Journal of the Indian Society of Soil Science, Vol. 65, No. 1, pp 48-53 (2017)
DOI: 10.5958/0974-0228.2017.00007.X

Particle Size Distribution, Soil Organic Carbon Stock and Water Retention Properties of Some Upland Use System of Odisha and Assessing their Interrelationship

Gouranga Kar*, Ashwani Kumar, Sunita Panigrahi, Pravat Ranjan Dixit and Himadri Nath Sahoo

ICAR-Indian Institute of Water Management, Bhubaneswar, 751 023, Odisha

Analyzed particle size distribution, soil water retention properties and organic carbon (SOC) stock of some upland cropping/land use systems of a watershed of Odisha (Kadalipal watershed, Dhenkanal, Odisha) *viz.,* forest grazing land, maize, rice, groundnut, cucumber, okra, cowpea, cashew nut plantation and barren land and assessed their interrelationship. An overview of soil texture of the samples revealed that sandy clay loam texture constituted about 60% of all samples in different cropping systems and at different depths. Clay loam, sandy loam and loamy texture represented 20, 15 and 5%, respectively. Bulk density (BD) of surface layer ranged from 1.39 Mg m^{-3} in C_7 (cashew plantations) to 1.48 Mg m^{-3} in forest grazing land (C_O). The average clay content in the soil profile ranged from 23.8% in C_0 (grazing land) to 32.6% in C_6 (cowpea). The SOC at surface (0-0.15 and 0.15-0.30 m) layers were higher in forest grazing land (9.6 to 10.8 g kg^{-1}) and inside cashew plantation (12.3 to 13.5 g kg^{-1}) whereas, SOC was low in crop cultivated plots. Continuous tillage and cultivation of nutrient exhaustive crops might have favoured rapid rate of mineralization than that of accumulation of SOC in these fields. Among crop fields, legumes (groundnut, cowpea) hold promise for greater accumulation of SOC in the long-term. Soil water retention was found to be significantly correlated with SOC at 0-0.15 m depths only rather than the SOC of whole profile. Soil pH, BD, porosity had significant relationship ($P< 0.05$) with SOC content.

Key words: Particle size distribution, soil organic carbon, soil moisture retention, upland

Based on the simulation of global circulation models (GCMS) under different scenarios, future global average temperatures are expected to rise. In wake of global warming and climate change, sequestration of carbon from atmosphere or reduction of its emission are the two options to minimize the rate of global warming and thus climate change. Carbon sequestration is one of the mechanisms for long-term mitigation of carbon and global warming, however, the extent of carbon storage in soil depends on the type of vegetation it supports, edaphic and climatic factors of the specific area (Lal 2004; Palumbo *et al*. 2004; Koul and Panwar 2012). It is thus imperative to have information on carbon storage under site-specific land-use and cropping systems under specific management practices to enhance carbon uptake by plants and storage in soils. Due to carbon storage and modifications of management practices, soil organic matter changes which may affect soil structure, adsorption properties and soil water retention properties (Rawls *et al*. 2003). Soil water retention is a major soil hydraulic property which determines available water capacity of soils and greatly affects cropping pattern and length of the growing period of a region. Keeping the importance of above points in view, in this study we assessed particle size distribution, SOC stocks and water retention properties of some upland cropping systems of eastern India and correlation matrix was developed by correlating soil water retention at -33 kPa and -1500 kPa with particle sizes (clay, sand and silt), SOC and some other soil properties. Simulation model that rely on particle size distribution, SOC can use their relationships for determining soil water retention properties.

*Corresponding author (Email: kar_wtcer@yahoo.com)

Materials and Methods

Soil sample collection and analysis of basic soil properties

Nine major land use/ cropping systems of upland of the Kadalipal watershed, Dhenkanal, Odisha. (20°60′ N latitude and 85°57′ E longitude, altitude 69 m above mean sea level) namely forest grazing land (C_O), maize (C_1), rice (C_2), groundnut (C_3), cucumber (C_4), okra (C_5), cowpea (C_6), cashew plantation (C_7) and barren land (C_8) were selected for assessing their carbon (C) stock in the profile. Soil samples (disturbed and undisturbed) were collected at 3 locations from each land use/cropping system at 0-0.15, 0.15-0.30, 0.30-0.45, 0.45-0.60, 0.60-0.90, and 0.90-1.20 m depths for laboratory analyses and results were averaged. For determining bulk density, the undisturbed core samples were taken at respective depths with the help of 5 cm inner diameter and 5.1 cm height stainless steel cores. Along with undisturbed core samples, a sufficient amount of disturbed soil samples were taken from each depth within the profile for the analysis of soil pH, particle size distribution (% sand, silt and clay), organic carbon content, soil water retention at different suctions. Particle size distribution was analyzed by the Bouyoucos hydrometer method. The disturbed soil samples were placed in a refrigerated container to minimize any mineralization of organic matter prior to determination of organic carbon content. Soil organic carbon (SOC) was analyzed using the Walkley and Black (1934) method and SOC pool of the profile (Mg ha^{-1}) was computed by multiplying the SOC concentration (g kg^{-1}) by the bulk density (Mg m^{-3}), depth (m) and factor by 10. Soil pH was determined in distilled water at a ratio of 1:2 (soil: water).

The water content at different suctions *viz*., -33 kPa (field capacity), -100 kPa, -300 kPa, -500 kPa, -1000 kPa and -1500 kPa (permanent wilting point) was measured using pressure plate apparatus (Soil Moisture Equipment Corporation, USA) (Klute 1986) and soil moisture characteristics curve (matric suction-soil moisture relationship) for each land use systems and depths were derived. Correlation matrix was developed among SOC, water retention at field capacity, permanent wilting point, BD, particle size distribution (sand, silt, clay) and pH. The R^2 and slope of different relationship (single/ multiple/regression) were computed. The organic carbon and water retention at saturation, field capacity (-33 kPa) and permanent wilting point (-1500 kPa) were grouped depth wise and R^2 and slope of the relationship between water retention at field capacity and permanent wilting points of the particular depth and SOC of that layer were derived.

Using PROC CORR of SAS 9.2 software, correlation matrix of water retention, soil organic carbon and other soil properties was established.

Results and Discussion

Particle size distribution, BD, pH, SOC and soil water retention

The depth-wise particle size distribution (sand, silt, clay) and BD of the soil samples were analyzed. Study revealed that the average clay content in the soil profile ranged from 23.8% in C_0 (grazing land) to 32.6% in C_6 (cowpea). The sand content varied between 42.8% in C_6 (cowpea) to 60.1% in C_8 (barren soil). An overview of soil texture of the samples revealed that sandy clay loam texture constituted about 60% of all samples in different cropping systems and at different depths. Clay loam, sandy loam and loamy texture represented 20%, 15% and 5% respectively. Bulk density of surface layer ranged from 1.39 Mg m^{-3} in C_7 (cashew plantations) to 1.48 Mg m^{-3} in forest grazing land (C_O). The forest grazing land (C_O) and uncultivated open barren land (C_8) showed relatively higher BD apparently from compaction from rain drops and reduced root activity. Barren uncultivated soils were observed more compact as it had not been cultivated since long. Growing of no vegetation on it leads to less organic matter returned to soil and hence creates more compactness. Among crop fields, the BD of surface layers (0-0.15 and 0.15-0.30 m) of legume cultivated plots (C_3 and C_6) was lower (1.40-1.41 Mg m^{-2}) than that of cereals (C_1 and C_2) and vegetables (C_4 and C_5). Incorporation of biomass of legumes might be one of the reasons for creating surface layers with low BD. Bulk density increased as the depth of profile sampling increased. The soils of cashew plantation had relatively lower BD (1.39 to 1.41 Mg m^{-3}) at upper layers (0-0.35 m) as compared to the other sites. Litter contribution from the cashew plant might be the reason for the relatively higher porosity on the surface (0-0.30 m) and less BD. Bulk density increased with increasing depth in most cases, which might be attributed to higher porosity of surface soils. Lower BD in surface layers can also be correlated with more organic content which leads to better structure and more porosity. Increased BD with increasing depth was also observed by Christine (2006a) and Koul and Panwar (2012).

The SOC was lower in crop fields and decreased with soil depth in almost all the treatments. The organic carbon at surface (0-0.15 and 0.15-0.30 m) layers ranged from 0.85 to 1.04, 0.46 to 0.60, 0.45 to 0.58, 0.68 to 0.74, 0.53 to 0.57, 0.55 to 0.65, 0.68 to 0.78, 1.09 to 1.35% in Co, C_1, C_2, C3, C_4, C_5, C_6, C_7 and C_8 treatments, respectively. Among crop cultivated fields, SOC in soil profile was low in C_1, C_2, C_4 and C_5 cropping system as compared to other treatments. Continuous tillage and cultivation of these nutrient exhaustive crops favoured rapid rate of mineralization than that of accumulation of SOC in these fields. As a result, these treatments recorded the lowest carbon storage due to faster mineralization of organic carbon. Among field crops, the surface layer of groundnut (C_3) and cowpea (C_6) cultivated fields showed higher SOC content namely, 0.74 and 0.78%, respectively at surface layers. It appears cropping with legumes hold promise for greater accumulation of SOC in the long-term. These legume crops shed a large proportion of foliage with characteristic lignified tissues and litter added to the soil mineralizes slowly to increase the stock of carbon in the soil. Treatment C_7 (cashew plantation) recorded the highest SOC (1.35 and 1.10% at 0-0.15 and 0.15-0.30 m depths, respectively). Litter contribution from the cashew plantation may be the reason for the relatively higher SOC content of surface layers.

The profile soil organic carbon (PSOC) pool was also determined from the SOC content, BD and soil depth as per the procedure mentioned in the methodology. The PSOC stock within 1.2 m depth was 111.1, 59.1, 94.8, 70.2, 62.8, 80.2, 128.4 and 30.61 Mg ha^{-1} for C_0, C_1, C_2, C_3, C_4, C_5, C_6, C_7 and C_8 treatments, respectively (Fig. 1).

Less soil pH was observed in soils where SOC accumulation was more. Since, organic matter was more in surface layers and less in deeper layers, soil pH was less in surface layers and it increased with increase in soil depth. The lower pH in surface layers might be attributed to the leaching of the bases from light textured soils and also due to formation of organic acid during decomposition of organic matter.

Soil water retention and other soil properties

The soil water retention characteristics curves were developed by relating moisture content data at -33 kPa (field capacity), -100 kPa, -300 kPa, -500 kPa, -1000 kPa and -1500 kPa (permanent wilting point) and corresponding suction values (Fig. 2). The soil metric suction-moisture content relationship curve displayed a sharp decrease in moisture content from initially higher to lower values; from -33 kPa to -100 kPa or -300 kPa following a gradual decline till -500 kPa; and the change became negligible thereafter. It was also revealed that higher was the clay and organic carbon content greater was the moisture retention capacity on the surface layers (0-0.30 m). The water retention at field capacity at surface (0-0.15 m) layers were 0.278, 0.314, 0.302, 0.292, 0.288, 0.299, 0.311, 0.344, 0.264 m^3 m^{-3} in C_0, C_1, C_2, C_3, C_4, C_5, C_6, C_7 and C_8 treatments, respectively. Differences in clay and SOC might have played crucial role for variation in soil moisture content. The correlation matrix among

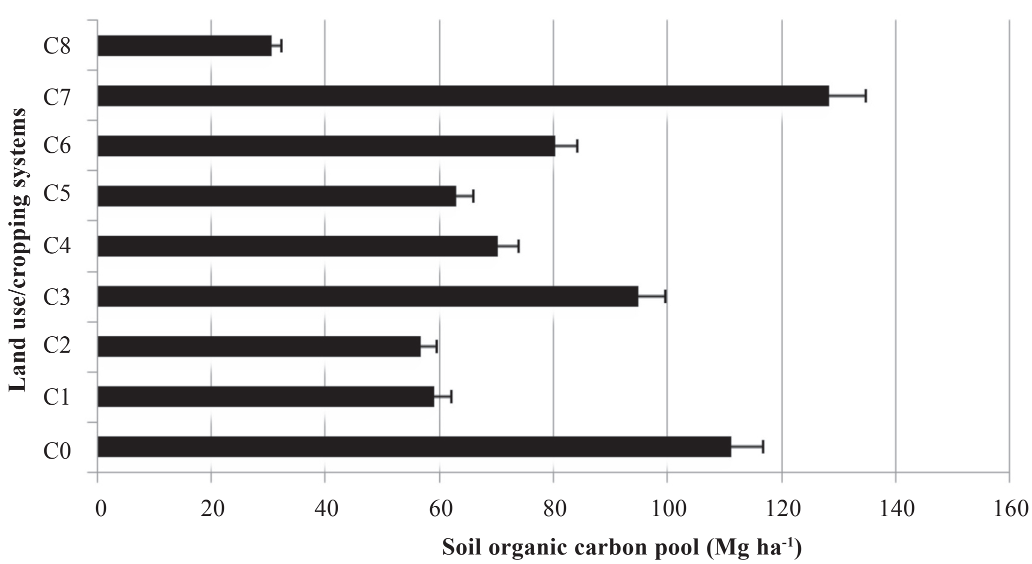

Fig. 1. Soil organic carbon pool in soils under different land use systems (The 'line' above the 'bars' represents standard error of mean)

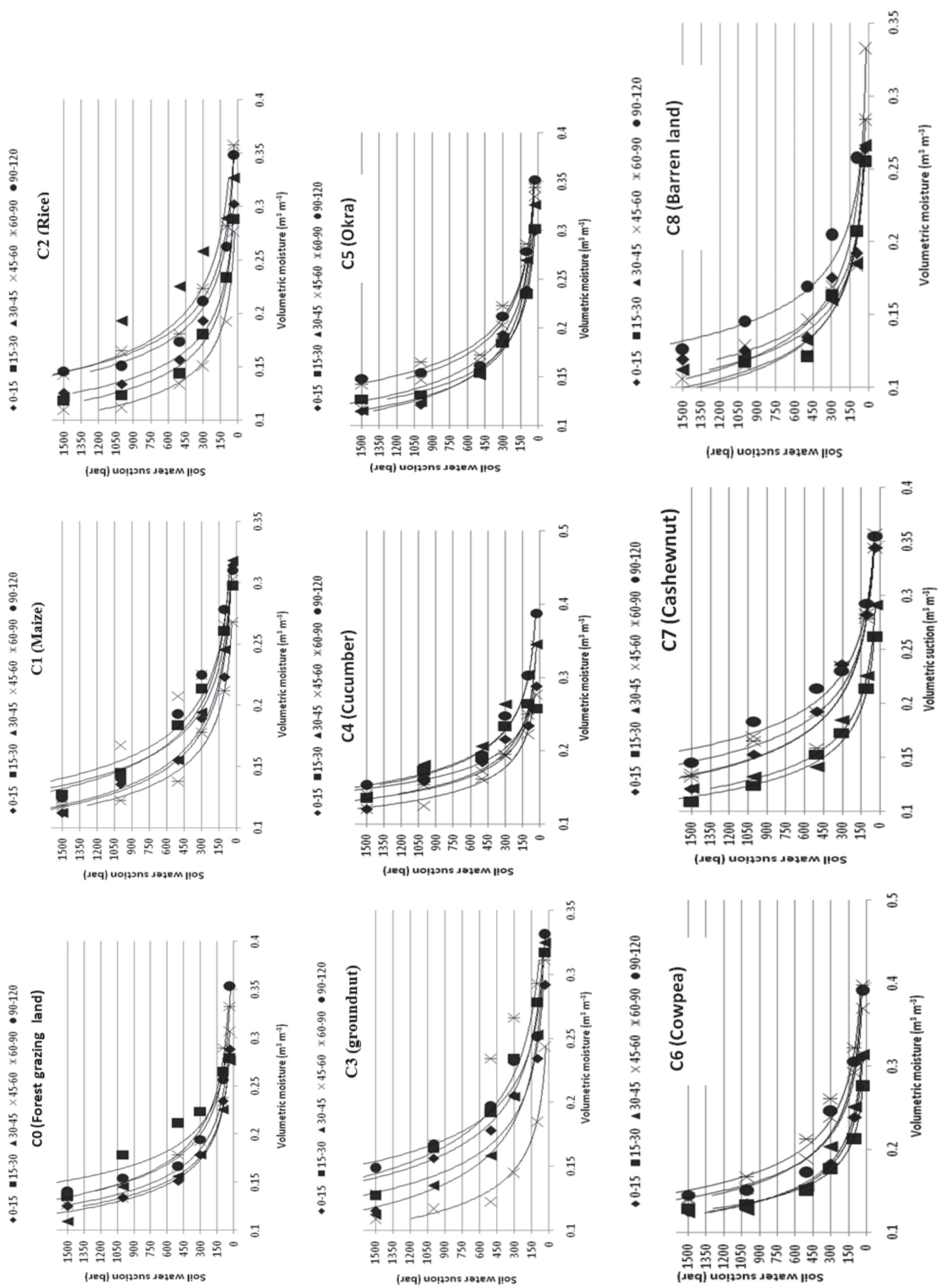

Fig. 2. Water retention characteristics curve of soils of different land use system at six depths

organic carbon, sand, silt, clay, pH was established to develop pedo-transfer functions in order to determine soil water retention at -33 kPa and -1500 kPa (Table 1 and 2).

The R^2 and slope of the relationship between water retention at field capacity, PWP and other soil properties were determined and presented in table 3. It was observed that organic carbon alone is not a good predictor for water retention but when it was couple with clay, the R^2 value increased (0.407). When SOC was associated with sand, silt, BD and pH, the R^2 value further increased. (0.512). When layer-wise SOC and water retention at FC and PWP were correlated it was observed that soil water retention at field capacity (-33 kPa) was significantly correlated with SOC for 0-0.15 m depth with the R^2 value of 0.566 but the SOC of the whole profile was not found significant (Table 4). Beyond that 0-0.15 m depth, no correlation was observed between SOC and water retention. It might be due to the fact that SOC

Table 1. Correlation matrix among water retention at field capacity, soil organic carbon (SOC) and other soil properties

Parameter	Field capacity (m^3m^{-3})	SOC (%)	Clay (%)	Silt (%)	Sand (%)	Bulk density ($Mg\ m^{-3}$)
SOC (%)	0.085					
Clay (%)	0.620*	-0.355				
Silt (%)	0.459	0.312	0.182			
Sand (%)	-0.672*	-0.056	-0.655*	-0.861*		
Bulk density ($Mg\ m^{-3}$)	0.088	-0.796*	0.435	0.300	0.006	
pH	0.290	-0.790*	0.559*	-0.129	-0.188	0.736*

Table 2. Correlation matrix among water retention at permanent wilting point (PWP), soil organic carbon (SOC) and other soil properties

Parameter	PWP (m^3m^{-3})	SOC (%)	Clay (%)	Silt (%)	Sand (%)	Bulk density ($Mg\ m^{-3}$)
SOC (%)	0.0003					
Clay (%)	0.667*	-0.355				
Silt (%)	0.392	0.312	0.182			
Sand (%)	-0.645*	-0.056	-0.655*	-0.861*		
Bulk density ($Mg\ m^{-3}$)	0.055	-0.796*	0.435	-0.300	0.006	
pH	0.162	-0.790*	0.559*	-0.129	-0.188	0.736*
Porosity (%)	0.113	0.599*	-0.187	0.415	-0.221	-0.764*

*Significant at 5% probability level
PWP = Permanent wilting point (-1500 kPa)

Table 3. The slope and R^2 value of the relationship between soil properties and water retention at different suctions of whole profile

Predictors	θ_{FC} (-33 kPa)		θ_{PWP} (-1500 kPa)	
	R^2	Slope	R^2	Slope
Organic carbon	0.007	0.010	0.028	0.008
Clay	0.634*	0.007	0.662*	0.002
Sand	0.490*	-0.0034	0.463*	-0.001
Sand+ Silt + Clay	0.509*	0.101	0.522*	0.030
SOC + Clay	0.407	0.108	0.510*	0.022
SOC + Clay+ Sand + Silt	0.509*	0.101	0.545	0.020
SOC + Clay + Sand + Silt + BD	0.516*	0.271	0.550	0.086
SOC + Clay+ Silt + Sand+ pH	0.512*	0.059	0.55	0.057
Clay + Silt + Sand + SOC + BD + pH	0.521*	0.244	0.558	0.102

*Significant at 5% probability level
SOC = Soil organic carbon (%); θ_{FC} (-33 KPa) = Moisture content at field capacity ($m^3\ m^{-3}$); θ_{PWP} (-1500 KPa) = Moisture content at permanent wilting point ($m^3\ m^{-3}$); BD = Bulk density ($Mg\ m^{-3}$)
Sand, silt and clay are in percentage

Table 4. The slope and R^2 value of the depth wise relationship between soil organic carbon (%) and water retention at θ_{FC} (-33 kPa) and θ_{PWP} (-1500 kPa)

Predictors	θ_{FC} (-33 kPa)		θ_{PWP} (-1500 kPa)	
	R^2	Slope	R^2	Slope
SOC at 0-0.15 m depth	0.566*	0.054	0.276	0.011
SOC at 0.15-0.30 m depth	0.393	0.061	0.223	0.021
SOC at 0.30-0.45 m depth	0.151	0.015	0.201	0.029
SOC at 0.45-0.60 m depth	0.024	0.031	0.123	0.028
SOC at 0.60-0.90 m depth	0.266	0.124	0.415	0.107
SOC at 0.90-1.20 m depth	0.204	0.125	0.126	0.042

*Significant at 5% probability level

SOC = Soil organic carbon (%); θs (0 kPa) = Moisture content at maximum saturation ($m^3 m^{-3}$); θ_{FC} (-33 kPa) = Moisture content at field capacity ($m^3 m^{-3}$); θ_{PWP} (-1500 kPa) = Moisture content at permanent wilting point ($m^3 m^{-3}$)

decreased but water retention increased due to more clay content at higher depths. No significant relation was observed between organic carbon at different depths and soil water retention at higher suction (-1500 kPa, PWP). From this fact, it can be concluded that organic carbon content appeared to be an important soil property to improve estimation of soil water retention from particle size distribution at lower suction values. This may be related to the fact that the structure forming effect of organic matter affects soil water retention at water content close to field capacity to a larger extent than water retention close to wilting point. At higher suction soil water retention was more significantly correlated with clay which dominates over all other factors. It was also observed that SOC of the soil profile as a whole was not significantly correlated with clay, sand or water retention at FC and PWP but have significant correlation with soil the profile BD, porosity and pH.

Conclusions

Soil water retention at field capacity (-33 kPa) was found to be correlated with SOC at 0-0.15 m depths only rather than the SOC of whole profile. Soil pH, BD, porosity had significant relationship with SOC content. From this fact, it can be concluded that organic carbon content appeared to be an important soil property to improve estimation of soil water retention at lower suction values. No significant relation was observed between organic carbon at different depths and soil water retention at higher suction (-1500 kPa, PWP). This may be related to the fact that the structure forming effect of organic matter plays an important role in soil water retention at water content close to field capacity to larger extent than water retention close to wilting point.

Litter contribution from the cashew plantation may be the reason for the relatively higher SOC content. The SOC content in soil profile was low in maize and rice, cucumber, okra cultivated plots than that of legumes. Continuous tillage and cultivation of these nutrient exhaustive crops favoured rapid rate of mineralization than that of accumulation of SOC. Legumes hold promise for greater accumulation of SOC in the long-term.

References

Christine, J. (2006) *YLAD Living Soils Seminars*: Eurongilly- 14 February, Young- 15 February.

Koul, D.N. and Panwar, P. (2012) Soil carbon buildup and bioeconomics of different land uses in subhumid tropics of West Bengal, India. *Annuals of Forest Research* **55,** 253-264.

Klute, A. (1986) *Water retention: laboratory methods*. In *Methods of Soil Analysis Part-I, ASA Monograph* (A. Klute, Eds.), Madison, Wisconsin, USA. pp. 635–662.

Lal, R. (2004) Soil carbon sequestration to mitigate climate change. *Geoderma* **123,** 1-22.

Palumbo, A.V., McCarthy, J.F., Amonette, J.E., Fisher, L.S., Wullschleger, S.D. and Daniels, W.L. (2004) Prospects for enhancing carbon sequestration and reclamation of degraded lands with fossil-fuel combustion by-products. *Advanced in Environmental Research* **8,** 425-438.

Rawls, W.J., Pachepsky, Y.A., Ritchie, J.C., Sobecki, T.M. and Bloodworth, H. (2003) Effect of soil organic carbon on soil water retention. *Geoderma* **116,** 60-76.

Walkley, A. and Black, I.A. (1934) An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37,** 29-38.

Revised received 25 January 2017; Accepted 04 March 2017