Vol. 14, No. 2, pp. 213-218 (2014)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Short Communication

Organic Carbon, Bulk Density and Aggregate Stability of a Vertisol as Affected by Varying Plantations / Vegetation Covers in South Gujarat

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The high water-holding capacity of Vertisol is controlled primarily by the relative proportion of clay and different sized soil aggregates fraction. However, clay mineralogy plays an important role in aggregation and stability of high clay soils. Plantation/trees, annual crops, legumes or other vegetation can provide effective surface cover and arrest soil erosion and thereby, minimize runoff and loss of nutrients. The aggregate dynamics vary among crops, crop rotations and the cover crops. Vegetation cover can influence soil aggregate stability through litter, plant roots and root exudates, and rhizo-depositions (Pohl *et al*., 2009). Soil aggregation is also strongly influenced by tillage, cropping systems and climate (Guerif *et al*., 2001). Thus, in the same soil under different vegetation covers, factors affecting aggregate stability and the mechanisms could be different and controlled by quantity and quality of litter, shades and microclimate including rainfall, soil and environmental temperature that exist under these vegetation covers. For any particular soil under varying vegetations, root physical environment, water and nutrient cycles are controlled by formation of water stable aggregates and soil aggregate stability (Mohanty *et al.,* 2012). Keeping all the points in view, a study was undertaken in a Vertisol of South Gujarat to find out the influence of nine different plantations/ vegetation covers along with their recommended management practices on organic carbon status, bulk density and aggregate stability.

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Nine different plantations / field crops on Vertic/ Typic Chromustert at Navsari Agricultural University, Main campus, Navsari (20^{o} 57′ N latitude and 72^{o} 54′ E longitude) were selected for the study. All the plantations/ field crops are managed with recommended practices since last 14-15 years. The topography is flat and the soils are deep, clayey with dominance of smectite clay, have high water holding capacity, and medium to poor drainage (Table 1).

Average annual rainfall is 1355 mm, of which majority is received during July to August. Treatments include: 1) Oil palm plantation, 2) Sapota plantation, 3) Mango plantation, 4) Sugarcane crop, 5) Rice crop, 6) Pulses and oilseed crops, 7) Banana plantation, 8) Vegetable crops, and 9) Floriculture crops. Details of plantations / vegetation covers and management practices being followed in soils of NAU Campus are given in Table 2. The treatments have been grouped into three broad categories *i.e.*, tree/ plantation (*i.e.,* Oil palm**,** sapota and mango plantation), agriculture (Sugarcane, rice and pulses, & oilseed crops) and Horticulture (*i.e.*, banana, vegetable and floriculture plants). Ten undisturbed bulk surface soil samples were collected from all the plantations/ vegetative covers. Depth of sampling was 0-30 cm for

Table 1. General characteristics of soil of Navsari Agricultural University Campus, Navsari

Characteristics	Value
Sand (%)	14.4
Silt (%)	23.4
Clay (%)	62.2
Texture	Clay
pH (1:2.5)	7.4
EC (1:2.5), dS m^{-1}	0.21
Organic carbon (g kg^{-1})	5.9
Bulk Density (Mg m^{-3})	1.53
Water Stable Aggregates (≥0.25 mm), %	70.3

plantations, while it was 0-22.5 cm for the rest of the treatments. The samples were air-dried, cleaned, processed and analyzed for pH, EC, organic carbon, bulk density and water stable aggregates (WSA). The pH and EC were determined at 1: 2.5 soil: water ratio while organic carbon was determined by Walkley and Black rapid titration method (Jackson, 1979). The WSA was determined following Yoder's wet sieving method (Yoder, 1936). In this method, 50 g of 3-5 mm size range aggregate were collected from undisturbed air-dried bulk soil samples. These were then wet sieved using a set of sieves with mesh openings of 2, 1, 0.50 and 0.25 mm, respectively. The size distribution of WSA was determined based on the dry weight of aggregates retained in each sieve, and characterized by mean weight diameter (MWD) of soil aggregates (Kemper and Roseneau, 1986).

Soil organic carbon (SOC) differed significantly from 4.55 to 9.70 g kg^{-1} among plantations /vegetative covers treatments. The highest SOC (9.70 g kg^{-1}) was associated with oil palm plantation, which was higher than all treatments except sapota and mango plantation (Table 3). Significantly lower SOC (4.55 g kg^{-1}) was recorded under floriculture. The SOC under sugarcane crop was at par with pulses and oil seeds, but was significantly higher compared to that in rice, banana, vegetables and floriculture plants. However, SOC under rice and banana were similar. The tree/plantation group had significantly higher SOC over the agriculture and horticulture groups, possibly due to the combined effect of higher organic matter through litter, green manuring, more shading and least disturbance of soils by tillage**.** On the contrary, lesser addition of organic biomass, low canopy coverage and soil disturbance by tillage could be responsible for low SOC content under floriculture. A comparatively higher SOC in soils under agricultural crops and banana over vegetables and floriculture was possibly due to the addition of bio-compost over last 3-4 years as part of good management practices for obtaining higher crop yields. Results were in agreement with Kumar *et al.* (2006), Zhang *et al.* (2006) and Dhaliwal *et al.* (2008), who had reported higher SOC under tree plantation in forests and other plantation area as compared to agricultural and waste land. The SOC is a good indicator of soil quality and the productivity potential (Zhang *et al.,* 2003 and Andrews *et al.,* 2004). Therefore, soils under vegetables and floriculture could be of poor quality in respect to productivity potential, and should be improved through appropriate management practices.

Soil PH significantly varied from 5.8 to 8.0 (Table 3). Significantly higher pH (8.0) was recorded under sapota plantation, while pH was significantly low (5.82) in rice. Variations in soil pH were higher, except between oil palm (7.3) and pulses & oil seed crops (7.3) and also between banana plantation and floriculture. Varying quantity of fertilizers and manures, irrigation water and variation in tillage practices might have caused the wide differences in soil pH. Singh *et al.* (2006) reported slightly higher soil pH in orchard. Results also corroborated with Negassa and Gebrekidan (2003).

Soil EC varied between 0.27 and 0.52 dS m^{-1} and differed significantly among the treatments, but salinity was not a problem (Table 3). Significantly higher and lower soil EC were recorded under rice and mango, respectively. Order of salinity was: rice > sugarcane > banana > floriculture > oil palm > sapota > pulses & oil seeds > vegetables > mango. Significantly higher EC was recorded in surface soil of rice (0.52 dS m^{-1}), sugarcane (0.51 dS m^{-1}) and banana (0.47 dS m^{-1}) might be attributable to higher frequency

Table 2. Details of plantations / vegetation covers and management practices at NAU Campus

Plantations / vegetation covers / Management Practices	Fertilizer/other inputs				Green manuring etc.	Tillage operation	Irrigation/ watering etc.
	Inorganic			Organic/others			
	N	P_2O_5	K_2O				
Oil Palm (Var. Tanera)	-	-	-	100 kg FYM/bio-compost + 5 kg NC per plant	Sesbania in inter-row in monsoon	2 ploughings	Sprinkler irrigation (February- June)
Sapota (Var. Kali Patti, Cricket ball)	1.0 kg/ plant	0.5 kg/ plant	0.45 kg/ plant	50 kg FYM/ bio-compost per plant	Sunhemp in inter-row in monsoon	3 ploughings	3 surface irrigation in part and drip irrigation in part after monsoon
Mango (Var. Alphanso, Kesar, Rajapuri etc.)	0.75 kg/ plant	160g/ plant	675g/ plant	100 kg FYM/ bio-compost per plant	Calocasia / Glyricidia in inter-row in monsoon	3 ploughings	Rainfed
Sugarcane (Var. CoN-95132, CoN 91131, CoN 85134 etc.) (Sugarcane-Sugarcane ratoon, Sugarcane-Mung/ sunhemp/ karanj)	250 kg/ ha (plant crop) 300kg/ ha (ratoon crop)	32 kg/ ha (plant crop) 16kg/ ha (ratoon crop)	125 kg/ ha (plant crop) 125kg/ ha (plant crop)	60kg S/ha in plant crop only. 12 to 15 t/ha bio- compost/ PM + sugarcane trash mulching (2 t/ha) in standing crop.	Mung/ sunhemp/ karanj as specified under rotation	1 Plough, 1 disk harrow, 2 cultivator, 2 inter culturing	15–20 irrigation (surface)
Rice (Var. GR-101/102/ 103/104, NVSR-1, NVSR-5 etc.)	50kg/ ha or 180 kg/ha	30kg/ ha	0 kg/ ha	25kg $ZnSO_4$ in every 3 years10 t/ha FYM/ bio compost or 0.5 t/ ha CC/NC	Sunhemp	2-3 tillage (tractor drawn), irrigation and puddling	Flood irrigation as per recommendation
Pulses & Oil seed (Var. Gram GG-1/ 2 / Gujarat Castor hybrid verity, mustard-GM-1)	Univ. recommended dose	Univ. recommended dose	Univ. recommended dose	20kg S / 25kg $ZnSO_4$ as per recommendation 10 t/ha FYM bio- compost	Mung been/ Indian been	Ploughing with cultivator, two/three harrowing and planking	Flat bed – furrow irrigation as per recommendation
Banana (Var.Basrai/ Grand Nine/ Others) (Banana-Banana ratoon-Banana)	200-300 kg/ha (plant) based on variety 300 kg/ ha (ratoon)	90kg / ha (plant and ratoon)	200kg / ha (plant and ratoon)	10kg FYM/ bio-compost/ 1kg CC / 1kg NC per plant	Turmaric as inter crop or Sunhemp as green manure crop	Ploughing, two times harrowing and planking and during growth period earthening & 5-6 inter -culturing	5-6 times furrow irrigation as per Univ. recommendation
Vegetable (Brinjal, chilli and cabbage of different University released varieties)	100-200 kg/ ha (depending upon vegetable)	0-80 kg/ ha (depending upon vegetable)	45 kg/ ha for all crops	15-20 t / ha FYM bio- compost / 1 t/ha CC / NC	No green manuring	Ploughing with cultivator, two times harrowing and planking	Furrow irrigation as per Univ. recommendation
Floriculture (Spider lily,Rose)	200g/plant	200g/plant	200g/plant	10kg FYM/ bio-compost/ 1kg CC / 1kg NC per plant	No green manuring	Ploughing with cultivator, two times harrowing and planking	Drip irrigation in ridges and furrow system

Table 3. Organic carbon, pH, EC, bulk density, water stable aggregates (WSA) and mean weight diameter (MWD) of a Vertisol as affected by varying plantation/vegetation cover along with their management

Name of plantations/ Vegetation covers	OC ($g\ kg^{-1}$)	$pH_{2.5}$	$EC_{2.5}$ ($dS\ m^{-1}$)	B.D. ($Mg\ m^{-3}$)	WSA per cent					MWD (mm)
					≥ 2.0 mm (a)	1.0-2.0 mm (b)	0.5-1.0 mm (c)	0.25-0.5 mm (d)	≥0.25mm (a+b+c+d)	
Oil palm	9.70	7.33	0.36	1.49	27.35	20.50	12.00	18.25	78.10	1.43
Sapota	9.49	8.00	0.35	1.46	32.10	22.65	11.78	16.29	82.82	1.61
Mango	9.57	7.76	0.27	1.45	30.90	25.20	7.22	21.30	84.62	1.59
Sugarcane	7.99	7.88	0.51	1.51	23.20	15.35	19.63	14.45	72.63	1.24
Rice	7.45	5.82	0.52	1.62	09.10	4.25	10.90	25.20	49.39	0.56
Pulses and oil seeds	7.93	7.31	0.35	1.58	22.60	20.20	15.93	13.60	72.33	1.26
Banana	7.47	7.61	0.47	1.59	19.55	17.20	8.92	28.90	74.57	1.12
Vegetable	5.41	7.48	0.35	1.70	13.20	11.00	19.95	25.10	69.25	0.87
Floriculture	4.55	7.69	0.42	1.71	11.43	13.16	18.36	26.30	69.25	0.83
SEm±	0.094	0.032	0.015	0.006	0.79	0.64	0.59	0.70	0.54	0.02
C.D.(P=0.05)	0.26	0.091	0.042	0.018	2.21	1.80	1.66	1.96	1.52	0.06

of irrigation water as part of recommended practices. Our results are supported by the findings of Somasundaram *et al.* (2009). Minimum salt accumulation under mango plantation might be due to rainfed situation in the existing plantation coupled with less surface evaporation owing to higher canopy coverage.

Bulk density (BD) of the soil varied between 1.45 and 1.71 Mg m^{-3} (Table 3). The minimum and maximum BD values were obtained in soils under mango and floriculture, respectively. The BD under mango plantation was similar to sapota, and was significantly lower as compared to others. The BD was similar between pulses & oil seeds and banana plantation, and also between vegetables and floriculture plants. This could be due to similar kind organic matter in soils and tillage operations. Soils under tree/ plantation had significantly lower BD (1.45-1.49 Mg m^{-3}), possibly due to higher organic matter addition through leaf litter and green manuring. Similar explanation was given by Mathan and Kannan (1993). The higher soil BD was recorded under floriculture (1.71 Mg m^{-3}) and vegetables (1.70 Mg m^{-3}) due to less organic matter addition, minimum canopy coverage and oxidation of SOC. Intermediate BD values of soils under other vegetation covers were due to combined effect of litter fall, green manuring, vegetation cover and tillage practices. Results are in good agreement with Dhaliwal *et al.* (2008).

Significantly higher WSA (84.6%) was found in soils under mango, while the lowest WSA (49.5%) was obtained in rice soil (Table 3). Total WSA significantly differed between treatments, except pulses/oil seeds and sugarcane which had similar WSA. Vegetables and floriculture plants also recorded similar WSA. Varying amount and kind of organic matter in soils under different plantations/ vegetations were responsible for varying WSA. Results further indicated that distribution of different size aggregates varied widely due to varying tillage and management practices, type and content of aggregate forming agents, nature, amount and composition of litter, plant root turnover, exudates and rhizo-deposition (Pohl *et al.*, 2009). Thus, significantly higher

(32.10%) large size aggregates (≥ 2 mm) was obtained in soil under sapota, which was at par with mango plantation. Significantly lower (9.1%) aggregates (≥ 2 mm) were recorded in soil under rice, which could be due to higher mechanical disintegration of macro-aggregates/structures as a result of puddling. This apart, less conducive condition and less accessibility of aggregate binding agents would be other possible reasons for formation of least macro–aggregates in the rice field. In general, tree/plantation crops produced significantly higher amount of ≥2 and 1-2 mm size aggregates compared to agricultural and horticultural crops. On the contrary, agricultural and horticultural soils contained significantly higher amount of smaller size aggregates (0.5-1.0 and 0.25-0.5 mm) as compared to soils under tree/plantation crops. These differences could be attributed to variation of organic matter content, mechanical disruption of aggregates by tillage operation and soil surface cover. Kahlon (2006) observed higher per cent of water stable aggregates under forest plants followed by arable cultivated land. Guerif *et al*. (2001) reported that soil structure and aggregation were strongly influenced by processes such as tillage and cropping systems, and smaller size aggregates were predominant in soils subjected to intensively disrupted tillage, as reported by Pinheiro *et al.* (2004). Soils under agriculture and horticulture, where proportion of macro-aggregates was less, require more addition of organic matter and adoption of conservation agriculture practices to sustain soil health, improve crop yield and expand minimum energy for ecological stability (Zhang *et al.* , 2008).

Mean weight diameter (MWD) of aggregates ranged as 0.62 to 1.63 mm and was significantly higher under sapota, and lower under rice. However, MWD was similar between sapota and mango plantations, sugarcane and pulses/oilseeds, and vegetable and floriculture. The MWD were recorded in the following order: sapota (1.61 mm) > mango (1.59 mm) > oil Palm (1.43 mm)> pulses and oil seeds (1.26 mm) > sugarcane (1.24 mm)> banana (1.12 mm) > vegetable (0.87 mm)> floriculture (0.83mm) > rice (0.56 mm). Results clearly indicate that tree and plantation crops had significantly higher MWD compared to agricultural and horticultural crops because of higher percentage of larger size aggregates (Table 1). Agricultural soils, barring rice soil, exhibited significantly higher MWD over the horticultural soils. Higher aggregate stability under tree/ plantation over other soils was also reported by Martens (2000). The MWD of water stable aggregates was positively and significantly correlated (0.76, $p \leq 0.01$) with SOC and the simple regression equation between the two parameters revealed that 57% variation ($R^2 = 0.57$, $P \leq 0.05$) of MWD could be controlled by the SOC content.

The present study clearly indicated that SOC, soil BD, formation of WSA and their stability in a Vertisol significantly differed among the plantation and vegetation covers. Plantation crops exhibited significantly higher SOC and soil aggregate stability, and lower soil BD due to higher organic matter content coupled with less disturbance by tillage operation, compared to agricultural/ horticultural field crops. Application of more organics and proper crop rotation with good canopy coverage would be appropriate measures particularly for soils under rice, floriculture and vegetables.

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Received: May 7 2014; Accepted: August 21 2014