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Assessment of the Agronomic Potential of Soils in Dimbokro (Côte d'Ivoire) for Improved Agricultural Production

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Abstract

In Ivory Coast, a pedological study was carried out in the locality of Dimbokro (6˚38'48" North and 4˚42'18" West) to find out about the agronomic potential of the soils in this locality due to the insignificant harvests observed among the area's farmers. To this end, the soils of 12 villages were characterized in situ using soil pits, and samples were taken from the 0 - 20 cm and 20 - 40 cm layers for analytical data. Mean values of soil parameters in savannah zones were compared with those in forest zones, using analysis of variance (ANOVA). In both savannah and forest areas, silt (53.5% - 49%) accounts for almost half of the fine soil. Sand and clay are moderately present in these soils. In forest zones, the soils are highly acidic (pH: 5.1) with a high moisture content at depth. In contrast, savannah soils are slightly acidic (pH: 5.8) and dry. Overall, in both savannah and forest, organic matter (1.01% - 1.8%), nitrogen (0.03% - 0.07%), potassium (K: 0.09 - 0.11 $cmol\cdot kg^{-1}$), calcium (Ca: 0.64 - 0.79 $cmol\cdot kg^{-1}$) and magnesium (Mg: 0.39 - 0.64 $cmol\cdot kg^{-1}$), as well as chemical properties (S: 1.21 - 1.62 $cmol\cdot kg^{-1}$, CEC: 4 - 9 $cmol\cdot kg^{-1}$ and V: 43% - 18.26%) are relatively low for agricultural production, requiring the addition of organic matter in the form of compost. It is also important to raise the pH levels of the soils at the sites studied by means of limestone amendments. These different techniques would help to improve the physical and biological properties of the soils and mobilize certain chemical nutrients needed for better harvests in these populations.

Subject Areas

Agriculture, Food Safety

Keywords

Food Security, Chemical Deficiency, Clay-Humus Complex, Dimbokro, Ivory Coast

1. Introduction

In Côte d'Ivoire, in the Dimbokro region (6˚38'48" North and 4˚42'18" West), sandy to sandy-silty colluviums and alterites abound and constitute easily erodible soil covers [1]. These conditions may justify the low harvests noted among farmers in rural areas. This food deficit is set to worsen, with average annual temperatures over the last ten years rising from 31˚C to 37.1˚C, and even 49˚C in the hot season (February-March) [2], and longer drought periods, while average annual temperatures in Côte d'Ivoire are between 27.4˚C and 29.3˚C [2]. In addition, the climate in this locality has become increasingly harsh, and fertile land has reached an advanced level of degradation, which has a negative impact on agricultural productivity, mainly food crops. With the population's living conditions becoming a matter of concern, the need to strengthen the resilience of these farming communities in the face of declining crop yields calls for a study of the local soil characteristics. Ultimately, the aim is to improve the physico-chemical characteristics of the area's soils, for better agricultural production.

2. Material and Methods

2.1. Material

The study was conducted in the locality of Dimbokro (6˚38'48" North and 4˚42'18" West), during the 2020 and 2021 cropping seasons (**Figure 1**). The region has a humid tropical climate, with a very hot, dry period (November to February) and a long rainy period (March to October). Over the last ten years, the average annual temperature has risen from 31˚C to 37.1˚C, and even 49˚C in the hot season (February-March) [2]. Islets of forest and savannah [3] coexist and are mainly underlain by Birimian schists [4]. Intensive cocoa and coffee monocultures have largely contributed to accentuating the acidic conditions of the environment, modifying soil structure and depleting the soil of nutrients [5].

2.2. Methods

2.2.1. In Situ Soil Characterization

The soils of twelve villages in forest and savannah zones were characterized, in situ, using soil pits opened on topo-sequences [6]. Soil samples were taken from these pits, in the 0 - 30 cm layers, for analytical data.

2.2.2. Laboratory Soil Analysis

Soil samples were air-dried under cover, then sieved (2 mm) before being

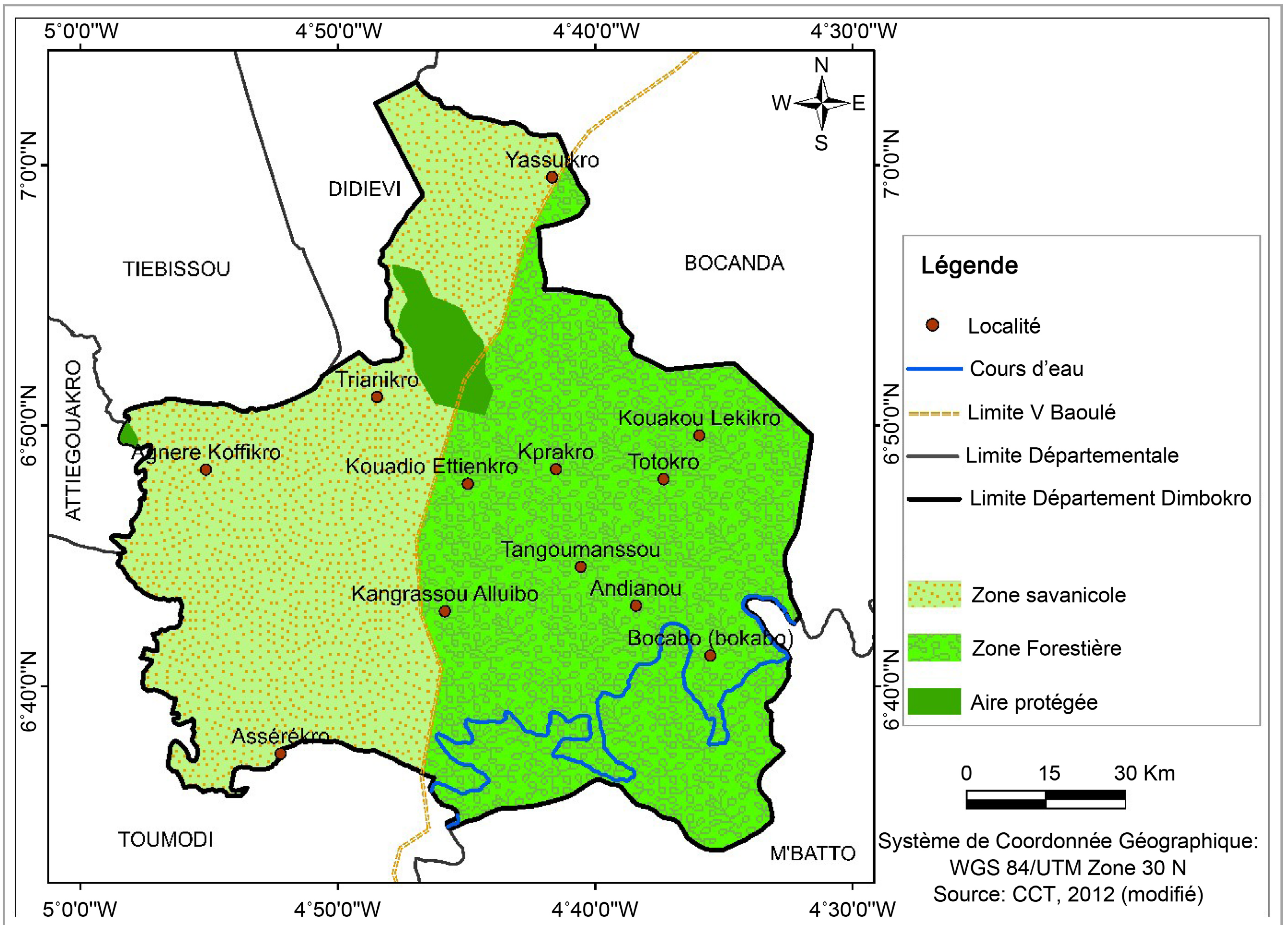

Figure 1. Location map of study sites.

ground. pH was determined using a glass electrode in a 1:2.5 ratio, as described by Thomas [7]. Soil organic C content was determined by the Walkley and Black method [8]. Granulometry was determined by the sedimentation method using the Robinson-Köhn pipette. Exchangeable bases (Ca, Mg and K) were determined by extraction with ammonium acetate buffered at pH 7.0 prior to atomic absorption spectrometer reading (Ca, Mg) and flame spectrometer reading (K). Total nitrogen (total N) was determined by the Kjeldahl method [9]. Mean values of soil parameters in savanna zones were compared with those in forest zones using analysis of variance (ANOVA).

3. Results

Physicochemical and chemical characteristics of Dimbokro's forest and savannah zones.

3.1. Soil Mineral Particle Proportions

Table 1 shows the average proportions (%) of sand, silt and clay in forest and savannah soils. In forest and savannah zones, sand, silt and clay contents are significantly different. In both forest and savannah soils, silt occupies almost half the mass of fine soil (45.87% - 53.52%). Sand and clay are moderately represented by medium to low contents, with a slight increase in clays at the expense of sands in the forest zone.

3.2. Organic Matter Characteristics (OM, N and C/N)

Table 2 shows the average contents of organic matter (OM), nitrogen (N) and the C/N ratio. Nitrogen is well represented in forest soils (0.07%) than in savannah soils (0.04%); ($p = 0.0001$). Organic carbon (C) concentrations recorded in forest and savannah soils indicate soils 2 to 3 times lower in organic matter. At all the sites studied, the ratio of carbon (C) to nitrogen (N) concentrations in savannah and forest soils was around 15.

3.3. Alkaline (K^+, Na^+) and Alkaline-Earth (Ca^{2+}, Mg^{2+}) in Forest and Savannah Soils

Average soil K^+, Na^+, Ca^{2+} and Mg^{2+} contents in forest and savannah soils are shown in Table 3. Overall, differences in content were noted according to vegetation type. Except for sodium (Na^+) ($p \geq 0.05$), soils under forest are more enriched ($p \leq 0.05$) in K^+, Ca^{2+} and Mg^{2+} than those under savannah. Ionic equilibrium ratios in the soils, all below 1, are similar from one zone to another, except for K^+/Mg^{2+}, which is almost 2 times greater in the forest.

3.4. Haracteristics of Adsorbent Complexes in Forest and Savannah Soils

The characteristics of adsorbent complexes in forest and savannah soils include

Table 1. Average proportions of sand, silt and clay in forest and savannah soils.

P-minérales	savannah	forestt	P ≥ F	E-T
sand (%)	27.5b	15.0a	0.0001	10.63
silt (%)	53.5b	45.9a	0.004	10.45
clay (%)	18.2a	37.8b	0.0001	13.47

P-minérales: mineral particles; E-T: standard deviation; Pr > F: probability threshold. In the same line, mean contents with the same letter (a or b) are identical. On the contrary, they are different with a < b at the 5% threshold.

Table 2. Average organic matter (OM), N and C/N content of forest and savannah soils.

P-chimiques	savannah	forest	P ≥ F	E-T
MO (%)	1.01a	0.80b	0.002	1.02
N (%)	0.04a	0.07b	0.0001	0.04
C/N	15.26a	15.49a	0.88	5.89

E-C: chemical elements; E-T: standard deviation; Pr > F: probability threshold. In the same line, mean contents with the same letter (a or b) are identical. On the contrary, they are different with a < b at the 5% threshold.

pH, cation exchange capacity (CEC), base saturation rate (V) and sum of exchangeable bases (S) (**Table 4**). Soils are acidic in savannah zones (pH = 5.8) and very acidic in forest zones (pH = 5.1). CEC (8.87 vs. 3.57) and S (1.62 vs. 1.22) values are higher ($p \leq 0.05$) in forest soils than in savannah soils, while adsorbent complexes appear more saturated with exchangeable bases in savannah soils ($p \leq 0.05$).

4. Discussion

4.1. Proportions of Mineral Particles in the Soils of the Sites Studied

In both forest and savannah zones, silt occupies almost half of the fine soil mass. Sand and clay are moderately represented. Soils are highly susceptible to capping [10]. In these areas, even the slightest rainfall is enough to make the soils very loose, more or less asphyxiating on the surface [11], as evidenced by the recorded capping indices, which appear to be very unfavorable [12]. Similarly, the predominance of silts exposes the soils of this locality to water erosion with loss of nutrients, as noted by Quittet in 1967.

Table 3. Average K^+, Na^+, Ca^{2+} and Mg^{2+} contents in forest and savannah zones, as well as ionic ratios.

P-chimiques	savannah	forest	p	ET
K^+	0.09a	0.11b	0.01	0.02
Na^+	0.08a	0.07a	0.89	0.05
Ca^{2+}	0.64a	0.79a	0.03	0.27
Mg^{2+}	0.39a	0.65a	0.01	0.37
K^+/Mg^{2+}	0.36a	0.22a	0.005	0.19
K^+/Ca^{2+}	0.16a	0.15a	0.61	0.06
Mg^{2+}/Ca^{2+}	0.60a	0.84a	0.06	0.48

P-C: paramètres chimiques; E-T: standard deviation; Pr > F: probability threshold. In the same line, mean contents with the same letter (a or b) are identical. On the contrary, they are different with a < b at the 5% threshold.

Table 4. Average characteristics of adsorbent complexes by zone.

P-chimiques	savane	foret	p ≥ F	E-T
pH	5.8b	5.1a	0.0001	0.61
CEC ($cmol \cdot kg^{-1}$)	3.57a	8.87b	0.0001	4.89
S ($cmol \cdot kg^{-1}$)	1.22a	1.62b	0.004	0.56
V (%)	52.65b	23.40a	0.0001	28.14

p-Chimiques: chemical parameters; E-T: standard deviation; Pr > F: probability threshold. In the same line, mean contents with the same letter (a or b) are identical. On the contrary, they are different with a < b at the 5% threshold.

4.2. Organic Matter Characteristics (OM, N and C/N)

Average nitrogen contents in forest and savannah soils of less than 1% to 2% appear low, indicative of nitrogen (N)-depleted soils [13]. Compared with normal levels in tropical soils [1.6% - 1.75%] [13], organic carbon (C) concentrations in forest and savannah soils indicate soils 2 to 3 times lower in organic matter (OM) [14]. This shows soils in conditions of low OM decomposition [15], justified by calculated C/N ratios above 15. Scarce rainfall and rising soil temperatures are factors that influence OM decomposition and the availability of nutrients such as N [16].

4.3. Alkaline (K^+, Na^+) and Alkaline-Earth (Ca^{2+}, Mg^{2+}) in Forest and Savannah Soils

Except for sodium (Na^+) ($p \geq 0.05$), soils under forest are more enriched ($p \leq 0.05$) in K^+, Ca^{2+} and Mg^{2+} than those under savannah. Ionic balance ratios in soils, all below 1, are satisfactory [17], indicating a better balance between soil nutrients, apart from that of K^+/Mg^{2+}, which is almost 2 times greater in forest soils. In soil situations where the observed K^+/Mg^{2+} ratio is greater than 2, the response to magnesium fertilization is systematic. Potassium uptake by crops decreases, while magnesium uptake increases [18].

4.4. State of Adsorbent Complexes in Forest and Savannah Soils

The CEC and S values obtained ($p \leq 0.05$) for forest and savannah soils compared with normal literature levels [19] are considered low. In addition, Dimbokro soils show severe limitations [20] due to CEC, which is low in forest zones and very low in savannah zones.

This results in very limited nutrient fixation on the adsorbent complex [20], justifying the low exchangeable base saturation rates recorded. pH values of around 5.5 provide the conditions for the fixation of sesquioxides, notably aluminum, manganese etc., on the clay-humus complex, with probable crop toxicity [16], one of the probable reasons for the drop in harvests observed among farmers in the area.

5. Conclusion

The present work was carried out in Côte d'Ivoire, in the Dimbokro region (6˚38'48" North and 4˚42'18" West). The aim was to characterize the physical and physicochemical properties of local soils and suggest recommendations for improving agricultural yields. The soils are acidic in forest zones and strongly acidic in savannah zones. In both forest and savannah soils, organic matter and nitrogen levels are low. The characteristics of the clay-humus complexes are moderately good. It is important to raise the pH levels of the soils at the sites studied by means of limestone amendments. The addition of organic matter in the form of compost is necessary to attenuate the defective characteristics of clay-humus complexes and silts. These different techniques would help improve the properties of these soils and mobilize certain chemical nutrients needed for better harvests in these populations.

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Conflicts of Interest

The authors declare no conflict of interest.

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