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Full Length Research Paper

Soil organic carbon status in a vegetable cropping systems in Southern Benin: A rapid assessment

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Assessing and monitoring soil organic matter (SOM) is important for determining and developing management practices that will enhance agricultural soil quality. This study is aimed at assessing soil organic carbon (SOC) stocks and pools resulting from agricultural practices in the upper soil depths (0-10 cm and 10-20 cm) in vegetable cropping systems in peri-urban areas in southern Benin. The study was conducted on plots that have been amending since 2006 with poultry manure (S+PM) and sheep dung (S+SD). Two particle-size fractions of SOM: Particulate Organic Matter (POM: 2-0.053mm) and Fine Organic Matter (FOM: 0-.053mm) were separated at 0-10 cm and 10-20cm depths and their respective carbon contents were determined through Loss On Ignition (LOI) methods. Results showed that SOC stock was the highest in fallow with 22.93 t.ha^{-1}and 25.87 t.ha^{-1} respectively at 0–10 cm and 10–20 cm depths. The cultivation leads to a depletion in organic carbon stocks compared to the herbaceous fallow. Although no significant difference was found for SOC stocks between S+PM and S+SD for the both depths, the PM application over the time could lead to increase in SOC stocks compared to the SD application. However, their SOC distribution in fraction is similar.

Keywords: Soil Organic Carbon; agricultural practices; particle-size fractionation; vegetable cropping systems, Southern Benin.

INTRODUCTION

In Southern Benin, vegetable production is mainly practiced in a context of peri-urban agriculture (Temple and Moustier, 2004) as this part of the country concentrates the largest cities. Economic development and increased demography at urban level due to rural exodus have both given incentives to a high demand by vegetable consumers and conducted to land pressure. Arable land in peri-urban areas is becoming scarce and the challenge for vegetable growers is to produce more on the same land while keeping low production costs. Consequently, agricultural management practices in these vegetable cropping systems get more intensive and include the simultaneous use of mineral fertilizers and organic manure from neighboring livestock farms to lessen the expenses involved in buying mineral fertilizers.

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The farmyard manure application improves soil quality as it increases the level of soil organic matter (SOM) and soil organic carbon (SOC) as well (Aoyama et al., 1999; Banger et al., 2010). The SOC is the preponderant attribute for monitoring soil quality, early and long-term changes (Reeves, 1997; Shukla et al., 2006) and then, its maintenance is necessary for sustainable agro ecosystems (Gregorich et al., 1994; Wang et al., 2014), especially in the context where the importance of soils in terms of ecosystem services (ESs) is gaining awareness regarding its carbon sink potential (Lal, 2011).
Particle-size fractionation allows a physical separation of SOM into fractions varying in degree of decomposition, recalcitrance, and turnover rate that can be related to SOM pools (DeGryze et al., 2004; Von Lützow et al., 2007). *In facto*, two major groups of SOM fractions are generally identified: Particulate Organic Matter (POM)

the size-fraction between 0.053 and 2 mm and fine amorphous organic matter (FOM), consisting of the size-fraction <0.053 mm (Cambardella and Elliot, 1992). The POM is considered as a labile SOM pool (Solomon et al., 2000) while the FOM is referred to as a recalcitrance SOM pool (Mando; 2005).

Farm activities ranging from land preparation to post-harvest, along with particular factors that prevail within agricultural ecosystems can influence the SOM kinetics. Many studies have reported that organic resources quality, tillage, and crop production have different effects on SOM pools, depending on regional climate, soil type, residue management practice (Qin et al., 2010; Stockmann et al., 2013, Yang et al., 2015). Ouédraogo et al. (2006) showed that tillage increased the contribution of particulate organic carbon to total organic carbon in semi-arid West Africa. Yan et al. (2012) concluded that the conversion of cereal fields into highly intensive vegetable systems in China leads to marked differences in C and N stabilization dynamics.

In Benin, most of the studies related to soil management practices effects on SOC focused on comparison between those practices with regard to the soil carbon stocks and dynamics within cereals-legumes cropping systems (Azontondé, 2000; Barthès et al., 2004) and palm oil cropping systems (Djegui et al., 1992; Aholoukpè et al., 2016). Limited data exist on the soil organic carbon stocks and pools dynamics in such vegetable cropping systems where farmyard manures are highly used. Such knowledge might prove useful in selecting management practices that maintain adequate levels of appropriate forms of SOM.

In this paper, we assessed SOC stocks and dynamics resulting from agricultural practices in the upper soil depths (0-10 cm and 10-20 cm) as it occurs in vegetable cropping systems in peri-urban areas in Southern Benin. There were three main goals of this study: (i) quantifying and comparing the effects of repeated applications of two farmyard manures usually used in peri-urban areas in Southern Benin on SOC stocks and fractions; (ii) determining relative contributions of different SOC fractions on total soil C content, and (iii) analyzing the impacts of the agricultural practices on SOC stocks and dynamics in these cultivated soils by comparing to results from a five-year fallow land used as reference.

MATERIALS AND METHODS

Study site description

The study was carried out upon the gardening experimental fields located within the Benin's National Agricultural Researches Institute at the station of Agonkamey (6°40'94''N latitude, 2°33'18''E longitude and 19 m altitude) in Southern Benin. Agonkamey is a peri-urban area located in the commune of Abomey-calavifar 9 km away from Cotonou, the metropolis of Benin. The study site belongs to the ''Programme Cultures Maraîchères" which is the research department of Benin's National Agricultural Researches Institute devoted to carrying out studies on horticulture and vegetables cropping systems.

The soil was a sandy, textured *rhodic ferralsol* (*Eutrustox*) (Djegui et al., 1992). The climate of the region is sub-equatorial with a bimodal rainfall pattern typically characterized by two rainfall seasons occurring from mid-march to mid-July and mid-September to mid-October respectively.

Land use and fertilization management history of the study site

The study was carried out on two plots located within the same site but differing by the organic manure that have been applied to vegetables. The first ones have been manured since 2000 with sheep dung composted in the animals litter consistent with fodder residues (C/N 13.74 in 2013) and the second from 2000 to 2006 with composted cotton seed (C/N 15.7 in 2001) and since 2006 with poultry manure mixed with sawdust (C/N 8.27 in 2013). Table 1 shows details about the fertilization management history.

(Table 1)

A five-year fallow was chosen near the cultivated plots and was used as control. Vegetation type in this fallow was a disturbed herbaceous meadow with species like *Imperata cylindrica*, *Cleome viscosa*, and *Ricinus comosus.*

Soil sampling and characteristics

The soil was sampled in 0–10 cm and 10–20 cm depths during August 2013 with an auger. The soil receiving poultry manure is designated by S+PM and S+SD for the one receiving sheep dung. The soil samples were a composite of four random subsamples per plot, collected from the control (the 5 years fallow) and the cultivated plots before the tillage. The samples were then air-dried and sieved through a 2 mm mesh for laboratory analyses. Both depths samples were concerned by the soil organic carbon stock measurement and fractionation. However, initial physical and other chemical properties of the soil were determined only for the topsoil depth (0-10 cm) using soil analysis routine methods described in Okalebo et al. (2002).

Undisturbed soil was sampled per depth with a steel cylinder (5.25 cm x 5.25 cm, three per depths) to determine the bulk density (Blake and Hartge, 1986).

(Table 2)

Soil organic carbon stock calculations

The sampled soils were neither gravelly nor rich in

Table 1. Land use management history of the study site.

Plots receiving organic resources	Periods	Culturalhistory	Doses
Cotton seed	2001-2002	*Solanummacrocarpum*	20 t.ha^{-1}
	2002-2003	*Amaranth*uscruentus/ fallow/*Solanummacrocarpum*	
	2004	*Capsicum annum* / one month fallow / *Capsicum annum* / two months fallow	
	2005	2 monthsfallow/ *Lycopersiconesculentum*	
	2006	*Amaranthuscruentus/ Capsicumannum*	
Poultrymanure (PM)	2010-2011	*Launeataraxacifolia- Ocimumgratissimum*	10 t.ha^{-1} of PM+ 100 kg.ha^{-1}d'urea
	2011-2012	*Launeataraxacifolia-Ocimumgratissimum*	10 t.ha^{-1} of PM + 100 kg.ha^{-1} of urea
	End of 2012	*Lycopersiconesculentum*	10 t.ha^{-1} of PM + 200 kg.ha^{-1} of NPKSB +100 kg.ha^{-1} K_2SO_4 +100 kg of urea
	Earlierin 2013	*Lycopersiconesculentum*	10 t.ha^{-1} of PM + 200 kg.ha^{-1} NPKSB +100 kg.ha^{-1} K_2SO_4 +100 kg of urea
Sheep dung (SD)	2000-2001	*CitruluslanatusLycopersiconesculentum*/*Amaranthuscruentus* / *Solanummacrocarpum*/*Amaranthuscruentus*	20 t.ha^{-1}
	2002-2003	*Lycopersiconesculentum*/*Amaranthuscruentus* /*Lycopersiconesculentum*	
	2004	2 months fallow/ *Capsicum annum* /*Amaranthuscruentus*	
	2005	*Capsicum annum* /*Amaranthuscruentus*/ *Capsicum annum*	
	2006	*Amaranthusspp*/ *Capsicum annum*	
	2011	*Lycopersiconesculentum*	10 t.ha^{-1} of SD + 200 kg.ha^{-1} NPKSB
	2012	Short fallow (twomonths)	-
	Earlierin 2013	*Vitex doniana*	0,5 kg ; 1 kg or 1,5 kg per plant

concretion. As such, we used the following slightly modified formula to assess the soil C stock:

Soil C stock = [C] x ρ_b x t

layer bulk density (g.cm^{-3}) and t: thickness of soil layer (dm);

For the determination of soil carbon concentrations, 5 g subsamples were oven-dried at 65°C up to constant weight and set in a muffle furnace for dry combustion at 700 °C during 2 hours according to the process of Loss

Where Soil C stock: carbon stock of a soil layer (t.ha^{-1}); [C]: carbon concentration in the soil layer (mg.g^{-1}); ρ_b:

OnIgnition (LOI). The weight of each ashed sample was recorded and used for the determination of organic matter concentration ([OM]) (Donato and Kaufmann, 2012). The soil carbon concentration was calculated as:

[C] = [OM]/1.724[C]: carbon concentration in the soil layer; [OM]: organic matter concentration in the soil layer.

Table 2. The Top soil (0-10 cm) characteristics of the study sites.

		S+PM	S+SD	Fallow
% Sand		82.54	83.27	-
% Silt		4.85	4.5	-
% Clay		12.6	12.15	-
Bulk density ($g.cm^{-3}$)	0-10 cm	1.51	1.59	1.73
	10-20 cm	1.64	1.71	1.82
$pH(H_2O)$		5.5	5.72	6.6
C ($g.kg^{-1}$)	0-10 cm	8.9	6.18	13.2
	10-20 cm	0.84	0.915	1.422
N ($g.kg^{-1}$)		0.49	0.17	0.87
P Exchangeable ($mg.kg^{-1}$)		293.73	99.59	116.56
K ($cmol.kg^{-1}$)		0.1	0. 06	0. 23
C/N		18.16	36.35	15.17

Table 3. The SOC ($g.\ kg^{-1}$) for 0–10 and 10–20cm depths in the manured plots and fallow.

	0-10 cm	10-20 cm	0-20 cm
Fallow	22,93±1,68aA	25,87±0,11aA	24,40±1,09a
S+PM	13,55±0,22bA	13,81±0,04cA	13,68±1,12b
S+SD	9,82±0,09bB	15,64±0,18bA	12,73±1,68b
$Lsd_{0.05}$ manure resources	1,62	3,93	1,89
$Lsd_{0.05}$depths	7,24	0,99	0,9

Means ± standard deviation; Mean values by different lowercase letters in the same columns are significantly ($p<0.05$) different between manure managements, and mean values by different capital letters in the same line are significantly ($p<0.05$) different between two depths.

Soil physical fractionation and calculations

The technique of determining particle size distribution proposed by Feller (1979) based on physical dispersion and proved on the coarse textured and poor in humus tropical soil was used. This method shows a good accuracy and avoids carbon dissolution. Hundred grams of soil were dispersed in 300 ml of distilled water containing three glass bullets and shaken for 1 h in a reciprocal shaker. The soil suspension was then wet-sieved through 2 and 0.053 mm sieves to give coarse fraction 2–0.053 mm (Particulate Organic Matter: POM), and fine fraction < 0.053 mm (Fine Organic Matter: FOM).
The C concentration of these fractions is referred to as Particulate Organic Carbon (POC) and Fine Organic Carbon (FOC) respectively.
Plant materials consisting of plant debris and roots partially decomposed in the coarse fractions (F1) were gently separated. The fractions were oven-dried (65°C) and weighed, grounded and analyzed for carbon concentrations as previously described.
The carbon enrichment factors (Ec) of each fraction have been calculated for each size class with the following equation used by Christensen (2001):

$$\mathbf{Ec = Cfrac/Corgtot}$$

Cfrac ($mg.g^{-1}$): the carbon content in the soil fraction and Corgtot ($mg.g^{-1}$): the total carbon content in the whole soil sample.
In this study, this formula has been multiplied by 100 to determine as a percentage. The carbon enrichment factors (Ec) allowed the comparisons among concentrations of organic carbon in various particle-size fractions isolated from different soils.
The Sensitivity Index (SI) was computed for the fractions using the following equation (*Banger* et al., 2010; Wanget. al., 2014).

$$\mathbf{SI = \frac{Cfractioninsoilofagiventreatment - Cfractioninreferencesoil}{Cfractioninreferencesoil}}$$

The SI is used to compare the magnitude of changes in different labile soil organic carbon C fraction that is relative to the reference soil. The Sensibility Index *(SI)* had been calculated for the both fractions for the

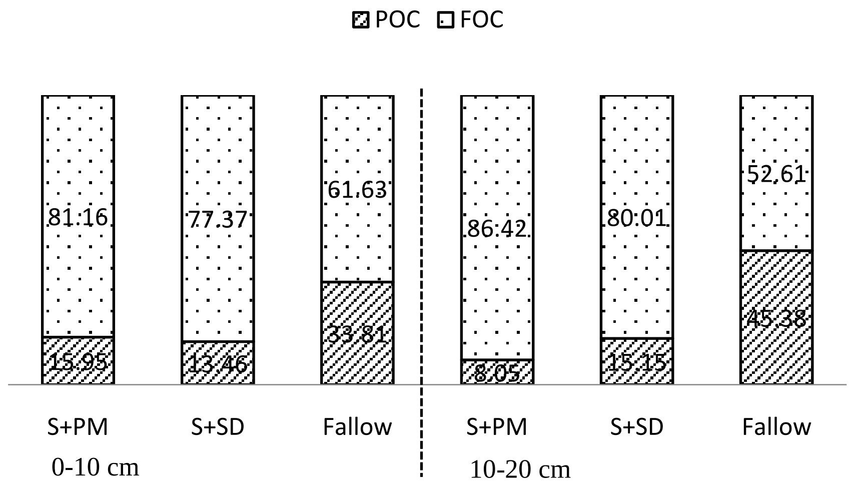

Fig. 1. Carbon enrichments proportions of soil organic matter fractions

Table 4. The POC (g. kg^{-1}) for 0–10 and 10–20cm depths under the manured soils and fallow

	0-10 cm	10-20 cm	0-20 cm
Fallow	4.48±0.44aB	6.4±0.09aA	5.46±0.5a
S+PM	1.43±0.0bA	0.68±0.03cB	1.05±0.2b
S+SD	0.83±0.01bB	1.39±0.2bA	1.1±0.3b
$Lsd_{0.05}$ manure resources	1.1	0.3	1.2
$Lsd_{0.05}$ depths	1.9	0.1	0.3

Means ± standard deviation; Mean values by different lowercase letters in the same columns aresignificantly ($p<0.05$) different between manure managements, and mean values by different capital letters in the same line are significantly ($p<0.05$) different between two depths.

cultivated plots, the fallow has been considered as the reference.

Statistical analysis

Data were subjected to ANOVA two ways analysis using the GLM procedures of the Statistical Analysis System (SAS v. 9.2). Fisher Least Significant Difference (LSD) test was performed to determine significant differences (p < 5%).

RESULTS

Soil organic carbon (SOC) stocks

The effects of farmyard manures on the stock of Soil Organic Carbon (SOC) in the both depths (0-10 cm and 10-20 cm) are shown in Table 3. At 0–10 cm, the SOC stock did not differ between the manure sources, with 13.55 t.ha^{-1} for S+PM and 9.82 t.ha^{-1}for S+SD. The similar trend is also found in 10–20 cm depth with 13.81 and 15.61 t.ha^{-1} respectively. The SOC stock is the highest in the fallow with 22.93 t.ha^{-1}and 25.87 t.ha^{-1} respectively for 0-10 cm and 10-20 cm (Table 3)

Organic Carbon concentrations in fractions

The Particulate Organic Carbon (POC)

Average concentrations of the Particulate Organic Carbon (POC) (0.053mm < particle size < 2 mm) increased with soil depth for fallow land and S+SD while decreasing for S+PM (Table4). Furthermore, at both depths, fallow shows the highest values (4.48 g.kg^{-1}; 6.4 g.kg^{-1}). The POC concentrations were significantly lower under S+PM than the occurrence under S+SD at 10-20cm. For the S+PM, the mean values varied from 1.43 g.kg^{-1}(0-10 cm) to0.68 g.kg^{-1}(10–20 cm), while changed from 0.83 g.kg^{-1}(0-10 cm) to 1.39 g.kg^{-1}(10-20 cm) for S+SD. However, the POC values of S+PM and S+SD are not significantly different at the bulk layer (0-20 cm) with 1.05 g.kg^{-1}and 1.1 g.kg^{-1} respectively.

Table 5. The FOC (g. kg^{-1}) for 0–10 and 10–20cm depths under the amended soils and fallow.

	0-10 cm	10-20 cm	0-20 cm
Fallow	8.12±0.07aA	7.47±0.01aB	7.8±0.1a
S+PM	7.26±0.08bA	7.28±0.04aA	7.2±0.03ab
S+SD	4.78±0.07cB	7.32±0.07aA	6.0±0.7b
$Lsd_{0.05}$ manure resources	0.34	0.2	1.4
$Lsd_{0.05}$ depths	0.3	0.4	0.4

Means ± standard deviation; Mean values by different lowercase letters in the same columns are significantly ($p<0.05$) different between manure managements, and mean values by different capital letters in the same line are significantly ($p<0.05$) different between two depths.

Table 6. Sensitivity index of the soil organic matter fractions for 0–10 and 10–20 cm depths

	POM		FOM	
	S+PM	S+SD	S+PM	S+SD
0-10 cm	0,68 b	0,81a	0,11b	0,41a
10-20 cm	0,89a	0,78b	0,02a	0,02a
0-20 cm	0,78a	0,8a	0,06a	0,21a

Means value designated by lowercase letterson the same line are significantly ($p<0.05$) different between two depths.

(Table 4)

The Fine organic carbon (FOC)

Farmyard manure application significantly affects the Fine organic carbon (FOC) (particle size < 0.053 mm). Difference between depths was also significant (Table 5). Fallow shows the highest values of FOC at the two depths (respectively 8.12 g.kg^{-1} and 7.47g.kg^{-1}). In the amended soils, FOC concentration was significantly higher in S + PM compared to S+SD at 0-10 cm. No significant difference were observed among the two soils at the 10-20cm, while the FOC concentration in S+PM is higher than S+SD for the bulk soil (0-20cm).

(Table 5)

Carbon enrichments of soil organic matter fractions

In general, FOC contributes more to the total SOC than POC for the both soil depths, and the fallow presents the highest values. In 0-10 cm, the average POC accounts for about 33.81% while the fine fraction weights 61.63% of the total SOC in fallow. In cultivated plots, the FOC and POC proportions were respectively 81.16% and 15.95% for S+PM while 77.37% and 13.46% respectively for S+SD (Fig.1). The same tendency is observed for the 10-20 cm where values vary from 52.61 to 45.38 % respectively for POC and FOC in the fallow. In cultivated plots, the POC contribution was 8.05% while FOC is 86.42% in S+PM. The POC and FOC contributions were 15.15% and 80.01% respectively in S+SD.

(Figure 1).

Sensitivity Index (SI) of the carbon fractions

The SI values of the POM for the S+PM were 0.68 and 0.89 for 0–10 cm and 10–20 cm depths, and the values for S+SD were 0.81 and 0.78 for 0–10 cm and 10–20 cm, respectively (Table6). For the bulk layer (0-20 cm), values were 0.78 and 0.8 respectively for S+PM and S+SD and no significant difference where noted between them. The SI values of the FOM are lower than those found for the POM. The SI values of the FOM for the S+PM were 0.11 and 0.02 for 0–10 cm and 10–20 cm depths, and the values for S+SD were 0.41 and 0.02 for 0–10 cm and 10–20 cm, respectively. For 0-20 cm, values were 0.06 and 0.21 respectively for S+PM and S+SD. No significant difference where noted between them.

(Table 6)

DISCUSSION

Comparative effects of farmyard manures types upon SOC stocks and fractionsin the upper soil depths

The average carbon stock in *ferralsols* in Benin does not exceed 22 t.ha^{-1} within 0-20 cm,with 50% of variation coefficient (Volkoff et al., 1999). The data from the Soil Profile Database Representativeness world level (Batjes, 1996) assume that the mean organic carbon contents for this soil type is 57 t.ha^{-1} with 60 % of variation coefficient for 0-30 cm depth intervals. Our results support these earlier studies with values ranging from 9.83 to 25.87 $t.ha^{-1}$.

The effects of farmyard manure application on soil organic carbon (SOC) contents and dynamics has been widely documented, but that on manure types (animal species) or specific manure characteristics have been studied to a lesser extent. Maillard and Angers (2014) implemented a meta-analysis on papers related to animal manure application and soil organic carbon stocks and highlighted the need for further studies on the long-term impact of manure characteristics (animal species). Qualitative aspects of the farmyard manure seem to play an important role in SOC stocks and dynamics in this study. Although there was no statistical difference between SOC stock in the S+PM and in S+SD (13.55 $t.ha^{-1}$ and 9.82 $t.ha^{-1}$respectively), we found that SOC stock in the S+PM is relatively higher compared to the S+SD. Besides, the FOC and POC contribution to total SOC contents were respectively 81.16% and 15.95% for S+PM while 77.37% and 13.46% respectively for S+SD. These results are presumably due to the management history of this plot. Indeed, this plot received composted cotton seed for some years before shifted to poultry litter. In addition, the poultry litter contains an amount of sawdust, a lignified and degradation resistant organic material.

The effectiveness of the amendments at increasing soil organic C levels is directly related to the biodegradability of the amendments (Annabi et al. 2011). Higher levels of compost biodegradability correspond to smaller increases in soil organic C contents.

No significant differences were found between SOC stocks in the surface soil (0–10 cm) as compared to subsurface soil (10–20 cm) except for S+SD. This underlines the similitude of the two upper soil depths where the SOC contents, strongly related to root C inputs and manure application are often accumulated (Qin et al., 2010). Moreover, tillage in this coarse textured soil may lead to the C stocks homogenization within the tilled layer.

SOC stocks and fractions as resulting of agricultural practices in the upper soil depths

There are complex interactions of combined management practices that affect SOC dynamics in terms of quantity and quality (Yan et al. 2012). In this study, the SOC stocks in the cultivated plot with manure application were lower than in fallow. The cumulative manure-C input is the main factor explaining SOC response to manure application. Maillard and Angers (2014) reviewed that cumulative manure-C input explain at least 53% of the variability in SOC stock differences compared to mineral-fertilized or unfertilized reference treatments. However, the concomitant soil tillage and the application of mineral fertilizers including nitrogen fertilizers such as urea with the organic manures application may contribute to lessen soil carbon stocks comparatively to fallow (Aoyama and Kumakura, 2001; Luoet al., 2010). In addition, crop residues that could improve the stock of organic matter of the plots were routinely removed from the field for sowing beds preparation and weeds management while the fallow is permanently provided in fresh organic matter through litter deposits composed of dead leaves, branches...This abundant litter decayed gradually and continuously supply the soil with organic resources. This analysis is consistent with many previous findings that reported similar effects of the quoted factors of SOC depletion. Six et al. (2002a) indicated that with years under no tillage, both tropical and temperate soils had an increasing SOC stock compared with conventional tillage. Feller et al. (1991) concluded that land cultivation (including tillage) causes an average decrease of 30 to 40% of organic stock in West African soils.

Aholoukpè et al., 2016 observed that a 10 years-recycling of pruned fronds as smallholders' management practices in palm oil adult plantations improved soil fertility, porosity and bulk density at 0-20 cm depths in southeastern Benin. Bilgo (2005) observed in the Sub Sudanian region of Burkina Faso that the short fallows (5-6 years) have a positive effect in the raising of the level of carbon on surface soil depths 0-10 cm and the long-term fallow allows a 75% significant improvement in carbon contents and Dolan et al. (2006) reported that plant residue returned to soils tended to increase SOC indifferently to the tillage systems. About nitrogen fertilizers impacts on SOC contents, Su et al. (2006) reported by 18% on average reduction of SOC concentration as affected by a long-term nitrogen fertilizers (N, NP, or NPK) application under a wheat–wheat–maize cropping system in China and concluded that long-term application of inorganic fertilizers were inadequate to maintain levels of SOC and nutrients under conventional management with no above ground crop residues returning to the soil. In general, the long-term application of inorganic fertilizers can increase SOC content relative to no-fertilizer treatments when crop yields increase and residue is returned to the soil (Haynes and Naidu, 1998; Banger et al., 2010).

This finding highlights once again the benefits of fallowing as a good practice for sustainable land management in tropical Africa. The noticeable scarcity of fallowing in recent years is partly due to the land pressure which leads to the intensification of vegetable systems in Southern Benin.

The FOC contributes more to the total SOC than POC for the both soil depths, and fallow presents the highest values of FOM contribution. High carbon contents in FOM fractions other than POM is presumably due to the physical protection of organic matter occurring within silt and clay particles (defined as <0.053 mm, organo-mineral complexes) and contribute to build up the FOM recalcitrance. POM is non-protected and not occluded within soil aggregates (Hassink, 1997; Six et al., 2002b). Indeed, aggregates physically protect FOM by forming physical barriers between microbes and enzymes and their substrates, controlling food web interactions and consequently microbial turnover (Six et al., 2002b). Many previous studies revealed the strong relationship between the SOM and textural properties, especially clay or silt-clay particle size (Feller et al., 1991; Balabane and Plante, 2004; Chivenge et al., 2007; Bajgai et al. 2015). Bajgai et al. (2015) pointed out the role of the textural properties in total soil carbon concentration. Chivenge et al. (2007) reported that Organic C in the particle-size fractions increased with decreasing particle-size of the fractions. Feller et al. (1991) found a close relationship between carbon and fine mineral particle size in surface horizons of soils in West Africa. Feller (1995) argues that the organic matter turnover rate is twice higher for sandy particle size than for silt-clay particle size. Balabane and Plante (2004) confirms that soil texture exerts a significant control over the rate of decomposition of SOM, and SOM associated with clay is as an important sink of long-term stabilized C. Moreover, tillage operations may accelerate coarse residues (POM) decay, increasing its decomposition rate and lead to a rapid conversion to the FOM. Numerous studies show that POM is more affected by cultivation and long-term management practices than FOM (Cambardella and Elliott, 1992; Puget et al., 1998). This finding confirmed by Sensitivity Index (SI) calculation that POM as a labile organic fractions is more sensitive to the agricultural management practices, regarding the high amplitude of difference between POM and FOM sensitivity index. These results corroborate previous findings by Banger et al. (2010), Liang et al. (2012) and Wang et al. (2014).

The fact that fallow presents the highest values of FOM contribution can be explained by the soil micro aggregates breaking up through tillage that may bring to the exposure of the physically protected FOM and lead to the loss of SOC in the cultivated land (Six et al., 2002b; Bajgai et al., 2015). Furthermore, under very suitable conditions for biological decomposition and humification, like those found in the tropics, POM generally represents only a small portion of the total reserve of organic carbon in the soil (Bayer et al., 2001).

CONCLUSION

This study highlights the effects of agricultural management on the SOM stocks and dynamics in vegetable cropping systems. The cultivation leads to a significant depletion in organic carbon stocks compared to herbaceous fallow. Although no significant difference was found for SOC stocks between S+PM and S+SD for the 0–10 cm and 10–20 cm depths, the PM application over the time could lead to increases in SOC stocks compared to the SD application. However, their SOC distribution in fractions is similar.

The depths 0-10 and 10-20 cm in these soils could belong to the same soil layer in the sense where there is no difference between their SOC stocks. We confirmed that POM is more sensitive to the agricultural practices than FOM and corroborate that the Sensibility Index (SI) is a pertinent tool for evaluating changes in soil organic carbon (SOC).

These intensive vegetable cropping systems that rely on total residue removal and a frequent hand plowing might drive to a certain unsustainability. There is a need for further studies including soil organic carbon dynamics, nutrients cycle (especially N) in the entire soil profile, with an enlarged study area and more accurate soil C analysis protocols to deeper investigate on the carbon dynamics in these systems.

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