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Depth wise physical properties of soils under different cropping systems in inceptisols and Vertisols of Northern Telangana Zone

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Abstract
A survey was carried out during 2019-2020 to find out the impact of different Cropping Systems (Rice-Rice, Rice-Maize, Cotton-Fallow and Turmeric-Sesamum) on the behavior of physicochemical properties of soil in both the soil types (Inceptisols and vertisols). Samples were collected from three depths (0-15, 15-30 and 30-45 cm at each cropping system site) of Northeren Telangana Zone (Adilabad, Nizamabad and Karimnagar). The results of the present investigation revealed that all the soil samples are neutral to alkaline in nature, low in salinity, majority of the soil samples were Sandy Clay Loam and Clay in texture in inceptisols and vertisols respectively. Low to medium in soil organic carbon content, Bulk Density and Clay had greater influence on organic carbon specially in vertisols. Sand content had showed significant negative influence, while clay has positively related SOC. All the parameters analysed were decreasing with increasing depth, except for Electrical conductivity.

Keywords: Depth, physical, soils, cropping systems, inceptisols

Introduction
The present investigation was carried out in Vertisols and Inceptisols of Northern Telangana Zone, as they are the major soil types found predominantly in Telangana state than other soil types. The physico-chemical properties like pH, EC, BD, Texture and organic carbon play important role in relation to availability of nutrients in soils and thereby on crop growth and production. Also inappropriate selection of cropping system and their management practices cause Degradation of soil quality.

So there is a need to study about the suitable cropping system practice and the soil type, which is capable of maintaining soil quality and also improving crop productivity. Have selected four cropping systems which are predominantly cultivated in Northern Telangana Zone such as Rice-Rice, Rice-Maize, Cotton-Fallow and Turmeric-sesamum cropping systems. And also the behavior of physico-chemical properties of these soils can be known through depth wise anaylsis. Therefore, in this study, an attempt was made to assess the depth-wise behavior of Physicochemocal properties of selected cropping systems of Vertisols and inceptisols of NTZ.

Materials and Methods
Soil Samples were collected from three districts of northern Telangana zone i e., Adilabad, Karimnagar, Nizamabad in which a total of 26 mandals have been covered representing 5 sites for each cropping system. A total of 4-7 representative soil samples were collected from three depths(0-15, 15-30, 30-45 cm) at each site randomly. All the soil samples were shade dried. The dried soil samples were passed through 2.0 mm sieve for the analysis of the physical properties following standard methods (Page *et al*., 1982) [11].

pH
The pH of the soil was determined in 1: 2.5: soil: water and soil: 0.02 M $CaCl_2$ suspension by using digital pH meter (Jackson, 1973) [9].

Electrical conductivity
Electrical conductivity (EC) of soil-water suspension (1: 2) was estimated with the help of a direct reading conductivity meter (Model: systronics, 363) outlined by (Jackson, 1973) [9].

Bulk density (BD)
Bulk density was determined by core sampler (5.0 cm length and 5.0 cm diameter) method following the protocol of Blake and Hartge (1986). The method involved sampling a soil core at 0.2 m depth by using a core sampler and measured bulk density through the mass-volume relationship as:

$$\text{Bulk density } (Mgm^{-3}) = \frac{\text{Oven dry weight of the soil core at } 105^{\circ}C}{\text{Volume of the soil core}}$$

Soil Texture: The different size fractions of the experimental soil were determined by bouyoucos hydrometer method as outlined by Gee and Bauder (1986) [6].

Table 1: Sand, silt, clay content (percentage) and textural class of experimental sites

		Inceptisols											
		Rice-Rice			Rice-Maize			Cotton –Fallow			Turmeric-Sesame		
		0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
Site 1	Sand	47.5	52.6	59.3	62.3	63.2	80	65.1	71.3	77.4	67.1	66.1	67.6
	Silt	18.7	18.7	18.2	9	18.8	8.9	8	10.9	7.6	15.6	16.9	17
	Clay	33.8	28.7	22.5	28.7	18	11.1	26.9	17.8	15	17.3	17	15.4
	Class	SCL	SCL	SCL	SCL	SL	LS	SCL	SL	SL	SL	SL	SL
Site 2	Sand	46.6	65	67.3	55.6	56.7	63.8	71.1	74.3	70.1	78.2	72.6	74.2
	Silt	17	12	11.7	15.6	15.5	14.4	8.1	11.7	12	8.4	12.1	12.4
	Clay	36.4	23	21	28.8	27.8	21.8	20.8	14	17.9	13.4	15.3	13.4
	Class	SC	SCL	SCL	SCL	SCL	SCL	SCL	SL	SL	SL	SL	SL
Site 3	Sand	47.1	55.9	53.4	50.3	63.1	65.6	59.2	66.3	68	58.4	65.1	60.7
	Silt	14.8	9.7	17.1	15.6	14.6	13.2	11	13.7	13	14.1	14	14.6
	Clay	38.1	34.4	29.5	34.1	22.3	21.2	29.8	20	19	27.5	20.9	24.7
	Class	SC	SC	SCL	SC	SCL	SCL	SCL	SCL	SL	SCL	SCL	SCL
Site 4	Sand	55	61	60	61.8	69.3	68.1	59.1	69.5	68	70.4	69.7	66.1
	Silt	10.4	15.9	19	9.2	18.7	14	9.9	10.8	16.7	6.3	10.1	13.2
	Clay	34.6	23.1	21	29	12	17.9	31	19.7	15.3	23.3	20.2	20.7
	Class	SCL	SCL	SCL	SCL	SL	SL	SCL	SL	SL	SCL	SL	SCL
Site 5	Sand	45.2	70.1	68.9	50.2	60.2	58.3	63	68	70	69.2	70.1	68.9
	Silt	16	9.5	10.5	18.9	18.1	17.6	9	12.3	9	11.2	13.1	12.5
	Clay	38.8	20.4	20.6	30.9	21.7	24.1	28	19.7	21	19.6	16.8	18.6
	Class	SC	SCL	SCL	SCL	SCL	SCL	SCL	SL	SCL	SL	SL	SCL
		Vertisol											
		Rice-Rice			Rice-Maize			Cotton –Fallow			Turmeric-Sesame		
		0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
Site 1	Sand	22.8	24.4	26.8	26.8	25	25.8	35.5	39.1	40.6	42.3	42.5	49.7
	Silt	14.2	15.6	17	18.8	23.4	23.8	15	11.4	10.9	12.4	14.7	10.1
	Clay	63	60	56.2	54.4	51.6	50.4	49.5	49.5	48.5	45.3	42.8	40.2
	class	C	C	C	C	C	C	C	C	C	C	C	SC
Site 2	Sand	31.8	34	32.8	29.8	31.8	26.1	39.5	48	48	44.8	54	46
	Silt	12.8	14.5	12.7	23.5	25.9	28	18	15	15	12.5	14	18
	Clay	55.4	51.5	54.5	46.7	42.3	45.9	42.5	37	37	42.7	32	36
	Class	C	C	C	C	C	C	C	SC	SC	C	SCL	SC
Site 3	Sand	25.5	27.1	29.4	30.7	31.5	33	30.5	29.1	32.1	39.3	44.7	46.7
	Silt	9.5	11.5	10.7	10.5	16.2	26.5	21.4	25.7	27.8	12.2	11.2	10.8
	Clay	65	61.4	59.9	58.8	52.3	40.5	48.1	45.2	40.1	48.5	44.1	42.5
	Class	C	C	C	C	C	C	C	C	C	C	C	SC
Site 4	Sand	26.4	23.7	30.6	24.9	32.1	32.9	37.1	38.8	37	45.9	51.5	46.8
	Silt	17.2	23.7	20.9	16.2	13.5	13.4	20.5	21	25	13.6	11.1	14.8
	Clay	56.4	52.6	48.5	58.9	54.4	53.7	42.4	40.2	38	40.5	37.4	38.4
	Class	C	C	C	C	C	C	C	C	CL	SC	SC	SC
Site 5	Sand	34.1	33.9	43.5	47.6	45.5	52.9	50.8	50.1	57.1	36.8	30.4	38.8
	Silt	13.2	13.7	17.5	14	14	11.4	10.7	12.1	11.4	17.2	20.9	17.4
	Clay	52.7	52.4	39	38.4	40.5	35.7	38.5	37.8	31.5	46	48.7	43.8
	Class	C	C	C	SC	SC	SC	SC	SC	SCL	C	C	C

SCL: Sandy Clay Loam, SC: Sandy Clay, SL; Sandy Loam, LS: Loamy Sand, C; Clay, CL: Clay Loam.

Organic carbon: Organic carbon in soil sample was analysed by wet chromic acid digestion outlined by Walkley and Black (1934). To a 0.5 g of 0.5 mm sieved soil in 500 mL conical flask, 10 mL of 1 N potassium dichromate and 20 mL of conc. H_2SO_4 were added and mixed gently for a min and allowed the mixture for reaction to take place on asbestos sheet for 30 min. At the expiry of 30 min, 10 ml of orthophosphoric acid, 200 mL distilled water and 1 mL of diphenylamine indicator were added. Then the solution was back titrated against 0.5 N ferrous ammonium sulphate till the appearance of green colour. A blank was run without soil simultaneously.

$$\text{Organic carbon } (\%) = \frac{10(B-S)}{B} \text{ x } \frac{100}{\text{wt of the soil (g)}} \text{ x } 0.003$$

Where,
B – Blank titre value
S – Sample titre value

Results and Discussion

Physio-chemical properties of soil

Basic physical and Physio-chemical properties of the soils under different treatments are presented in Table 2.

Soil reaction pH

Soil reaction (pH) of the selected soil sites were neutral to alkaline in nature. Irrespective of cropping systems, soil pH values were significantly higher in vertisols (S_2) over inceptisols (S_1) in all the three depths (0-15, 15-30 and 30-45 cm). Results also showed that soil pH increased with soil depth in all the treatments (Table 2.).

Under four cropping systems compared, the higher pH value was recorded in 30-45 cm depth under rice-rice (CS_1) cropping system (8.23) and the lowest pH value was recorded in surface soils (0-15 cm) of cotton - fallow (CS_3) (7.30) cropping system. At surface soil (0-15 cm) CS_3 has recorded significantly lower pH value (7.30), whereas other cropping systems pH values were on par with each other.

The interaction effect among soil orders and cropping systems on soil pH was found to be significant. On an average of three depths, soil pH values were in the order of rice-rice (CS_1) (8.18) followed by turmeric- sesame (CS_4) (7.76) > rice-maize (CS_2) (7.60) and cotton – fallow (CS_3) (7.16) under inceptisols. But the results of pH under vertisol order has not followed the same trend, pH was in the decreasing order of rice-maize (CS_2) (8.22) > rice-rice (CS_1) (7.88) > cotton-fallow (CS_3) (7.85) and turmeric- sesame (CS_4) (7.81).

Electrical conductivity (d Sm^{-1})

Soil electrical conductivity (EC) of all the sites were found to be low and non-saline (Table 2.). Electrical conductivity values were significantly higher under inceptisols in all the three depths over vertisols. EC values ranged from 0.17 to 0.27 dS m^{-1}. Under cropping systems, rice-rice cropping system showed higher values, which were on par with rice-maize and turmeric-sesame cropping systems, on the other hand cotton-fallow showed significantly lower EC values. The values of EC ranged from 0.15 to 0.27 dS m^{-1}.

The interaction effect among soil orders and cropping systems on soil EC was found to be significant in 0-15 and 15-30 cm soil depths where as at 30-45 cm values were on par. Soil EC was in the decreasing order of R-R (0.28) >T-S (0.24) > R-M (0.23) and C-F (0.18) cropping system in inceptisol. But the results of EC under vertisol order has not followed the same trend, T-S (0.22) followed by R-R = R-M (0.20) and C-F (0.13).

Table 2: Effects of cropping systems on depth-wise variations of Physio-chemical properties of soil under inceptisol and vertisols

Soil order	pH			EC (d Sm-1)			BD (Mg m-3)			SOC (g kg-1)		
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
S_1	7.48	7.72	7.82	0.27	0.23	0.21	1.41	1.46	1.51	4.96	3.86	2.97
S_2	7.83	7.94	8.05	0.21	0.18	0.17	1.46	1.51	1.56	5.29	4.46	3.26
S.Em±	0.1	0.07	0.07	0.01	0.01	0.01	0.02	0.01	0.01	0.11	0.08	0.07
CD	0.29	0.2	0.19	0.03	0.02	0.02	0.05	0.04	0.04	0.33	0.23	0.2
Cropping System												
CS_1	7.84	8.02	8.23	0.27	0.24	0.21	1.38	1.44	1.5	6.16	5.25	3.99
CS_2	7.77	7.94	8.02	0.26	0.2	0.19	1.43	1.5	1.54	5.15	4.09	3.14
CS_3	7.3	7.57	7.65	0.17	0.15	0.15	1.49	1.53	1.58	4.41	3.43	2.49
CS_4	7.73	7.78	7.85	0.25	0.23	0.21	1.44	1.47	1.52	4.77	3.86	2.84
S.Em±	0.14	0.1	0.09	0.01	0.01	0.01	0.03	0.02	0.02	0.16	0.11	0.1
CD	0.41	0.28	0.27	0.04	0.03	0.03	0.07	0.06	0.05	0.46	0.32	0.28
Interactions												
S_1CS_1	8	8.18	8.35	0.32	0.29	0.24	1.33	1.41	1.48	5.99	5.14	3.84
S_1CS_2	7.46	7.62	7.71	0.26	0.22	0.22	1.41	1.49	1.51	4.88	3.56	2.96
S_1CS_3	6.76	7.34	7.38	0.2	0.16	0.18	1.47	1.5	1.55	4.28	3.11	2.38
S_1CS_4	7.71	7.73	7.84	0.28	0.24	0.21	1.41	1.45	1.51	4.68	3.63	2.69
S_2CS_1	7.67	7.86	8.1	0.22	0.19	0.18	1.43	1.47	1.52	6.32	5.36	4.13
S_2CS_2	8.07	8.25	8.32	0.26	0.18	0.16	1.45	1.52	1.57	5.43	4.62	3.32
S_2CS_3	7.83	7.81	7.92	0.14	0.14	0.12	1.5	1.55	1.62	4.54	3.74	2.59
S_2CS_4	7.74	7.83	7.86	0.23	0.22	0.2	1.47	1.5	1.54	4.86	4.1	2.98
S.Em	0.2	0.14	0.13	0.02	0.02	0.02	0.04	0.03	0.02	0.23	0.16	0.14
CD	0.58	0.4	0.38	0.05	0.04	NS	NS	NS	NS	NS	NS	NS
CV	5.87	3.95	3.7	17.1	16.4	18.6	5.67	4.41	3.58	9.84	8.4	9.9

S_1- inceptisols, S_2- Vertisols, CS_1- Rice-Rice, CS_2- Rice-Maize, CS_3- Cotton –Fallow, CS_4- Turmeric-Sesame, SE m: Standard error of mean, CD: Critical difference, CV: Critical Variance

Bulk Density (Mg m^{-3})

Irrespective of depth, bulk density values ranged from 1.41 to 1.56 Mg m^{-3}. Vertisols showed significantly higher values over inceptisols in all the three depths. Bulk density values increased with increasing depth which might be due to more compaction of finer particles, low organic matter and less aggregation (USDA, NRCS. 2008). Higher values of bulk density with depth are also reported by Bhattacharya *et al.*, 2003. Cropping systems have also influenced soil bulk density significantly. At surface soil (0-15 cm) significantly higher bulk density was recorded under cotton-fallow (1.49) cropping system, which was on par with turmeric-sesame (1.44) and rice-maize (1.43), at par with rice-rice (1.38) cropping system. However, the sequence in sub surface soils (both 15-30 and 30-45 cm) were cotton-fallow > rice-maize > turmeric-sesame and rice-rice. There was a negative correlation between soil organic carbon (SOC) concentration (g kg^{-1}) and the BD (Fig.1.). Similar to the relationship were reported by Gebrehiwot *et al.*, 2018. Soil BD decreased with the increasing SOC concentration (Zhou *et al.*, 2020) [16]

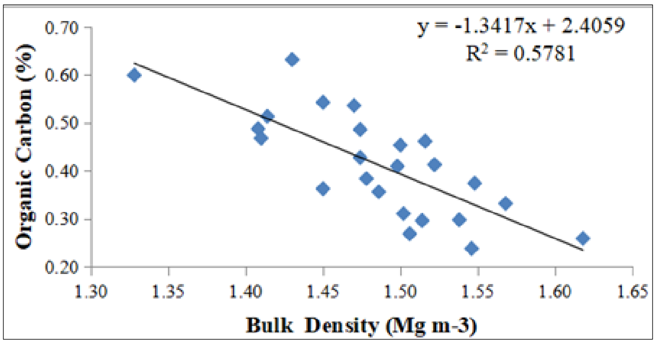

Fig 1: Relationship between soil organic carbon (SOC) concentration (%) and bulk density (Mg m^{-3}) of soils.

Soil organic carbon (SOC)

Soil orders and cropping systems have significantly influenced SOC concentration in soils. Vertisols have showed 6.65, 15.54 and 9.76 % higher amount of SOC in 0-15, 15-30 and 30-45 cm depths, respectively over inceptisols (Table 2). This might be due to amount and type of clay content present in vertisols, which might bind carbon physically, chemically and biochemically (Venkanna *et al.*, 2014). Irrespective of soil order, found abrupt decline in SOC concentration along soil depth (Fig. 2. a), with middle (15-30 cm) and lower (30-45 cm) layers contained only 33.51 and 25.12% of total profile (0-45 cm) carbon content.

In cropping systems, CS_1 has maintained higher amount of SOC (6.16 g kg^{-1}) followed by CS_2 (5.15 g kg^{-1}) > CS_4 (4.77 g kg^{-1}) > CS_3 (4.41 g kg^{-1}) at surface soil (0-15 cm). The same trend was observed in the sub surface soils also (Fig. 2. b). CS_1 and CS_2 have shown significantly higher SOC in all the three soil depths over other cropping systems. This may be due to rice-rice cropping system was under submergence for 8-9 months in a year, prolonged water logging conditions may reduced the decomposing of added crop residues (Mandal *et al*., 2008) [10]. Rice-maize system was under submergence for 3-4 months, which has recorded on par SOC values. On the other hand, arable condition under cotton fallow and turmeric-sesame might cause oxidation of soil organic carbon, hence showed significantly lower SOC content in soil.

Interaction effect of soil orders and cropping systems were non-significant.

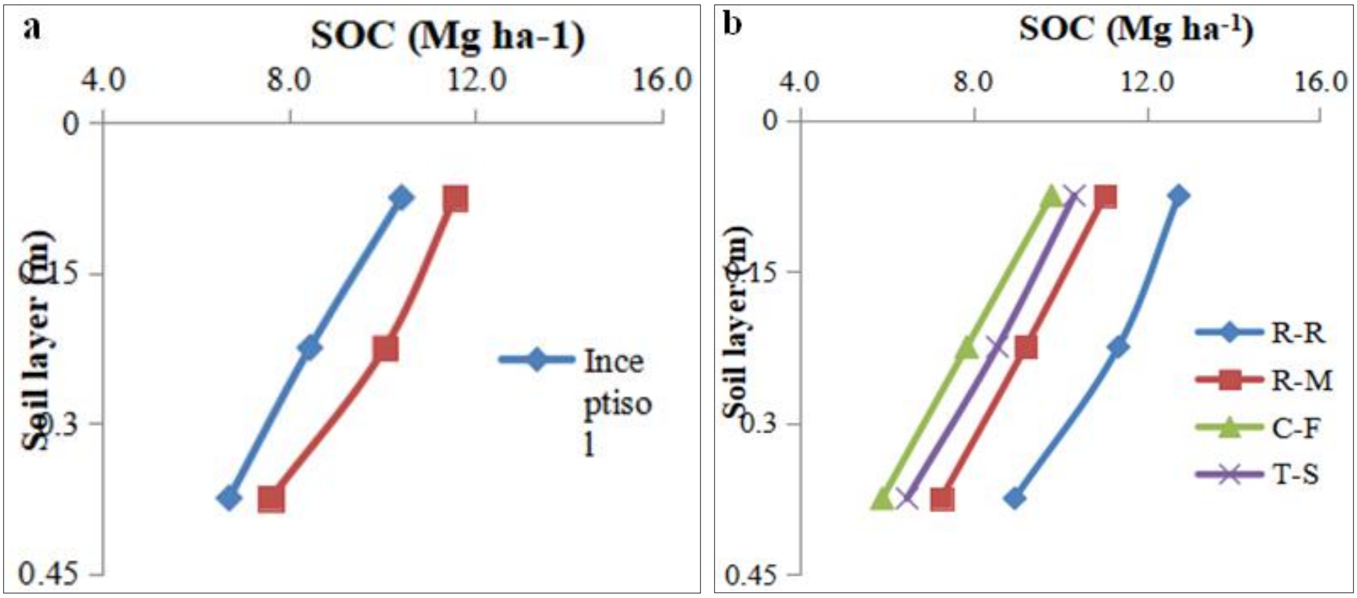

Fig 2 a, b: Soil organic carbon (Mg C ha^{-1}) content of the soils along depth under different a) soil types and b) cropping systems

Soil texture

Sand, silt and clay content of soils under different cropping system and soil types were given in Table 2. Under inceptisol sand, silt and clay contents were in the range of 45.2 to 80.0, 6.3 to 19.0 and 11.1 to 38.8 percent, respectively. Whereas, under vertisols sand, silt and clay contents were in the range of 22.8 to 57.1, 9.5 to 28.0 and 31.5 to 65.0 percent, respectively.

Results has shown that SOC and soil clay were positively correlated under both inceptisols (Y=0.011X+0.139; R^2=0.446) and vertisols (Y=0.008+0.0.21; R^2=0.423) (Fig. 3. a, b). Bonde *et al*. (1992) [2] and Saggar *et al*. (1996) [12] noted that, in general, more than half of the total SOC is associated with the clay (< 2.0 µm) fraction, probably due to the protection effect of clay on SOC mineralization. The degree of protection provided by clay appears to be dependent on the type of clays with the higher porosity (eg. allophane), expanding and high surface-charged clays (eg. montmorillonite) (Zech *et al*., 1997) [15] offering more protection than kaolinite (Hassink, 1994; Franzluebbers *et al*., 1996) [8, 5].

With increase in sand content in soil SOC content declined proportionally i.e., sand and SOC were negatively correlated under inceptisols (Y=-0.008X+0.929; R^2= 0.360) and vertisols (Y= -0.005X+0.652; R^2= 0.241) (Fig.3. c, d). Sand particles have a limited capacity to stabilize organic compounds on mineral surfaces compared with clay (Feng *et al*., 2013) [4] and the association is more labile Christensen (1992) [3].

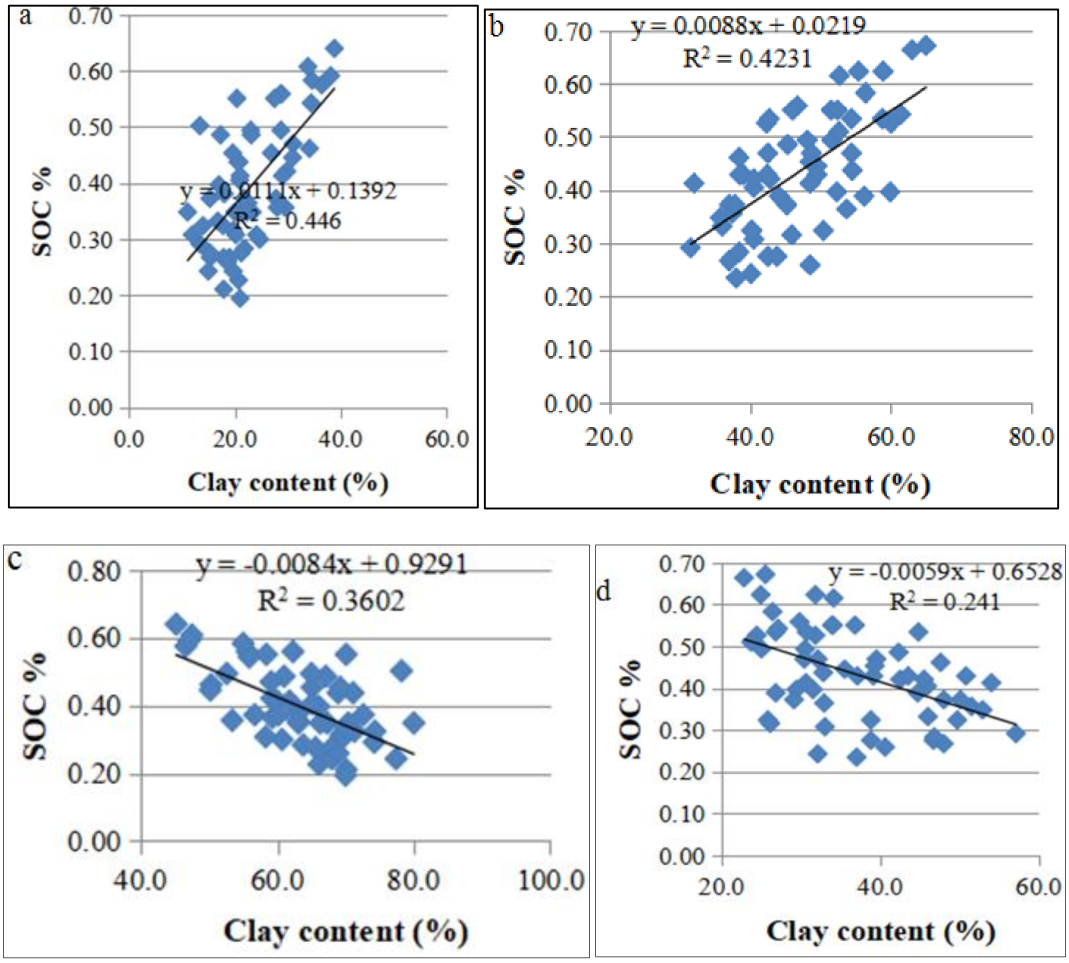

Fig 3: Relationship between SOC with soil clay and sand content a. Clay and SOC under inceptisol; b. Clay and SOC under vertisol; c. Sand and SOC under inceptisol; d. Sand and SOC under vertisols.

Conclusion

Physical properties such as pH, EC, BD, organic carbon are having decreasing value with increasing depth. Overall performance of all these properties monitored were better in vertisols of Rice-Rice cropping system when compared to inceptisols. As Vertisols has more clay content, which may bind carbon Physicaly, chemically and biochemically in it. CS1 has greater root biomass and prolonged submerged conditions.

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