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Research Paper

Effect of Agricultural Inputs on the Water-soil Couple in Cocoa-growing Area in the Department of Soubré, Southwestern of Côte d'Ivoire

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ABSTRACT

Background: The cocoa crisis in the 1970s decade in Côte d'Ivoire was manifested by the proliferation of crops pests, reduced production and decreased rainfall. To cope with all these constraints, the producers adopted various strategies, including the use of agricultural inputs to improve the production. Thus, this study aimed to characterize the effects of these inputs on water-soil couple.

Methods: First, 12 soil and surface water samples were taken for analysis. Second, the determination of trace metal content was done using an atomic absorption spectrophotometer (AAS). Also, chemical elements were analyzed using a HACH DR 6000 spectrophotometer.

Results: Soil concentrations of exchangeable base Ca^{2+}, K^{+} and Mg^{2+} are low with average values of 5.71 cmol/kg, 0.35 and 1.66 cmol/kg, respectively. The soils of cocoa orchards are quite rich in assimilable phosphorus (P). The average phosphorus content is 24.31 cmol/kg with a minimum of 3.92 cmol/kg and a maximum of 78.4 cmol/kg. The study of surface water quality showed that the average values of biochemical oxygen demand for 5 days (BOD_5) (18.64 mg/L) and chemical oxygen demand (COD) (15.49 mg/L) are lower than the respective standards of 25 and 125 mg/L of the world health organization (WHO) standard. These surface waters have average concentrations of 0.015 mg/L for cadmium (Cd), 0.042 mg/L for zinc (Zn) and 0.062 mg/L for manganese (Mn), below the respective standards of 0.003, 3 and 0.4 mg/L.

Conclusion: This study shows that surface waters are not yet very polluted by these inputs.

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1. Introduction

Commonly called "pest killers" pesticides are chemicals products used to kill bacteria and viruses. Their unique feature is that they are toxic to living organisms. When pesticides are sprayed, some of this treatment ends up in the soil and then seeps into the groundwater through runoff and dissolves there.

Cocoa is the main engine of the Ivorian economy, accounting alone for 40% of exports and providing employment for 30% of the population. It is also the main source of income for farmers. The volume of production increased from 1,440,450 tons for the period 2012-2013 to 1,740,842 tons in 2016-2017 [1]. The incomes from cocoa sale have helped finance development projects such as the opening up of the Soubré department in southwestern Côte d'Ivoire, which today represents the new cocoa loop. This region provides alone 34% of national production. This crop, which is grown in forest areas, is threatened by deforestation and a low soil productivity due to land degradation [2].

In fact, continuous application of fertilizers, especially inorganic, poses a number of some problems such as the decrease in the level of organic matter (OM) and the deterioration of the soil structure [3]. If all these problems affect the sustainability of cocoa production, the possible presence of trace metal elements (TMEs) in the couple water-soil constitutes a concern [4]. In fact, the recent studies [5] carried out in Eastern of Côte d'Ivoire, have shown that cocoa-growing soils in this area had high levels of TMEs: iron (Fe), manganese (Mn), copper (Cu), zinc (Zn) above the threshold values. Thus, iron and Mn, the most abundant elements, have caused, respectively, iron toxicities and the acidification of these soils and waters. Then, the dynamism phenomenon TMEs observed in East of Côte d'Ivoire would not be present also in south area or would not extend in all areas of Côte d'Ivoire. The purpose of this study was to understand the problems posed by excessive use of agricultural inputs containing the TMEs on the quality of soils and waters used by the populations.

Presentation of the study area

The department of Soubré is located in the southwest of Côte d'Ivoire and is part of the Nawa region. It lies between longitudes 6°19' and 6°57' West and latitudes 5°26' and 6°13' North (Figure 1). It has four sub-prefectures which are Grand-Zattry, Okrouyo, Liliyo and Soubré. It is bordered to the north by the department of Issia, to the south by the departments of Méagui and Sassandra, to the east by the departments of Gagnoa and Gueyo and to the west by the department of Buyo. The area of the department is 4779 km^2. The population of the department is 464,554 inhabitants [6]. The native

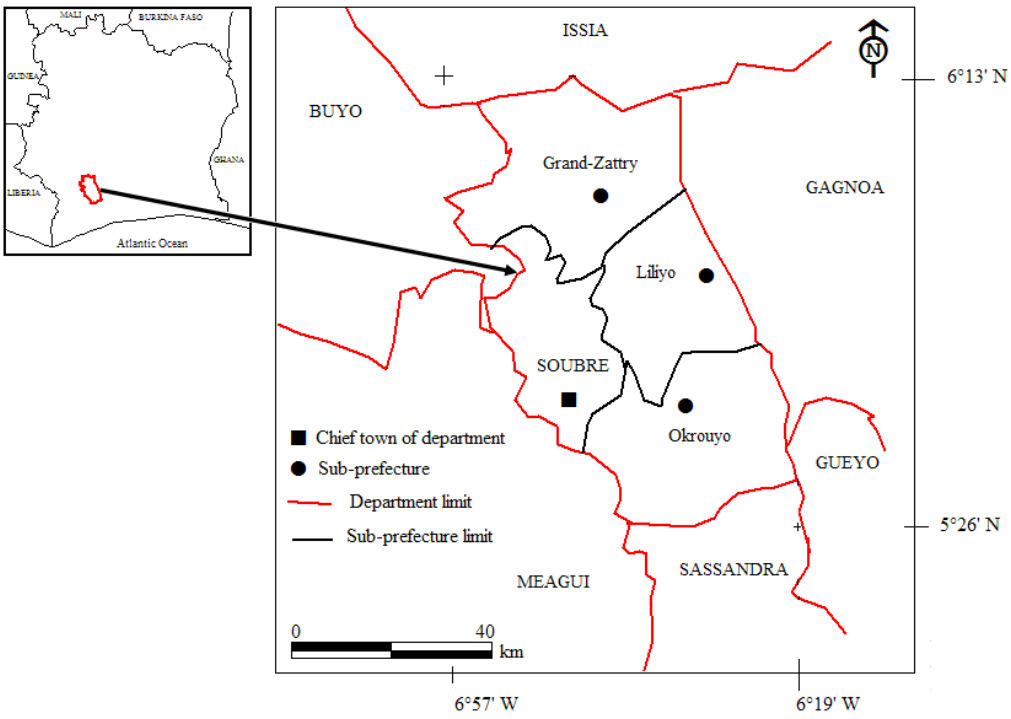

Figure 1. Map localisation of the study area

populations are Bakoué, Bété, and Kouzié. The relief is characterized by vast plateaus surmounted in some places by a few elevations consisting of hills, including Mount Trokoa, located in the Okrouyo sub-prefecture. The climate is sub-equatorial, characterized by two rainy seasons between April-June and September-November and two dry seasons between July-August and December-March. Rainfall is abundant (1600-1800 mm) and reaches a maximum in June and July. Temperatures oscillate during the year between 26 and 32°C [7]. The vegetation is marked by dense and humid forest, which today gives way to remnants of forest and immense plantations of traditional or industrial perennial crops. The hydrographic network is made up of permanent waterways, the most important of which are the Sassandra River and its main tributaries, which are the Lobo, the Davo, the N'Zo and the Gô.

Geologically, the main formations encountered are Archean (migmatite, biotite gneiss, anatexis granodiorite) followed by Middle to Lower Birimian (1800-2500 Ma) (oriented granodiorite, two-mica granite, micaschist, tuffaceous sandstone, sericite or chlorite shale) [7].

The soils encountered have a clayey and silty texture. They are generally ferralitic soils, strongly and moderately reworked, with a covering of schists and granites, or pseudogleyic and cambisols [8]. The horizons are humus-bearing and not very thick, but rich in OMr and well-structured under dense forest. These soils are adapted to the cultivation of cocoa, coffee, oil palm and rubber trees.

2. Materials and Methods

Field visit

A field visit carried out from January to July 2019 in the department and in the national agricultural research center (CNRA) of Soubré, allowed on the one hand, to list the different pesticides used in the area and on the other hand to take water and soil samples. A total of 12 water and soil samples were collected from 12 sites in the region.

Water and soil sampling method

The analysis of water quality in the plantations of Soubré department was based on surface water samples. The chemical elements concerned were the biochemical oxygen demand for 5 days (BOD_5) and chemical oxygen demand (COD). Soil samples were collected with a small Van-Veen bucket and then placed in a cooler at 4°C. The parameters concerned were calcium (Ca^{2+}), potassium (K^{+}), magnesium (Mg^{2+}), phosporus (P); OM and cation exchange capacity (CEC). Chemical elements were analyzed using a HACH DR 6000 spectrophotometer. Figure 2 shows a soil profile in the low slope of Yabayo.

Determination method of TMEs

The TMEs: Mn, Cu, cadmium (Cd) and Zn were extracted from the soils using an ethylene diamine tetra-acetic acid (EDTA) solution and then measured by atomic absorption spectrophotometry (AAS) at CIAPOL chemical analysis laboratory. These elements are, on the one hand, TMEs at

Figure 2. Soil profile in the lower slope of Yabayo

risk for human health and on the other hand, contaminants most often cited in the census of polluted sites and soils [9].

3. Results and Discussion

Pesticides inventory

Table 1 presents the pesticides used in Soubré department. They are nodrox in Yabayo, algomil in Liliyo, callicopper in Méagui, fongex C77 in Okrouyo, fongicao 72%WP in Oupoyo, kocide 2000 in Buyo, manconil 72% in Soubré, nordox 75 in Mayo, tropic 66WP in Kragui, actara 25 WG in Koda and the caodiaz 600 in Kipin. Some pesticides are shown in Figure 3.

Soils study

Soils features

The soil samples were taken after harvest at 62, 76 and 83 days of cultivation after the rainy season. The soil profile carried out in Soubré revealed the features of region's soils. On the whole, these soils present some same morphological features such as good drainage, good porosity and high content of coarse elements (Tables 2 and 3). The depths above 1 meter are favorable to cocoa farm [10].

The soils porosity varies considerably from one layer to another layer. The depth of superficial horizon is 15

Table 1. Pesticides used in Soubré department

Site	Pesticide Name	Locality
ST1	Nodrox 75	Yabayo
ST2	Algomil 72%	Liliyo
ST3	Callicuivre (2)	Méagui
ST4	Fongex C77	Okrouyo
ST5	Fongicao 72% WP	Oupoyo
ST6	Fongio plus 72% WP	Grand-Zatri
ST7	Kocide 2000	Buyo
ST8	Manconil 72%	Soubré
ST9	Nordox 75	Mayo
ST10	Tropic 66 WP	Kragui
ST11	Actara 25 WG	Koda
ST12	Caodiaz 600	Kipin

Figure 3. Some listed pesticides

Table 2. Description of the soil profile in the lower slope of Yabayo

Depth	0-8 cm	8-18 cm	>18 cm
Color	Humus	Little humuse	Very little humus
Texture	Sand-silty	Sand-silty	Sandy-clay
Coarse elements	Low load of coarse elements	High load of coarse elemnts	High load of coarse elements
General structure	Fragmentary	Polyhedral fragmentary	Particular
General porosity	Porous (centimetric)	Porous (centimetric)	Porous (centimetric to millimetric)
Horizon type	$A_{11}G$	$A_{12}G$	$A_{13}G$

Table 3. Porosity characteristics

Time (s)	Soil Characteristics	Pore Diameter	Water Dynamic
20-40	High porous	Centimetric	Free water circulation
40-60	Porous	Centimetric to millimetric	Water retention available for plants
>60	Little porous	Millimetric	Water retention no available for plants

cm in average with minimums of 0 cm ad maximums of 20 cm. The surface horizons provide more water to the plants than the deep horizons, since the majority of the roots are located there.

Physico-chemical features of the soils

The results of the 12 soils samples are shown in Table 4. The soil pH has a minimum value of 5 and a maximum value of 7.10 with an average of 5.91. The soils are acidic. OM has a minimum content of 1.41 mg/kg and a maximum content of 12.21 mg/kg with an average of 4.29 mg/kg. The average percentage of clay is 42.08 for a minimum of 15% and a maximum of 70%. CEC has an average of 10.74 cmol/kg for minimum value of 2.50 cmol/kg and a maximum value of 17.40 cmol/kg.

Soil concentrations of exchangeable base (Ca^{2+}, K^{+} and Mg^{2+}) are also low. The average values are 5.71 cmol/kg, 0.35 cmol/kg and 1.66 cmol/kg, respectively, for Ca^{2+}, K^{+} and Mg^{2+}. On the whole, the soils of the 12 cocoa or-

Table 4. Physico-chemical characteristics of the soils

Variables	Unit	Number of Cocoa Trees Orchards	Min	Max	Mean±SD
pH	-	12	5.00	7.10	5.91±0.76
OM*	mg/kg		1.41	12.21	4.29±2.96
Argile	%		15.00	70.00	42.08±19.47
CEC*	cmol/kg		2.50	17.40	10.74±5.20
Ca^{2+}	cmol/kg		0.93	12.82	5.71±3.78
K^{+}	cmol/kg		0.11	0.64	0.35±0.15
Mg^{2+}	cmol/kg		0.45	3.29	1.66±0.88
P	cmol/kg		3.92	78.45	24.31±25.54

OM: Organic matter; CEC: Cationic exchange capacity.

chards are fairly rich in assimilable phosphorus (P). The average value is 24.31 cmol/kg, with a minimum of 3.92 cmol/kg and a maximum of 78.48 cmol/kg.

Surface waters quality study

Table 5 presents the elementary statistics of the physico-chemical parameters of surface waters. BOD_5 concentrations in surface waters during the rainy season range from 0 mg/L to 150 mg/L, with an average of 18.64 mg/L. In the dry season, BOD_5 concentrations range from 4 to 41 mg/L with an average value of 14.93 mg/L. These values show that BOD_5 concentrations are higher in the wet season than those in the dry season. In surface waters, in the rainy season, COD varies between 2.10 and 33.610 mg/L with an average of 15.89 mg/L. On the other hand, in the dry season, this parameter varies between 10.10 and 93.46 mg O_2/L, with an average of 33.71 mg O_2/L. Mn values are high during the rainy season. They vary from 0.1624 to 0.051 mg/L against 0.0411 to 0.036 mg/L in the dry season. In the rainy season, the Zn concentration ranges from 0 to 0.241 mg/L, with an average of 0.042 mg/L. In the dry season, the concentration fluctuates between 0 and 0.1 mg/L with an average of 0.018 mg/L. The average concentration in the rainy season is higher than the average in the dry season. These values are in accordance with the World Health Organization (WHO) standard (3 mg/L). Cu is present in surface waters only in the wet season, with concentrations ranging from 0 mg/L to 0.127 mg/L, averaging 0.013 mg/L. Cu concentrations are low in accordance with the WHO standards of 2 mg/L. In the rainy season, Cd concentrations varies from 0 mg/L to 0.140 mg/L with an average of 0.056 mg/L. In contr ast, in the dry season, the value ranges from 0 to 0.071 mg/L with an average of 0.015 mg/L. The average in the rainy season is higher than the average in the dry season.

The main effects of long-term exposure to Cd are chronic obstructive disease, kidney disease, and cancer [11]. The origin of Cd is superficial [12]. The presence of Cd as a contaminant in fertilizers used in agriculture may contribute to this pollution [13]. Also, a sudy claims that in aquatic environments, Cd, can come from industrial activities, natural erosion, leaching of agricultural soils (phosphate fertilizers), dissolution of some galvanized or plastic pipes as well as industrial landfills and industrial processing of mines [14]. The work of [15] showed that the TMEs: Mn, Cu, Zn, Cd are significantly more abundant in leaves than in soils and water. These results are in agreement with our results that showed low values of TMEs in surface water. TMEs tend to accumulate more in the aerial parts of cocoa trees than in water. These results are confirmed by the authors [16] who showed significant accumulations of TMEs in plant leaves.

4. Conclusion

This study showed the effect of agricultural inputs on the water-soil relationship in the cocoa-growing area of Soubré Department. The soils have good drainage, opened 0 porosity and a good content of coarse elements. They are acidic with an average pH of 5.91. Soil phosphorus (P) values are high, with a minimum of 3.92 cmol/kg, a maximum of 78.48 cmol/kg and an average of 24.31 cmol/kg. Chemical analyses of surface water show average values of 15.89 mg/L in the dry season versus 33.71 mg/L in the rainy season. As for BOD_5, its average value is 18.64 mg/L with a maximum of 150 mg/L in the dry season. In the rainy season, its average is 14.93 mg/L with a minimum of 4 mg/L and a maximum of 41 mg/L. The levels of trace metals of Mn, Zn, Cu, Cd in surface waters do not exceed

Table 5. Elementary statistics of the physico-chemical parameters of surface waters

Parameters	Unit	Dry Season			Rainy Season			WHO [17]
		Min	Max	Average	Min	Max	Average	
BDO_5	mg/L	0.000	150.000	18.640	4.000	41.000	14.930	25
CDO	mg/L	2.100	33.610	15.890	10.100	93.460	33.710	125
Mn	mg/L	0.051	0.162	0,162	0.036	0.041	0.036	0.4
Zn	mg/L	0.000	0.241	0.042	0.000	0.100	0.018	3
Cu	mg/L	0.000	0.127	0.013	0.000	0.000	0.000	2
Cd	mg/L	0.000	0.140	0.056	0.000	0.070	0.015	0.003

the WHO guidelines. This study constitutes an awareness of the risks incurred by soils and waters in cocoa production with the use of agricultural inputs.

Ethical Considerations

Compliance with ethical guidelines

There was no ethical consideration to be considered in this research.

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Authors' contributions

All authors equally contributed to preparing this file.

Conflict of interest

The authors declare no conflict of interest.

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