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RESEARCH ARTICLE

EVALUATION OF THE PHYSICAL FERTILITY OF THE HYPERDYSTRIC FERRASOLS USED IN RAINFED RICE IN THE CENTRE-WEST OF CÔTE D'IVOIRE: CASE OF GAGNOA

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ABSTRACT

Background: The study was conducted in Gagnoa, in central-western Côte d'Ivoire in one of the main areas of rainfed rice production. **Objective:** The objective of this study was to assess the natural physical fertility status of the soils used for rainfed rice in the Gagnoa area. **Methods:** The test was carried out on the top of a slope at the research station of the National Center for Agronomic Research (CNRA) of Gagnoa. The methodology adopted consisted of the description of an open soil pit at the study site for the characterization of physical soil parameters (texture, coarse element rates, color). **Results:** The results obtained showed that the soils are slightly humiferous, soft and have good internal drainage at the level of the upper horizons (0-5 cm). Soil colouring ranges from 10 YR (0-60 cm) to 7.5 YR (60-80 cm) to reach 2.5 YR colouring in the lower soil horizons (80-100 cm). These soils also have a compact horizon, with a high rate of coarse elements (> 50%) between 20 and 40 cm, essentially consisting of ferruginous nodules, gravels and quartz fragments. **Conclusions:** The presence of a compact horizon with a high rate of coarse elements in the surface layers of soil constitutes the constraints to the proper development of plateau rainfed rice in the Gagnoa region. Identifying these parameters could be a start in finding solutions to improve the productivity of plateau storm rice in the Gagnoa region.

INTRODUCTION

In Côte d'Ivoire, rice (Oryza sp.) is the main component of food for both urban and rural populations (Péné *et al.,* 1996). It has evolved from a basic cultural food in the western and central-western regions of the country, to an almost daily diet for Ivorians. It is the first cereal consumed, with an annual per capita share of 58 kg (Bagal and Vittori, 2010). In terms of food production, rice ranks third after yam and cassava. Its cultivation accounts for more than half (57 %) of the area cultivated in cereals (RNA, 2001) and employs more than 600,000 people (FIRCA, 2011). This performance is assured by rainfed rice, which provides 80 % (Charpentier *et al.,* 1999) of the estimated annual national rice production of 700,000 tonnes of bleached rice. However, rice yields in this cropping system are low (Yemefack and Nounamo 2000), rarely exceeding 1.5 t ha^{-1} (Harré 1989; Maclean *et al.,* 2002), although improved varieties are used (Koné *et al.,* 2010). This situation forces Côte d'Ivoire to import more than half of its rice consumption needs (FIRCA, 2011), while according to Hirsch (1984), Côte d'Ivoire, due to its natural potential, is able to fill its rice consumption with its production. In order to compensate for these declines in yields, it appeared appropriate to assess the state of the natural physical fertility of soils which, according to Mauricio and Ildeu (2005) could constitute a constraint to the proper development of plants. Indeed, according to (Yao-Kouamé *et al.,* 2010), the presence of coarse elements in the shallow depths of the soil could constitute cultural constraints, especially for the root development of plants. Evaluation of these physical soil parameters could be an approach to assess soil fertility and propose necessary amendments to increase plateau rainfed rice production and contribute to safety rice food security in Côte d'Ivoire.

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MATERIALS AND METHODS

Characteristics of the test site: The study was carried out at the research station of the National Center for Agronomic Research (CNRA) in Gagnoa, in the Centre-West of Côte d'Ivoire (altitude: 376 m, latitude: 7°44' N, longitude: 5°04'W), one of the country's main rice production areas as shown in Figure (1). The study site consisted of vegetation of *Panicum maximum* (Guinea Grass) and *Chromolaena odorata* (Lao Grass).

The mean annual temperature is 27°C (Koné 2004). The rainfall regime is bimodal, with one peak in June and the other in October. Precipitation ranges from 1400 to 1600 mm per year, with a mean annual of 1460 mm. In recent years, rainfall in this region has been declining (Ndabalishye, 1995), which can be a major constraint on the region's agriculture and, in particular, on rainfed rice. The bedrock is essentially granite, with intrusions from shale bands (Dabbadie, 1996). The soils observed are ferralsols (FAO 2002), clay-sandy to clayey (Kassin and Yoro 2009).

Place Figure 1 here

Conduct of the study: The test site was a natural fallow of at least three years. The test is located on the top slope. The physical characteristics of the soil in the test were described using the Morpho-soil method (Eschenbrenner and Badarello 1978). A toposequence was installed along the larger slope line, perpendicular to the contours of the level, to intersect the test and locate it along the toposequence. A soil pit was opened on the study site and the soil horizons in the profile were described according to the following parameters: texture, internal drainage, nature and rate of coarse elements, color.

Methods for determining physical soil parameters: Physical parameters were determined after description of the soil pit. Descriptions of soil profiles included the following parameters. Soil texture was assessed, in situ, from the formation of pudding (Yoro 2002; Koko *et al.,* 2009), indicating, where appropriate, the estimated clay content.

The coarse element rate was evaluated by weighing a quantity of soil (Weight P1) using a household scale. Then a square mesh sieve of 2 mm diameter of this quantity of soil was carried out (Weight P2) and the coarse element rate was obtained by the relation ((P1 – P2)/P1) x 100;

Color was determined using the Munsell code.

RESULTS

Granulometric characteristics of the horizon 0-20 cm: Chemical analyses of the 0-20 cm horizon soils revealed that the soil texture is sandy-clayey with 44.80 % of coarse sand and 22.85 % of clay (Table 1).

Table 1. Granulometric distribution of soil in the horizon 0-20 cm of the study site

	Description of the elements				
	Clay	Fine silt	Coarse silts	Fine sand	Coarse sand
Values (%)	22.85	6.20	7.37	17.57	44.80

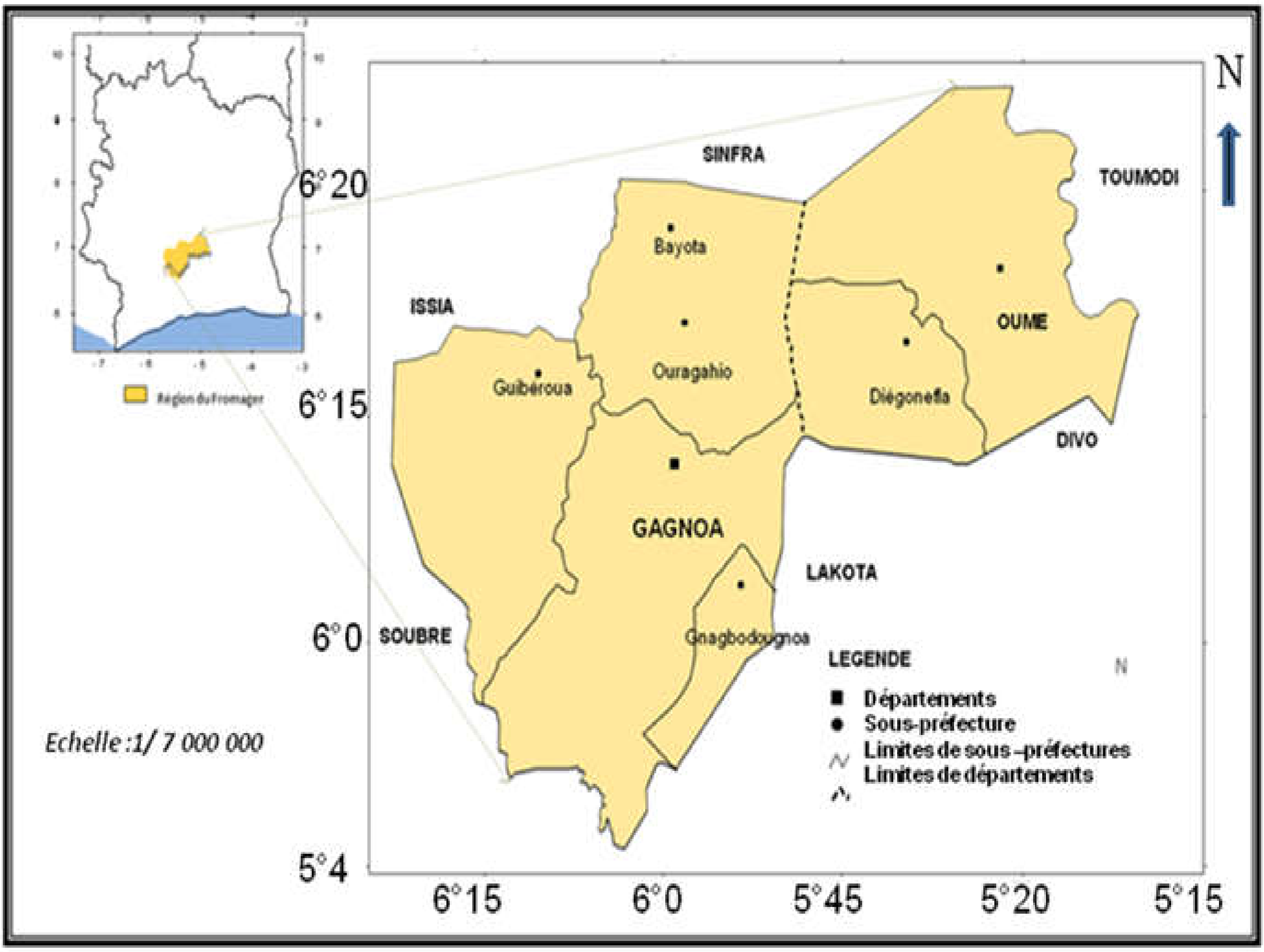

Fig. 1. Geographic and administrative map of the Gagnoa area (Source: Kouadio, 2003)

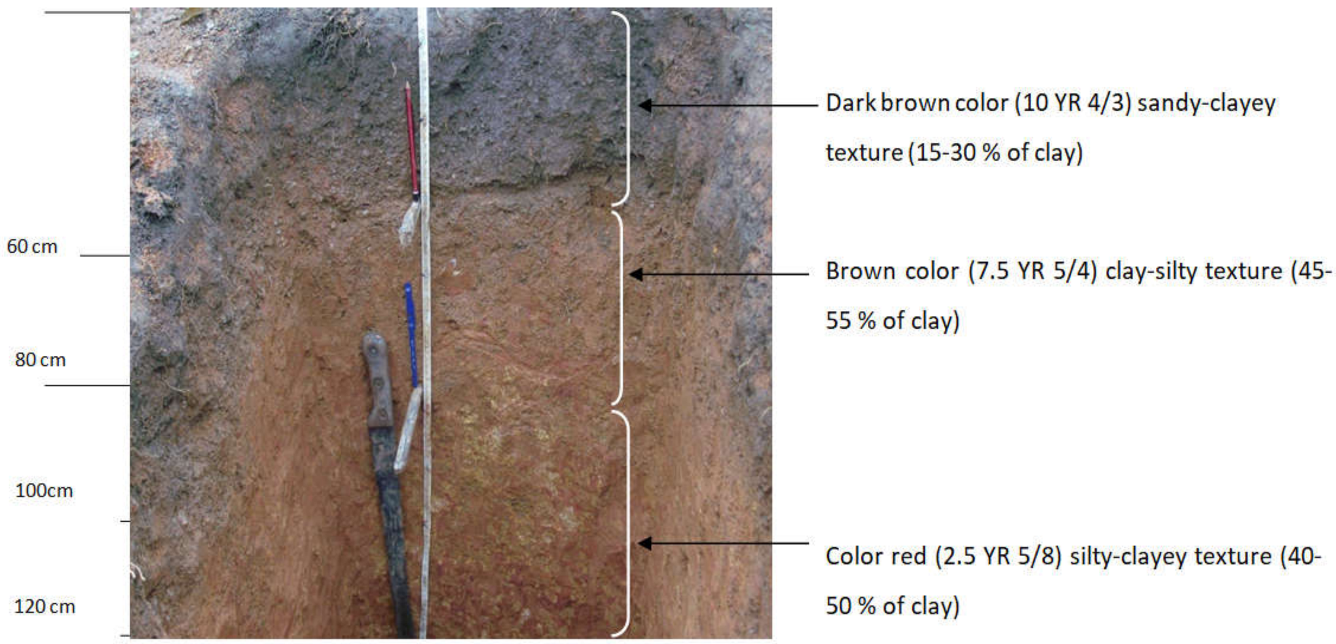

Fig. 2. Main soil colors of the profile opened on the study site

Soil morphology characteristics of the study site in the horizon 0-20 cm: The soils are slightly humiferous, with a sandy-clayey texture. They are soft and have good internal drainage. However, these soils have a compact horizon with a high rate of coarse elements (> 50 %), consisting mainly of ferruginous nodules, gravel and quartz fragments. Soil colours are in the range 10 YR with dark brown color as shown in Figure 2.

DISCUSSION

The proportion of coarse sands (44.80 %) in the upper horizons of the study site soils, higher than the proportions of silt (13.57 %) and clay (22.85 %) appears likely to be a consequence not only, the slope, but also the effect of erosion, which would have washed away the finest elements (silts and clays) and enriched the site soil with coarse elements. The soils of the upper horizons of the open profile at the study site are brown (10 YR 4/3 to 7.5 YR 5/4) while those of the lower horizons are red (2.5 YR 5/8). The brown color of the soils of the surface horizons would be related to the combination of the black color of the plant debris and the red or orange color of the iron oxides present in the soil, attributed to the dynamics of biological activity as indicated by Yao (2006).

The decomposition and transformation of plant residues mixed with iron oxides into organic matter gave their brown color to the upper horizons of the soil. In fact, according to Soltner (1992) and Arrouays et vion (1993), these are the bridges established by iron hydroxides between humus and clays, for the construction of a clay complex-iron-humus hydroxide which causes the brown coloring of soils. As for the reddish color of soils in depth horizons, it could be explained by the dynamics of iron due to leaching, as observed by Koné *et al.,* (2009) on ferralsols. In fact, leaching results in the departure of iron oxides and hydroxides from the upper horizons towards the deep layers of the soils (Mauricio and Ildeu, 2005), responsible for the reddish coloring of the depth horizons. Leaching of these iron hydroxides was facilitated by the loose structure and good internal drainage observed in the upper soil horizons of the study site. Indeed, according to Mauricio and Ildeu (2005), in the areas with dominant drainage, as is the case in the upper horizons of the soils of our study site, there is a departure of iron hydroxides towards the horizons of depth, then turn reddish in color. These results indicate the existence of a vertical gradient of the variation in soil color across the entire profile.

The presence of a compact horizon, with a high rate of coarse elements (>50 %) at shallow depths, is thought to be related to runoff and erosion (O'Halloran *et al.,* 1997). This presence of coarse elements in the shallow depths of the soil could constitute cultural constraints (Yao-Kouamé *et al.,* 2010), especially for the root development of plants. The existence of color variation in the various soil horizons in the profile indicates that the soil at the study site is a phenomenon of rejuvenation of soils. This phenomenon could be explained by several parameters, including the topography, the alteration of the underlying rock by the hydrolyzing action of rainwater. According to Bech *et al.,* (1983), the hydrolyzing action of rainwater, by favoring the weathering of rocks, releases different oxides and bases, thus causing various colorations in the soil profile. The presence of a very abundant rate of coarse elements in the intermediate horizons and the accumulation horizons, throughout the profile, indicates in addition to the phenomenon of rejuvenation, a phenomenon of disturbance of soil which, according to Duchaufour (1977), it is a secondary process that plays a role in soil evolution, most often from pre-existing rock or proportions of organic matter.

Conclusion

This study essentially consisted of characterizing the soils of production of Gagnoa rainfed rice, one of the main rice areas in Côte d'Ivoire, in order to evaluate their natural physical fertility. The results obtained showed that the soils are slightly humiferous, soft and have good internal drainage at the level of the upper horizons (0-5 cm).

Soil coloring ranges from 10 YR (0-60 cm) to 7.5 YR (60-80 cm), to 2.5 YR (80-100 cm). However, the presence of a compact horizon, with a high rate of coarse elements (> 50 %) between 20 and 40 cm could be the major physical constraint that could be the basis for declines in rainfed rice yields in the Gagnoa area. Inputs of organic amendments at lower cost and available could be proposed to producers in order to improve the physical fertility of soils, increase the production of rainfed rice and contribute to the food security of rice in Côte d'Ivoire.

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Conflict of Interest: The authors claim that they have no conflict of interest.

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