Agr. Foo. Nat. Res. J. Volume 3, Issue 2, Page 378 - 386

e-ISSN: 1597-7153 | p-ISSN: 3043-5420

Agriculture, Food and Natural Resources Journal

The Official Journal of the Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria

Journal homepage: https://journals.unizik.edu.ng/afnrj

Original Article

Environmental pollution concern of cocoa pod husk on soils in cocoa plantations within Ekiti State, Nigeria

OPEN ACCESS

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DOI: https://www.doi.org/10.5281/zenodo.14512083

Editor: *Dr Onyekachi Chukwu, Nnamdi Azikiwe University, NIGERIA*

Received: *June 16, 2024*
Accepted: *September 8, 2024*
Available online: *September 30, 2024*

Peer-review: *Externally peer-reviewed*

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Conflict of Interest: The authors have no conflicts of interest to declare

Financial Disclosure: *The research was funded by the Tertiary Education Trust Fund (TETFund): IBRG2016/EKSU/ORD*

ABSTRACT

Abstract

The accelerated production of cocoa would result in a pileup of cocoa pod husk (CPH) within the plantation. Decomposition, which would enhance soil fertility and cause environmental pollution. This study evaluated the CPH piles influence on heavy metal status, contamination potentials, and selected soil properties in the cocoa plantations in Ekiti State. Surface (0-15 cm), sub-surface (15-30 cm), and undisturbed soil core samples were taken at 0, 5, 10, 20, and 50 m from the CPH piles in three cocoa plantations of over 20 years, each in Afolu-Ekiti, Ifaki-Ekiti, and Aare-Ekiti, and analyzed. The soils were loamy sand at both depths, with an average bulk density of 1.34 g cm^{-3} on the surface compared to 1.51 g cm^{-3} in the control. The soil chemical properties decreased with distance from the CPH pile (0 m), and values at the surface depth were significantly higher than the control except for the exchangeable bases. Heavy metals content were generally below the maximum permissible limits. The pollution indices imply varying degrees of heavy metals contamination in the cocoa plantations' soils with an overall moderate contamination. Hence, cocoa pod husk is of potential to improve soil health with minimal environmental concern that could be averted by proper management.

K E Y W O R D S : *Bulk density, Cocoa pod husk, Heavy metals, Pollution indices*

INTRODUCTION

Increase in human activities and the application of modern technologies to meet needs have made the pollution and contamination of the environment inevitable (Yusuf *et al*., 2003). Heavy metal contamination has become critical for the assurance of food and environmental qualities (Radwan & Salama, 2006). Heavy metals are non-biodegradable and persistent environmental contaminants (Singh &Kumar, 2006). Various agricultural commodities can be affected by pollution caused by anthropogenic sources needed for the production, especially agronomic practices which modify the physical and chemical properties and heavy metals' bioavailability in the soils (Yusuf & Osibanjo, 2006).

Cocoa is crucial to the economy of Nigeria as the leading non-oil export commodity, having 30% annual increased cultivated area (800,000 million ha) (FMARD, 2011). Shanbahdeh (2022), reported approximately 238,000 tons

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of cocoa beans in 2012/2013 with an expectation of about 280,000 tons in 2021/2022. Each tonne of dry beans produced generates 10 tonnes of cocoa pod husk (CPH) (Khanahmadi *et al*., 2015). Hence, enormous 2.8 million tonnes of CPH is expected as waste from cocoa production in Nigeria. Decomposition of the CPH could either enhance soil fertility and/or results in environmental pollution. The organic constituents and nutrients rich CPH are usually left in heaps in cocoa plantations without proper management but incessantly burnt as farm sanitation and disease control measures. Recently, there were reported works on soil properties and heavy metals content in cocoa plantation soils (Aikpokpodion, 2010; Ajiboye *et al*., 2015; Eteng & Essien, 2020; Manga *et al*., 2020; Adewoye & Amusa, 2021) however, those soil properties and heavy metals pollution potentials in relation to CPH piles implications have not been explored particularly in Ekiti state. Therefore, this study evaluates the selected soil properties, heavy metals' status and contamination potentials using pollution indices as influenced by CPH piles in the cocoa plantations' soils in Ekiti State.

MATERIAL AND METHODS

Study area

The study was done in 2018–2019 in Ekiti State in the rainforest zone of Nigeria where cocoa is a major tree crop. Geographically located between latitude 4º 45'–5º 45' and longitude 7º 45'–8º 5' belonging to the sub-humid tropics with distinct rainy (wet) and dry (hot) seasons with mean precipitation and temperature at 1800 mm and 28 ºC per annum. The land resources allow large-scale cultivation of tree crops and arable crops. The chosen sites, representing Ekiti state Senatorial Districts were Afolu-Ekiti in Ise/Orun Local Government Area, Ifaki-Ekiti in Ido-Osi Local Government Area and Aare-Ekiti in Irepodun Local Government Area. The plantations were aged between 20–25 years with an average CPH piles' spots age of 10 years.

Soil sampling and analysis

At each site (block), three cocoa plantations were randomly identified as replicates and soil samples taken at varying distances from the CPH piles (0 m), 5, 10, 20 and 50 m at depths 0–15 (surface) and 15–30 cm (subsurface) for analysis. Undisturbed core samples were also taken at each sampling point for bulk density and percentage porosity determinations. The analysis was performed at the Soil Laboratory of Ekiti State University, Ado-Ekiti, Nigeria. The selected soil properties and heavy metal contents were determined by procedures described in Okelabo *et al.* (2002).

Analysis of data and environmental pollution indices

Data for the selected soil properties and heavy metal contents were subjected to analysis of variance (ANOVA) using randomized complete block design (RCBD) and means separated by Duncan multiple range test (DMRT) at 5% probability level.

The extent of heavy metals pollution in the sites were determined by the following pollution indices.

Contamination factor (C_f): This method is an overall indicator of contamination by integrating data for several heavy metals based on calculating the contamination factor for each pollutant as the ratio of mean concentration in the soil to background unpolluted soil.

$$Contamination\ factor, C_f = {C_{sample}}/{C_{background}} \quad (1)$$

Where C_{sample} and $C_{background}$ are means of metal concentration in polluted soil and unpolluted background value. The categories of C_f according to Hakanson (1980) are low contamination ($C_f < 1$), moderate contamination ($1 \leq C_f < 3$), high contamination ($3 \leq C_f < 6$) and very high contamination ($6 \leq C_f$).

Modified contamination degree (mC_d): Expressed as the sum of all contamination factors for a given set of HMs divided by the number of analyzed heavy metals.

$$Modified\ degree\ of\ contamination, mC_d = \frac{\sum_{i=1}^{i=1} c^i f}{n} \quad (2)$$

Where n, i and C_f were respectively the number of analyzed elements, ith element and contamination factor. The descriptive classification is presented in Table 1 (Abrahim, 2008).

Pollution load index (PLI): The PLI is a simple but comparative method for evaluating the extent of metal pollution for individual site. And it is expressed as:

$$Pollution\ load\ index, PLI = \left[C_{f1} \times C_{f2} \times C_{f3} \times \ldots \times C_{fn}\right]^{1/n} \quad (3)$$

Where C_f and n are contamination factor and number of metals evaluated. PLI value >1 implies pollution whereas value <1 indicates no pollution (Thomilson *et al*., 1980).

Enrichment factor (EF): Enrichment factors are means of identifying and quantifying human interference with global element cycles and are also used to differentiate origin of trace metals, either anthropogenically or lithologically. Iron (Fe), except otherwise, has been proposed as an acceptable reference metal element (Deely & Fergusson, 1994) being the most abundant in the earth crust and not considerably influenced by human activities (Sutherland, 2000).

Table 1: Descriptive classification of modified degree of contamination (mC*d*)

mCd Value	Designation of quality
mC*d* < 1.5	Nil to very low degree of contamination
1.5 ≤ mC*d* < 2	Low degree of contamination
2 ≤ mC*d* < 4	Moderate degree of contamination
4 ≤ mC*d* < 8	High degree of contamination
8 ≤ mC*d* < 16	Very high degree of contamination
16 ≤ mC*d* < 32	Extremely high degree of contamination
mC*d* ≥ 32	Ultra-high degree of contamination

Source: Abrahim (2008).

$$Enrichment\ factor, EF = \frac{C_n(sample)/C_{ref}(sample)}{B_n(background)/B_{ref}(background)} \quad (4)$$

Where Cn (sample) and Cref (sample) are the contents of the target metal in the examined environment and the reference metal in the examined environment; and Bn (background) and Bref (background) are contents of the target metal in the background environment and the reference metal in the background environment. EF categories were presented in Table 2.

Table 2: Contamination categories based on enrichment factor (EF)

EF Value	Designation of quality
EF < 2	Deficiency to mineral enrichment
EF = 2 – 5	Moderate enrichment
EF = 5 – 20	Significant enrichment
EF = 20 – 40	Very high enrichment
EF > 40	Extremely high enrichment

Source: Sutherland (2000).

Geoaccumulation index (I*geo*): It indicates the degree of pollution of soil with regards to the geochemical background concentrations of the heavy metals of interest. The I_{geo} values were calculated by multiplying the geochemical background concentrations of the metals each time by a constant of 1.5 to allow natural fluctuations of a given substance in the environment as well as very small anthropogenic alterations (Loska *et al*., 1997). Geoaccumulation index is mathematically expressed below and distinguished classes shown in Table 3 (Forstner, 1990).

$$Geoaccumulation\ Index, I_{geo} = \log_2 C_n/1.5\ B_n \quad (5)$$

Where C_n and B_n are the concentration of a given element in the soil tested and in the earth's crust.

Table 3: Classes of geo-accumulation index of heavy metals

I_{geo} class	I_{geo} value	Interpretation
0	$I_{geo} \leq 0$	Practically uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated to moderately contaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderate to strongly contaminated
4	$3 < I_{geo} < 4$	Strongly contaminated
5	$4 < I_{geo} < 5$	Strongly to very strongly contaminated
6	$5 < I_{geo}$	Very strongly contaminated

Source: Forstner (1990).

Nemerow's pollution index (Pn): Nemerow's pollution index assess the degree of soil ecosystem pollution and provide a comprehensive description of the contamination status of the study area (Guan *et al*. 2014). It caters for the lapses of geo-accumulation index which measures individual metal contamination impact. The soil contamination classes based on Pn are shown in Table 4.

$$Nemerow's\ Pollution\ Index, P_n = \frac{(MaxPi^2 + AvePi^2)}{2} \quad (6)$$

Where P_i, C_i and S_i are respectively, the pollution index of the *i*th heavy metal (C_i/S_i), measured concentration of the *i*th heavy metal and the required standard of the *i*th heavy metal.

Table 4: Contamination classes based on Nemerow's Pollution Index

Class	Nemerow's pollution index	Interpretation
0	$0 < Pn \leq 0.5$	Uncontaminated
1	$0.5 < Pn \leq 1$	Uncontaminated to moderately contaminated
2	$1 < Pn \leq 2$	Moderately contaminated
3	$2 < Pn \leq 3$	Moderate to heavily contaminated
4	$3 < Pn \leq 4$	Heavily contaminated
5	$4 < Pn \leq 5$	Heavily to extremely contaminated
6	$Pn > 5$	Extremely contaminated

Source: Guan *et al*. (2014).

RESULTS AND DISCUSSIONS

Physical and chemical properties of cocoa plantation soils

The soil physical properties are presented in Table 5. The soils were loamy sand except at 20 m distance (surface) that was sand in texture like the control soil. The particle size distribution trend was similar at both depths. The loamy sand texture encountered in the cocoa plantation compared to the distinct sandy control soil could be attributed to the significantly higher organic carbon content particularly at 20 m distance (Table 6). The soil organic carbon is a function of soil organic matter that could have resulted from the piled CPH and litter falls in the cocoa plantations. The bulk densities observed in the soils were non-significantly lower than that of the control soil except at 0 m (1.20 g cm^{-3}) at the subsurface soils (Table 5). Subsurface soils recorded an increasing bulk density with distance away from CPH pile unlike the surface soils with irregular pattern. The higher surface soil bulk density (1.41 g cm^{-3}) compared to the subsurface value at 0 m is an indication that human activities around the CPH piles in cocoa plantations mainly causes surface soil compaction although the soils in the cocoa plantations were generally less compacted. The mean percentage porosity were 0.49 and 0.47% respectively in the surface and subsurface soils with the control having a significantly lower value at surface (0.43%) but higher value (0.73%) at the sub-surface soil.

Table 5: The physical properties of surface and sub-surface soils impacted by CPH in cocoa plantation

Sample distance (m)	Sand	Silt	Clay	Bulk density	Porosity	Textural class
	(%)			(g cm^{-3})	(%)	
			Surface soil			
Control	88.00	6.40	5.60c	1.51	0.43c	Sand
0	84.60	6.07	9.33ab	1.41	0.47b	Loamy sand
5	83.40	8.90	7.70b	1.22	0.54a	Loamy sand
10	81.43	7.90	10.67a	1.46	0.45bc	Loamy sand
20	89.40	3.70	6.90b	1.35	0.49ab	Sand
50	86.60	6.93	6.47bc	1.28	0.52a	Loamy sand
Mean	85.09	6.70	8.21	1.34	0.49	Loamy sand
			Sub-surface soil			
Control	88.00a	6.40b	6.40b	1.62a	0.73a	Sand
0	80.93ab	7.07b	7.07b	1.20b	0.55b	Loamy sand
5	80.90ab	8.90ab	8.90ab	1.40a	0.47b	Loamy sand
10	77.27b	10.47a	12.27a	1.59a	0.40b	Loamy sand
20	85.90a	6.70b	7.40b	1.44a	0.46b	Loamy sand
50	84.27ab	6.93b	8.80b	1.59a	0.46b	Loamy sand
Mean	81.85	8.01	9.80	1.44	0.47	Loamy sand

Means without alphabets in the same column are not significantly different.

Soil chemical properties are presented in Table 6. Soil pH measured in water was generally higher at the surface soils. Following a decreasing pattern away from the CPH pile at both depths, the mean pH values indicate slightly acidic soil conditions which may enhance heavy metal solubility and availability to the plants (Manga *et al*., 2020). However, the 0 m had significantly higher pH values of 7.26 (surface) and 7.11 (subsurface) compared to the controls and implied neutral soil reactions. The higher pH values in cocoa plantation soils particularly at 0 m could be due to basic cations from decomposed CPH and plantation litters in addition to agrochemical usage. Ayeni (2010) and Bahrun *et al*. (2018) have reported that cocoa pod husk has a tendency to increase soil pH levels. Findings suggest that CPH application is needed for soil maintenance. Soil organic carbon in cocoa plantation surface soils ranged from 1.75–3.07% with significantly higher value at 20 m distance compared to 1.02% in the control soil. Whereas, values at the sub-surface layer were not significantly different, ranging from 0.76–1.32% even with the control (1.30%). An indication

Table 6: Chemical properties of surface and sub-surface soils impacted by CPH in cocoa plantation

Sampling distance (m)	pH (H_2O)	Org. Carbon (%)	Total N	Avail. P (mg kg^{-1})	Exch. Acidity (cmol kg^{-1})	Ca	Mg	K	Na
				Surface soil					
Control	6.11b	1.02b	0.17ab	72.05ab	0.80a	1.88a	0.82bc	0.91a	0.80a
0	7.26a	2.70ab	0.26ab	89.70a	0.29b	1.35ab	1.33a	0.23b	0.13bc
5	6.80ab	2.12ab	0.19ab	36.48b	0.56ab	1.88a	1.19ab	0.07b	0.16b
10	6.41b	2.04ab	0.18ab	23.85bc	0.37b	0.92b	1.00bc	0.03b	0.09bc
20	5.34c	3.07a	0.29a	19.80bc	0.48ab	0.50b	0.74c	0.05b	0.09bc
50	6.04bc	1.75ab	0.15b	10.78c	0.37b	0.72b	1.10b	0.03b	0.07c
Mean	6.37	2.07	0.21	30.12	0.41	1.07	1.07	0.08	0.09
				Sub-surface soil					
Control	5.60b	1.30	0.15	48.65ab	0.64a	1.69a	0.82	0.70a	0.60a
0	7.11a	1.21	0.12	79.37a	0.19b	0.94ab	0.85	0.17b	0.12b
5	5.96b	1.29	0.11	13.70b	0.64a	1.06ab	0.79	0.04b	0.09bc
10	5.86b	1.22	0.10	11.82b	0.37ab	0.07b	0.72	0.09b	0.07c
20	5.43b	0.76	0.06	7.13b	0.68a	1.01ab	0.56	0.03b	0.08bc
50	5.76b	1.32	0.06	10.73b	0.96a	0.94ab	0.69	0.02b	0.06c
Mean	6.02	1.16	0.09	24.55	0.57	0.80	0.72	0.07	0.08

Means without alphabets in the same column are not significantly different.

that the CPH and plantation litters contributes more to the soil organic carbon content of the surface soil. Studies by Ayeni (2010) and Manga *et al*. (2020) also showed that cocoa pod ash increased soil organic carbon, N, P, K, Ca and Mg.

Total N on average was generally rated low (0.09%, subsurface) to medium (0.21%, surface) (Tekalign, 1991). The values generally decreased away from the CPH piles and the lower values at 50 m distance could be attributed to the sparsely populated cocoa trees at that distance in most evaluated plantations. Control soil recorded moderate total N at both depths but the values were not significantly different except at 20 m (3.07%, surface). The available phosphorus at both layers was significantly higher at 0 m which implies CPH's responsibility. On average, the available P values at 30.12 (surface) and 24.55 mg kg^{-1} (subsurface) were rated above moderate (Jones, 2003). Available P values in the control soils were lower but not significantly different from the soils at cocoa pod husk piles (0 m). The basic cations were significantly lower compared to the control except for Ca and Mg, particularly at 0 and 5 m both depths. On average, the exchangeable Ca, K and Na were rated very low while Mg was rated moderate (FAO, 2006) in cocoa plantations soils in Ekiti State. The generally lower basic cations in the cocoa plantation soils could possibly be due to the higher amount required of these nutrient elements for tree crops growth compared to the less lignified annual vegetations on the control soils.

Heavy metals content in cocoa plantation soils in Ekiti state

The concentrations of the heavy metals were presented in Table 7. Values recorded at 0 m were higher (except Fe) but not significantly different from other distant soils with exceptions of Ni, Cu and Cr at 10–50 m at the surface soils and Cu, Mn and Cr at subsurface soils. Heavy metals content in the control soil were lower compared to means in the cocoa plantation soils. Moreover, both depths had very similar distribution pattern in relation to distance from the CPH piles with the surface depth soils having higher heavy metals concentration. Fei-baffoe *et al*. (2017) reported similar depth-wise distribution of Cu and Zn in cocoa growing soils of Ghana and attributed it to the method of applying copper-based fungicides and the inorganic foliar fertilizers, as farmers spray these agrochemicals directly on the cocoa plant without taking keen interest in the amounts that gets to the soil. Hence, higher heavy metals content in the cocoa plantation soils compared to the controls were attributed to the agrochemical usage. However, in control soils and cocoa plantation soils, the heavy metals were generally below the WHO/FAO (2001) maximum permissible limits of 100 mg kg^{-1} Cu, 300 mg kg^{-1} Zn, 50 mg kg^{-1} Ni, 100 mg kg^{-1} Cr, 2,000 mg kg^{-1} Mn and 50,000 mg kg^{-1} Fe. The results implies that the heavy metals are not yet at toxic and/or intervention levels which could be detrimental to the environment and plant growth. Hence, assessment of heavy metals concentrations are vital to provide baseline data of the existing levels.

Table 7: Heavy metals content in soils in cocoa plantations in Ekiti State

Sampling distance (m)	Zn	Ni	Cu	Fe	Mn	Cr
	(mg kg^{-1})					
	Surface soil					
Control	15.00b	4.00c	9.50c	7880.0c	1100.0b	18.00b
0	47.17a	14.50a	32.50a	25167.0b	1824.0a	42.00a
5	28.00ab	12.50a	30.50a	35313.0a	1200.0ab	35.67a
10	40.00a	10.33ab	24.67ab	28458.0ab	1317.0ab	15.00b
20	28.50ab	9.50bc	16.00bc	31750.0ab	1512.7ab	14.00b
50	29.33ab	6.67bc	19.33bc	24625.0b	1475.0ab	8.33b
Mean	34.60	10.70	24.60	29062.60	1465.74	23.00
	Sub-surface soil					
Control	14.00b	3.00b	5.00c	7040.0b	1000.0ab	10.00b
0	37.00a	13.00a	24.33a	24083.0a	1588.7a	30.00a
5	25.50ab	12.00a	20.50a	31313.0a	894.0b	24.67a
10	38.00a	8.83ab	18.33ab	24792.0a	1083.3ab	13.00b
20	25.00ab	7.50ab	10.00c	29313.0a	1200.0ab	11.67b
50	24.00ab	9.50ab	12.67bc	22583.0a	1196.0ab	6.33b
Mean	29.90	10.17	17.17	26416.80	1192.4	17.13

Means without alphabets in the same column are not significantly different.

Heavy metals pollution assessment in cocoa plantation soils in Ekiti state

Contamination factor (C_f): Based on contamination factors' categories, the sites were of moderate metal contamination to high metal contamination except for Cr at 10–50 m (surface) and at 50 m (subsurface) and Mn (5 m subsurface) having low contamination (Table 8).

The soils at 0 m generally had higher C_f values at both depths except for Fe, which could be attributed to its more lithological source rather than anthropogenic sources and its distribution was non-related to other heavy metals (Deely & Fergusson, 1994).

Modified contamination degree (mC*d*): The mC*d* values ranged from 1.76 at 50 m distance in the surface soil implicating low degree of contamination (Table 1) to 3.31 at 0 m in the subsurface soil, indicating moderate degree of contamination. Anthropogenic impact of heavy metals in the cocoa plantation soils in Ekiti State implicated.

Pollution load index (PLI) and Nemerow's pollution index (Pn): As shown in Table 8, the heavy metals' PLI for the sites indicate deterioration in the site quality with values ranging from 1.53 at surface soils to 3.11 at subsurface soils of the cocoa plantation. Moreover, the PLI value decreased away from 0 m, an indication of metal dilution and dispersion with increasing distance (Thambavani & Mageswari, 2013) and higher values of PLI imply appreciable input from anthropogenic sources. Similar, Adewoye & Amusa (2021) reported cocoa farms in Oyo state to be polluted based on PLI values ranging from 1.14 to 4.11. Whereas, the Pn values of 1.16 and 1.19 respectively in the surface and subsurface soils (Table 8) indicates moderate heavy metal pollution (Table 4). Both indices provide comprehensive and valuable information that guide policy and decision making on the pollution levels of cocoa plantation soils in Ekiti State and the environs.

Enrichment factor (EF): The EF of heavy metals in the cocoa plantation soils shown in Table 8 indicates deficient to mineral enrichment (Table 2). Thus, heavy metals encountered are lithogenically sourced. The average EF values of the assessed heavy metals in the cocoa plantation soils in Ekiti state were generally lower compared to values recorded by Aikpokpodion (2010) in some cocoa plantations in Ondo state. It should however be noted that, the heavy metals were more enriched at the CPH piles (0 m) which could eventually increase in the near future.

Geoaccumulation index (Igeo): The Igeo of heavy metals in cocoa plantation soils in Ekiti State are in Table 8. The Igeo indices indicated that the assessed cocoa plantation soils were rated uncontaminated to moderately contaminated (Forstner, 1990), mainly at CPH pile and 5 m distance at both depths particularly with Cu, Fe and Ni. The Cr and Mn exhibiting negative mean Igeo values at both depths indicate practically uncontaminated soils with these heavy metals unlike others. Conversely, Adewoye and Amusa (2021) reported higher positive Igeo mean values for Cr (0.003) and Mn (0.18) in similar cocoa plantation soils in Oyo state.

Table 8: Pollution indices of heavy metals in cocoa plantation soils in Ekiti State

Sampling distance (m)	Zn	Ni	Cu	Fe	Mn	Cr	mC*d*	PLI	Pn
				Contamination factors (CF)					
					Surface soil				
0	3.14	3.63	3.42	3.19	1.66	2.33	2.90	2.80	1.16
5	1.87	3.13	3.21	4.48	1.09	1.98	2.63	2.38	
10	2.67	2.58	2.60	3.61	1.20	0.83	2.25	2.00	
20	1.90	2.38	1.68	4.03	1.38	0.78	2.02	1.79	
50	1.96	1.67	2.03	3.13	1.34	0.46	1.76	1.53	
Mean	2.31	2.68	2.59	3.69	1.33	1.28	2.31	2.10	
					Sub-surface soil				
0	2.64	4.33	4.87	3.42	1.59	3.00	3.31	3.11	1.19
5	1.82	4.00	4.10	4.45	0.89	2.47	2.96	2.58	
10	2.71	2.94	3.67	3.52	1.08	1.30	2.54	2.29	
20	1.79	2.50	2.00	4.16	1.20	1.17	2.14	1.93	
50	1.71	3.17	2.53	3.21	1.20	0.63	2.08	1.80	
Mean	2.14	3.39	3.43	3.75	1.19	1.71	2.60	2.34	
				Enrichment factors (EF)					
					Surface soil				
0	0.98	1.14	1.07	1.00	0.52	0.73			
5	0.42	0.70	0.72	1.00	0.24	0.44			
10	0.74	0.72	0.72	1.00	0.33	0.23			
20	0.47	0.59	0.42	1.00	0.34	0.19			
50	0.63	0.53	0.65	1.00	0.43	0.15			
Mean	0.65	0.73	0.72	1.00	0.37	0.35			
					Sub-surface soil				
0	0.77	1.27	1.42	1.00	0.46	0.88			
5	0.41	0.90	0.92	1.00	0.20	0.55			
10	0.77	0.84	1.04	1.00	0.31	0.37			
20	0.43	0.60	0.48	1.00	0.29	0.28			
50	0.53	0.99	0.79	1.00	0.37	0.20			
Mean	0.58	0.92	0.93	1.00	0.33	0.46			
				Geo-accumulation index (Igeo)					
					Surface soil				
0	1.07	1.27	1.19	1.09	0.14	0.64			
5	0.32	1.06	1.10	1.58	-0.46	0.40			
10	0.83	0.78	0.79	1.27	-0.33	-0.85			
20	0.34	0.66	0.17	1.43	-0.13	-0.95			
50	0.38	0.15	0.44	1.06	-0.16	-1.70			
Mean	0.59	0.79	0.74	1.28	-0.19	-0.49			
					Sub-surface soil				
0	0.82	1.53	1.70	1.19	0.08	1.00			
5	0.28	1.42	1.45	1.57	-0.75	0.72			
10	0.86	0.97	1.29	1.23	-0.47	-0.21			
20	0.25	0.74	0.42	1.47	-0.32	-0.36			
50	0.19	1.08	0.76	1.10	-0.33	-1.24			
Mean	0.48	1.15	1.12	1.31	-0.36	-0.02			

mCd = modified contamination degree; PLI = Pollution load index and Pn = Nemerow's pollution index.

CONCLUSION AND RECOMMENDATIONS

The study revealed that cocoa pod husk improves the bulk density, pH, and organic carbon, total N, available P, exchangeable K and Mg of the cocoa plantation soils. Heavy metals concentrations were generally below the maximum permissible limits stipulated by WHO/FAO (2001) with non-consistent distribution pattern from the cocoa pod husk pile. However, the pollution indices generally indicates moderate metal pollution in the soils. Cf and EF implies heavy metals in the soils to be of lithogenic origin while mCd, PLI, Igeo and Pn indicates anthropogenic sources whether from the cocoa pod husk piles and/or other agronomic practices. Findings are pointers to potential environmental concern which could be averted by active management of the cocoa pod husk and/or adoption of organic techniques for sustainable cocoa production, thus provides a greater opportunity to improve nutrient cycling.

Acknowledgement

Authors acknowledge Fund of Tertiary Education Trust (TETFund) for funding this research through Research Projects (RP) Intervention

Authors' Contributions

OSS conceived the research idea and worked with OJA in the development of the methodology and both were involved in the final production of the manuscript. AOAI participated in the sample collection and coordinated the data analysis, interpretation and manuscript preparation. AAA managed the laboratory analyses along with JCE who assisted others through all the research activities. All authors read and approved the final manuscript.

Ethical Statement

Not applicable

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