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Physical and Chemical Properties of Cocoa Pod Husk Dumpsites in Etung Cocoa Farms Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Assessment of some physical and chemical properties of cocoa pod husk dumpsites in Etung, Nigeria, was carried out to ascertain the particle size distribution, nutrients, and some soil fertility indices. Five cocoa-growing communities were purposely selected for sampling. Soil samples were collected at 0–25 cm and 25–50 cm in each cocoa farm dumpsite and non-dumpsites in the cocoa plantations. A total of 20 samples were collected, processed, and subjected to standard laboratory analysis. The results obtained indicated that there was no difference in soil textural classes between dumpsites and non-dumpsites on the plantations. pH in dumpsites ranged from 4.2 to 6.0, and plantation soils ranged from 3.9 to 5.6 Electrical conductivity. Surface dumpsite soils ranged from 0.0068 to 0.941 ds/m, and plantation soils ranged from 0.084 to 0.0816 ds/m. Total N in dumpsites ranged from 1.14–1.98% and 0.73–1.08% in plantation soils. P in dumpsites ranged from 9.61 to 13.42 mg/kg and 5.98 to 11.34 mg/kg in plantation soils. Exchange cations were higher in dumpsites than plantation soils. The students T-test (t-0.05) showed significantly higher pH, N, P, organic C, and CEC in dumpsite sites than plantation soils and significantly higher surface than

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subsurface soil depth. Though nutrient levels were higher in cocoa pod husk dumpsites, the levels were within the sufficiency threshold levels. The higher organic carbon content of cocoa pod husk dumpsites is an indicator of higher soil organic matter content for good sorption and retention of both macro- and micro-cationic nutrients to prevent their excess release that could degrade the soils.

Keywords: Cocoa; pod husk; dumpsite; plantation; soil fertility; crop residues; nutrient.

1. INTRODUCTION

Soil fertility is one of the major determinants of cocoa and other crop yields, in addition to other technical challenges such as the quality of planting materials as well as diseases and pests.

Cocoa production is an important source of livelihood for thousands of people in cocoa-growing areas of the world. In Nigeria, Cross River State is the second largest producer (19%) of the 14 producing states, next to Ondo State with 21% production [1]. Cocoa pod husk (CPH) is a lignocellulosic biomass that is rich in minerals (in particular, potassium), fibers (especially lignin, cellulose, hemicellulose, and pectin), and antioxidants and phenolic acids [2]. However, it is still largely underexploited. Appropriate use of this lignocellulosic material could offer economic benefits and reduce its environmental impact [3]. The cocoa bean constitutes one-third (33%) of the fruit weight, leaving behind 67% of the fruit as cocoa pod husk as a waste by-product [4]. In other words, ten tons of wet CPH are generated for each ton of dry cocoa beans, thereby representing a serious disposal problem and an underexploited resource [5]. The productivity of tropical soils hinges on organic matter input and status. The major sources of organic matter input to soils are litter droplets, crop residue, and waste. In addition to organic matter input into the soil, organic waste improves soil fertility and increases crop yield [6]. Cocoa requires at least 3.5 percent organic matter in the top 15 cm, with about 2 percent carbon. Cocoa thrives in soils with a pH of 6 to 7.5 and is rich in essential nutrients and trace elements [7]. Crop waste, when incorporated into the soil, increases the organic matter content. This enhances soil structure, improves water-holding capacity, and provides a source of carbon for soil microorganisms [8]. Soil organic matter plays an important role in cocoa-producing soils. [9] reported an increase in soil nutrients due to the application of cocoa pod husk ash to kola seedlings. The cocoa pod husk ash positively enhanced leaf tissue content. In soils where Ca, K, Mg, and P are found to be low, [10] recommended that for sustainable and optimal cocoa production on such soil, organic materials should be incorporated, as they in turn boost the nutrient status of the soil. Organic colloidal materials have a much greater base exchange capacity per unit weight than mineral colloidal materials, and hence they may act as buffers in soil.

Though wastes are categorized as infectious (hospital), hazardous (industrial), and municipal (household), which have been implicated in soil and environmental degradation, crop residues are described as major resources for soil health and sustainable productivity. An estimated 10 tons of wet cocoa pod husk are being generated from each ton of dry cocoa beans, thereby presenting a serious disposal problem and an unexploited resource [5]. With the high nutrient demand of cocoa trees to produce pods, the high volume of pod husk waste in cocoa farms, and the paucity of research information on the nutrient status of the husk dumpsites, there is a need to access the nutrient status of cocoa pod husk dump sites with a view to harnessing its potential for nutrient restoration in cocoa farms.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Etung Local Government in Central Cross River State, Nigeria. Etung is geographically located at latitudes 5^{o} 48’ 24’’ N and longitude 8^{o}42’ 29’’ E. It is situated within the tropics and shares a common boundary with the Republic of Cameroon in the east. The soils are generally described as heavy-textured soils because of their clay-related textures [11].

2.2 Sampling Technique and Tools

Purposeful random sampling of five cocoa-growing communities was carried out. The communities were: Last Motor, Bendeghe, Effraya, Ajassor, and Etomi. Soil samples were collected from dump sites and non-dump sites in the cocoa plantation using a soil auger.

2.3 Sample Collection and Preparation

Two (2) soil samples were collected at each location from the dump site and the plantation at a depth between 0–25 cm (top soil) and 25–50 cm (subsoil). A total of 20 samples were collected, packed in black polythene bags, labeled appropriately, and taken to the agronomy laboratory of the University of Cross River State, where they were air dried and homogenized by crushing with a mortar and pestle and then sieving with a 2 mm-diameter sieve. The soils were packed in envelopes and then taken for standard laboratory analysis at the Nigeria Institute of Soil Science (NISS) Soil Testing Laboratory, Abuja.

2.4 Sample Analysis

The prepared soil samples were subjected to laboratory analysis using the following procedures:

Particle size distribution (PSD): This was determined by the Bouyoucos (hydrometer) method procedure by Udo et al.[12]. This involves the suspension of soil samples with sodium hexametaphophate (calgon). The reading on the hydrometer was taken at 40 seconds. The second reading was taken three hours later. The particle size was then calculated using the following formulas:

Sand = 100- (H_1 + 0.2 (T_1 – 68)-2.0)2.,
Clay = (H_2 + 0.2 (T_2 (T_2-68) -2.0)2
Silt= 100 – (% sand + % clay)

Where:

H_1 = Hydrometer first reading at 40 seconds-
T_1 = temperature first reading at 40 seconds
H_2 = Hydrometer second reading after 3 hours
T_2 = Temperature second reading after 3 hours

2.5 Soil Chemical Properties

i. **Soil pH:** This was determined in both water and 0.1 N KCL in a ratio of 1:1 soil to water and 1:2.5 soil to KCl, respectively. After stirring the soil suspension for 30 minutes, the pH values were read using the glass electrode pH meter [13].

ii. **Organic Matter:** This was determined by the Walker-Black method as outlined by Page et al. [14], which involves the oxidation of dichromate with tetraoxosulfate vi acid (H_2 SO_4). The excess was titrated against ferrous sulfate. The organic carbon was then calculated using the relationship:

$$\% \text{ Org.C} = \frac{N(Vi - V_2)}{W} 0.3f$$

Where:

N = Normality of Ferous Sulphate solution

V_1 = Ml Ferrous Ammonium Sulphate for the black

V_2 = ml Ferrous Ammonium Sulphate for the sample

W = mass of sample = farm
F = correction factor = 1.33
% organic matter in soil = % org.C x 1.729

iii. Nitrogen is in the soil. Total nitrogen in soil was determined by the macro-Kjeldahl method as described by Udo et al. (2009). The soil samples were digested with tetraoxosulfate (vi) acid (H_2 $S0_4$) after the addition of excess caustic soda. This was distilled into 2% boric acid (H_3BO_4) and then titrated with 0.01 HCl. And the nitrogen was obtained from the relationship.

% N = T x Mx14 x100 / N

Where:

T = Titre value
M = Molarity of HCl
W = Weight of soil used
N = Normality of H_2SO_4

iv. **Available Phosphorus:** Available P was determined by the Bray 1 method as outlined by Page et al. [14]. This involved mechanical shaking of the sample in an extracting solution, then centrifuging the suspension at 2000 rotations per minute for 10 minutes. Using the ascobic acid method, the percentage transmittance on the spectrophotometer at 660 nm wave length was measured. The optical density (OD) of the standard solution was then plotted against the phosphorus ppm, and the extractable P of the soil was then calculated.

v. **Cation Exchange Capacity (CEC) and Exchangeable Acidity (EA):** This was determined by the Kjeldahl distillation and titration method as outlined by IITA [15]. Using ammonium acetate solution, the soil samples were leached, then the soil washed with methyl alcohol and allowed to dry. The soil was then distilled in the Kjeldahl operation to a 4% Boric acid solution. The distillate was then titrated with a standard solution of 0.1 N HCl.

vi. **Exchangeable Cations:** This was determined by the ammonium acetate extraction method as described by IITA [15]. The soil samples were shaken for 2 hours, then centrifuged at 2000 rpm for 5–10 minutes. After decanting into a volumetric flask, ammonium acetate (30 ml) was added again, shaken for 30 minutes, centrifuged, and the supernatant transferred into the same volumetric flask. An atomic absorption spectrophotometer (AAS) was used to read the cations.

2.6 Statistical Analysis

The student T-test was used to compare nutrient status in the dump sites and adjoining plantation soils and surface and subsurface depths.

3. RESULTS AND DISCUSSION

3.1 Particle Size Distribution of Dumpsites and Plantation Soils

The results of the particle size distribution (PSD) and textural classes of the dumpsites and plantation soils are presented in Table 1.

The results indicated that sand particles ranged from 22 to 48% in the top (0–25 cm) soils of the dumpsites in Last Motor, Bendeghe, Effraya, Ajassor, and Etomi, with Ajassor having the highest. At the subsoil (25–50 cm depth), the sand particles ranged from 21–46%, with Ajassor having the highest. The silt content ranged from 23 to 46% in the top soils of dumpsites, and the subsoil content ranged from 29 to 49%, with Etomi having the highest. The clay content of the dumpsite soils ranged from 29–32% in the top (0–25 cm) soils and 25–35% in the lower (25–30 cm) soils. The sand content in the top soils of the cocoa plantation ranged from 23-50%, with Ajassor having the highest content, and the sand content ranged from 22-46% in the subsoils. The silt content ranged from 27–49% in top soils and 26–48% in subsoils, with Last Motor having the highest. The clay content of the cocoa plantations ranged from 26-38% in the top soils to 28–35% in the subsoils. The textural class of all the location soils in both top and subsoils is clay loam, with the exception of Ajassor, whose texture is sandy clay loam in both top and subsoils. Soils from the cocoa pod dumpsites and the adjoining soils in the cocoa plantations were primarily similar, exhibiting the same range of particle size distribution and textural classification of clay loam for Last Motor, Bendeghe, Effraya, Etomi, and sandy clay loam (SCL) for Ajassor. The higher clay content in the subsoils may act as sorption sites for elements wasted downward from the top soils by percolating moisture and preventing such elements from leaching. The relatively high silt and clay content can provide a suitable soil condition for element retention in these soils. This higher particle size of clay and silt, though with no change in texture class, agrees with the observations of Obianefo et al. [16]. However, the high silt content of the

Table 1. Particle size density of dumpsites and plantation soils

Location	Dumpsite					Plantation			
	Sample Dept.	Sand %	Soil %	Clay %	TC	Sand %	Soil %	Clay %	TC
Last Motor	0 -25	22	46	32	Cl	20	49	31	Cl
	25-50	25	46	29	Cl	22	48	30	Cl
Bendeghe	0-25	23	45	32	Cl	23	39	38	Cl
	25-50	23	43	35	Cl	23	43	35	Cl
Effraya	0-25	27	43	30	Cl	28	42	30	Cl
	25-50	22	46	32	Cl	27	38	35	Cl
Ajassor	0-25	48	23	29	SCl	50	27	26	SCl
	25-50	46	29	25	SCl	46	26	28	SCl
Etomi	0-25	25	46	29	Cl	23	45	32	Cl
	25-50	21	49	30	Cl	24	44	32	Cl

TC = Textural class, Cl= Clayloam, SCL = Sandy Clay Loam soils in this study area was at variance with the findings of Esu,et al. [17], who reported lower levels of silt in Etung, but compares similarly with values obtained by Kekong [6] on Etung cocoa soils. The predominant clay loam texture of the study area also agrees with the findings of Kekong [6].

3.2 Soil Chemical Properties, Fertility Indices and Cations

Result of soil chemical properties in cocoa pod husk dumpsites and the nondump sites of the plantation soils is presented in Tables 2 and 3.

pH. The pH (in water) of soils at dumpsites has a range of 4.9–6.0 in the top (0–25 cm) soil and 4.2–5.8 in the subsoil (25–50 cm) depth. In the plantation soils, the pH of the top soil (0–25 cm) was 4.6–5.6, while in the subsoil (25–50 cm), it ranged from 3.9–5.6 in all the locations. The pH of CaCl in the dumpsite soils ranged from 3.7 to 5.4, while in the plantation soils, the pH ranged from 3.0 to 4.9 in both surface and subsurface soils.

Organic carbon: The organic carbon content of dumpsites' top soil (0–25 cm) ranged from 17–21% in the study locations, while the subsoil organic carbon of the dumpsites ranged from 10.90–14.8%. In the plantation soils, the organic carbon ranged from 12.6–17.6% in the top soils, with Ajassor having the least. In the subsoils of the locations of the cocoa plantations, the organic carbon ranged from 9.2-13.8%.

3.3 Electrical Conductivity (EC)

The electrical conductivity of the cocoa pod husk dumpsites in surface soils ranged from 0.068 to 0.941 ds/m, while the EC of the subsurface soils ranged from 0.038 to 0.905 ds/m. In the plantation soils, the EC of the surface soils ranged from 0.084 to 0.186 ds/m, while the EC of the soils at the subsurface level ranged from 0.058 to 0.290 ds/m.

The total nitrogen (N) content in the surface dumpsite soils ranged from 1.14–1.98%, while the total N content of the subsoils of the dumpsites ranged from 0.51–1.49%. The total N levels in the plantation soils ranged from 0.73–1.08% in the surface soils and 0.64–1.06% in the subsurface (25–50 cm) soils.

The available phosphorous (P) content in the cocoa pod dumpsites at the surface (0–25 cm) soils ranged from 9.61–13.42 mg/kg, with a mean value of 11.57 mg/kg. The available P content of the subsurface (25–50 cm) soil depth ranged from 4.92–9.15 mg/kg, with a mean of 7.87 mg/kg. In the cocoa plantation soils, the available P levels ranged from 5.98 to 11.34 mg/kg in the top soils, while the subsoil (25–50 cm) depth of the soils ranged from 5.66 to 9.36 mg/kg with a mean of 7.30 mg/kg.

The pH range of 4.9–6.0 with a mean of 5.74 is an indication that the dumpsite surface soils are strongly acidic to near moderately acidic, while the subsoil pH of the dumpsites, which ranged from 4.2–5.8 with a mean of 5.1, showed that the soils are strongly acidic. In the plantation soils, the pH of the top soils ranged from 4.6 to 5.6 with a mean of 5.18, which indicated strongly acidic soil, while the pH range of the cocoa plantation subsoils was 3.9 to 5.6 with a mean of 4.62, which showed that the subsoils of the plantation soils are very strongly acidic. This pH range of soils in Etung is similar to the values reported by Esu et al.[17,18], who reported Etung soils pH to range from 4,8–5.2, describing the soils as very strongly acidic in reaction. Due to the strongly acidic nature, the pH values of the cocoa pod husk dumpsite soils were higher than those of the non-dumped cocoa pod husk plantation soils. The higher pH of the dumpsites in this study is similar to the reports of Obianefo et al. [16] and [19]. The soil organic carbon content of the dumpsite surface soils that ranged from 17–21% was high by the rating of Havlin et al.[20], while the subsoil range of 9.20–13.8% was medium. The Org. C content of the surface soils of the plantation soils, which ranged from 12.6 to 17.6%, was moderately high, while the range of 9.2-13.8% of the subsoils of the plantation soils was low to moderate [20]. The higher organic carbon content of the cocoa pod husk dumpsite is a function of biodegradable organic wastes. This higher organic carbon is similar to the report of Anikwe et al. [21], who reported that the decomposition of biodegradables increases soil organic matter in dumpsite soils.

The electrical conductivity (EC) of the dumpsites surface soils with a range of 0.068–0.941 ds/m was high, while that of the subsoils range of 0.038–0.905 ds/m was also high compared to the EC of the non-dumped cocoa pod husk plantation soils that ranged from 0.084–0.0186 ds/m and 0.058–0.290 ds/m for the surface and subsoils, respectively, which were lower than the dumpsites soil EC. The levels of EC in dumpsites were above the critical limits, while those of the plantation soils, especially the subsurface soils, were below the critical limits, as established by Ibiremo et al. [22]. This is indicative of more soluble salts in the soil solution of the dump sites. The total N and available P of the dumpsites were higher than the levels in the cocoa plantation farms. The high organic matter content in the dumpsites, as evident by the high organic carbon content compared with the cocoa plantation soils, must have boosted microbial activities, which in turn increased the rate of mineralization and influenced the high concentrations of N and P. This nutrient content of N and P is in agreement with the report of Ideriahet al. [23], who noted that the high organic carbon content of the dumpsites is the source of most of the N and P, and [8] reported that the major source of soil organic matter is crop waste. Similarly, [24] reported the recorded beneficial effects of microorganisms in dumpsite soils whose activities will increase the nutrient content of the soil.

3.4 Exchangeable Cations

Result of exchangeable cations is presented in Table 3.

Exch. Calcium (Ca) The result of exchangeable cations indicated that calcium (Ca) in the top soils of the dumpsite ranged from 4.05 to 5.99 cmol/kg, while the subsoil (25–50 cm) depth ranged from 2.63 to 4.71 cmol/kg, while the subsurface soils Ca levels in plantation soils ranged from 2.89 to 3.82 cmol/kg.

Exch. Magnessium (Mg). Mg in the dumpsites' top soils ranged from 0.60 to 0.66 cmol/kg, and in the subsoils, the values ranged from 0.57 to 0.60 cmol/kg. In the plantation farms, the Mg concentration ranged from 0.41 to 0.60 in the surface (0–25 cm) soil depth and 0.39 to 0.54 cm/kg in the subsoils (25–50 cm) depth. The concentration of exch. K in the surface soils (0–25 cm) of the dumpsite ranged from 3.4-0.47 cmol/kg, while the subsoil (25–50 cm) had 0.21-0.37 cmol/kg. In the plantation soils, the exchange K in the top soil ranged from 0.20-0.28 cmol/kg, while the subsoil concentration was 0.11–0.20 cmol/kg.

Table 2. Soil properties of pH OC, EC, total n, available P

Location	Depth (cm)	pH		OC (%)	EC (ds/m)	Total N (%)	Av. P (mg/kg)
		H_2O	Cacl				
				Dumpsite			
Last Motor	0-25	4.9	3.9	17.4	0.272	1.58	10.21
	25-50	4.2	3.7	13.8	0.062	1.25	8.87
Bendeghe	0-25	5.8	4.8	21.1	0.073	1.98	13.42
	25-50	5.8	4.7	9.20	0.064	0.83	7.64
Effraya	0-25	6.0	5.4	19.10	0.941	1.88	12.81
	25-50	4.7	3.7	10.6	0.905	1.43	8.76
Ajassor	0-25	5.9	5.0	18.1	0.093	1.14	10.82
	25-50	5.1	4.1	13.0	0.038	0.51	4.92
Etomi	0-25	6.1	5.0	19.2	0.068	1.51	10.61
	25-50	5.7	5.0	13.4	0.065	1.49	9.15
				Plantation soils			
Last Motor	0 -25	4.6	3.6	16.0	0.096	1.04	11.34
	25-50	3.9	3.0	11.1	0.089	1.00	6.51
Bendeghe	0-25	5.6	4.7	17.6	0.150	1.05	9.85
	25-50	4.7	3.6	12.1	0.094	0.92	7.84
Effraya	0-25	5.3	4.5	17.2	0.186	1.07	10.05
	25-50	5.0	4.8	11.8	0.290	1.06	9.36
Ajassor	0-25	5.4	4.0	12.6	0.084	0.73	5.96
	25-50	5.0	3.3	14.8	0.058	0.64	5.66
Etomi	0-25	5.0	3.4	15.6	0.092	1.08	7.84
	25-50	4.5	4.9	10.9	0.081	0.89	7.10

OC = Organic Carbon, EC = Electrical Conductivity

The exchangeable acidity of H and Al in the top soils of the dumpsites ranged from 0.50 to 1.40 to 1.20 to 1.60 cmol/kg in the plantation soils; the EA for the top soils ranged from 0.40 to 2.80 cmol/kg, while in the subsoils of the soils the range was 0.40 to 3.00 cmol/kg.

The cation exchange capacity (CEC) of the dumpsite top soils ranged from 9.83 to 11.57 cmol/kg, while the subsoils ranged from 7.42 to 9.82 cmol/kg.

The results obtained in all locations indicated higher basic cations in the dumpsite, especially the surface (0–25 cm) soils, than the plantation soils. The result of this study is similar to the findings of Asare and Száková [25], who reported that wastes deposited in dumpsite soils significantly contributed to the high accumulation of macronutrients (Ca, K, S, and micronutrients) and high CEC attributed to anthropogenic activities of waste deposits.

The Ca content in dumpsites, especially in Last Motor, Bendeghe, and Etomi, was all above the critical sufficiency limits of 5.0 cmol/kg [26], while the content of Ca in all plantation soils was below the critical limits. Mg in both dumpsites and plantation soils was all below the critical limit of 0.9 cmol/kg, according to Aikpokpodion [27].

The K content of the cocoa pod husk dumpsite, particularly at the surface soils, was above the critical limit of 0.25 cmol/kg, while all the plantation farm soil locations were below the critical limits. This higher K content, a product of the mineralization of organic water, reflects the input of K into soil from organic sources.

The exchangeable acidity (EA) of H and Al in both dumpsite and plantation soils at the locations was below critical levels, though higher in the plantation soils. The reduced and lower level of EA in the dumpsites could be the result of the possible complexation of Al^{3+} and H^{+} by the higher organic carbon in the dumpsites. Organic carbon, which converts to organic matter, has been reported by Ano et al. [28-29] to reduce the deleterious effects of aluminum and hydrogen ions in soil solutions.

Table 3. Exchangeable cations of Dumpsites and plantation soils

Location	Depth (cm)	Ca	Mg	K	Na	H+Al	CEC	BS
		→			**Cmol/kg**	←		
Dumpsite								
Last Motor	0-25	5.22	0.66	0.34	0.57	1.40	9.83	
	25-50	3.60	0.61	0.21	0.57	1.20	7.58	
Bendeghe	0-25	5.76	0.61	0.39	0.57	0.60	11.57	
	25-50	4.71	0.60	0.23	0.57	0.40	8.76	
Effraya	0-25	4.05	0.60	0.41	0.56	0.50	10.38	
	25-50	2.63	0.59	0.33	0.56	1.60	7.42	
Ajassor	0-25	4.96	0.60	0.43	0.57	1.01	10.72	
	25-50	4.03	0.57	0.27	0.56	0.80	9.10	
Etomi	0-25	5.99	0.61	0.47	0.56	0.80	10.63	
	25-50	4.69	0.58	0.37	0.56	0.60	9.82	
			Plantation soils					
Last Motor	0 -25	4.68	0.60	0.20	0.57	1.60	8.39	
	25-50	2.68	0.54	0.12	0.57	1.80	7.56	
Bendeghe	0-25	4.76	0.51	0.28	0.57	2.80	9.90	
	25-50	3.05	0.40	0.11	0.50	0.40	8.37	
Effraya	0-25	4.05	0.41	0.21	0.56	0.40	8.37	
	25-50	3.53	0.39	0.20	0.56	0.40	6.67	
Ajassor	0-25	4.11	0.59	0.23	0.56	0.80	8.20	
	25-50	2.89	0.48	0.15	0.56	3.00	7.06	
Etomi	0-25	4.75	0.50	0.24	0.56	0.40	9.41	
	25-50	3.82	0.48	0.20	0.56	0.90	8.48	

BS = Base Saturation

3.5 Site and Depth Effect of Cocoa Pod Husk Dumpsites and Plantation Soil

The differences in concentration of primary plant nutrients and some soil fertility indices in cocoa pod dumpsites and plantation soils are presented in Tables 4, 5, 6, and 7. The result indicated that total nitrogen and available phosphorus were significantly higher ($P<0.05$) in cocoa pod husk dumpsites than the adjoining cocoa plantation soils (Tables 4 and 5). The concentration of these nutrients was also higher in the surface surface soils than in the subsurface soils of the dumpsites. The organic carbon content, the cation exchange capacity, and the soil pH were significantly higher in cocoa pod husk dumpsites than in plantation soils (Tables 6 and 7).

This result shows, in part, a correlation between pH and available P in soils. The higher pH in dumpsites could have facilitated the reduction of P fixation in dumpsites. In another view, the continuous uptake of P and N can lead to their lower levels in cocoa plantation farms. The higher CEC and N in dumpsites could be expected because the higher organic carbon in the dumpsites is likely to influence the CEC and the total N in the soils. The higher the N content in the dumpsites, the higher the OC in the dumpsites. The report by Hartemink et al. [30] had earlier noted that the N in cocoa farm litter (organic matter) is higher than the N exported from cocoa beans. The higher nutrient concentration in the surface soils of the dumpsites reflects the higher OM in this soil depth, which is responsible for the sorption and retention of these nutrients.

Table 4. Total N and available P of dumpsites and plantation soils

Location	Depth (cm)	Dumpsite	Plantation	Dumpsite	Plantation
		Total N (g/kg)		Av. P (mg/kg)	
Last Motor	0-25	1.58	1.04	10.21	11.34
	25-50	1.25	1.00	8.87	6.51
Bendeghe	0-25	1.98	1.05	13.42	9.85
	25-50	0.83	0.92	7.64	7.84
Effraya	0-25	1.88	1.07	12.61	10.05
	25-50	1.43	1.06	8.76	9.36
Ajassor	0-25	1.14	0.73	10.82	5.98
	25-50	0.51	0.64	4.92	5.66
Etomi	0-25	0.51	1.08	10.61	7.84
	25-50	1.49	0.89	9.15	7.10
$\bar{X}$		1.36	0.95	9.72	8.1
SE		3.80		2.37	

N = Nitrogen, P = Phosphorus

Table 5. pH, Org. C and CEC of dumpsites and plantation soils

Location	Depth (cm)	Dumpsite Ph	Plantation	Dumpsite OC	Plantation	Dumpsite CEC	Plantation
Last Motor	0-25	4.9	4.6	17.4	16.0	9.83	8.39
	25-50	4.2	3.9	13.8	11.1	7.58	7.56
Bendeghe	0-25	5.8	5.6	21.1	17.6	11.57	9.90
	25-50	5.4	4.7	9.20	12.1	8.76	8.37
Effraya	0-25	6.0	5.6	19.10	17.2	10.38	8.37
	25-50	4.7	5.0	10.6	11.8	7.422	6.67
Ajassor	0-25	5.9	5.4	18.1	12.6	10.72	8.20
	25-50	5.1	5.0	13.0	14.8	9.10	7.06
Etomi	0-25	6.1	5.0	19.2	15.6	10.63	9.41
	25-50	5.7	4.5	13.4	10.9	9.82	8.48
$\bar{X}$		5.42	4.90	15.49	13.97	9.58	8.24
SE		3.29		2.79		5.36	

OC = Organic carbon, CEC = Cation exchange capacity

Table 6. Total N, available P of dumpsites surface and subsurface soils

	Dumpsite N Surface (0-25)	Subsurface (25-50cm)	Available P Surface (0-25)	Subsurface (25-50cm)
Last Motor	1.58	1.25	10.21	8.87
Bendeghe	1.98	0.83	13.42	7.64
Effraya	1.88	1.43	12.81	10.05
Ajassor	1.14	0.51	10.82	4.92
Etomi	1.51	1.49	10.61	9.15
$\bar{X}$	1.618	1.102	11.87	8.13
SE	2.72		2.86	
Plantation soils				
Last Motor	1.04	1.00	11.34	6.51
Bendeghe	1.05	0.92	9.85	7.84
Effraya	1.07	1.06	10.05	9.36
Ajassor	0.73	0.64	5.98	5.66
Etomi	1.08	0.89	7.84	7.10
$\bar{X}$	0.98	0.90	9.01	7.29
SE	2.54		2.07	

Table 7. Organic C, pH and CEC of surface and subsurface soils of dumpsites and plantations

	Organic C		pH		CEC	
	Surface (0-25)	Suburface (25-50)	Surface (0-25)	Subsurface (25-50cm)	Surface (0-25)	Subsurface (25-50cm)
Last Motor	17.4	13.8	4.9	4.2	9.83	7.58
Bendeghe	21.1	9.2	5.8	5.4	11.57	8.76
Effraya	19.1	10.6	6.0	4.7	10.38	7.42
Ajassor	18.1	13.0	5.9	5.1	10.72	9.10
Etomi	19.22	13.4	6.1	5.0	10.63	9.82
$\bar{X}$	18.98	12.00	5.74	4.88	10.62	10.52
SE	4.78		5.48		0.27	
Plantation soils						
Last Motor	16.0	11.0	4.6	3.9	8.39	7.56
Bendeghe	17.6	12.1	5.6	4.7	9.90	8.37
Effraya	17.2	11.8	5.6	5.0	8.37	6.07
Ajassor	12.6	14.8	5.4	5.0	8.20	7.06
Etomi	15.6	10.9	5.0	4.5	9.47	8.48
$\bar{X}$	15.8	12.12		5.24	8.85	7.63
SE	6.06			7.75	7.2	

4. CONCLUSION

The results obtained in this study indicated that the dumping of cocoa pod husk, an agricultural farm waste, is not a threat to soil deterioration. This is so because the physical property of texture was not changed. The soil pH was increased, as was the EC, indicating more nutrients in the solution. The increased soil organic carbon, which transmits to soil organic matter, is a sorption and retention site for both macro- and micronutrient elements, especially cationic elements, which prevent their excess release into the soil liquid phase. The findings also suggest that relocating cocoa pod husk dumpsites within the cocoa farms could create nutrient-enriched new sites for growing new cocoa or intercrops in the old dumpsites.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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