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Inventory of Soil Pollution by Chemical Fertilizers in the Cotton Growing Area of Togo: Case of Kolo-Kope

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Abstract: The search for higher and higher agricultural yields leads to the use of chemical fertilizers and phytosanitary products. The abusive or repeated use of these agricultural inputs results in soil, surface water and groundwater pollution. With the development of this new form of agriculture, the input of heavy metals to the soil has increased. Research on the fate of these pollutants in the environment is important. It is within this framework that this study was undertaken to evaluate the level of pollution due to trace metals in soils in the cotton growing zone in southern Togo. Soil samples were taken in cotton fields during the dry season. The first analyses led to the determination of some physico-chemical characteristics of the soils including pH, granulometry as well as the cation exchange capacity (CEC). These first two parameters revealed that the soil was slightly acidic and essentially clayey in texture. Then, after mineralization of the soils, the solutions obtained were analyzed with an atomic absorption spectrophotometer (AAS). Twelve (12) metals (V, Cd, Hg, Na, Cr, Ni, Sn, Pb, As, Zn, Cu, Fe) were studied. The concentration of metal ions varies from 0.0038 mg/kg (for vanadium to 5647.31 mg/kg (for iron). The order of abundance for the elements is as follows: V< Ni < Cr < Cd < Na < Hg < Sn < As < Pb < Cu < Zn < Fe. The values found during the analyses compared to the French standards (0.7mg/kg for Cd and 60 mg/kg for Pb) shows that no investigation threshold is reached.

Keywords: Soil, Granulometry, Pollution, Agricultural Inputs, Metallic Trace Elements, Investigation Threshold

1. Introduction

Cotton is one of the major cash crops in Africa and is characterized by intensive use of chemical inputs. It is estimated that two to three million households in West and Central Africa grow cotton on fields averaging 1 ha in size) [1]. West Africa is the fourth largest cotton exporter in the world, displaced from third place by India and threatened by Brazil [2]. In 2008, of the eight countries in the WAEMU space (Benin, Burkina Faso, Côte d'Ivoire, Guinea Bissau, Niger, Mali, Senegal, and Togo), Togo was the fifth country in terms of superficie (159,000 ha out of a total of 1,656,000 ha) and tonnage (190,000 tons out of a total of 1,699,000 tons) of cotton cultivation, ahead of Senegal, and the second (1196 kg/ha) in terms of yield, behind Côte d'Ivoire [3, 4].

The soil, in its role as a support for production and plant cultivation, is a heritage whose sustainable management must be a major concern, because of its role as a vital interface between the biosphere, man and the environment and its practically non-renewable character on the scale of human generations [5]. Agriculture is one of the main sources of income in developing countries whose industrialization is a very recent fact. In Sub-Saharan Africa, soil degradation is one of the main causes of low agricultural productivity and food insecurity [6, 7]. The decrease in fertility is mainly explained by a demineralization of the soil in carbon elements, major plant elements (N, P, K) and secondary elements (B, S, Mg...) [8, 9]. It is in this perspective that industrial engineering appeared to relieve both the agricultural and industrial world by the massive production of chemicals such as chemical fertilizers to intensify agriculture. Agricultural inputs make it possible to increase agricultural yields, but their use, even with precaution, can present risks, the most important of which are toxicity to humans, damage to biodiversity, imbalances in fauna and resistance of the intended targets [10].

It is therefore important to evaluate the impact of this use on the health of populations and the environment and to monitor the fate of these different inputs used in cotton cultivation. It is within this framework that this study is situated, the main objective of which is to take stock of soil pollution by chemical fertilizers in the cotton-growing zone in a humid savannah agricultural research center in Kolo-Kopé, Togo.

2. Materials and Methods

2.1. Study Setting

The site chosen for this study is an experimental area on which cotton is grown every year and other experimental plants are also grown. The site is a very large area of about 400 ha with areas that are regularly cultivated, others that are fallow and areas that are never cultivated. The cultivated plots receive the same types of crops each year for several years before going into fallow.

The Wet Savannah Agronomic Research Center (CRA-SH) in Kolo-Kopé is located 12 km east of the town of Anié on the right bank of the Mono River. Located at 74 meters above sea level, Kolo-Kopé has the following geographic coordinates: 6°27'53" N and 1°14'2" E in DMS (degrees, minutes, seconds) or 6.46472 and 1.23389 (in decimal degrees) (figure 1).

Figure 1. *Sampling site.*

2.2. Sampling

Samples were taken from four different sites in the domain: the first site has never been logged (No. 1), sites No. 2 and No. 3 are regularly logged, and the last site has been fallow for more than a decade (No. 4). Site 2 is subdivided into several plots grouped in small clusters of five. Plots in the same group receive identical treatments. But from one group to another, the treatments are different and are defined as follows:

L+ 1/2D: ploughed soil receiving half a dose of fertilizer (S6).

L+ D: ploughed soil receiving a normal dose of fertilizer (S5).

Space N°3 receives an overdose of fertilizer at 200kg/ha (in N. P. K-SB) + 50kg/ha (for urea) (S4).

NL+PG+D: Unplowed soil + mulch (soil covered with cotton stems) with Normal Dose of fertilizer (S3).

L+TPC+D: Ploughed soil and receiving Terre de Parc (sheep waste) with Normal Dose of fertilizer (S2).

The Normal Dose of fertilizer used for both types of fertilizer is 150kg/hectare (for NPK) + 50kg/ha (for urea).

In the following, the spaces No. 1 and No. 4 will be named respectively (So) and (S1).

A total of seven (7) soils were sampled. At the level of each soil, samples were taken from two horizons (0 - 20 cm and 20 cm - 40 cm). Figure 4 shows the appearance of the sampled soil.

The samples were taken according to the method described by (Mathieu and Pieltain) [11]. which consists of making delimited areas of 10 m x 10 m in the middle of the field inside which nine (9) samples were taken between 0 and 20 cm deep, (Figure 2). The elementary samples taken are mixed to constitute pre-treated composite samples (homogenization - quartering - air drying - sorting and clod reduction - sieving) for the different analyses.

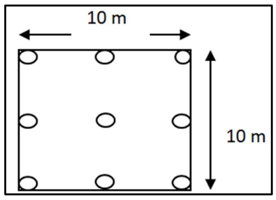

Figure 2. *Soil sample collection method.*

Figure 3. *Hand auger.*

Figure 4. *Aspect of the soil sampled in dry season.*

2.3. Analysis of Trace Metals

The samples taken in the plastic bags are dried at room temperature (27°C) for two weeks and finely ground. The grindings are sieved to 63 µm then mineralized for the various physicochemical analyses with the SAA Atomic Absorption Spectrophotometer brand iCE 3000 SERIES THERMO FISCHER but coupled to the VP100 hydride generator for the analysis of arsenic.

3. Results and Discussion

3.1. Physico-chemical Parameters: Granulometry, pH-metry and Organic Matter

The particle size distributions of the two horizons for the sampled areas are similar and give the following values: Clay: 47%, silt: 20%, fine sand: 33%. The results are shown in figures 5a and 5b.

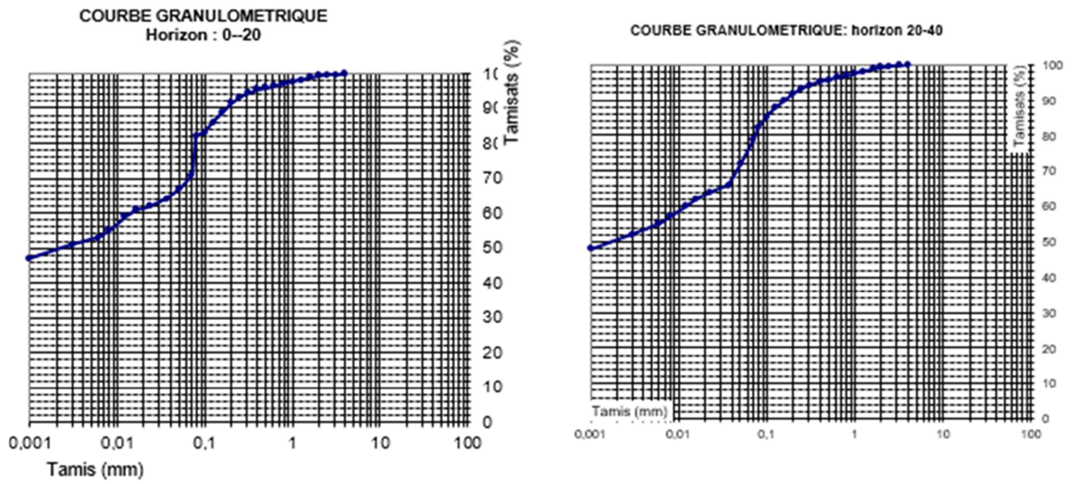

Figure 5. *a Curve of granulometry in horizon 0-20 cm; b Curve of granulometry in horizon 20-40 cm.*

The pH ranges from 6.230 to 6.80 depending on the soil samples. All the soils are relatively acidic.

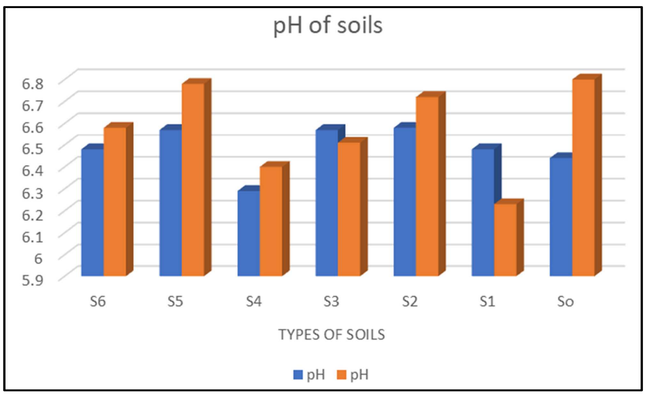

Figure 6. *Soil pH by horizon.*

The highest organic matter levels are found in the control soil (8.7948%) for the surface horizon and 6.1536% for the 20-40 cm horizon. It can be said that the abundance of organic matter decreases mainly with depth. The average content of the two horizons combined is similar. However, considering only the surface horizons of the exploited areas, OM concentrations remain relatively low and are between 3 and 4%, reflecting the progressive depletion caused by the use of soils for cotton cultivation, without regular organic fertilization (S6, S5, S4). The highest OM content (8.7948%) found for the surface horizon of the control soil is explained by its non-use since the creation of the CRASH research center and permanently under forest cover. Thus, it benefits from conditions that are conducive to OM enrichment.

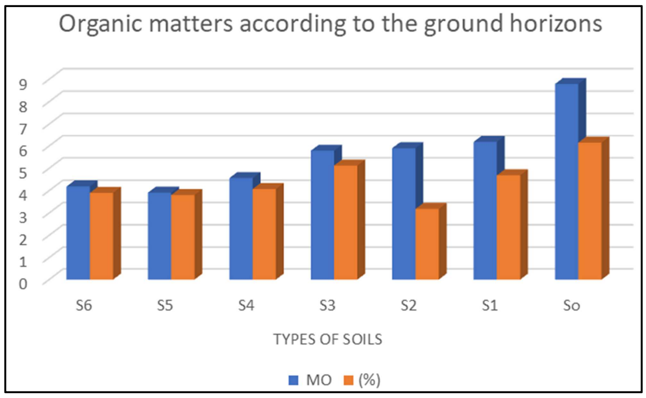

Figure 7. *Organic matter content of soils according to horizons.*

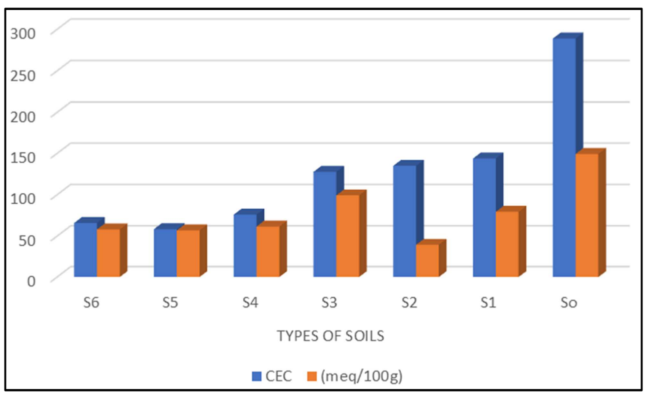

Figure 8. *Cation exchange capacity of soils according to horizons.*

3.2. Total Contents of Trace Metal Elements in the Samples

3.2.1. In Fertilizers

Table 1. *Below shows the results of the fertilizer analyses.*

samples	Cu (mg/Kg)	Pbb (mg/Kg)	As (mg/Kg)	Cd (mg/Kg)	Zn (mg/Kg)
NPK-SB 12-20-18-5-1	0,52	0,59	*0,89818*	9,16	22,64
Urée 46%	0,62	0,11	0,20399	n. d	0,09

The NPK fertilizer contains all the studied metallic trace elements. Their order of abundance is as follows: Cu < Pb < As < Cd < Zn. In urea, concentrations range from non-detectable (nd) for cadmium to the highest value 0.62 mg/kg for Cu.

3.2.2. In the Soils

In both horizons of the seven sampled soils, total concentrations were measured for the twelve (12) MTEs studied. The iron whose content is the most removed (between 4247.46 and 5647.31 mg/kg) compared to other elements is followed by the elements Zn and Cu whose contents are respectively between 13.79 and 22.69 mg/kg and between 8.73 and 19.48 for all horizons combined. The elements V, Sn, Ni, Cr, Cd, Hg and Na are weakly represented while As and Pb are moderately present.

The approximate order of abundance is as follows: V< Ni < Cr < Cd < Na < Hg < Sn < As < Pb < Cu < Zn < Fe.

These concentrations are expressed using the figures (Figures 2a and 2b).

Considering the difference between the values, the contents of the different elements are represented by groups: the elements of low contents whose concentrations do not exceed 1mg/kg of soil are gathered in the group A then the elements whose values of concentrations are included between 1 and 23 mg/kg make from the group B. Iron is not represented because of its very high value.

The TME contents of soils S6, S5 and S4 are such that TS6 < TS5 < TS4. This can be explained by the fact that they respectively receive increasing doses of fertilizer and that these soils are of the same nature, i.e. they belong to the same domain without other inputs with the same particle size and similar pH (in short, similar physico-chemical properties). Therefore, the kinetics of the TMEs would also be similar, resulting in the same order of contents in the deep horizons.

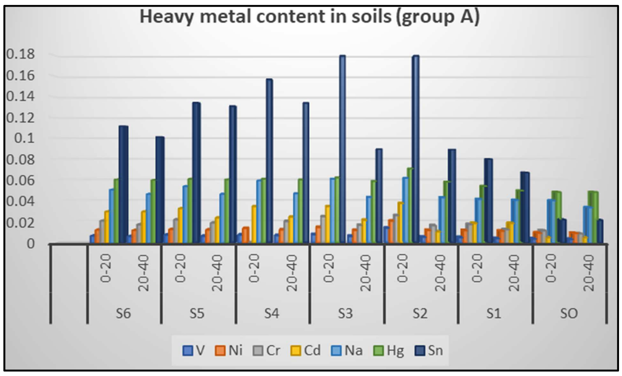

Figure 9. *Heavy metal content whose concentrations are less than 1mg/kg of soil.*

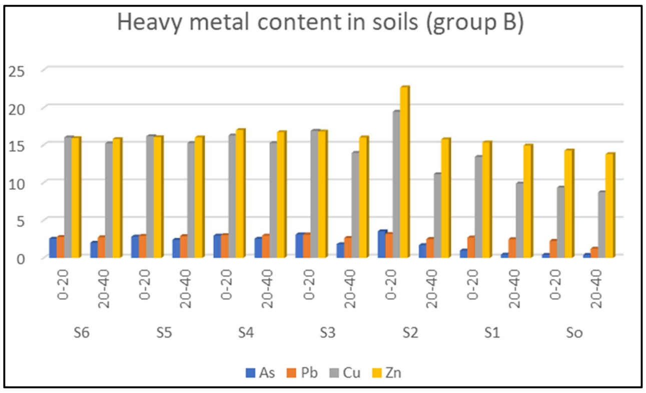

Figure 10. *Heavy metal content whose concentrations are between 1 and 23mg/kg of soil.*

The figures also show that the surface horizons have the highest concentrations. This situation can be attributed to the fact that surface horizons are richer in organic matter than deep horizons. Many researchers have already discussed the subject that the richness in organic matter of a soil increases its retention capacity [12]. This analysis help to explain why the two amended soils (NL+PG+D and L+TPC+D) have the highest concentrations. In fact, the difference in fertilizer dose between these two soils and the overdosed soil is only 50 kg NPK/ha. It is the amendment of these two soils that is responsible for the high concentration values. The amendment has enriched the soil in organic matter by allowing it to increase its water retention and infiltration capacity [13].

The horizons of the control soil have the lowest content, followed by the fallow soil. After more than a decade of fallow, the lead content of the fallow soil has evolved towards that of the control soil.

The lead values of the two horizons are constant with an average of 3.02 for the 0-20 cm horizon and 2.9 for the 20-40 cm horizon.

3.3. Comparative Studies of Results

The variation of the pH is one of the parameters influencing the mobility of metals in the soil. An acidic soil favors the mobility of elements while a basic soil maintains the immobility of heavy metals [14].

The average pH of the samples is 6.54. These values show that the soil has an acid pH. The work of BAFAI (2014) and Mawussi (2008) also showed that the soil of Kolo-kopé is acidic with an average pH of 6.29 for Bafai and pH values between 6.13 and 6.43 for Mawussi who worked in three different areas of kolo-kopé.

Our travauw displayed a granulometric texture with dominant clay (47%) against 27% for Bafai and a maximum of 28.25 for Mawussi [15, 16].

In Togo, there are no reference standards for TME content in soils. The interpretation of the results found are compared with those from the literature.

In reality, a threshold value of a standard can only serve as a "warning signal" above which a more detailed investigation is necessary.

Table 2 allows to compare the levels of different elements in the soils studied with the proposed threshold values expressed in mg/kg of the decree of January 8, 1998 in France and with the German recommendation by use (recreational areas). The values in the tables will serve as a comparison [17].

Table 2. *Some threshold values (mg/kg).*

ETM	Some threshold values (mg/kg)						
	Ni	Cr	Cd	Pb	As	Cu	Zn
French	50	150	20	100		100	300
Germany			1 à 15		20 à 80	50 à 600	150 à 3000

4. Conclusion

During this study, the state of chemical pollution of the soil of the CRASH experimental space of Kolo-kope was evaluated. To achieve this objective, the total concentrations of ETM were measured in the highlighted soils.. In addition, the surveys of farmers at the CRASH site revealed information that allowed to estimate that the only inputs of TMEs to agricultural soils are due to crop inputs and atmospheric deposition. Therefore, the inflows linked to cultivation practices are almost nil, at least since the establishment of this center. This can explain the small difference observed between the control values and those of the exploited areas. Among the TMEs studied, the largest inflows are observed for Cu and Zn and more strongly for iron. According to the results of the analyses, it appears that the cultivated soil is more enriched than the control soil. There is therefore contamination of the site. The most abundant elements, including Cu and Zn, have concentration differences with respect to the control soil of approximately 10.12 and 14.93 mg/kg respectively at the 20-40 cm horizon. In the enhanced soils, the most represented TMEs in both horizons are still Cu and Zn with extreme values of 19.48 and 22.69 mg/kg. The results reveal a more accentuated contamination of copper compared to zinc. To assess the risk of pollution, the levels of the elements are compared to those of the threshold values of France (Baiz) and Germany due to the lack of existence of national values. This comparison reveals a slow contamination of the site but rules out the provisional risk of pollution.

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