Location and Land use effects on Soil Carbon Accretion and Productivity in the Coastal Savanna Agro-ecological Zone of Ghana

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Abstract

Land use type, climate and soil properties are major determinants of soil carbon storage and productivity, especially in low-input agriculture. In this study, we investigated the interactions among these factors at four (4) locations, namely Accra Metropolis, Ga West, Ga East and Shai Osudoku, within the Coastal-Savannah agro-ecological zone of Ghana. The land use types were maize-based cropping, cassava-based cropping, woodlot/plantations and natural forests. The impact of these on soil productivity at a given location was assessed in terms of soil carbon stocks and a Soil Productivity Index (*SPI*). The *SPI* is a composite value derived from routine soil properties such as: soil texture, available water capacity, pH, cation exchange capacity, soil organic carbon, available P, exchangeable K, potentially mineralizable nitrogen, and basic cations, among others. Principal component analysis was used to select soil properties that were used to estimate SPI. The results showed that the locations differed with respect to rainfall regimes and soil types. Locations with slightly heavier soil texture and relatively higher rainfall regimes (Ga East and Shai Osudoku) had significantly higher soil carbon storage and *SPI* values than the lighter soil textured locations (Accra Metropolis and Ga West). With regards to land use, forest had significantly higher soil carbon storage and *SPI* than all the other land use types, irrespective of location. The order of soil carbon storage and *SPI* were: forest > woodlot/plantation > cassava > maize. It was observed that though the Accra Metropolis location hosted the oldest forest, soil carbon was still low, apparently due to the lighter soil texture. We concluded that the soil productivity restorative ability is an interactive effect of carbon management (land use), soil texture and other properties. This interaction hitherto has not been adequately investigated, especially in low-input agriculture.

Introduction

Soil carbon storage and productivity are major determinants of sustained crop growth and yields. Brams (1971) showed that a 50% reduction in the soil organic carbon (SOC) after only 5 years of forest land clearing in Sierra Leone resulted in major soil productivity decline. Adiku et al. (2009) also showed in Ghana that where residues were removed (e.g. by burning or converted to feed animals with no return of manure), SOC declined sharply from the long-term fallow land value of 18 g/kg to 7 g/kg within 4 years of maize cropping. Associated with SOC loss was a drastic reduction in maize yields over time, including crop failure in the 3rd year when seasonal rainfall was below normal. However, where residues were maintained as mulch, SOC decline progressed at a significantly slower rate, from 18 g/kg to 15 g/kg in 4 years and crop yields were sustained over time. Estimates by Lal (2006) indicated that maize yield could increase by 30 to 300 kg/ha for every 1.0 ton/ha of SOC increase in crop root zone.

Soil productivity determines the overall function and ability of a soil to support plant growth (Karlen, 2005). Soil productivity is not permanent but can change rapidly depending on land use and management (Reynolds et al., 2015; Waddington et al., 2010; Zerihun, 2017). The bulk of literature (e.g., Batlle-Aguilar et al., 2011; Burras et al., 2001; Sa et al., 2001) indicated that once a forest land is converted to agriculture and other forms of land use, soil productivity will change. Soil productivity can be characterized by a composite Soil Productivity Index (*SPI*). The index can be derived from soil chemical, physical and biological properties. The SOC is a major factor of *SPI* because it mediates in many soil properties (Pan et al., 2009) and also is a major reservoir of plant nutrients in low-input agriculture (Sanchez et al., 2009). However, other soil factors such as texture, pH, cation exchange capacity, available P, exchangeable K, available water capacity, among others, are also important determinants of *SPI*.

Both SOC accretion and *SPI* depend on soil management in terms of land use and soil properties even within a given agro-ecological zone. A high build-up of the SOC is expected under forest land use type because of long term continuous litter addition (Brinson et al., 1980), avoidance of cultivation, reduced decomposition due to lower temperatures under the canopy, among others. For croplands, the constant disturbance due to tillage would enhance SOC decomposition rates (Dalal et al., 1991; Hulugalle et al., 1984; Lal, 1997). Further, the constant seasonal harvesting or removal of plant organic material (Feller, 1993) and partial exposure of the soil to high temperatures during off–seasons when vegetation cover is reduced or absent would accelerate SOC decomposition. Climate factors such as rainfall would also affect its SOC accretion because of its influence on vegetation growth, SOC decomposition and carbon input. However, research results on the effect of land use types on SOC accretion remain inconclusive. For instance, Bessah et al. (2016) found no significant correlation between soil carbon storage and land use types in the interior forest-savannas transition zone of Ghana.

Conceivably, apart from land use, spatial differences in rainfall, vegetation and soil textures and other properties even within a given agro-ecological zone could impact soil productivity differently. Locations receiving high rainfall and hence supporting vegetation growth and carbon input would be expected to accrue higher SOC, resulting in higher productivity. With regard to soils, heavier textures with higher water holding capacity would support higher vegetation growth and improve soil productivity, whereas locations with lighter textures would have lower SOC, cation exchange capacity and water retention properties, resulting in lower productivity. The interaction between location (climate, soil texture and other properties) and land use type on soil productivity has not been investigated sufficiently in tropical low-input agriculture. Much of the research had focused on the land use impact than on differences in location. The focus of this paper is to investigate how local variations in soil texture and other properties, vegetation and climate interact with land use types to determine the overall soil productivity within the Coastal Savannah agro-ecological zone of Ghana.

Materials and Methods

Study locations

Four locations within the coastal savannah zone of Ghana were selected for this study. The

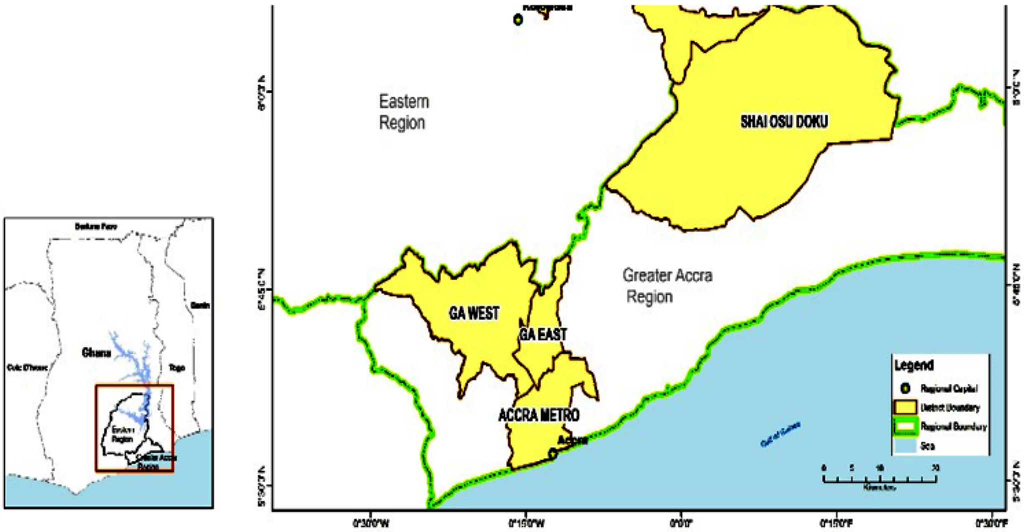

Fig. 1 Map of Ghana showing locations under investigation

coastal savannah zone was selected because of a general lack of land use impact studies, even though rapid conversion of native land to agriculture is progressing rapidly in many parts of the zone. The four locations within the ecological zones were also selected to reflect differences in rainfall and soils for the various land use types. The locations were Accra Metropolis, Ga-West, Ga-East and Shai Osudoku (Fig. 1). Accra Metropolis receives the lowest rainfall amount of 700 mm, with Ga West and Ga East both receiving 800 mm and Shai Osudoku being the wettest zone with 1000 mm of rainfall (Table 1). Rainfall is bimodally distributed, with a major wet season from March to July and a minor wet season from September to November. Though all locations carry savannah grassland vegetation interspersed with residual forests, the proportion of forest cover at the locations increased with rainfall. Also, the soils are mostly loamy sand and sandy loam, however, heavier clay loams can be found at Ga East and Shai Osudoku (Table 1).

TABLE 1

Physiography and land use systems at the locations

Ecological Zones	District	Rainfall (mm)	Land use	Age (yrs)	Soil Texture
Coastal savannah	Accra-Metropolis	700	Maize	10	Loamy sand
			Cassava	10	Sandy loam
			Woodlot (Teak)	20	Loamy sand
			Forest	>150	Loamy sand
	Ga-West	800	Maize	4	Sandy loam
			Cassava	10	Loamy sand
			Plantation (Oil palm)	10	Sandy loam
			Forest	>70	Loamy sand
	Ga –East	800	Maize	5	Sandy loam
			Cassava	8	Sandy loam
			Plantation (Plantain)	6	Sandy clay loam
			Forest	>70	Loam
	Shai Osudoku	1000	Maize	> 50	Loam
			Cassava	> 50	Sandy clay loam
			Plantation (Mango)	7	Sandy loam
			Forest	> 100	Sandy loam

Four land use types were identified at each location, (i) maize-based cropping, (ii) cassava-based cropping, (iii) woodlots or plantations and (iv) forests. (Table 1). The forest represented the oldest vegetation types at each location, with some older than 70 years. At Accra Metropolis, the plantations comprised a teak (*Luceanna species*) woodlot whereas those at Ga West, Ga East and Shai Osudoku were oil palm (*Elaeis guineensis*), plantain (*Musa species*) and mango (*Mangiferra indica*), respectively. The cropped fields comprised maize (*Zea mays*) and cassava (*Manihot esculenta*). Maize fields periodically received modest fertilizer application of not more than 30 kg N/ha. The soils under the croplands were regularly tilled conventionally, whereas those under the woodlot and forest experienced no mechanical disturbance.

Soil sampling and analysis

Top soil (0-20 cm) was sampled in triplicate from each of the four locations under each of the four land use types from April to May 2017, giving a total of 144 units. The sampling followed a random order. For each sampling unit of undisturbed soil cores was taken, oven dried an used to estimate soil bulk density. Disturbed soils were air-dried, crushed and sieved through 2 mm (fine-earth fraction) and used for the determination of texture, total soil carbon, pH, total nitrogen, available phosphorus, and exchangeable cations (Ca, Mg, K, Na). Soil texture was determined following the procedure of Bouyoucous (1951) as modified by Day (1965) using sodium hexametaphosphate as dispersant. Available water capacity (AWC) was estimated using data of soil texture, bulk density, and soil organic matter, using models proposed by Saxton et al. (1986).

Soil chemical determinations include the pH, using a 1:1 soil water ratio with the electrode MV88 Praitronic pH meter. Available phosphorus (AvP) was determined colourimetrically after extraction with Bray 1 solution (Bray and Kurtz, 1945) and the concentration measured using a UV – Spectrophotometer. Exchangeable bases were determined by extraction with 250 ml of buffered 1.0 M ammonium acetate (pH 7.0) followed by flame photometric determination while the concentration of Calcium and Magnesium in the extract were determined by Atomic Absorption Spectrophotometer (AAS) (Model Buck 200A). Sodium (Na) and K were determined using Flame emission photometer. Total soil carbon and nitrogen were determined using TruMac Carbon, Nitrogen and Sulphur analyzer (Model N1914). The potential mineralizable nitrogen (PMN) was estimated from total nitrogen using relations by Dodor and Tabatabi (2007). The Cation Exchange Capacity (CEC) was determined using ammonium acetate (NH_4OAc) extract buffered at pH 7.0.

Determination of soil carbon storage

Soil carbon stocks (C_{st}) were computed for the top 20 cm for each land use type using the equation:

$$C_{st} = A \times \rho_b \times Z \times SOC \qquad (1)$$

where A is the land area (1 ha = 10^4 m^2), Z is the soil depth (m), and ρ_b is the soil bulk density (kg/m^3). The carbon sequestration potential for each land use type was determined as the difference between the current carbon stock and that of the forest, with the latter used as the reference. Given the land use history and duration since establishment, which was obtained through farmer surveys by Owoade et al. (2017), the rate of soil carbon sequestration, k (%/year) for a given land use was determined following Lal and Kimble (2000) as:

$$k = \left(1 - e^{\frac{(lnC_0 - LnC_t)}{\Delta t}}\right) \times 100\ \% \qquad (2)$$

where C_0 is the initial *SOC* (assumed here to be the forest SOC), C_t is the current SOC and Δt is time since land use began.

Derivation of the Soil Productivity index (SPI)

Our formulation of the Soil Productivity Index (*SPI*), as an index of the ability of the soil to sustain crop growth followed the Soil Quality Index concept of Andrews et al. (2004). Numerical values of the soil properties determined in section above were scaled on a 0 – 1 basis using graphical relations reproduced by Brady and Weil (2014). To avoid subjective scaling, equations were fitted to the graphs published by Brady and Weil (2014) (Table 4) and these equations were used to transform the measured data. The overall *SPI* was then derived as:

$$SPI = \sum_{i=1}^{i=n} w_i PI_i \qquad (3)$$

where w_i is the weighting factor, n is the total number of selected properties and PI_i stands for the 0 – 1 soil variable score, (e.g. a SOC value of 20.0 g/kg would yield a scale value of *SOCI* = 0.50 using equation 2 in Table 4). Not all the soil properties were used in the determination of the *SPI*. In this study, we applied the Principal Component Analysis (PCA) to select the soil properties of relevance, using MINITAB statistical software. In all, seven soil variables were selected for the computation of the *SPI* (Tables 2 and 3). The PCA approach was used to reduce the effect of

TABLE 2
Pearson Correlations among soil variables

	pH	**PMN**	**C**	**P**	**K**	**CEC**	**AWC**
pH	1						
PMN	-0.603***	1					
C	0.384**	-0.136	1				
P	-0.016	0.041	0.294**	1			
K	0.401**	-0.237	0.188	0.054	1		
CEC	0.613***	-0.352**	0.765***	0.338**	0.338	1	
AWC	0.117	-0.061	0.583***	0.027	0.234	0.403**	1

*P ≤ 0.05, ** P ≤ 0.01, *** P ≤ 0.001
Cell Contents: Pearson correlation P-Value

TABLE 3
Principal Component Analysis

	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
pH	-0.434	0.428	0.102	0.117	-0.345	**0.670**	-0.192
PMN mg/kg	0.306	**-0.546**	-0.144	-0.278	-0.643	0.305	0.061
C (g/kg)	-0.466	-0.369	-0.096	0.227	-0.228	-0.386	**-0.621**
P Mg/kg	-0.165	-0.443	**0.739**	-0.216	0.337	0.250	-0.085
AWC mm/m)	-0.323	-0.354	-0.612	0.016	**0.474**	0.391	0.136
CEC cmol/kg	**-0.525**	-0.117	0.141	0.119	-0.279	-0.241	0.736
K (mg/kg)	-0.307	0.218	-0.137	**-0.892**	-0.013	-0.191	-0.081
Eigenvalue	2.9434	1.3945	0.9836	0.7897	0.4948	0.2309	0.1632
Proportion	0.420	0.199	0.141	0.113	0.071	0.033	0.023
Cumulative	0.420	0.620	0.760	0.873	0.944	0.977	1.000

Highlighted values are the selected loading for each variable

TABLE 4
Equations for Normalizing Soil Property Values

	Soil/Environmental Property	Equations
1	Available Water (mm/m)	$AWCI = -4 \times 10^{-9} \times AWC^3 + 2 \times 10^{-6} \times AWC^2 + 0.0022 \times AWC - 0.0528$
2	Soil Organic Carbon (g/kg)	$SOCI = 10^{-5} \times SOC^3 + 0.001 \times SOC^2 + 0.0014 \times SOC - 0.007$
3	pH	$pHI = -0.028 \times pH^2 + 0.36 \times pH - 0.15$
4	Cation Exchange Capacity (cmol/kg)	$CECI = 0.225 \times Ln(CEC) + 0.0024$
5	Available P (mg/kg)	$AvPI = 4 \times 10^{-7} \times AvP^3 - 0.0002 \times AvP^2 + 0.0249 \times AvP + 0.133$
6	PMN + N application (kg/ha)	$NI = \frac{1}{[1 + \exp(2 - 0.05N)]}$
7	K (mg/kg)	$KI = \frac{5.5027 \times Ln(K) + 66.55}{100}$

multi-collinearity as soil properties are often correlated (Braimoh et al., 2004). In selecting the soil variables, properties corresponding to the highest loadings in each PC was selected as highlighted in Table (3) and their weighting factors w_i in equation (3) were taken as the proportion of the total variation explained by a given PC (Bhardwaja et al., 2011).

Results and Discussion

Climate and soil properties

As shown in Table 1, both rainfall (assumed to be the main climatic element) and soil texture and other properties varied within the agro-ecological zone. There was a wetting gradient from Accra Metropolis towards Shai Osudoku which was also depicted in vegetation type. Shai Osudoku District lies at the fringe of the forest-savannah transition and had more forest vegetation than the other locations. This would also imply a greater carbon input into the soil than the other locations. The Accra

TABLE 5
Soil physical and chemical properties for the different District Locations and Land use systems

	Land use	Sand	Clay	BD	AWC**	pH	SOC	TN	CEC	K	Av-P	PMN**	Carbon stock
		%	%	g/cm³	mm/m		g/kg	%	(cmol/kg)		(mg/kg)		(kg/ha)
Accra-Metropolis	Maize	61.64	7.5	1.42	107.7	4.1	7.03	0.4	3.38	0.97	0.5	18	19834
	Cassava	64.15	5.0	1.39	103.3	4.4	8.6	0.4	2.72	0.98	0.45	15.57	24205
	Woodlot	57.43	7.5	1.19	120	4.7	13.5	0.5	2.49	0.95	0.32	11.76	22320
	Forest	64.51	5.83	1.08	113.3	4.4	20.4	0.5	3.9	0.98	0.68	29.75	43844
Ga-West	Maize	65.56	3.75	1.45	103	5.6	6.77	0.4	3.68	0.99	0.48	16.76	28829
	Cassava	68.59	10	1.34	93.3	4.96	11.52	0.4	2.48	0.98	0.32	8.01	30930
	Plantation	62.63	14.17	1.43	103.3	5.02	10.37	0.4	2.91	0.98	0.39	8.76	28843
	Forest	60.93	10	1.31	113.3	4.63	17.31	0.4	3.15	0.97	0.36	9.87	44847
Ga -East	Maize	65.44	14.17	1.41	100	5.94	12.19	0.3	4.08	0.99	0.39	11.27	29075
	Cassava	63.97	16.67	1.2	100	5.62	11.07	0.2	4.08	1	0.38	11.93	27701
	Plantation	58.68	17.5	1.37	110	5.86	10.74	0.3	3.84	1	0.37	10.57	28936
	Forest	60	20	1.11	170	5.16	28.33	0.1	5.26	1	0.35	9.51	58549
Shai Osudoku	Maize	55.57	16.67	1.52	163	5.6	26.74	0.1	6.31	0.99	0.47	10.05	56093
	Cassava	18.82	35	1.32	110	6.81	24.07	0.1	7.77	1	0.46	10.76	51152
	Plantation	61.13	18.33	1.42	123	6.37	19.49	0.1	5.88	0.99	0.48	11.66	41180
	Forest	58.63	18.33	1.35	120	5.84	23.84	0.4	7.12	0.98	0.49	15.87	58802

**Derived values

Metropolis, is comparably the driest location amongst all four locations.

Soil texture is commonly within sandy loams and loamy soils, with slightly higher clay content at some fields at Ga East and Shai Osudoku (Table 5), reflecting a relatively higher Available Water Capacity (AWC), an important factor for soil productivity maintenance especially under rain-fed agriculture. The soil under the maize farm at Shai Osudoku, for example, had high AWC of 163 mm/m. Soil pH varied from 5.1 (acidic) to 6.8 (near neutral), but the soils under the forest land use had the lowest pH. Though crops will display varying sensitivities to acidity and alkalinity because pH affects the availability of nutrients and soil biological activity, crop yields are normally high on soils with pH values between 5.5–6.5 (Motsara and Roy, 2008). Thus, with respect to pH, most of the locations within the agro-ecological zone are suitable for crop production.

Soil organic carbon and indeed, carbon stocks varied with land use types (Table 5). Forest soils held the highest SOC, with carbon stocks ranging from 43844 (maize) to 58802 kg/ha (forest). There was an increasing trend in carbon stocks from the driest zone (Accra Metropolis) to the wettest zones (Ga East and Shai Osudoku). Except for Shai Osudoku District, where the establishment duration of the plantation land use was relatively short (Table 1), carbon stock of the plantations at the other locations were higher than those of the maize fields. The total nitrogen varied with land use type, but appeared also to be affected by the plant species used for the plantation. The 18-year old leguminous *Leucaena leucocephala* plant used for the woodlot fallow at the Accra Metropolis effectively increased the Total Nitrogen (TN) more than those under the other plantations. The relatively low level of the TN under maize soils may be attributed to lower organic matter additions or the periodic destruction by burning of organic residues as well as the continuous uptake of nutrients by plants with limited fertilizer application.

Land use impact on soil carbon accretion rates

The determination of the carbon accretion rates under the various land use types (using equation 2) was handicapped by the poor documentation of the farm management histories. Interviews of farmers failed to capture reliable histories, especially regarding the age of the various land use types and the field management history prior to the establishment of the land use types. It was only for the woodlot at Accra Metropolis that the age of the woodlot was estimated as between 18 to 20 years. Even in this case, the initial SOC prior to the establishment of the woodlot was unknown. Given that the woodlot was established on a previously cultivated long-term cropped land, we assumed that the initial SOC was similar to that of the current maize fields which continues to be cropped to date and hence degraded. Hence, our estimation of the soil carbon accretion rate following equation (2) gave k = 2.6 %/year for the Accra Metropolis woodlot. Similar rates of SOC sequestration have been observed for forest lands (Lal and Kimble, 2000). The Mean Residence Time (MRT) given by $1/k$ suggests that it would take about 38 years for the *Luceanna* woodlot at Accra Metropolis to restore the SOC from the initial value to that of the current forest SOC. While the *Luceanna* woodlot land use would be effective for SOC restoration, the practice would take land out of cultivation for many years and this will be met

TABLE 6
Location and land use effects on soil productivity factors

(a) Location

District	SOC (Mean, g/kg)	*SPI* score
Accra Metropolis	11.35	0.42
Ga-West	11.49	0.40
Ga –East	15.60	0.43
Shai Osudoku	23.54	0.50
P-values	$p = 0.00$	$p = 0.00$

(b) Land use

District	SOC (Mean, g/kg)	*SPI* score
Maize	13.19	0.44
Cassava	13.82	0.42
Plantation	12.49	0.42
Forest	22.48	0.47
P-values	$p = 0.00$	$p = 0.04$

with practical challenges.

Using the current SOC under forest land use type as the potential SOC accretion at any given location, it can be inferred that maize-based systems which had the lowest SOC also offered the greatest opportunity for increased SOC sequestration. However, the relatively lower rainfall which translates to low carbon input rates and the frequent soil tillage disturbance under maize cropping, especially at Accra Metropolis, would imply that the attainment of potential carbon sequestration would not be feasible within reasonable time. A more feasible approach to attain a rapid SOC build-up, while also ensuring cropping activity, could be the rotation of the *Leucaena* woodlot system with the maize fields, somewhat akin to the indigenous shifting cultivation systems. While, it is not the focus of this study to rekindle a debate on shifting cultivation, sustainable cropping in the tropics must take advantage of the contribution of trees to enhance soil productivity maintenance (Kang, 1993).

Impact of location and land use on soil carbon storage and SPI

Based on the PCA analysis (Table 3), the complete *SPI* equation (see equation 3) was derived as in equation 4:

$$SPI = 0.39 \times CEC + 0.22 \times PMNI + 0.14 \times AvPI + 0.11 \times Exch\ KI + 0.07 \times AWOCI + 0.05 \times pHI + 0.02 \times SOCI \qquad (4)$$

Considering the weightings, the derived *SPI* equation suggested a higher impact of *CEC* and other soil variables on the *SPI* than the SOC. This is in contrast to many earlier studies that have indicated the dominant role played by the SOC in determining the soil productivity (e.g. Chandel et al. 2018; Khaki et al., 2017; Lal, 2014; Masto et al., 2008) and accordingly have obtained relatively high rating for SOC (Masto et al., 2008; Mukherjee and Lal, 2014, Ivezić et al., 2015). While our observation is supported somewhat by studies

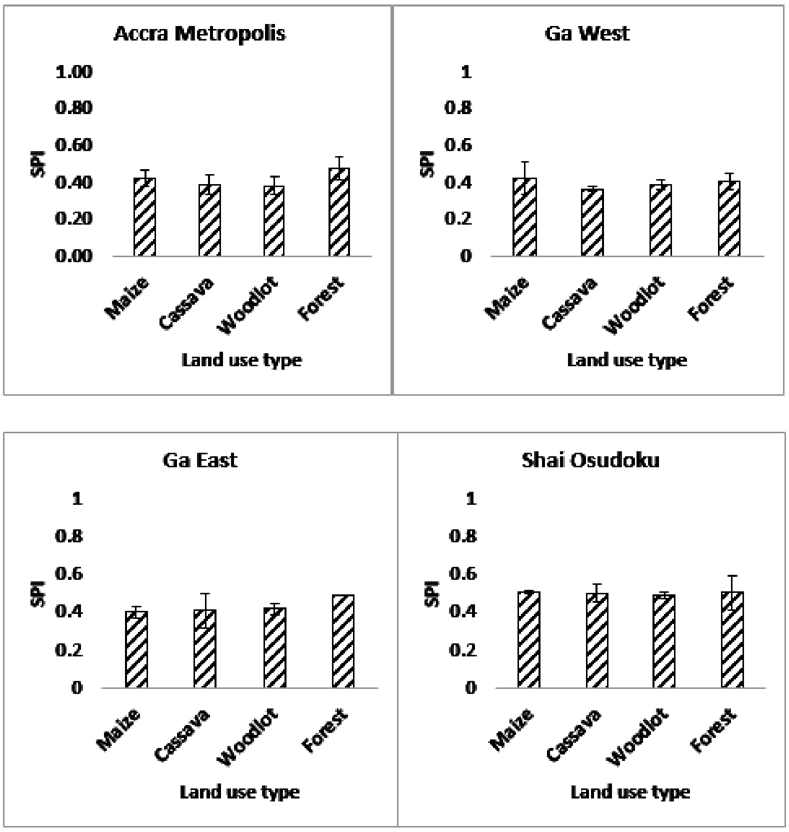

Fig. 2 Soil productivity indices (SPI) for different locations and land use types within the Greater Accra (Coastal savanna) Region

such as Vasu et al. (2016), it must be noted that the SOC also mediates several soil properties (e.g. PMN, CEC, and AWC) which have high weightings in the *SPI* equation.

It is a major focus of this study to assess whether local variations in soil properties and climate (in this case rainfall) interact with land use types to determine the productivity of the soils, even within a given agro-ecological zone. The results of this study clearly indicated that this is the case (Table 6; Fig. 2). Though the significantly ($p = 0.000$) higher SOC and *SPI* at Ga East and Shai Osudoku locations could be attributed to the increased carbon input because of greater vegetation growth, the role of higher clay content at the two locations (Table 5) suggests that soil factors cannot be ignored. In the same vein, the impact of the land use type cannot be ignored either. As shown in Table 6, forests, in particular, tended to significantly ($p < 0.01$) increase the SOC and *SPI* ($p = 0.050$) though the interaction between the land use type and location was not significant ($p = 0.666$). Given that the interaction between land use type and location was not significant, the observation that forest at Accra Metropolis, which was much older (> 150 years) than those of the other locations (Table 1) held a lower SOC suggest that some other factors (either biotic or abiotic) may have limiting effect on SOC accretion.

For instance, clay content, mineralogy of soil, structural stability, landscape position, soil moisture and temperature regimes, are important abiotic factors that control soil carbon sequestration (Jimenez et al., 2007). In our case, location and climate (low rainfall) and soil type (coarse-texture, low AWC) inhibit soil carbon accretion at Accra Metropolis forest (refer to Fig. 1). This is further supported by the significant correlation ($p < 0.01$) between AWC and SOC (Table 2). Evidently, carbon accretion in soil is not a linear function of organic litter input (due to land use), and this complicates interpretation of vegetation cover as index of SOC in terms of *SPI*. For example, Bessah et al. (2016) found no significant differences between soil carbon storage among land use types in the interior forest-savannas transition zone of Ghana. Whether it is the carbon input rate (land use impact) or soil carbon storage capacity (soil texture factor) that should guide the management of lands for productivity maintenance is still a matter for further investigation.

Conclusion

The interactive effect of the local differences in climate (rainfall), soil texture and other properties and land use types on soil productivity of 4 locations (Accra Metropolis, Ga East, Ga West, and Shai Osudoku), within the Coastal Savannah agro-ecological zone of Ghana was investigated in this study. The *SPI* was used to compare how four land use types, namely: (i) maize and (ii) cassava farms, (iii) woodlot/plantations and (iv) natural forests, impacted on the soil productivity at the four locations. With regard to land use impact on soil productivity, the order of the *SPI* was: forest > wooldlot/plantation > cassava > maize. Forests accrued the highest carbon stocks and also had the highest *SPI*s; an indication that carbon is a key determinant of soil productivity. In terms of the impact of location (climate and soil texture and other properties) on soil productivity, the order for *SPI* was: Shai Osudoku > Ga East > Ga West > Accra Metropolis. Though the forest in Accra Metropolis was the oldest, it did not hold the highest carbon stockindicating that light textured soils hold less carbon compared to heavy soils. We conclude that carbon input alone did not determine the soil carbon storage capacity nor the productivity maintenance capacity of soils.

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