Research Article

Soil Physicochemistry and its implication on Fertility Status: Case studies of soils from Nanga-Eboko and Bertoua, Cameroon

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Abstract

Nine soil samples collected at Nanga Eboko and Bertoua (Cameroon) were subjected to physicochemical and fertility status studies. The analyses required for this aim were carried out at the International Institute of Tropical Agriculture (IITA). Grain size analysis was assessed using Robinson's pipette method, and Structural Stability Index (SSI) was calculated using Pieri's formula. The chemical parameters studied were determined by specific evaluation methods dedicated to each parameter. The results show that sand is the most important granular family. Soil structural stability is average at Bertoua, with a low risk of degradation (7 Â SSI d" 9), while soils at Nanga Eboko are subject to degradation (SSIÂ 5). Nutrients such as organic matter (OM), total nitrogen (TN) and organic carbon (C) have reached standard levels in Bertoua, whereas values for these parameters are low in Nanga Eboko. All samples have an acid pH (pHH"6) with acceptable levels of exchangeable bases (Ca2+, Mg2+, Na+) except for K+, which is low at both sites (Â0.04 cmol/kg). Cation exchange capacity (CEC) values are also within the standard range (10-25 cmol/kg) at both sites. Assessment of fertility status revealed that soils of Nanga Eboko have a very low fertility level, while Bertoua soils may have a low or medium fertility level.

Keywords: fertility, pH, structural stability, exchangeable bases, cation balance.

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Résumé

Neuf échantillons de sol prélevés à Nanga Eboko et Bertoua (Cameroun) ont fait l'objet d'études physico-chimiques et de l'état de leur fertilité. Les analyses nécessaires ont été effectuées à l'Institut International d'Agriculture Tropicale (IITA). L'analyse granulométrique a été évaluée par la méthode de la pipette de Robinson, et l'indice de stabilité structurelle (ISS) a été calculé à l'aide de la formule de Pieri. Les paramètres chimiques étudiés ont été déterminés par des méthodes d'évaluation spécifiques à chaque paramètre. Les résultats montrent que le sable est la famille granulaire la plus importante. La stabilité structurale des sols est moyenne à Bertoua, avec un faible risque de dégradation (7 Â SSI d" 9), tandis que les sols de Nanga Eboko sont sujets à la dégradation (SSIÂ 5). Les éléments nutritifs tels que la matière organique (MO), l'azote total (AT) et le carbone organique (C) ont atteint des niveaux standards à Bertoua, alors que les valeurs de ces paramètres sont faibles à Nanga Eboko. Tous les échantillons ont un pH acide (pHH"6) avec des niveaux acceptables de bases échangeables (Ca^{2+}, Mg^{2+}, Na^{+}) sauf pour K+, qui a une teneur faible dans les deux sites (Â0,04 cmol/kg). Les valeurs de la capacité d'échange cationique (CEC) se situent également dans la fourchette admise (10-25 cmol/kg) sur les deux sites. L'évaluation de l'état de fertilité a révélé que les sols de Nanga Eboko ont un niveau de fertilité très faible, tandis que les sols de Bertoua ont un niveau de fertilité faible ou moyen.

Mots clés : fertilité, pH, stabilité structurale, bases échangeables, équilibre cationique

1.0 INTRODUCTION

Planet Earth is currently facing a food shortage due to a strong demographic explosion. It is essential to feed humanity, because in some places, people are suffering from famine. This reality compels us to turn to agriculture, which appears to be a promising sector for meeting humanity's food needs. With this in mind, there is a need to encourage an explosion in agricultural practices. Knowledge of soil properties is a prerequisite to support this approach. For this reason, researchers around the world have taken an interest in agronomy. (Mulumba and Lal, 2008; Dumanski and Pieri, 1992)

In Cameroon, research regarding soil fertility and cropland management has also intensified. A number of studies have focused on the description of soil profiles, providing a better understanding of soil structure. (Kamgang Kabeyene, 1998; Nyeck et al., 1999; Samba et al., 2020). Other research has focused on soil properties in relation to fertility and cultivation practices. (Azinwi et al. , 2018 ; Azinwi et al., 2020 ; Lotse Tedontssah et al., 2022 ; Temgoua et al., 2014; Tsozué et al., 2016 ; Nguemezi et al., 2019 ; Yemefack et al., 2016 ; Tematio, 2005 ; Tematio et al., 2011). This research has considered multiple amendments when soil fertility is poor (Nkouathio et al., 2004). The aim is to achieve good agricultural yields. Very often, however, this aim comes up against a number of limitations linked either to the intrinsic properties of the soil, or to the plant material used, or to the uncontrolled use of fertilizers, which can have unfortunate consequences for consumer health and the environment. For this purpose, it is advisable, in any agricultural project, to consider at the same time the assessment of soil fertility, cultivation skills and environmental preservation.

The present work is a contribution to the understanding of the physicochemical properties of unused soils from two sites in Cameroon, in order to assess their fertility status.

2.0 STUDY AREA AND METHODS

2.1 Study Area

The samples used for this study come from two regions of Cameroon, namely the East (Bertoua) and Centre (Nanga Eboko) regions. In the Central region at Nanga - Eboko, samples were taken from the Etog Nang site. The study area is located between latitudes 04°37' and 04°53' north and longitude 12°20' and 12°33' east, covering an area of around 720 km2. In Bertoua's eastern region, the samples were collected in localities of Bertoua 1, Doume and Diang from latitudes 4°18'0 " to 4°42'0"N and longitudes 13°18'0" to 13°42'0"E respectively, at an average altitude of 673m above sea level.

The study areas are both subject to a transitional equatorial climate with 4 seasons unevenly distributed throughout the year (Suchel, 1987). A short rainy season which runs from mid March to mid-June, a short dry season from July to August, a long rainy season from August to mid-November and a long dry season from mid-November to mid-March.

The geological formations in the study area all belong to the ancient basement which occupies three quarters (3/4) of Cameroon (Gazel and Gérard, 1954). This basement belongs to the Central African Pan-African chain (Nzenti et al., 2001; Toteu et al., 2004), more precisely in the Central Cameroon domain crossed by the Sanaga fault (Ganwa et al., 2016). It is presented by granites and metamorphic rocks, approximately 2.2 to 1.9 Ga in age (Li et al., 2017). The soil at Nanga Eboko develops on amphibolite while that at Bertoua develops on granite (Fig.1). Granite formations cover the entire study area. The granite facies represented is a calc-alkaline biotite granite (Ganwa et al., 2016). Its petrographic composition includes quartz, K-feldspar, plagioclase, biotite and, secondarily, apatite (Li et al., 2017). The granite in the region is derived from palaeopetroterozoic magmatic activity that resumed during the Pan-African orogeny (Nzenti et al., 2001). In addition, amphibolites can be seen in the southeastern and the northeastern ends of the study area. They are fairly common in the study area, but do not form large masses. Quartz veins are common in the Nanga-Eboko amphibolite outcrops and are sometimes thicker than the amphibolites (Martin, 1966). The amphibolites in the study area are greenish-grey to black. They have a foliation characterised by metric bands of amphiboles and millimetre to centimetre beds of quartz on a macroscopic scale. Microscopically, the amphibolite is holomelanocratic and has a grano to nematoblastic texture. It consists mainly of green hornblende, garnet, quartz and opaque minerals. The protolith is basalt (Owona et al., 2013).

Three classes of soils derived from the basement formations are found in the study area, namely: undeveloped soils, ferrallitic soils and hydromorphic soils (Martin, 1966). The soil samples used in this study were taken from ferrallitic soils which are dominant at the sampling sites. These soils generally have three levels: alterite at the base of the profile, intermediate nodular horizons and superficial clay horizons (Martin, 1966). Soils derived from the alteration of amphibolites are thinner, dark red (10R 3/3) to red (10R 3/6) and clayey to clayey-gravelly. Unweathered quartz fragments are abundant in the weathering material. Soils developed on granite are fairly thick, grey brown (10YR 3/2) to ochre (5YR 4/6 to 5YR 5/8) and sandy clay.

2.2 Methods

Soil samples were collected in nine wells at a depth of 50 cm using hand tools in the Etoug nang savannah at Nanga Eboko(four samples) and in the Ndoumbi rainforest at Bertoua(five samples) (Fig.1). The samples were then packed into labelled plastic sampling bags. Once packaged, the samples were transported to International Institute of Tropical Agriculture of Yaoundé laboratory for analysis of physico-chemical parameters enabling soil fertility to be studied.

Physicochemical analysis consisted in determining the particle size, using the international method of Robinson pipette. The textural diagram (FAO-ISRIC, 2020) constructed from the particle size data allows to define the different textural classes of the samples. The structural stability index (SSI), which is a physical parameter that determines the degree of erodibility of a soil, was evaluated using the Pieri equation (1), as follows (Pieri, 1992):

$$SSI = \frac{1.724 \times OC}{(Cl + S)} \times 100 \quad (1)$$

Where, OC is the soil Organic Carbon content; S is the silt fraction and Cl is the clay fraction. The interpretation of this parameter shows that for: a SSI >9% indicates stable structural soil; 7% < SSI > 9% indicates low risk of structural degradation; 5% < SSI >7% indicates high risk of degradation, and SSI < 5% indicates structurally degraded soil.

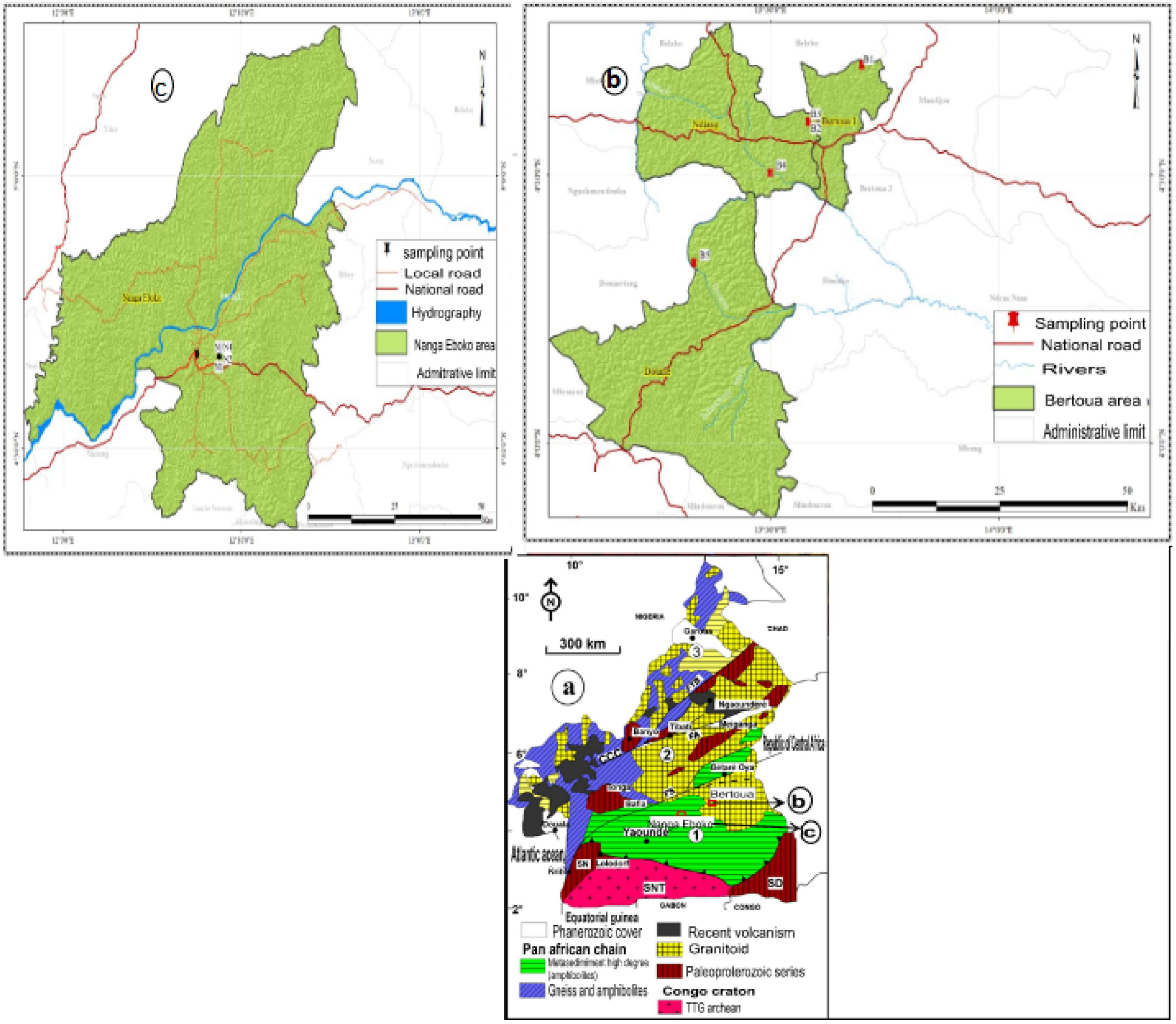

Figure 1: Geology of study area, Asaah et al., 2015 (a): sampling maps; Bertoua site (b); Nanga Eboko site (c)

The chemical elements determined were: organic carbon, using the Walkley and Black (1934) method; total nitrogen, using the Kjeldahl method; pH-water, using a pH meter with (1/ 2.5) as the soil-water ratio; total phosphorus, using the Bray1 method; Cation exchange capacity (CEC), by extraction with 10% KCl followed by distillation using the Kjeldahl method and exchangeable cations (Ca, Mg and K), by Atomic Absorption Spectrophotometry (AAS). Some cationic balances were established (Dabin, 1961; Martin, 1979; Nyeck et al., 1989). These balances make it possible to study fertility scales and highlight the impact of the content of one cation on the absorption of the other(s) using binary diagrams (K/Mg; Ca/Mg), the influence of pH on nitrogen nutrition (N/pH) or triangular diagram (Ca/Mg/Ca).

The chemical fertility classes and corresponding criteria for soil fertility were used to identify soil fertility levels (Tab.1). There are four levels of classification. Class I indicates high fertility level: soils are in this class when the characteristics have no or only slight limitations. Class II corresponds to medium fertility level: soils are in this class when the characteristics have no more than 3 moderate limitations, possibly combined with slight limitations. Class III is regarding low fertility level: soils in this class have more than 3 moderate limitations associated with a single severe limitation and Class IV defines very low fertility level: soils in this class have more than one severe limitation.

Table 1: Criteria for soil fertility (Amonmidé et al., 2019)

Parameters			Level of fertility		
	Very high level/ degree 0	**High level/ degree 1**	**Medium level/degree 2**	**low level/ degree 3**	**very low level/degree 4**
	without limitation	low limitation	medium limitation	severe limitation	very severe limitation
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	05-2	<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	5,3-5,3 8,3-8,5	>5,2 >8,5

OM : organic matter ; Pass : assimilable phosphorus ; V : saturation rate ; T : sum of bases ; N : nitrogen ; K^+ : potassium ion ; CEC : cation exchange capacity

3.0 Results

3.1. Physicochemical properties

The results of grain size analysis (sand, clay and silt) are recorded in Table 2, Sand proportion remains most abundant with respective averages of 56.484% and 55.15% in Bertoua (B1, B2, B3, and B4) and Nnanga Eboko (N1, N2, N3, and N4) soils. Clay contents are average for both soil groups at Bertoua (35.532%) and Nanga Ebogo (35.375%). Silt percentages are low at both Bertoua (7,984%) and Nanga Eboko (9,475%). Plotting the soil samples in the textural digram (Fig.2) enabled to identify the texture of each soil sample. The textural diagram shows that Bertoua soils have either a sandy clay texture (B1, B2 and B5) or a sandy clay loam texture (B3 and B4). Soils at Nanga Eboko have a clay texture (N1 and N2), a sandy clay loam texture (N3) and a loamy sand texture (N4). SSI values show a variation from 7.24 to 14.89% with an average of 9.606% in Bertoua corresponding to soils that aren't structurally degradable or present a low risk of degradation. While in Nanga Eboko, the result runs from 0.37 to 1.20% with an average of 0.785 indicating structurally degraded soils.

Table 2: Results of grain size analysis

Localities	Soil samples	Sand (%)	Clay (%)	Silt (%)	SSI (%)
	B1	56,54	35,89	7,57	8.25
	B2	52,4	41,96	5,64	7.24
Bertoua	B3	64,47	27,96	7,57	14.89
	B4	60,47	29,96	9,57	10.55
	B5	48,54	41,89	9,57	7.10
	Average	**56,484**	**35,532**	**7,984**	**9.606**
	N1	34,2	59,8	6	1.17
Nanga Eboko	N2	42,9	47,9	9,2	1.20
	N3	61,8	24,5	13,7	0.40
	N4	81,7	9,3	9	0.37
	Average	**55,15**	**35,375**	**9,475**	**0.785**

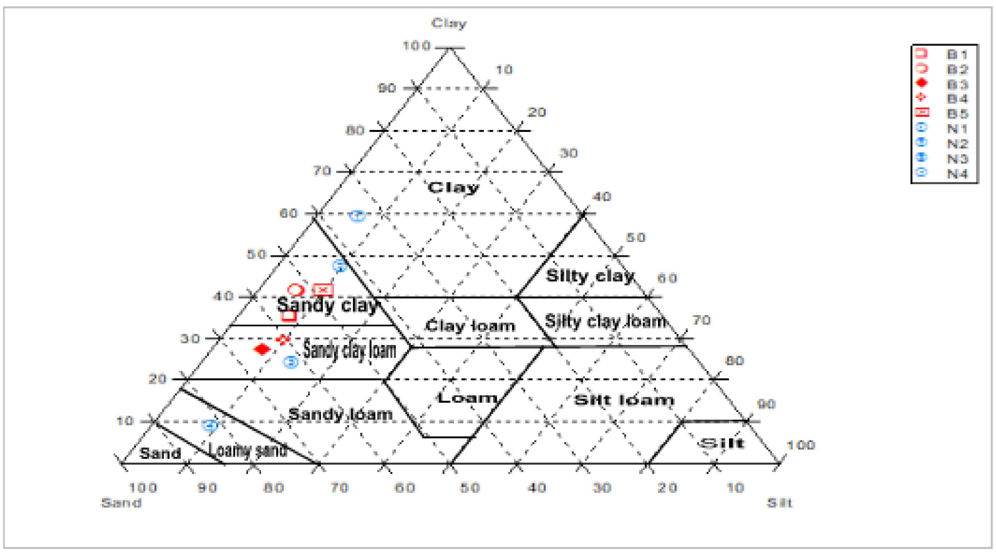

Figure 2: Textural diagram of samples

Chemical analysis allowed the assessment of some parameters (Organic matter, Organic Carbon, Nitrogen, C/N ratio, Total Phosphorus). Organic matter (OM) plays an important role in soil fertility as it is the source of mineral-producing litter after decomposition. Table 4 shows that the average organic matter content of the samples is 4.672% for Bertoua soils, this value drops to 0.4275 for Nanga Eboko soil samples. The results obtained for the Bertoua soil group are execllent as the standard value indicates a range oscillating between 2- 3% while the OM content is very low compared to the norm corroborating those obtained by Amonmidé et al., (2019). The evolution of organic carbon (C) is similar to that of organic matter, with an average of 50.254% above the reference range of 0.5-3% in Bertoua soil samples, compared with a very low value (0.2%) for Nanga Eboko soils. N levels show a similar evolution in comparison to OM and C. The average obtained in soils Bertoua is 0.208%, compared with 0.0% for Nanga Eboko soils.

Comparing these values with the reference interval of 0.1-0.15, it appears that the average N fertility of Bertoua soils is very good, whereas it is very poor for Nanga Eboko soils. The C/N ratio, which is used to assess the mineralization rate, also shows that this parameter is moving in the right direction for the Bertoua soils (10.98%), with reference to the standard (9-11%), whereas the C/N ratio is below this standard at Nanga Eboko (3.01%). Total phosphorus (TP) levels show no particular influence, since the averages obtained in the two soil groups are almost identical (372.72 mg/kg in Bertoua and 315.51 mg/kg in Nanga Eboko) and close to the average (450 mg/kg). The samples studied reflect a soil water pH ranging from 4.75 to 8.38 with an average of 6.44 for Bertoua soils and from 6.27 to 8.07 with an average of 7.275 for Nanga Eboko soils (Tab.3). Table 3 shows also the cation exchange capacity values of the samples that range from 6.83 to 18.70 cmol/kg with an average of 11.20 cmol/kg. According to the Table 3, Mg^{2+} contents range from 0.57 to 1.37 cmol/kg, with an average of 1.012 cmol/kg for Bertoua soils, whereas these contents range from 0.86 to 1.22 cmol/kg, with an average of 1.0625 cmol/kg. Ca^{2+} content range from 1.63 to 21.59 cmol/kg, with an average of 7.73 cmol/kg for Bertoua soils. While for Nanga Eboko soils, content fall but remain within the admissible range, varying from 0.76 to 8.71 cmol/kg with an average of 3.6075 cmol/kg. K^+ values range from 0.11 to 0.25 cmol/kg, with an average of 0.158 cmol/kg in Bertoua, and from 0.04 - 1.57 cmol/kg, with an average of 0.4525 cmol/kg in Nanga Eboko. Na+ content ranges from 0.01 to 0.02 cmol/kg, with an average of 0.014 cmol/kg in Bertoua, and from 0 to 0.058 cmol/kg, with an average of 0.037 cmol/kg in Nanga Eboko.

Table 3: Chemical characteristics

Localitiy	Samples	OM(%)	TN(%)	C(%)	C/N	TP (mg/kg)	pHw	PHKCL	Ca^{2+} (cmol/kg)	Mg^{2+} (cmol/kg)	K^+ (cmol/kg)	Na^+ (cmol/kg)	CEC (cmol/kg)	S/T
	B1	4,16	0,19	2,08	11,07	254,7	6,11	5,48	4,32	1,37	0,12	0,02	8,87	67
	B2	4	0,16	2	12,4	297,38	4,75	4,03	1,63	0,57	0,17	0,02	6,83	35
Bertoua	B3	6,12	0,25	3,07	10,82	472,89	8,38	7,93	21,59	1,1	0,25	0,01	18,7	76
	B4	4,84	0,22	2,42	11	345,83	6,6	6	6,4	1,01	0,11	0,01	10,45	72
	B5	4,24	0,22	2,12	9,8	492,8	6,36	5,5	4,71	1,01	0,14	0,01	11,34	55
	Average	**4,672**	**0,208**	**2,338**	**11,018**	**372,72**	**6,44**	**5,788**	**7,73**	**1,012**	**0,158**	**0,014**	**11,238**	**61**
	N1	0,78	0,05	0,45	8,99	258,92	7,39	6,15	2,96	1,22	0,11	0,058	31,8	14
	N2	0,7	0,06	0,4	0,06	333,42	7,37	5,57	2	0,86	0,09	0,05	16,7	18
Nanga Ebogo	N3	0,16	0,05	0,09	1,71	331,96	8,07	5,77	0,76	0,96	0,04	0	6,9	26
	N4	0,07	0,04	0,04	1,28	337,74	6,27	5,05	8,71	1,21	1,57	0,04	3,74	308
	Average	**0,4275**	**0,05**	**0,245**	**3,01**	**315,51**	**7,275**	**5,635**	**3,6075**	**1,0625**	**0,4525**	**0,037**	**14,785**	**91,5**
	Standard values	**2-3**	**0.1-0.15**	**0.5-3**	**9-11**	**450**	**6,5-7,5**	**5.5-6**	**2,3-3,5**	**1-1,5**	**0,2-0,4**	**0,3-0,7**	**10-25**	**40-60**

Figure 3 shows that, in most soil samples from Nanga-Eboko and Bertoua, the Ca-Mg equilibrium is respected, except for N3 (deficient in Mg) and B4 or N4 (excess in Ca). The Mg/K ratio values found are not ideal for all samples taken with the exception of N4 (Fig.3). The optimum Ca/Mg/K K ternary diagram revealed that, samples examined cluster around the ideal point, with the exception of samples B3 and N3 (Fig.3).The results obtained are very similar to those reported by Samba et al. (2020), who examined the fertility of alluvium in the Nyong valley, and those of Nguemezi et al., (2020), who studied the fertility of soils in the Tombel region from Cameroon.

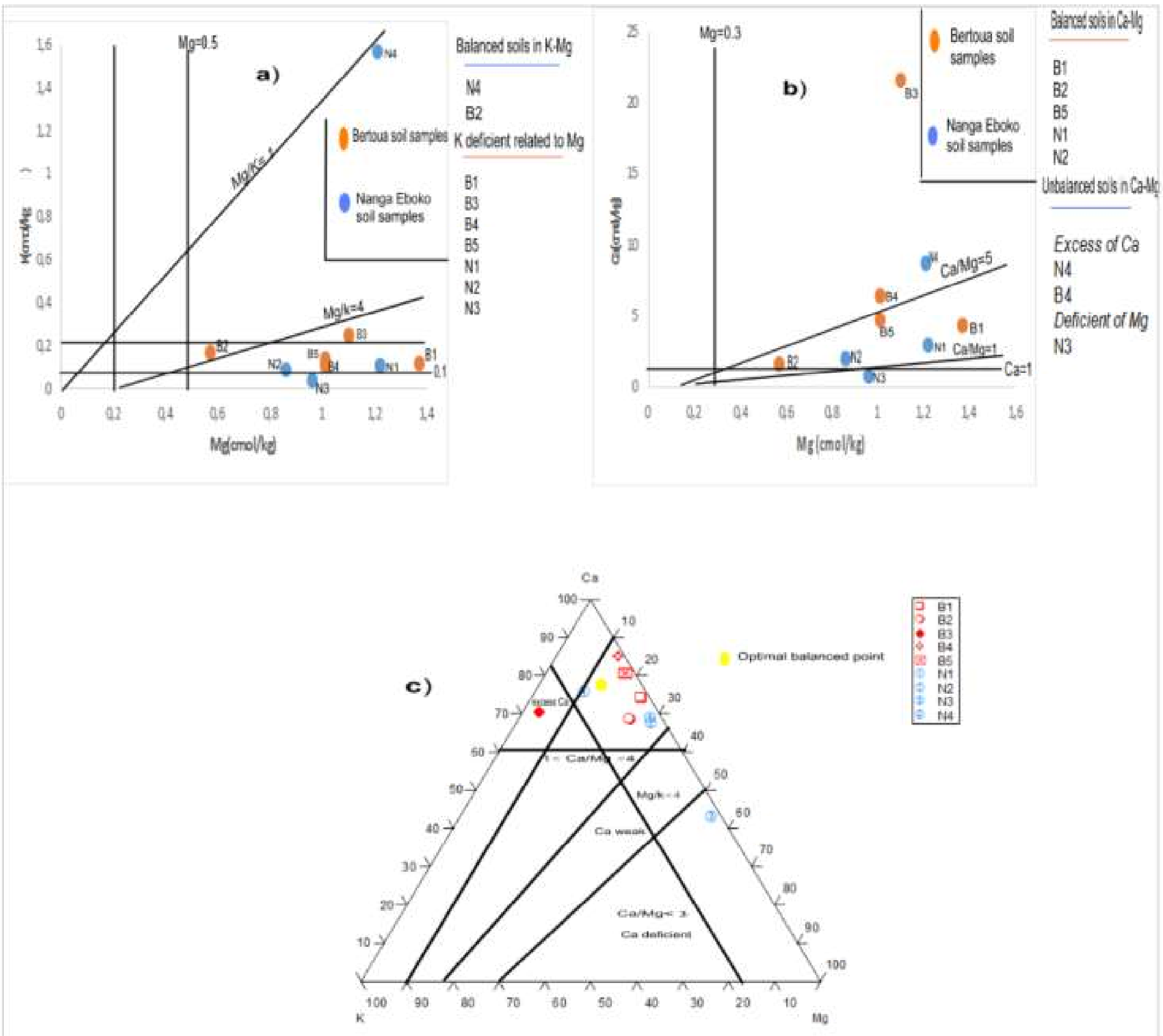

Figure 3: Graphs of some cationic balances: a) K-Mg equilibrium; b) Ca-Mg equilibrium; c) Ca-Mg-K equilibrium

3.2 Fertility status

The evaluation of the physico-chemical parameters of soil samples enables the deduction of their fertility status. Soil fertility status is related to degree of fertility, level of fertility, fertility classes and limitations. The results obtained (Tab. 4) show that samples B3, B4 and B5 present a single limitation corresponding to classes II and III indicating a medium to low degree of fertility. Other soil samples present more than one limitation, including at least one severe limitation corresponding to class IV that reflects a very low degree of fertility.

Table 4: Criteria of soils fertility status

	OM(%)	N(%)	K+	S (Cmol/kg)	V(%)	PH	CEC (Cmol/kg)	Limitations	Degree	Fertility Level	Class
B1	4,16	0,19	0,12	5,83	67	6,11	8,87	K+, CEC	Low	3	III
B2	4	0,16	0,17	14,7	35	4,75	6,83	K+, CEC, S	Very low	4	IV
B3	6,2	0,25	0,25	22,95	76	7,15	18,7	K+ moderate	Average	2	II
B4	4,84	0,22	0,11	7,53	72	6,6	10,45	K+	Low	3	III
B5	4,25	0,22	0,14	5,87	55	6,3	11,34	K+	Low	3	III
N1	0,78	0,05	0,11	4,308	14	7,39	31,8	OM, K+, S	very low	4	IV
N2	0,7	0,06	0,09	3	18	7,37	16,17	OM, K+, S	Very low	4	IV
N3	0,16	0,05	0,04	1,76	26	5,77	6,9	OM, K+, CEC	Very low	4	IV
N4	0,07	0,04	1,57	11,53	308	6,27	3,74	OM, K+, CEC	Very low	4	IV

4.0. DISCUSSION

4.1. Physicochemical properties

The results of grain size analysis are in agreement with those reported in the work of Lotse Tedontsaah et al., (2022); Tsozue et al., (2016); Tsozue et *al.,* (2019). The distribution of the three granular families (sand, clay, silt) is consistent with the plutonic and massive natures of the parent rock and the weathering processes. These elements come from plutonic rocks (granite and amphibolite) made of by quartz, micas and plagioclase. Quartz alters to form sand, while clay and silt come from the alteration of micas and plagioclases (Ndjigui, 2008). In relation to soil fertility, the results obtained are at odds with the textural balance established by Antoine (2006); Baize and Jabiol (2011), namely 15-25% clay; 30-35% silt and 40-50% sand. However, the samples analyzed show high proportions of sand with very low percentages of silt, with quantities of clays varying greatly from one sample to another. The soil texture may play an important role known as soil signature. This is due to the fact that it is difficult to be altered in the short run by types of land use or soil management (Nguemesi et al., 2020; Lotse Tedontsaah et al., 2022). The results of SSI parameter are at odds with the work of Nguemesi et al., (2020), regarding volcanic soils in southwestern Cameroon. The level of OM has a direct influence on the bioavailability of elements such as organic carbon (C), nitrogen (N) and total phosphorus (TP), depending on the quantity of OM and its mineralization process (Samba et al. , 2020). The level of OM also has a direct influence on CEC through humus- clay-complex (Tsozué et al., 2019; Yemefack et al., 2004). The results of organic Carbon and C/N ratio establish the similarity with those reported by Forster (1972); Samba et al., (2020) and Amonmidé et al., (2019). pH parameter has a direct influence on soil fertility. When pH is low, it induces toxicity, and when it is high, the availability of certain nutrients such as iron and manganese decreases. When it is close to neutral, all soil elements can be assimilated (Dabin, 1961; Kamgang Kabeyene, 1998; Meyim-Dayambo, 2000; Samba et al., 2020). The pH values obtained are in line with work carried out on ferralitic soils and associated terrains with a pH below 7 (Tsozoué et al. , 2011; Azimwi Tamfuh et al. , 2018; Nguemesi et al. , 2020; Lotse Tedontsah et al. , 2022). On the other hand, in volcanic soils, the pH rises to the basic range, enabling good soil fertility to be achieved (Tematio et al., 2004). What's more, an examination of soil fertility, highlighting pH and nitrogen, reveals that only samples B3, B4 and B5 show good fertility (Fig. 4). Regarding the reference interval, 10 < CEC <25 (Amonmidé et al., 2019), the results reflect a good soil cation balance. The low values of the S/T saturation rate provide a better understanding of CEC behavior. The saturation rate values are significant (S/T> 10%) compared with the reference interval (60% <S/T <80%) (Nkouathio et al., 2007; Samba et al., 2020). The results obtained are in accordance with most fertility studies carried out in acid soil (Tsozoué et al., 2011; Azimwi Tamfuh et al., 2018; Nguemesi et al., 2020; Lotse Tedontsah et al., 2022). Exchangeable bases (Mg2+, Ca2+, K+ and Na+) are a source of nourishment for plants and perform a variety of specific functions during their development. Cationic reference values vary from one cation to another: Mg^{2+} from 1 to 1.5 cmol/kg; K^{+} from 0.2 to 0.4 cmol/kg Ca^{2+} from 2.3 to 3.5 cmol/kg and Na^{+} from 0.3 to 0.7 cmol/kg (Nkouathio et al., 2007; Amonmidé et al., 2019). When soil is acidic, these elements are not bioavailable, as they are strongly retained by the clay-humus complex. The results obtained are similar to those of authors who have examined the fertility of soils with several limitations (Tsozué et al., 2011; Azimwi Tamfuh et al., 2018; Amonmidé et al., 2019; Samba et al., 2020).

The assessment of some cationic balance allowed to study Ca / Mg equilibrium that is used to examine the possibility of optimum plant uptake of the Ca2+ ion in the presence of Mg^{2+} and vice versa (Boyer, 1982). The imbalance appears in case of excessive or deficient levels of either of the cations within the reference interval (1 Â Ca / Mg Â 5). These results of Ca / Mg balance are in disagreement with the work of Nguemezi et al., (2020), who reported a Ca/Mg ionic imbalance in most Tombel soils. The Ca / Mg equilibrium and the optimum Ca/Mg/K K ternary diagram are in line with the results obtained by Samba et al., (2020), who examined the fertility of alluvial deposits in the Nyong valley, and those of Nguemezi et al. (2020), who studied the fertility of soils in the Tombel region.

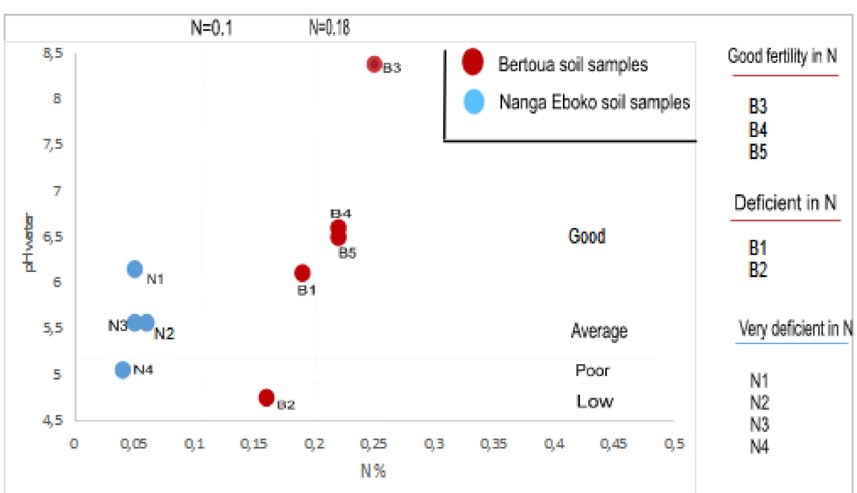

Figure 4: Graph of N-pH equilibrium

4.2. Fertility status

The results allow to understand that, the fertility status of soil results from a combination of interdependent physical and chemical fertility factors (Dabin, 1961; 1961) including the geological nature of soil. These results are similar to those obtained by Amonmidé et al., (2019) following the evaluation of soils under cotton cultivation in Benin. Since the nine samples studied come from ferralitic soil, the results obtained are in line witth conclusion drawn by some authors indicating that ferralitic soil present a low level of fertility and more than one limitation (Tsozué et al., 2011; Azimwi Tamfuh et al., 2018). In contrast, fertility status of some areas as volcanic terrains or valleys reflect good level of fertility without more than one limitation (Lotse Tedontsah et al., 2022).

5.0 CONCLUSIONS

This study aimed to characterize some physical and chemical properties of soil samples taken in Bertoua and Nanga Eboko, in order to highlight their fertility status. At the end of this research, the main conclusion reached indicates very low degree of fertility (class IV) in Nanga Eboko. However, in Bertoua, fertility levels are sometimes medium to low (classes II to III). To obtain good agricultural yields on these soils, physical and chemical amendments and a preliminary study of cultural aptitudes should be considered.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

Amonmidé, I., Dagbenonbakin, G., AGbangla, C.E., Aponikpè, P., Contribution à l'évaluation du niveau de fertilité des sols dans le système de culture à base de coton au Benin. Int. J.Biol.Chem.sci., 2019, vol. 13 n°3: pp: 1846-1860.

Antoine, D. (2006) : Guide simplifié pour la description des sols, chambre d'agriculture, TARN. , 37p.

Asaah AV, Zoheir B, Lehmann B, Frei D, Burgess R, Suh CE.(2015) : Geochemistry and geochronology of the ~ 620 Ma gold-associated Batouri Granitoids. Cameroon. Int Geol Rev, 2015, vol. 57, pp: 1485-1509

Azinwi Tamfuh, P., Chotangui, A.H., Katte, V.Y., Achantay, and R, D. (2020): Land characteristics and agricultural suitability. Status along a toposequence in Santa, Bamenda, Cameroon. J. Atmos.sci., vol. 4, 022. https://doi.org/10.24966/AES-8780/100022

Azinwi Tamfuh, P., Temgoua, E., Wotchoko, P., Boukong, A., Bitom, D. (2018): Soil property and land capacity evaluation in a mountainous ecosystem of north –west Cameroon. J. of geoscience and environment protection; vol.6. pp: 15-33 https://doi.org/10.4236/gep.2018.67002

Bijanzadeh, E.M. and Mokarrem, E.M. (2017): Assessment of the soil fertility classes for common bean (Phaseolus vulgaris L.) production using fuzzy–analytic hierarchy process (AHP) method. Australian journal of crop science (AJC), vol.11 (4), pp: 464-473.

Baize, D et Jabiol B. (2011) : Guide pour la description des sols, 2ié édition Quae, Paris, 430p

Boyer, J. (1982): Ferralitic soils: Fertility factors and soil use, Init. Doc. tech. ORSTOM, Paris; 1982, vol pp: 52,384

Dabin, B. (1961) : Les Facteurs de Fertilité des Sols des Régions Tropicales en Cultures irriguée. Association française d'Etude du Sol (AFES). Bull; 1961, s.L.

FAO-ISRIC. (2015): World Reference for Soil Resources First Update 2015, World Soil Ressources Reports; 2014, vol. 106.

Forestier, J. (1960) : Fertilité des sols des caféières en RCA. Agron. Trop. XIV, vol.pp: 306–348

Ganwa, A.A., Klot Zli, U.S., Hau Zenberger, C. (2016): Evidence for Archean inheritance in the pre-panafrican crust of Central Cameroon. Insight from zircon internal structure and LAMCIP-MSU/pb ages. Journal of African Earth Sciences ; vol. 120 pp : 12-22.

Gazel, J.et Gérard, G. (1954) : Notice explicative sur la feuille Batouri-Ouest, carte géologique au 1/500.000 ; 1954, 44 p.

Hartati, W. and Sudarmandji, T. (2016): Relationship between soil texture and soil organic mater contenton mined out land in Baru. East Kalimantan, Indonesia. Nusantara Bioscience, Vol.8 (1), pp: 83-88.

Kamgang, K .B. V. (1998) : Evolution supergène des roches et incidence phytogéographique : Cas du contact forêt-savane au Sud-Est Cameroun. Thèse d'état, SC. Nat, Univ. Yaoundé I, 208p.

Li, X.H., Chen, Y., Tchouanhoué, J.P, Liu, C.Z., Li, J., Ling, X.X., Tang, G.Q., et Liu, Y. (2017): Improving geochronological frome work of the pan-african oregeny in Cameroon: SIMS zirconand monazitebU-pb age constraints. Precambrian Research; 2017, vol. 294, pp: 307-321.

Lotse Tedontsah, V, P., Mbog, M, B., Ngon Ngon, G, F., Edzoa, R, C., Tassongwa, B., Bitom, D., Etame, J. (2022): Physicochemical properties and fertility assessment of soils in Foumban (West - Cameroon). Applied and environmentalsoil science, Vol. 2023, id 7889430, 14p. https://doi.org/10.1155/2022/7889430

Martin, D., Sieffermann, G. (1966) : Le département du Mungo (Ouest Cameroun) ; Etude des sols et leur utilisation. Cah. ORSTOM. Ser. Pedol, Vol.9 (1), pp : 27–49 s.l.

Martin, D. (1979) : Fertiliteé chimique des sols d'une ferme du Congo. Cah. ORSTOM. Ser. Pedol, vol.17 pp : 47–64

Meyim-Dayombo, S.L(2000) : Effet de diverses jacheres sur l'evolution de la fertilité d'un sol ferrallitique des environs de Yaoundé (Cameroun). Application à l'évaluation des terres pour les principales cultures pratiquées dans la région : Arachide, banane-plantain, mais, manioc. 2000 s.l. s.n.

Mulumba, L.N., Lal, R. (2008): Mulching effects on selected soil physical properties; SoilTillage Res, vol. 98 pp: 106–111.

Ndjigui, P.D.(2008) : Altération supergène des serpentinites et distribution des Eléments du Groupe du Platine dans les profils latéritiques du complexe ultrabasique de Lomié (Sud Est Cameroun). Thèse présentée en vue de l'obtention du Doctorat/Ph.D de Géologie. 2008, Université de Yaoundé 1, 255 p

Nguemezi, C., Tématio, P., Yemefack, M., Tsozué, D., Silatsa, T.B.F. (2020): Soil quality and soil fertility status in major soils groups at the Tombel area, South –West Cameroon. Heliyon; 2020, vol.6 e03432.

Nkouathio, D.G. (2004): Wandji, P., Bardintzeff, J.M., Kagou Dongmo, A; Pyroclastic rocks as natural fertilizers in Cameroon; vol. 14, S06d-pt-148

Nzenti, J.P., Mingem, D., Tchouankoué J.P., Eno Belinga, S.M. (2001) : Le panafricain.Histoire géologique du Cameroun, Les classiques Camerounais, pp:39-55.

Oklo, A, D., Amstrong, I, A., Idoko, O, M., Iniengev, T, S., Emmanuel, A, A. (2021): Assessment of soil fertility in terms of essential nutriments contents in the lwer Benin River basin, Nigeria. Access library journal, vol. 8, e7222. https://doi.org/10.4236/oalib

Owona .S. Mbola-Ndzana, S.P., Mpesse, J.E., Mvondo-Ondoa, J., Schulz, B., Pfänder, J., et Ekodeck, G...E. (2013): Petrogenesis of amphibolites from the Neoproterozoic Yaounde Group (Cameroon, Central Africa): Evidence of MORB and implications on their geodynamic evolution, Comunicações Geológicas Comunicações Geológicas; 2013, vol. 100, 1, pp: 5-13.

Pieri, C.J.M.G. (1992): Fertility of Soils: A Future for Farming in the West African Savannah s.l.: s.n properties of soils under different land uses and topographic positions at Gola Wacha subwatersheed, Eastern Ethiopia. Applied and environmental science, vol 2023 id 9988485, 13p. https://doi.org/10.1155/2023/9988495

Rashidi, M and Seilsepour. (2009): Modeling of soil soil total Nitrogen based on soil organic carbon. ARPN.J.Agric.Biol.Sci, vol.4. 1-5.

Ravikumar, P., Somashakar, R.K. (2013): Evaluation of nutriment index using organic carbon available P and available K concentrationas a measure of soil fertility in Verati River basin, India. Proceeding of the international academy of ecology and environmental science; 2013, vol.5, pp: 330-343.

Samba, A.P., Kouayep, L. S., Okomo, A. L. C., Kamgang, K. B. V. (2020): Evaluation of the Fertility of Alluvium From Nyong Valley (Cameroon): Prospection of Agricultural Areas; IJETAE vol.8,12p. DOI:10.46338/IJETAE0720_04

Suchel, J. B ; Les climats du Cameroun. Ph. D. Dissertation, Université Bordeaux III ; 1987, 350p

Tematio, P. (2005) : Etude cartographique et petrologique des sols a caracteres ferrallitiques et andosoliques dans les Monts Bambouto (Ouest Cameroun) : Influence de la lithologie et des facteurs du milieu sur la nature et la distribution des sols en région de montagne tropical Agric. Sci; 2005, vol. 1, pp: 34–40.

Tematio, P., Tsafack, E.I., Kengni, L. (2011): Effects of tillage. Fallow and burning on selected properties and fertility status of Andosols in the Mounts Bambouto. West Cameroon. Agric. Sci; 2011, vol.2, pp: 334–340.

Temgoua, E., Djoukouo, J., Likeng, J., Tematio, P. (2014): Structural stability of andosols and Ferralitic soils from mount bambouto. West Cameroon highlands. Cameroon J. Exp. Biol; 2014, vol 10, pp: 26–34.

Toteu, S.F., Penaye, J., Pondjom Djanami, Y. (2004): Geodynamic evolution of the pan-africanbelt in Central Africa with special reference to Cameroon. Cameroon Journal Earth Sciences; vol. 41, pp: 73-85.

Tsozue, D., Nghonda, J., Tematio, P., Djakba Basga, S. (2019): Changes in soil properties and soil organic carbon stocks along an elevation gradient at Mount Bambouto, Central Africa. Catena, vol.175, pp: 251–262

Tsozue, D., Tematio, P., Azinwi Tamfuh, P. (2016): Relationship between soil characteristics and fertility. Implications in two typical dystrandept soils of the Cameroon western highland. J. Soil Sci; 2016, vol. 11 (2) pp: 36–48.

Verma, V.K., Patel, L.B., Toor, G.S., Shama P, K. (2005): Spatial distribution of macronutriments in soils of arid tract of Punjab. Indian Journal of Agricultural and Biology, 7,295-297.

Willy, D.K., Muyanga, M., Mbuvi, J., Jayne, T. (2019): The effect of land use onsoil fertility parameters in densely populated areas of Kenya. Geoderma, vol.343, pp: 255-262

Yemefack, M., Jetten, V.G., Rossiter, D.G.(2006): Developing a minimum data set for characterizing soil dynamics in shifting cultivation systems. Soil Till. Res, vol. 86 pp: 84 98