Physicochemical Characterization of Agricultural Soils at the Davie Littoral Agricultural Research Center, Togo

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Abstract: The degradation and contamination of agricultural soils by trace metal elements represent major environmental issues. Crop productivity and product quality are strongly influenced by the physicochemical characteristics of soils. The present study aimed to characterize the soil of the CRAL in Davié, a strategic agricultural research center in Togo. Standardized physicochemical analyses revealed an acidic soil, with a mean pH of 5.49, low organic matter content of 1.72%, and organic carbon content of 0.99%. Atomic absorption spectrophotometric analysis yielded mean concentrations of 51.80 mg/kg nitrogen, 2,474.75 mg/kg phosphorus, 98.35 mg/kg potassium, 718.33 mg/kg calcium, 337.468 mg/kg magnesium, and 188 mg/kg sodium. Particle size analysis showed a predominantly sandy texture, with sand representing 87% of the soil. FTIR results suggested the presence of kaolinite and quartz. Cadmium and lead concentrations were 0.148 mg/kg and 14.626 mg/kg, respectively, remaining below the applicable regulatory limits. Overall, the soil is acidic and low in organic matter, suggesting that organic amendments such as biochar or alkaline compost may be effective in correcting acidity and improving soil fertility.

Keywords : *FTIR, Soils, Nutrients, Togo, CRAL.*

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I. INTRODUCTION

Nowadays, the degradation and contamination of agricultural soils by trace metal elements (TMEs) represent a major environmental and public health concern worldwide. It is estimated that 14-17% of the world's agricultural land is contaminated by at least one toxic metal, while nearly 40% of global land has already been degraded under the combined pressure of anthropogenic and climatic factors (UNCCD, 2024; Chen *et al.*, 2015). In sub-Saharan Africa, the situation is especially alarming, with nearly 65% of soils degraded as a result of overexploitation, erosion, intensive farming practices, and multiple contamination sources (Aduayi-Akue & Gnandi, 2015; IITA, 2024). This degradation leads to nutrient depletion, lower crop productivity, and poorer food quality.In Togo, several studies have reported contamination of soils, plants, and aquatic resources by heavy metals, particularly in the Lomé-Hahotoé and Kpémé areas (Boateng & Bennoah, 2020; Motlagh, 2024; Aziablé *et al*., 2016). Elevated cadmium and lead concentrations have also been detected in moringa leaves and in fish and seafood from contaminated environments, indicating a possible transfer through the food chain (Senou *et al*., 2019; Barbade *et al.*, 2025). The main local sources of metal contamination include phosphate extraction and processing, industrial activities such as the CIMTOGO cement plant, illegal dumping, inappropriate use of fertilizers and pesticides, and gasoline-powered machinery such as tractors (Gnandi *et al*., 2008; Baize, 2021).Unlike organic pollutants, trace metal elements are non-biodegradable; they can accumulate in soils over long periods, persist in the environment, and exert toxic effects even at low concentrations (Wuana & Okieimen, 2011; Kotnala *et al*., 2025). Several TMEs are recognized as carcinogenic, genotoxic, or neurotoxic, including Pb and Hg. For instance, lead exposure through ingestion or inhalation can cause anemia and severe damage to the central and

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peripheral nervous systems (WHO and IARC, 2022). Mercury, particularly in its organic form, may cause severe neurological disorders and renal damage (Environment, 2019; Pacyna *et al.*, 2009).Despite these concerns, studies on the physicochemical characterization of agricultural soils remain limited in several areas of Togo. The Agricultural Research Center of the Littoral (CRAL) in Davié is a strategic site for agricultural research in southern Togo. Assessing soil quality is therefore essential not only to ensure the safety of agricultural production, but also to establish baseline data for future monitoring and sustainable land management strategies.The present study aimed to characterize the agricultural soils of the CRAL in Davié and to investigate their mineralogical characteristics using Fourier transform infrared spectroscopy (FTIR).

II. MATERIAL AND METHODS

➢ *Study Site Description*

The soil samples analyzed in this study were collected at the Agricultural Research Center of the Littoral (CRAL). The CRAL is situated in Davié, Zio Prefecture, Maritime Region of Togo, at approximately 6°23′5″ N and 1°12′18″ E, roughly 30 km north of Lomé along National Road 1 (RN1). The site is located in a humid subequatorial climatic zone characterized by two rainy seasons and two dry seasons. The first rainy season occurs from April to July, and the second from September to October. The first dry season extends from November to March, while the second corresponds to August. Mean air temperatures range from 25°C to 30°C, and relative humidity remains generally high throughout the year. Annual rainfall ranges from 900 to 1,200 mm. Surrounded by cultivated fields, plantations, and rural settlements, the CRAL provides a suitable environment for applied agronomic research. The center is affiliated with the Togolese Agricultural Research Institute (ITRA). The geographical location of the study site is shown in Figure 1.

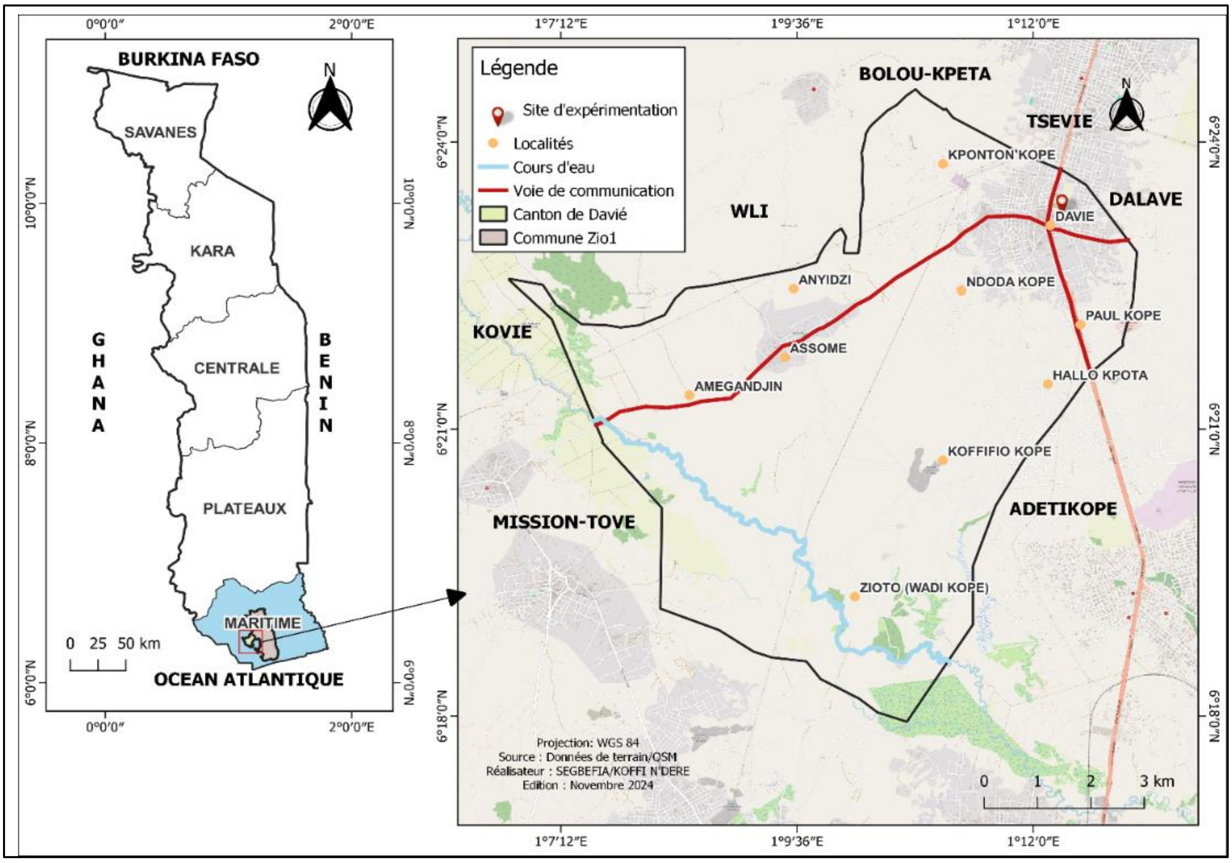

Fig 1 Location Map of the CRAL de DAVIE Site.

➢ *Sampling Method Description*

Soil samples were collected from the 0-40 cm horizon using a 40 cm depth auger, following the method described by Abile *et al*. (2025). The study site was divided into five subplots. In each subplot, five subsamples were collected from the four corners and the center of the plot area, with a constant separation distance of 15 cm between sampling points. These subsamples were then homogenized to form a composite sample for laboratory analysis. Using the auger, samples were extracted to a depth of 40 cm, combined in a clean bucket, thoroughly mixed, and homogenized. The resulting composite sample was placed in a specific plastic bag for soil sampling, with stones, leaves, and wood fragments removed. Samples were transported to the Laboratory of Waste Management, Treatment, and Valorization (GTVD) at the University of Lomé, where they were sieved, ground, and stored for analysis. Figure 2 illustrates the adopted sampling design.

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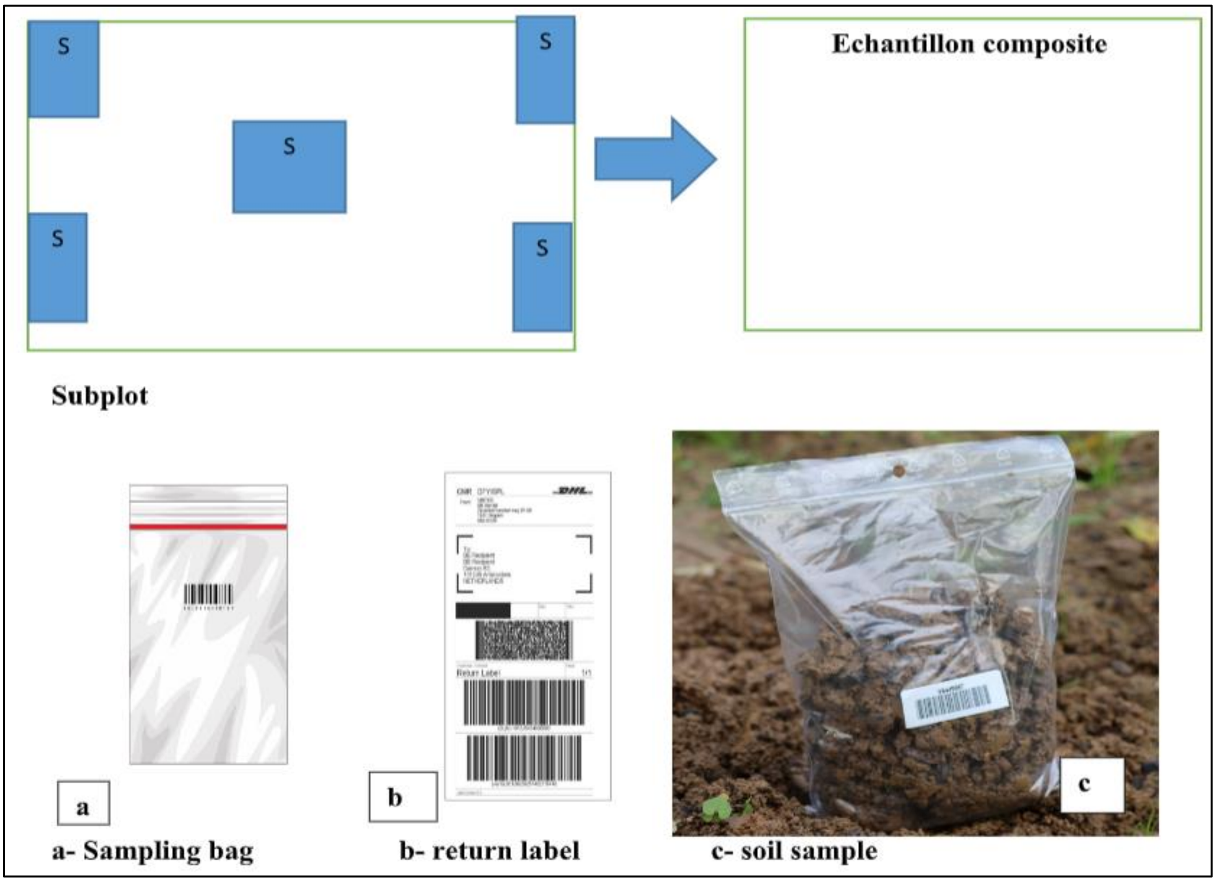

Fig 2 Sampling Device

➢ *Physico-Chemical Soil Analysis*

The collected soil samples were oven-dried at 105 °C for 24 h and manually ground using a laboratory mortar to obtain a fine powder for analysis.

- *Determination of Soil pH and Electrical Conductivity (EC)*

Soil pH and EC were determined following the method described by Bodjona *et al*. (2024) using a HANNA (HI22091-01) multifunctional pH meter. This involved mixing 20 g of dry soil with 100 mL of distilled water (1:5 m/V ratio). The suspension was shaken for 1 h, allowed to settle for 2 h, and then filtered. The pH and EC of the soil were taken as equivalent to the values measured in the filtered aqueous extract.

- *Determination of Soil Organic Matter*

Soil organic matter was determined using the loss-on-ignition method as described in NF ISO 10694 and reported by Aziablé *et al.* (2016). This involved weighing 50 g of oven-dried soil sample using an electronic balance, followed by calcination in a muffle furnace preset at 550 °C for 4 h. Organic matter content was calculated from the weight loss after ignition using the following formula:

$$MO(\%) = \frac{W1-W2}{W1} X100 \quad (1)$$

Where W1 is the initial dry soil weight (g) and W2 is the weight after ignition (g).

Total organic carbon (TOC) content was derived from organic matter using the Van Bemmelen factor (1.724):

$$TOC\ (\%) = OM\ (\%) \times 0.58 \quad (2)$$

- *Particle Size Analysis*

Particle size distribution was determined using the standardized NF X31-107 pipette method. A 20 g mass of air-dried soil sieved to 2 mm was used for analysis (Touhtouh *et al.*, 2015). Organic matter was destroyed with hydrogen peroxide, and carbonates were removed with hydrochloric acid, followed by addition of sodium hexametaphosphate as a dispersing agent. The resulting suspension was mechanically stirred to ensure thorough particle disaggregation. The sand fraction was recovered by passing the suspension through a 50 µm mesh sieve. Silt and clay fractions were separated by sedimentation based on Stokes' law. After 24 h of sedimentation in columns, the clay fraction was sampled by siphoning at a depth of 30 cm. Each granulometric fraction was oven-dried at 105 °C for 24 h and weighed.

- *Determination of Nutrient and Trace Metal Contents*

Total nitrogen (N) content in the coconut shell-based biochar was determined using the DR3800 procedure method 10071.

Calcium (Ca), magnesium (Mg), and sodium (Na) contents were measured following NF EN ISO 7980.

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Available potassium (K) and phosphorus (P), and sodium (Na) contents in the biochar were determined according to NF T 90-020.

Lead (Pb), cadmium (Cd), iron (Fe), chromium (Cr), and arsenic (As) contents were analyzed using the method described in FD T 90-112.

- *FTIR Spectroscopy of Soils*

Fourier transform infrared (FTIR) spectroscopy was performed using a Thermo Scientific Nicolet Summit X spectrometer equipped with a KBr beamsplitter (spectral range: 8100–350 cm⁻¹; resolution < 0.5 cm⁻¹) on finely sieved soil powders (<50 µm). Spectra were acquired in ATR mode using OMNIC software, enabling identification of functional groups in the soil samples.

The Table 1 summary of techniques and methods used for analytical parameter determination.

Table 1 Summary of Techniques and Methods Used for Analytical Parameter Determination.

analytical parameter	methods	Equipment used
Calcium	Flame atomic absorption spectrometry(NF EN ISO 7980)	AASiCE 3000 SERIES THERMO FISCHER
Potassium and sodium	Flame atomic absorption spectrometry (NF T 90-020)	AAS iCE 3000 SERIES THERMO FISCHER
magnesium	Flame atomic absorption spectrometry (NF EN ISO 7980)	AAS iCE 3000 SERIES THERMO FISCHER
Cadmium	Flame atomic absorption spectrometry (NF EN ISO 5961)	AAS iCE 3000 SERIES THERMO FISCHER
lead	Flame atomic absorption spectrometry (FD T 90-112)	AAS iCE 3000 SERIES THERMO FISCHER
Arsenic	Steam hydride (NF EN ISO11969)	AAS iCE 3000 +VP100
nitrogen and phosphorus	Colorimétrie (Méthode 10071 de la procédure DR3800) Colorimétrie (NFT90-023)	HACH DR 3800

The simplified official decision-making table 2 of the US Department of Agriculture (USDA, 2017) is used for the interpretation of particle size analyses.

Table 2 USDA Simplified Official Decision-Making Table (USDA, 2017)

Classe texturale	%sable	% Argile et %Limon
SABLE	≥ 85%	argil< 12% ; Silt < 25%
loamy sand	70-90%	Argil < 15% ; Silt 15-30%
Loamy clay sand	45-85%	Argil < 20% ; Silt < 28%
LOAM	23-52%	Argil 7-12% ; Silt 28-50%
silt loam	0-50%	Argil 12-18% ; Silt50-88%
clay loam soil	20-45%	Argil 27-40% ; Silt20-45%
sandy clay	45-65%	Argil 27-40% ; Silt40-60%

III. RESULTS

- *pH and Electrical Conductivity of the Soil*

The soil pH measurement revealed acidic values ranging from 5.32 to 5.62 with an average of 5.49 while the electrical conductivity ranges from 0.049 dS/m to 0.054 dS/m with an average value of 0.050 dS/m.Table 3 presents the soil pH in water values.

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Table 3 pH to Soil Water and Reference Values for Interpretation (Thiaw et al., 2024a)

Parameter	**our values**				**Reference values**(Thiaw et al., 2024)			
Sol (n=5)	**Min**	**Max**	**Mean**	**SD**	**Acid to the extreme**	**strongly acidic**	**Acid**	**Neutral**
pH	5.32	5.62	5.49	0.19	<4.6	4.6-5.4	5.4-5.5	6.7-7.3

pH: no units; Min = minimum value; Max = maximum value, SD: standard deviation.

Table 4 Electrical Conductivity (EC) of Soil and Interpretation Reference values (Thiaw et al., 2024a)

Parameter	**Ours values**				**Référence value** (Thiaw et al., 2024)			
Sol (n=5)	**Min**	**Max**	**Mean**	**SD**	**non-ionic**	**ionic**	**Very salty**	Extremely salty
EC (*dS/m*)	0,049	0,054	0,050	0,020	<0,025	0,05-0,1	0,1-0,2	>0,2

➢ *Soil Organic Matter and Organic Carbon*

Results of soil organic matter (OM) and organic carbon (OC) contents are presented in Table 5. OM content ranged from 0.55 to 1.55% (mean: 0.99%), while OC varied from 0.32 to 0.90% (mean: 0.57%, SD: 0.06).

Table 5 Organic Matter, Soil Organic Carbon and Reference Values for Interpretation

Parameter	**our values**				**Reference values**			
Soil (n=5)	**Min**	**Max**	**Mean**	**SD**	**Poor**	**medium**	**Rich**	**Great**
OM	0.55	1.55	0.99	0.07	<1.00	1-2	2-3	>3
OC	0.32	0.90	0.57	0.06	<0.76	0.76-1.37	>1.37	>5.10

Sources: (Thiaw *et al*., 2024b; Zongo *et al.*, 2024); OM and OC are in %.

➢ *Soil Particle Size Distribution*

Particle size analysis of the samples yielded the results shown in Table 6. The soil exhibited a coarse sand content of 68.49%, fine sand of 18.85%, fine silt of 5.44%, and coarse silt of 4.92%.

Table 6 Soil Particle Size Distribution.

Parameter	**loam**	**fine silt**	**coarse silt**	**fine sand**	**coarse sand**
Teneurs (%)	2.30	5.44	4.92	18.85	68.49

➢ *Soil Fertility Elements*

The chemical characteristics of soil fertility elements are presented in Table 7. Nutrient concentrations in the studied soil samples ranged from 50.91 to 52.34 mg/kg for nitrogen, 815.00 to 1077.50 mg/kg for phosphorus, 49.57 to 144.54 mg/kg for potassium, 518.75 to 1100.00 mg/kg for calcium, 114.75 to 337.47 mg/kg for magnesium, and 115.00 to 275.00 mg/kg for sodium. Soil fertility is commonly described by the availability of key nutrients such as N, P, K, Ca, and Mg.

Table 7 Chemical Properties of Soil Fertility Elements and Value Reference for Interpretation.

Parameter	ours **values**				**Reference values *(FAO, 2015)* And interpretation**			
Soil (n=5)	**Min**	**Max**	**Mean**	**SD**	**Poor**	**medium**	**Rich**	**great**
N	50.91	52.34	51.80	0.70	<50	50-100	100-200	>200
P	815.00	1077.50	924.50	120.24	**<15**	15-30	30-50	>50
K	49.575	144.54	98.35	4.29	**<90**	90-150	150-250	>250
Ca	518.75	1100	718.33	22.88	<800000	800000-2000000	2000000-4000000	>4000000
Mg	114.75	518.75	337.47	179.93	<100000	100000-300000	300000-700000	>700000
Na	115.00	275.00	188.00	75.79	<50000	50000-100000	100000 -200000	>200000

Les valeurs sont exprimées en mg/kg.

➢ *FTIR Spectrum of Soil*

Fourier transform infrared (FTIR) analysis of the Davié site soils produced the spectrum shown in Figure 3. FTIR spectra of soils are commonly used to describe the overall chemical profile of both organic and mineral components.

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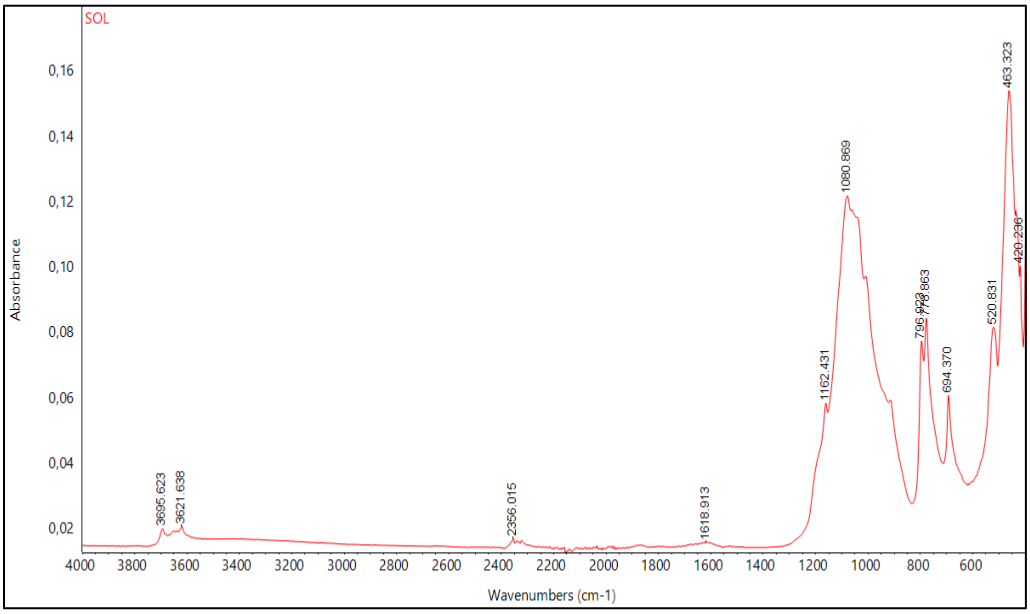

Fig 3 FTIR Spectrum of the Soil.

➤ *Trace Metal Elements in Soils*

The determination of trace metal elements revealed cadmium ranging from 0.076 mg/kg to 0.186 mg/kg with an average of 0.148 mg/kg and lead from 13.03 mg/kg to 17.02 mg/kg with an average value of 14.626 mg/kg. However, arsenic and chromium were not revealed(Table 8).

Table 8 Trace Metal Element Contents in Soils et the Thresholds Accepted by the FAO and the Canadian Standard (IRSA)

Element	our values (mg/kg)				FAO accepted thresholds(mg/kg)	Threshold accepted by IRSA Canada (mg/kg)
	Min	**max**	**mean**	**SD**		
Cd	0.075	0.186	0.1480	0.043	<1	< 1.5
Pb	13.03	17.02	14.626	1.500	<70	<70
As	Nd	Nd	Nd		<20	<12
Cr	Nd	Nd	Nd		<100	<64

All values are expressed in mg/kg, nd: not detected.

IV. DISCUSSION

➤ *Soil pH in Water and Electrical Conductivity (EC)*

The results showed soil pH in water values ranging from 5.32 to 5.62, with a mean of 5.49, and a mean electrical conductivity (EC) of 0.050 dS/m, ranging from 0.049 to 0.054 dS/m. According to the classification proposed by Bocoum (2004) and adopted by Thiaw et al. (2024), the soils studied are slightly to moderately acidic. These results are consistent with those reported by the Ministry of Agriculture, which indicates that a large proportion (84%) of Togolese agricultural soils are acidic, with pH values ranging from 5.5 to 6.5, while 99% show low salinity levels (EC < 0.5 dS/m). Comparable values were reported by Abile et al. (2025) in the Liben Jawi district, Ethiopia, where soil pH was 6.06 and EC was 0.08 dS/m, whereas more acidic values (4.4) were observed by Bassole et al. (2023) in Burkina Faso. These pH differences may result from a combination of natural and anthropogenic factors, including parent material, climate, agricultural practices, and the leaching of exchangeable bases under humid tropical conditions. Soil acidity may reduce the availability of certain nutrients such as phosphorus, calcium, and magnesium, limit biological activity and soil structural stability, and at the same time enhance the mobility and bioavailability of some heavy metals. In this context, organic amendments such as compost and alkaline biochar could be promising options to alleviate soil acidity and improve soil fertility. However, this effect should be verified through field trials using well-defined application rates.

➤ *Soil Organic Matter and Soil Organic Carbon*

Soil organic matter content ranged from 0.55 to 1.55%, with a mean of 0.99%, whereas soil organic carbon ranged from 0.32 to 0.90%, with a mean of 0.57% and a standard error of 0.06. These results indicate soils that are poor in organic matter and organic carbon. They are consistent with reports from the Ministry of Agriculture, which indicate that a large proportion (84%) of Togolese agricultural soils are poor in organic matter and very poor in organic carbon, with organic matter contents below 2%. Higher values (2.98%) were reported by Aziablé et al. (2016) for soils around the phosphate processing plant at Kpémé in Togo, as well as by Ass et al. (2003), who recorded 11.85% for agricultural soils in Fez, Morocco. These differences may be explained by several factors, including climate, erosion, parent material, and the intensification of agricultural practices. Low organic matter content can limit cation exchange capacity, reduce water and nutrient retention, and promote soil structural degradation because of the weak ability of organic matter functional groups to complex metal cations. The studied soils therefore show low levels of organic matter and organic carbon, suggesting limited chemical fertility and increased

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vulnerability to structural degradation. In this context, organic amendments such as compost or biochar could help improve soil structure, increase carbon sequestration in the soil, and reduce the mobility of trace metal elements.

➢ *Soil Particle Size Distribution*

Particle size analysis showed a marked predominance of the sandy fraction, with 68.49% coarse sand, 18.85% fine sand, 5.44% fine silt, and 4.92% coarse silt. Overall, the sandy fraction accounted for 87.34% of the soil, whereas only 12.66% consisted of clay and silt particles. According to the USDA classification system and the Duchaufour textural triangle, the studied soil is therefore classified as sandy. These results are consistent with those reported by the USDA and FAO for several agricultural soils in West African countries. The low clay and silt contents suggest limited water and nutrient retention capacity, as well as low cation exchange capacity. In contrast, the high sand content favors soil aeration but also increases the leaching of exchangeable bases and dissolved contaminants. This texture also reduces aggregate cohesion because of the lack of an organo-clay fraction. Compared with other studies, Kombienou (2020) reported 14% clay, 18% total silt, and 68% total sand in soils from the Boukombé basin in Benin, while the rice-growing zone of Saga in Niger showed a finer texture with 25.17% clay, 5.73% silt, 45.34% fine sand, and 23.76% coarse sand. The very low clay content observed in these soils may indicate either an advanced stage of weathering or a quartz-rich sedimentary origin. In the context of soil remediation, this sandy texture represents a major constraint because it limits electrostatic interactions required for metal retention and contaminant sorption. The low specific surface area of sandy particles reduces adsorption and metal complexation, which may favor the mobility of trace metal elements in soil solution and their downward transfer. Figure 4 shows the USDA textural triangle for the Davié soil.

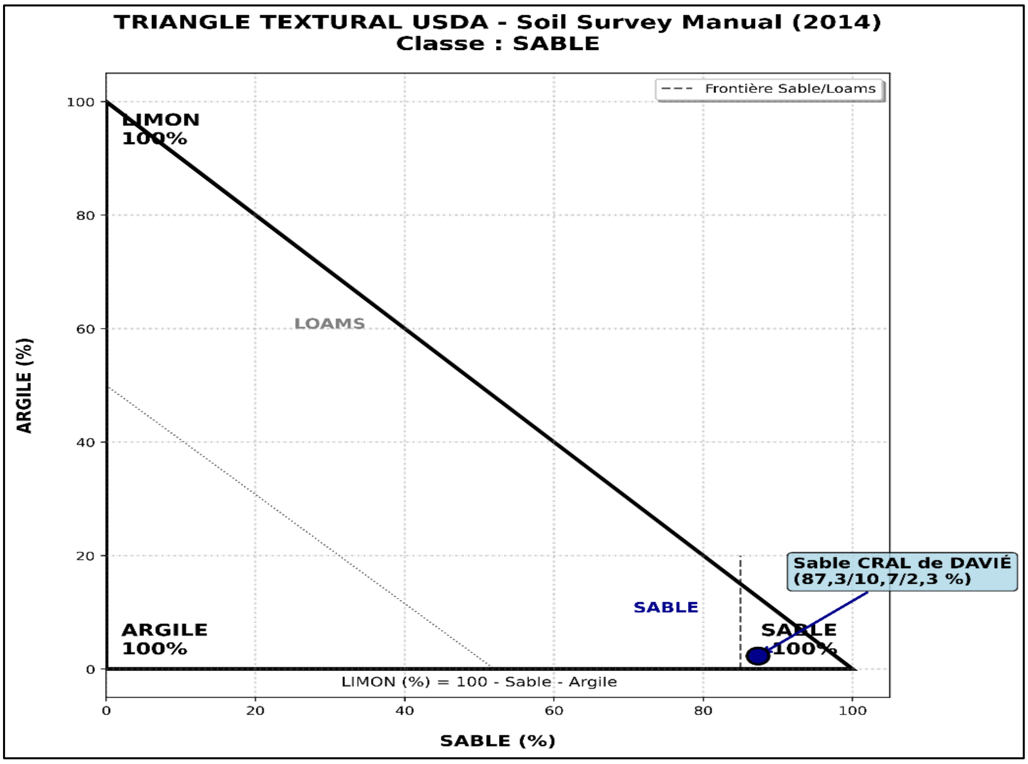

Fig 4 USDA Texturale Triangle du Sol du CRAL de Davié.

➢ *Fertilizer Elements in the Soil*

- *NPK Contents in Agricultural Soils of Davié*

The results reveal average contents of: 51.80 mg/kg for nitrogen; 924.50 mg/kg for phosphorus (P); 98.35 mg/kg for potassium (K); 718.33 mg/kg for calcium (Ca); 337.45 mg/kg for magnesium (Mg); and 188.00 mg/kg for sodium (Na). Analysis of these data indicates that these soils are better supplied with phosphorus and potassium than with nitrogen. According to the FAO classification of fertilizer elements, the studied soil can be considered very rich in phosphorus, moderately supplied with potassium and nitrogen (Table 9). This situation suggests that nitrogen amendments should be prioritized over phosphorus and potassium inputs. Nitrogen deficiency can limit vegetative growth, reduce yields, and constrain the efficiency of other nutrient utilization. The relatively high phosphorus content may stem from repeated applications or non-compliance with dosages of superphosphate fertilizers or phosphorus-rich organic amendments (Henao & Baanante, 2020). Excess phosphorus can induce nutritional imbalances and increase the risk of environmental transfers, particularly to surface waters. These findings align with those of other researchers, such as Buser et al. (2024), who observed variations among elements in agricultural soils. Comparatively, Bassole et al. (2023) reported 1200 mg/kg for nitrogen, 10 mg/kg for phosphorus, and 90 mg/kg for potassium in Burkinabé soils, while Diedhiou et al. (2024) reported 1000 mg/kg for nitrogen, 8 mg/kg for phosphorus, and 80 mg/kg for potassium in Senegalese soils. The nitrogen content in the studied soil is

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substantially lower than that reported in these countries. This variability may arise from multiple natural and anthropogenic factors, including the soil's geological and pedological nature, texture, climatic conditions, and agricultural practices. Abundant precipitation can promote the leaching of nutrients, particularly nitrogen and potassium (Abuni et al., 2025). Furthermore, repeated use and non-compliance with dosages of organic and chemical fertilizers can markedly alter nutrient stocks.

- *Exchangeable Bases in Soils*

The results of exchangeable base determinations show 718.328 mg/kg for calcium (Ca), 337.468 mg/kg for magnesium (Mg), and 188.000 mg/kg for sodium (Na). These findings indicate a dominance of calcium, followed by magnesium and sodium, revealing an uneven distribution of exchangeable bases in the soil. Exchangeable cations represent a reservoir of readily mobilizable nutrients for plant roots. The sum of exchangeable bases at the site reaches 7.426 cmol(+)/kg, suggesting acceptable chemical fertility but requiring ongoing monitoring. Comparatively, Thiaw et *al.* (2024) reported 177 mg/kg for calcium, 52.9 mg/kg for magnesium, and 6.2 mg/kg for sodium in soils from the Niayes site in Senegal. These contents are lower than those found in the present study. The differences may be attributed to soil texture, mineralogy, pedoclimatic conditions, and agricultural practices (Reza *et al*., 2017; Thiaw *et al*., 2024).

➢ *FTIR Analysis of the Soil*

FTIR analysis reveals a matrix primarily dominated by minerals, characterized by low-intensity absorption bands. The bands observed around 3695.623 cm^{-1} and 3621.638 cm^{-1} correspond to stretching vibrations of structural hydroxyl (-OH) groups in clay minerals, particularly kaolinite, which is consistent with highly weathered tropical soils. The broad band centered around 3400 cm^{-1} is attributable to stretching vibrations of -OH bonds from adsorbed water and hydroxyls associated with organic matter. The band at 2356.015 cm^{-1} is classically attributed to adsorbed atmospheric carbon dioxide in the soil matrix or an instrumental artifact commonly encountered in FTIR analyses of natural materials. The band around 1619 cm^{-1} may be associated with stretching vibrations of aromatic C=C bonds in humified organic matter, but more broadly, it corresponds to H–O–H deformation vibrations of water bound to clay minerals. In the low-frequency region, the bands around 1089 cm^{-1} and 994 cm^{-1} are attributable to Si–O stretching vibrations originating from quartz, feldspars, and silicate clays. The bands at 798 cm^{-1}, 695 cm^{-1}, 520 cm^{-1}, and 463 cm^{-1} confirm Si–O and Al–O deformation vibrations, reinforcing the hypothesis of a material rich in quartz, feldspars, and phyllosilicates. This spectrum indicates that these soils are siliceous, rich in kaolinite and quartz, with low organic matter content. The absence of C–H peaks at 2900 cm^{-1} supports the low organic matter content, in agreement with the organic matter determination results.

➢ *Heavy Metals in Soils*

The analyses reveal detectable concentrations of cadmium at 14.626 mg/kg and lead at 0.148 mg/kg, while arsenic (As) and chromium (Cr) were not detected. These results confirm a heterogeneous distribution of heavy metals (HMs) within the soil profile. The predominance of Cd over Pb may reflect both geogenic contributions and anthropogenic inputs, including fertilizers, pesticides, and atmospheric deposition. Comparatively, Zaakour et al. (2023) reported 40.00 mg/kg Pb, 0.60 mg/kg Cd, 3.00 mg/kg As, 60.00 mg/kg Cr, and 25.00 mg/kg Ni in agricultural soils of the Doukkala region in Morocco. Bortey-Sam et al. (2015) reported 7.2 mg/kg Pb, 0.05 mg/kg Cd, 21 mg/kg Cr, 4.4 mg/kg As, and 3.7 mg/kg Ni in agricultural soils of Tarkwa, Ghana. These differences may be explained by the geochemical origins of the soils and agricultural practices. The concentrations obtained in this study are substantially below the thresholds recommended by current standards, particularly those of the FAO for agricultural soils.

V. CONCLUSION

This study aimed to characterize the soils of the CRAL site in Davié in order to assess their physicochemical properties, mineralogical composition, and level of contamination by trace metallic elements. The results indicate a sandy soil with an acidic pH (5.49), low organic matter content (1.72%), and low total organic carbon content (0.99%), reflecting a limited capacity to retain nutrients and contaminants. FTIR analysis revealed a mineralogical assemblage dominated by quartz and kaolinite, which is characteristic of highly weathered soils, with a limited but real mineral retention capacity. The levels of fertilizing elements indicate a moderate status in nitrogen, phosphorus, potassium, and exchangeable bases, whereas lead and cadmium concentrations remain low relative to reference thresholds, and arsenic and chromium were not detected. Overall, these results suggest anthropogenic contamination.

The rational application of organic amendments, particularly biochar, therefore appears to be a relevant option for correcting soil acidity, improving chemical fertility, and enhancing the retention of trace metallic elements. Further studies on metal speciation and the effects of biochar on soil properties are needed to better guide sustainable management strategies for these soils.

➢ *Conflict of Interest*

The authors declare that they have no conflict of interest.

➢ *Authors' Contributions*

MN performed the study and drafted the manuscript. DDB supervised the work, reviewed, and corrected the manuscript. MBB co-supervised the study and contributed to the manuscript writing. KCMA assisted with laboratory procedures. KK assisted with sampling and laboratory handling. GT advised on and supervised the study. All authors read and approved the final manuscript.

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