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Land Assessment for Cocoa Cultivation in Opeji Village, Odeda Local Government Area, Ogun State

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Abstract

Cocoa is a major agricultural export crop and it serves as a key employer of labour in the producing countries. This study was carried out to assess the soils suitability and fertility evaluation for cocoa production in Opeji village. A standard profile pit was established and described; and bulked samples taken at a depth of 0-20cm and 20-40cm depth. Collected soil samples were analyzed and results showed that morphologically, the soil is shallow, characterized with stones, and iron concretions. The colour was gray in the surface horizon and dark reddish brown in subsoil. The surface horizon was weak, medium and angular blocky while subsoil was single-grained. Physical properties indicated that sand dominated the particle size. Chemical properties of the top soils for fertility evaluation ranged accordingly: soil pH varied from 6.56 - 6.73, OC (0.30 - 0.94%), N (0.02 - 0.07%), Available P (1.63 - 1.73 mg/kg), K (0.28 - 0.31 cmol/kg), Ca (2.50 - 2.59 cmol/kg), Mg (0.93 – 1.03 cmol/kg), Mn (12.56 – 21.05 mg/kg), Fe (2.07 – 3.86 mg/kg), Cu (0.09 - 0.18 mg/kg) and Zn (1.88 - 4.36 mg/kg). Generally, the soils lacked sufficient nutrients needed for sustainable cocoa production. The soils currently rated marginally suitable (S3) for cocoa production due to its physical condition (shallow depth and high gravel contents) and very low organic matter content. Therefore, the area was recommended not to be used for economic production of cocoa except proper irrigation (during the dry season because of poor water retention ability of sandy soils) and fertility management would be done.

Keywords: Cocoa cultivation, soil management, fertilizer recommendation, Ogun State.

Introduction

The use of soil without proper evaluation for agricultural purposes can lead to its mismanagement. Information obtained through detailed survey and soil characterization is vital for land-use planning and soil management, because soils cannot be properly managed without proper understanding of their characteristics (Idoga *et al.,* 2005). Soil suitability of a given piece of land is its natural ability to support a specified land use; such as rain-fed agriculture, livestock production, forestry. Suitability, therefore, is the fitness of a given type of soil for a defined agricultural use (FAO, 2016). The knowledge of soil limitations arising from land evaluation reports aim at ameliorating such limitations before or during cropping period. Therefore, soil as a medium for cultivation needs to be assessed (surveyed/characterized) scientifically. The performance assessment is based on matching qualities of different land units in specific area with the requirements of actual or potential land use types. This assessment results in classification of lands as to their suitability to produce specific crops or combination of crops (Ezeaku, 2011).

The cocoa industry plays uncountable roles in the producing countries as its importance cannot be overemphasized. It contributes significantly to the national economy in terms of employment and foreign exchange earnings. The crop ranks first among agricultural export crops in its contribution to foreign exchange earning in Nigeria (Tijani *et al.,* 2001, Afolayan 2020). The need to increase cocoa production due to its relevance to Nigeria's economy necessitates that the potential and the nutrients level of the soils to be used should be evaluated. It becomes necessary therefore to evaluate soils of the study area to determine the most appropriate landuse in which the soils can be subjected and the most effective ways of conserving them. The farm was investigated with a view to characterize, determine the soil nutrient status and assess its suitability for cocoa production.

Materials and Method

Study Location

The study was conducted in Opeji village, Odeda Local Government Area (LGA), Ogun State, Nigeria on latitude 7º 19' N and longitude 3º 21' E at about 72 m above sea level. The vegetation of the farm is presently secondary forest, occupied mainly with Neem trees (*Azadirachta indica*) and grasses. The land is relatively flat and the vegetation is uniform. The coordinates of selected points on the land were taken and mapped as shown in Figure 1. According to Osinuga and Oyegoke (2017), the rainfall pattern of the area is bimodal with rainy season occurring between April and November while dry season stretches from December to March. Mean temperature of 27°C and relative humidity is rarely below 70%. Equally, there is a short period of relative coldness and hazy weather from late December to February, known as the Harmattan season. Mean annual rainfall for the study area for 11 years (2014- 2024) as presented in Fig. 2 shows that rainfall was consistently higher than 1500mm in most of the years.

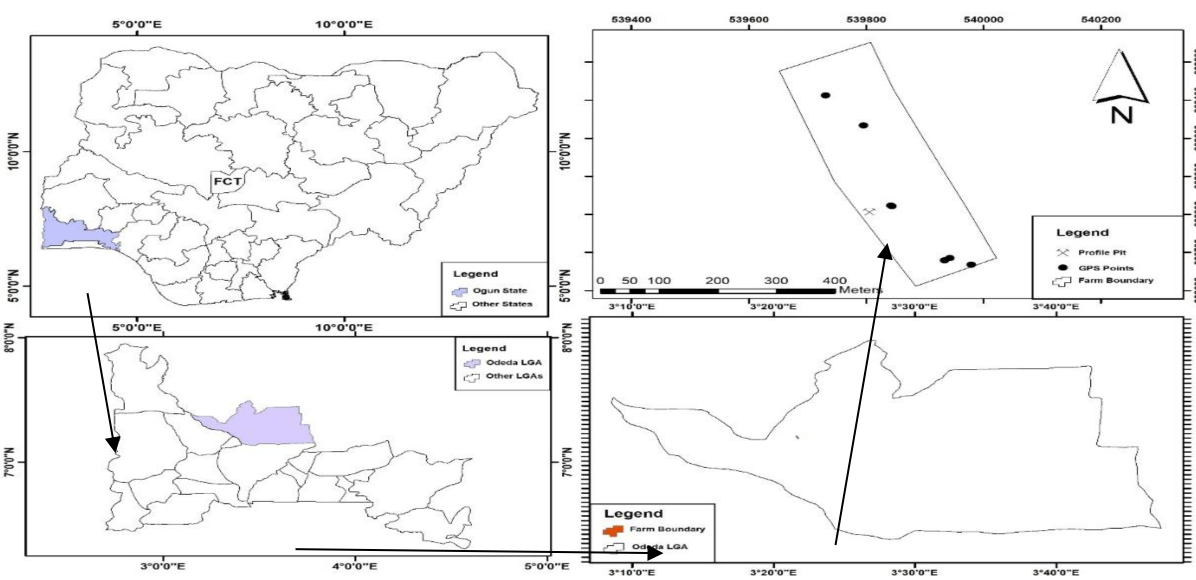

Figure 1: Map of the study area

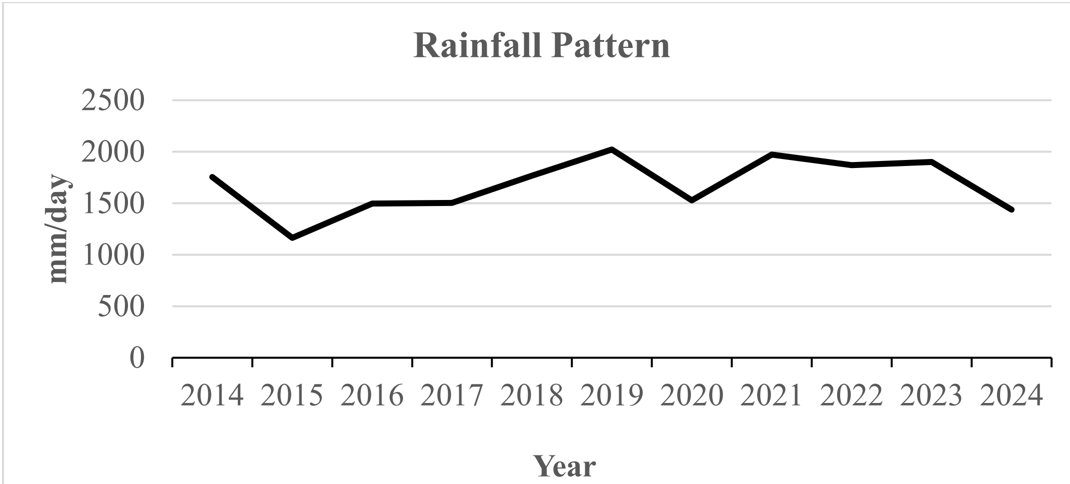

Fig.2: Mean annual rainfall of the study area
Source: NASA, (2025)

Soil sampling

The topography (relatively flat) and vegetation of the farm is uniform, thus, a standard profile pit was established - latitudes: 7º 19’ 01.58’’ N, longitudes: 3º 21’ 39.58’’ E on an altitude of 72 m and described according to FAO (2010) guidelines then soil samples were taken from the identified pedogenic horizons. Soil samples were collected using a soil auger at the depths of 0-20 cm and 20-40 cm and at a distance of 20 m apart. Twenty-five core soil samples were collected at each depth and bulked together to give a composite sample. The soil samples collected were air dried, pulverized and sieved through a 2mm sieve to separate materials larger than 2 mm (gravels and stones). The less than 2 mm fraction was retained for the laboratory analyses. Particles sizes larger than 2 mm were weighed as gravel content and expressed as percentage:

$$\frac{\text{Weight of the gravel X 100\%}}{\text{Total weight of the soil sample}}$$

Laboratory analysis

Particle size analysis was determined by Bouyoucos hydrometer method (Gee and Or, 2002). Soil pH in water and KCl was determined with the use of pH meter (Thomas, 1996). Organic carbon was determined by dichromate wet oxidation method of Walkey and Black as described by Nelson and Sommer (1982). Total nitrogen was determined by Macro-kjeldahl digestion method (Bremner, 1996). Available P was extracted using Bray-1 extractant followed by Molybdenum blue colorimetric (Kuo, 1996). Exchangeable acidity was determined by the KCl extraction method by Mclean (1965). The cations and micronutrients (Ca, Mg, K, Na, Cu, Zn, Fe and Mn) were extracted with 1.0 M ammonium acetate (NH4OAc) solution at pH 7.0. The exchangeable Ca and Mg, Cu, Zn, Fe and Mn in the leachate were determined by atomic absorption spectrophotometer while exchangeable K and Na were determined by flame photometer (Sparks, 1996). The effective cation exchange capacity (ECEC) was calculated from the sum of all exchangeable cations while base saturation (BS) was obtained by expressing the sum of exchangeable bases as a percentage of ECEC using the formula: BS = [TEB/ECEC] X 100%.

Land Evaluation

The land evaluation was carried out using conventional (non-parametric) and parametric approaches (FAO 2006; Udoh *et al.,* 2006). For the conventional evaluation, the profile pit was first placed in suitability classes by matching its characteristics with the established requirements of cocoa production (Table 1). The aggregate suitability classes were indicated by the most limiting characteristics of the soil unit. For the parametric method, each characteristic was rated and the index of productivity (IP) for the profile pit was calculated using the square root method equation:

$IP = A \times \sqrt{B/100 \times C/100 \times \ldots \times F/100}$

Where: A is the overall lowest characteristic rating and B, C,…F is the lowest characteristic ratings for each land quality group (Udoh *et al.,* 2006). “Five land quality groups climate (c), topography (t), soil physical properties (s), wetness (w) and fertility (f) were used in this method of evaluation” (Table 1) as reported by (Ogunkunle, 1993) and only a member of each of the five land quality groups was used in the calculation because there is a strong correlation among members of the same group. Overall suitability class ratings S1, S2, S3 and N1 and N2 are equivalent to IP values of 100-75, 74-50, 49-25, and 24-12 and 12-0 respectively.

Results and Discussion

Morphological properties of the soil

Morphological features of the soils are presented in Table 2. Visual field observation (the vegetation) showed that the soils of the area were generally shallow. This was confirmed with a standard profile pit dug which was characterized with stones, iron and concretions. Cocoa is a tap-rooted plant and needs at least depth of 100-150 cm for a well-developed and deep root system which will guarantee a noble anchorage against tropical storm and appropriate moisture supply in the dry season (Egbe *et al*., 1989). The colour of the soils varied from gray (7.5YR 5/1) to brown (7.5YR 4/2) and dark reddish brown 5YR 3/4 in the subsoil. Soil texture is related to physical properties of soil such as ease of tillage, plasticity, water holding capacity, permeability, fertility and overall soil productivity (Boul *et al.,* 2003). The texture of the surface soil was sandy loam while sub soil was gravelly sandy clay. The structure of the soil was weak medium angular blocky at the surface and structureless at subsoil. The soil consistence was loose when moist; non-sticky and non-plastic when wet. Horizon boundary was clear and wavy. Many fine roots were observed at the surface horizons and its concentration decreased with soil depth.

Physical properties of the soil

Physical properties of the soil are presented in Table 3 showed that sand dominated the particle size fraction. Dominance of sand in the studied soil could be attributed to parent material rich in quartz mineral, an essential component in granite (Wilson, 2012). Sand fraction of the soil profile decreased while silt increased with increasing depth. The sand and silt values ranged from 76.40 to 94.40% and 2 to 10% respectively. Clay content followed irregular pattern and its content varied from 2.60 to 13.60%. Ritung *et al.,* (2007) stated that cocoa requires a deep (> 100 cm), fine to medium textured soil (Sandy clay, clay, silty clay), well drained soils with high water holding capacity.

Table 1: Factor ratings of land use requirements for cocoa production

Land, soil and climatic characteristics	S1 (100%)	S2 (85%)	S3 (60%)	N1 (40%)	N2 (20%)
Climate (c) Annual rainfall (mm)	1,600-2,500	1,400-1,600	1,200-1,400	-	<1,200
Mean annual temperature (°C)	23-28	28-35	20-25	35-38	>38
Length of dry season (months)	1-2	2-3	3-4	>4	Any
Dryest month (%)	40-60	35-65	30-75	Any	-
Relative humidity (%)	40-65	35-75	30-85	Any	-
Topography (t)					
Slope (%)	<8	<16	<30	-	Any
Wetness (w)					
Drainage	Well	Moderate/better	Imperfect/better	Poor/better	Very poor/better
Flooding	No	No	F1	F1	Any
Physical soil condition(s)					
Soil depth (cm)	>150	>100	>50	>50	Any
Coarse fragments (Vol.%)	<15	15-35	35-55	>55	Any
Texture/structure	C-60s to SC	C+60s to SCL	C+60s to LFS	C+60s to LFS	Cm to Cs
Fertility status (f)					
Soil pH (in water)	6.0 -7.0	7.0 – 7.6	5.5 – 6.0	5.5 – 4.0	>7.6
Base saturation (%)	>60	50-35	<20	-	-
Apparent CEC (Meq/ 100 g soil)	>16	12-16	8-12	<8	-
Organic matter (% C, 0-15cm)	>3	2.5-1.5	1.5-0.8	0.6-0.8	<0.6

S1 = highly suitable, S2 = moderately suitable, S3 = marginally suitable, N1 = presently not suitable, N2 = permanently not suitable. **Source:** Modified from Sys *et al*. (1993).

Table 2: Morphological description of the soil

Horizon	Depth (cm)	Colour (moist)	Texture	Structure	Consistence (moist/wet)	Horizon Boundary	Root distribution and other observation
Ap	0-32	7.5YR 5/1 (Gray)	Sandy loam	Weak, medium and angular blocky	Loose; non-sticky and non-plastic	Clear and wavy	Few coarse, few medium and many fine roots.
AB	32-60	7.5YR 4/2 (Brown)	Gravelly sand	Structureless (single grained)	Loose; non-sticky and non-plastic	Clear and wavy	Many fine, very few medium roots, presence of stones.
Btv	60-90	5YR ¾ (Dark reddish brown)	Gravelly sandy clay	Structureless (single-grained)	Loose; non-sticky and non-plastic	-	Absence of roots with presence of concretions.

Table 3: Physical properties of the soil

Horizon	Depth (cm)	Sand	Silt	Clay	Gravel content	Textural class
		←		(%)	→	
Ap	0-32	94.40	2.00	3.60	31	Sand
AB	32-60	94.40	3.00	2.60	72	Sand
Btv	60-90	76.40	10.00	13.60	79	Sandy loam

Chemical properties of the soils

The soil chemical properties are presented in Table 4. The result showed that the soil pH (H_2O) ranged from 6.33 to 6.67. The pH is adequate for cocoa production and for overall availability of plant nutrients. Cocoa can grow in soils with a pH in the range of 5.0-7.5. It can therefore cope with both acid and alkaline soil, but excessive acidity (pH 4.0 and below) or alkalinity (pH 8.0 and above) must be avoided (International Cocoa Organization, 2023). The results also showed that the soils were low in organic matter. The values of organic carbon (OC) were below the critical value of 3% stated to be the best for suitable soils for cocoa production in Nigeria. The soils' nitrogen content is relatively inadequate. The values decreased irregularly with soil depth and lower than 0.1% which is the established ideal value (Ipinmoroti and Ogeh 2014). Nitrogen is needed by the cocoa tree for the growth, flowering, and development of beans (Sonii, 2008). The soils' calcium (Ca^{2+}) and available phosphorus (AP) contents are insufficient for ideal cocoa production. Their values were lower than the critical levels of 5.0 cmol/kg and 10 mg/kg respectively (Ipinmoroti and Ogeh 2014). Therefore, addition of Ca^{2+}, and P fertilizers would be necessary on the soil for optimal cocoa production. The soils' magnesium (Mg) are adequate while potassium (K) was only sufficient at the surface level. The soils' exchangeable acidity was low. This implies that the soil acidity is not a threat on the farm.

Micronutrients are elements that are essential for plant growth and development but are present and required in small amounts. Its deficiencies can become one of the major constraints in sustaining crop production in the present day exploitative arable agriculture and even so in plantation crops (Ogeh and Ipinmoroti, 2014). The soils' manganese (Mn), copper (Cu), and iron (Fe) contents are insufficient while Zn is adequate at the soil surface only.

Table 4: Soil chemical properties

Soil Properties	Profile pit horizons		
	0-32 cm	32-60 cm	60-90 cm
Soil pH	6.67	6.57	6.33
OC (%)	0.61	0.25	0.24
TN (%)	0.084	0.043	0.052
AP (mg/kg)	2.13	2.03	6.81
Ca (cmol/kg)	2.68	2.73	2.66
Mg (cmol/kg)	1.21	1.17	1.73
K (cmol/kg)	0.30	0.16	0.24
Na (cmol/kg)	0.40	0.30	0.36
Al+H (cmol/kg)	0.11	0.10	0.08
ECEC (cmol/kg)	4.70	4.46	5.07
Base Saturation (%)	97.66	97.76	98.42
Mn (mg/kg)	14.55	3.95	5.81
Fe (mg/kg)	1.13	3.42	4.32
Cu (mg/kg)	0.16	0.41	0.21
Zn (mg/kg)	3.28	2.49	2.14

Soil suitability evaluation

According to NASA (2025), the mean annual rainfall recorded in the study area between 2014-2024 is about 1674 mm, the mean minimum and maximum temperature is 14 and 34°C respectively. Relative humidity, wind speed and wind direction are 84%, 1.56 m/s and 205° respectively. The mean annual rainfall of the area is highly suitable when compared with rainfall requirement for cocoa production (1600-2500 mm) while the mean annual temperature is moderately suitable (Table 1). With reference to flooding and drainage, the soil is highly suitable. Average soil rooting depth of the profile pit fall within marginal suitability class. In terms of organic matter, the soil is presently not suitable for ideal economic cocoa production.

Overall, current and potential suitability of the soil under parametric approach was calculated according to Udoh *et al.* (2006). The result (Table 5) indicated that the soil is presently marginally suitable for commercial production due to its physical condition and very low organic matter content. However, the potential suitability which is a reflection of what is expected after good soil fertility management was moderate.

Table 5: Land suitability rating of the study area for cocoa production

Land, soil and climatic characteristics	Pit 1(A)	Pit 1(B)
Climate (c)		
Annual rainfall (mm)	100	100
Mean annual temperature (°C)	85	85
Topography (t)		
Slope (%)	100	100
Wetness (w)		
Drainage	100	100
Flooding	100	100
Physical soil condition(s)		
Soil depth (cm)	60	60
Coarse fragments (Vol.%)	85	85
Texture/structure	60	60
Fertility status (f)		
Soil pH (in water)	100	100
Base saturation (%)	100	100
Organic matter (% C, 0-15cm)	40	100
Aggregate suitability	**29**	**55**
Suitability symbol	**S3**	**S2**

A = actual/current suitability class, B = potential suitability class (after soil fertility improvement)

Overall soil fertility evaluation and management for yield enhancement in the study area

The soil pH values ranged between 6.56 in the topsoil and 6.73 in the sub soil (Table 6). The soil pH is slightly acidic and falls within the acceptable range for cocoa production and for overall satisfactory availability of plant nutrients. The organic carbon content of the topsoil (0.3%) was low and fell below the recommended organic carbon of 3% (Egbe *et al.* 1989, Ipinmoroti and Ogeh 2014) which is an indication of low fertility status of the soil. Soil organic matter plays an important role in soil fertility management. There is therefore needed to increase soil organic carbon content using organic fertilizer and appropriate crop residues management. Soil total nitrogen values ranged between 0.019% in the top soil and 0.072% in the sub-soil. This was below the critical level of 0.1% required by cocoa. Available phosphorus contents of the soil ranged between 1.63mg/kg in the top soil and 1.73mg/kg in the sub-soil which was grossly below the critical value of 10mg/kg required by cocoa. Phosphorus fertilizer will be required for optimum productivity of cocoa in that land.

Exchangeable potassium of the soil ranged between 0.28 cmol/kg in the topsoil and 0.31

cmol/kg in the sub-soil. The soil exchangeable magnesium values were adequate. The soil texture of the study areas was sandy and will require irrigation during the dry season because of poor water retention ability of sandy soils. Cocoa requires well drained clayey soil texture ranging from sandy clay loam to sandy clay to ensure an adequate moisture supply during the dry months. Therefore, the organic matter of these soils need to be greatly augmented through effective crop residue management, increased use of leguminous plants as well as the use of inorganic fertilizers integrated with organic fertilizers to cushion the negative effects of sandy soil on crop productivity.

Micronutrients contents of the soil especially copper and zinc values were low. Micronutrients are essential nutrient elements needed by plants in very small amounts. Although they are utilized in only minute quantities, plants cannot complete their life cycle without them (Brady and Weil, 2008). The availability of micronutrients in the right amounts and proportions plays a vital role in the absorption of other nutrient elements, particularly nitrogen, phosphorus and potassium. The use of organic fertilizer to build up their level in the soil suggests itself.

Table 6: Physical and chemical properties of top and sub soils

Soil Properties	Depth	
	0-20 cm	20-40 cm
Sand (%)	92.40	93.40
Silt (%)	4.00	2.00
Clay (%)	3.60	4.60
Textural class	Sand	Sand
Soil pH	6.56	6.73
OC (%)	0.30	0.94
TN (%)	0.019	0.072
Available P (mg/kg)	1.63	1.73
Exchangeable K (cmol/kg)	0.28	0.31
Ca (cmol/kg)	2.50	2.59
Mg (cmol/kg)	1.03	0.93
Na (cmol/kg)	0.46	0.40
Al+H (cmol/kg)	0.09	0.06
ECEC (cmol/kg)	4.36	4.29
Base Saturation (%)	97.94	98.60
Mn (mg/kg)	12.56	21.05
Fe (mg/kg)	3.86	2.07
Cu (mg/kg)	0.18	0.09
Zn (mg/kg)	1.88	4.36

Fertilizer Calculation and Recommendations

The soil test values for the macro nutrients were used for the calculation of nutrients and fertilizers required for optimum cocoa production. The types and quantities of fertilizers to be applied per hectare and per cocoa stand based on the calculated nutrient required are shown in Table 8. Cocoa specific inorganic Fertilizer-Cacao Bold (167.4 kg) was recommended as option A. Organic fertilizer integration with inorganic fertilizer will be required to make up for the low organic carbon contents of the soils in the study area, therefore combination of cocoa specific inorganic fertilizer(167.4kg) with organic fertilizer/compost (500kg/ha or 450g/cocoa stand) was recommended as option B. The inorganic fertilizers should be applied in two equal doses. The first dose should be applied in May/June while the second dose will be applied in August/September. Organic fertilizer should be applied in just one dose in May/June.

Table 7: Fertilizers Recommendation per Hectare and per Cocoa Stand per Annum

Options	Fertilizer types	Quantity/per hectare (kg/ha/year)	Quantity/cocoa stand(g/stand)
Option A- Inorganic fertilizer only	$N:P_2O_5:K_2O:CaO:MgO:B_2O_3$: 5:10:35:18:4:0.7	167.4kg/ha	151g/stand/year
Option B- Combination of	$N:P_2O_5:K_2O:CaO:MgO:B_2O_3$: 5:10:35:18:4:0.7	167.4 kg/ha	151g/stand/year
both Organic and inorganic fertilizer	Organic fertilizer/Compost	500 kg/ha	450g/stand/year

Conclusion and Recommendation

The study revealed that fertility status of the soils is low; deficient in macro and micro elements. The low level of fertility observed from the organic matter content and other soil mineral composition signifies that the soils cannot be used to grow cocoa economically unless fertilizers are supplied to augment the soil nutrients. Cocoa specific inorganic Fertilizer-Cacao Bold (167.4 kg) was recommended as option A while combination of cocoa specific inorganic fertilizer (167.4kg) with organic fertilizer/compost (500kg/ha or 450g/cocoa stand) was recommended as option B.

Suitability evaluation of the soils showed that presently, the soils are marginally suitable for cocoa production due to soils' physical condition and very low organic matter content. Economic production of cocoa is not advisable on the land except proper management and irrigation would be done. The soils physical properties (the depth, gravel contents and texture) that put limitation to cocoa production in this area are unchanging in nature and cannot be altered or changed without excessive price.

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