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Physical and Chemical Characteristics of Soils in Agricultural Land Use Systems in Eastern Cameroon

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Abstract

Purpose of this study is to improve knowledge of the physicochemical traits that determine the degree of soil fertility in Eastern Cameroonian farming systems. Using an auger and a completely randomized block design, soil samples were taken from the 0–30 cm stratum in accordance with a randomization procedure. In the laboratory, sixteen identified and conditioned samples were analyzed. According to the analyses, the texture of cocoa is clayey-sandy, that of oil palm is sandy-clayey, that of fields (maize + peanut) is sandy-loamy, and that of forests is sandy. The pH of the soil is acidic across agricultural systems. Agricultural systems contain both the proportion of organic matter and the amount of organic carbon. The range of the total nitrogen content is 1.58 to 1.98 g/kg. The range of the carbon-nitrogen ratio is 13.10 to 15.32. The available phosphorus levels range from 4.08 to 5.8 mg/kg. Total potassium levels fall between 8.31 to 10.73 g/kg. The range of the sum of exchangeable cations is 5.21 to 9.17 cmol+/kg. The cation exchange capacity falls between 6.33 to 11.67 cmol+/kg. The percentage of exchangeable bases in the soils under investigation ranges from 77.18 to 82.3%. It is possible to recover low levels of potassium, phosphorus, sum of cations exchange, and cation exchange capacity by creating organic matter locally and using agricultural residues effectively. This research leads us to conclude that the soil of Eastern Cameroon, endowed with notable fertility, favors agricultural systems such as the cultivation of cocoa, oil palm and fields.

Keywords: Agronomy; Physicochemical; Cocoa; Cultivating Fields; Oil Palm, Cameroon

Introduction

The integration of African economies in the new millennium has not excluded agriculture, which continues to be the key component of economic and social advancement [1]. Agriculture is essential to the population's well-being in many African nations. The majority of people engage in this wealth-generating activity [2]. Some writers contend that both urban and rural households' living conditions have improved as a result of agricultural development [3]. In Cameroon, agriculture has also progressed without methods aimed at optimizing production, but seeking to reduce ecological and climatic risk [4]. Therefore, the issue of soil management is at the heart of discussions concerning the sustainability of agricultural production systems [5]. Soil, an essential resource for improving agricultural production [6], faces strong human pressures and increasingly adverse climatic conditions, which risks leading to soil degradation similar to current practices [4]. This outcome circumstance undermines production systems and makes agricultural activity precarious [7], by limiting the cultivable area to 64 % of arable land. In Cameroon, and more broadly in Africa, there is an increase in agricultural production accompanied by an acceleration of land depletion and a decline in fallow land [8].

The ability of soils to support sustainable agricultural output is threatened by a number of issues that affect soil productivity in agricultural systems around the world, including erosion, nitrogen depletion, organic matter degradation, and acidification [9]. Unsustainable farming practices, global warming, and population growth all exacerbate these issues [10]. To address these challenges, it is crucial to adopt innovative solutions and sustainable agricultural methods to preserve and strengthen soil fertility.

The rate of decomposition of plant litter is mainly related to soil fertility [11]. Organic soil plays the dual role of carbon reserve and source of energy and nutrients for agricultural land use systems [12]. The organic content of a cultivated soil is defined not only by climatic conditions, but also by its physicochemical characteristics and organic matter return practices related to agricultural systems [11]. A thorough understanding of natural soil fertility and the impact of agricultural techniques on productivity will help refine cultivated land management strategies. However, to our knowledge, no study has been conducted to date on the fertility level of agricultural soils in the Eastern zone of Cameroon. It therefore seems essential to understand agricultural land management based on scientific knowledge and farmers' skills to ensure sustainable agricultural production. This study aims to deepen knowledge of the physicochemical properties that determine the level of land fertility in agricultural land use systems located in Eastern Cameroon.

Materials and Methods

Research site

The study is conducted in the Belabo locale of the Lom and Djerem region in eastern Cameroon. It has an area of 6,000 km² and is situated between latitudes 4°55'59.99 North and longitudes 13°18'0.00 East (Figure 1). It has a tropical savannah climate, according to the Köppen-Geiger classification [13]. The average annual rainfall in this area is 778.4 mm, while the temperature ranges from 16°C to 32°C. An elevation that is a component of the vast southern Cameroonian plateau marks the relief [14]. This plateau is pénéplaine, meaning it is very large and has relatively low elevations, ranging from 400 to 900 meters. The primary economic sectors in Bélabo are agriculture, forestry, fishing, and rail transportation [15] (Figure 1).

Data collection

Soil samples were collected between May and June 2025. Within each 50 m x 50 m section, five 0.25 cm x 0.25 cm subsections were placed (Figure 2). Soil samples were collected at a depth of 0-30 cm using an auger, following a randomization protocol, at five distinct locations; the center and four corners of each farming system. For each farming system, 20 samples were randomly collected over a one-hectare area and then carefully combined into one sample for examination. These prepared samples were examined at the Soil Analysis and Environmental Chemistry Laboratory (LABASCE) located in Dschang (Figure 2).

Methods of analysis

Once the samples arrived at the laboratory, they were prepared for analysis. This preparation involved air-drying the samples for three days. Following drying, the samples were crushed in a porcelain mortar and then sieved through a 0.2 mm mesh. Soil particle size assessment involved removing organic matter using hydrogen peroxide, followed by dispersion with a 0.1 M sodium pyrophosphate solution, and finally separating the fractions by sedimentation. Soil texture classification was based on the USDA Texture Triangle [16].

The assessment of the hydrogen potential (pH) of water was carried out in a water/soil suspension at a ratio of 1:2.5 using a pH meter [17]. The Kjedahl and Olsen approaches were used to establish the total nitrogen (N) level and the amount of available phosphorus (P_2O_5), respectively, in accordance with NF ISO 10694 [18]. As

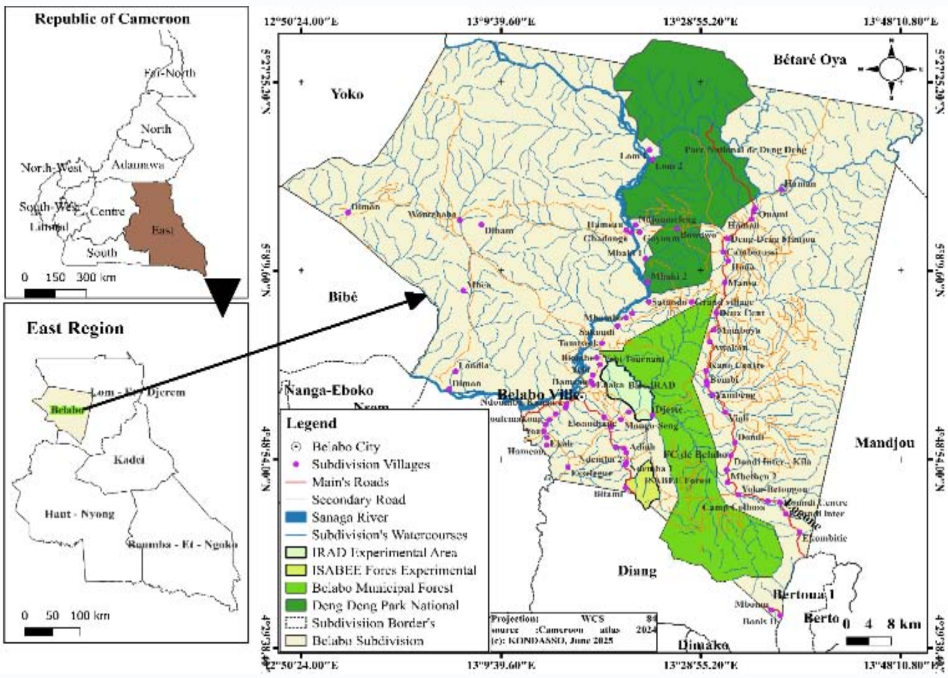

Figure 1: Map displaying the location of the study area.

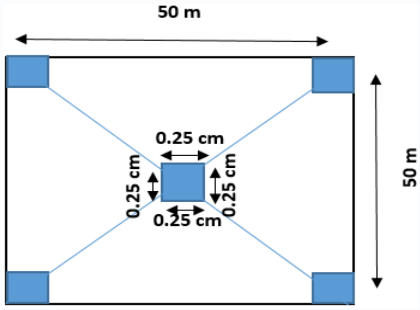

Figure 2: Soil sampling device in different agricultural systems (Cocoa, oil palm, fields) and in the control (Forest).

for potassium (K_2O), it was isolated from the soil samples using ammonium acetate [8].

Carbon was determined by Walkley and Black method according to the NF ISO 10694 standard, while total nitrogen was determined by the Kjeldahl technique. Soil pH was measured using a pH meter, using a soil-water ratio of (1/2.5) according to the NF ISO10390 standard [19]. The amount of available phosphorus was determined according to the Bray method1, and the cation exchange capacity (CEC) was evaluated by extraction with 10 % KCl, followed by distillation using the Kjeldahl technique according to the AFNOR NF X31-130 standard [20]. Exchangeable cations such as Ca^{2+}, Mg^{2+}, Na^+ and K^+ were analyzed by Atomic Absorption Spectrophotometry, as was exchangeable aluminum according to the NF ISO 11263 standard [21].

Soil fertility assessment

The soil fertility assessment was based on the fertility classification criteria proposed by [8] presented in Table 1.

Statistical analysis

All statistical analyses were performed using STATGRAPHICS plus version 5.0 for Windows. One-way analysis of variance (ANOVA) was used to compare soil physicochemical parameters of the different agricultural systems studied using Duncan's test. A p-value of 0.05 was used to determine statistical significance.

Results

Physiochemical characteristics

The results of the particle size classification of the analyzed soils are presented in four texture categories. The particle size analysis indicates that the cocoa soil is sandy-clayey, the oil palm soil is clayey-sandy, the field soil (maize + peanut) has a sandy-loamy texture, and finally, the control soil (forest) is characterized by its sandy nature (Table 2). Analysis of variance revealed a significant variation in sand particles (F= 15.03; p=0.018<0.05), clay (F=8.84; p=0.015<0.05) and silt (F=10.42; p=0.024<0.05) between agricultural systems and the control group (forest) (Table 2).

In the three agroforestry crops, the pH value of the soil samples is highest in the cocoa agroforestry (6.32 ± 0.02). The water pH of the three agroforestry crops is higher than that of the control (forest with pH = 5.17 ± 0.01) (Table 3). Examination of variance showed no notable differences in soil pH (F=01.85; p=0.54>0.05) between the agricultural systems and the control (forest) (Table 3).

The percentage of organic matter in the three agroforestry plantations fluctuates between 3.48 ± 0.02 and 4.8 ± 0.02 %. In

Table 1: Criteria for assessing soil fertility classes.

Characteristic	Soil fertility assessment				
	Very high	high	Medium	Low	Very low
OM (%)	> 2	2-1.5	1.5-1	1-0.5	< 0.5
N (%)	> 0.08	0.08-0.06	0.06-0.045	0.045-0.03	< 0.03
P.ass (cmol+/kg)	> 20	20-15	15-10	10-5	< 5
K+ (cmol+/kg)	> 0.4	0.4-0.3	0.3-0.2	0.2-0.1	< 0.1
S (cmol+/kg)	> 10	10-7.5	7.5-5	5-2	< 2
V (%)	> 60	60-50	50-30	30-15	< 15
CEC (cmol+/kg)	> 25	25-15	15-10	10-5	< 5
pH	5.5-6.5 6.5-8.2	5.5-6.0 6.5-7.8	5.5-5.3 7.8-8.3	5.3-5.2 8.3-8.5	< 5.2 >8.5

Legend: OM: Organic matter; N: Nitrogen; Pass: Available phosphorus; K+: Potassium; S: sum of cations exchange; CEC: Cation exchange capacity; V: Saturation Rate.

agroforestry practices, the concentration of organic matter is higher in the field soil (maize + peanut) (4.8 ± 0.02 %). Analysis of variance shows that there is no significant difference in organic matter (F=02.15; p=0.21>0.05) between the agricultural systems and the control (forest) (Table 4).

The three agroforestry crops show a variation in organic carbon content ranging from 20.82 ± 0.13 to 28.65 ± 0.13 g/kg. In agroforestry systems, the amount of organic carbon is higher in the field soil (maize + peanut), reaching 28.65 ± 0.13 g/kg. Analysis of variance shows that there is no significant difference in organic carbon (F=01.02; p=0.11>0.05) between the agricultural systems and the control (forest) (Table 4).

In the three agroforestry crops, the total nitrogen concentration fluctuates between 1.58 ± 0.01 and 1.98 ± 0.01 g/kg. The total nitrogen concentration is higher in the oil palm soil (1.98 ± 0.01 g/kg) compared to the other agroforestry crops. Analysis of variance shows that there is no significant difference in total nitrogen concentration (F=0.98; p=0.31>0.05) between the agricultural systems and the control (forest) (Table 4).

The C/N ratio of the three agroforestry systems fluctuates between 13.10 ± 0.05 and 15.32 ± 0.05. Among the three agroforestry systems, the C/N rate is higher in the field soil (maize + peanut) (15.32 ± 0.05). Analysis of variance shows that there is no significant difference in C/N ratio (F=0.08; p=0.81>0.05) between the agricultural systems and the control (forest) (Table 4).

The available phosphorus concentration in the three types of agroforestry crops fluctuates between 4.08 ± 0.03 and 5.8 ± 0.03 mg/kg. Among the three agroforestry cropping systems, the available phosphorus concentration is higher in the field soil (maize + peanut) (5.8 ± 0.03 mg/kg). Analysis of variance shows that there is no significant difference in available phosphorus concentration (F=0.58; p=0.09>0.05) between the agricultural systems and the control (forest) (Table 4).

The total potassium content of the three agroforestry crops ranged from 8.31 ± 0.05 to 10.73 ± 0.05 g/kg. Among the three agroforestry crops, the total potassium content was higher in the field soil (maize + peanut) (10.73 ± 0.05 g/kg). Analysis of variance shows that there is no significant difference in total potassium (F=0.65; p=0.06>0.05) between the agricultural systems and the control (forest) (Table 4).

The average exchangeable calcium in the three agroforestry crops

Table 2: Soil texture of agricultural land use systems and control.

Parameters	Agricultural land use systems			Control
	Cocoa	Oil palm	Fields (maize + Peanuts)	Forest
Clay	36.52± 0.28c	53± 0.39d	5.95± 0.21b	3.58 ± 0.12a
Loam	8.09 ± 0.11a	37 ± 0.27c	20.05 ± 0.19b	10.42 ± 0.15a
Sand	55.39 ± 0.32b	10 ± 0.14a	74 ± 0.54c	86 ± 0.62d
Textural class	Clayey-sandy	Sandy-clayey	Sandy-loamy	Sandy

In each lines, the values assigned the same letter are not statistically different (P >0.05; Duncan test).

Table 3: Soil reaction (pH) of agroforestry crops and control.

Parameters	Agricultural land use systems			Control
	Cocoa	Oil palm	Fields (maize + Peanuts)	Forest
Soil pH	6.32 ± 0.02a	5.82 ± 0.02a	5.63 ± 0.02a	5.17 ± 0.02a

Legend: pH: Soil reaction. In each lines, the values assigned the same letter are not statistically different (P >0.05; Duncan test).

Table 4: Organic matter content and total elements of the soils studied.

Parameters	Agricultural land use systems			Control
	Cocoa	Oil palm	Fields (maize + Peanuts)	Forest
OM (%)	3.48± 0.02a	4.45± 0.02a	4.80± 0.02a	5 ± 0.02a
C(g/kg)	20.82 ± 0.13a	25.95 ± 0.13a	28.65 ± 0.13a	28.12 ± 0.13a
Total N (g/kg)	1.58 ± 0.01a	1.98 ± 0.01a	1.87 ± 0.01a	1.80 ± 0.01a
C/N ratio	13.17 ± 0.05a	13.10 ± 0.05a	15.32 ± 0.05a	15.62 ± 0.05a
P. ass (g/kg)	4.34± 0.03a	4.08± 0.03a	5.8± 0.03a	4.44± 0.03a
Total potassium (g/kg)	8.31± 0.05a	8.33± 0.05a	10.73± 0.05a	6.48± 0.05a

Legend: OM: Organic Matter, C: Carbon, N total: total nitrogen, C/N: Carbon nitrogen ratio, Pass: available phosphorus, P total: Total phosphorus, K total: Total potassium. In each lines, the values assigned the same letter are not statistically different (P >0.05; Duncan test).

Table 5: Sum of exchangeable cations, cation exchange capacity and exchangeable base saturation rate.

Parameters	Agricultural land use systems			Control
	Cocoa	Oil palm	Fields (maize + Peanuts)	Forest
Ca^{2+}(cmol+/kg)	5.21± 0.02a	4.01± 0.02a	6.31 ± 0.02a	3.53 ± 0.02a
Mg^{2+}(cmol+/kg)	2.01 ± 0.01a	1.03 ± 0.01a	2.58 ± 0.02a	1.06 ± 0.01a
K^{+}(cmol+/kg)	0.18 ± 0.01a	0.12 ± 0.01a	0.27 ± 0.01a	0.15 ± 0.01a
Na^{+}(cmol+/kg)	0.01 ± 0.00a	0.05 ± 0.01a	0.01 ± 0.00a	0.04 ± 0.01a
SCE (cmol+/kg)	7.41 ± 0.03b	5.21 ± 0.02a	9.17 ± 0.04c	4.78 ± 0.01a
CEC (cmol+/kg)	9.60 ± 0.05c	6.33 ± 0.03b	11.67 ± 0.07d	5.16 ± 0.03a
V (%)	77.18 ± 0.32a	82.30 ± 0.35a	78.57 ± 0.35a	92.63 ± 0.52a

Legend: Ca^{2+}: Calcium; Mg^{2+}: Magnesium; K+: Potassium; Na+: Sodium; S: sum of cations exchange; CEC: Cation exchange capacity; V: Saturation Rate. In each lines, the values assigned the same letter are not statistically different (P >0.05; Duncan test).

was between 4.01 ± 0.02 and 6.31 ± 0.02 $cmol^{+}$/kg. The field soil (maize + peanut) had a higher concentration of exchangeable calcium (6.31 ± 0.02 $cmol^{+}$/kg). Analysis of variance shows that there is no significant difference in average exchangeable calcium (F=0.45; p=0.08>0.05) between the agricultural systems and the control (forest) (Table 5).

The average exchangeable magnesium concentration in the three agroforestry crop types ranged from 1.03 ± 0.01 to 2.58 ± 0.02 $cmol^{+}$/kg. The exchangeable magnesium content was higher in the field soil (maize + peanut), at 2.58 ± 0.02 $cmol^{+}$/kg. The exchangeable magnesium level in the control (forest) (1.06 ± 0.01 $cmol^{+}$/kg) was higher than that in oil palm, but was lower than that in cocoa and other crops (maize + peanut). Analysis of variance shows that there is no significant difference in average exchangeable magnesium concentration (F=0.55; p=0.06>0.05) between the agricultural systems and the control (forest) (Table 5).

The average exchangeable potassium concentration for the three types of agroforestry crops fluctuates between 0.12 ± 0.01 and 0.27 ± 0.01 $cmol^{+}$/kg. The exchangeable potassium level is higher in the field soil (maize + peanut) (0.27 ± 0.01 $cmol^{+}$/kg). The control (forest) has an exchangeable calcium concentration of 0.15 ± 0.01 $cmol^{+}$/kg, which is higher than that of the oil palm. However, it remains lower compared to that of cocoa and the field (maize + peanut). Analysis of variance shows that there is no significant difference in average exchangeable potassium concentration (F=0.25; p=0.14>0.05) between the agricultural systems and the control (forest) (Table 5).

The average exchangeable sodium concentration in the three agroforestry crop types fluctuates between 0.01 ± 0.00 and 0.05 ± 0.01 $cmol^{+}$/kg. The exchangeable sodium content is higher in the oil palm soil (0.05 ± 0.01 $cmol^{+}$/kg). The control (forest) has an exchangeable sodium level of 0.04 ± 0.01 $cmol^{+}$/kg, which is higher than that of cocoa and field (maize + peanut), although it remains below the level

Table 6: Identification of Soil Parameters.

Parameters	Agricultural land use systems			Control
	Cocoa	Oil palm	Fields (maize + Peanuts)	Forest
OM (%)	3.48 ± 0.02a	4.45 ± 0.02a	4.80± 0.02a	5 ± 0.02a
N. total (g.kg^{-1})	1.58 ± 0.01a	1.98 ± 0.01a	1.87 ± 0.01a	1.80 ± 0.01a
P. ass(mg.kg^{-1})	4.34± 0.03a	4.08± 0.03a	5.8± 0.03a	4.44± 0.03a
K^+(cmol+/kg)	0.18 ± 0.01a	0.12 ± 0.01a	0.27 ± 0.01a	0.15 ± 0.01a
SCE (cmol+/kg)	7.41 ± 0.03b	5.21 ± 0.02a	9.17 ± 0.04c	4.78 ± 0.01a
CEC (cmol+/kg)	9.60 ± 0.05c	6.33 ± 0.03b	11.67 ± 0.07d	5.16 ± 0.03a
V (%)	77.18 ± 0.32a	82.30 ± 0.35a	78.57 ± 0.35a	92.63 ± 0.52a
pH	6.32 ± 0.02a	5.82 ± 0.02a	5.63 ± 0.02a	5.17 ± 0.02a

Legend: OM: Organic Matter, N total: total nitrogen, Pass: available phosphorus, K+: Potassium; SCE: sum of cations exchange; CEC: Cation exchange capacity; V: Saturation Rate. In each lines, the values assigned the same letter are not statistically different (P >0.05; Duncan test).

Table 7: Soil Fertility Assessment.

Parameters	Agricultural land use systems			Control
	Cocoa	Oil palm	Fields (maize + Peanuts)	Forest
M.org (%)	Very high	Very high	Very high	Very high
N. total (g.kg^{-1})	Very high	Very high	Very high	Very high
P. ass(mg.kg^{-1})	Verylow	Verylow	Low	Verylow
K^+(cmol+/kg)	Low	Low	Medium	Low
SCE (cmol+/kg)	Medium	Medium	High	Low
CEC (cmol+/kg)	Low	Low	Medium	Low
V (%)	Very high	Very high	Very high	Very high
pH	Very high	Very high	Very high	Low

of oil palm. Analysis of variance shows that there is no significant difference in average exchangeable sodium concentration (F=0.85; p=0.39>0.05) between the agricultural systems and the control (forest) (Table 5).

The total exchangeable cations for the three agroforestry crops ranged from 5.21 ± 0.02 to 9.17 ± 0.04 cmol$^+$/kg. The field soil (maize + peanut) had a higher total exchangeable cations, at 9.17 ± 0.04 cmol$^+$/kg. The total exchangeable cations in the control (forest) (4.78 ± 0.01 cmol$^+$/kg) were lower than those in the three agroforestry plantations. Analysis of variance shows that there is significant difference in total exchangeable cations (F=8.34; p=0.04<0.05) between the agricultural systems and the control (forest) (Table 5).

The cation exchange capacity of the three agroforestry crops ranged from 6.33 ± 0.03 to 11.67 ± 0.07 cmol$^+$/kg. The field soil (maize + peanut) had a higher cation exchange capacity (11.67 ± 0.07 cmol$^+$/kg). The control (forest) had a cation exchange capacity of 5.16 ± 0.03 cmol$^+$/kg, which was lower than that of the three agroforestry crops. Analysis of variance shows that there is significant difference in cation exchange capacity (F=9.02; p=0.03<0.05) between the agricultural systems and the control (forest) (Table 5).

Between the three agroforestry crops analyzed, the percentage of saturation in exchangeable bases of the observed soils fluctuates between 77.18 ± 0.32 and 82.30 ± 0.35 %. There is a greater proportion in the oil palm soil (82.30 ± 0.35 %). The control soil has a saturation rate in exchangeable bases (992.63 ± 0.52 %) which largely exceeds that of the three agroforestry crops. Analysis of variance shows that there is no significant difference in cation exchange capacity (F=0.24; p=0.23>0.05) between the agricultural systems and the control (forest) (Table 5).

Identification of soil parameters and soil fertility assessment

According to the analysis results in Tables 6 and 7, the fertility parameters are largely low to very low for phosphorus, potassium, SCE, and CEC in the agroforestry crops studied. Very high levels of organic matter and total nitrogen are noted, as well as acidic soil reactions and the saturation rate of exchangeable bases. In the proper management of these soils, increasing the percentage of organic matter appears to be an essential solution to most of these problems. Indeed, organic matter helps reduce the loading point for releasing nitrogen and phosphorus through mineralization (Table 6 and 7).

Discussion

Our research has shown that the soils of the agricultural systems and the control (forest) analyzed have distinct textures: sandy-clay for cocoa, clay-sandy for oil palm, sandy-loam for the field and sandy for the forest. It referees a significant amount of sand and clay, as seen by the clay-sandy soil on which the cocoa growers push. These results corroborate the studies of various authors such as [22, 23, 24, 25]. The soil where oil palm are pushed to grit is clay-sandy, meaning that there is a significant amount of sand mixed with a preponderance of clay. These results corroborate the studies of various authors such as[26, 27]. The cultural soil (maize + Peanuts) is sandy-loam, meaning it contains a significant amount of sand and loam. These results corroborate the studies of various authors such as [28; 29]. The forest's control sol is sable, indicating that sand makes up the majority of its composition.

Agricultural systems and the control forest can exhibit soil acidity for several reasons. In agricultural systems, the use of fertilizers, particularly those rich in nitrogen, can acidify the soil over time.

In addition, the process of mineralization of organic matter, while beneficial, can release protons (H+ ions) that increase acidity. In forests, the accumulation of decaying organic matter, rich in acidic compounds, contributes to soil acidity, especially in humid climates where leaching removes bases. Soil acidity in agricultural systems and forests is a natural phenomenon linked to complex biological and chemical processes, as well as climatic conditions. These results corroborate those of the study by [30]as well as [31]. pH, which is an essential factor in the chemical composition of the soil, determines the availability of nutrients for plants and soil microorganisms [32]. According to [8], the slightly acidic pH of the analyzed soils is a beneficial factor for the cultivation of cocoa, oil palm and field.

Soil organic matter is higher in agroforestry systems combining maize and peanuts due to the contribution of organic matter by both crops, as well as the improvement of soil structure and nitrogen fixation by legumes such as peanuts. Corn and peanuts, when grown together, contribute more organic matter to the soil. Crop residues (leaves, stems, roots) left after harvest decompose and enrich the soil with organic matter. These findings concur with those of [33].

The organic carbon content is higher in a soil cultivated with corn and peanuts together, due to the varied enrichment of the soil by these two types of crops, the soil cover provided by plant debris and the improvement made to the soil structure. According to [34], the combination of maize and peanuts promotes a diversity of organic matter input, better soil cover and improved soil structure. This leads to increased storage of organic carbon in the soil.

Total nitrogen concentration is higher in oil palm plantation soil due to several factors, including high nitrogen fertilizer inputs, abundant leaf and root litter, and the crop's unique nitrogen cycle. According to [35, 36], oil palm generates a significant amount of organic matter, particularly leaves and roots, which gradually degrade. This organic substance, which contains a high concentration of nitrogen, is deposited in the soil, increasing its overall nitrogen content.

The C/N rate is higher in the field soil (maize + Peanuts), meaning that there is more carbon than nitrogen, which can slow down decomposition by microorganisms. According to various authors such as [37, 38], the association of corn, which has a higher C/N ratio, and nitrogen provided by peanuts, generates a harmony in the soil that affects the decomposition of organic matter and the accessibility of nutrients for plants.

Several factors, including those related to mixed cropping and soil characteristics, could explain the higher presence of available phosphorus in the field (rnaize + peanut). Usually, crops such as corn and peanut have specific phosphorus requirements, and their co-cultivation can affect the availability of this nutrient in the soil. In addition, interactions between these two crops can lead to changes in soil characteristics, thus increasing phosphorus availability. These findings concur with those of [39,40]. Several factors could explain the higher potassium concentration in the corn and peanut field, including the specific potassium requirements of these plants, the use of potassium-containing fertilizers, or the release of potassium from organic matter. According to [41], a combination of crop, fertilization and soil chemistry factors may explain high potassium content in corn and peanut field soil.

Several factors associated with the co-cultivation of corn and peanuts explain the increased presence of exchangeable calcium, magnesium, and potassium in the soil of these fields. Peanut and corn roots have distinct root systems that explore the soil in a complementary manner, promoting more efficient extraction of these nutrients. In addition, peanuts, as a legume, have the potential to fix nitrogen from the air and make it accessible to other plants, which also encourages their uptake of cations.

Several factors related to oil palm physiology and soil characteristics may explain the increased concentration of exchangeable sodium present in the soil beneath these plants. First, oil palms are distinguished by their vigorous growth and high biomass production, which results in significant nutritional requirements, including sodium. Sodium, although not essential, can be absorbed and stored by the plant, which contributes to its increased concentration in the surrounding soil. Second, oil palms have a propensity to acidify the surrounding soil, as their roots excrete protons to capture cations. This acidification can stimulate the release of sodium adsorbed on soil colloids, thus increasing its availability and concentration in the exchangeable soil.

Third, the use of fertilizers, generally rich in sodium, in oil palm crops can also contribute to increasing the exchangeable sodium level. Our research is consistent with the work of [35]who demonstrated that oil palm has the ability to accumulate sodium in its tissues, which can influence the composition of the surrounding soil. And that the combination of the oil palm's high nutritional requirements, soil acidification caused by the plant, and fertilizer application can cause an increase in the exchangeable sodium concentration in the soil beneath its crown.

Due to their specific nutritional requirements, their usually high cation exchange capacity, the addition of limestone corrections and proper soil management, oil palm soils display a higher saturation rate of exchangeable bases.

Soil studies indicate that the agroforestry crops examined have a phosphorus and potassium deficiency, as well as limited cation exchange capacity (CEC) and cation exchange (SEC), which indicates low fertility. Although the organic matter and total nitrogen content are high, the soils have high acidity and low base retention capacity. Therefore, increasing organic matter represents a crucial solution to optimize fertility, as it can promote the release of nutrients through the mineralization process.

Conclusion

Following the research aimed at analyzing the physicochemical characteristics of soils for sustainable farm management in cocoa, oil palm, and field-based cropping systems in Cameroon, the analysis of the particle distribution of the soil studied revealed the interaction between the soil and different textures such as sandy clay, sandy clay, and sandy loamy clay. The soils of the crops examined have a pH ranging from acidic to moderately acidic and contain more or less adequate levels of the main elements. The C/N ratio suggests that the mineralization of the organic matter present is extremely slow. Optimizing crop residues and local production of organic matter, which is the basis for improving and maintaining soil fertility, can rectify the very low levels of phosphorus, potassium, SCE, and CEC. This results in improved agricultural yields, thus ensuring reliable food security. Furthermore, the importance of CEC decreases as soil organic matter content increases, resulting in limited cation exchange capacity even with limited nutrient capacities.

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