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Heavy metal soil contamination in cocoa plantations in South West Region, Cameroon

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The status of heavy metal contamination of surface soils in two cocoa plantations of approximately 30 years in Cameroon was evaluated. The bioavailable fractions of Fe, Cu, Zn, Cd and Cr were used to assess the extent of heavy metal contamination using a selection of contamination indices. In addition, other physicochemical properties including organic matter, particle size, CEC and pH were assessed. One of the farms was dominated by sand (64.56 - 73.46% sand) in contrast to the other (2.56 to 37.51%) and the latter had a higher clay content. The order of abundance of heavy metals, as expressed by the mean values, is as follows: Fe > Cu > Zn > Cr > Cd in soils from the two areas. Contamination factors of Cu-, Zn- and Cd are considerable for clay-dominated soil. The potential ecological risk of the metals in both soils was low with the exception of Cd in the clayey soil. Results for hazard assessment showed Cu levels were within the low ISQC sediment criteria in the clay-dominated soil; possibly linked to the long-term application of Cu-fungicide.

Key words: Heavy metal, contamination indices, cocoa plantation, Cameroon.

INTRODUCTION

In Cameroon, like in many other developing countries, agricultural practices rely heavily on agrochemicals to prevent and/or control the crops threatening diseases (Emoghene and Futughe, 2016). Cameroon was the fifth highest cocoa producer in the world in 2013/2014 (Ngalaume, 2014). Cameroon’s cocoa outputs increased from 211,000 metric tons in 2013/2014 to 232,000 metric tons in 2014/2015, although some projections indicated that cocoa production would decrease to 230,000 metric tons in 2015/2016 (Statistical Portal, 2016). Cocoa production is however, threatened by a range of pests and diseases. In Cameroon, among the most common and highly destructive cocoa pests are mirids (Bisseleua et al., 2011; Babin et al., 2010), which could be responsible for between 30 to 70% of cocoa yield losses (Anikwe et al., 2009). The emergence of climate change as a global environmental problem conspicuously undermines cocoa productivity with persistent droughts coupled with outbreak of pests and diseases (Oyekale, 2017). Farmers commonly rely heavily on the use of...
pesticides in the management and prevention of cocoa pests and diseases. Copper-based fungicide is the most important component of pest and disease control programs in cocoa production systems (Olujide and Adeogun, 2006; Adabe and Ngo-Samnick, 2014).

Long term use of Cu fungicides is detrimental to soil microorganisms (Merrington et al., 2002) and are responsible for reducing respiration and microbial carbon: total carbon ratio (Gaw et al., 2003). Aikpokpodion et al. (2010) attributed copper contamination of soils in some cocoa plantations in Nigeria to the use of copper-based fungicides in treating black pod disease. Toselli et al. (2009) explained the accumulation of copper in soil as a result of repeated application of fungicides to control fungal diseases of pear and grapes in Italy. A study conducted in India also revealed that high levels of Bordeaux mixture application resulted in significant accumulation of copper in topsoil and subsoil (Savithri et al., 2003). Chaignon et al. (2001) reported that plants take in copper (Cu) as well as other metals, more intensely from contaminated soils which are poor in iron (Fe) and zinc (Zn). The concentration of cadmium, lead, copper and arsenic in cocoa beans is of the interest as these metals or trace elements (in high concentrations) are generally considered toxic to human beings. Previous research has investigated the content of cadmium (Cd), copper (Cu), lead (Pb), and arsenic (As) in cocoa beans from various countries as well as in some chocolate products (Aikpokpodion et al., 2010, 2013). Soil copper contamination can be as a result of long-term application of fungicides. The contamination of such soils with other heavy metals such as Cd, Cu, Pb, and As on which cocoa is grown is another means through which these metals can get into cocoa beans. Such contamination however could result from the nature of the parent material from which the soils are formed and the presence of other sources of contamination. Vítola and Ciprovíča (2016) investigated the potential risk and safety of heavy metal contamination up the value chain from cocoa beans.

Total metal content in soil neither represents bioavailability nor toxicity of that metal. Metal availability to plants can be assessed using selective extraction and chemical speciation. The readily soluble fraction of heavy metals is generally considered to be phytoavailable. The estimation of heavy metal phytoavailability in soils is becoming more important as a risk assessment because, total metal concentrations may not be the best predictors of metal phytoavailability. Single extraction is the most widely used method for evaluating phytoavailability of heavy metals in soils. There is limited information on the extent of soil contamination in cocoa plantations in Cameroon, despite the importance of cocoa cultivation in Cameroon. Previous studies by Manga et al. (2014) attributed the lack of such information to the absence of effective policies to manage land contamination and soil pollution risk arising from anthropogenic sources in the country. The present study evaluates the status of heavy metal contamination in the surface soils of approximately 30 years old cocoa plantations. The bioavailable fractions of Fe, Cu, Zn, Cd and Cr are used to assess the extent of heavy metal contamination by a selection of contamination indices (Contamination Factor, Degree of Contamination, Ecological Risk Index and Pollution Load Index).

MATERIALS AND METHODS

Study area
The study was carried out in Ekombe-Mbalangi, which is located in Meme Division, South West Region, Cameroon (Figure 1). The area falls within the equatorial climatic zone and has two main seasons; the rainy season which lasts for about 8-9 months (from March - October) and a dry season that runs from November - February. Annual rainfall varies between 2,500-3,250 mm, with a mean monthly temperature of about 25°C. The relief is undulating, with altitudes ranging from 155-848 m above sea level. The area is well drained by several streams (Kindongi, Mbalangi, Ota-Lobe, Basinge and Anyangari) that empty into the Mungo River. The primary vegetation comprises fragmented patches of forests and the continuous expanse of the Southern Bakundu Forest Reserve (the reserve itself being under threat from human activities). The geology is dominated by the Mungo River Formation (MRF) of Upper Cretaceous age (Turonian – Cenomanian) and ascribed to the Douala Sedimentary Basin. The MRF consists of limestones, shales, marls, sandstones, siltstones, claystones and mudstones. The study area is located to the West of the Mungo River, where significant limestone and isolated basaltic rocks are exposed, while in the north (around Ediki) isolated shaley units are exposed. Limestone and recent alluvium occur closer to the banks of the Mungo River (Diko and Ekosse, 2013). Typically, ferrallitic soils are found in the lowly-lying areas, while some of the highland areas have modified orthic soils. Sandy soils are also found in some parts of the region. There is the presence of rich volcanic soils, which have favored the cultivation of a lot of food crops (cassava, maize and yam). Cocoa cultivation dominates the cash crops activities of the area.

Two farms, referred to henceforth as Farm A and B, were included in the study. Farm A covered a surface area of approximately 7 ha and has been under continuous production for 30 years. Farm B, with a surface area of about 6.5 ha, has also been under production for over 30 years. In both farms, agricultural chemicals like insecticides and pesticides are used in an attempt to check the ravaging effects of pest and diseases on the yield of cocoa. Sanitary harvesting is practiced here, where infected pods are harvested, placed in a pit and burned, in order to reduce the spread of the pathogens to uninfected pods. Lastly, intercropping is also carried out in the cocoa fields to sustain the farmers with income during non-peak cocoa periods.

METHODOLOGY

Soil samples were collected from Farms A and B and the samples shall hereafter be referred to as soils A and B respectively. Six composite samples were collected from each farm, giving a total of 12 soil samples;

Farm A = (A1, A2, A3, A4, A5 and A6) and
Farm B = (B1, B2, B3, B4, B5 and B6).
Samples were collected using a soil auger at depths of 0-15 cm. The sample collection was at this depth because the build-up of Cu is more in the surface soil, between 0-15 cm (Savithri et al., 2003). A control sample was collected from a primary forest in the Southern Bakundu Forest Reserve, part of which is in Ekombo-Mbalangi for Farm B, while another control for Farm A was retrieved in primary forested land closer to the banks of the Mungo River. The soil samples were air-dried for 3 weeks and taken to the Geology Laboratory of the University of Buea where they were crushed with a ceramic mortar and pestle and sieved through the 2 mm sieve. The less than 2 mm fraction was collected and homogenized for subsequent analyses. Part of the samples was analyzed for routine soil physic-chemical parameters in the Institute of Agricultural Research for Development (IRAD) Ekoma, while the other part was parcelled and shipped to a laboratory in Ontario, Canada for heavy metal analysis. Particle size composition was determined using the modified Bouyoucos hydrometer (Estefan et al., 2013). Organic carbon content was obtained using Walkley and Black method (Walkey and Black, 1934); available phosphorous was determined according to Bray and Kurtz method (Bray and Kurtz, 1945) and total nitrogen was extracted by modified Macro Kjeldahl method (Pauwels, 1992). Soil pH was measured in 1:2.5 soil:water suspension as well as in soil:CaCl₂ suspension using a glass electrode pH (Black, 1965). The soils were leached with 1M neutral ammonium acetate to obtain leachates for the determination of exchangeable bases and soil cation exchange capacity (USDA-NRCS, 1996). Another portion (1 g) of the soil was extracted with 10 ml of 0.1 N hydrochloric acid and the extracts were used to analyse for Cu, Pb, Zn, Cd and Fe using atomic absorption spectroscopy, AAS (Baker and Amacher, 1982).

**Geoaccumulation index**

The Geoaccumulation Index (Igeo) is used in determining metal pollution in soils (Singh, 2001). It is expressed as (Equation 1):

$$I_{geo} = \log_2 \left( \frac{C_n}{1.5 \times B_n} \right)$$  \hspace{1cm} (1)

$C_n$ = measured metal concentration at sampling point; 
$B_n$ = background concentration value for element; 
$1.5$ = the background matrix correction factor due to lithogenic effects.

The Geoaccumulation Index scale consists of seven grades (0 – 6) ranging from unpolluted to very highly polluted. These seven descriptive classes are as follows:

$<0$=practically uncontaminated; $0$-$1$=uncontaminated to slightly contaminated; $1$-$2$=moderately contaminated; $2$-$3$=moderately to highly contaminated; $3$-$4$=highly contaminated; $4$-$5$=highly to very highly contaminated and $>5$=very highly/strongly contaminated.

**Contamination factor (CF)**

Adopted from Hakanson (1980), this refers to the quantification of the degree of contamination as a single metal index (CF) (Equation 2) and as overall degree of contamination ($C_{deg}$) (Equation 3). The measurement reflects the relative quantification of the respective
metal to a measured background value:

\[ CF = \frac{C_m}{B_m} \]  \hspace{1cm} (2)

\[ C_{deg} = \sum \left( \frac{C_m}{B_m} \right) i \]  \hspace{1cm} (3)

Where:

\( I \) = The respective metals (Cu, Pb, Zn, Cd),
\( C_m \) = The measured concentration in soil while
\( B_m \) = The background (adjacent forest) concentration value of metal (m) within the area of study.

The assessment of soil contamination was carried out using the contamination factor and the degree of contamination, which is based on four classification categories (Hakanson, 1980), as shown in Table 1.

**Table 1. Contamination factors and degree of contamination categories and terminologies.**

| CF classes | CF and Cdeg terminologies | Cdeg classes |
|------------|---------------------------|--------------|
| CF < 1     | Low CF indicating low contamination/low Cdeg | Cdeg < 8 |
| 1 ≤ CF < 3 | Moderate CF/Cdeg          | 8 ≤ Cdeg < 16 |
| 3 ≤ CF < 6 | Considerable CF/Cdeg      | 16 ≤ Cdeg < 32 |
| CF ≥ 6     | Very high CF/Cdeg         | Cdeg ≥ 32   |

Ecological risk factor (Er).

Er is quantitatively calculated to express the potential ecological risk of a given contaminant as suggested by Håkanson (1980) is given in Equation 4:

\[ Er = T_i.Cf \]  \hspace{1cm} (4)

Ti is the toxic response factor (Hakanson) assigned as follows, Cu (5), Zn (1), Cd (30) and Cr (2)

The following terminologies are used to describe the ecological risk factor:

\( Er I < 40 \), low potential ecological risk;
\( 40 \leq Er < 80 \), moderate potential ecological risk;
\( 80 \leq Er < 160 \), considerable potential ecological risk;
\( 160 \leq Er < 320 \), high potential ecological risk; and
\( Er \geq 320 \), very high ecological risk.

The potential ecological risk index (RI) was in the same manner as degree of contamination defined as the sum of the risk factors (Equation 5):

\[ RI = \sum Er \]  \hspace{1cm} (5)

Where: \( Er \) = The single index of ecological risk factors.

Hakanson (1980) and Yang et al. (2009) suggested that RI represents heavy metals toxicity and the environmental response to all five risk factors (Pb, Cd, Cu, Zn, and Cr) as total Cr in playground soils. In this study, only 4 of the 5 metals have been used and Cr concentration is the bioavailable concentration instead of total Cr. The following terminologies are used for the potential ecological risk index as given by (Hakanson, 1980):

\( RI < 150 \), low ecological risk; \( 150 \leq RI < 300 \), moderate ecological risk; and \( RI > 600 \), very high ecological risk.

**RESULTS AND DISCUSSION**

**Soil characteristics**

The soils in this study vary widely in their properties (Table 2 and Figure 2). Mean soil pH values are 5.28 and 6.2 in Farm A and B soils respectively; classifying these soils as low to moderate acid, which may enhance heavy metal distribution and availability to the plants. Average CEC values are low (11.75) to moderate (21.26) for soils A and B respectively. Sandy soils dominate Farm A soils (64.56 - 73.46% sand). These soils are located close to the banks of the Mungo River where the geology is composed of recent alluvium (Diko and Ekosse, 2013). In fluvial and alluvial soils, the redistribution of heavy metals within fractions occurs relatively quickly; it is not retained in the exchangeable fraction, which considerably decreases the risk of its mobility and inclusion into the food chain. Soils B on the other hand can be classified as retentive. They have compositions varying from 2.56 to 37.51% sand and therefore have higher clay contents. The most likely source of this characteristic is the parent material composition. Diko and Ekosse (2013) identified the presence of shaley material in these soils. Clayey soils are known for their high-water retention capacity, metal adsorption capacity, and nutrient storage. The clay content can be attributed to the soil mineralogy (especially the secondary clay minerals). Exchangeable cations (particularly Ca\(^{2+}\) and Mg\(^{2+}\)) and CEC values are higher in soils B. The CEC range, for both soils, qualify them favorable for agricultural use considering that none displays a low capacity for nutrient storage (CEC < 10 cmol kg\(^{-1}\)).

The mean available phosphorous in both soils is > 10, which is suitable for crop production (FAO, 1976). The concentrations of heavy metals are presented in Table 3. The order of abundance of heavy metals, as expressed by the mean values, is as follows: Fe > Cu > Zn > Cr > Cd in soils from the two areas. The average concentrations are higher than the background levels in both soils; indicating possible contamination in these...
Table 2. Physico-chemical properties of the soils used in the study.

| Soil | OC  | Tot. N | Av P | pH$_{(H_2O)}$ | pH$_{(CaCl)}$ | Na$^+$ | K$^+$ | Mg$^{2+}$ | Ca$^{2+}$ | Al$^+H$ | CEC |
|------|-----|--------|------|---------------|---------------|-------|-------|---------|---------|--------|-----|
| Farm A |     |        |      |               |               |       |       |         |         |        |     |
| A1   | 2.17 | 0.1   | 9    | 5.63          | 4.35          | 0.03  | 0.14  | 0.31    | 1.39    | 0.25   | 15.05 |
| A2   | 2.58 | 0.12  | 8    | 5.22          | 3.75          | 0.04  | 0.07  | 1.34    | 0.69    | 0.87   | 16.27 |
| A3   | 1.85 | 0.1   | 9    | 6.34          | 5.17          | 0.04  | 0.14  | 0.67    | 1.39    | 0.12   | 9.75  |
| A4   | 1.36 | 0.94  | 48   | 4.18          | 3.46          | 0.03  | 0.12  | 0.83    | 2.08    | 1.75   | 9.8   |
| A5   | 1.8  | 0.1   | 13   | 5.9           | 4.72          | 0.06  | 0.12  | 1.38    | 0.69    | 0.17   | 9.76  |
| A6   | 1.13 | 0.76  | 35   | 4.4           | 3.74          | 0.06  | 0.12  | 0.48    | 2.09    | 1.81   | 9.86  |
| Mean | 1.82 | 0.35  | 20.33| 5.28          | 4.2           | 0.04  | 0.12  | 0.84    | 1.39    | 0.83   | 11.75 |
| Farm B |     |        |      |               |               |       |       |         |         |        |     |
| B1   | 3.28 | 0.22  | 13   | 5.63          | 4.53          | 0.08  | 0.47  | 3.45    | 3.76    | 0.18   | 25.07 |
| B2   | 3.61 | 0.37  | 21   | 5.78          | 4.81          | 0.07  | 0.6   | 7.58    | 4.69    | 0.07   | 25.66 |
| B3   | 2.05 | 0.07  | 49   | 6.42          | 5.12          | 0.06  | 0.2   | 6.36    | 2.89    | 0.11   | 16.82 |
| B4   | 3.87 | 0.31  | 8    | 6.38          | 5.49          | 0.18  | 1.21  | 9.17    | 9.32    | 0.17   | 25.22 |
| B5   | 2.73 | 0.16  | 6    | 6.52          | 5.29          | 0.07  | 0.18  | 4.76    | 3.7     | 0.04   | 16.54 |
| B6   | 2.71 | 0.28  | 13   | 6.7           | 5.86          | 0.08  | 0.34  | 6.23    | 2.29    | 0.43   | 18.25 |
| Mean | 3.04 | 0.24  | 18.33| 6.24          | 5.18          | 0.09  | 0.5   | 6.26    | 4.44    | 0.17   | 21.26 |

Organic matter=OC %*1.72.

Figure 2. Soil particle size distribution soils from A and B.
soils. The results of a two-sample t-test (Table 4) show that there are significant (P < 0.05) differences between the means of the soils and the control values, with the exception of Cd in Farm A and Fe in Farm B. This suggests that Cu, Zn and Cr inputs to the soils may be attributable to anthropogenic activities, specifically agriculture. Cadmium, Cd and Fe, in Farm A and B respectively, may be linked to anthropogenic activities. Besides Fe, average concentration heavy metals in soils B are higher than those in soils A. These variations may be attributed to; the differences in parent rock composition, the rates of metal solubility in soils (predominantly controlled by pH), amount of metals (Cations Exchange Capacity), organic carbon content, and oxidation state of the system (Ghosh and Singh, 2005).

### Pollution indices

Results of the Geoaccumulation Index, $I_{geo}$, (Table 5) show the mean for Cu in Farm A as 1.3 and in Farm B as 1.73. This classifies soils from both farms as moderately contaminated. These values are similar to those earlier reported in a study of cocoa farms in Cross River State, Nigeria (Aikpokpodion et al., 2010). While anthropogenic

### Table 3. Concentration of heavy metals (cmol/kg) in the study area.

| Sample | Sample | Cu  | Zn  | Fe (%) | Cd  | Cr  |
|--------|--------|-----|-----|--------|-----|-----|
| A1     | 23.77  | 4.0 | 0.18| 0.03   | 1.2 |     |
| A2     | 9.55   | 3.9 | 0.15| 0.03   | 1.1 |     |
| A3     | 13.59  | 3.5 | 0.15| 0.02   | 1.2 |     |
| A4     | 14.14  | 2.2 | 0.15| 0.01   | 1.2 |     |
| A5     | 24.48  | 3.6 | 0.13| 0.03   | 1.0 |     |
| A6     | 11.72  | 1.2 | 0.13| <0.01  | 1.0 |     |
| Control| 4.40   | 1.9 | 0.02| 0.02   | 0.1 |     |

### Table 4. Comparison of heavy metal concentration (cmol/kg) between study and control sites.

| Element | Mean | t-stat | p-value | Confidence level (95%) |
|---------|------|--------|---------|------------------------|
|         |      |        |         | Lower | Upper |
| Soils A | Cu   | 16.21  | 4.78    | 0.002 | 9.55  | 22.87 |
|         | Zn   | 3.07   | 2.55    | 0.025 | 1.89  | 4.25  |
|         | Fe (%) | 0.148 | 17.13  | 6.2E-06 | 0.13  | 0.17  |
|         | Cd   | 0.024  | 1       | 0.19* | 0.014 | 0.034 |
|         | Cr   | 1.17   | 25.3    | 8.9E07 | 1.02  | 1.22  |
| Soils B | Cu   | 23.51  | 5.13    | 0.0018 | 14.09 | 32.93 |
|         | Zn   | 18.93  | 4.84    | 0.0024 | 10.41 | 27.45 |
|         | Fe (%) | 0.08  | 1.77    | 0.068* | 0.039 | 0.12  |
|         | Cd   | 0.34   | 2.97    | 0.016  | 0.09  | 0.59  |
|         | Cr   | 1.02   | 6.37    | 0.0007 | 0.64  | 1.44  |

Significant at p<0.05; *Insignificant.
activities (particularly the use of Cu-based fungicides) may account for these observations in both cases, these effects may also be mediated by the differences in lithology, especially since exchangeable Cu is bound to OM in soil (Teusch et al., 1999). Farm B, with a slightly higher OM content should therefore have a higher potential for Cu adsorption. This capacity may be enhanced (compared to Farm A) by the higher pH of Farm B, given that previous research has also reported increases in bound Cu in soil, reducing its mobility in the process (Teusch et al., 1999).

The mean values of Igeo of Zn and Cd in Farm A are 0.11 and -0.32 respectively. These qualify them as practically uncontaminated and negligible (that is, no contribution for Cd). In Farm B the Igeo values for Zn and Cd are 2.12 and 2.18 respectively, qualifying them as moderately to highly contaminated. At pH>5.2, Zn is probably bound to Fe-, Mn-, Al-rich oxides and OM. The stability of these phases is known to affect the depletion/enrichment of Zn in soils (Manga et al., 2014). The range of Igeo for Cd is very similar, with means of 2.9 and 3.1 for Farms A and B respectively. This value classifies the soils as being highly contaminated with Cd. Considering the absence of any dominant source of anthropogenic pollution, lithologic composition may be a likely factor contributing to Cd content in both cases.

Contamination Factor (CF) values are widely used to make inferences on natural versus anthropogenic origins of contamination. It has been suggested that metals having CF values between 0.5 and 1.5 are entirely derived from crust materials or natural processes; whereas CF values greater than 1.5 are more likely to be anthropogenic (Akoto et al., 2008). The calculated values of CF are shown in Table 4. The values obtained vary from 1.2 - 11.2 and 5.0 - 12.7 for soils A and B respectively, with Cr having the highest value in both cases. According to Hakanson (1980), Cd contamination is low while those for Cu and Zn are moderate in soil A. On the other hand, Cu-, Zn- and Cd-contaminations are considerable for soil B, implying that these metals are derived from anthropogenic sources. In view of the fact that the study site is far from urban activities, the most likely source is therefore agricultural inputs. The degrees (Cdeg) of contamination rank both soils as considerably contaminated; however, the contribution in soil A is mostly attributable to Cr levels while in that of soil B to the other metals (that is, Zn and Cd which are also contaminants).

Potential ecological risk indices of Cu, Zn, Cd and Cr are also shown in Table 4. As for the single-factor pollution, the average values range from 61.1 to 261.0, implying that the potential ecological risk of the metals in both soils are of low ecological risk, with the exception of Cd in soil B which is 204.0. This is rated as a high potential ecological risk. The comprehensive potential ecological risk is higher in soil B with a value of 261.0 attributable mostly to Cd. The input of Cd into the soils of the study area is of great concern because of its high toxic response factor. Agricultural inputs, particularly fungicides, inorganic fertilizers and phosphate fertilizers have variable levels of Cd, Cr, and Zn, depending on their sources. Cadmium enrichment also occurs due to the application of sewage sludge, manure and limes (Yanqun et al., 2005). Cadmium increases are most noticeable in certain crops, particularly in leafy vegetables (lettuce, spinach etc.), which may be consumed by animals or human being (Singh and Kumar, 2006). In addition, cocoa has been reported to accumulate excessive levels of Cd in its beans (Mounicou et al., 2003). Cadmium is highly toxic to human beings and as such, a lot of caution needs to be taken if intercropping is to be practiced in soils B with the use of agrochemicals.

Hazard assessment

Table 5 compares the average bio-available concentrations of heavy metals in the study area with soil quality guidelines, to assess the degree of contamination and potential adverse biological effects. The New York Sediment Criteria and Provincial Sediment Quality Guidelines for metals are divided into low effect range (ISQG-Low) and high effect range (ISQG-High). ISQG-Low level indicates the sediment contaminants would not have adverse effects on aquatic organisms in sediment. ISQG-H level indicates that the sediment contaminant certainly has adverse effects on organisms that live in the

| Heavy metal | Farm A | | | Farm B | | |
|-------------|--------|--------|--------|--------|--------|--------|
|             | Cf     | Er     | Igeo   | Cf     | Er     | Igeo   |
| Cu          | 3.40   | 19.10  | 1.30   | 5.00   | 25.00  | 1.73   |
| Zn          | 1.60   | 1.61   | 0.11   | 6.53   | 7.14   | 2.12   |
| Cd          | 1.20   | 36.00  | -0.32  | 6.80   | 204.00 | 2.18   |
| Cr          | 11.20  | 22.30  | 2.90   | 12.70  | 25.40  | 3.09   |
| Cdeg        |        |        |        |        |        |        |
| RI          | 79     |        |        |        |        |        |

Table 5. Determined indices of pollution for the studied soils (CF, Er, and Igeo).
sediment. The level of sediment contamination that is between ISOG-L and ISOG-H also shows that the contaminants probably have adverse effects (Nweke and Ukpai, 2016) (Table 6).

Based on these criteria, the soils under investigation are below the lowest effects and ISQC-L levels for Zn and Cr, indicating that these metal levels are not contaminating. The exception, however is the average value for soils B for Cu, which is quite close (including +SD) to the low effects level. Previous studies have reported the accumulation of Cu in soils treated with Cu-fungicide (Akinnifesi et al., 2006; Aikpokpodion et al., 2013). These studies point out that accumulation of copper in cocoa plantation could be a consequence of continuous, long term use of copper-based fungicides.

Conclusions

The study has revealed the present status of heavy metal contamination of soils under cocoa cultivation in Meme Division, Cameroon. The pollution indices identify the soils, particularly those in Farm B as moderately polluted; implying that continuous application can lead to major contamination problems. The indices, CF and Igeo are high in both soils, with the possibility that Cr content is not influenced by anthropogenic factors, but rather could be rather associated with parent rock composition and atmospheric deposition. The values for these indices point to moderate contamination of levels of Cd, Cu and Zn in soils B, possibly influenced by anthropogenic sources. Among the elements, Cu levels are within the low ISQC sediment criteria in soil B. Its concentration is associated with the long-term application of Cu-fungicide. Cd levels in soils B, are of high ecological risk following the Er index.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

Table 6. Comparison of heavy metals in this study with sediment quality guidelines in μg/g.

| Quality guideline            | Cu  | Zn  | Cd  | Cr  |
|------------------------------|-----|-----|-----|-----|
| **New York Sediment criteria** |     |     |     |     |
| Lowest effects range         | 16  | 120 | 0.6 | 26  |
| Severe effects range         | 110 | 270 | 9.0 | 110 |
| **Sediment quality criteria** |     |     |     |     |
| Lowest effects range (ISOG-L) | 16  | 120 | 0.6 | 26  |
| Severe effects range (ISOG-H) | 110 | 220 | 10  | 110 |
| Soils A (This study)         | 16.2| 3.1 | 0.024| 1.17|
| Soils B (This study)         | 23.5| 18.9| 0.340| 1.02|

* New York State Department of Environmental Conservation Division of Fish, Wildlife and Marine Resources, (1993); †Wisconsin Department of Natural Resources (2003).

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