Ferralsols of southern Côte d’Ivoire under strong land pressure: What alternative to an improving soil fertility for a sustainable cassava production?

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Abstract

A study carrying on the morphological and physical properties of soils has been conducted in the South of Côte d’Ivoire, in the locality of Dabou. This region is submitted to a strong land pressure and a competition between food and industrial crops. This competition took place to the detriment of cassava on ferralsols poor in organic matter. In order to understand the behavior of these soils, the main physical parameters have been described. The transects of about 300 m were opened in three villages and the pedological profiles have been described on a scale of 1/5000. The pH has especially been put in evidence because the soils under industrial crop are frequently fertilized to the detriment of food crops. The studies put in evidence an acidification phenomenon of the ferralsols. The soils were modal ferralsols or typical in absence of coarse element. It has also been noted an enrichment of the soils in thin element in depth but neither of cuirassing nor compactness. The morphology of soil was not a constraint for plant but an important constraint bound to the acidification of soils exists. To overcome this constraint, the use of organic manure was recommended in a good cropping system.

Keywords: ferralsol, fertility, acidification of soil, sustainable production, Côte d’Ivoire

INTRODUCTION

The Ivorian south soil belongs to the group of impoverished ferralsols very desaturated (Perraud, 1971). When they are developed on sandy deposits of Continental terminal, they are difficult to differentiate, referring to their morphology. To characterize these soils and their evolution, the main criterion is based on the constitution of their size (Roose and Cherroux, 1966; Caliman, 1990; Hartmann, 1991). These authors showed that these soils evolve from a sandy pole (less than 10% clay) to sandy clay pole (more than 40% clay). There are also hydromorphic soils located in the bottom of the slope and in the shallows. The characteristics of these soils are due to one dominated by the presence of a stream change as a result of a temporary surface engorgement, depth, or as a result of the rise of groundwater (Aubert and Segalen, 1966). The presence of water is linked to...
low level and topographical conditions. Ferralsols of this region are characterized by the presence of quartz and sand along the shoreline. The high rainfall of this area promotes a significant leaching of fine elements of this zone. These are soils developed on recent or current marine sands, which cover only a few hundred meters wide along the coast. The explored area is one of the largest economic zones. Indeed, the region of Dabou has rubber cultivation as a major agricultural activity for its population followed by palm oil. These crops are grown at an industrial scale to the detriment of food crops. Soils under these industrial crops are regularly fertilized. However, cassava, the main food is considered as a marginal crop. Its cultivation is done on unsuitable soils for agriculture, providing yields around 6 to 10 t/ha. This yield is below according to its estimated potential of more than 60 t/ha. However, cassava is the main staple food of the population in this area. Our study was to highlight the potential of ferralsols of this locality subjected to high land pressure and to describe their physical fertility in the current context. The study aims at determining the agricultural capability of the soils of the southern region of Côte d’Ivoire to sustainable agricultural production, including cassava. It is i) to identify the types of morphopedological landscapes of the environment and describe them, ii) to determine the physical parameters and the pH of these soils and iii) identify the constraints to the production of crops, especially cassava which derived products are popular beyond its production and consumption areas in Côte d’Ivoire.

MATERIAL AND METHODS

Study area

The study was conducted in three villages in the area of Dabou precisely in the South West region of Abidjan, the economic capital of Côte d’Ivoire. The geographical coordinates of the villages were mentioned in the table 1. Dabou is one of the main production and consumption areas of cassava in Côte d’Ivoire.

Material

The study was carried out with the usual materials used in pedology. These materials are used for digging pits manually and describing soil parameters.

Methods

A topographical sequence was identified in each locality along the morphopedological landscape. A length of 300 m trail was opened. On this toposequence, a pit was located on the slope of the top and in the mid and bottom sides. This method allows identifying the types of soil present in each site (Eschenbrenner and Badarello, 1978). The pit dimensions were 1.20 m deep, 1 m long and 1 m wide. The scale study was 1/5000 along the transect. This means that a profile was opened every 50 m on each site. Thus, 9 profiles were opened in all three (3) villages. Surface states have been described in the location of each pit. The relation between soil fertility and color has been established by using Munsell chart. This method has been presented by Kone et al. (2009). The parameters of soils such as the porosity, the coarse elements, the compactness, the rooting of the plants, the drainage, the texture and the structure (Baize and Jabiol, 1995), the stains of hydromorphy were analyzed.

Collecting soil samples

After the description of the soil profiles, the horizons were delimited from the differences of color, the contents in coarse element, the organic material, the roots and other noticeable pedological indications on the face of the profile. The tactile method was used to appreciate the texture. After description, soil samples were collected from each horizon to be analyzed in the laboratory. The particle size was determined in the laboratory by the pipette method of Robinson. The determination of the different pH of soils was achieved in a ratio soil / solution 1/2.5 (Carter and Gregorich, 2006).

Determination of the soils suitability classes

The comparison of the quality of the parameters of the soil on the one hand, and with the requirements of cassava on the other, resulted in the impacts of the likely effects of the constraints and the potentialities of the soils on the output of this culture served as a basis to the classification of the ability of the studied soil in the town.
of Dabou. Most existing methods have been spread by FAO since the 1970s. The soil suitability classes were determined by taking into account the quality of the soil (FAO, 1983):

- Suitability type class S2 (very capable soils); in this case the risks of weak output bound to soils are very weak, or even inexistent (less than to 20%). Soil-related constraints are very low.
- Suitability type class S2 (fairly capable soils); the risks of weak outputs bound to soils are weak to means (20 to 60%). Soil-related constraints are of middle severity.
- Suitability type class S3 (marginally suitable soils); the risks of weak outputs bound to soils are very elevated (60 to 80%). The pedological constraints are of high severity.
- N-type suitability class (unfit soil); the risks of weak outputs bound to soils are very high (80 to 100%). In this case, the constraints are very stern and cannot be raised without important amenities to the level of the soil.

RESULTS

The morphological characteristics considered most relevant to the assessment of the agricultural capability of the soils are: color, texture, structure, coarse elements, compactness, porosity, drainage and the presence of hydromorphy stains. In the town of Dabou, nine (9) profiles were observed and described. The pH was determined to better assess soil acidification.

Physical properties and soil fertility of the locality of Debrimou

In Débrimou, the landscape, generally flat, is weakly waved at the hills.

On this site, three horizons were put in evidence: horizon A1, A3 and AB (figure 1).

Profile 1: top side

0-32 cm: horizon A1: Dark brown (7.5 YR 3/2); fresh; humiferous; sandy; the structure is lumpy with a subangular polyhedral tendency, with numerous roots (millimeter) and subhorizontal orientation; the soil is not coherent, very porous (millimeter pore size) with a lack of distasteful and hydromorphy stain. The drainage is good; the transition is gradual with a limit that is more or less regular.

32-65 cm: horizon A3: grayish brown (7.5 YR 3/3); fresh; humiferous; sandy clay; subangular blocky structure, with many roots (millimeter to centimetric) with subhorizontal orientation; not coherent; very porous (millimeter pore size); no distasteful; lack of hydromorphy

stain; good drainage; gradual transition, more or less regular limit.

65-110 cm: horizon AB; transition horizon; ocher brown (2.5 YR 4/4); dry; apparently not humiferous; sandy clay; subangular centimetric blocky structure; cohesive soil; low porosity (pore size millimeter); many roots (millimetric to centimetric) with subhorizontal orientation; no distasteful; lack of hydromorphy stain; good drainage.

Soil type: modal Ferralsol

Profile 2: mid-slope

0-30 cm: horizon A11: Dark brown (7.5 YR 3/2); fresh; humiferous; sandy; lumpy structure with a subangular blocky tendency, with numerous roots (millimetric to centimetric) and subhorizontal orientation; coherent; very porous (millimeter pore size); absence of coarse elements; no stains; good drainage; the transition is gradual with a limit that is more or less regular.

30-60 cm: horizon AB: transition horizon, brown (7.5 YR 4/3); fresh; humiferous; sandy clay; subangular centimetric blocky structure; coherent soil; very porous (millimeter pore size); many roots (millimetric to centimetric) with subhorizontal orientation; absence of coarse elements; no stains; good drainage; diffuse transition with a more or less regular limit.

60-110 cm: B horizon: reddish brown (2.5 YR 4/3); fresh to dry; apparently non humiferous; sandy clay; subangular centimetric blocky structure; coherent and porous soil (millimeter pore size); some roots (millimetric to centimetric) with subhorizontal orientation; no coarse elements; no stains; good drainage.

Soil type: modal Ferralsol.

Profile 3: Bottom of the slope: three horizons (A11, A12 and A3) were identified and described.

0-15 cm: horizon A11: Dark brown (7.5 YR 3/2); fresh; humiferous; sandy; the structure is lumpy with a subangular polyhedral tendency, with a (millimeter to centimeter) size, with many roots (millimeter) with subhorizontal orientation; coherent to loose; very porous (millimeter pore size); absence of coarse elements; no stains; good drainage; gradual transition with a limit that is more or less regular.

15-40 cm: horizon A12: light brown (2.5 YR 6/4); fresh horizon; not much humiferous; sandy clay (5 to 10% clay); subangular blocky structure, centimetric size with few roots (millimetric to centimetric) of subhorizontal orientation; coherent; very porous (millimetric pore size); no stains; absence of coarse elements; good drainage; distinct transition with a limit that is more or less regular.

40-110 cm: horizon A3: yellowish red (5 YR 5/6); fresh to dry horizon; not humiferous; sandy clay (5-10% clay); subangular blocky structure of centimetric size with few roots (millimetric) with subhorizontal orientation; coherent soil; porous (millimetric pore size); absence of coarse elements; no stains; good drainage.

Soil type: modal Ferralsol.
Potential of the soil in the locality of Okpoyoum

In Okpoyoum, the slopes were generally low (0-3%).

Profile 1: On the top (Figure 2); three (3) horizons (A11, A12 and AB) were determined.
- 0-20 cm: horizon A11: dark gray (7.5 YR 3/2); fresh horizon; humiferous; sandy; lumpy structure with a subangular blocky tendency with many roots (millimetric) with subhorizontal orientation; soil not much coherent; very porous (millimetric pore size); absence of coarse elements; no stains; good drainage; gradual transition with a limit more or less regular.
- 20-50 cm: horizon A12: dark gray (7.5 YR 3/2); fresh; humiferous; sandy clay (5-10% clay); subangular blocky structure with centimetric size and few roots (millimeter) and subhorizontal orientation; coherent soil; porous (millimetric pore size); no coarse elements; no stains; good drainage; distinct transition with a limit more or less regular.
- 50-110 cm: horizon AB: yellowish red (5 YR 6/6); fresh; apparently humiferous; sandy clay (5-10% clay); subangular blocky structure with very few roots (millimetric) with sub-horizontal orientation; coherent soil; porous (millimetric pore size); no coarse elements; no stains; good drainage.

Soil type: modal Ferralsol.

Profile 2: Mid-slope. Two distinct horizons (A and B) were determined.
- 0-20 cm: horizon: yellowish brown (10 YR 6/6); fresh; not much humiferous; sandy clay (5 to 10% clay); lumpy soil with a subangular blocky structure tendency with some subhorizontal roots (millimetric); coherent soil; very porous (millimetric pore size); absence of coarse elements; no stains; good drainage; distinct transition with a limit more or less regular.
- 20-110 cm: B horizon: yellow ochre (10 YR 7/8); fresh to dry; apparently humiferous; sandy clay (15-20% clay); subangular blocky structure, with few roots (millimetric)
Figure 3. Soil profiles observed along the toposequence of Lopou

with sub-horizontal direction; very consistent; porous (millimeter pore size); absence of coarse element; no stains; average drainage.

Soil type: modal Ferralsol

Profile 3: Bottom slope (Figure 2). Three main horizons (A11, A12 and A3) were observed.

0-10 cm: horizon A11: dark gray (5 YR 4/1); fresh to dry; humiferous; sandy; lumpy structure with a subangular blocky tendency with many roots (millimetric) with subhorizontal orientation; not much coherent; very porous (millimeter pore size); absence of coarse elements; no stains; good drainage; diffuse transition with a limit more or less regular.

10-65 cm: horizon A12: dark gray (5 YR 4/1); fresh; apparently humiferous; sandy clay; subangular blocky structure with some roots (millimetric) with subhorizontal orientation; coherent; porous (millimeter pore size); absence of coarse elements; no stains; good drainage; gradual transition with a limit more or less regular.

65-110 cm: A3 horizon light brown (7.5 YR 6/3); fresh; apparently humiferous; sandy clay; subangular blocky structure with very few roots (millimetric) with subhorizontal direction; coherent; porous (millimeter pore size); absence of coarse elements; absence of coarse elements; no stains; good drainage.

Soil type: modal Ferralsol.

Profile 1: Top side(Figure 3). Three horizons (A11, A12 and A3) were determined.

0-15 cm: horizon A11: brown (7.5 YR 4/3); fresh to dry; humiferous; sandy; lumpy structure with a subangular blocky structure tendency with many roots (millimetric) and subhorizontal orientation; soil not much coherent; very porous (millimeter pore size); absence of coarse elements; no stains; good drainage; gradual transition with a limit more or less regular.

15-75 cm: horizon A12: brown (7.5 YR 4/3); fresh; humiferous; sandy clay; subangular blocky structure with some roots (millimetric) and subhorizontal orientation; coherent; very porous (millimeter pore size); absence of coarse elements; no stains; good drainage; clear transition with a limit more or less regular.

75-110 cm: horizon A3: ocher brown (7.5 YR 5/4); fresh; apparently humiferous; sandy clay; subangular blocky structure with scarce roots (millimetric to centimetric) with subhorizontal orientation; coherent; very porous (millimeter pore size); absence of coarse elements; no stain; good drainage.

Soil type: Rhodic Ferralsol

Profile 2: Mid-slope. Two main horizons (A and B) were determined.

0-30 cm: horizon A: gray-brown (7.5 YR 4/1); fresh; apparently humiferous; sandy clay; subangular blocky structure with centimetric size; coherent; many roots (millimetric) with subhorizontal orientation; absence of coarse elements; stains; good drainage; diffuse transition with a limit more or less regular.

30-110 cm: horizon B: light brown (7.5 YR 6/3); fresh; apparently humiferous; sandy clay; subangular blocky structure with few roots (millimetric) and sub-horizontal orientation; coherent soil; very porous (millimeter pore size).

Physical properties and soil fertility of the locality of Lopou

In Lopou the landscape is generally flat with some trays. The slopes are of low average.

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size); absence of coarse element; no stains; good drainage.
Soil type: Ferralsol modal
Profile 3. Bottom slope (figure 3). Two main horizons (A11 and A12) were identified.

0-100 cm: horizon A11: brown (7.5 YR 4/1); fresh; humiferous; sandy; lumpy tends subangular blocky structure tendency with numerous roots (millimetric) and subhorizontal orientation; the soil in this region is less coherent and loose; very porous (millimetric pore size); absence of coarse elements; no stains; good drainage; gradual transition with a limit more or less regular.

100-110 cm: horizon A12: brown (7.5 YR 4/1); fresh; apparently humiferous; sandy clay; subangular blocky structure of centimetric size, with scarce roots (millimetric) and subhorizontal orientation; coherent soil; porous (millimetric pore size); absence of coarse elements; no stains; good drainage.
Soil type: modal Ferralsol.

**pH of soils in the landscape**

It was observed that the soil of Debrimou are more acidic (4.1) than the others. It was followed respectively by soil of Okpoyou (pH=4.6) and the soil of Lopou (pH=5.0) (Figure 4). Overall, all soils recorded had an acidic pH.

**DISCUSSION**

**Physical soil properties and potentialities**

The results carrying on the physical parameters of the soils of the three localities showed that soils essentially belong to the class of the modal ferralsols, with an absence of gravels. These soils are essentially sandy over the ground level with relative proportions of organic matter demonstrated by the dark or gray color. It has been noted that the content of organic matter has varied from the top of the profiles towards the depth. It has also varied from the summit to the bottom of the toposequence. But these contents of organic matter must be quantified to better assess the level of the fertility of the soils. This observation was made by Brahma et al. (2009: 2014). On all the three (3) sites, the clay contents do not exceed 20%. The clay horizons were observed in the shallow in all the localities, reflecting the washing of the thin elements from the summit to the bottom of the slope. It follows an enrichment of the soil of the shallow with significant clay content (Hartmann, 1994). The enrichment of the soils of the shallow is also under the control of a vertical drainage. The presence of the clay is the sign of this phenomenon. The soils of the three studied sites have a flat landscape with small variations of the slope. The physical properties of these soils are generally normal: deep soils and absence of coarse elements, porous soil, good drainage. The soils have favorable physical parameters for food crops such as cassava. For Haeringer (1972), cassava grows well in porous sandy soils of tertiary formations close to the coast. In this region, no stress related to morphological and physical soil parameters was observed. These ferralsols can be classified into the soil group suitable for food crop in the S2 class (FAO, 1983). The dominant character of these sandy ferralsols is their degree of desaturation and the weakness of their cation exchange capacity not studied in this work. The described superficial horizon being very sandy, it gives to the entire profile, a loose and porous soil suitable for the penetration of the roots of the crops. These soils favor tree crops such as rubber and palm oil. This explains why the soil in this region is mostly used for rubber and palm oil. Protected by the litter on the surface, depth horizons, richer in clay, stay fresh all year long. The structure is weak, but no compact horizon was met. No cuirass was observed up to a depth of 120 cm. This is an advantage for the crops and mainly for trees as rubber. The characteristics of these ferralsols have already been underlined elsewhere (Sys, 1978). These soils can be
Soils (Duchaufour, 1997). Low contents of fine particles leading role in the physical and chemical properties of the fine fraction of the soil is particularly reactive and plays a role in the absence of coarse element. It is recognized that the soils have been demonstrated in food crop (El-Magd et al., 2006; Islami and al., 2011). Empoverished soils in the soils contain a significant proportion of fine soil in the absence of coarse element. It is recognized that the fine fraction of the soil is particularly reactive and plays a leading role in the physical and chemical properties of the soils (Duchaufour, 1997). Low contents of fine particles observed in the soils of Dabou are probably due to leaching phenomena as showed by Wang and Alva (1996; 1998). Rainfall is particularly abundant in this area. Rainfall over 2000 mm/ year is recorded (Eldin, 1971).

Soil pH and its consequences

As for the pH, the soils studied were all acids. This fact could be the result of constant fertilization practices upon the soil under cultivation of rubber and palm oil. It was noted the harmful role of mineral fertilizers in soil acidification when misapplied. Soil acidification is a natural process with significant effects on the plants growth. As the soil becomes more and more acidic, especially when the pH drops below 4.5, it is more and more difficult to produce food crops. When the pH drops, the supply of most plant nutrients decreases as aluminum and some micronutrients become soluble and toxic to plants. Minerals such as phosphorus are fixed and not available for plants (Zhaochai et al., 2013). These problems are particularly acute in the humid tropical regions where soils are highly spoiled by the elements (Harter, 2007). In light of the pH of the soil in these three localities, we can say that the high acidity observed could be a major constraint for crops. In this condition, reducing the soil acidity should be done by liming to reduce the pH. Indeed, cassava, the main crop is always associated with rubber and palm oil over two (2) to three (3) years as from the third year, palm oil and rubber canopies make up a constraint due to shading. Indeed, shading was generating the growth and productivity of cassava which is a sun-loving plant (Howeler, 2008). Furthermore, cassava is a demanding plant in organic matter. Therefore, a combination with these industrial crops cannot be beneficial for a better performance of the food crop like cassava in the area.

CONCLUSION

Morphopedological properties of the soils of this region showed that the soil does not present a major constraint for the development of food crops. Indeed, the landscape is almost flat, slightly wavy. The soils are deep and favorable to industrial crops such as rubber and palm oil. However, it has been shown that they are essentially sandy on the surface and relatively less rich in organic matter. These ferralsols are fragile and vulnerable for sustainable agricultural production in the absence of fertilization. In addition, the measured pH are all acids on the surface as well as in depth. This raises the problem of the availability of phosphorus for the plants with a solubility of aluminum ions. It follows an almost permanent acidification of the soil that is unfavorable to crops. Therefore, amendments should be made to reduce the pH by incorporating leguminous plants and organic fertilizer in cropping systems and the organic manure such as the droppings of poultry of which the beneficial effects on soils for the cultures are recommended.

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REFERENCE


