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Estimate of Organic Carbon Stocks of Some Soils under Cotton Growing in the North of Côte d'Ivoire: Case of Korhogo department.

Alui Konan Alphonse[1], N'Guessan Kouamé Antoine[1], Goure Doubi Bi Irie Herve[1]& Yao-Kouamé Albert[2].

Abstract

The present work, initiated in Korhogo, the north department of Côte d'Ivoire, aims to assess the level and the dynamics of the organic stocks of some soils under cotton crops through changes in the total amount of both carbon and nitrogen. For this purpose, we used rural sites under two main modes of soil management: plots of cotton growing and the shrubby savanna left fallow which was considered as the reference site. Tests including morpho-pedological characterizations and physico-chemical analyses were performed on soil samples and the organic carbon stocks were evaluated. The characterized soils are of Cambisol type with amajorpedogenetic phenomenon of reworking. Combination of the organic matter with concretions and ferruginized nodules gives the soils their characteristic brown coloring. The dynamics of the organic matter stock in these soils indicate that their continued cultivation results in an acceleration of the mineralization (C/N = 1.2 to 2.12) and as a result, a decrease in the organic matter stock (2.07 to 2.31 t/ha for soils under cotton growing against 9.42 to 9.81 t/ha for soils under fallow).

Keywords: Carbon Organic, Cambisol, Culture of Cotton, Organicmatter.

1. Introduction

The northern Côte d'Ivoire soils are very solicited and cultivated for several decades for the production of crops including mangoes, cashews, vegetables, cotton, without the slightest concern for the organic stock reconstitution. It is well-known that the soil cultivation, especially the agriculture intensification, coupled with the non-restitution of crop wastes contributes to the depletion of soilinorganic matter, with decrease rates in the order of 2 to 3% (Le Villo*et al.*, 2001). The organic matter plays a mainly role in maintaining the soil physical properties (Le Villo*et al.*, 2001).Several works highlight the strong positive correlations that exist between organic matter and structural stability of soil on which depend porosity, runoff, erodibility (Le Bissonnais et Arrouays, 1997) or the cohesion of the other constituents of the soil (Balesdent, 1996). Furthermore, the presence of organic matter in the soil can indirectly contribute to improve aeration, root penetration, water infiltration, the resistance of the soil to compaction and thus limiting the risk of erosion and/or soil loss (Balesdent, 1996).

Accordingly, it seemed appropriate to conduct the present work to estimate the rate of the organic stock of some soils under cotton growing in northern Côte d'Ivoire (Korhogo).Specifically, (i) the dynamics of this organic matter was appreciated, mainly through the variations of the total amounts of both carbon and nitrogen, and (ii) their effect on other solid constituents of the soil was assessed, especially the change in the values of C/N ratio which is considered as one of the major indicators of organic matter mineralization.

2. Materials and methods

2.1. Geographical setting

[1]UniversitéPeleforo GON COULIBALY Korhogo, UFR des Sciences Biologiques, Département de Géosciences. email: aluialphonse@gmail.com
[2]Université Felix HOUPHOÜET-BOIGNY, UFR des Sciences de la Terre et des RessourcesMinières, Département des Sciences du Sol.

The works were carried out in Korhogo department (north of Côte d'Ivoire). The relief of the investigated area is monotonous, with altitudes varying, on average, between 300 and 400 m. However, graniticinselbergs sometimes, rising to more than 500 m of altitude exist in the landscape. The department consists of lateritic plateaus that may exceed three meters high, witnesses of oldpeneplains. These plateaus are affected by a very weak and regular slope. The average annual rainfall is around 1200 mm. The area consists of forest galleries, woodland and shrubby savannah (Brou, 2005).The geological formations of the zone are made up of a succession of bands of schistosemigmatite and plutonic rocks.They are essentially granites, granodiorites, undifferentiated schists and sericitousschists (Yacé, 2002), from which several types of soils are derived, namely: Ferralsols, Cambisols, Fluvisols and Luvisols (Koné*et al.*, 2009). The selected areas are the sites situated around the villages of Zonguitakaha and Kafiguekaha (Fig 1).

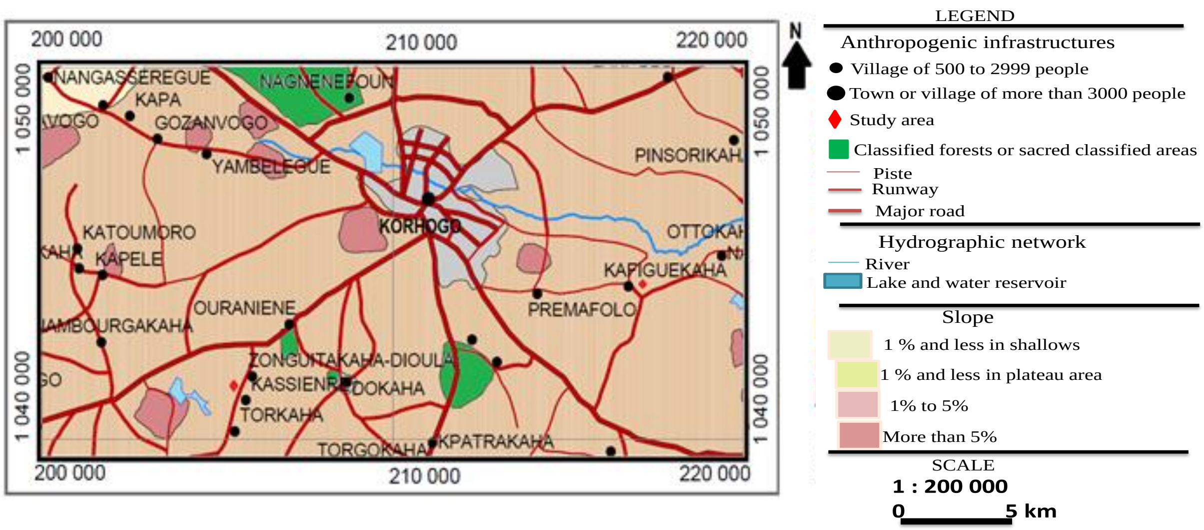

Fig 1: Geographical location of thestudied sites

2.2. Experimental devices

Experimental devices are composed of sites in the rural medium under two main modes of land management including the cotton growing plots and the shrubby savannah in fallow. Four (04) cotton plots, with two (02) in the Zonguitakaha area and two (02) in the Kafiguekaha area, were selected. These parcels are continuously cultivated for more than three years. The plowing is done using the plows at an average depth of 10 cm. Mineral fertilizers are usede very year for cotton growing. The reference sites at the two localities are derived from the medium-dense tree shrub savanna Anogeissusleiocarpu, Piliostigmathonningii and Parkiabiglobos. According to the farmers, the fallows used as reference sites are not cultivated for more than five years. But, this savanna is sometimes burned accidentally.

2.3. Morpho-pedological characterization of soils

For each culture parcel or reference, five (05) pedological pits of 100 cm x 80 cm x 120 cm in dimension, including four (04) at the top and one (01) in the middle of the field, were opened and described. In each case, composite samples of soils were made up from the ones collected at the level of three horizons (0-20, 20-40, 40-60 cm). The sampling was performed at all four sides of each profile and in each of the above-mentioned soil horizons. For the various laboratory analyzes, we selected a total of thirty-six (36) composite samples, eighteen (18) per site.

2.4. Physical and physico-chemical characterization of soil samples

The apparent density (da, g.cm^{-3}), which is the mass of a volume unit of soil dried at 105°C was taken into account in this study. It was measured by the cylinder method (Blake et Hartage, 1986). The analyses were consisted of the determination of the granulometry, pH, total carbon (Walckley et Black, 1934); and total nitrogen by Kjeldahl method (Bremner, 1965).

2.5. Evaluation of the organic carbon stock

The estimation of the organic carbon amount (q) was calculated according to equation (Eq 1) (Belkacem*et al.*, 1998;Evans*et al.*, 2001)

$$\boldsymbol{q(i) = 0.1 \times da(i) \times Ci} \qquad \text{(Eq 1)}$$

Where

- q(i):$C_{organic}$ content in the horizon (i) in the soil ($t.ha^{-1}$)
- Ei: thickness of the horizon (i) (cm)
- da(i): apparent density of the fine fraction (<2 mm) in the horizon (i) ($g.cm^{-3}$)
- Ci: organic carbon concentration in the fine earth for the horizon (i) ($g.kg^{-1}$)

The total amount of carbon (Q) in the soilup to a selected depth is the sum of the quantities in each horizon:$\boldsymbol{Q = \sum(q(i))}$.

2.6. Statistical analyses of the data

The different performed measurements underwent an analysis of variance, followed by the Tukey post-ANOVA test. The statistical difference between carbon and other parameters of analyzed soil is identified with the Pearson correlation test. These statistical analyses were performed using the STATISTICA 7.1 software.

3. Results and discussion

3.1. Morphological characteristics of the soils of the different sites

3.1.1.Cultivated soils

The cultivated soils collected from the surface horizons at (0-20 cm) have a greyish- or dark-brown coloration with red speckles. Most of these horizons are fresh and dry. The textures of soils predominantly vary from loamy to sand-clay (fine and coarse sand) with sometimes a particulate, polyhedraland/or sub-angular structure. These soils are more or less coherent and porous with horizons of types A2, AB, B1 and B2. Many millimetric and centimetric roots are observed at a certain level. The horizon depths of (20-60 cm) are brown, cool, dry, apparently free from humus inochercolor. They have a low porosity and possesssub-angular polyhedral structures. Their texturesare mainly of clay-sand-silty having rare sub-horizontal millimetric roots with drainage classes around 6.8.

3.1.2. Soils of short-duration fallows

Most of follow soils collected from the surface horizons of (0-20 cm) are characterized by a greyish brown coloration. These horizons are fresh and dry with textures ranging from loamy to sand-clay (fine and coarse sand) possessing a particulate, polyhedral and/or sub-angular structure. These soils are more or less coherent and porous with horizons of types A1, A2. There are many millimetric and centimetric roots at a certain level. In horizons of (20-60 cm), the soils are brown, fresh with a dry tendency apparently free from humus in ocher color with low porosity. The structure is mainly polyhedral sub-angular with a siltyclay loamtexture. The few rare roots observed are millimetric sub-horizontal with drainage classes around 4.2.Most of the prospected soils are Cambisols with a major pedo-genetic phenomenon of reworking regardless of the management mode. However, a slight rejuvenation is observed at mean depth.

3.2. Physical characteristics of the studied soils

The table 1 shows the average values of the physical elements characteristic of the soil horizons as a function of the depth and the management mode. The clay (A) content of the soil increases from the surface to depth regardless of the management mode. The values obtained (43.67 to 56.37 $g.kg^{-1}$) do not have a significant difference (F_{cal} = 1.44, $P_{cal} \geq 0.05$) according to the statistical analyses. The silt content (fine and coarse) varies very little regardless of the soil depth. These contents do not exceed more than 4 kg^{-1} and do not have a major significant difference. The apparent density values are lower at short-duration fallow sites (< 1 $g.cm^{-3}$) than the ones of cotton crops soils (> 1.30 $g.cm^{-3}$).

3.3. Physicochemical characteristics of the studied soils

The pH of soils expresses the acidity and ranges from 1 to 14. It provides information about the nature of the rocks on which the soil is formed and also about the activity of microorganisms. Results reported in table 2 indicate that soils of short-duration fallow sites less acidic (pH = 6 - 6.6) in comparison to those of the different crops(pH = 5 - 6).

The statistical analyses performed on the acidity of the different soils indicate a significant difference (F_{cal} = 21.78*, $P_{cal} \leq 0.05$). Carbon, nitrogen and organic matter contents decrease with soil depth, and vary according to the different management methods. They are higher in fallow soils (C = 1.62 to 2.27 $g.kg^{-1}$; N = 0.2 to 0.28 $g.kg^{-1}$ and OM = 2.61 to 3.90 $g.kg^{-1}$). The C/N ratio values are higher in fallow soil horizons (7.6 to 9.19) than those in cotton growing soils (1.5 to 2.12).

Concerning the carbon stocks (Q), the data indicate that they are relatively higher (9.42 to 9.81 $t.ha^{-1}$) in fallow soils than those containing in cotton crops (2.07 to 2.31 $t.ha^{-1}$).

Table1:Physical characteristics of the studied soils

Test areas	Experimental devices	Depth (cm)	Granulometry ($g.kg^{-1}$) and apparent density ($g.cm^{-3}$) of the soils samples					
			A	**Lg**	**Lf**	**Sg**	**Sf**	**Da**
Zonguitakaha	Short-duration fallow	0-20 cm	43.67 a	3.31 a	2.02 a	42.06 a	8.96 b	0.68 b
		20-40 cm	53.56 a	3.01 a	1.32 a	17.78 a	24.34 a	0.97 b
		40-60 cm	54.12 a	3.37 a	1.65 a	30.24 a	10.62 b	0.98 b
	Cotton crop	0-20 cm	56.35 a	2.11 a	0.12 a	32.11 a	9.31 b	1.37 a
		20-40 cm	57.3 a	1.18 a	0.21 a	31.13 a	10.18 b	1.33 a
		40-60 cm	54.37 a	3.11 a	1.09 a	32.12 a	9.31 b	1.34 a
Kafiguekaha	Short-duration fallow	0-20 cm	46.35 a	2.63 a	1.33 a	40.47 a	9.22 b	0.62 b
		20-40 cm	55.62 a	2.23 a	1.07 a	32.04 a	9.04 b	0.94 b
		40-60 cm	56.13 a	2.04 a	1.54 a	29.27 a	11.02 b	0.96 b
	Cotton crop	0-20 cm	55.44 a	2.06 a	0.14 a	32.04 a	10.32 b	1.35 a
		20-40 cm	56.18 a	1.22 a	1.23 a	31.06 a	10.31 b	1.31 a
		40-60 cm	56.37 a	1.11 a	1.05 a	32.23 a	9.24 b	1.32 a
	F calculated		1.44 ns	2.14 ns	1.47 ns	3.22 ns	24.62*	37.38 *
	P calculated		0.41	0.00	0.42	0.18	0.011	0.024
	P theoretical		≥ 0.05	≥ 0.05	≥ 0.05	≥ 0.05	≤ 0.05	≤ 0.05

The average~~s~~ values affected by the same letter, in the same column, are not significantly different, at the threshold α = 0.05, according to Tukey's method. ns = not significant; * = significant.

Table 2: Physicochemical characteristics of the studied soils

Test areas	Experimental devices	Depth (cm)	Acidity, Organic matter ($g.kg^{-1}$) and organic carbon stock($t.ha^{-1}$)						
			Water pH	C	OM	N	C/N	q	Q
Zonguitakaha	Short-duration fallow	0-20 cm	6.4 a	2.27 a	3.90 a	0.27 a	8.40 a	3.08 a	9.81 a
		20-40 cm	6.2 a	1.93 ab	3.31 ab	0.21 a	9.19 a	3.74 a	
		40-60 cm	6.1 a	1.52 ab	2.61 ab	0.2 a	7.6 a	2.97 a	
	Cotton crop	0-20 cm	5.3 b	0.34 b	0.58 b	0.16 b	2.12 b	0.93 b	2.31 b
		20-40 cm	5.6 b	0.28 b	0.48 b	0.14 b	2 b	0.74 b	
		40-60 cm	5.5 b	0.24 b	0.41 b	0.12 b	2 b	0.64 b	
Kafiguekaha	Short-duration fallow	0-20 cm	6.3 a	2.12 a	3.64 a	0.28 a	7.57 b	2.6 a	9.42 a
		20-40 cm	6.2 a	1.97 ab	3.38 a	0.23 a	8.56 b	3.7 a	
		40-60 cm	6.2 a	1.61 ab	2.76 ab	0.21 a	7.66 b	3.09 a	
	Cotton crop	0-20 cm	5.2 b	0.34 a	0.58 b	0.16 b	2.12 b	0.9 b	2.07 b
		20-40 cm	5.6 b	0.23 a	0.39 b	0.15 b	1.53 b	0.6 b	
		40-60 cm	5.4 b	0.21 a	0.36 b	0.14 b	1.5 b	0.55 b	
	F calculated		21.78*	33.52*	44.67*	56.43*	97.63*	26.45*	147.75**
	P calculated		0.047	0.036	0.038	0.023	0.015	0.045	0.0076
	P theoretical		≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.01

The ~~averages~~ values affected by the same letter, in the same column, are not significantly different, at the threshold α = 0.05, according to Tukey's method. ns = not significant; * = significant.

3.4. Relations between the organic matter stocks, the acidity and the physical characteristics of the investigated soils

The different correlation tests carried out between the organic carbon stocks, the acidity and the physical characteristics of the soils yielded several levels of significance (table 3). Thus, at the fallow sites, the most significant correlations were observed between the stocks of organic matter and the clay content on the one hand and between the organic matter stocks and the C/N ratio on the other hand. The pairs of variables (Q – A and Q – C/N) obtained have a correlation coefficient of r = 0.82 and r = 0.86 respectively. For cotton growing sites, organic matter stocks are negatively correlated with: the fine silts (Lf) with correlation coefficient r = -0.91; and with the apparent densities (Da) for r = 0.87 and at C/N ratios with r = 0.85.

Table 3:Correlation between the soils parameters of the different management modes.

Soil management mode	pair of variable	Correlation coefficient r	r^2	t	(Pr> |t|)	Significance
Short-duration fallow	Q - A	0.82	0.6724	9.21	0.0112	*
	Q - C/N	0.86	0.7396	3.42	0.0268	*
Cotton crop	Q - Lf	-0.91	0.8281	-4.28	0.0128	**
	Q - Da	0.87	0.7569	3.62	0.0222	*
	Q - C/N	0.84	0.7056	3.19	0.0332	*

* = significant, ** = highly significant.

4. Discussion

The morpho-pedological descriptions carried out on the different soils indicate that most of them are Cambisols and therefore of the same pedological type. In fact, the soils observed are very rich in coarse elements, mainly ferruginized concretions and nodules, coated by an organic matter cortex, which confer the particular brown color as it has been shown in the earlier work of Yobouéet *al.* (2018).

The correlation test carried out shows that the organic matter stock (Q) is positively correlated (r = 0.82) with the clay content (A) at the soil level submitted to short-duration fallow. This could be explained by the fact that at the level of Cambisols, clay provides physical protection for organic compounds when the latter are absorbed or located in the pores of the mineral fraction. This observation was also made by Pallo et al. (2008) at the level of the Cambisols of Burkina Faso and widely admitted in the literature (Arrouays*et al.,* 2012). With total organic matter content of the order of 0.36 to 0.58 $g.kg^{-1}$, soils under cotton crops can be considered as very poor, according to the work done by Pallo et al. (2008). Generally, the organic matter content is not very high in the soils under cotton crop because of the high temperature and moisture conditions that accelerate the mineralization on the one hand, and because of their cultivation by repeated plowing for many years on the other hand (Grosbellet, 2008). Indeed, the plowing appears to be the main cause of the decrease in carbon contents, and in the stock of organic matter that accompanies the degradation of the soil structure (Ben Hassine*et al.,* 2008).

The relative richness of total organic matter in soils under fallow (2.76 to 3.90 g.kg-1) can be explained by the fact that many shrubs release a lot of plant debris that decompose to provide organic carbon, as shown by Le Villo et al. (2001) during their works on the estimates of the quantities of organic matter from some French loam soils with a view to their restoration and maintenance. The soils under short periods fallow have relatively high levels of organic matter because, as observed during the works of Pallo et al. (2009), the non-tillage atcertain relevant time induces an accumulation of the total carbon associated with an increase in soluble carbon and microbial biomass.

The analyses of the collected soil samples show that regardless of the management method, the surface horizons possess higher amount in organic matter than those located indepths. In fact, the organic matter will first concentrate in the surface horizons before being subsequently transferred to the deepest soil levels. However, only a small part of the organic matter is transferred toward the depth under the action of the hypodermic runoff water (Eglin, 2005). Therefore, the different management methods considered mainly affect the C content of the superficial horizons. Assuming that these soils were initially identical, the results of our investigations indicate that organic C stocks have significantly decreased in soils under cotton growing.

The positive and significant correlations observed between organic carbon stocks and C/N ratios regardless of the soil management mode, reflect the speed of decomposition of organic matter.In the case of soils under cotton growing, the very low values of the C/N ratio (1.5 to 2.12) indicate a more or less accelerated mineralization according to the aeration of the soil with low contributions of crop residues correlated with the soil erosion (Eglin, 2005).For fallow soils, the C/N values (7.6 to 9.19) which strongly affect nitrogen mineralization, indicate that the latter is almost slow. This can be explained by the fact that the stock of raw organic matter is constantly renewed (Duguet, 2005). Indeed, fallow soils are covered by vegetation that regularly provides them with plant debris; however, it is known that the accumulation of organic matter could give rise to a surplus of nitrogen (not taken by the plants) with all the consequences that this can induce (Eglin, 2005).

5. Conclusion

The plants that cover the fallow soils as well as their content in various coarse elements, mainly ferruginized concretions and nodules constitute organic matter traps for these soils. But the stock of this organic matter decreases considerably as a result of their continuous cultivation. The decrease in organic matter, which is more sensitive in the case of soils under cotton crops, is also observed in the more clay-rich horizons. The decomposition speed of organic matter is much faster in soils under cotton growing and tends to normalize in fallow soils. It is noted that the more the soil is grown continuously, the lower the carbon content and the pH are.

The restoration of the quality of the soils requires an increase in the amount of organic carbon. For example, the use of cultivated land and agricultural practices that aim to store carbon sustainably in soils could play an important role in the fight against global warming. Therefore, our study suggests as a first perspective, for soils under crops, a substantial contribution of organic matter from composting, in order to stabilize the clays, limit leaching and increase the soil CEC. In a second time it seems important to practice a fallow even if it is not long (at least 5 years). The crop rotation deserves to be encouraged in the case of soils under cotton crops since such soils become increasingly poor, compacted and therefore degraded.

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