Physicochemical Soil Analysis of Rejuvenated Cocoa Plantation Farms in Obaagun Area of Osun State

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ABSTRACT: *Theobroma cacao, which is also known as cacao tree is an important commercial plantation crop of the world used in the production of a variety of products such as cocoa powder, chocolate products, beverages, butter, biscuits, wine, soap, cream, cocoa bread, livestock feeds among others. This study evaluated the soil quality of rejuvenated cocoa plantation farms in Obagun area of Osun state, it compares the soil qualities and properties of these cocoa plantations and determine if the soils in the area are well suitable for cocoa cultivation. Twenty-four (24) soil samples each were collected from 2 cocoa plantations (A and B) of similar ages and agricultural practices. The samples were collected from the depths of 0-15cm and 15-30cm from the two sites respectively. The physical properties were analyzed to know the percentage of sand, clay and silt. The chemical properties were analyzed for particle sizes, pH, hydrogen, organic carbon, organic matter, total nitrogen, available phosphorus, cation exchange capacity, base saturation, sodium, potassium, calcium, magnesium, and the heavy metals were also analyzed for zinc, iron, manganese, copper, lead, cadmium, chromium, and cobalt. When analyzing the physical properties of the two sites, it was observed that silt as the highest percentage of soil particles with 79.72% on site B at a depth of 0-15cm and clay as the lowest percentage of soil particles of 6.58% at a depth of 0-15cm on site B. Analyzing the chemical properties on both sites, it was observed that base saturation as the highest percentage with a value of 96.94% on site B at a depth 0-15cm and Hydrogen as the lowest percentage of 0.10 on site B at a depth of 15-30cm. The presence of heavy metal was also evaluated, it was observed that zinc as the highest value of 0.93mgkg^{-1} on site A at a depth of 0-15cm and both copper and chromium are absent on site A at a depth of 15-30 cm. The long-term residence of the cocoa plantation on the soil resulted in the decline of micronutrients in the soil. There is need for the soil nutrients to be replenished to ensure continued good production of the cocoa plantation.*

KEYWORDS: Rejuvenated Cocoa, Physicochemical, Soil Analysis, Cocoa plantation, Heavy metals.

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INTRODUCTION

Cocoa *(Theobroma cacao)* is an important commercial plantation crop of the world. It is a crop of humid tropics and so it was introduced as a mixed crop in areas where the environment suits the crop. The natural habitat of cocoa trees is in the lower story of the evergreen rainforest, and climatic factors,

particularly temperature and rainfall, are important in encouraging maximum growth. Cocoa is a perennial crop and can withstand different seasonal variations with good health and yield potential. There are three (3) varieties of cocoa namely Criollo, Forastero, and Trinitario (Malhotra and Elain Apshara, 2017).

Cocoa is propagated by seeds. Seeds are to be extracted from the pods. The pods take 150 – 170 days from pollination to be ready for harvesting (Tamil Nadu Agricultural University, 2013). The stage of harvesting is marked by change in color from green to yellow (Forastero) and red to yellow (Criollo). Harvested seed pods can be store in shade for a week. Viviparous germination is reported in ripe cocoa which may affect the percentage of germination if it is stored for more than a week. Seeds are to be sown immediately after extraction from the pods.

Theobroma cacao, which is also referred to as cocoa tree is a small (4-6m tall evergreen tree in the family Malvaceae (Genus Theobroma, 2010; Theobroma cacao, 2012). Cocoa beans can be used in the production of a variety of products such as cocoa powder, chocolate products, beverages, butter, biscuits, wine, soap, cream, cocoa bread, livestock feeds among others (Arueya 1989; Olubamiwa *et al,* 2000 and Hamzat *et al,* 2003).

Cocoa has played a significant socio-economic role in Nigeria. It accounts for at least 2% of the national export earnings and over 200,000 rural households in 14 Cocoa-producing states depend on cocoa as their main source of livelihood (National Cocoa Development Committee NCDC, 2008). Nigeria was the second largest producer of cocoa in the world leading but due to a combination of factors its production has fallen over time. Nigeria is currently the fourth largest producer of cocoa in the world after Cote d'Ivoire, Ghana, and Indonesia, (ICCO, 2009/2010). In Nigeria, the main cocoa-producing areas are concentrated in southwestern and eastern parts of the country, which cover for more than 70% of total annual production (Famuwagun, Agele and Aiyelari, 2017).

In recent years Nigeria's output of cocoa has declined, in 2010, cocoa production amounted to only 0.3% of agricultural GDP, this decline in production has been attributed to a number of factors including poor soil quality. It has been shown experimentally by the Cocoa Research Institute of Nigeria (CRIN) that continuous cultivation of cocoa on the same farmland leads to gradual depreciation of the physicochemical properties of the soil. Land use changes have remarkable effects on the dynamics of soil properties (Biro et al., 2013). Land use changes from forest cover to cultivated land may lead to a decline in the input or organic residues that lead to reduced soil fertility (Muñoz-Rojas et al., 2015), increased rates of erosion (Biro et al., 2013), loss of soil organic matter and nutrients (Saha and Kukal, 2015), and an accelerated rate of soil degradation (Barua and Haque, 2013).

Soils are vital resources that are not capable of being renewed on the human time scale (Herbert et al., 2006). They are also living, dynamic natural bodies that perform many important functions in terrestrial ecosystems. Examples of such functions are, sources of available nutrients to plants, maintenance in hydrological stability and biological diversity. Sustaining soil ecosystem and environmental features are the most effective methods for ensuring sufficient food supply to support life, reduce soil degradation and improve soil health (Soares et al., 2005).

According to (Ololade A. et al., 2010), crop production involves a complex interaction between the environment, soil properties and nutrient dynamic based on which soils must be studied in terms of productive potential. (Eneje et al., 2012) affirm that the most important factor in continuous productivity of tropical soils is the maintenance and improvement of soil physical characteristics and the capacity of the soil to hold the trees.

Future success on cocoa production in Nigeria therefore depends on the introduction of an ecologically prudent farming system which can prevent deterioration of soil physical properties and increase soil organic matter and employ less external input.

MATERIALS AND METHODS

The study was carried out on two (2) cocoa plantations A (site A) and B (site B), of sizes within 3-5 acres in Obaagun area of Osun state (latitude 7º50" North of the equator and longitude 4º East of the Greenwich meridian). These two cocoa plantations were about 70years old but rejuvenated 17 and 20 years ago respectively. On the two sites, soil samples were collected randomly. A total of 24 samples were collected from each site using the soil auger. The surface litter was scrapped from the soil then samples were collected at the depth of 0-15cm and the depth of 15-30cm respectively and the samples were bagged. The soil samples were air dried for 72 hours, weighed and then passed through a 2 mm sieve and weighed again (EPA Method 3052) to get the percentage gravel content. The sieved samples were then packed in well labelled polythene bags and were subjected to both physical and chemical analysis.

Determination of gravel content of soil
The soil sample was dried, weighed, and passed through a 2 mm sieve. The content of the sieve was weighed and expressed as a percentage of the initial weight of the soil.

Soil particle distribution (the hydrometer method)
50 g of air-dried, fine-textured soil was weighed into a baffled stirring cup. The cup was half fill with distilled water and 10ml of sodium hexametaphosphate solution was added. The cup was placed on a stirrer and stir until the soil aggregates are broken down. The stirred mixture was quantitatively transferred into the settling cylinder by washing the cup with distilled water, the cylinder was filled to the lower mark with distilled water after placing hydrometer in the liquid. The hydrometer was removed, the suspension was Shaked vigorously in a back-and-forth manner. The cylinder was placed on a table and the time was recorded. After 20 seconds, the hydrometer was carefully inserted and read at the end of 40 seconds and recorded on a data sheet, the temperature of the suspension was measured. The suspension inside the cylinder was re-shake and placed on a table where it will not be disturbed. The hydrometer reading was retaking after 2 hours.

Soil pH Determination
The soil was assessed chemically by determining the pH of the soil according to the method of Peech, 1965. 20g 0f fine earth was weighed into 100 ml polythene wide mouth bottle 50ml 1 M KCl solution was added, the bottle was capped and shaken for 2 hours. Before measuring the bottle was shaken by hand then the electrode was immersed in the upper part of the suspension and the pH was read when the reading stabilized (accuracy 0.1 unit).

Percentage organic matter (loss of weight on ignition)
A 10.0 g of sieved soil was weighed into an ashing vessel. The ashing vessel with the soil was placed into a drying oven set at 105 °C and dry for 4 hours. The ashing vessel was removed from the drying oven and placed in a dry atmosphere. When cooled, it was weighed to the nearest 0.01 g. The ashing vessel with soil was placed into a muffle furnace, and the temperature was brought to 400 °C. Ash in the furnace for 4 hours. The ashing vessel was removed from the muffle furnace, cooled in a dry atmosphere, and weigh to the nearest 0.01g. The percentage of OM is given by:

$$\text{Percent organic matter (OM)} = \frac{W_1-W_2}{W_1}$$

Where: W1 is the weight of soil at 105 °C, W2 is the weight of soil at 400 °C. The percent of organic C is given by: % OM $\times$ 0.58.

Organic carbon Determination
The organic carbon was determined according to the method of Walkley-Black, 1982. 5g of fine earth was grinded and passed through a 0.25 mm sieve, 1g of the sieved earth was weighed into a wide mouth flask including a control sample. 10.00ml of dichromate solution was added including 2 blanks to determine the molarity of the ferrous solution. 20ml of sulphuric acid was carefully measured into a measuring cylinder, swirled, and allowed to stand for 30 minutes. 250ml of water and 10ml of phosphoric acid was carefully added with a measuring cylinder and allowed to cool 1ml indicator solution was added and it was titrated with ferrous sulphate solution while the mixture was being stirred.

Percentage Nitrogen Determination
The procedure of micro-Kjeldah1 was followed. 5 g of fine earth was grinded and passed into 0.25 mm sieve, 1 g was weighed into a digestion tube of soil rich in organic matter and 2.5 ml of digestion mixture was added. 3 aliquots of 1 ml hydrogen peroxide were added. The tube was placed on the heater and heated for 1hr at 200ºC, the temperature was turned up to a temperature of 330ºC for about 2hrs until the temperature is transparent. The tube was removed from the heater and allowed to cool, 10ml of water was added with washing bottle while swirling.

Determination of Percentage Phosphorous
The method of Olsen et al., 19094 was followed. A 5kg of fine earth was weighed into a 250 ml polythene shaking bottle. 100 ml of sodium bicarbonate solution of pH 8.5 was added and shake for 30mins. A Whatman 42 hardened filter was used to filter, 3 ml of the standard series, the blanks and sample extracts was pipette into the test tube. 3 ml of the mixed reagent was added by pipette and swirl CO_2 evolved. The absorbance was measured on spectrophotometer at 882 mm.

Cation Exchange Capacity
The procedure of Lavkulich ,1981 was followed. 10 g of soil was weighed into a 100 ml centrifuge tube, a blank including quality control sample was prepared. 40 ml of 1 M NH_4OAc was added to the centrifuge tube. The tube and was stoppered and shaken for 5 min on a reciprocal shaker. The tubes were removed from the shaker, agitated to rinse down soil adhering to the sides of the tube, and let stand overnight. The tube was shaken again for 15 minutes. The Buchner funnels were prepped with Whatman No. 42 filter paper and placed above 500 ml filtering flasks. The contents of the tube were transferred to the funnel with suction applied. The tube and the stopper were rinsed with 1 M NH_4OAc

from a wash bottle. The soil in the Buchner funnel was rinsed with four 30 ml portion s of 1 M NH_4OAc. Each portion was allowed to drain completely before adding the next, but not allowed the soil to become dry or cracked. The leachate was transferred to a 250 ml volumetric flask, the filtering flask was rinsed with 1 M NH_4OAc and made up to volume with 1 M NH_4OAc. Mixed well and a portion of the extract saved for analysis of Al, Ca, Mg, K, and Na. samples were kept refrigerated prior to analysis. For Cation exchange capacity (CEC), which is a measure of the amount of ions that can be adsorbed, in an exchangeable fashion, on the negative charge sites of the soil (Bache, 1976), the funnels containing the ammonium-saturated soil is placed onto the filtering flasks. To remove the residual NH_4OAc from the soil, the soil in the Buchner funnel was washed with three 40 ml portions of isopropanol, again letting each portion drain completely before adding the next. The isopropanol washings were then discarded, and the flask was rinsed with tap water followed by distilled water. The funnels were replaced onto the flasks and the soil was leached with four 50 ml portion s of 1 M KCl, again letting each portion drain completely before adding the next. The leachate was transferred to a 250 m L volumetric flask. The filtering flask was rinsed into the volumetric flask with distilled water and made up to volume with distilled water. Mixed well and a portion of the extract saved for analysis of NH_4 by auto analyzer.

The calculation is: $P\ (kg/ha) = \dfrac{A}{1\ 000\ 000} \times \dfrac{50}{5} \times \dfrac{2\ 000\ 000}{5} = 4A$

Where: weight of the soil taken = 5 g.

Volume of the extract = 50 ml.

Volume of the extract taken for estimation = 5 ml.

Amount of P observed in the sample on the standard curve = A (µg).

Weight of 1 ha of soil down to a depth of 22 cm is taken as 2 million kg.

Preparation of standard curve for zinc

The reagents required are Standard Zn solution, Glass-distilled or demineralized acidified water of pH 2.5 ± 0.5, Working Zn standard solutions. The procedure is; flaming the solutions: Atomize the standards on an AAS at a wavelength of 213.8 nm (Zn line of the instrument). Prepare a standard curve of known concentrations of Zn solution by plotting the absorbance values on the y-axis against their respective Zn concentration on the x-axis.

Preparation of standard curve for copper.

The reagents required are Standard Cu solution, Glass-distilled or demineralized acidified water of pH 2.5 ± 0.5, Working Cu standard solutions. Standard Cu solution, Glass-distilled or demineralized acidified water of pH 2.5 ± 0.5, Working Cu standard solutions. The procedure is: Flame the standards on an AAS at a wavelength of 324.8 nm (Cu line of the instrument). Prepare the standard curve with the known concentration of Cu on the x-axis by plotting against the absorbance value on the y-axis.

Preparation of standard curve for iron

The reagents required are: Standard Fe solution, Glass-distilled or demineralized acidified water of pH 2.5 ± 0.5, Working Fe standard solutions. The procedure is: Flame the standards on an AAS at a wavelength of 248.3 nm (Fe line of the instrument). Prepare the standard curve with the known concentration of Cu on x-axis by plotting against the absorbance value on the y-axis.

Preparation of standard curve for manganese

The reagents required are Standard Mn solution, Glass-distilled or demineralized acidified water of pH 2.5 ± 0.2, Working Mn standard solutions. The procedure is: Flame the standards on an AAS at a wavelength of 279.5 nm (Mn line of the instrument). Prepare the standard curve with the known concentration of Mn on the x-axis by plotting against the absorbance value on the y-axis.

RESULTS AND DISCUSSION

The physico- chemical properties of the two different cocoa farm soils were analysed at different depths. As shown in table 1 the percentage clay soil on site A at the depth of 0-15cm is 7.28% and it is higher than depth of 15-30cm which is 6.90%. On site B at the depth of 0-15cm the percentage clay was 6.58% and it is lower than depth of 15-30cm which was 7.8%. The silt of site A at the depth 0-15cm is 78.75 was higher than that of 15-30cm which is 75.77 and on site B the silt at the depth of 0-15cm is 79.72 is higher than that of 76.73 which was recorded at the depth of 15-30cm. However the soil contain significant percentage of sand, in both farms and at different layers. Soils composed small proportion of silt and clay don't compress (collapse) as they lose water. Such soils continue to have high permeability to oxygen during sub aerial exposure. Soils of intermediate grain size composition exhibit partial compression. Indeed, compressibility has been found to be linearly correlated to silt-clay content (Adewole et al., 2011). This compressibility as experienced may be responsible for the high quality of cocoa in Obaagun area of Osun State.

Table 1. Values of Physical Properties of the Site

S/N	Type of soil	SITE A		SITE B	
		Depth (cm)		Depth (cm)	
		0-15	15-30	0-15	15-30
1	Sand	14.06	16.85	13.55	16.03
2	Silt	78.75	75.77	79.72	76.73
3	Clay	7.28	6.90	6.58	7.85

The chemical properties of the soil are shown in table 2. The effect of soil pH is profound on the solubility of minerals and nutrients and It is regarded as a useful indicator of other soil parameters (Ololade et al., 2010). Particularly, it provides useful information about the availabilities of exchangeable cations (e.g Ca_2^+, Mg_2^+, K^+, e.t.c) in soils (Adwole et al., 2011). Most minerals and nutrients are more soluble or available in acid soils than in neutral or slightly alkaline soils (Ololade et al., 2010). The pH is neutral and varies with depth on site A with pH of 6.51 at a depth of 0-15cm

and a pH of 6.04 at depth of 15-30cm as shown in table 2. The pH slightly decreases with depth on site B, with a pH of 6.64 at depth 0-15 and pH of 6.15 at depth 15-30cm. Several factors may be responsible for the fluctuating nature of the pH with depth. This may include variability in the use of fertilizer and some other chemicals and also the year of establishment (Ololade et al., 2010).

Table 2. Values of Chemical Properties of the Site

S/N	Chemical properties	SITE A		SITE B	
		Depth		Depth	
		0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)
1	pH	6.51	6.04	6.64	6.15
2	Hydrogen	0.14	0.11	0.13	0.10
3	Sodium $Cmolg^{-1}$	0.44	0.38	0.46	0.40
4	Potassium Cmolg-1	0.56	0.54	0.60	0.55
5	Calcium Cmolg-1	0.29	0.26	0.29	0.26
6	Magnesium Cmolg-1	1.15	0.79	1.27	0.86
7	Organic Carbon (%)	10.69	8.86	10.55	8.77
8	Organic Matter (%)	18.46	15.28	20.38	15.30
9	Nitrogen (%)	0.74	0.16	0.92	0.14
10	Available Phosphorus $mgKg^{-1}$	7.83	6.72	8.18	7.00
11	Cation Exchange Capacity	2.52	2.10	2.66	2.17
12	Base saturation (%)	95.49	94.9	96.94	95.25

The organic matter of soils as shown in table 2 includes the remains of plants, animals and microorganisms in all stages of decomposition. The organic matter of on site A cocoa farm at a depth of 0-15cm is 18.46cm which is higher than the organic matter of 15.28 at a depth of 15-30cm on the same site. The organic matter of on site B cocoa farm at a depth of 0-15cm is 20.38cm which is higher than the organic matter of 15.30 at a depth of 15-30cm on the same site B. The level of organic matters in soils influences a number of soil chemical and physical properties (Adwole et al., 2011). The high organic matter content of cocoa farm in Obaagun area of Osun State were responsible for the high yield of cocoa, because of high decayed plants and animals. Nitrogen is the most critical element obtained by plants from the soil and is a bottleneck in plant growth (Kekane et al., 2015). The Nitrogen of the soil at depth of 0-15cm is 0.74 on site A and 0.16 at a depth of 15-30cm on site A. The Nitrogen of the soil at depth 0-15cm is 0.92 on site B and 0.14 at a depth of 15-30cm on site B. The Nitrogen recorded in the two farms were greater than 0.2% minimum requirement of nitrogen needed for plant growth and higher than the world average nitrogen content (<0.15%) (Brady, 1990).

The cation exchangeable capacity (CEC) is a measure of the soil's ability to adsorb (and release) cations (Ololade et al., 2010). It is highly needed for the estimation of contaminant transport potential and sorption capacity for any soil location i.e. the total number of cations it can retain on its adsorbent complex at a given pH. The CEC's across the various sites ranged from 2.66 to 2.10 meq/100g, this is similar to the value obtained by Ololade et al., 2010. These values falls within low to very low CEC based on EPA's ESES guidelines (Russell, 1994). The presence of these low values of CEC indicates the presence of less clay and organic matter (Liber et al., 1996). The organic carbon of site A at depth of 0-15 cm (10.69 %) was higher than that of depth 15-30 cm (8.86%). The organic carbon of site B at depth of 0-15 cm (10.55 %) was higher than that of depth 15-30 cm (8.77%). The Phosphorus of site A at depth of 0-15 cm (7.83 mgKg^{-1}) was higher than that of depth 15-30 cm (6.72 mgKg^{-1}). The organic carbon of site B at depth of 0-15 cm (8.18 mgKg^{-1}) was higher than that of depth 15-30 cm (7.00 mgKg^{-1}). The mineral element of the soil are shown in table 3. The presence of trace quantity of heavy metals like cadmium and zinc is an indication that the soil may be toxic for planting food crops and the nearby streams of water may contain high level of contaminants (Vilas 2010).

Table 3. Values of Heavy Metals of the Site

S/N	Type of soil	SITE A		SITE B	
		Depth (cm)		Depth (cm)	
		0-15	15-30	0-15	15-30
1	Zn (mgKg-1)	0.93	0.51	0.95	0.55
2	Fe (mgKg-1)	0.60	0.39	0.92	0.51
3	Mn (mgKg-1)	0.18	0.05	0.14	0.15
4	Cu (mgKg-1)	0.32	0.13	0.44	0.17
5	Pb (mgKg-1)	0.03	0.01	0.02	0.01
6	Cd (mgKg-1)	0.02	0.01	0.02	0.01
7	Co (mgKg-1)	0.01	0.00	0.00	0.01
8	Cr (mgKg-1)	0.01	0.00	0.00	0.01

*Zn=Zinc, Fe=Iron, Mn=Manganese, Cu=Copper, Pb=Lead, Cd=Cadmium, Cr=Chromium

CONCLUSION

From the results of the physicochemical analysis carried out on soil samples from the 2 research sites it can be concluded that; Both soils have very similar physical properties, chemical properties and heavy metals. It can also be concluded that the soils are well suited to cocoa production in the long term. The soil is of good quality but has a slightly low concentration of Nitrogen, Phosphorus, and Potassium.

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