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Gladis R
Department of Soil Science & Agricultural Chemistry, College of Agriculture, Vellayani Thiruvananthapuram, Kerala Agricultural University, Thrissur, Kerala, India

Aparna B
Department of Soil Science & Agricultural Chemistry, College of Agriculture, Vellayani Thiruvananthapuram, Kerala Agricultural University, Thrissur, Kerala, India

Biju Joseph
Department of Soil Science & Agricultural Chemistry, College of Agriculture, Vellayani Thiruvananthapuram, Kerala Agricultural University, Thrissur, Kerala, India

Correspondence
Gladis R
Department of Soil Science & Agricultural Chemistry, College of Agriculture, Vellayani Thiruvananthapuram, Kerala Agricultural University, Thrissur, Kerala, India

Carbon dynamics in major soils of south Kerala

Gladis R, Aparna B and Biju Joseph

Abstract
A study was conducted in four major soils of Kerala namely red loam (Vellayani series), laterite (Trivandrum series), coastal sandy (Kazhakuttam series) and forest soil (Kallar series) to assess the impact of different agricultural land use systems on soil carbon dynamics. Surface soil samples (0-15 cm depth) were collected and analyzed for soil properties and carbon pools following standard procedures and carbon stock in soil was also calculated. The results indicated that various land use categories had a significant effect on soil properties and carbon pools. The soil organic carbon values ranged from 2.96 to 9.93 g kg^{-1}. The highest value was recorded under rubber land use in Kallar soil, which is significantly higher (about 3.6 times) than the coconut land use in Kazhakuttam soil which had the least value. The highest carbon stock of 23.02 kg m^{-2} was recorded in rubber land use in Kallar soil. The total particulate organic carbon concentration was also found to be the highest in rubber land use (Kallar series). The highest concentrations of labile carbon were found in soils from coconut plantation site (2516 mg kg^{-1}), followed by rice field (2187 mg kg^{-1}), whereas the lowest concentration was detected in homestead site (940 mg kg^{-1}). Hot water soluble carbon in soil ranged between 18.14 and 76.45 mg kg^{-1} Cumulative amount of carbon mineralized in 15 days of incubation ranged from 2.86 to 6.39 mg C kg^{-1} soil.

Keywords: Carbon dynamics, carbon pools, organic carbon stock, land uses

Introduction
Soils play an important role in carbon cycling and land use is a major determinant factor that affects soil carbon storage. Various land uses have different potential for carbon sequestration due to differential soil organic carbon content and aggregation dynamics (Blanco *et. al*., 2007) [1]. Agricultural land use can have significant direct and indirect effects on soil carbon pools due to changes in plant species, primary productivity, and litter quantity and quality and soil structure. The SOC fractions like labile, hot water soluble and aggregate-associated carbon have been proposed as sensitive indicator of change in land use and management practices (Cambardella and Elliott, 1992) [2]. Estimation of soil carbon pools will help to identify the carbon fractions which are dominant in different land uses and help to prioritize land use systems for carbon sequestration thereby reducing emission of greenhouse gas (CO_2).

Materials and Methods
A study was conducted in four major soils of Thiruvananthapuram district name lyredloam (Vellayani series), laterite (Trivandrum series), coastal sandy (Kazhakuttam series) and forest soil (Kallar series) under different agricultural land use systems viz., coconut, rice, vegetables, rubbber, banana, tapioca and homestead to assess the soil carbon dynamics. The study area extends between 8º 11' - 8º 52' N latitude and 76º 40' - 77º 17' E longitude. The average elevation of the study area is 14 to 1161 meters above Mean Sea Level. The climate is tropical with annual average rainfall 1529.6 mm and temperature 27.65º C. Surface soil samples(0-15 cm depth) were collected from 60 different sites selected randomly for the study and analyzed for soil properties like texture, bulk density, pH, cation exchange capacity and water stable aggregates as per standard procedures. The soil carbon pools namely soil organic carbon (Walkley and Black wet oxidation method), labile carbon (Potassium permanganate oxidation method), hot water soluble carbon (hot water dissolution and wet oxidation method), particulate organic carbon (sodium hexa-meta phosphate dissolution method) and mineralizable carbon (incubation method) were analyzed following standard procedures. Carbon stock in soil was calculated by the equation SOC% *BD*depth(cm).The data obtained were analyzed statistically using analysis of variance for completely randomized design using SAS package.

Results
Soil Properties
Examination of various soil properties revealed that the texture of most of the soil series varied

from sandy loam to sandy clay loam(Table 1). In all the soils, the sand content (46.43 – 83.63 %) was found to be the highest, followed by the silt (8.19- 27.86%) and the clay (8.06- 25.76%) content. Among the different land uses, the highest sand content was noticed in coconut land use. Silt and clay content were found to be more in other land use systems in various soil series. The soil properties *viz.*, bulk density, pH, and CEC were found to be significantly influenced by different agricultural land use systems in all the series. The bulk density of the soil varied from 1.10 Mg m^{-3} in coconut land use of Vellayani series to 1.59 Mg m-3 in rice land use of Kazhakuttam series. The pH of various soil series ranged from 4.29 to 5.77, which were slightly acidic to moderately acidic in nature. The highest pH was recorded in tapioca land use of Trivandrum series. The cation exchange capacity of soil under different agricultural land use systems of various soil series ranged from 3.65 to 6.88 c mol (p+) kg^{-1} soil. The highest value was recorded in vegetable land use of Vellayani series. The land use systems *viz.*, vegetable in Vellayani series, tapioca in Trivandrum series, rice in Kazhakuttam series and rubber in Kallar series possessed highest CEC compared to other land uses in the respective series. In Vellayani series, total water stable aggregates ranged between 73.42 and 81.14 % where the highest value was observed in coconut land use. In Trivandrum series, total water stable aggregates varied between 49.50 and 72.30 % where the highest value was noticed in tapioca land use, In Kazhakuttam and Kallarseries the highest WSA % was observed in rice(76.26%) and rubber(88.48%) land use respectively.

Soil Carbon Pools

The various land use categories had a significant effect on soil organic carbon (SOC) values that ranged from 2.96 to 9.93 g $kg^{-1}$and thus the carbon stock of bulk soil (Table 2). The maximum value was recorded under rubber land use in Kallar soil, which is significantly higher than the coconut land use in Kazhakutam soil which had the least value. Coconut land use recorded the lowest SOC content when compared to other land use systems in all the soils studied. The highest carbon stock of 23.02 kg m^{-2} was recorded in rubber land use in Kallar soil.

The highest concentration of LC were found in soils from coconut plantation site(2516 mg kg^{-1}), followed by rice field(2187mg kg^{-1}),whereas the lowest concentration was detected in homestead site (940 mg kg^{-1}).Hot water soluble carbon (HWSC) in soil ranged between 18.14 and 76.45 mg kg^{-1}. In Vellayani soil, the highest HWSC was observed in vegetable land use and the lowest was observed in coconut land use system. Rubber land use recorded the highest value in Kallarsoil. The land use systems *viz*., coconut (Trivandrum soil) and rice (Kazhakuttam soil) recorded the highest concentration compared to other land uses in the respective soils.

The total particulate organic carbon (TPOC) concentration was found to be higher in vegetable (Vellayani series), homestead (Trivandrum series), rice (Kazhakuttam series) and rubber (Kallar series) compared to other land uses in the respective soil series. Cumulative amount of carbon mineralized in 15 days of incubation ranged from 2.86 to 6.39 mg C kg^{-1} soil. Higher amount of carbon was mineralized in banana (Vellayani series), rubber (Kallar series), rice (Kazhakuttam series) and tapioca (Trivandrum series) land uses.

A positive correlation was observed between soil properties like silt and clay content, bulk density, water stable aggregates and cation exchange capacity with soil carbon pools like organic carbon content, water soluble carbon, labile carbon, particulate organic carbon and mineralisable carbon. Sand content and pH are negatively correlated with soil carbon pools.

Discussion

Soil Properties

The soil texture play an important role in soil organic carbon stabilization and it increases as soil becomes finer. The presence of more silt and clay particles in these soils may interact with organic matter and form aggregates which protect SOC from biological mineralisation. The highest bulk density (BD) noticed in cultivated rice soil might be due to the influence of organic matter content which in turn enhanced the aggregation of soil particles. The difference in pH among soils under different land use systems may be attributed to the variation in rhizosphere activity and rate of decomposition of organic matter that produces organic acids. The highest cation exchange capacity of soil (CEC) in different land uses is due to the regular addition of organic carbon though crop residues and also due to high clay content. The existence of litter and humus in the soil might have contributed towards higher proportion of water stable aggregates (WSA) in different land use systems. Similar results were also reported by Lal *et al*. (2004).

Soil Carbon Pools

The various land use categories had a significant effect on soil organic carbon (SOC) values and thus the carbon stock of bulk soil (Table 2). The average SOC % for various land uses varied in the order rubber > rice > vegetable > banana > homestead >tapioca > coconut. The soil carbon stock also varied in accordance with SOC concentration. The highest SOC and carbon stock was recorded in rubber land use. This may be attributed to input of C through litter fall and greater root biomass and to the chemical stabilization of organic carbon in soil matrix. The lowest organic carbon noticed in coconut land use could be due to low organic matter input coupled by reduced physical protection of SOC as a result of oxidation of soil organic matter (Houghton, 1995) [3].

Significant difference in labile carbon (LC) concentration was detected among different land use systems in all the soils. Labile fraction of organic carbon was largely dependent on the amount of SOC in the soil and it represents an easily decomposable fraction of soil organic matter. Higher level of LC in coconut plantation site indicates greater turnover of organic matter and higher availability of other nutrients also as reported by Jinob *et al.* (2006) [4]. The HWSC is a subset of SOC pool, relatively labile in nature and represents the easily degradable fraction of soil organic matter. Higher value of HWSC noticed in the different land uses indicates lower stability of soil organic matter in these soils as reported by Lal *et al*. (2004).

The presence of higher particulate organic carbon content in different land uses represents the un complexed organic matter and is the most active pool of the SOC and is a sensitive indicator of soil management effects on SOC (Sreekanth *et al.*, 2013) [6]. Higher amount of carbon was mineralized in banana (Vellayani series), rubber (Kallar series), rice (Kazhakuttam series) and tapioca (Trivandrum series) land uses. Application of organic sources resulted in increased carbon mineralization in these soils. The differences in the rates of C mineralization are indicative of variable amounts of labile organic carbon accumulated in different land use systems as reported by Sreekanth *et al.* (2013) [6].

The results indicated that agricultural lands have a greater potential for carbon sequestration. Soil organic carbon stock indicates the carbon storage capacity of soils and from the study the maximum SOC stock was found in rubber plantation soil (Kallar) followed by rice soil (Kazhakuttam). The higher magnitude of POC, a subset of SOC was also observed in the rubber plantation and rice field than coconut plantation which indicated the prevalence of conducive conditions for the building up of carbon in the respective land uses. The labile carbon concentration, hot water soluble carbon, total particulate organic carbon and cumulative amount of carbon mineralized were also significantly influenced by land use systems in all the soils studied. Thus by incorporating suitable land use systems the carbon stock in soil can be increased and thereby reducing the greenhouse effect.

Table 1: Influence of agricultural land uses on physical and chemical properties of major soils of Kerala

Soil (Soil series)	Agricultural land use	Soil Texture	Sand %	Silt %	Clay %	Bulk Density Mg m^{-3}	pH	CECC mol (+) kg $^{-1}$	WSA %
Red loam soil (Vellayani series)	Coconut	sl	69.52	15.67	14.48	1.10	4.94	4.95	81.16
	Banana	sl	67.33	15.43	15.33	1.28	4.72	6.69	73.42
	Vegetables	sl	65.23	15.33	16.19	1.28	4.80	6.88	74.95
Laterite soil (Trivandrum series)	Coconut	sl	79.72	10.85	13.92	1.52	5.32	3.88	57.32
	Tapioca	sl	49.33	24.85	25.76	1.36	5.77	5.31	72.30
	Homestead	sl	49.38	26.80	22.76	1.49	5.07	4.99	49.50
Coastal sandy soil (Kazakuttam series)	Coconut	sl	70.05	14.65	12.67	1.30	5.38	3.65	67.58
	Rice	scl	46.43	27.86	25.70	1.59	4.29	5.21	76.26
	Homestead	scl	83.63	8.19	8.06	1.28	5.28	4.76	58.44
Forest soil (Kallar series)	Coconut	sl	83.09	8.67	8.24	1.20	5.74	5.05	53.25
	Rubber	scl	58.32	21.81	19.87	1.55	5.22	5.94	88.48
	Banana	sl	63.23	21.15	15.63	1.16	5.13	5.03	45.94
CD (P=0.05)	-	-	-	-	-	0.10	0.15	0.86	7.82

sl-sandy loam, scl- sandy clay loam

Table 2: Influence of agricultural land uses on organic carbon stock and carbon pools in major soils of Kerala

Soil (Soil series)	Agricultural land use	SOC g kg^{-1}	SOC Stock kg m^{-2}	LC mg kg^{-1}	HWSC mg kg^{-1}	TPOC mg kg^{-1}	MC mg kg^{-1}
Red loam soil (Vellayani series)	Coconut	6.16	10.23	1093	35.70	2044	4.44
	Banana	7.56	14.59	1699	29.90	2233	5.52
	Vegetables	8.73	16.70	1997	46.25	2747	5.20
Laterite soil (Trivandrum series)	Coconut	6.53	14.82	2516	45.51	1247	5.61
	Tapioca	6.83	13.87	1828	20.76	1130	5.84
	Homestead	7.30	16.32	2052	21.07	1280	5.42
Coastal sandy soil (Kazakuttam series)	Coconut	2.96	5.85	948	36.48	1201	5.40
	Rice	8.90	21.22	2187	76.45	3310	6.39
	Homestead	6.36	12.29	940	32.20	1483	5.62
Forest soil (Kallar series)	Coconut	3.33	5.94	1068	18.14	1738	2.86
	Rubber	9.93	23.02	1349	56.71	3980	4.04
	Banana	6.33	10.96	1147	44.58	2150	3.48
CD (P=0.05)		1.50	3.15	119	6.90	226	0.74

Table 3: Relationship between soil properties and soil carbon pools

	Sand	Silt	Clay	BD	WSA	pH	CEC
SOC	-0.999**	0.799	0.998*	0.890	0.790	- 0.667	0.927
HWSC	0.6- 0.626	0.958	0.638	0.168	0.021	0.199	0.258
LC	-0.983	0.705	0.980	0.946	0.896	-0.766	0.971
TPOC	-0.962	0.945	0.967	0.707	0.563	-0.406	0.768
MC	-0.678	0.139	0.667	0.951	0.992	-0.998*	0.919

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