was conducted with five integrated nutrient management treatments in a randomized block design with three replications in castor-groundnut rotation in Alfisol soils. The INM treatments comprised of the following: T1: Control, T2: 100% N (inorganic), T3: 50% N (compost) + 50% N (inorganic), T4: 50% N (gliricidia) + 50% N (inorganic), and T5: 100% N (organic). The soil samples collected from these experiments were analyzed for various soil quality indicators using standard methodologies as described in Sharma et al. (2009).

Methodology for Computation of Soil Quality Index (SQI):

The key indicators requisite to compute the soil quality indices were identified using Principal Component Analysis (PCA) and Linear Scoring Technique (LST). The soil quality indices were computed by following the procedures earlier adopted by Doran and Parkin (1994), Andrews et al. (2002), Sharma *et al.* (2005) and Sharma *et al* (2008) and the detailed methodology has been presented earlier (Sharma *et al*., 2009).

Results and Discussion

Experiment 1 : The data pertaining to the soil quality parameters is presented in Table 1. The soil reaction of these rainfed Alfisol soils was found to be near neutral with pH varying from 6.12 to 7.35. Electrical conductivity was also found to be normal. Highest amount of organic C (4.7 g kg^{-1}) was recorded with application of FYM @ 4t ha^{-1} followed by 10-20-20-NPK kg ha^{-1} + FYM @ 4 t ha^{-1} (4.1 g kg^{-1}), whereas, control plot recorded, organic C content as low as 2.6 g kg^{-1}. The INM treatments significantly influenced the available N, P and K content in soil. Available N was found to be very low in these soils ranging from 113.0 to 168.9 kg ha^{-1}. Significantly highest amounts of available N (168.9 kg ha^{-1}) and K (218.4 kg ha^{-1}) were recorded with application of 10-20-20- NPK kg ha^{-1} + FYM 4t ha^{-1}. The highest available P (67.9 kg ha^{-1}) was recorded with application of sole inorganic sources of nutrients to the crop (20-40-40 kg NPK) followed by T2 + $ZnSO_4$ @ 50 kg ha^{-1} (54.6 kg ha^{-1}), whereas in

Table 1 : Effect of different integrated nutrient management treatments on different soil quality indicators at Anantapur

	pH	EC (dS m^{-1})	OC g kg^{-1}	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B	DHA (µg TPF hr^{-1} g^{-1} soil)	MBC (µg g^{-1} soil)	LC (µg g^{-1} soil)	BD Mg m^{-3}	MWD mm
				kg ha^{-1}			c mol kg^{-1}		µg g^{-1}										
T1	6.66	0.05	2.6	113.0	10.4	114.0	3.84	1.29	12.6	0.17	6.10	0.54	15.17	0.53	1.70	154.7	239.9	1.38	0.18
T2	6.12	0.11	2.5	129.5	67.9	197.1	3.56	0.90	35.2	1.18	6.00	0.36	16.75	0.55	2.08	174.2	256.5	1.36	0.21
T3	7.35	0.07	4.7	127.9	14.0	174.5	3.54	2.16	14.1	5.11	4.48	0.74	9.40	0.82	3.56	255.6	270.2	1.29	0.27
T4	7.05	0.14	4.1	168.9	35.8	218.4	3.54	2.17	12.6	2.26	4.79	0.51	8.91	0.79	2.66	269.0	289.3	1.30	0.25
T5	6.44	0.11	3.6	126.0	54.6	211.1	2.77	0.91	24.5	9.30	10.20	0.46	23.60	0.70	2.17	254.7	265.7	1.36	0.24
T6	6.05	0.07	4.0	134.4	41.0	201.1	3.45	1.21	15.3	2.78	13.28	0.68	25.46	0.61	2.56	296.3	290.8	1.37	0.23
CD (0.05)	0.39	0.02	0.07	5.00	5.88	7.23	0.07	0.15	2.56	0.98	0.271	0.09	1.891	0.185	0.30	26.4	NS	NS	0.03

T1: Control, T2: 20-40-40 NPK kg ha^{-1}, T3: FYM @ 4 t ha^{-1}, T4: 10-20-20- NPK kg ha^{-1} + FYM 4t ha^{-1}, T5: 20-40 40 NPK kg ha^{-1} + $ZnSO_4$ @ 50 g ha^{-1} (once in 3 years, T6: 20-40-40 NPK kg ha^{-1} + G.nut shells @ 4 t ha^{-1}

control, the available P content was 10.4 kg ha^{-1}. The integrated nutrient management treatments showed a conspicuous influence not only on the major soil fertility parameters, but also on secondary and micronutrient contents of the soil. Exchangeable Ca and Mg, in these soils varied between 2.77 to 3.84 c mol kg^{-1} and 0.90 to 2.17 c mol kg^{-1} soil respectively. Available S was found to vary between 12.6 to 35.2 µg g^{-1} across the management treatments and was significantly influenced. Among the micronutrients, DTPA extractable Zn content was found as high as 9.30 µg g^{-1} and 5.11 µg g^{-1} in 20-40 40 NPK kg ha^{-1} + $ZnSO_4$ and FYM applied @ 4 t ha^{-1} respectively. The contents of Zn in control plot declined to as low as 0.17 µg g^{-1}. DTPA extractable Fe (13.3 µg g^{-1}) and Mn (35.5 g g^{-1}) were found to be significantly highest with application of 20-40-40 NPK kg ha^{-1} + Groundnut shells @ 4 t ha^{-1}. While the application of sole organic treatment as FYM @ 4 t ha^{-1} recorded the highest Cu (0.74 µg g^{-1}) and B (0.82 µg g^{-1}) contents in this system. The conjunctive nutrient use treatments applied to groundnut in these Alfisols showed a conspicuous influence on the biological parameters viz., DHA and MBC while LC was not influenced. Among the INM treatments practiced for 20 years, it was observed that, application of sole organic sources of nutrients as FYM @ 4 t ha^{-1} recorded significantly highest DHA of 3.56 µg TPF hr^{-1} g^{-1} soil while application of sole inorganic sources of nutrients along with groundnut shells (20-40-40 NPK kg ha^{-1} + G.nut shells @ 4 t ha^{-1}) recorded the highest MBC to the tune of 296.3 µg g^{-1} soil. Labile carbon in these soils, irrespective of the insignificant influence of the INM treatments was to the extent of 239.9 to 290.8 µg g^{-1} soil. Even, practicing these treatments for all these years under this groundnut cropping system did not influence the bulk density of the soils. But the mean weight diameter of the soil aggregates, which varied from 0.18 to 0.27 mm was significantly influenced by the management treatments. The plots receiving FYM in sole form or in combination with inorganic sources improved the mean weight diameter of the soil aggregates in these rainfed Alfisols.

Soil quality

Of the 19 soil quality variables selected for the soil quality assessment studies in groundnut based system at Anantapur, 17 parameters were proved to be significantly influenced by the nutrient management treatments and only two parameters viz., BD and LC were not influenced by any of the management treatments and hence were not included for the PCA. In the PCA of 17 variables, four PCs had eigen values > 1 and explained a variability of 90.2% in the data set. Under PC_1, the highly weighted variables included OC, Mg, and DHA. A correlation matrix run for these variables in order to retain the best-represented variable in this PC, revealed a significant positive relation with each other. But irrespective of the criteria of retaining only the variable with the highest correlation sum which best represented the group, all the three variables were retained for the MDS considering their relative importance and role they play in these rainfed Alfisols. In PC_2, again two variables viz., Ca and K were highly weighted and were retained for the final MDS in spite of their significant negative correlation with each other. In PC_3, the highly weighted variables included EC, Fe and Cu of which, EC and Cu showed a significant negative correlation while Fe had no correlation with any other variable. Hence, of these three variables, EC and Fe were retained for the final MDS. Under PC_4, N and Zn were the highly weighed variables which when tested for correlation also did not reveal any relationship and hence were retained for the final MDS. Hence, the final MDS consisted of EC, OC, available N, K, Fe, Zn, exchangeable Ca, Mg, and DHA as the key indicators. The final MDS variables when regressed as independent variables with average groundnut yield which varied from 470 to 585 kg ha^{-1} across the treatments (AICRPDA, 2008) as management goal as dependent variables, only three variables i.e. available N, K, and Fe revealed their significance. However, the variables, which were retained in the final MDS, were used to compute the soil quality indices. The soil quality indices as influenced by different integrated nutrient management practices were computed using key indicators viz., EC, OC, available N, available K, available Fe, available Zn, exchangeable Ca, exchangeable Mg, and DHA and the indices varied from 1.32 to 1.96 across the management treatments (Table 5). It was observed that the treatments which supplied FYM @ 4 t ha^{-1} and 10-20-20- NPK kg ha^{-1} + FYM 4t ha^{-1} had SQI of 1.96 and proved to be significantly superior in maintaining the soil quality in these Alfisols. The next best treatment in maintaining the soil quality was application of 20-40-40 NPK kg ha^{-1} + G.nut shells @ 4 t ha^{-1} which had a SQI of 1.75. However, the control plot maintained the lowest SQI (1.32). The relative order of performance of the treatments in maintaining soil quality was: T3: FYM @ 4 t ha^{-1} (1.96) = T4: 10-20-20- NPK kg ha^{-1} + FYM 4t ha^{-1} (1.96) > T6: 20-40-40 NPK kg ha^{-1} + G. nut shells @ 4 t ha^{-1} (1.75) > T5: 20-40 40 NPK kg ha^{-1} + $ZnSO_4$ @ 50 g ha^{-1} (once in 3 years) (1.64) > T2: 20-40-40 NPK kg ha^{-1} (1.45) > T1: Control (1.32). The RSQI values across the treatments varied from 0.66 to 0.98. The percent contributions of key soil quality indicators towards soil quality indices were: EC (7%), OC (17%), available N (4%), K (16%), exchangeable Ca (16%), Mg (16%), available Fe (6%), Zn (2%), and DHA (16%) (Fig 1).

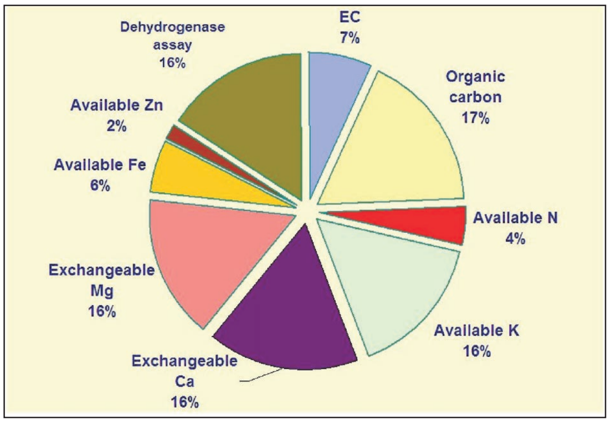

Fig. 1 : Percent contribution of key indicators towards soil quality indices as influenced by different integrated nutrient management treatments under groundnut crop at Anantapur

Experiment 2

Data presented in Table 2 indicated significant influence of tillage and nutrient management practices on most of the soil quality attributes. Organic carbon status in these soils was observed to be low ranging from 0.20 to 0.40 g kg^{-1}. The soil nutrient management practices, though followed for six years in these Alfisol soils did not show a conspicuous build up in the organic matter content. In addition to this, neither the influence of conventional nor low tillage practices on organic carbon enhancement was observed. But the performance of the nutrient management treatments was quite encouraging which showed that application of nutrients through 100% organic sources resulted in the highest amount of organic carbon content (3.95 g kg^{-1}) compared to other treatments. Of all the treatments, irrespective of the statistical significance, the highest amount of Organic C content (3.9 g kg^{-1}) was recorded in CT +100 % organic sources of nutrients, which was followed by LT +100 % organic (3.6 g kg^{-1}) and CT+ 50 % organic+ 50 % inorganic (3.6 g kg^{-1}). As this was six-year-old experiment only, low tillage + herbicide +100 % inorganic combination of treatments maintained relatively lower amount of organic C (2.0 g kg^{-1}). Despite using different combinations of tillage and nutrient sources, available N content of soil across the treatments remained low (112.2 to 135.7 kgha^{-1}) and was influenced neither by the tillage practices nor by different nutrient management treatments. Nitrogen deficiency looks to be the predominant constraint in these soils. The available P status in these soils varied between 35.3 to 50.6 kg ha^{-1} across the treatments. Though, there was no absolute P control in this experiment, nevertheless, considering the low to medium status of P in these soils, a considerable build up of available P was recorded across the treatments. Application of nutrients through sole inorganic sources recorded the highest available P to the extent of 47.4 kg ha^{-1} compared to other treatments. Hence, considering the level of P sink or removal rate by the crops such as groundnut, there is a need to appropriately regulate the P application in these soils. The soil nutrient management treatments showed a conspicuous influence on available K, which ranged from 190.8 to 280.9 kg ha^{-1} across the treatments. Practicing low tillage could significantly enhance the available K and also application of nutrients through organic sources improved the K content in the soil (259.1 kg ha^{-1}). Coming to secondary and micronutrients, it was observed that tillage practices significantly influenced exchangeable Ca, available S, and DTPA extractable Fe, Cu and Mn. Even among the tillages, practices, conventional tillage significantly improved the available S as well as the micronutrient contents compared to low tillage practice. Application of nutrients to groundnut crop in these Alfisols through sole organic sources and in conjunctive mode improved the available Zn status (3.75 μg g^{-1}) compared to sole inorganic source (1.18 μg g^{-1}). Available Zn content was also found improved considerably over the general recommended critical limits (0.60 μg g^{-1}). Most of the management treatments in this set of experiment appeared to be in soil aggradation mode. Practicing

Table 2: Effect of tillage, herbicide and conjunctive use of organic and inorganic sources of nutrients on different soil quality indicators under groundnut cropping system in Alfisols at Anantapur

	pH	EC (dS m^{-1})	OC g kg^{-1}	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B	DHA (µg TPF hr^{-1} g^{-1} soil)	MBC (µg g^{-1} soil)	LC (µg g^{-1} soil)	BD Mg m^{-3}	MWD mm
				kg ha^{-1}			c mol kg^{-1}		µg g^{-1}										
T1F1	6.76	0.09	3.9	112.2	27.5	213.6	2.60	1.72	13.01	3.52	7.80	0.46	14.65	0.76	3.20	273.0	309.7	1.35	0.24
T1F2	6.12	0.13	3.5	112.2	46.4	249.9	2.72	0.87	19.53	3.71	11.4	0.38	19.72	0.85	2.72	250.3	296.3	1.37	0.22
T1F3	6.19	0.09	3.0	121.0	50.6	207.3	2.55	0.84	36.70	1.66	15.8	0.31	21.83	0.81	1.62	225.6	236.3	1.40	0.24
T2F1	7.30	0.13	3.6	135.7	36.1	280.9	2.50	1.68	14.61	5.06	6.00	0.27	9.90	0.81	8.12	291.4	205.6	1.36	0.28
T2F2	6.19	0.14	2.6	114.3	45.4	253.2	3.55	1.17	21.15	2.94	10.2	0.22	20.03	0.67	3.71	276.4	289.4	1.39	0.24
T2 F3	6.33	0.10	2.6	112.7	43.1	190.8	3.19	0.62	25.56	1.28	8.46	0.30	18.37	0.73	2.57	232.6	235.3	1.41	0.23
T3 F1	6.60	0.12	3.5	130.1	35.3	282.8	1.98	1.56	12.04	2.69	6.86	0.43	16.42	0.84	4.22	252.8	302.1	1.37	0.27
T3 F2	6.18	0.14	2.5	113.1	44.3	246.4	1.99	0.89	10.78	4.62	10.1	0.33	18.21	0.67	2.11	240.9	295.4	1.38	0.22
T3 F3	5.56	0.10	2.0	112.2	48.5	203.0	2.43	0.63	13.85	0.60	15.0	0.34	21.48	0.66	1.84	235.8	228.0	1.39	0.23
CD (0.05)																			
Tillage	0.12	0.01	NS	NS	NS	14.9	0.21	NS	1.99	NS	0.88	0.03	1.39	NS	0.32	NS	NS	NS	NS
Fertilizers	0.16	0.00	0.03	NS	5.60	9.01	0.12	0.11	1.24	0.39	0.51	0.04	1.37	0.06	0.58	21.3	20.9	NS	0.03
Fertilizer at same tillage	0.28	0.01	NS	NS	NS	15.6	0.22	0.19	2.14	0.68	0.89	0.07	2.37	0.10	1.00	NS	NS	NS	NS
Tillage at same or different fertilizer	0.25	0.01	NS	NS	NS	17.3	0.24	0.18	2.35	0.67	1.00	0.06	2.22	0.11	0.85	NS	NS	NS	NS

T1 F1: CT + 100% organic, T1 F2: CT + 50% organic + 50% inorganic, T1 F3: CT + 100 % inorganic, T2 F1: LT + 100% organic, T2 F2: LT + 50% organic + 50% inorganic, T2 F3: LT + 100 % inorganic, T3 F1: LT + Herbicide + 100% organic, T3 F2: LT + Herbicide + 50% organic + 50% inorganic, T3 F3: LT + Herbicide + 100 % inorganic

Table 3: Effect of different integrated nutrient management treatments on different soil quality indicators in castor +groundnut system in Alfisols at Anantapur

	pH	EC (dS m^{-1})	OC g kg^{-1}	N	P	K	Ca	Mg	S	Zn	Fe	Cu	Mn	B	DHA (µg TPF hr^{-1} g^{-1} soil)	MBC (µg g^{-1} soil)	LC (µg g^{-1} soil)	BD Mg m^{-3}	MWD mm
				kg ha^{-1}			c mol kg^{-1}		µg g^{-1}										
T1	5.93	0.05	1.7	117.5	15.1	141.1	2.85	1.63	14.7	0.40	8.73	0.39	21.8	0.53	2.23	157.4	211.1	1.38	0.20
T2	5.47	0.14	2.8	120.9	62.7	201.6	3.86	1.45	34.1	2.47	13.8	0.53	26.5	0.68	1.07	257.3	222.9	1.34	0.24
T3	5.93	0.10	2.4	134.4	55.2	227.0	2.19	1.28	25.4	0.99	12.2	0.45	27.4	0.43	1.40	269.3	223.6	1.33	0.25
T4	6.19	0.12	3.2	140.1	55.5	240.5	3.87	1.23	25.3	1.48	12.1	0.79	29.7	0.57	2.68	277.0	254.6	1.32	0.21
T5	6.35	0.08	2.8	137.5	28.0	194.9	2.99	1.49	13.7	1.14	6.77	0.92	16.2	0.65	3.21	290.6	261.5	1.31	0.29
CD (0.05)	0.36	0.02	0.77	16.6	5.06	19.3	0.54	0.20	0.65	0.52	1.68	0.10	1.61	0.06	0.63	28.9	21.8	NS	0.05

T1: Control, T2: 100% N (inorganic), T3: 50% N (compost) + 50% N (inorganic), T4: 50% N (glyricidia) + 50% N (inorganic), T5: 100% N (organic) tillage for 6 years did not show any influence on physical as well as biological soil quality parameters, except DHA where, practice of low tillage resulted in significantly highest amounts of DHA to the extent of 4.80 µg TPF hr^{-1} g^{-1}. While the different fertilizer treatments applied to groundnut crop showed a conspicuous influence on all the biological as well as physical soil quality parameters except bulk density. Even, the interactive effects of tillage and fertilizer sources did not significantly influence any of these parameters except DHA. Among the different nutrients sources applied, organic sources of nutrients resulted in significantly highest amount of MBC (272.4 µg g^{-1}) while the conjunctive nutrient application showed highest LC (293.7 µg g^{-1}). Though these soils suffer from poor physical structure, practice of tillage and nutrient management treatments for 6 years did not alter the soils bulk density. The results may be quite conspicuous, if these practices are practiced over a long-term period.

Soil quality

Of the 19 soil quality variables selected for the soil quality assessment study, 17 variables were significantly influenced by the tillage and nutrient management treatments while two variables viz., available N and BD were non-significant and hence were dropped from PCA. The PCA of 17 variables showed four PCs with eigen value > 1 and explained 78.9 % variance in the data. In PC_1, pH, Mg, Fe, Mn, DHA and LC were the highly weighted variables of which only Mn was dropped and the rest were retained and included in the final MDS, irrespective of their significant correlations with each other. While in PC_2, the highly weighted variables included EC and Cu and were correlated with each other. Hence, only EC was retained for MDS and Cu was dropped. The highly weighted variables in PC_3 and PC_4 included only exchangeable Ca and available B respectively and were retained for the final MDS. Hence, the final MDS consisted of pH, EC, exchangeable Ca, Mg, available Fe, available B, DHA and LC as the key indicators. The final key indicators retained in the MDS when regressed as independent variables with groundnut average yield (varied from 948 to 1020 kg ha^{-1}) and SYI (0.51 to 0.56) as dependent variables (AICRPDA, 2006), only B was found significant.

The key soil quality indicators, which were retained in the final MDS viz., pH, EC, exchangeable Ca, exchangeable Mg, available Fe, available B, DHA and LC were employed to compute the soil quality indices. In this set of management treatments, the soil quality indices varied from 2.01 to 2.77 (Table 5). It was observed that the effect of tillage, herbicide and conjunctive use of organic and inorganic sources of nutrients in aggrading the soil quality under groundnut cropping system in Alfisols at Anantapur was quite conspicuous. Among the tillage practices, low tillage played a significant role in improving the soil quality (SQI 2.43) which was followed by conventional tillage practice (SQI 2.37) while the application of herbicide in addition to low tillage practice could aggrade the soil quality to a lowest extent (SQI 2.28). Among the conjunctive nutrient treatments, the sole 100% organic treatment (SQI 2.62) was proved quite superior in improving the soil quality followed by conjunctive nutrient application as 50% organic + 50% inorganic (SQI 2.35), while the sole 100% inorganic nutrient application could aggrade soil quality to the lowest extent (SQI 2.10). Of all the treatments, low tillage + 100% organic maintained the highest SQI of 2.77 followed by low tillage + Herbicide + 100% organic (2.56) which was at par with conventional tillage + 100% organic with SQI of 2.53. The treatment that could maintain the lowest soil quality was low tillage + 100 % inorganic with SQI of 2.01. However, the relative order of performance of the treatments in maintaining soil quality was T2 F1: LT + 100% organic (2.77) > T3 F1: LT + Herbicide + 100% organic (2.56) = T1F1: CT + 100% organic (2.53) = T2F2: LT + 50% organic + 50% inorganic (2.50) > T1F2: CT + 50% organic + 50% inorganic (2.34) = T1F3: CT + 100 % inorganic (2.22) = T3F2: LT + Herbicide + 50% organic + 50% inorganic (2.20) = T3F3: LT + Herbicide + 100 % inorganic (2.07) = T2F3: LT + 100 % inorganic (2.01). The RSQI values varied from 0.70 to 0.97 across the management treatments. The percent contributions of key indicators towards soil quality indices were also computed and were as follows: pH (21%), EC (6%), exchangeable Ca (4%), Mg (15%), available Fe (16%), B (4%), DHA (13%) and LC (21%) (Fig 2). It was observed that, of all the indicators, labile carbon played a major role in influencing or aggrading the quality of the soils followed by soil pH.

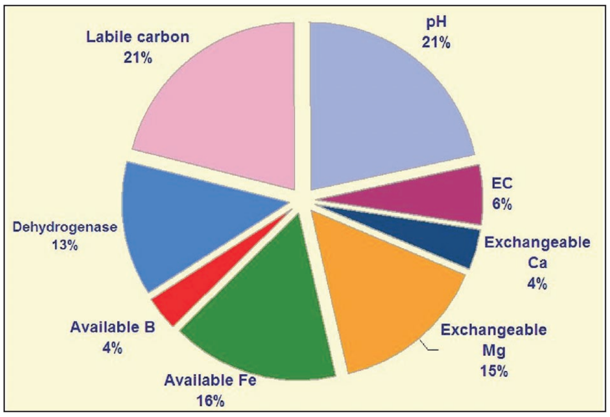

Fig. 2 : Percent contribution of key indicators towards soil quality indices as influenced by different tillage, herbicide and conjunctive use of organic and inorganic sources of nutrients under groundnut cropping system in Alfisols at Anantapur

Experiment 3:

In this experiment, the soil quality assessment study was under taken after 8th year of experimentation. This set of management treatments significantly influenced most of the soil quality indicators (Table 7). Across the INM treatments practiced, the soil reaction varied from slightly alkaline range to near neutral, the variation being from 5.47 to 6.35. The highest amount (3.2 g kg^{-1}) of organic C was recorded in 50% N (glyricidia) + 50% N (inorganic) (T4) followed by 100% N (inorganic (T2) (2.8 g kg^{-1}) and 100% N (organic) (T5) (2.8 g kg^{-1}). As in case of previous combinations of management treatments, this set of treatments also showed build up of P, the variation being 15.1 (control) to 62.7 kg P ha^{-1} (100 % inorganic). Status of available N remained low with variation from 117.5 (control) to 140.1 (50% N (glyricidia) + 50% N (inorganic). The INM treatments followed in this castor-groundnut system proved to be quite effective in influencing the other chemical soil quality parameters viz., exchangeable Ca and Mg as well as DTPA extractable micronutrients. Of all the INM treatments, application of 100% inorganic source of fertilizers recorded significantly highest amounts of available S (34.1 µg g^{-1}), Zn (2.47 µg g^{-1}), Fe (13.8 µg g^{-1}), and B (0.68 µg g^{-1}) while application of 50% N (glyricidia) + 50% N (inorganic) recorded the highest Mn content (29.7 µg g^{-1}). From the study, it was observed that the INM treatments significantly influenced all the biological parameters as well as the mean weight diameter. The application of nutrients through sole organic sources recorded significantly highest amounts of DHA (3.21 µg TPF hr^{-1} g^{-1}), MBC (290.6 µg g^{-1}), labile carbon (261.5 µg g^{-1}) and mean weight diameter (0.29 mm) followed by their conjunctive application.

Soil quality

Among the set of 19 soil quality indicators chosen for the study, except BD, all the variables were found to be significantly influenced by the management treatments and hence were considered for PCA. In the PCA of 18 variables, four PCs had eigen value >1 and explained 89.9% of variance in the data.. In PC_1, EC, P and S were the highly weighted variables and were also observed to have significant correlation with each other.. But considering their importance in these soils, all the three variables were retained for the final MDS. In PC_2, Cu and LC were the highly weighted variables of which only LC was retained for the MDS considering its significant correlation with Cu. In PC_3 and PC_4, B and MWD were the highly weighted variables respectively and hence were retained for the MDS. Hence, the final MDS consisted of EC, available P, available S, available B, LC and MWD. These were the key indicators, which significantly represented soil quality under groundnut-castor rotation system in Alfisols of Anantapur. The key indicators when regressed as independent variables with management goals (groundnut and castor yields and their SYIs) as dependent variables (AICRPDA, 2006), the coefficient of determination varied from 0.969 to 993 and available S, B and MWD were significant (Table 4). The soil quality indices were computed using six key indicators viz., EC, available P, available S, available B, LC and MWD, which were qualified and retained in the final MDS. The soil quality indices as influenced by different nutrient management treatments on soil quality indices in castor + groundnut system varied from 0.85 to 1.73 across the treatments (Table 5). It was observed that application of 100% N (inorganic) maintained significantly highest soil quality with SQI value of 1.73. This was followed by application of 50% N (glyricidia) + 50% N (inorganic) with an SQI of 1.52. The control plot maintained the lowest soil quality. The relative order of performance of the treatments in maintaining soil quality was: T2: 100% N (inorganic) (1.73) > T4: 50% N (glyricidia) + 50% N (inorganic) (1.52) > T3: 50% N (compost) +

Table 4 : Multiple regressions of the minimum data set (MDS) components with management goal attributes at different probability (*P*) levels

Goal or Function	R^2 **	Most Significant MDS Variables	P
Groundnut pod average yield under mono cropping system	0.993	S, B	> 0.002, >0.009
Groundnut SYI under mono cropping system	0.992	S, B	> 0.003, >0.011
Castor average yield under mono cropping system	0.948	MWD	> 0.056
Castor SYI under mono cropping system	0.969	MWD	> 0.054
Groundnut pod average yield under groundnut-castor rotation system	0.980	S, MWD	> 0.011, > 0.095
Groundnut SYI under groundnut- castor rotation system	0.978	S, MWD	> 0.011, > 0.095

** Significant at $P = 0.01$ level

Table 5 : Soil quality indices and relative soil quality indices as influenced by different soil and nutrient management practices under different cropping systems in Alfisols at Anantapur

S.No.		SQI	RSQI
Experiment 1: Integrated Nutrient Management for Groundnut			
T1	Control	1.32	0.66
T2	20-40-40 NPK kg ha^{-1}	1.45	0.73
T3	FYM @ 4 t ha^{-1}	1.96	0.98
T4	10-20-20- NPK kg ha^{-1} + FYM 4t ha^{-1}	1.96	0.98
T5	20-40 40 NPK kg ha^{-1} + $ZnSO_4$ @ 50 g ha^{-1} (once in 3 years)	1.64	0.82
T6	20-40-40 NPK kg ha^{-1} + G.nut shells @ 4 t ha^{-1}	1.75	0.87
Experiment 2: Tillage and Nutrient Management for Resource Conservation in Groundnut (TMV-2)			
T1 F1	CT + 100% organic	2.53	0.89
T1 F2	CT + 50% organic + 50% inorganic	2.34	0.82
T1 F3	CT + 100 % inorganic	2.22	0.78
T2 F1	LT + 100% organic	2.77	0.97
T2 F2	LT + 50% organic + 50% inorganic	2.50	0.87
T2 F3	LT + 100 % inorganic	2.01	0.70
T3 F1	LT + Herbicide + 100% organic	2.56	0.89
T3 F2	LT + Herbicide + 50% organic + 50% inorganic	2.20	0.77
T3 F3	LT + Herbicide + 100 % inorganic	2.07	0.72
Experiment 3: Integrated nutrient supply system for rainfed semiarid tropics under Castor + Groundnut rotation			
T1	Control	0.85	0.48
T2	100% N (inorganic)	1.73	0.97
T3	50% N (compost) + 50% N (inorganic)	1.41	0.79
T4	50% N (glyricidia) + 50% N (inorganic)	1.52	0.85
T5	100% N (organic)	1.12	0.63

50% N (inorganic) (1.41) > T5: 100% N (organic) (1.12) > T1: Control (0.85). The percent contribution of these key indicators towards soil quality indices was: EC (23%), available P (21%), available S (22%), available B (9%), LC (21%) and MWD (4%) (Fig 3). It was observed that out of the key indicators, EC, available P, available S and LC played an equal and major role in influencing the quality of these Alfisols under castor-groundnut rotation.

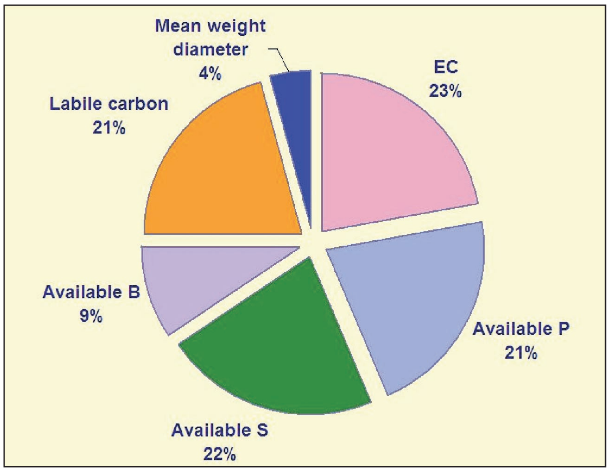

Fig. 3 : Percent contribution of key indicators towards soil quality indices as influenced by different integrated nutrient management treatments in castor + groundnut system in Alfisols at Anantapur

Thus, in the present study, key soil indicators were identified and soil and nutrient management treatments were evaluated for their performance in terms of their influence on soil quality. Researchers can select the few treatments for further study and future recommendations to the farmers.

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