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Soil Organic Matter Distribution of Contrasting Landscapes in Egbema, Southeastern Nigeria

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Abstract
Soil organic matter plays significant role in soil physical, chemical and biological properties and also in the global carbon circle. Distribution of SOM in three different landscapes (Levee, Floodplain and Upland) in Egbema, Southeastern Nigeria was evaluated. This included the evaluation of total organic carbon (TOC), labile organic carbon (LOC), non-labile organic carbon (NLOC), cold water carbohydrate (CWC), hot water carbohydrate (HWC), dilute acid carbohydrate (DAC), mobile or free, bound to cations and strongly bound humic acid humus compounds (MH, Hcad and Hsad respectively), mobile or free, bound to cations and strongly bound fulvic acid humus compounds (MF, Fcal and Fsad respectively), total humic, fulvic and humic : fulvic acid ratios (TH, TF and TH: TF respectively) and the degree of organic matter humification (DH). Relationship between selected soil properties and the SOM components was also determined. The TOC, LOC and NLOC differed significantly (LSD 0.05) with depth and ranged from 5.80-25.50, 1.4-3.90 and3.80-21.60 g kg^{-1} respectively, with means varying as 2.70, 1.80 and 2.13 (LOC), 18.43, 14.33 and 6.63 (NLOC) and 22.03, 16.13 and 8.77 g kg^{-1} for levee, floodplain and upland landscapes respectively being higher in the levee compared to the others. The CWC and HWC significantly (LSD 0.05) decreased but DAC irregular with depths, with means varying as 0.37, 0.47 and 0.17 mg kg^{-1} (CWC), 0.60, 0.73 and 0.50 mg kg^{-1} (HWC) and 8.20, 8.20 and 6.13 mg kg^{-1} (DAC) in the levee, floodplain and upland landscapes respectively and higher in the floodplain than the others. Humic and fulvic acid fractions distinctly varied with soil depths and landscapes with concentrations being an increasing order of free or mobile < bound to cations < strongly bound or high molecular weight humus compound fractions. Total humic and fulvic acid contents varied with soil depths, with mean humic acid contents higher in the levee and fulvic acid in the floodplain compared to the other landscapes. Variation in humic: fulvic acid ratio showed that the SOM was more matured and stable with respect to the levee followed by floodplain and upland landscapes. Degree of humification varied with soil depth with means decreasing as Upland > floodplain > levee. Concentrations of the SOM components were affected by soil properties. Results of this study showed that SOM storage varied as levee > floodplain > upland suggesting that the capacity of the levee for carbon sequestration was better than the other landscapes.
Keywords: SOM, landscapes, Egbema, Southeastern Nigeria and carbon sequestration

1.0 Introduction

Soil organic matter (SOM) refers to the heterogeneous mixture of interacting polymers (Sposito, 1989) that plays important role in soil physical, chemical and biological properties and thus an index of soil quality, fertility and productivity (Gregorich et al., 1994; Chen et al., 2009). It is a highly carbon enriched organic compound and as such important in the global carbon cycle (Onti and Schulte, 2012).

Equilibrium soil organic matter concentration depends on the balance between the input and losses of organic materials in the soil (Blair et al., 1995; Barbara et al., 2010). Interaction of several ecosystem processes especially photosynthesis, respiration and decomposition influence soil organic matter dynamics (Onti and Schulte, 2012). Impact of photosynthesis includes promotion of SOM level through increased biomass production while microbial decomposition and respiration depresses its concentration through carbon dioxide evolution. Fluxes in CO_2 through removal for biomass production and releases through microbial respiration and decomposition of SOM are important in carbon sequestration and global climate change. It has been reported that through photosynthesis agriculture helps sequester organic matter while it promotes its losses and hence global warming through increased concentration of atmospheric CO_2, a potent green house gas via respiration and decomposition (IPCC, 2007; Onti and Schulte, 2012).

Land use types and soil management practices affect soil organic matter concentrations (Guggenberger et al., 1994; 1995). According to Lal, (2009), the conversion of natural ecosystem to agriculture since the industrial revolution, has resulted in the depletion of soil organic carbon levels releasing 50 to 100 GT of carbon from the soil to the atmosphere. This has been attributed to the combined results of reduction in the amount of plant roots and residues returned to the soil, increased decomposition from soil tillage, and increased soil erosion (Lemus & Lal 2005). Also, Davison and Ackerman (1993) noted that the conversion of natural ecosystem to agriculture as well as intensive tillage depressed soil organic matter due to reduced input of organic materials and reduced physical protection of soil organic carbon due to tillage. Furthermore, it has been indicated that upon conversion from forest to crop and from grassland to crop, soils lost about 42% and 59% of their organic carbon stocks respectively (Guo et al., 2002). Similarly, impacts of soil management practices included increased SOM concentration with residue and conservation tillage practices (Chen et al., 2009) and decreased levels with soil cultivation (Lal,2009). This variation in soil organic matter concentrations due to land use and soil management practices have been related to differences in climate, soil type, mineralogy, residue management, quality of organic material and crop rotation (Puget and Lal, 2005).

Within a local or watershed scale, distribution of SOM may vary depending on landscape heterogeneity (Yu et al., 2012). This may affect rates of carbon input and losses, resulting to differences in SOM concentration along topographic gradients (Thompson and Kulka, 2005). Variation in SOM concentrations with landscapes has been reported to be influenced by some ecosystem processes especially rainfall infiltration, erosion, temperature and deposition of sediments (Barbara et al., 2010; Yu et al., 2012; Onti and Schulte, 2012). For instance, erosion and sediment deposition processes have been noted to redistribute SOM along the topography of the landscape, with low-lying areas such as floodplains often having increased SOM relative to upslope positions (Onti and Schulte, 2012). Earlier, Gregorich et al. (1998), reported that losses in SOM at the submit and mid slopes of a landscape occurs due to high erosion that results to its deposition in the toe-slope where SOM accumulation is high. Also due to oxygen deficit and low microbial decomposition of organic matter in waterlogged or wetland soils, concentration of SOM tends to be higher in floodplains compared to well drain upland regions (Barbara et al., 2010).

Soil organic matter pools vary and affect ecosystem functions. These pools include the labile or active and the non labile or passive pools. Labile SOM includes the non stable fraction that is easily susceptible to microbial degradation and consists of microbial biomass carbon, particulate organic carbon, dissolved organic carbon, hot water extractable carbon and permanganate oxidizable carbon especially carbohydrates, amino sugars and protein (Ghani et al., 2003; Chen et al., 2009). Non labile SOM consists of the recalcitrant and stable fraction that is resistant to microbial decomposition and includes humus especially humin, fulvic and humic acids (Evans et al., 2001; Barbara et al., 2010).

In Nigeria, yearly seasonal flooding occurs in the months of September-November. This flood transports a lot of materials including mud, silt, organic and sediments that are deposited at the low lying regions as it journeys to the ocean. The fate of these deposited organic materials especially; the decomposition, mineralization and transformation processes varies depending on the landscape characteristics particularly, the drainage and topography. This will seriously affect the SOM distribution, carbon sequestration and global warming phenomenon via carbon dioxide emission of the landscapes. Egbema lies in the low land region of Southeastern Nigeria that is usually influenced by seasonal annual flooding. Presently, few studies on SOM characteristics of soils of this region have been limited to fertility and structural stability of soils of varying land uses and management practices (Adesodun et al., 2001; Mbah et al., 2007). The objective of this study was therefore to evaluate the distribution of the SOM in relation to contrasting landscapes in Egbema, southeastern Nigeria. Knowledge gained from the study could be useful in understanding the capacity of landscapes for carbon sequestration and mitigation of problems associated with global warming phenomenon.

2.0 Material and Methods

2.1 Study Location

The study site was Egbema located between latitudes 5^o 20^1-5^o 40^1 N and longitudes 6^o 40^1-6^o 47^1E. Mean annual rainfall ranged from 2450-2500 mm, mean annual temperature range of 26.5-27.5^o C, mean relative humidity of 65-75%, evapotransipiration of 1445-1450 mm/yr and an altitude of 45-70 m.a.s.l. Geology of the area is characterized by quarternary, alluvium, meander belt, wooded back swamp, fresh water swamps and the Sombreiro-Warri Deltaic plains with deposits of petroleum and natural gas (Orajiaka, 1975). Soils of the area have been classified as Eutric Tropofluvent (FDALR, 1985). Environments of the studied landscapes consisted of well drained, sub angular blocky structure, presence of plant roots in the A-horizon, evidence of termite activity and climax vegetation dominated by mixtures of cassava (Manihot esculentum), oil palm(Elaeis guineensis, Jacq) and bamboos (Bambusa vulgaris) in the upland, poorly drained, platy to angular blocky structure, absence of termite activities and climax vegetation of raffia palm (Raphia farinifera) and outcrops of bamboos (Bambusa vulgaris) in the floodplain and a poorly drained, platy to sub angular blocky structure and a climax vegetation of raffia palm (Raphia farinifera) and riparian forest in the Levee. Economic activities in Egbema consist of farming, fishing, trading and crude oil exploitation.

2.2 Sample Collection and Laboratory Analyses

Three (3) mini pedons (60 x 60 x 50cm^3) were dug per landscape (Levee, Floodplain and Upland) and 4 sub-soil samples taken from the 0-15, 15-30 and 30-45 cm depths of each mini pedon. Samples from similar depths of mini pedons of each landscape were bulked to obtain a composite and given a total of 27 samples consisting of 3 x 3 x 3 of mini pedons, soil depths and landscapes respectively. The samples were air dried, sieved to pass through 2 mm diameter mesh and stored for laboratory investigations. Subsamples were then subjected to the following routine analyses; Texture (Gee and Or, 2002), total nitrogen (Bremner and Mulvaney, 1982), OM

(Nelson and Sommers, 1996), pH in 1: 2.5 solute/suspension ratio using the glass electrode of a pH meter and ECEC (Thomas, 1996). Other analyses included: (a) Total organic carbon (TOC) by dry combustion on an Elementar Vario EL C/N analyzer.

(b) Carbohydrate Content

Dilute acid, hot water and cold water extractible carbohydrates were determined using the phenol-sulphuric acid method (Piccolo, 1996). In this, 1g subsample of the different soils was mixed with 10mls of 0.25M H_2S0_4 solution (dilute sulphuric acid extractable carbohydrate), hot distilled water (85°C) and heated for 2.5 hr (hot water extractable carbohydrate) and cold distilled water (25 °C) (cold water extractable carbohydrate) respectively in a 50 ml centrifuge tube and shaken on a rotary shaker for 16 hrs. All extractions were in duplicates and the suspensions centrifuged for 10 mins at 5800 x g. The clear supernatants were decanted into a 20ml plastic container and 2ml aliquot of each supernatant used for carbohydrate determination using a Shimadzu UV 1201 V Spectrophotometer at a wave length of 490 nm.

(c) Labile and Non-labile SOM

Permanganate oxidizable carbon ($KMnO_4$-C) was determined using the method described by Blair et.al. (1995) and Viera et al. (2007). In this, 20 mg of the finely ground air-dried soil sample was mixed with 50 mL 0.333M $KMnO_4$ solution and shaken on a rotary shaker for 1 hr at 60 rpm. The suspension was then centrifuged at 2000 x g for 5 mins and the clear supernatant diluted and measured spectophotometrically at 565 nm. The amount of oxidized carbon was estimated to be the labile carbon and the difference between the TOC and the labile carbon was assumed to be the non-labile carbon.

(d) Humic and Fulvic Acid

Fractionation of humic and fulvic acids was conducted using the scheme described by Duchaufour and Jacquin (1966). In it, 5 g air-dried soil sample was first mixed with 100 cm^3 of a mixture of 0.1 M sodium diphosphate ($Na_4P_2O_7$) and 7.5% sodium disulphate (Na_2SO_4) at pH 7.0 in a 50 ml centrifuge tube (mobile or free humus compound) and shaken for 24 hrs. The solution was then centrifuged for 30mins at 4000 x g and the clear supernatant decanted. The residue from the treatment above was treated with 100 cm^3 of 0.1M sodium diphosphate (Na_2SO_4) solution (humus bound to cations) and shaken for 24 hrs, centrifuged and decanted as before. Finally, residue from the second treatment was reacted with 100 cm^3 of 0.1M sodium hydroxide (NaOH) (strongly bound and high molecular weight humus compounds), shaken for 24 hrs, centrifuged and decanted as usual. Humic acid content of the extracts was precipitated by treating 50 cm^3 aliquot of each of the 3 extracts with 0.05 M H_2SO_4. The precipitates were then redissolved with 0.1 M NaOH before oxidation with potassium permanganate ($K_2Cr_2O_7$) solution. The carbon (humic acid) content was then determined on a spectrophotometer (Shimadzu UV 1201 V). The carbon content of the fulvic acid was determined as a difference between the carbon content of the extracts and the carbon content of the humic acid. Degree of humification of the SOM was obtained as a percentage of the sum of the humic acid plus fulvic over the TOC (Ciavatta et al. 1990). Also the type of humus was determined from the ratio of the humic and fulvic acid as follows; humic (humic acid: fulvic acid > 1.5), fulvic-humic (humic acid: fulvic acid = 1.0-1.5) and humic-fulvic (humic acid: fulvic acid = 0.5-1.0) (Grishina, 1986).

3.0 Statistical Analysis

All data generated were subjected to analysis of variance (ANOVA) and means separated using LSD at 5% probability level with the Genstat statistical package (Buysse et al., 2004). Also correlation analysis was used to determine the relationship between soil properties and SOM components.

4.0 Results

4.1 Soil Characterization

Sand, silt and clay contents differed significantly (LSD 0.05) with depth in all landscapes. Whereas, sand content was significantly (LSD 0.05) higher in the 0-15 cm depth, clay was in the 30-45 cm of most landscapes while distribution of silt was irregular with depths. Mean sand contents were 889.66, 576.40 and 808.47g kg^{-1}, silt contents 16.24, 241.80 and 65.97g kg^{-1} and clay contents 94.10, 181.80 and 125.57 g kg^{-1} in the levee, floodplain and Upland landscapes respectively, with sand contents higher in the levee and silt and clay in the floodplain compared to the other landscapes. Soil texture was dominantly sandy with distribution amongst soil depths varying as loamy sand in the Levee and Upland and sandy loam in the Floodplain soils (Table 1). Soil OM, TN, ECEC and P ranged from 2.30-32.30 g kg^{-1}, 0.30-0.60 g kg^{-1}, 1.55-6.24 Cmol (+) kg^{-1} and 2.76-14.97 $mgkg^{-1}$ respectively with most decreasing significantly (LSD 0.05) with soil depth in the landscapes. Mean concentrations included 8.83, 21.87 and 20.63 g kg^{-1} (OM), 0.37, 0.50 and 0.50 g kg^{-1} (TN), 1.55, 5.44 and 2.98Cmol (+) kg^{-1} (ECEC) and 3.96, 3.04 and 11.36 $mgkg^{-1}$ (P) in the levee, floodplain and upland respectively with all except P higher in the floodplain than the other landscapes. Soil pH ranged from 5.21-6.67 in the landscapes and decreased significantly (LSD 0.05) with soil depths, exception being the floodplain. Mean pH was lower in the floodplain (pH = 5.51) than the others (pH = 6.61) indicating its high acidity relative to other landscapes.

4.2 Total, Labile and Non-Labile Organic Carbon Contents

Labile organic carbon (LOC), non-labile organic carbon (NLOC), total organic carbon (TOC), ratio of LOC: TOC and NLOC: TOC were significantly (LSD 0.05) higher in the top 0-15 than15-30 and 30-45cm soil depths in most landscapes (Table 2). Mean values included 2.70, 1.80 and 2.13 g kg^{-1} (LOC), 18.43, 14.33 and 6.63 g kg^{-1} (NLOC), 22.03, 16.13 and 8.77 g kg^{-1} (TOC), 0.12, 0.13 and 0.26 (LOC:TOC) and 0.84, 0.87 and 0.74 (NLOC:TOC) in the Levee, Floodplain and Upland landscapes respectively with concentrations higher in the levee than the other landscapes. In general, NLOC was about 5 times greater than the LOC and constituted more than 60% of TOC while LOC was about 10-34% of TOC in the landscapes. This showed that more than half of total organic content was present as recalcitrant non-labile SOM fraction that is resistant to microbial decomposition.

4.3 Soil Carbohydrate

Extractable carbohydrate fractions differed (LSD 0.05) with soil depths in all landscapes (Table 3). Except floodplain where hot water soluble carbohydrate (HWC) increased with depth, concentrations of cold and hot water soluble carbohydrates significantly (LSD 0.05) decreased with soil depths. Distribution of the dilute H_2SO_4 soluble carbohydrate (DAC) varied irregularly with soil depth in most landscape. Mean concentrations of carbohydrates were 0.37, 0.47 and 0.17 mg kg^{-1} (CWC), 0.60, 0.73 and 0.50 mg kg^{-1} (HWC) and 8.20, 8.20 and 6.13 mg kg^{-1} (DAC) in the Levee, Floodplain and Upland respectively, with concentrations of most fractions higher in the floodplain than the other landscapes. Generally, mean carbohydrate concentrations increased in the order CWC < HWC < DAC in the landscapes.

4.4 Humic, Fulvic Acids, Degree of Humification and Types of Humus in the Soils

Humic and fulvic acid fractions distinctly varied with soil depths in the landscapes (Table 4). Distribution of the mobile or free humic acid humus compound ($Na_4P_20_7$+Na_2SO_4) was similar in different soil depths of the landscapes. Whereas, cation bound humic acid humus compound ($Na_4P_20_7$) increased significantly with depth, distribution of the strongly bound humic acid humus compound (NaOH) was irregular with soil depths in most landscapes. Also, whereas, distribution of mobile or free fulvic acid humus compound ($Na_4P_20_7$+Na_2SO_4) was irregular with depth in most landscapes, cation bound ($Na_4P_20_7$) and strongly bound (NaOH) fulvic acid humus compounds increased with depths in the levee and upland but decreased distinctly with depth in the floodplain. Mean concentrations of the humus compounds were 0.20, 0.23 and 0.20 g kg^{-1} (mobile or free), 0.57, 0.50 and 0.67 g kg^{-1} (cation bound) and 2.97, 2.13 and 1.50 g kg^{-1} (strongly bound) humic acid fractions in the Levee, Floodplain and Upland respectively and 0.40, 0.33 and 0.17 (mobile or free), 0.40, 0.47 and 0.40 (cation bound) and 1.20, 1.27 and 1.43 (strongly bound) fulvic acid fractions in the Levee, Floodplain and Upland landscapes respectively. This showed wide discrepancies in the distribution of the humic and fulvic acid fractions of the landscapes. In general, concentrations of the humus compounds increased in the order mobile or free < cation bound < strongly bound humic and fulvic acid bound humus compounds.

Concentrations of total humic and fulvic acids ranged from 1.90-4.40 and 1.30-3.10 g kg^{-1} respectively and differed with soil depth in the landscapes (Table 5). In the levee and floodplain, both acids were significantly (LSD 0.05) higher in the 30-45 cm soil depth while only humic acid was better in the 0-15 cm and fulvic acid in the 15-30 cm depths for Upland landscape. Mean values were 3.73, 2.87 and 2.30 g kg^{-1} (humic acid) and 2.00, 2.07 and 2.00 g kg^{-1} (fulvic acid) in the Levee, Floodplain and Upland landscapes respectively, signifying variation in decreasing order of Levee > Floodplain > Upland for humic and Floodplain > Levee = Upland for fulvic acids. Ratios of the humic and fulvic acids varied distinctly with depths in the various landscapes, yielding different humus types, with the humic type humus greater in the levee than the other landscapes. Degree of humification varied with depth, with means varying as levee (60.29 g kg^{-1}) < floodplain (63.14 g kg^{-1}) < upland (65.36 g kg^{-1}).

4.5 Effects of Soil Properties on Soil Organic Matter Content of the Landscapes

Influence of soil properties on SOM contents of the various landscapes is presented on Table 6. There was significant ($P < 0.05$) relationship between LOC and soil pH (r = 0.42) and ECEC (r = -0.49), NLOC with P (r = -0.70) and OM (r = -0.54), TOC with P (r = -0.69) and OM (r = -0.53), CWC with sand (r = -0.40), silt (r = 0.45), pH (r = -0.54), ECEC (r = 0.42) and P (r = -0.68), HWC with sand (r = -0.46), silt (r = 0.50), ECEC (r = 0.42), OM (r = 0.52) and N (r = 0.40) and DAC with P (r = -0.68). There was also a significant correlation between MH and sand (r = -0.62), silt (r = 0.62), clay (r = 0.61), ECEC (r = 0.45) and OM (r = 0.59), Hcad with ECEC (r = -0.42) and P (r = 0.41), Hsad with P (r = -0.58) and OM (r = -0.52), MF with P (r = -0.59) and OM (r = -0.40), TH with ECEC (r = -0.42), P (r = -0.54) and OM (r = -0.52) and DH with clay content (r = 0.40). There was no significant ($P < 0.05$) correlation between Fcad, Fsad, TF and TH: TF with any of the soil properties (sand, silt, clay, pH, ECEC, P, OM and TN).

5.0 Discussion

Texture of soils of the landscapes was dominantly sandy attributable to similarity in their origin. It has been reported that soils of the area are derived from alluvial deposits (Orajiaka, 1975). Probably due to the increased deposition of mud and sediments by the flood erosion, concentrations of silt, clay, OM and nutrients were better in the floodplain than the other landscapes. Similar observation has been reported (Ehrenfeld et al., 1992; Thompson and Kolka, 2005). Phosphorus concentration was lower in the floodplain than others probably due to the absence of P rich sediments. High acidity of the floodplain than the other landscapes has been ascribed to the oxidation of organic sediments by megaplantons and the release of protons (H^+) (Follet et al., 2012).

Increased concentrations of the labile, non labile and total organic carbon in the Levee followed by Floodplain could be due to poor microbial activity from the low oxygen levels associated with high moisture or poor drainage conditions (Follet et al., 2012; Onti and Schulte, 2012). It could also be due to the deposition by erosion of high organic materials in the low than upland regions of the landscape (Onti and Schulte, 2012). Accumulation of SOC in the Levee and Floodplain suggests that their capacity for carbon storage or sequestration will be high compared to Upland landscape. It has been indicated that wetlands have high carbon storage of about 20-25% of global soil organic carbon reserves (Clark et al., 2007; Mariusz etal., 2008; Mcnamaran et al., 2008). The high accumulation of SOC in the Levee and Floodplain also means that the tendency of CO_2 discharge into the atmosphere and consequent global warming impact will be low in the landscapes (Thompson and Kolka, 2005; Barbara at al., 2010).

Soil carbohydrate constitutes about 5-25% of labile SOM pool that is easily degraded by microorganisms (Stevenson, 1994; Evans et al., 2001). Its high content in the floodplain than the other landscapes indicates that a large fraction of the TOC in the landscape could be labile and subject to ready microbial oxidation. However, the decreased landscape concentration with soil depth showed its degradation will only be rapid in the soil surface than sub soils probably due to adsorption by clay particles (Hassink et al. 1997; Feller and Bernoux, 2008). Concentration of the dilute acid soluble fraction was greater than the cold water and hot water soluble forms due to the high extraction strength of the former than the later (Cheshire et al., 1990).

Non labile SOM constitutes the stable and resistant microbial degradable fraction (Evans et al., 2001). Its components include humic acid, fulvic acid and humin (Stevenson, 1994; Six et al., 2002). Humin could be obtained as deference between the non-labile SOC and the sum of the humic and fulvic acid fractions. In this study, mean values of the humin fraction were 12.70 g kg^{-1} (Levee), 9.39 g kg^{-1} (Floodplain) and 2.33 g kg^{-1} (Upland). High humic acid, fulvic acid and humin contents of the Levee and Floodplain than the Upland corroborates the high non labile and total organic carbon contents of these landscapes (Table 2) thus confirming the greater than 60% non labile organic carbon of TOC. The accumulation of this highly microbial resistant non labile SOC fraction confirms the capacity of these landscapes (Levee and Floodplain) for better carbon sequestration. The importance of humic and fulvic acids in SOM storage was confirmed by the dominance of the most resistant strongly and cation bound than the mobile or free humus compound fractions. Ratios of the humic and fulvic acids help indicate the degree of maturity and stability of SOM (Follet et al., 2012). The high value and presence of the more stable humus type in the Levee than the other landscapes signifies the dominance this stable fraction in this landscape. According to Stevenson, (1994), humic substances play important role in soil sorption process and in the formation of soluble and insoluble complexes with soil particles. The low concentration of the humic substances (fulvic acid, humic acid and humin) in the Upland landscape could be attributed to rapid organic matter transformation due to its high drainage (Barbara et al., 2010; Follet et al., 2012).

Variation in the degree of humification could be associated with differences in soil moisture and type of organic materials (Barbara et al., 2010). Degree of humification was higher in the Upland than the other landscapes probably due to its better drainage condition. According to Follet et al. (2012), drained soils have low organic matter concentrations due to increased rates of humification and mineralization.

Influence of soil properties on organic matter components suggests that the behavoiur and concentration of SOM varies depending on factors imposed by soil properties especially texture (sand, silt and clay), OM, ECEC, P and pH as have been reported by others (Barbara et al., 2010; Dijkstra and Morgan 2012; Follet et al., 2012).

6. Conclusion

Texture of the soils was dominantly sandy due to similarity in their origin. Soil organic matter and nutrient contents varied, with concentrations higher in the floodplain than the others probably due to richer sediment deposition in the landscape. Total, labile, non-labile, humic and fulvic acid humus compounds were better in the Levee than the other landscapes. Also levee had more matured and stable SOM as indicated by the presence of greater humic humus type than the others. Degree of humification was better in the Upland leading to poor SOM concentration from the high drainage condition relative to the others. In general the capacity for carbon sequestration in the landscapes decreased as Levee > Floodplain > Upland, with Upland landscape more prone to atmospheric CO_2 concentration and consequent global warming.

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Table 1. Selected Physical and Chemical Properties of the Soils Studied

Depth cm	Sand g kg^{-1}	Silt	Clay	OM	TN	ECEC Cmol(+) kg^{-1}	P mgkg^{-1}	pH	TC
					Levee				
0-15	907.00a	14.60a	78.40a	15.80b	0.50ab	1.81a	4.55a	6.70a	S
15-30	873.77b	30.43b	95.80b	8.40c	0.30a	1.55c	4.22b	6.62a	LS
30-45	888.20c	3.70c	108.10c	2.30a	0.30b	1.29b	3.10c	6.52b	LS
Mean	**889.66**	**16.24**	**94.10**	**8.83**	**0.37**	**1.55**	**3.96**	**6.61**	
					Floodplain				
0-15	633.20a	208.20a	158.60a	8.70a	0.40ab	6.24a	3.19a	5.21a	Sl
15-30	528.40b	273.40b	198.20b	32.30b	0.50a	5.20b	3.16a	5.97b	Sl
30-45	567.60c	243.80c	188.60c	24.60c	0.60b	4.89c	2.76b	5.34c	Sl
Mean	**576.40**	**241.80**	**181.80**	**21.87**	**0.50**	**5.44**	**3.04**	**5.51**	
					Upland				
0-15	828.40a	63.40a	108.20a	25.00b	0.70b	3.38b	14.79c	6.75a	LS
15-30	828.40a	43.40b	128.20b	19.30a	0.40a	2.79a	10.36b	6.44b	LS
30-45	768.60b	91.10c	140.30c	17.60c	0.40a	2.77a	8.92a	6.64a	LS
Mean	**808.47**	**65.97**	**125.57**	**20.63**	**0.50**	**2.98**	**11.36**	**6.61**	

Means followed by different letter are significantly different at LSD 0.05
OM = Organic matter, TN =Total nitrogen, S = Sand, LS = Loamy sand, SL = Sandy loam and TC Textural class

Table 2. Labile, Non-Labile, Total Organic Carbon and ratio of Labile and Non- Labile to Total Organic Carbon

Depth cm	LOC	NLOC g kg^{-1}	TOC	LOC:TOC	NLOC:TOC
			Levee		
0-15	3.90a	21.60a	25.50a	0.15a	0.85a
15-30	1.40c	16.40c	20.50b	0.07b	0.80b
30-45	2.80b	17.30b	20.10b	0.14a	0.86a
Mean	**2.70**	**18.43**	**22.03**	**0.12**	**0.84**
			Floodplain		
0-15	0.20c	19.60a	19.80a	0.01c	0.99a
15-30	2.20b	13.40b	15.60b	0.14b	0.86b
30-45	3.00a	10.00c	13.00c	0.23a	0.77c
Mean	**1.80**	**14.33**	**16.13**	**0.13**	**0.87**
			Upland		
0-15	2.50a	7.90a	10.40a	0.24b	0.76b
15-30	1.90b	8.20a	10.10a	0.19c	0.81a
30-45	2.00ab	3.80b	5.80b	0.34a	0.66c
Mean	**2.13**	**6.63**	**8.77**	**0.26**	**0.74**

Means followed by different letters are significantly different at LSD 0.05
LOC = Labile organic carbon, NLOC = Non-Labile organic carbon and TOC = Total organic carbon

Table 3. Carbohydrate Content (mg kg^{-1}) of the Soils

Soil depth (cm)	Cold water soluble	Hot water soluble	Dil. H_2SO_4 soluble
		Levee	
0-15	0.60a	0.80a	8.80a
15-30	0.20c	0.60b	8.80a
30-40	0.30b	0.40c	7.00b
Mean	**0.37**	**0.60**	**8.20**
		Floodplain	
0-15	0.50a	0.60c	6.50b
15-30	0.50a	0.90a	9.00a
30-45	0.40b	0.70b	9.10a
Mean	**0.47**	**0.73**	**8.20**
		Upland	
0-15	0.20a	0.60a	4.00c
15-30	0.20a	0.60a	8.80a
30-45	0.10b	0.30b	5.60b
Mean	**0.17**	**0.50**	**6.13**

Means followed the same letters are not significantly different at LSD 0.05

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Table 4. Humic and Fulvic Acid Fractions (g kg^{-1}) in the soils Studied

Soil Depth(cm)	Humic Acid Fractions			Fulvic Acid Fractions		
	$Na_4P_2O_7$+Na_2SO_4	$Na_4P_2O_7$	NaOH	$Na_4P_2O_7$+Na_2SO_4	$Na_4P_2O_7$	NaOH
		Levee				
0-15	0.20a	0.40c	3.00ab	0.50a	0.20c	0.60b
15-30	0.20a	0.60b	2.40b	0.50a	0.40b	0.70b
30-45	0.20a	0.70a	3.50a	0.20b	0.60a	2.30a
Mean	**0.20**	**0.57**	**2.97**	**0.40**	**0.40**	**1.20**
		Floodplain				
0-15	0.20b	0.40b	2.00b	0.40a	0.20b	1.30a
15-30	0.30a	0.40b	2.00b	0.10b	0.20b	1.30a
30-45	0.20b	0.70a	2.40a	0.50b	1.00a	1.20b
Mean	**0.23**	**0.50**	**2.13**	**0.33**	**0.47**	**1.27**
		Upland				
0-15	0.20a	0.60b	2.00a	0.10b	0.30c	1.20b
15-30	0.20a	0.70a	1.30b	0.20a	0.50a	1.90a
30-45	0.20a	0.70a	1.20c	0.20a	0.40b	1.20b
Mean	**0.20**	**0.67**	**1.50**	**0.17**	**0.40**	**1.43**

Means followed by the same letters are not significantly different at LSD 0.05

Table 5. Total Humic and Fulvic Acid contents, Ratio of humic to fulvic acid, degree of Humification and Humus Type

Soil depth cm	Humic Acid g kg^{-1}	Fulvic Acid	Humic: Fulvic	Degree of humification %	Humus Type
			Levee		
0-15	3.60ab	1.30c	2.74a	57.75a	Humic
15-30	3.20b	1.60b	2.05b	59.96b	Humic
30-45	4.40a	3.10a	1.41c	63.15c	Fulvic-Humic
Mean	**3.73**	**2.00**	**2.07**	**60.29**	
			Floodplain		
0-15	2.60b	1.90b	1.37a	63.40a	Fulvic-Humic
15-30	2.70b	1.60c	1.68b	61.50b	Humic
30-45	3.30a	2.70a	1.22a	64.51a	Fulvic-Humic
Mean	**2.87**	**2.07**	**1.42**	**63.14**	
			Upland		
0-15	2.80a	1.60a	1.71a	61.30a	Humic
15-30	2.20b	2.60b	0.84b	68.74b	Humic-Fulvic
30-45	1.90c	1.80a	1.06c	66.05c	Fulvic-Humic
Mean	**2.30**	**2.00**	**1.20**	**65.36**	

Means followed by different letters are significantly different using LSD 0.05.

Table 6. Simple Correlation between Soil Properties and SOM fractions

Soil Properties	LOC	NLOC	TOC	CWC	HWC	DAC	MH	Hcad	Hsad	MF	Fcad	Fsad	TH	TF	DH	TH:TF
Sand	0.33	0.14	0.23	-0.40	-0.46	-0.20	-0.62	0.32	0.31	0.06	-0.18	0.01	0.32	-0.05	-0.23	0.37
Silt	-0.33	-0.09	-0.17	0.45	0.50	0.21	0.62	0.38	-0.28	-0.01	0.13	-0.08	-0.30	-0.01	0.16	-0.30
Clay	-0.33	0.27	-0.36	0.26	0.33	0.19	0.61	-0.15	-0.38	-0.17	0.27	0.15	-0.37	0.19	0.40	-0.53
pH	0.42	-0.17	-0.07	-0.54	-0.37	-0.28	-0.27	0.32	0.06	-0.29	-0.28	-0.04	0.08	-0.24	-0.19	0.32
ECEC	-0.49	-0.09	-0.21	0.42	0.42	0.00	0.45	-0.42	-0.39	-0.07	0.01	-0.03	-0.42	-0.05	0.23	-0.37
P	0.02	-0.70	-0.69	-0.68	-0.36	-0.68	-0.29	0.41	-0.58	-0.59	-0.20	0.09	-0.54	-0.16	0.35	-0.28
OM	0.16	-0.54	-0.53	0.08	0.52	0.03	0.59	-0.13	-0.52	-0.40	0.01	-0.18	-0.52	-0.27	0.17	-0.19
TN	0.31	-0.37	-0.36	0.13	0.40	-0.29	0.15	-0.11	-0.23	-0.21	-0.08	-0.25	-0.23	-0.24	-0.06	0.01

LOC = Labile organic carbon, NLOC = Non-labile organic carbon, TOC = Total organic carbon, CWC = Cold water carbohydrate, HWC = Hot water carbohydrate, DAC = Dilute acid carbohydrate, MH = Mobile or $Na_4P_2O_7$ + Na_2SO_4 humic acid, Hcad = Cation adsorbed or Na_2SO_4 humic acid, Hsad = Strongly bound or NaOH humic acid, MF = Mobile or $Na_4P_2O_7$ + Na_2SO_4 fulvic acid, Fcad = Cation adsorbed or Na_2SO_4 fulvic acid, Fsad = Strongly bound or NaOH fulvic acid, TH = Total humic acid, TF = Total fulvic acid and DH = Degree of humification