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Soil Organic Carbon Stock under Different Age Ranges of Cashew Agroecosystems in the Sudano-Sahelian Zone of Cameroon

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Abstract: The aim of this study was to quantify the current soil organic carbon stock under different age ranges of cashew agroecosystems in the Sudano-Sahelian zone of Cameroon in the context of greenhouse gas emissions and land degradation. It is so crucial for combating climate change and improving ecological restoration. Random field sampling was carried out on 0-10, 10-20 and 20-30 cm depths were collected in three age groups (0-10; 10-20; over 20 years old) of Cashew agroecosystems. Soil bulk density, Soil reaction (pH), moisture content, total nitrogen, C/N ratio, particle size distribution and soil organic carbon were determined using standard laboratory procedures and calculations. The results of the study did not reveal a significant difference in soil organic carbon stock across the different age groups of the cashew agroecosystems (P>0.05). The highest values of soil organic carbon stocks were observed in the 0-10 cm depth. Soils under plots with over 20 cashew agroecosystems in Bénoué subdivisions recorded higher SOCS values (36.30±2.92 tC/ha). Similarly, the SOCS decreased with soil depth in all three age groups of Cashew agroecosystems. The mean SOC concentrations (%) ranged from 0.20±0.02-0.41±0.10%. Soil organic carbon stock ranged from 16.45±0.73-37.04±2.32 tC/ha depending on depth between the three age ranges of Cashew agroecosystems studied in the four subdivisions. The Cashew agroecosystems soils with high C stock are those with sandy loamy texture (25.79±2.29 tC/ha). Results showed a positive and significant (P<0.05) correlation between soil organic C stock with bulk density, moisture content, C/N ratio, SOC; negative and significant (P<0.05) with Soil reaction (pH), Total Nitrogen, but negative and non-significant (P>0.05) with % Sand, % Silt, % Clay, % Silt + Clay. The results show the potential contribution of Cashew agroecosystems to improve soil organic carbon sequestration and environmental protection. This information will be necessary for developing appropriate technological and political solutions to increase agricultural sustainability and combat environmental degradation in the Sudano-Sahelian zone of Cameroon.

Keywords: Cameroon, Cashew, Carbon, Soil Organic Carbon Stocks

Introduction

Carbon dioxide (CO_2) is the main Greenhouse Gas (GHG) linked to human activities (FAO, 2017). Globally, nearly 35 billion tons of CO_2 were emitted in 2013 by the consumption of fossil oil, gas or coal reserves and by the production of cement (FAO, 2017). Terrestrial ecosystems mitigate the impact of these emissions by capturing more than a third of them through photosynthesis. Soil organic matter is the most important reservoir of organic carbon, ahead of plant biomass (Dengiz *et al.*, 2019). Greenhouse gases are gaseous components of the atmosphere, both natural and anthropogenic and whose properties are responsible for the greenhouse effect (Victor *et al*., 2020). Carbon is the major constituent of two greenhouse gases, CO_2 and CH_4, without which there could be no life on earth; its recycling particularly influences biological productivity and the climate (Dass *et al*., 2018). The organic carbon stock present in natural soils presents a dynamic balance between the contributions of plant debris and animal excrement and the loss due of decomposition (Wang *et al.*, 2020). Not all soils store the same amount of carbon depending on their nature and especially their use. Thus, limiting plowing or maintaining the forest improves carbon storage in the soil. Plants absorb carbon from CO_2 in the air of photosynthesis (FAO, 2017). The plant photosynthesis consists in reducing carbon dioxide from the atmosphere by the water absorbed by the roots using solar energy captured by the leaves, in the presence of mineral salts, with the release of oxygen, in order to produce carbohydrates (Bossio *et al*., 2020).

Lefèvre *et al*. (2017), the main greenhouse gas responsible for climate change from global warming in the Earth's atmosphere are water vapor (H_2O), Carbon dioxide (CO_2), Nitrous Oxide (N_2O), methane (CH_4) and Ozone (O_3). This warming is associated with an unprecedented increase in anthropogenic GHG emissions since pre-industrial times, mainly due to economic and population growth (FAO, 2017). In addition, these climate changes are unprecedented in speed of global rates; at least for more than 1000 years (Smith *et al*., 2015). The carbon sequestration by soils is a way to reduce GHG emissions from agriculture and the establishment of a market for reducing carbon emissions would allow farmers to benefit economically from this process. Soil is for this purpose a very important reservoir of Carbon (C).

The carbon sequestered by the soil remains in the form of organic compounds (Schlesinger and Amundson, 2019). This organic matter usually comes from dead bodies and organizations, mainly plants, animal waste, the root exudates and living organisms. The Organic Matter (OM) then undergoes biotransformation in soil: Biodegradation and eventually mineralization, which renders the carbon to the atmosphere as CO_2 (Victor *et al*., 2019a). Carbon exchanges between the atmosphere and terrestrial ecosystems are about ten times greater than the emissions caused by the use of fossil fuels (Amundson and Biardeau, 2018). The biosphere plays an important role in the change since a low emission or sequestration rate cycle can cause a major change in carbon budget level (Yeasmin *et al*., 2020). To be able to predict climate change and find solutions to bearing or mitigate the problems predicted by the experts, it is important to quantify and better understand the dynamics of GHG compartments (Lefèvre *et al*., 2017). In the soils of some large ecosystems, such as African savannas or tropical forests, the storage of organic matter in the soil proceeds at the same rate as its degradation (Yeasmin *et al*., 2017). In agro-ecosystems, on the other hand, a balance can be upset by many factors, likely to favor the accumulation of organic matter, or conversely its mineralization. Rainfall and temperature play a major role (Lee *et al*., 2020). For example, low or too high humidity hinders the activity of decomposing organisms in soils, which therefore naturally accumulate more organic matter than others. Conversely, microbiological activities are multiplied by a factor of 2 to 3 when the temperature increases by 10°C (Lee *et al*., 2020). Climate change, which currently stimulates plant productivity (atmospheric CO_2 concentrations, temperature) and the mineralization of organic matter, has an impact that is difficult to assess on carbon storage. Finally, the physical and chemical nature of soils also reduces mineralization, through their ability to "protect" organic matter (Lee *et al*., 2020). Cashew agroecosystems are an important part of the plant community of the high altitude in the Sudano-Sahelian zone of Cameroon. They occupy a very important place for these values ecological, economic and social. Where he played for several roles user populations such as livestock feed in all periods including food scarcity period and supply of timber and firewood. According to our bibliographic investigations, no further work has hitherto targeted quantification of soil carbon stock of cashew agroecosystems. They play several roles for the user populations, such as feeding the livestock at all times, particularly during periods of food shortage and providing timber and fuelwood. The objective of this study is to assess the Soil organic carbon stock under different age ranges of cashew agroecosystems in the Sudano-Sahelian zone of Cameroon.

Materials and Methods

Study Area

The study was carried out in the north region of Cameroon. This region is located between 9°18'N to 8°10'N latitude and 13°23'E to 12°16'E longitude (Victor *et al*., 2019a). The northern region of Cameroon has a tropical climate of the Sudano-Sahelian type. The relief is a vast pediatric plain between the Mandara Mountains (1,442 m) in the North and the Adamawa Plateau in the South. The soil is of ferruginous type formed by degradation of sandstone from the Middle Cretaceous (Victor *et al*., 2020). The vegetation encountered is a shrubby Sudanian savannah with a clear and degraded savannah appearance (Victor *et al*., 2020). The fauna is rich and very diverse (Victor *et al*., 2019b). Economic activities concern: Agriculture, animal husbandry, fishing, social economy and handicrafts, transport and trade. Agriculture is the main activity of the populations of the North Cameroon region.

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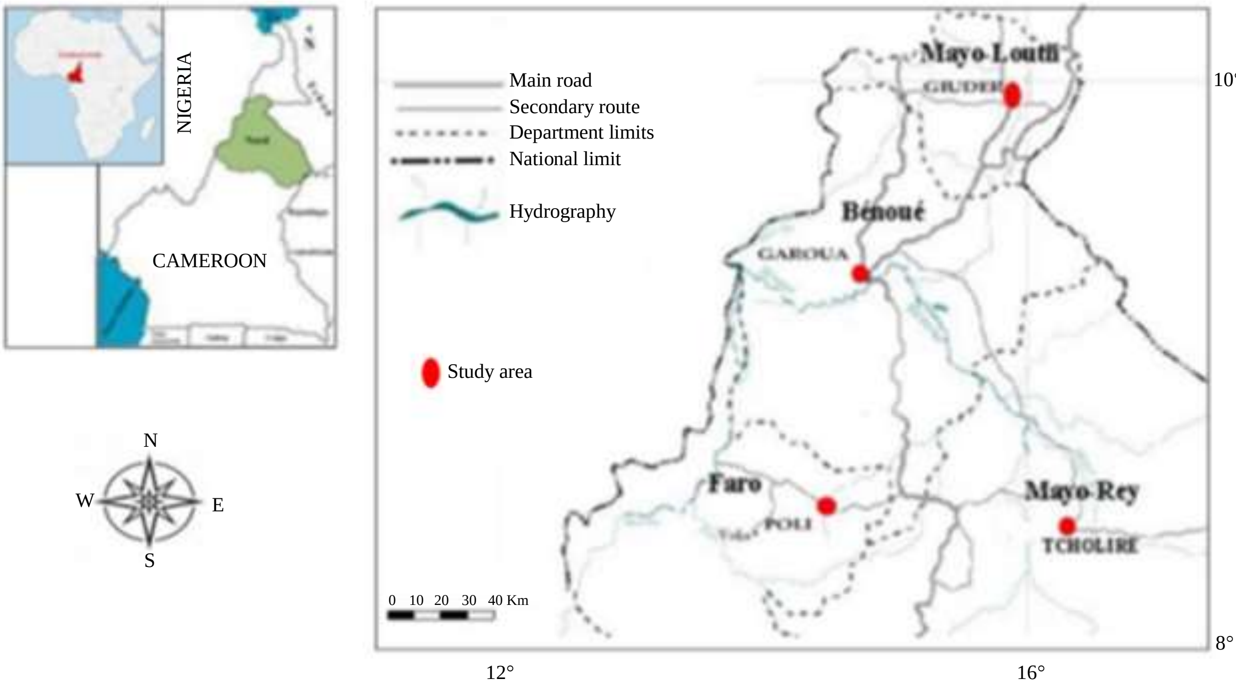

Fig. 1: Geographic location of the study area in North Cameroon Region

Data Collection

Study Methods

Soil samples are taken from August to September 2018. In each 2000 m² survey, soil samples were taken in 0.25×0.25 m frames. These samples are taken at 0-10, 10-20 and 20-30 cm depth were collected in three age groups (0-10; 10-20; over 20 years old) of Cashew agroecosystems. The age of agroecosystems was determined by surveys of cashew growers. The survey was carried out among cashew producers. The targeted planters were those registered by the fruit production subdivision of IRAD in Garoua during the agricultural seasons from 2010 to 2018. The use of the report from IRAD in Garoua made it possible to get an idea of the situation in the areas. Strong cashew plantations as well as the soil types of the terroir. The choice of planters surveyed was made randomly among those with at least 1.5 hectares of agroecosystems. Thus, the investigation concerned 20 producers. The survey was carried out with one of the tools of the active method of participatory research and planning (the semi-structured interview). It took place at home and/or in the field at the convenience of each planter. The purpose of the survey was to obtain information on the age of cashew agroecosystems in the study area. Each level of soil depth was sampled using a machete and trowel and then immediately put in a closed bag in a cooler, in the shade to avoid evaporation. A total of 3 samples were taken per drilling unit, which corresponds to a total of 36 samples per site and then homogenized to obtain an aggregate sample. A total of 144 samples (3 sites ×3 depths ×4 replicates ×4 areas) for all four sites in the two regions studied were dug into the soil to a depth of 30 cm. These three groups were then weighed and oven-dried at a constant temperature of 70°C to a constant dry weight, which was measured. When the weight became constant, it was deduced that all the water contained in the material had completely evaporated and the resulting mass was that of the biomass. Once all samples were collected, they were taken for laboratory analysis.

Laboratory Methods

The laboratory method consists of determining, evaluating or measuring the physico-chemical parameters of the soils.

The determination of the bulk density was carried out by sampling a defined volume of soil using a cylinder driven into the ground. After drying the sample in an oven at 105°C for 48 h, it was weighed again. The dry weight of the sample P divided by the sample Volume (V) gave the Bulk Density (BD) in g/cm^3. It is calculated using the following formula Da = P/V. The pH measurement was carried out on a sol-water solution for the pH water and a sol-KCL solution for the pH in a ratio of 1/2.5 using a PH-meter with a glass electrode. The moisture content at 105°C which allows to estimate the water content. It consists in introducing 5 g of the fresh sample into a previously tared flask, then let the soil sample dry in the oven at 105°C for 24 h; then let it cool in a desiccator and weigh. The equivalent moisture is thus determined by the following formula: H = (P gross air-dried)-(P gross air-dried at 105°C)/(P net air-dried) ×100. Total Nitrogen was obtained by the (Kjeldahl, 1883) method after heat treatment of the sample with a mixture of sulphuric acid (H_2SO_4) and salicylic acid ($C_6H_4(COOH)(OH)$. The granulometric analysis was carried out by the Robinson pipette method on air-dried soil samples sieved at 2 mm. The organic matter was previously destroyed by hydrogen peroxide attack. The soil was then dispersed by rotary agitation in flasks after the addition of sodium hexa-metaphosphate $(NaPO_3)_6$. The different particle size fractions were determined by pipetting for the clay and silt fractions and by sieving for the sand. The textural classes were found by using the FAO Textural Triangle, once the proportions of the different textural fractions were calculated. Soil organic carbon was determined by method of (Walkley and Black, 1934), which is an oxidation with potassium bicarbonate ($K_2Cr_2O_7$) in an acid medium (H_2SO_4). The dosage was done by calorimetry. The organic matter content was obtained by multiplying the organic carbon rate by the Sprengel factor which is 1.724 for cultivated soils and 2 for uncultivated soils. Soil Organic Carbon (SOCS) (tC/ha) = BD. (% OC). S. P (Victor *et al.*, 2020) with BD: Bulk density in tones/m^3; % OC: Organic carbon content of the soil; S: Area in m^2; p: Depth m.

Data Analysis

The data were encoded in Excel 2007 software and then analyzed using Statgraphics 2007 and R software. Pearson correlation and Significance tests were performed using ANOVA and Duncan's 5% test.

Results

Soil Physical Characteristics

The bulk density varies from 0.80±0.01-1.20±0.12 g/cm^3 depending on the depth between the three age ranges of Cashew agroecosystems studied in the four subdivisions. Data analysis shows that there is no significant difference in bulk density between depths (P = 0.058>0.05) on the one hand and between the three age groups of Cashew agroecosystems studied (P = 0.075>0.05) on the other hand (Table 1).

Moisture content varies from 19.08±2.03-39.27±2.98% depending on depth between the three age ranges of agroecosystems studied in the four subdivisions. The highest moisture content values were recorded at depths of 20-30 cm. Data analysis shows that there is no significant difference in moisture content between depths (P = 0.195>0.05) on the one hand and between the three age groups of Cashew agroecosystems studied (P = 0.112>0.05) on the other hand (Table 2).

The granulometry distribution made it possible to distinguish 3 textural classes including sandy loam, sandy clay and silt soils. The soils studied are predominantly sandy. Data analysis for the textural fractions of the soils (Clay: P-value = 0.0268; Silt: P-value = 0.0000 and Sand: P-value = 0.0004) show that there is a variation in the textural composition of the soils at different depths between the three age groups of Cashew agroecosystems studied in the four subdivisions (Table 3).

Table 1: Variation in bulk density as a function of depth under different of Cashew agroecosystems

Subdivisions	Depths (cm)	0-10 years	10-20 years	Over 20 years
Bénoué	0-10	0.86±0.05a	1.12±0.11a	0.98±0.10a
	10-20	0.96±0.07a	1.05±0.10a	1.13±0.08a
	20-30	0.94±0.03a	1.06±0.10a	0.98±0.04a
	Mean	0.92±0.05A	1.07±0.03A	1.03±0.08A
Faro	0-10	0.80±0.01a	1.10±0.12a	0.81±0.01a
	10-20	0.85±0.02a	0.80±0.01a	1.18±0,12a
	20-30	0.83±0.04a	0.98±0.16a	0.96±0.11a
	Mean	0.82±0.02A	0.96±0.15A	0.98±0.18A
Mayo-Loutii	0-10	0.94±0.11a	0.91±0.14a	1.25±0.14a
	10-20	0.86±0.02a	0.83±0.03a	0.98±0.13a
	20-30	0.89±0.01a	0.86±0.10a	1.10±0.12a
	Mean	0.89±0.04A	0.86±0.04A	1.11±0.13A
Mayo-Rey	0-10	1.15±0.13a	1.20±0.12a	1.02±0.13a
	10-20	0.83±0.04a	0.93±0.04a	0.90±0.06a
	20-30	0,88±0.03a	0.98±0.01a	0.97±0.11a
	Mean	0.95±0.17A	1.03±0.14A	0.96±0.06A

Values assigned the same letter are not statistically different (p>0.05; Duncan's test)

Table 2: Variation of moisture content as a function of depth under different of Cashew agroecosystems

Subdivisions	Depths (cm)	0-10 years	10-20 years	Over 20 years
Bénoué	0-10	20.32±2.08a	23.21±2.44a	33.67±2.86a
	10-20	22.46±2.14a	25.63±2.52a	35.96±2.94a
	20-30	25.34±2.18a	28.86±2.86a	39.27±2.98a
	Mean	22.85±2.13ab	26.38±2.60b	36.30±2.92A
Faro	0-10	20.08±2.02a	24.48±2.42a	32.35±2.51a
	10-20	20.15±2.08a	24.80±2.47a	33.93±2.67a
	20-30	20.31±2.12a	25.87±2.68a	35.36±2.71a
	Mean	20.18±2.07a	25.47±2.52b	34.66±2.63A
Mayo-Loutii	0-10	19.08±2.03a	20.68±2.30a	31.25±1.23a
	10-20	19.90±2.08a	23.58±2.38a	32.18±1.15a
	20-30	20.84±2.12a	25.88±2.45a	34.85±1.11a
	Mean	19.93±2.07a	23.81±2.76ab	34.43±21.84A
Mayo-Rey	0-10	20.95±2.13a	24.20±2.42a	26.07±2.58a
	10-20	21.78±2.20a	26.27±2.54a	28.65±2.74a
	20-30	24.05±2.27a	28.86±2.68a	30.39±2,95a
	Mean	22.51±2.20ab	26.60±2.54b	28.37±6.92A

Values assigned the same letter are not statistically different (p>0.05; Duncan's test)

Table 3: Soil texture under the different of Cashew agroecosystems

		Textural fractions			
Subdivisions	Ages	% sand	% silt	% clay	Textural classes
Bénoué	0-10 years	52.01±5.42b	27.46±7.74b	20.52±6.73bc	Sandy clay
	10-20 years	67.48±8.14bc	20.15±6.54ab	12.36±3.19a	Sandy loam
	0ver 20 years	63.99±7.29bc	19.01±6.20a	16.99±5.38b	Sandy loam
Faro	0-10 years	60.11±7.30bc	24.45±5.24ab	22.09±9.53bc	Sandy clay
	10-20 years	48.87±3.56a	18.44±4.98a	32.68±11.71c	Sandy clay
	Over 20 years	71.86±8.24c	17.83±4.67a	10.30±3.72a	Sandy loam
Mayo-Loutii	0-10 years	44.16±3.78a	39.63±13.35c	16.20±5.58b	Silty
	10-20 years	48.08±3.07a	27.96±7.80b	23.95±8.44bc	Sandy clay
	Over 20 years	56.17±5.98b	31.86±9.64bc	11.96±3.49a	Sandy loam
Mayo-Rey	0-10 years	61.71±7.51bc	22.33±6.08ab	15.95±5.66b	Silty
	10-20 years	56.68±6.05b	30.03±9.08bc	13.28±3.12a	Sandy loam
	Over 20 years	56.49±5.58b	27.57±7.42bc	15.93±4.68ab	Sandy loam

Values assigned the same letter are not statistically different (p>0.05; Duncan's test)

Table 4: Variation of pH as a function of depth under different of Cashew agroecosystems

Subdivisions	Depths (cm)	0-10 years	10-20 years	Over 20 years
Bénoué	0-10	6.80±1.48a	6.40±1.14a	5.67±1.06a
	10-20	6.46±1.14a	6.33±1.12a	5.57±1.04a
	20-30	5.94±1.04a	5.06±1.10a	5.08±1.00a
	Mean	6.40±1.22A	5.93±1.12A	5.44±1.03A
Faro	0-10	6.88±1.52a	6.54±1.32a	6.41±1.21a
	10-20	6.85±1.50a	6.30±1.31a	5.93±1.17a
	20-30	6.70±1.47a	5.67±1.06a	5.36±1.11a
	Mean	6.81±1.49A	6.16±1.23A	5.90±1.16A
Mayo-Loutii	0-10	6.98± 1,63a	6.61±1.34a	6.25±1.23a
	10-20	6.95±1.62a	6.43±1.32a	6.18±1.15a
	20-30	6.89±1.60a	5.86±1.20a	5.34±1.11a
	Mean	6.94±1.61A	6.30±1.28A	5.59±1.16A
Mayo-Rey	0-10	6.95±1.63a	6.20±1.12a	6.06±1.10a
	10-20	6.78±1.60a	6.03±1.04a	5.65±1.04a
	20-30	6.67±1.57a	5.86±1.01a	5.39±1.01a
	Mean	6.80±1.60A	6.03±1.05A	5.70±1.05A

Values assigned the same letter are not statistically different (p>0.05; Duncan's test)

Soil Chemical Characteristics

Soil reaction (pH) varies from 5.06±1.10-6.98±1.63 depending on the depth between the three age ranges of Cashew agroecosystems studied in the four subdivisions. The highest soil reaction (pH) values were recorded at depths of 0-10 cm. Data analysis shows that there is no significant difference in pH between depths (P = 0.075>0.05) on the one hand and between the three age groups of Cashew agroecosystems studied (P = 0.092>0.05) on the other hand (Table 4).

Total nitrogen levels ranged from 2.3±0.25-4.1±1.44 kg depending on the three age ranges of Cashew agroecosystems studied in the four subdivisions. Nitrogen levels are highest in the 0-10 year plots in all four regions studied. At only 5%, Data analysis (F = 1.19; P = 0.3443) revealed no significant difference in nitrogen content between the three age groups of Cashew agroecosystems studied and between the subdivisions (F = 0.40; P = 0.7544>0.05) (Table 5).

As for the mineralization of organic matter, it seems to be slower in the plots of more than 20 years old compared to the other plots of 0-10 years and 10-20 years old. At only 5%, Data analysis (F = 14.03; P = 0.0000) reveals a significant difference between the C/N ratios of the different plots studied. However, high values were recorded in plots older than 20 years and 10-20 years and different from those found for 0-10 year plots. Considering areas and ages, the 20-year-old Cashew agroecosystems in Bénoué subdivision had the highest C/N ratios. Data analysis did not show any significant difference in nitrogen content between subdivisions (F = 0.15; P = 0.9237>0.05) (Table 5).

Table 5: Total nitrogen and C/N ratio under the different of Cashew agroecosystems

Subdivisions	Ages	Total Nitrogen	C/N ratio
Bénoué	0-10 years	3.30±0.43ab	8.29±1.33bc
	10-20 years	2.70±1.30ab	9.14±1.16def
	Over 20 years	2.30±0.25a	10.33±0.22f
	Mean	2.76±0.50A	8.92±1.53A
Faro	0-10 years	3.80±0.81ab	6.01±0.42ab
	10-20 years	3.10±1.10ab	8.35±1.51cd
	Over 20 years	2.60±0.85ab	9.80±0.57ef
	Mean	3.16±0.60A	8.05±1.91A
Mayo-Loutii	0-10 years	4.10±1.44b	8.54±0.20a
	10-20 years	3.10±0.95ab	8.31±0.58cd
	Over 20 years	2.50±0.43ab	10.12±0.36f
	Mean	3.23±0.80A	7.99±2.30A
Mayo-Rey	0-10 years	3.30±0.75ab	8.56±0.59ab
	10-20 years	2.80±0.72ab	8.70±0.12de
	Over 20 years	2.70±0.26a	9.75±0.16ef
	Mean	2.93±0.32A	8.33±1.62A

Values assigned the same letter are not statistically different (p>0.05; Duncan's test)

Table 6: Mean SOC concentrations (%) under the different of Cashew agroecosystems

Subdivisions	Depths (cm)	0-10 years	10-20 years	Over 20 years
Bénoué	0-10	0.31±0.04bc	0.30±0.04abc	0.38±0.07bc
	10-20	0.20±0.03ab	0.21±0.03ab	0.27±0.05abc
	20-30	0.20±0.03ab	0.21±0.03ab	0.25±0.04ab
	Mean	0.24±0.06A	0.23±0.03A	0.30±0,07A
Faro	0-10	0.32±0.07bc	0.26±0.05ab	0.41±0.10c
	10-20	0.21±0.04ab	0.33±0.07bc	0.21±0.04ab
	20-30	0.20±0.03ab	0.20±0.02a	0.20±0,03a
	Mean	0.24±0.06A	0.25±0.07A	0.27±0.08A
Mayo-Loutii	0-10	0.26±0.05bc	0.33±0.74bc	0.25±0.04b
	10-20	0.21±0.02a	0.27±0.06bc	0.24±0.04b
	20-30	0.20±0.02a	0.20±0.02a	0.21±0.03a
	Mean	0.21±0.04A	0.26±0.07A	0.23±0.020A
Mayo-Rey	0-10	0.24±0.05ab	0.23±0.05ab	0.33±0.07bc
	10-20	0.23±0.04ab	0.26±0.06abc	0.25±0.05ab
	20-30	0.20±0.02a	0.21±0.04ab	0.20±0.02a
	Mean	0.22±0.03A	0.24±0.04A	0.25±0,06A

Values assigned the same letter are not statistically different (p>0.05; Duncan's test)

The mean SOC concentrations (%) ranges from 0.20±0.02-0.4±0.10%. The highest values of the mean SOC concentrations (%) were observed in the depth 0-10 cm. Data analysis does not reveal any significant difference in the mean SOC concentrations (%) between the depths on the one hand (P = 0.353>0.05) and between the three age groups of Cashew agroecosystems studied on the other, share (P = 0.408> 0.05) (Table 6).

Soil organic carbon stock varies from 16.45±0.73-37.04±2.32 tC/ha depending on depth between the three age ranges of Cashew agroecosystems studied in the four subdivisions. The highest values of soil organic carbon stocks were observed at depths of 0-10 cm. Cashew agroecosystems older than 20 years had the highest values of soil organic carbon stocks. Data analysis did not show a significant difference in soil organic carbon stocks between depths (P = 0.5178>0.05) and between the three age groups of Cashew agroecosystems studied (P = 0.4560>0.05) (Table 7).

Relationship between Soil Organic Carbon Stock and Soil Pysico-Chemical Characteristis

Soils with high C stock are sandy loamy textured soils (25.79±2.29 tC/ha or 36% of total soil C stock) followed by sandy clay soils (22.79±2.09 tC/ha or 34% of total soil C stock). On the other hand, soils containing large portions of silt are those with a low carbon stock (20.13±1.3 tC/ha or 30% of total soil carbon stock). Data analysis reveals a significant difference in soil C stock between textural classes (F = 6.11; P = 0.0185<0.05; Fig. 2).

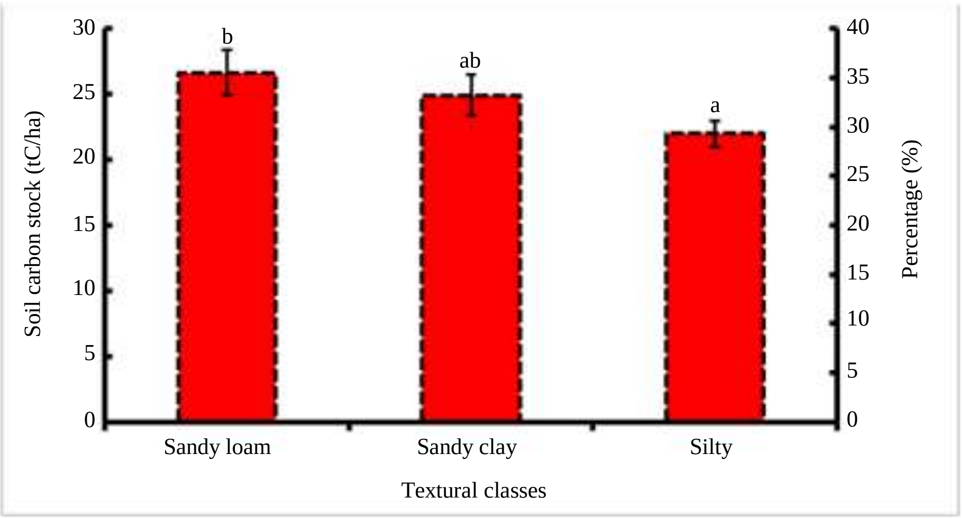

Fig. 2: Soil organic carbon stocks according to soil textural classes. Values assigned the same letter are not statistically different (p>0.05; Duncan's test)

Table 7: Variation of soil organic carbon stock as a function of depth under different of Cashew agroecosystems

Subdivisions	Depths (cm)	0-10 years	10-20 years	Over 20 years
Bénoué	0-10	26.79±1.45bc	29.18±1.78cd	37.04±2.32de
	10-20	20.10±1.05ab	22.52±1.26abc	29.94±1.97cd
	20-30	19.20±1.02a	21.77±1.20ab	24.01±1.43bc
	Mean	22.03±4.14A	24.49±4.07A	30.33±6.52A
Faro	0-10	25.76±1.43bc	26.95±1.55bc	33.04±2.12d
	10-20	17.68±0.88a	26.08±1.50bc	24,54±1.54bc
	20-30	16.93±0.77a	18.42±0.96a	18.72±0.97a
	Mean	20.12±4.89A	23.81±4.69A	25.43±7.20A
Mayo-Loutii	0-10	23.97±1.37bc	29.57±1.89cd	31.23±2.05de
	10-20	16.94±0.82a	22.07±1.27abc	23.07±1.32bc
	20-30	16.73±0.70a	15.30±0.54a	22.90±1.28abc
	Mean	19.21±4.12A	22.31±7.13A	25.73±4.76A
Mayo-Rey	0-10	28.06±1.68cd	27.36±1.65cd	33.25±2.20cd
	10-20	18.67±0.98a	24.55±1.54bc	22.05±1.25abc
	20-30	16.45±0.73a	20.97±1.18ab	18.23±0.93a
	Mean	21.06±6.16A	24.29±3.20A	24.51±7.80A

Values assigned the same letter are not statistically different (p>0.05; Duncan's test)

Table 8: Pearson correlation (R²) result of SOC stocks with other parameters

	Soil organic carbon stocks		
Parameters	0-10 cm	10-20 cm	20-30 cm
Bulk density	0.895***	0.903***	0.896***
pH	-0.943***	-0.962***	-0.985***
Moisture content (%)	0.983***	0.981***	0.980***
Total nitrogen (Kg)	-0.881***	-0.854***	-0,870***
C/N ratio (%)	0.754**	0.610**	0.580*
% OC	0.982***	0.988***	0.708***
% Sand	0.241ns	0.213ns	0.234ns
% Silt	0.229ns	0.224ns	0.245ns
% Clay	0.232ns	0.230ns	0.068ns
% Silt + Clay	0.282ns	0.41ns	0.289ns

The coefficients at $p<0.05$ are significantly correlated; *: $p\leq0.05$; **: $p\leq0.01$; ***: $p\leq0.001$ (test de Pearson); ns: non significative ($p>0.05$)

The results showed a positive and significant ($P<0.05$) correlation between soil organic C stock with bulk density, moisture content, C/N, SOC; negative and significant ($P<0.05$) with Soil pH, Total Nitrogen, but negative and non-significant ($P>0.05$) with % Sand, % Silt, % Clay, % Silt + Clay according to the three depth ranges of 0-10 cm, 10-20 cm and 20-30 cm respectively (Table 8).

Discussion

The bulk density varies from 0.80±0.01-1.20±0.12 g/cm^3 depending on the depth between the three age ranges of Cashew agroecosystems studied in the four subdivisions. This may be due to soil compaction which is variable across the three age groups of Cashew agroecosystems studied and also their soils are softened due to fine root mat, microbial and arthropod activities, leading to soil aeration. Cashew agroecosystems soils with high carbon stock are those with sandy loamy texture (25.79±2.29 tC/ha). This is normal since one of the main characteristics that influence the organic matter content and consequently the CO content of the soil is its texture (Dumoulin and Rollin, 2017). Cashew agroecosystems soils have a high OM decomposition rate with normal values (C/N between 8 and 12). Several other factors would explain these variations in C/N ratios such as particle size and pH. This ratio is higher the finer the texture and the more acidic the soil (Decoopman *et al.*, 2013). The soil reaction (pH) varies from 5.06±1.10-6.98±1.63 depending on the depth between the three age groups of Cashew agroecosystems studied in the four subdivisions. These results are similar to those of (Bessah *et al.*, 2016). Moisture content varies from 19.08±2.03-39.27±2.98% depending on the depths between the three age groups of Cashew agroecosystems studied in the four subdivisions. This would be influenced by the vegetation cover. The texture of these soils would also influence its moisture content. Indeed, a sandy soil allows water to pass easily while a clay soil retains water (Coudurier and Bourgogne, 2012). As for the pH, it is more acidic in forest soils. Indeed, tree growth involves taking ions from the soil by releasing others with identical electrical charges in order to maintain their electrical balance (Munguakonkwa, 2018). Since they need many cations rather than anions, their growth therefore releases many cations (often H+) into the soil, making it more acidic (Ranger, 2018). The texture of these forest soils will also justify their pH (Munguakonkwa, 2018). In fact, clay soils have a more acidic pH than sandy soils (Carrier, 2003).

The mean SOC concentrations (%) ranges from 0.20±0.02-0.41±0.10%. The highest values the mean SOC concentrations (%) were observed in the depth 0-10 cm. Therefore, the introduction of better land use management practices such as Sustainable Agricultural Land Management (SALM) practices will increase the stored SOC stocks (Verified Carbon Standards, 2014 in Bessah *et al.*, 2016) The relevance of climate, soil type, vegetation, terrain and topography in the study area has no impact on the horizontal variability in SOC stocks due to it homogeneity (Bessah *et al.*, 2016). Therefore, horizontal variability being insignificant in this study can also be attributed under different age ranges of cashew change. The top 0-10 cm depth recorded the highest SOC stocks under different age ranges of cashew agroecosystems but varied across land use types because land use management practices have a higher influence at top soil. Soil organic carbon stock varies from 16.45±0.73-37.04±2.32 tC/ha depending on depth between the three age ranges of cashew plantations studied in the four subdivisions. This result is within the range 9.80 and 49.63 tC/ha reported by (Bessah *et al.*, 2016) in different land-use systems in Ghana. Vegetation types can alter soil carbon stocks due to several key factors, including litter fall and root turnover, soil chemistry, root exudates and microclimate (Victor *et al.*, 2019a). Low carbon stocks in 0-10-year-old cashews are explained by the fact that agricultural practices such as deforestation, turning and frequent tillage, etc. cause a decrease in soil carbon stock (Swiderski *et al.*, 2012).

Results showed a positive and significant (P<0.05) correlation between soil organic C stock with bulk density, moisture content, C/N ratio, % OC; negative and significant (P<0.05) with Soil reaction pH, Total Nitrogen, but negative and non-significant (P>0.05) with % Sand, % Silt, % Clay, % Silt + Clay. Soil organic carbon stocks decreased with increasing depth in all three age groups of Cashew agroecosystems as reported in several results (Yan *et al*., 2012; Bessah *et al*., 2016; Victor *et al*., 2019a). The maximum depth of 0-10 cm recorded the highest soil organic carbon stock under all three age groups of Cashew agroecosystems (Bessah *et al*., 2016; Victor *et al*., 2019a; 2020).

Conclusion

This study gives us a better understanding of the soil organic carbon stock in the Cashew plantations studied. Soil is a non-renewable resource whose quality must therefore be preserved for its environmental functions. The soils under the plots of more than 20 cashew agroecosystems in Bénoué recorded higher SOCS values (36.30±2.92 tC/ha). Similarly, the SOCS decreased with soil depth in all three age groups of Cashew agroecosystems. The mean SOC concentrations (%) ranged from 0.20±0.02-0.41±0.10%. Soil organic carbon stock ranged from 16.45±0.73-37.04±2.32 tC/ha depending on depth between the three age ranges of Cashew agroecosystems studied in the four subdivisions. The Cashew agroecosystems soils with high C stock are those with sandy loamy texture (25.79±2.29 tC/ha). Results show that soil organic carbon stock is higher in Cashews over 20 years old. However, the evolution of COS stocks is more or less increasing as the cashew agroecosystems age. Of all the soil physico-chemical parameters measured, only bulk density, moisture content, C/N, % OC shows a strong and positive linear correlation with soil C stock among all the physico-chemical parameters measured. Soil physico-chemical parameters (texture, total nitrogen, C/N ratio, soil reaction (pH), soil bulk density, moisture content) also vary according to the three age groups of Cashew agroecosystems.

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Author's Contributions

Awé Djongmo Victor: Designed, collected and checked the analyzed data; prepared the draft manuscript and approved the final manuscript.

Noiha Noumi Valery: Designed research plan and supervised this work.

Zapfack Louis: Designed research plan and supervised this work.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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