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Carbon stocks in major cashew growing soils of coastal Karnataka, India

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Abstract

This study was taken up to assess the soil organic carbon (SOC) stock under cashew plantations in different management conditions *viz.,* natural (cashew mixed with forest trees and cashew in scrub land conditions) and intensive management (research stations) in regions/locations of coastal Karnataka. Profile study was undertaken and six major soil series were identified. Horizon-wise soil samples were collected from different layers of soil profiles and the major soil properties *viz.,* bulk density, pH, EC, particle size distribution and SOC were determined using standard laboratory procedures. The SOC stock was high in surface soils (2.0 to 8.23 kg C m^{-2}) compared to subsoils (0.08 to 3.28 kg C m^{-2}) and it decreased with depth. The maximum SOC was found in mixed forest land use system followed by cashew plantation in scrub land and in research farm. The SOC stock in different depths (0-30, 30-100 and 0-100 cm) of the soils varied from 2.37 to 9.70 kg C m^{-2} and 1.48 to 5.69 kg C m^{-2}, respectively. Result indicated that cashew plantation under natural management has more SOC stock and high carbon sequestration potential-than intensively managed cashew plantations.

Keywords: Cashew, forest, coastal, soil organic carbon, carbon stock

Introduction

Soil carbon plays important role in soil quality and its productivity. Among the terrestrial reservoirs, soils are largest pool of carbon and impending for expanded soil carbon sequestration (Venkanna *et al.,* 2014**)**. It has a significant function in global carbon cycle as well (Batjes, 1996; Wang *et al.,* 2016). Soil organic carbon determines the fate of a terrestrial ecosystem as a potential sink or source of greenhouse gases (GHG) (Gal *et al.,* 2007). Small changes in soil organic carbon (SOC) storage can affect atmospheric carbon content plus global temperature rise and climate change (Johnston *et al.,* 2004). Several factors, such as climate change, land use change, land management (Lalitha and Praveen Kumar, 2016), *etc*., are the driving force which impacts the regulation of soil carbon storage (Xia *et al.,* 2010). Moreover, soil organic matter (SOM) could improve the soil physical and chemical properties and also an important surrogate for soil biological activity, a measure of soil productivity (Oliveira *et al.,* 2016).

Major source of soil organic matter is litter fall from forestry or plantations, which have the ability to increase the soil organic storage (Njar *et al.,* 2011; Lu *et al.,* 2013). Among the plantation crops, cashew is one of the major commercial crops in India, cultivating in several states. India is the largest producer, processor, consumer and exporter of cashew in the world with the current production level of 23 per cent of the global production. A large number of small and marginal farmers, particularly living on the coastal belts of India, depend on cashew for their livelihood. In Karnataka, cashew is mostly grown in laterite red soils and coastal sandy soils (Srinivasan *et al.,* 2013a). The fertility statuses of cashew soils are widely varied. Cashew can adapt to varying soil conditions without impairing productivity. The best soils for cashew are deep, friable, well drained sandy loam without a hard pan.

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Recently, Karnataka government is promoting the domestic cultivation of cashew in scrub lands and watersheds for improving the farmer's livelihood. Therefore, assessing soil quality through soil organic content (SOC) is an indicator of cashew yield and environmental quality. The present study was carried out to assess the soil organic carbon stock in major cashew growing soils in coastal Karnataka.

Materials and methods

Study area

The study was undertaken in major cashew growing districts of coastal Karnataka *i.e.,* Udupi and Dakshina Kannada (Table 1). The study location was identified by using toposheets (48L/13, 48P/1, 48 P/2, 48 P/5, 48 O/4, 48 K/11 and 48 K/15) and LISS III satellite data. The study area falls between 74º 48' 23.59" to 75º 40' 15.23" E longitude to 13º 59' 29.788" to 12º 27' 38.40" N latitude. Profile study was carried out in different land management system *viz.,* cashew mixed with forest tree (partial removal of forest trees and planting of cashew crops by forest department under afforestation scheme), cashew plantation in research farm (ICAR-Directorate of Cashew Research (DCR), Puttur and Agricultural Research Station (ARS), Ullal) and cashew plantation in scrub land (Trees, shrubs and grasses grown other than areas delineated by FSI). The forest has mixed tree species such as *Cinnamomum malabaricum, Holigarna arnottiana, Dalbergia latifolia, Ficus* spp.*, Xylia xylocarpa, Bambusa arundinaceae, Bombax ceiba, Acacia catechu, Cocos nucifera, Casuarina equisetifolia, Acacia auriculiformis, Acacia nilotica, Eucalyptus* spp. Study area had lateritic soils and the elevation ranged from 15 m to 120 m above mean sea level (Fig. 1). The climate was hot and humid throughout the year with an average annual rainfall of 3500 mm, distributed mainly from June to September. The mean annual temperature is 27.6 °C and mean maximum and minimum temperature were 36 °C and 20 °C, respectively. The area had *ustic* moisture regime and isohyperthermic temperature regime.

Table 1. Major cashew growing soils in coastal Karnataka

Land management system	Series	Location	Topography	Age of cashew plantations (years)	*USDA Soil classification
Forestry	1	Puttur	Hills	20-25	Loamy- skeletal, mixed, isohyperthermic Ustic Haplohumults
	2	Bantwal	Hills	25-30	Fine, mixed, isohyperthermic Oxic Dystrustepts
Research farm	3	Puttur	Nearly level	5-10	Clayey-skeletal, mixed,isohyperthermic Oxic Dystrustepts
	4	Mangalore	Level	10-15	Clayey-skeletal, mixed, isohyperthermic Typic Rhodustults
Scrub land	5	Bantwal	undulated	15-20	Clayey-skeletal, mixed, isohyperthermic Ustic Haplohumults
	6	Karkala	undulated	15-20	Clayey-skeletal, mixed, isohyperthermic Ustic Palehumults

USDA-United States Department of Agriculture*

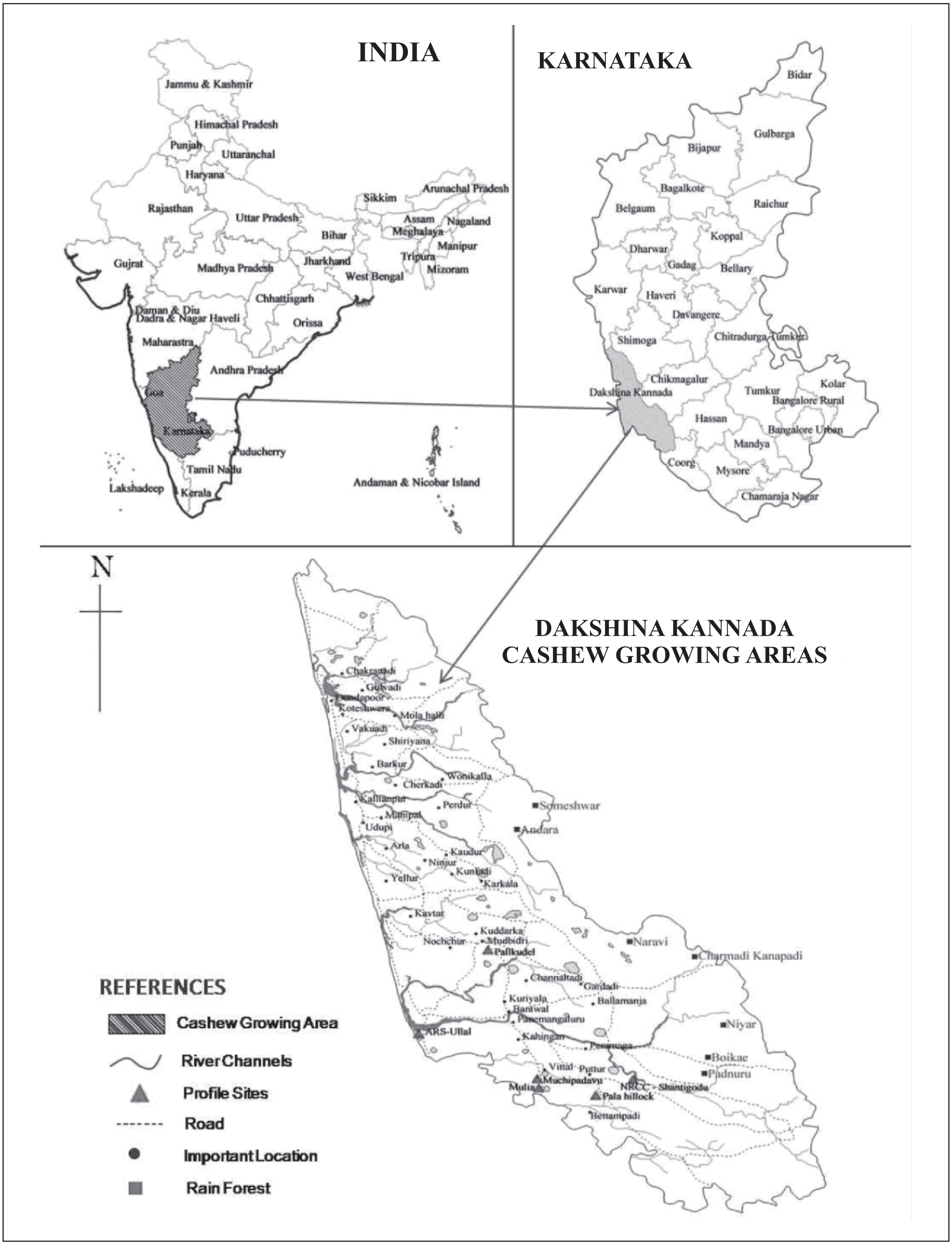

Fig. 1. Location of the study area

Field study

Soil profiles were opened in the selected locations, and studied in detail for all their physical and morphological characteristics. The soil and site characteristics were recorded for all profile sites as per the guidelines given in USDA Soil Survey Manual (Soil Survey Staff, 2010). Horizon-wise samples were collected for laboratory analysis. Profiles were grouped into soils based on identification characteristics and classified following USDA soil classification system.

Laboratory analysis

The soil samples collected horizon-wise were, air-dried, powdered and sieved using 2 mm sieve. Particle size analysis was carried out by International Pipette method (Piper, 1966). Soil organic carbon was estimated by Walkley and Black (1934) method. Bulk density was calculated for the sample collected from each horizon using core sampler method. Soil samples from the core was dried at 105 °C for 24 hours and cooled in desiccator. Weight of the dried sample was recorded. Volume of the core was measured (Jackson, 1973). The pH and electrical conductivity were measured in 1:2.5 soil water suspensions (Jackson, 1973). Available nitrogen was estimated by following alkaline permanganate method (Subbaiah and Asija, 1956).

SOC stocks estimation

For each of the soil profile SOC stocks were calculated by summing the stocks of different layers in proportion of their occurrence within this reference thickness. The total organic carbon stock in kg m^{-2} soil for each pedon was estimated using the general equation presented below (Grossman *et al.,* 2001).

$$\text{SOC stocks} = \sum_{i=1}^{n} [(1-\theta i\%) x \text{ pi } x \text{ Ci } x \text{ Ti}/100]$$

Where SOC (kg m^{-2}) is the SOC stocks of a soil profile within a depth (cm), *n* is the number of soil layers in the soil profile, θ_i represents the volumetric percentage of gravel (>2 mm) content, ρ_i is the soil bulk density (g cm^{-3}), C_i is the organic carbon content (C g kg^{-1}), and T_i represents the thickness (cm) of the layer *i*. The SOC stocks were calculated for top 0-30 cm, 30-100 cm and 0-100 cm by summing the stocks of different layers in proportion of their occurrence within this reference thickness by depth-weighted average (FAO, 2009).

Results and discussion

Soil properties

Six major soil series were identified from different cashew growing soils (forest, research farm and scrub land), are classified under Ultisols and Inceptisols. Soil depths were moderately deep (75-100 cm) to very deep (>150 cm). Coarse fragments were ranging from 10 to 40 per cent in surface and 15 to 80 per cent in subsoils. The clay content varied from 24 to 63 per cent and 29 to 66 per cent in surface and subsoils, respectively. Increase in clay content with depth might be due to downward translocation of finer particles from the surface layers (Bhaskar and Subaiah, 1995).

Bulk density of cashew growing soils in surface and subsurface were 1.21 to 1.44 and 1.13 to 1.60 mg m^{-3}, respectively. Bulk density of research farm (S4) soils was found to be high and it was found to be low in forest soils (S1). Variation in bulk density of these soils was attributed to high content of organic matter and Kaolinitic mineralogy. Bulk density of sub-surface horizons was higher than that of surface horizons and increased with depth, which might be due to compaction of finer particles in deeper layers caused by the over-head weight of the surface layers (Thangasamy *et al*., 2004).

Soil reaction (pH) was moderately acidic (4.9 to 6.0) in all the series and different lands which were decreasing with depth. The acidic nature of the soil might be because of leaching of bases due to the high rainfall and some extend due to the acidic parent materials (Srinivasan *et al.,* 2013a; Ngatunga *et al*., 2001). Electrical conductivity (EC) values were negligible (0.01- 0.58 dS m^{-1}) in all the soils. This is because of leaching of bases due to high rainfall received in the study areas.

The organic carbon content of the soils is high in surface soils (0.97-3.07%) and low to high in sub soils (0.13-2.04%). Surface soils of forest and scrub land systems were found to have higher organic carbon status due to less cultural disturbance and continuous addition of plant biomass, and also due to increased returns of organic matter to soils compared to research farm. Similarly available nitrogen content also varied from 216 to 429 in surface and 112 to 364 kg ha^{-1} in sub soils, rated as medium to low. Higher available nitrogen was found in surface soil. Similar results were also reported by Srinivasan *et al.* (2013b) and Sekhar *et al.* (2014).

SOC Stock

The SOC stock was higher in surface soils (2.0 to 8.23 kg m^{-2}) and low in subsoils (0.08 to 3.28 kg m^{-2}). The maximum was found in forest followed by scrub land system (Table 2 and Fig. 2). The high organic carbon content in the surface layer of forest and scrub are reason for the high SOC stocks. These might be due to the slow decomposition rate and high biomass addition. The litter fall from cashew plantations have ability to increase soil organic carbon (Lu *et al.,* 2013; Ogeh and Ipinmoroti, 2015). Research farm cashew soils are less SOC stock because of comparatively less biomass addition. The trend of decreasing SOC with increasing depth may be due to the increased proportion of slower cycling of SOC pools at depth (Jobbagy and Jackson, 2000). Overall, SOC stock is influenced by complex interactions of climate, soil type, altitude, slope, management and tree species or vegetation types (Lal, 2005).

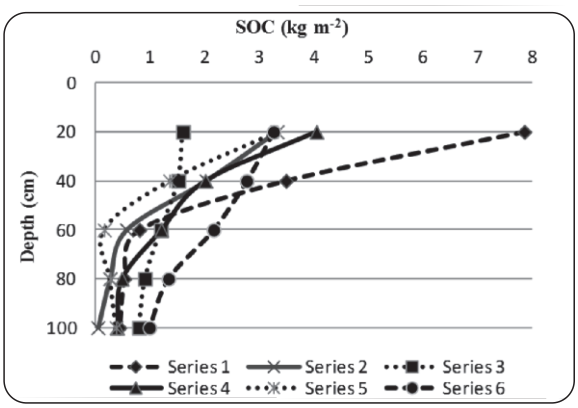

Fig. 2. Depth wise distribution of carbon stock in different soils

The SOC stock in different depths (0-30, 30-100 and 0-100 cm) of the soils (Table 2 and Fig. 3) ranged from 2.37 to 9.70 kg m^{-2} and 1.48 to 5.69 kg m^{-2}.

Among them, S1 (9.70 kg m^{-2}) and S5 (5.05 kg m^{-2}) had maximum SOC stock in 0-30 cm depths, S6 (5.69 kg m^{-2}) and S2 (3.64 kg m^{-2}) had maximum SOC stock in 30-100 cm depths. The highest SOC stock was observed in the order of forest, scrub land and research farm system. High SOC stock in forest system, due to old cashew plantation had dense canopy coverage of own and others trees and plants. On the other hand, cashew plantations have a vast potential for organic biomass for recycling (Dar and Sundarapandian, 2013). Availability of cashew leaf-litter from plantations of different age groups (10 to 40 years) ranged from 1.38 to 5.20 t ha^{-1} (Guruprasad *et al.,* 2009). Total SOC stock was not significantly correlated with cashew yield. The maximum yield found under research farm despite of low organic carbon stocks due to fertilizer application, better cultural managements and use of grafted plants (Fig. 3). Overall results indicated that forest and scrub land cashew plantations have more carbon stock and carbon sequestration. Therefore, large scale planting of cashew may be taken up in areas other than agricultural land of coastal Karnataka for improving SOC and sustaining cashew yield.

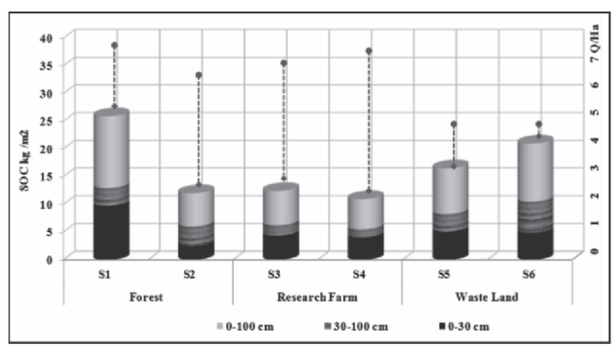

Fig. 3. Different depth wise distribution of carbon stock and yield in different soils

Conclusions

The present study about SOC stocks under different management of cashew cultivation revealed that SOC stock was higher in surface soils (2.0 to 8.23 kg m^{-2}) compared to subsoils (0.08 to 3.28 kg m^{-2}). The maximum SOC stocks were found in natural management compared to intensive management condition hence forestry and scrub land could make more C sequestration than under cultivated land. High SOC stock is indication of better land and soil quality and if the lands are better managed it could yield maximum in sustainable way.

Table 2. Depth wise distribution of major soil properties

Soil	Depth (cm)	Clay (%)	Coarse fragment (%)	Bulk density ($Mg\ m^{-3}$)	pH (1:2.5) water	EC ($dS\ m^{-1}$)	OC (%)	Available N ($kg\ ha^{-1}$)	SOC ($kg\ m^{-2}$)	SOC ($kg\ m^{-2}$) 0-30 (cm)	30-100 (cm)	0-100 (cm)	Yield ($kg\ ha^{-1}$)
Forest													
1	0-21	25.5	10	1.42	5.4	0.05	3.07	429	8.24	3.25	9.70	12.96	695*
	21-41	35.5	20	1.33	5.3	0.01	1.53	232	3.26				
	41-68	31.4	50	1.38	5.6	0.01	0.38	188	0.71				
	68-95	32.3	40	1.38	5.6	0.01	0.32	144	0.72				
	95-123	29.2	60	1.57	5.7	0.01	0.13	125	0.23				
2	0-25	63.0	35	1.27	5.5	0.01	0.97	216	2.00	2.37	3.64	6.01	685*
	25-50	65.1	25	1.21	5.3	0.01	0.82	207	1.86				
	50-84	62.1	20	1.13	5.5	0.02	0.50	169	1.54				
	84-128	66.4	15	1.13	5.3	0.00	0.40	153	1.69				
	128-160	58.3	15	1.14	5.4	0.03	0.26	232	0.00				
Research farm													
3	0-19	52.5	30	1.44	5.5	0.02	1.68	285	3.22	4.33	1.88	6.21	690
	19-42	50.6	30	1.49	5.6	0.01	0.97	201	2.33				
	42-71	51.2	80	1.45	5.7	0.01	0.70	189	0.59				
	71-90	42.1	80	1.50	6.0	0.01	0.14	119	0.08				
4	0-20	32.2	20	1.33	4.9	0.20	1.56	370	3.32	4	1.48	5.48	710
	20-40	35.8	40	1.36	4.8	0.08	0.83	263	1.35				
	40-70	44.2	60	1.52	5.1	0.25	0.13	254	0.24				
	70-99	52.1	60	1.60	5.2	0.58	0.45	252	0.55				
	99-127	48.2	70	1.60	5.3	0.27	0.36	257	0.48				
	127-165	45.4	60	1.58	5.1	0.04	0.27	244	0.00				
Scrub land													
5	0-17	40.6	40	1.31	5.5	0.29	2.80	367	3.74	5.05	3.21	8.26	461*
	17-41	52.4	60	1.23	5.4	0.05	2.04	364	2.41				
	41-60	61.2	70	1.36	5.5	0.01	1.42	326	1.10				
	60-90	57.9	70	1.23	5.5	0.02	0.65	279	0.72				
	90-155	38.8	70	1.20	5.3	0.04	0.43	197	1.01				
6	0-28	24.5	30	1.30	5.7	0.62	1.79	304	4.56	4.8	5.69	10.50	425*
	28-55	37.2	35	1.44	5.5	0.35	1.30	188	3.29				
	55-90	40.1	40	1.44	5.6	0.04	0.73	137	2.33				
	90-130	44.0	40	1.47	5.4	0.08	0.36	122	1.27				
	130-180	45.2	50	1.43	5.6	0.56	0.28	112	0.00				

***Yield details were collected from individuals**

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