Assessment Of The Physicochemical Characteristics Of Soils In Major Cocoa Producing Areas In The Dormaa West District Of Ghana

Okoffo, E. D., Ofori, A., Nkoom, M., Bosompem, O. A.

Abstract: The physicochemical properties of cocoa growing soils were assessed in four cocoa growing communities in the Dormaa West District of the Brong Ahafo Region of Ghana, to ascertain the variations in selected soil properties and the quality of these soils for cocoa production. Thirty-two (32) soil samples were collected between December 2014 and February 2015 from sixteen (16) selected cocoa farms and analysed using standard procedures. The results of the physicochemical properties of soils were in the ranges of: pH (7.35-8.49), EC (203-251 µS/cm), %OC (1.38-6.25%), %OM (2.38-10.8%), %TN (1.64-2.13%), Available phosphorous (0.63-2.47 mg/kg), Available potassium (0.35-0.85 ppm), NH_4^+ (34.8-45.0 mg/L), NO_3^- (25.7-40.6 mg/L), %Sand (50.8-67.8%), %Clay (11.7-25.0%), and %Silt (9.96-24.3%). The texture of the soils were generally sandy loam. In this study, the scientifically measured soil properties showed significant variations ($p<0.05$) in some of the soils properties except EC, available K, %TN, NH_4^+, %Clay, and Exchangeable K. Soil properties such as organic matter, electrical conductivity, available potassium and available phosphorous were below the minimum required value of soils for cocoa cultivation. In addition, total nitrogen and pH were above the recommended limit required for cocoa production. However, percent organic carbon and exchangeable potassium were within their respective critical limits for cocoa production. A guided application of fertilizer and manure is recommended to cocoa farmers for improved cocoa productivity.

Keywords: Assessment; Cocoa Farms; Cocoa production; Dormaa West; Physicochemical properties; Soil quality

INTRODUCTION

Ghana is currently the world's second largest producer of cocoa after Cote D'Ivoire, producing about 21% of West Africa's total output [1], [2]. Cocoa is one of the most important perennial tree crops grown in Ghana, and plays a strategic and crucial role in the Ghanaian economy [3], [4]. Smallholder farmers in the forest regions of Ghana have traditionally depended on cocoa production as a major source of livelihood and an avenue to earn foreign exchange for the country [4], [5]. Production of cocoa in Ghana has been fluctuating over the last decades ranging from 350,000 tons in 1998 to about 750,000 in 2004/2005 cocoa season. However, government's intervention increased cocoa production levels to an estimated record-breaking average of about 1 million tons in 2012 cocoa season [6]. Notwithstanding the above, yields of cocoa per hectare are generally lower in Ghana compared to other major producing countries [3]. According to [7], [8] cocoa yield/ha in Ghana is about 400kg and is substantially lower than those observed in some cocoa producing countries such as Malaysia (1800kg/ha) and Cote d'Ivoire (800kg/ha). Reasons for the low productivity has been partially attributed to a number of factors including the depleting of soil nutrient/quality [9], [6]. The concept of soil quality includes assessment of soil properties and processes as they relate to the capacity of a soil to function effectively as a component of a healthy ecosystem [10]. Its assessment therefore focuses on the dynamic aspects to evaluate the sustainability of soil management practices. According to [11], the model profile for good cocoa soils are deep and characterized by well drained non-gravelly top soil over sandy clay loam layer which usually contains both iron oxide concretions and quartz gravel which overlies sedentary mottled clay, which merges with the incompletely weathered parent material. Soils are vital resource that are not capable of being renewed on the human time scale [12]. They are also living and dynamic natural body that plays many key roles in terrestrial ecosystems, for instance, 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 [13]. According to [14], crop production involves a complex interaction between the environment, soil properties and nutrient dynamic and based on this, soils must be studied in terms of productive potential. In addition, [15] asserts 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. The Dormaa West District which is located in the Brong Ahafo Region of Ghana is known to be one of the

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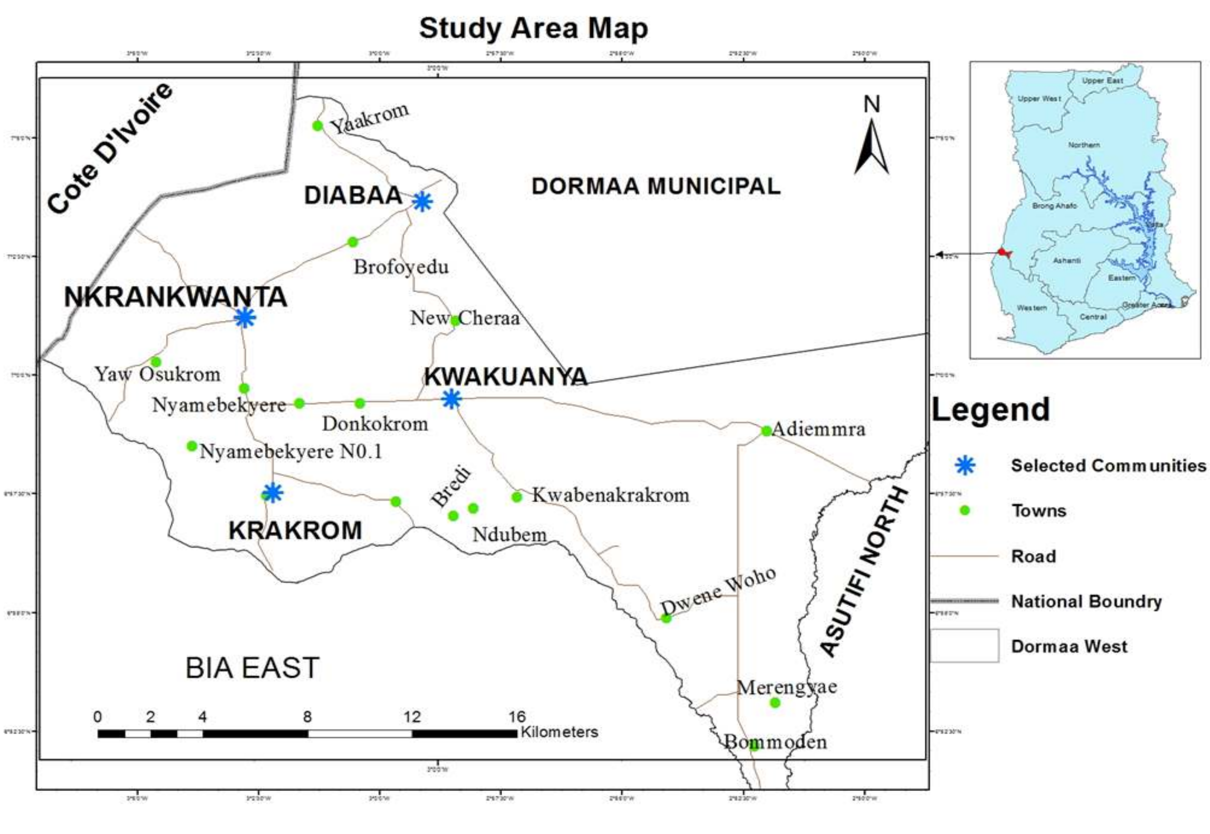
major cocoa producing district in Ghana. However, there is a decreasing trend in cocoa yield over the years due to declining soil fertility. Farmers are unable to purchase fertilizers, to improve soil fertility, to boost cocoa production due to their high cost. Therefore, there is the pressing need for the assessment of the physicochemical characteristics of cocoa farm soils to know whether they are of good quality for cocoa production. Unfortunately, there is little information on soil properties of cocoa farms soils in the district and the Region as a whole. In this present study, physiochemical characteristics of soils namely pH, electrical conductivity, total organic matter and carbon, available potassium, nitrogen, available phosphorus, ammonium, nitrate, exchangeable potassium, clay, silt and sand content, and soil texture were assessed in soils from selected cocoa farms in the Dormaa West District, in order to know the physicochemical status of cocoa farm soils.

MATERIALS AND METHODS

Study area and sampling design

The study was carried out in the Dormaa West District located at the western part of the Brong Ahafo Region of Ghana. The administrative capital of the district is Nkrankwanta and it shares boundary with Dormaa Central Municipality to the north, Asunafo North Municipality to the east, to the west with La Cote D'Ivoire and to the south-west with Bia East District [16]. The district lies in the sub-humid climatic zone. The total annual rainfall of the region ranges from 800 to 1200 mm with a bimodal rainfall pattern. The district is generally an agrarian economy which contributes immensely to the food basket of the country. Agriculture is the main source of employment (82%) in the district. The major economic activities in the district include the cultivation of food and cash crops (including cocoa), poultry and livestock farming, oil palm extraction, cassava processing and sand winning. Soils in the District belong to the Bekwai-Nzema compound Associations. The Nkrankwanta Association dominated the south-western section of the District. The Nzema series, which are made up of quartz gravels and ironstone are moderately well-drained. Currently, the soil types within the district tend to support cultivation of both commercial and domestic food crops, which include cocoa, coffee, oil palm, citrus, cola-nuts, plantain, cassava and maize [16]. The area is well drained as evidenced by the network of rivers spread out within the district. The rivers are mostly perennial due to the double maxima rainfall, which is experienced in the area. Notable among them are the Bia, Nkasapim and Pamu rivers. These rivers are mostly used as a source of water for the cultivation of vegetables such as tomatoes, pepper and okra during the dry season. [16]. Four cocoa growing communities were randomly selected from the study area. The communities selected were Nkrankwanta, Diabaa, Krakrom and Kwakuanya and were coded as sites S1, S2, S3 and S4 respectively. In each cocoa growing community randomly selected, four (4) cocoa farms (farms not less than 8 years and not more than 20 years) were identified and selected purposively, making a total of sixteen (16) cocoa farms. Soils samples were taken from December, 2014 to February, 2015.



Map of Dormaa West District showing study communities

Collection of soil samples and physicochemical analysis

In each selected cocoa farm, two quadrats of 80 x 80 metres were marked. In each quadrat, five (5) representative core soil samples were collected randomly at depth 0-20 cm using a soil auger and bulked together to form a composite sample. A total of 32 representative soil samples were used for analysis in the study. The soil samples were kept in a well-labelled sampling bags and transported to the Ecological laboratory of the University of Ghana for analysis. The soil samples were air dried at room temperature (21–27 ºC) for 7 days, and then oven-dried at 105ºC to constant weight. They were then grinded and passed through a 2 mm sieve before subsamples were taken for the soil physicochemical analysis. Soil physicochemical properties measured were pH, electrical conductivity, soil particle size distribution, organic carbon/organic matter, total nitrogen, ammonium, nitrate, available phosphorus, available potassium and exchangeable potassium. Soil pH and electrical conductivity were determined in a 1:1 soil to distilled water ratio [17], [18] using microprocessor pH Meter (Van London Phoenix Electrodes, USA). Particle size analysis of the soil was carried out using Bouyoucos hydrometer (POBEL, Spain) method modified by [19]. Soil organic carbon (SOC) was determined by a modified procedure by [20]. The amount of soil organic matter (SOM) was found by multiplying the percentage C by the factor 1.724 [20]. Total soil nitrogen was determined using the micro distillation [21] and titration method [22]. Available potassium was determined using the ammonium acetate method [23]. The available phosphorus was determined using the Bray 1 procedure [24] and exchangeable potassium determined using the flame photometer method [25].

Data analysis

Statistical Package for Social Sciences (SPSS) software version 20.0 was used to generate the ranges and means for the physicochemical properties of soil. One-way Analysis of variance (ANOVA) was used to test for the significant differences and similarities between the soil physicochemical properties from the various sampled sites. Significant means obtained were separated by least significant difference (LSD) method at 5% significance level. Pearson correlation analysis was also carried out to establish the degree of relationship between the physicochemical parameters of soil. The statistical significance tests were carried at 5% confidence level ($p < 0.05$).

RESULTS AND DISCUSSION

Table 1 presents the summary of the results of the physicochemical properties of soil samples from the study sites.

***Table 1** Summary of soil physico-chemical properties at the study area*

Sites	Nkrankwanta (S1)		Diabaa (S2)		Krakrom (S3)		Kwakuanya (S4)		Total	p-value
	Range	Mean± SD	Range	Mean± SD	Range	Mean± SD	Range	Mean± SD	Mean± SD	
pH	7.34-7.80	7.56±0.23	7.73-7.96	7.88±0.13	8.46-8.52	8.49±0.03	8.21-8.39	8.34±0.04	8.07±0.33	$p < 0.05$
EC (µS/cm)	138.0-296.0	210.0±79.8	163.0-282.0	242.0±68.4	183.0-239.0	203.0±30.9	156-283	204.0±68.9	214.8±14.3	$p > 0.05$
%OC	0.89-1.95	1.38±0.53	5.67-5.99	5.83±0.16	5.78-6.14	5.94±0.18	5.78-6.46	6.16±0.35	4.83±1.78	$p < 0.05$
%OM	1.54-3.36	2.38±0.92	9.78-10.3	10.0±0.28	9.96-10.6	10.3±0.31	9.96-11.1	10.6±0.60	8.32±3.07	$p < 0.05$
Ava-K (ppm)	0.39-0.95	0.59±0.30	0.45-0.50	0.48±0.03	0.36-0.89	0.64±0.27	0.21-0.50	0.35±0.15	0.52±0.10	$p > 0.05$
%TN	1.61-2.63	2.10±0.51	1.74-2.46	2.13±0.36	1.57-2.10	1.87±0.27	1.51-1.79	1.64±0.14	1.94±0.18	$p > 0.05$
Ava-P (mg/kg)	0.55-0.70	0.64±0.08	0.50-0.91	0.71±0.21	0.55-0.69	0.63±0.07	2.40-2.50	2.47±0.06	1.11±0.70	$p < 0.05$
NH_4^+ (mg/L)	23.1-46.9	38.9±13.7	30.1-42.0	34.8±6.35	43.4-48.3	45.0±2.83	35.0-49.0	42.9±7.18	40.4±3.49	$p > 0.05$
NO_3^- (mg/L)	23.8-29.4	25.7±3.23	33.6-45.5	40.1±6.04	38.5-44.1	40.6±3.05	28.0-30.1	28.9±1.07	33.8±5.93	$p < 0.05$
Ex-K (cmol/kg)	0.20-0.26	0.24±0.03	0.27-0.51	0.43±0.14	0.38-0.51	0.60±0.27	0.21-1.15	0.67±0.47	0.49±0.15	$p > 0.05$
%Sand	50.1-83.3	65.9±16.7	59.7-80.5	67.8±11.0	59.5-60.4	59.8±0.47	57.0-69.0	63.3±6.04	64.2±2.68	$p < 0.05$
%Clay	12.5-35.0	24.2±11.3	7.50-15.0	11.7±3.81	12.5-17.5	15.8±2.89	12.5-12.5	12.5±0.00	16.1±4.43	$p > 0.05$
% Silt	4.20-14.9	9.96±5.41	12.0-25.3	20.5±7.35	22.1-28.0	24.3±3.25	18.5-30.5	24.2±6.04	19.7±5.23	$p < 0.05$
Texture		SCL		SL		SL		SL		

SD=Standard deviation, %OC=Organic carbon, %OM=Organic matter, %TN=Percentage nitrogen, Ava-P=available phosphorus, Ava-K= available potassium, EC=Electrical conductivity, Ex-K=Exchangeable potassium, NO_3^-=Nitrate, NH_4^+=Ammonium, SCL=Sandy-clay-loam, SL=Sandy-loam

The measured pH of the soils ranged from 7.56 at Nkrankwanta (S1) to 8.49 at Krakrom (S3) with a mean value of 8.07±0.33. There were significant differences ($p < 0.05$) in pH of soil among the various sampled sites. However, analysis of variance revealed that there were no differences in pH between Nkrankwanta (S1) and Diabaa (S2) and between Kwakuanya (S4) and Krakrom (S3). The soil pH revealed that the soils were generally alkaline. This could be as a result of high concentrations of sodium and calcium in the soils of the selected cocoa farms as reported by [26]. In addition, this could be as a result of variability in the use of fertilizers, some chemicals, poultry manure and the year of establishment of cocoa farms in the study area as reported by [14]. The alkaline nature of the soils at the study area is not favourable to nutrient uptake by plants, which could result in poor cocoa production. According to [14], the effect of soil pH is profound on the solubility of minerals and nutrients, and as such regarded as a useful indicator of other soil parameters. Particularly, it gives an indication about the availability of exchangeable cations (e.g Ca^{2+}, Mg^{2+}, K^{+}, and etc.) in soils. Ololade et al. [14] claimed that most minerals and nutrients are more soluble or available in acidic soils than in neutral or slightly alkaline soils. The mean pH values recorded in this study were above the reported critical minimum of 6.5 and between 5.6-7.2 reported by [27], [11] to be the best soil pH ideal for cocoa production. Similarly, the mean pH values recorded in this study were higher than the mean pH values of 4.95-6.24, 4.90-6.40, 6.24-7.19 and 4.45-7.54 reported by [14], [15], [28], [29] in soil samples from selected cocoa farms in Abia State, Ondo State, Ondo State Central District and Ghana respectively. The measured conductivity (EC) ranged from 203.0 µS/cm at Krakrom (S3) to 242.0 µS/cm at Diabaa (S2) with a mean value of 214.8±14.3 µS/cm, which reflects the varying nature of soil types and their associated physical and chemical properties in most regions of Ghana [29]. There was however no significant difference ($p > 0.05$) in conductivity of soil among the various sampled sites. The mean EC values of soils analysed at the study sites were below the critical level of 4 dS/m for plants growth. The soils are therefore likely to contain very little amount of soluble salts which is very conducive for cocoa production. The organic carbon content of soils from the study sites ranged from 1.38% at Nkrankwanta (S1) to 6.12% at Kwakuanya (S4) with a mean value of 4.83±1.78 %. There were significant differences ($p < 0.05$) in percent organic carbon among the sites. However, analysis of variance revealed that there were significant differences in organic carbon content among the following sampled sites; Diabaa (S2), Krakrom (S3), Kwakuanya (S4) and Nkrankwanta (S1). All the sampling sites recorded mean values of organic carbon above the average 3% (i.e. organic carbon not less than 3%) as reported by [11] to be good for cocoa production except S1 (1.38%). The organic carbon content recorded in this study were however, higher than the mean values of 0.83-1.84% and 0.35-4.3% recorded by [14], [15] in soil samples from selected cocoa farms in Abia State and Ondo State, Nigeria but similar to those (1.28-7.43%) reported by [29] in soil samples from cocoa growing soils across cocoa-growing regions in Ghana. On the other hand, soil samples from the study sites had relatively high organic matter content (OM) with reference to the CSIR classification of soil organic matter [30]. The organic matter content of the soils ranged from 2.38% at Nkrankwanta (S1) to 10.6% at Kwakuanya (S4) with a mean value of 8.32±3.07 %. The organic matter content of the soils differed significantly ($p < 0.05$) among the various sampled sites. Similarly, analysis of variance revealed that there were significant differences in the organic matter content of soils among the following sampled sites; S2, S3, S4 and S1. Again, the organic matter contents recorded at S1 (2.38%), S2 (10.0%), S3 (10.3%) and S4 (10.6%) were below the organic matter content of 25% recommended to be ideal for optimum cocoa production as reported by [27]. In addition, the organic matter content of soils recorded in this study were higher than the mean values of 1.44-3.18% recorded by [15] in soil samples from selected cocoa farms in Abia State, Nigeria but similar to those (5.33-6.40%) reported by [28] in soil samples from cocoa farms in Ondo Central District, Nigeria. A high content of organic matter in the topsoil is essential for good growth, development and productivity. Despite the high rate of decomposition / depletion of organic matter often found in tropic soils as reported by [29], soils from the study sites were characterized by high organic carbon (OC) and organic matter (OM) content perhaps due to both microbial activities and increase in degraded organic litter. The organic matter of soils includes the remains of plants, animals and microorganisms in all stages of decomposition. Soil organic carbon and organic matter are known to influence the dynamics and behaviour of both inorganic and organic pollutants in soils as well as a number of soil chemical and physical properties [31], [32]. The available potassium concentration ranged from 0.35 ppm at Kwakuanya (S4) to 0.64 ppm at Krakrom (S3) with a mean value of 0.05±0.10 ppm. There were no significant differences ($p > 0.05$) in potassium among the sampled sites. The potassium concentrations of the sampled soils in the various cocoa farms were generally below the critical level of 100 ppm of potassium required for cocoa cultivation [26]. The nitrogen content of the soils analysed ranged from 1.64% at Kwakuanya (S4) to 2.13% at Diabaa (S2) with a mean of 1.94±0.18 %. There were however, no significant differences ($p > 0.05$) in the nitrogen content among the various sampled sites. The percentage nitrogen content of the soils at S1 (2.10%), S2 (2.13%), S3 (1.87%) and S4 (1.64%) indicates adequacy for cocoa production, since all the values were higher than the critical level of 0.09% required for cocoa cultivation as reported by [26]. This may be attributed to the high content of nitrogen in the annual litter fall which is about 20% to 45% of the total N in the vegetation and 2% to 3% of the total N in the soil as reported by [26]. The available phosphorus ranged from 0.63 mg/kg at Krakrom (S3) to 2.47 mg/kg at Kwakuanya (S4) with a mean value of 1.11±0.70 mg/kg. There were significant ($p < 0.05$) difference in available phosphorus among the sampled sites. However, LSD showed there were differences in available phosphorus among S2, S3, S1 and S4. The amount of available phosphorous in soils from the selected cocoa farms were appreciably below the required maximum concentration of 35 ppm required for optimum cocoa cultivation as reported by [27], [26]. Anim-Kwapong and Frimpong [11] also added that the best soils for cocoa production should have an average soil available P greater than 20ppm in the 0-5 cm and 15 ppm in 0-20 cm layer respectively. However, the mean values of available phosphorous recorded in the sampled soils at 0-20cm were below the recommended limit as stated by [11]. The concentration of ammonium in soil samples analyzed ranged from 34.8 mg/L at Diabaa (S2) to 45.0 mg/L at Krakrom (S3) with a mean value of 40.4±3.49 mg/L. There were however, no significant differences in the concentration of soil ammonium content ($p > 0.05$) among the sampled sites. The analysis of variance revealed significant difference ($p <0.05$) in soil nitrate among the various sites. The amount of nitrate measured in the soil samples analysed ranged from 25.7 mg/L at Nkrankwanta (S1) to 40.6 mg/L at Krakrom (S3) with a mean of 33.8±5.93 mg/L. Least significant difference (LSD) showed there were no differences in nitrate between Kwakuanya and Nkrankwanta. The level of exchangeable K measured in the soil samples ranged from 0.24 cmol/kg at Nkrankwanta (S1) to 0.67cmol/kg at Kwakuanya (S4) with a mean value of 0.49±0.15 cmol/kg. Statistically, there were no significant differences in exchangeable potassium ($p > 0.05$) among the sites. Similar observations was made by [14]. With the exception of soil samples from Nkrankwanta (S1) which recorded a mean exchangeable K value of 0.24 cmol/kg, all the other sampled sites recorded exchangeable K values that were above the 0.25/100g value reported by [11] to be the best soil exchangeable K value (exchangeable K not less than 0.25/100g) for high production of cocoa. According to [33], [34] the application of potassium fertilizer to soils with exchangeable K of < 0.30 mg/kg is recommended. According to [14], one possible confounding factor that could explain some of the variations in soil physicochemical characteristics from the various study sites is difference in grain size distribution. In general, the content of sand was greater than 50% at all the sampled sites and varied widely. However, there was no significant difference ($p > 0.05$) in the content of sand at the samples sites. The high proportions of sand in the soils may be attributed to the type of parent material from which the soil was formed. Also, the percentage of clay was lower than 20% in more than half of the analysed soil samples which showed significant differences ($p < 0.05$) among the sampled sites. The content of clay did not vary much across the sites. However, the comparison of the means, showed no significant differences in percent clay among S4, S1, S2 and S3. Clay content may play an important role in determining the fate of pesticides residues that may get into soil after its use in cocoa farms [31], [32]. Silt content of the soil was greater than 20% at almost all the sampled sites except Krankwanta (S1) which recorded a mean value of 9.96%. There were significant differences ($p < 0.05$) in percent silt at the various sampled sites. When the LSD was used to compare the means, there were no significant differences in percent silt among Diabaa (S2) and Krakrom (S3), but were however statistically different from Nkrankwanta (S1). Similar observations were made by [14], [28], [29] in soils of selected cocoa farms in Ondo State Central District, Ondo State, Nigeria and soils across cocoa-growing regions in Ghana respectively. According to [11], the model profile of good cocoa soils are deep and characterized by well drained non-gravelly top soil over sandy clay loam layer which usually contains both iron oxide concretions and quartz gravels. The soil particle size distribution revealed that the textural class of the study soils as mainly sandy loam (S2, S3 and S4) and sandy-clay-loam (S1) according to the United States Department of Agriculture (USDA) classification system [35].

Relationship between soil physico-chemical properties measured

Relationship between soils properties were analysed using the Pearson's correlation matrix (Table 2). A positive significant correlation was observed between pH and (NH_4^+), % OC and (nitrate (NO_3^-), exchangeable potassium (K), % Silt and % OM), % OM and (exchangeable K, % Silt and nitrate (NO_3^-)), nitrate (NO_3^-) and (% Silt), exchangeable potassium and (% Silt), NO_3^- and (% Silt), available K and (% Clay). On the other hand, negative significant correlation was observed between pH and (EC, TN, pH and % clay), EC and (NH_4^+), exchangeable potassium (K) and (% Sand), %TN and (NH_4^+, exchangeable K and available phosphorus (P), available potassium (K) and (available phosphorus (P) and % sand).

Table 2 *Pearson's product moment correlation coefficient between physicochemical parameters of soil*

	pH	EC	% OC	OM	% TN	NH_4^+	NO_3-	Ava. K	Ava. P	Ex-K	% Sand	% Clay	% Silt
pH	1.000												
EC	-0.701	1.000											
% OC	0.382	0.302	1.000										
OM	0.383	0.299	0.998**	1.000									
% TN	-0.632	0.540	-0.473	-0.475	1.000								
NH_4^+	0.799	-0.876	0.096	0.103	-0.738	1.000							
NO_3-	0.080	0.557	0.704	0.707	0.196	-0.196	1.000						
Ava. K	-0.580	0.520	0.011	0.019	0.387	-0.262	0.468	1.000					
Ava. P	0.420	-0.397	0.305	0.301	-0.844	0.390	-0.459	-0.676	1.000				
Ex-K	0.400	0.050	0.889*	0.892*	-0.751	0.378	0.442	0.074	0.492	1.000			
% Sand	0.309	-0.389	-0.421	-0.428	0.197	-0.020	-0.435	-0.803	0.133	-0.611	1.000		
% Clay	-0.761	0.248	-0.512	-0.506	0.372	-0.243	-0.179	0.782	-0.469	-0.291	-0.548	1.000	
% Silt	0.442	0.169	0.977**	0.979**	-0.593	0.266	0.650	0.065	0.341	0.956*	-0.518	-0.432	1.000

**Correlation is significant at the 0.05 level (2-tailed) ** Correlation is significant at the 0.01 level (2-tailed) OC=Organic carbon, OM=Organic matter, %TN=percentage nitrogen, Ava-P=available phosphorus, Ava-K=available potassium, EC=Electrical conductivity, Ex-K=Exchangeable potassium,* NO_3^-*=Nitrate and* NH_4^+*= Ammonium*

CONCLUSION AND RECOMMENDATIONS

The physicochemical properties of soils from some selected cocoa farms in the Dormaa West District of the Brong Ahafo Region of Ghana were assessed. The soil samples of the study area showed similar properties probably because they exit in the same agro ecological zone with similar parent materials. However, some differences in the physicochemical properties of soil among the sampling sites were observed. The differences in soil physical and chemical properties of the study area could be attributed to differences in farming practices such as fertilizers application and the use of pesticides. Some soil physical and chemical properties such as organic matter, electrical conductivity, available potassium and available phosphorous were observed to be below the minimum required value of soils for cocoa cultivation. On the contrary, soil properties such as total nitrogen and pH were found to be above the recommended limit required for cocoa production. Also soil properties such as organic carbon and exchangeable K were found to be within their respective critical limits for cocoa production. Based on the findings above, some of the soils sample analysed can be considered suitable for cocoa production. However, it was obvious that the dominant limiting factors of soil fertility included low organic matter content, available potassium and available phosphorous. Consequently, cocoa farmers are advised to increase the use of organic matter materials, and fertilizers containing potassium and phosphorus to enhance the water holding capacity of the soil to boost cocoa productivity. This may include addition of farmyard manure, green manures, and/or crop residues and inorganic fertilizers.

ACKNOWLEDGMENT

We wish to thank Mr. Emmanuel Ansah and Mr. Stephen Christian Drah of the Ecological Laboratory (ECOLAB), University of Ghana, Legon for his immense contribution during the laboratory analysis.

REFERENCES

[1] A. Ntiamoah and G. Afrane, “Environmental impacts of cocoa production and processing in Ghana : life cycle assessment approach,” J. Clean. Prod., vol. 16, no. 16, pp. 1735–1740, 2008.

[2] G. Afrane and A. Ntiamoah, “Use of pesticides in the cocoa industry and their impact on the environment and the food chain,” in Pesticides in the modern world—risks and benefits, Dr. Margarita Stoytcheva, Ed. InTech, 2011, pp. 51–68.

[3] E. N. A. Dormon, A. Van Huis, C. Leeuwis, D. Obeng-Ofori, and O. Sakyi-Dawson, “Causes of low productivity of cocoa in Ghana: farmers’ perspectives and insights from research and the socio-political establishment,” NJAS - Wageningen J. Life Sci., vol. 52, no. 3–4, pp. 237–259, 2004.

[4] B. T. Anang, “Market Structure and Competition in the Ghanaian Cocoa Sector after Partial Liberalization,” Curr. Res. J. Soc. Sci., vol. 3, no. 6, pp. 465–470, 2011.

[5] T. E. Akamani, K., Wilson, P. I., & Hall, “Barriers to collaborative forest management and implications for building the resilience of forest-dependent communities in the Ashanti region of Ghana,” J. Environ. Manage., vol. 151, pp. 11–21, 2015.

[6] G. Danso-abbeam, E. D. Setsoafia, I. Gershon, and K. Ansah, “Modelling Farmers Investment in Agrochemicals : The Experience of Smallholder Cocoa Farmers in Ghana,” Res. Appl. Econ., vol. 6, no. 4, pp. 1–15, 2014.

[7] J. N. Binam, J. Gockowski, and G. B. Nkamleu, “Technical Efficiency and Productivity Potential of Cocoa Farmers in West African Countries,” Dev. Econ., vol. XLVI, no. 3, pp. 242–63, 2008.

[8] S. W. Barrietos, K. Asenso-Okyere, D. Asuming-Brempong, S Sarpong, N. A. Anyidoho, R. Kaplinsky, and J. Leavy, “Mapping Sustainable Production in Ghanaian Cocoa.,” A report to Cadbury by the Institute of Development Studies and the University of Ghana., 2008.

[9] M. K. Abekoe, D. Obeng-Ofori, and I. S. Egyir, “Technography of Cocoa in the Forest Zone of Ghana.,” in Report presented at the- Convergence of Sciences‘ International Workshop, Benin. Unpublished project document, 29 pp., 2002.

[10] R. Lal, “Restoring Soil Quality to Mitigate Soil Degradation,” Sustainability, vol. 7, no. 5, pp. 5875–5895, 2015.

[11] G. J. Anim-Kwapong and E. B. Frimpong, “Vulnerability and Adaptation Assessment Under the Netherlands Climate Change Studies Assistance Programme Phase 2 (NCCSAP2): Vulnerability of agriculture to climate change-impact of climate on cocoa production,” Cocoa Research Institute of Ghana, 2004.

[12] D. G. Liu X, Herbert SJ, Hashemi AM, Zhang X, “Effects of agricultural management on soil organic matter and carbon transformation,” Soil Environ., vol. 53, pp. 531–543, 2006.

[13] W. L. M. Soares J. L. N., Espindola, C. R., & Pereira, “Physical properties of soils under soil acidity effects on nutrient use efficiency in exotic maize genotypes.,” J. Plant Soil Sci., vol. 192, pp. 9–13, 2005.

[14] I. A. Ololade, I. R. Ajayi, A. . Gbadamosi, O. Z. Mohammed, and A. G. Sunday, “A Study on Effects of Soil Physico-Chemical Properties on Cocoa Production

in Ondo State," Mod. Appl. Sci., vol. 4, no. 5, pp. 35–43, 2010.

[15] C. Eneje, R. C., Asawalam, D. O., & Ezemobi, "Variability in physicochemical properies of some selected cocoa growing soils in Umuahia North local government area of Abia State," Res. J. Eng. Appl. Sci., vol. 1, no. 4, pp. 235–239, 2012.

[16] Ghana Statistical Service, "2010 Population and Housing Census: District Analytical Report of Dormaa West," 2014.

[17] J. A. McKeague, Manual on soil sampling and methods of analysis. Ottawa, Canada: Canadian Society of Soil Science, 1978.

[18] E. O. McLean, "Soil pH and lime requirement," in Methods of Soil Analysis, Part 2: Chemical and microbiological properties, 2nd ed., A. L. Page, R. H. Miller, and D. R. Keeney, Eds. Madison, Wisconsin USA: American Society of Agronomy and Soil Science Society of America, 1982, pp. 199–224.

[19] P. R. Day, "Particle fractionation and particle-size analysis," in Methods of soil analysis, Part 1, C. A. Black, D. D. Evans, J. L. White, E. L. Ensminger, and F. E. Clark, Eds. Madison, WI: American Society of Agronomy, 1965, pp. 545–567.

[20] A. Walkley and I. A. Black, "An examination of the Degtjaref method for determining soil organic matter, and a proposed modification of the chronic acid titration method," J. Soil Sci., vol. 37, pp. 29–38, 1934.

[21] J. Kjeldahl, "Neue Methode zur Bestimmung des Stickstoffs in organischen Korpern," Fresenius. J. Anal. Chem., vol. 22, no. 1, pp. 366–382, 1883.

[22] J. M. Bremner and V. A. Mulvaney, "Steam distillation methods for ammonium nitrate and nitrite," Anal Chim Acta, vol. 32, pp. 485–495, 1982.

[23] M. Feech, Exchangeable Cations in Method of Soil Analysis. 1965.

[24] K. L. T. Bray, R.H., "Determination of total and organic and available forms of phosphorus in soils," J. Soil Sci., vol. 59, pp. 39–45, 1945.

[25] D. V. Chapman, "Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring," University Press, London: Chapman and Hall., 1996.

[26] P. E. Aikpokpdodion, "Nutrients Dynamics in Cocoa Soils , Leaf and Beans in Ondo State , Nigeria," J. Agric. Sci., vol. 1, no. 1, pp. 1–9, 2010.

[27] M. O. Ogunlade, G. O. Adeoye, R. R. Ipinmoroti, O. S. Ibiremo, and C. I. Iloyanomon, "Comparative effects of organic and NPK fertilizers on the growth and nutrient uptake of cocoa seedlings," Niger. J. Soil Sci., vol. 16, no. 1, pp. 92–98, 2006.

[28] A. F. Aiyesanmi and G. A. Idowu, "Organochlorine Pesticides Residues in Soil of Cocoa Farms in Ondo State Central District , Nigeria," Environ. Nat. Resour. Res., vol. 2, no. 2, pp. 65–73, 2012.

[29] E. Dankyi, C. Gordon, D. Carboo, and I. S. Fomsgaard, "Quantification of neonicotinoid insecticide residues in soils from cocoa plantations using a QuEChERS extraction procedure and LC-MS/MS," Sci. Total Environ., vol. 499, pp. 276–283, 2014.

[30] Council for Scientific and Industrial Research (CSIR), "Soil nutirnts (mineral) content grading," 1994.

[31] Y. Gale, N. L., Adams, C. D., Wixson, B. G., Loftin, K. A., & Huang, "Lead, zinc, copper and cadmium in fish and sediments from the Rig River and Flat River Creek of Missouri's Old Lead Belt.," Environ. Geochem. Health, vol. 26, pp. 37–49, 2004.

[32] B. J. Aiyesanmi, A. F., Tomori, W. B., & Owolabi, "Relative partitioning of some heavy metals in dumpsite soil using chemical speciation technique.," Int. J. Chem. Sci., vol. 1, no. 1, pp. 96–104, 2008.

[33] J. S. Adiningsih and M. Sudjadi, "Pengaruh penggenangan dan pemupukan terhadap tanah Podsolik Lampung Tengah.," Pemberitaan Penelit. Tanah dan Pupuk, vol. 2, pp. 1–8, 1983.

[34] R. Yost, A. Attanandana, and E. Tasne, "Predicting and testing site-specific potassium fertilization of maize in soils of the tropics - an example from Thailand," Soil Sci., vol. 171, no. 12, pp. 968–980, 2006.

[35] USDA, "USDA Textural Soil Classification," 1987.