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Morphological Characterization of a Sudanese Soil: Case Study of the Yilou in the Centre-North Region of Burkina Faso

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Soil data are essential to know the soils and improve agricultural yields, especially in a locality like Yilou in Burkina Faso. Soil samples were taken from five soil types, namely FLIPP, FLTC, FLIMP, BEHV/F and hydromorphic. The morphological and physicochemical parameters were studied according to the national reference of Burkina Faso. The results of the soil analyzes were compared with reference standard values. The morphological aspect indicates that FLIPP had a light yellowish brown (10YR 6/4) horizon at the beginning and becomes pale brown (10YR/6-3). FLIMP ranged from yellowish brown (10YR5/4) to yellowish yellow (10YR6/6) and BEHV/F had a pale reddish brown horizon (2.5YR6/3-2.5YR6/4). FLTC had a yellowish brown (10YR5/4) matrix color in the first 20 cm and turns light brown (7.5YR5/6) in the next three horizons. The hydromorphic soils were gray at the surface (2.5Y 5/1) and light brown gray (2.5Y 6/2) at depth. The textures of soils were sandy loams (FLIPP, FLTC, FLIMP and BEHV/F) and sandy clay loams (BEHV/F/F, hydromorphic). The soils were slightly acidic (Hydromorphic, FLIPP and FLTC), and slightly alkaline (FLIMP and BEHV/F) with an organic matter below the reference standard (3.6% <OM<6.5%). Hydromorphic soils had the level of very high fertility (OM>2). The total nitrogen content was lower (1.2-2.2%), except for hydromorphic soils (1.81%). The soils had a C/N ratio of 11, except for FLTC soils where

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C/N ratio was 10 below the baseline standard of 11-15. Hydromorphic and BEHV/F soils had the highest levels of assimilable phosphorus with respective values of 6.24 mg/Kg and 4.65 mg/Kg. The iron levels of the five soils varied from 968 to 1423 mg/Kg. Soils were low in exchangeable cations and the highest level was found in hydromorphic soils (8.37 meq (+)/100g) but remains below to reference standards (10 <CEC< 20). BEHV/F and hydromorphic soils were most fertile.

Keywords: Chemical; description; texture; toposequence.

1. INTRODUCTION

Agriculture in Burkina Faso faces many obstacles that are natural, structural and institutional. Among these obstacles, climatic hazards are at the top of the list. This is directly reflected in a drop in yields, mainly in the North and the Sahel. The process of land degradation the decline of forests in the Soudanian zone are increasing [1,2]. There are a significant losses of arable land affecting the yields of agroforestry crops. Reduced carbon or organic matter could affect the soil's water retention capacity and nutrient content, affecting soil fertility. Thus, phosphorus is one of the main limiting factors in agricultural production [3] in tropical regions. To improve soil productivity, the population is continuously seeking fertile soils for its agricultural or pastoral activities. Previous studies have investigated eight main soil types in Burkina Faso: soils with sesquioxides of iron and manganese constituted by the subclass of ferruginous soils or lixisols; poorly evolved soils due to erosion; browned soils; vertisols; ferralitic soils; hydromorphic soils; sodic or salsodic soils; raw mineral soils and halomorphic soils [4]. Unfortunately, these investigations do not cover all localities in Burkina Faso. In the village of Yilou located in the department of Guibaré in the Centre-north zone of Burkina Faso, farmers grown cereals in different agroecosystems but the yield is decreasing due to climate change effects and mainly soils degradation. In the arid zone it is important to characterize the types of soils that can affect agricultural yields. Assessing cationic exchange capacity can help characterize soil texture, and provide information on fertiliser input and for acid soil correction [5]. It is, therefore, necessary to carry out a study on the physicochemical characteristics of the surface and deep layers of the soils of the locality of Yilou following a toposequence gradient to better inform the physicochemical characteristics of the soils, fertility and guide the population in its agro-sylvopastoral activities.

The aims of this study is to characterize the physicochemical parameters according to the types of soils in Yilou. More specifically, it aims (i) to characterize the morphological parameters of soil types; (ii) assess the physical and chemical values of these soil types; (iii) to determine any correlations between the different types of soil studied.

2. MATERIALS AND METHODS

2.1 Location and Description of the Study Environment

The village of Yilou (Latitude North: 13°0'020; Longitude West: 1°32'777) belonging to the Guibaré commune (Fig. 1). It is bounded to the south by the village of Malou, to the south-west by the villages of Koulou and Tioussa, to the west by the villages of Goïra and Sindri, to the east by the villages of Goala and Tantallé, to the North-West by Guibaré and finally to the North by the villages of Gougré and Sawrzi.

2.2 Materials

The equipment used is the usual field study equipment used for the establishment of a toposequence and the opening of the soil pits, then the usual laboratory study equipment. Some elements of this material are shown in Fig. 2.

2.3 Methods

- ✓ Morphopedological characterization

A toposequence of North-South direction, of a mound on the banks of the Nakambé river was chosen. Five soil pits were implanted at the study site. The identification of these open soil pits was based on an unequal probability sampling device. The soil pits are oriented East-West in order to facilitate the observation of the horizons (illumination of the profile by the sun). Each profile (Fig. 2) was identified by its topographic position (Summit, shlouder, middle, foot slope and toe slope) according to the model described by [6]. At the location of the pits, geographical coordinates were recorded. These soil pits have been described, horizon by horizon. The scientific classification used is the one adopted by [7].

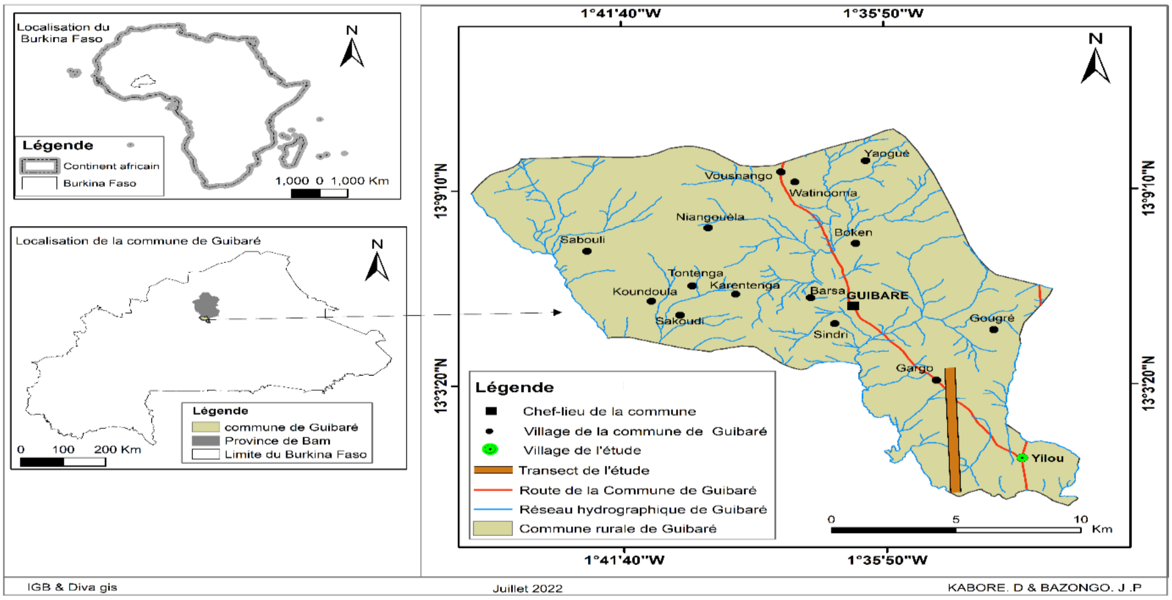

Fig. 1. Locality of soils collection

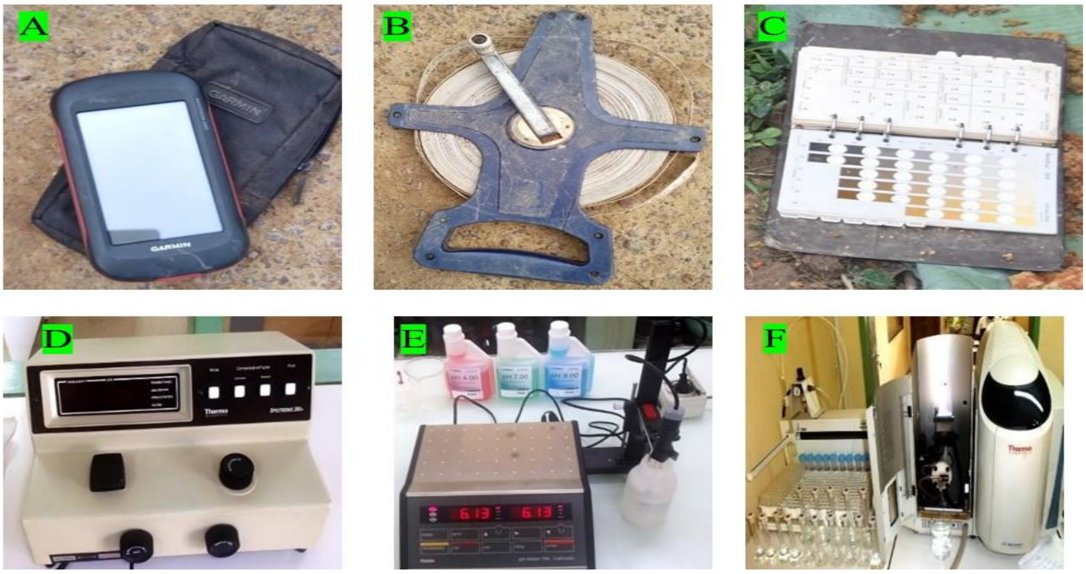

Fig. 2. Soil prospecting and laboratory equipment. A: GPS, B: Tape measure, C: Munsel code, D: Spectrocolorimeter, E: pH meter, F: Spectrometer

At each catena [8], summit, shoulder, middle, foot slope (BV) and toe slope, soil samples are taken. Sampling is done, horizon by horizon and from bottom to top, using the pedologist's knife and a spade (Fig. 4). After drying in the open air for 72 hours, the soil samples are sieved at 2 mm, then put in bags and carefully labeled for chemical analyzes in the laboratory.

- ✓ Phyicochemical analysis

The physicochemical analyzes of the samples taken were carried out in the soil laboratory of BUNASOLS in Ouagadougou. The results of these different soil analyzes were compared with threshold values from the literature or with international reference standards. The measurement of pH (water) was carried out by electrometry, in a suspension of soil in water in a ratio of 1/2.5. Organic carbon (C) was determined and the result was converted to organic matter (OM) by using the factor 1.724 (OM = C x 1.724). As for the total nitrogen, it was determined by the method [9]. Exchangeable bases and cationic exchange capacity were measured in a buffered extract solution containing ammonium acetate (CH_3COOH 1N) at pH7 [10]. Assimilable phosphorus was determined by the modified Olsen method. Total phosphorus was determined by colorimetry after being extracted with perchloric acid [11].

✓ Statistical analysis

The interpretation of the soil analysis results was made by referring to the criteria of the soil quality standards mentioned in Table 1 and according to the evaluation of the fertility classes indicated in Table 2 [12,13]. The interpretations of the soil results have also based on the standards for evaluating agricultural soil criteria described by [14]. The SIMCAP16 software was used to perform a principal component analysis between the physicochemical parameters to identify the correlations between the studied soils. The ratios between the exchangeable cations (Ca/Mg and Mg/K) were calculated by using the spreadsheet Excel 2016.

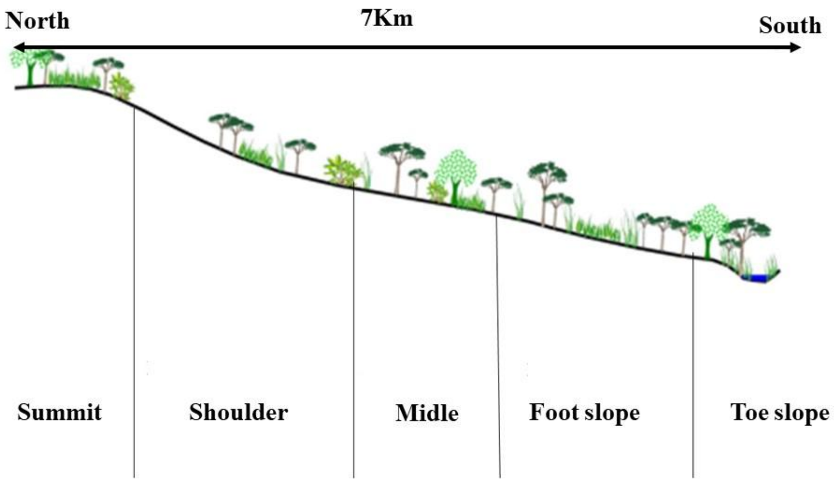

Fig. 3. Toposequence in Yilou

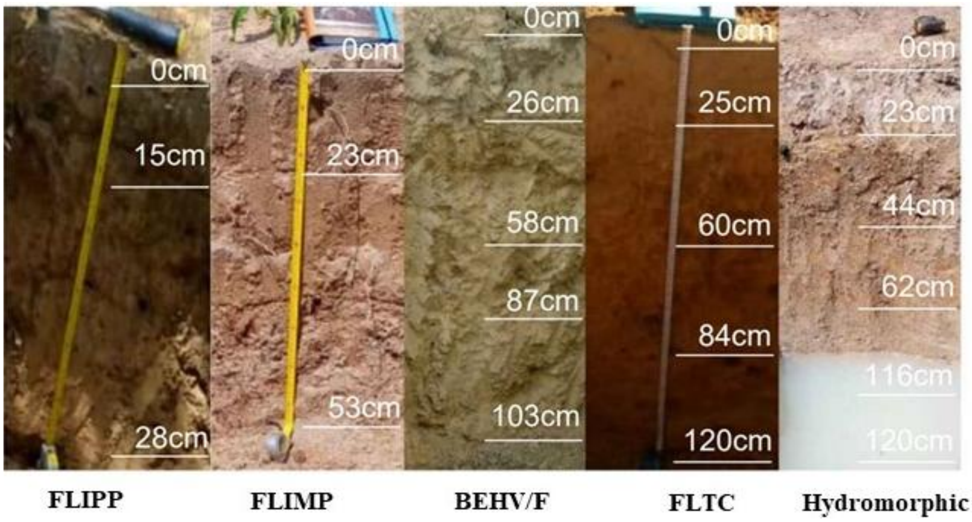

Fig. 4. Soil profile (A) and soils samples collected (B)

Table 1. Soil quality assessment standards [12]

Parameters	MO	C	N	C/N	Pass	Ca	Mg	K	Na	CEC	V
Threshold values	3.6-6.5	1.6-2.5	1.2-2.2	11-15	3-8	5-8	1.5-3.0	0.15-0.25	0.3-0.7	10 ≤ CEC ≤20	60 ≤ TS < 90

Legend: OM: organic matter; C: Carbon; N: Nitrogen; C/N: Carbon Nitrogen Ratio; Pass: Assimilable phosphorus; CA++: Calcium; Mg++: Magnesium; K+: Potassium; Na+: Sodium; CEC=Cation exchange capacity; V=Saturation rate

Table 2. Criteria for assessing soil fertility classes [13]

	Level of fertility				
	Very high	**High**	**Medium**	**Low**	**Very low**
Characteristics	**Level 0**	**Degree 1**	**Level 2**	**Level 3**	**Level 4**
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
AP (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
Sum of cations (cmol+/kg)	> 10	10-7.5	7.5-5	5-2	5-2
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	5.5-6.0	5.5-5.3	5.3-5.2	< 5.2
	6.5-8.2	6.5-7.8	7.8-8.3	8.3-8.5	>8.5

Legend: CEC: cation exchange capacity; OM: organic matter; K+: Potassium; AP: Assimilable phosphorus; N: Nitrogen; OM: organic matter, pH: water potential; V: Saturation rate

3. RESULTS AND DISCUSSION

3.1 Morphological Characterization

3.1.1 Ferruginous tropical soils leached indurated shallow

The physiographic position is located on a high slope glacis characterized by an almost flat topography. It has a slope of less than 1% with some laterite blocks on the surface mixed with fine gravel. The soils were shallow (25-28 cm) with a depth due to the appearance of induration of 25-28 cm. There were two horizons, one of which goes up to 15cm and the other goes from 15 to 28 cm respectively the color light yellowish brown (10YR 6/4) at the beginning and becomes pale brown (10YR/6-3) to the next horizon. The texture ranges from sandy loam to loamy clay. The roots are few and medium-fine-very fine type and are rather very coarse, medium and fine in depth. The biological activity is generally average with a clear transition between the two horizons.

3.1.2 Ferruginous tropical soils leached moderately deep

These soil depths were limited by induration after 58 cm. There were three horizons, the last of which is gravelly from 43 cm. The first two horizons had colors ranging from yellowish brown (10YR5/4) to yellowish yellow (10YR6/6). The structure was less massive with a hard consistence and finishes in a soft structure on the second horizon. The pores were quite numerous, fine-medium and wide. Biological activity was moderately developed overall with a distinct transition between the two horizons. Finally, we noted the presence of coprolite pockets in the first two horizons.

3.1.3 Brunified soil

The physiographic position was located on a medium slope glacis characterized by an almost flat topography with a slope of less than 1% with sheet and rill erosion characterized by imperfect drainage. The soils were characterized by a microtography marked by erosion claws, termite mounds and collapse shrinkage cracks. The depth of these soils was limited by induration after 103 cm. There were three horizons, the last of which were slightly less gravelly than the second with respectively 20% and 30%. They were less representative on the surface. The last two horizons have colors ranging from pale reddish brown (2.5YR6/3- 2.5YR6/4). Meanwhile, the color of the first horizon was pale red (10YR6/2). The texture was of the loam-clay-sandy type with more sand (49.45) which represents more than double the proportion of silt and clay (23.53% and 27.45%). Some coarse ferruginous type elements are observed and become scarce in the second horizon reaching 36%. The structure was not very massive marked by a very hard consistency and not very hard structure on the second horizon. The pores were few, fine, medium and large. The roots were few, very fine, thin and coarse along the described pit.

3.1.4 Ferruginous tropical soils with spots and concretions

These soils had a useful depth of more than 106cm. They had a yellowish-brown (10YR5/4) matrix color in the first 20 centimeters. It became bright brown (7.5YR5/6) at the next three horizons. The spots appear from 20 cm and were quite numerous with a percentage of 15 to 20%. They became more numerous as one descends in depth, reaching 40%. The texture, at the first horizon (0-20cm) were sandy clay loam. It was then clay loam up to 77cm deep. The texture finally became loam clay beyond. The gravelly load composed of ferruginous and ferro-manganese concretions varied between 20% and 35% between 20cm and 107cm. It was insignificant on the surface. The structure was subangular polyhedral weakly developed in the plowing horizon and became massive below. The consistency was soft on the surface and becomes very hard in depth. The porosity was good overall. As for the roots, they were concentrated in the first half meter and become rare beyond. Biological activity was moderately developed overall. Finally, the gradual transition in depth between the horizons was distinctly on the surface.

3.1.5 Hydromorphic soils

They were gray soils (2.5Y 5/1) on the surface, light brownish gray (2.5Y 6/2) in depth. Hydromorphic spots increased with depth. The structure was massive to subangular blocky in the early horizons. The texture was sandy-loamy to clayey beyond 20 cm. The mineral fragments were numerous. The porosity was quite average and the roots were numerous in the surface horizons, but decreased in the deeper layers.

3.2 Soil Granulometry

Table 3 is a summary of granulometric analysis parameters of the soils. The particle size analyzes of the soils indicate that there were three types of soil represented by a sandy loam texture (SL) namely FLIPP, FLIMP, FLTC soils and two types of soil having a sandy clay loam texture (SCL) namely BEHV/F and hydromorphic soils. The proportion of clay was distributed as follows: FLTC soil (11.76%), FLIMP (21.57%), FLIPP (21.3%), hydromorphic soils (23.01) and BEHV/F (27.45%). The highest loam soil value was found in hydromorphic soils (41.01), followed by FLTC (29.49%), BEHV/F (23.53%), FLIPP (22.6%) and FLIMP (21.01%) soils. The sand content was high in FLIMP (60.78%) soils compared to FLTC (58.82%), FLIPP (53.5%), BEHV/F (49.02%) and hydromorphic (35.98%). The soil texture found in this study was similar to sandy loam and sandy clay loam soils of [15] in their study literature review on water and soil conservation techniques in Burkina Faso which showed that this type of texture can be used for agriculture as well as for forestry.

Table 3. Granulometry parameters of soils

Soil texture	FLIPP	FLIMP	FLTC	BEHV/F/F	Hydromorphic
Texture	SL	SL	SL	SCL	SCL
Clay (%)	21.3	17.65	11.76	27.45	23.01
Loam (%)	22.6	21.57	29.42	23.53	41.01
Sand (%)	53.5	60.78	58.82	49.02	35.98

Legend: FLIPP (Ferruginous tropical soils leached indurated shallow), FLTC (Ferruginous tropical soils with spots and concretions), FLIMP (Ferruginous tropical soils leached moderately deep), BEHV/F (Brunified soils/ vertic hydromorphic eutrophic brown soils with ferruginized facies). SL: Sandy loam, SCL: Sandy clay loam

Table 4. Organic matter rate and physicochemical characteristics of soils

Parameters	FLIPP	FLIMP	FLTC	BEHV/F/F	Hydromorphic
OM (%)	0.731	1.362	0.802	1.584	3.12
Carbone total (%)	0.523	0.79	0.465	0.919	0.96
Total nitrogen (%)	0.056	0.07	0.047	0.082	1.81
C/N	11	11	10	11	11
Iron	1423	1338	1188	1033	968
Assimilable phosphorus (ppm)	1.3	2.16	1.36	4.65	6.24
Total phosphorus (ppm)	621	726	782	615	612
Total potassium (ppm)	1118	1198	879	1358	1445
Assimilable potassium (ppm)	18.23	14.71	19.82	9.91	97.3
pH (Water)	6.1	7.72	6.68	7.65	6.03

Legend: OM: Organic matter; C/N: Carbon Nitrogen Ratio

3.3 Physico-chemical Composition of Soils

The Table 4 shows the organic matter content and the chemical composition of the soils studied.

3.3.1 Organic matter

Soils sampled had an organic matter (OM) content of 3.12%, 1.584%, 1.362%, 0.802%, and 0.731% respectively in hydromorphic soils; BEHV/F/F, FLIMP, FLTC and FLIPP. This content in organic matter was below the soil analysis interpretation reference standard (3.6%-6.5%). But, according to the organic matter fertility scale described by [13], hydromorphic soils (OM>2) had a very high fertility level followed by BEHV/F soils (2<OM<1.5) characterized by high fertility level. For some authors, a rate of 1.5% is the theoretical critical limit, below which fertility declines rapidly. The low contents in the other soils confirm previous results in Burkina Faso which report the deficiencies of soil organic matter in general [16]. [17] found that in Pissila area located in Burkina Faso, the organic carbon is less rich generally in the soil deeper layers. In addition, in soils, poor in organic matter, it is therefore important to aim for a minimum rate of 2.5% in general, or even 3.5 to 4% in heavy soils [18]. These soils, poor in organic matter are favorable to the cultivation of potatoes according to [18].

3.3.2 Total carbon

Carbon levels were 0.465%, 0.523%, 0.79%, 0.919% and 0.96%, respectively, in FLTC, FLIPP, FLIMP, BEHV/F and hydromorphic soils. This level was low in the five soils studied as it does not reach the reference standard for the interpretation of soil analysis of 1.6% -2.5% and the threshold recommended by [14].

This carbon deficiency could be due to soil depletion or erosion that can lead to the decline of organic matter in the soil and also influence the carbon content. Moreover, the carbon stock of a soil is often confused with that of organic matter, thus 50 to 55% of the organic matter is made up of carbon [18]. The clayey texture being low in the soils studied would also partially explain the low proportion of the carbon rate. Indeed, according to [19], clay soils contain more carbon stock than sandy soils.

3.3.3 Total nitrogen

All soils had a total nitrogen level below the soil interpretation standard (1.2-2.2%), with the exception of hydromorphic soils. The contents were in increasing order of 0.047%; 0.056%; 0.07% and 0.082% and 1.81% in FLTC, FLIPP, FLIMP, BEHV/F and hydromorphic soils. The reference standard for the evaluation of soil fertility classes in nitrogen distinguishes hydromorphic soils and BEHV/F which are level 0 (very high fertility; N>0.08) followed by FLIMP soils of level 1 (high fertility; 0.08<N% <0.06) and level 2 soils such as FLIPP and FLTC (average fertility; 0.06<N% <0.045). Our results are similar to those of [4] who reported that ferruginous soils were low in total nitrogen with a rate generally below 1%. Nitrogen deficiency, according to [20] would come from the direct burial of crop residues, which would lead to phytotoxicity problems linked to the release of phenols.

3.3.4 The carbon-to-nitrogen ration C/N

The C/N ratio showed that the soils were characterized by a ratio of 11 except FLTC soils characterized by a C/N ratio of 10 which was not included in the reference standards for the interpretation of soil analyzes which was11-15. Carbon-to-nitrogen ratio (C/N) is an indicator of the ability of an organic product to decompose, it is designated as an indicator of the maturity of composts, so for a carbon to nitrogen ratio between 15 and 20 would indicate a mature compost [21]. This ratio makes it possible to characterize the organic matter, the restitutions and the nutrient contributions [22]. In our study, this ratio is between 10 and 11, which would indicate a release of nitrogen by microorganisms that could be used in plant nutrition. Our studied soils would therefore present an intense biological activity and a good mineralization of the organic matter.

3.3.5 Assimilable phosphorus

Hydromorphic and BEHV/F soils had the highest levels of assimilable phosphorus with respective values of 6.24 mg/Kg and 4.65 mg/Kg included in the 3-8 ppm interval of the reference standard for interpreting soil analyses. On the other hand, the remaining soils had lower values of assimilable phosphorus values of 1.3 ppm, 1.36 ppm and 2.16 ppm respectively in the FLIPP, FLTC and FLIMP soils. Phosphorus is a limiting factor in crop yields [22] and its deficiency decreases the capacity of nitrogen assimilation by the plant. It is essential for photosynthesis. Hydromorphic and BEHV/F soils have normal phosphorus contents but according to the assimilable phosphorus fertility scale defined by [13], these levels are listed in the low scale and very low level of fertility. Thus, FLIPP, FLTC and FLIMP soils will require a higher phosphate fertilizer supply strategy compared to hydromorphic and BEHV/F soils for their use for agricultural purposes. These results in relation to phosphorus deficiency, especially in ferruginous soils, are consistent with those found by [23] who pointed out that the ferruginous soils of the savannahs in Burkina Faso are poor in assimilable phosphorus.

3.3.6 Available potassium

The available potassium content was 9.91 mg/Kg, 14.71 ppm, 18.23 ppm, 19.82 ppm, 97.3 ppm respectively in BEHV/F, FLIMP, FLIPP, FLTC and hydromorphic soils.

3.3.7 Iron

Iron content was high in FLIPP (1423 mg/Kg), followed by FLIMP (1338), FLTC (1188 ppm), BEHV/F (1033 ppm) and hydromorphic (968 ppm) soils. This high iron content could be explained by the iron appearance of most soils.

3.3.8 pH (Water)

FLIPP (pH=6.1), hydromorphic (6.03) and FLTC (pH=6.68) soils were slightly acidic while FLIMP and BVF/ soils were slightly alkaline with respective pH of 7.72 and 7.65 (Fig. 5).

3.3.9 Exchangeable cations and cation exchange capacity

The values of the exchangeable databases are shown in Table 5. The 5 types of soil had a calcium content (Ca^{2+}) of between 1.11 meq (+)/100g and 1.86 meq/100g, which was lower than the reference standard of 5- 8 meq/100 g). The concentration of magnesium (Mg^{2+}) was approximately 0.65 to 0.95 meq/100g, which is also below the benchmark of 1.5 to 3.0 meq/ 100 g.

Potassium (K^{+}) concentration was higher in hydromorphic soils (1.75 meq/100g) followed by BEHV/F soils (1.22 meq/100g), FLIMP (0.41 meq/100g), FLTC (0.36 meq/100g) and FLIPP (0.34 meq/100g). These values were higher than the normal threshold of exchangeable potassium recommended in a soil, according to the reference standards 0.15-0.25 meq/100g. Hydromorphic soils, BEHV/F and FLIMP are classified according to the fertility scale in level 0 corresponding to very high fertility (>0.4 meq/100g) and FLTC and FLIPP soils are on level 1 corresponding to high fertility (0.4-03 meq/100 g).

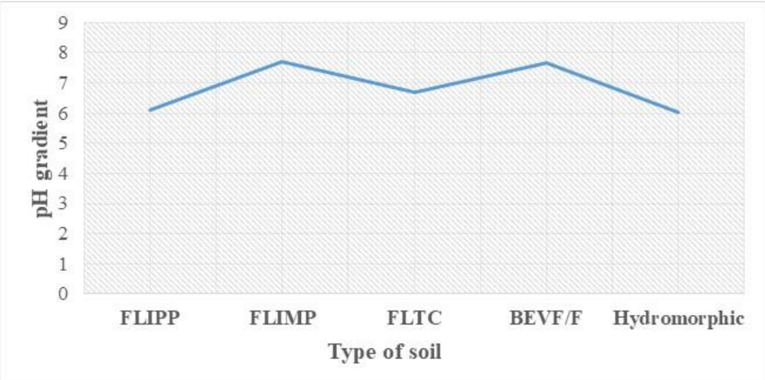

Fig. 5. pH water according to soil types

Table 5. Exchangeable cations and cation exchange capacity of the soils studied

Exchangeable bases (meq/100g)	FLIPP	FLIMP	FLTC	BEHV/F/F	Hydromorph
Calcium (Ca^{2+})	1.42	1.86	1.11	1.65	1.82
Magnesium (Mg^{2+})	0.83	0.79	0.65	0.9	0.95
Potassium (K^{+})	0.36	0.41	0.34	1.22	1.75
Sodium (Na^{+})	0.07	0.09	0.14	0.38	0.75
Sum of Bases	4	3.15	2.24	4.15	5.51
Cation Exchange Capacity	5	3.88	3.58	5.38	8.37
(meq (+)/100g) Saturation rate (%)	70	81	63	78	66

The sodium content (Na^+) in hydromorphic soils (0.75 meq/100g) was slightly higher than the reference standard (0.3-0.7 meq/100g) and in BEHV/F soils with a content of 0.38 meq/100g was included in the range of this reference standard. Moreover, this content remains low in FLTC (0.14 meq/100g), FLIMP (0.09 meq/100g) and FLIPP (0.07 meq/100g) soils.

The exchange capacity was low in the 5 soils with the highest value in hydromorphic soils (8.37 meq/100g) not reaching the reference standards (10 ≤ CEC ≤20).

This can be related to the texture (related to proportion of clay and sand) and the level of organic matter in the soils. Soils with high clay and/or organic matter content have high CEC, while sandy, low organic matter soils have low CEC [24].

The soils studied had a saturation rate within the norm (60 ≤ TS < 90). This indicates that the soils are well saturated with exchangeable cations.

3.3.10 Equilibrium between exchangeable cations

The calcium to magnesium ratio was 2.35, 1.91, 1.83, 1.71 and 1.70 respectively in FLIMP, hydromorphic, BEHV/F/F, FLIPP and FLTC soils (Table 6). As for the magnesium to potassium ratio, it was 2.30; 1.92; 1.91; 0.73 and 0.54 respectively in FLIPP, FLIMP FLTC, BEHV/F and hydromorphic soils.

All five soils had Ca/Mg ratios below the 3-4 standard prescribed by [14]. Moreover, which states that a ratio of less than 3 indicates soils whose phosphorus uptake may be inhibited. The Mg/K ratio of BEHV/F to hydromorphic soils was in 1:2 and 5:3 intervals of [14], which is optimal for most crops [23].

3.3.11 Soils correlation

The principal component analysis between the physicochemical parameters shows that R2X [1] and R2X [2] represent more than 86.9% of the variability (Fig. 6). From these results, the R2X [2] makes it possible to make a good discrimination of the soils and distinguishes two groups which are: group 1 (BEHV/F and hydromorphic) and group 2 (FLTC, FLIPP and FLIMP). Thus, the soils contained in each group have almost a similarity between the physicochemical parameters.

Table 6. Ratio between exchangeable cations

	FLIPP	FLIMP	FLTC	BEHV/F/F	Hydromorphic
Ca/Mg	1.71	2.35	1.70	1.83	1.91
Mg/K	2.30	1.92	1.91	0.73	0.54

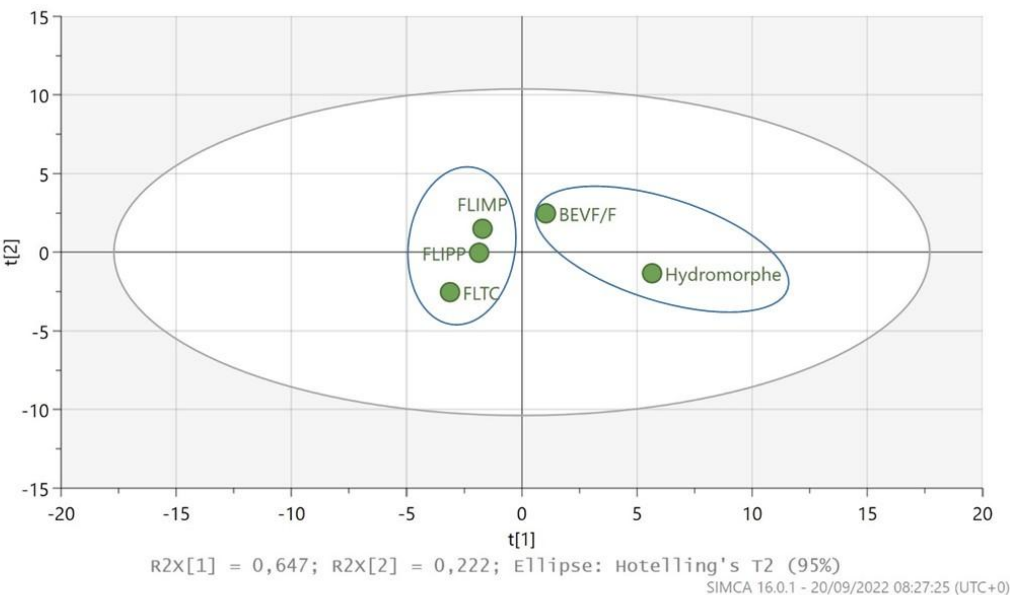

Fig. 6. Principal component analysis of the five soils according to the physico-chemical parameters

4. CONCLUSION

In Yilou the soils are sandy loam (FLIPP, FLIMP, FLTC) and sandy clay loam (Hydromorphic, BEHV/F/F). Hydromorphic and BEHV/F soils are more suitable for fertility and for agriculture compared to FLIPP, FLIMP, FLTC soils. Two groups of soils emerge, namely the group of hydromorphic soils and BEHV/F/F, and that of soils (FLTC, FLIPP and FLIMP). These results can be used as a preliminary database for information on the soil data of the locality of Yilou and could be used for agricultural and forestry purposes.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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