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Soil Evaluation for Cashew, Cocoa and Oil Palm in Akure, South-West Nigeria

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***Abstract*—**A key element in the sustainability of the soil-plant relationship in crop yield and performance is the soil's capacity to support tree crops prior to establishment. With the intention of determining the suitability and limitations of the soils of the locations, the northern and southern portions of Akure, a rainforest in Nigeria, were chosen for the suitability evaluation of land for tree crops. In the study area, 16 pedons were established with the help of the Global Positioning System (GPS), the locations were georeferenced and samples were taken from the pedons. The samples were subjected to standard physical and chemical testing. The findings revealed that soils in the research locations were deep to extremely deep, with pH ranging from highly acidic to slightly acidic (4.94 to 6.71). and that sand predominated. The soils had low levels of organic carbon, effective cation exchange capacity (ECEC), total nitrogen, and available phosphorus, whereas exchangeable cations were evaluated as low to moderate. The suitability result indicated that only Pedon 2 and Pedon 14 are currently highly suitable (S1) for the production of oil palms, while others ranged from moderately suitable to marginally suitable. Pedons 4, 12, and 16 were not suitable (N1), respectively, but other Pedons were moderately suitable (S2) and marginally suitable (S3) for the cultivation of cocoa. None of the study areas are currently highly suitable for the production of oil palms. The poor soil texture and low fertility status were the two main drawbacks found. Finally, sound management practices and soil conservation are essential for fertility sustainability.

***Keywords*—**Cashew, cocoa, land evaluation, oil palm, soil fertility suitability.

I. Introduction

SOIL evaluation is necessary in order to comprehend entities with varied features and to be able to utilize them sustainably. Humanity's most valuable resource is soil, which is readily damaged due to misuse and poor management which is lowers the land's ability to provide food. A growing nation like Nigeria must deal with inefficient and haphazard land usage, inadequate understanding and evaluation of the soil's potential for crop growth, and other issues [1]. Agricultural land should be utilized to the fullest extent possible. Studying the physical-chemical properties of the land as well as its economic situation is necessary for land appraisal, which aims to maximize the utilization of natural resources without compromising their quality [2]. Agricultural produce output is at risk because of minimized by matching the necessities of land use to land qualities which are that the role of land evaluation [3], [4]. Allocating land to those who can use it best is the most efficient strategy to maximize returns on agricultural soil, and this is frequently the initial technique of land conservation. It is important to manage soil resources so that planned adjustments to meet development needs can be implemented without reducing the likelihood that they will be used in the future [5]. Because palm, cocoa, and cashew were once major export crops for Nigeria, their production has increased dramatically in recent years due to increased consumer demand. These crops also serve as a source of raw materials for many companies, which in turn creates jobs for people.

Cashew along with other crops like cocoa, rubber, cocoa, and palm, has now been regarded as a significant economic tree that has made a considerable contribution to the nation's foreign earnings [6]. More land must be farmed in order to cultivate certain crops on a big scale. For non-professional users, such as farmers, information on the physical, chemical, and biological characteristics of the soil must be made available. The farmer will be well-informed and knowledgeable about the soil he works with. Evaluation of the soil's suitability status will improve the available knowledge about the area's soil and the Southwest since the two local government areas of Akure North and South lack sufficient information on their soil suitability. The study's goals are to evaluate the appropriateness and restrictions of the soils at the agricultural locations in Akure for the development of cashew, cocoa, and oil palm using the parametric technique.

II. Materials and Methods

A. Site Location

The study was carried out in Ondo State, Nigeria, in the local governments of Akure North and South. From March to September 2017, the analysis was completed in the analytical lab of the Federal University of Technology Akure's Crop Soil and Pest Management Department. The study sites are located between latitudes 7°15′ 2.7756′ and 5°12′ 36.9576′ and are between 228′ and 335′ above sea level. The study area is located on a terrain made up of low-lying plain, undulating and flat terrains within the rain forest of Southwestern Nigeria. The area experiences an annual rainfall of 1200 to 1500 mm although there are alternate dry and wet seasons, the environment is humid. Akure experiences bimodal rainfall regimes, with peaks in June, July, September and October. A prolonged drought that lasts from November to March occasionally follows this. The

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highest and lowest daily temperatures vary between 21 and 32 °C.

B. Fieldwork

In order to understand the vegetation, cropping patterns, and rural topography of the research region, reconnaissance was carried out. 16 pedons were established at Igoba, Saasa, Airport, Oda, Imafo-Ilado, Iju, Ogbese, Eleyo-Owo, Aladura, Alagbado, Adofure, Olokuta, Federal College of Agriculture (FECA) campus, Seebi and Federal University of Technology Akure (FUTA) and Ijoka-Olope. The areas are agricultural activities areas in Akure North and South Local Government Area (L.G.A). The pedon locations were geo-referenced with GPS. Soil samples were collected from each of the genetic horizons, packed into polythene bags, neatly labeled, and taken to the laboratory for physical and chemical analyses. The landform, vegetation/land use, drainage status and slope were described at each site.

C. Laboratory Analysis

Soil samples were air dried and sieved with a 2 mm sieve. Particle sizes over 2 mm were weighed as the gravel content and given as a percentage distribution according to [7]. The soil pH was determined with a glass electrode in a soil:water ratio of 2:1 [8]. Exchangeable bases were extracted with neutral NH_4OAc solution; Calcium (Ca^{++}) and magnesium (Mg^{++}) were determined by atomic absorption spectrophotometer (AAS) and potassium (K+) and sodium (Na^+) were determined by flame emission photometry [9] the Walkley Black oxidation method as described in [10] was used to isolate organic carbon (OC). The available phosphorus was determined using the Bray and Kurtz method as described in [11]. Total nitrogen was determined by the micro-Kjeldahl digestion and distillation method as described in [12]. The cation exchange capacity (CEC) was determined by the ammonium saturation method (NH_4OAc at pH-7) as described in [13] Percent base saturation was calculated.

D. Land Suitability Evaluation

Soils analyzed in the laboratory were used to generate soil data means. The land suitability evaluation was carried out using the conventional parametric method. The land characteristics (soil database) (Tables I and II) were matched with the agronomic requirements of cashew, cocoa and oil palm (Tables III, VI, and IX) to produce the suitability class scores shown in Tables IV, V, VII, VIII, X and XI respectively.

E. Parametric Square-Root Method

The index of productivity (IP, %) for each pedon was calculated, using the equation:

$$IP = A \times \sqrt{(B/100)} \times C/100 \times D/100 \times E/100 \times F/100$$

where A = Overall lowest characteristic rating and B, C, D, F are the lowest characteristic ratings for each land quality group [14].

The potential index of productivity (IPp) and the current or actual index of productivity (IPc) were calculated for each pedon using the established class scores. The basic difference between IPp and IPc, according to [14] is that exchangeable K, available P and total N are not part of the fertility (f) group in the calculation of IPp, the reason is that these soil properties can be easily managed by the application of fertilizer, however, these properties are put into consideration when rating for the current/actual productivity (IPc). In each pedon, only one member of each of the five land quality groups – climate (c), topography (t), soil properties (s), wetness (w) and fertility (f) were used in the calculation because there were strong correlations among members of the same group [15].

III. Result and Discussion

The land properties are shown in Tables I and II. The site consists of a gently undulating landscape developed on bedrock complexes that include granites and gneisses [16]. Floors were deep to very deep (70 cm to 150 cm) and had few restrictions at Pedon 3 Airport and Seebi, Pedon 14. The restriction was due to the hardpan. Hard pans and concretions have been reported to increase lateral water movement in the soil body, impeding drainage with accumulated water causing aeration problems, and greatly reducing hydraulic conductivity towards the hard pans [17]. Particle size distribution showed that sand dominated the soil particle size fraction in all profiles except Pedon 8 (Eleyowo). This indicates that the soils of the study area will be chemically and physically less active [18]. The coarse sandy texture of the soils will have good water penetration, but the soils can easily become depleted of essential nutrients and moisture through leaching [19].

The mean pH values of the soils ranged from strongly acidic to weakly acidic (4.94 to 6.71). The drop in pH could be caused by the effect of cultivation and leaching of nutrients in the profile and according to most plant nutrients they are at a very slightly acidic to very slightly alkaline soil reaction (pH range 6.2-7.3) therefore readily available at a pH below 6 makes phosphorus and other essential nutrients less available to plants, limiting the amount of nutrient uptake. These soils may need some liming due to their highly acidic nature. The generally low levels of OC in soils could be attributed to the effects of high temperatures and high relative humidity, which favor rapid mineralization of organic matter, and differential land use could also account for low OC levels and poor soil management practices such as crop residue incineration, intensive cultivation, and seasonal bush burning, which is common practice in the study area [19]. The low organic composition of the soil was consistent with the report [20] that human activities affect soil OC and thus nutrient balance. Farmers in the study area should employ cultural practices that encourage recycling and incorporation of plant/crop residues into the soil to increase soil organic matter content. The mean ECEC were low, ranging from 6.01 to 14.85 /cmol/kg. The value indicates that the soils have a low potential for storing plant nutrients and therefore require appropriate soil management strategies such as fertilization and the use of organo-mineral fertilizers. The total nitrogen content of the soils was low compared to the critical value of 2 g kg^{-1} recommended by [21]. The relationship between organic matter and total nitrogen has been established

[22].

TABLE I
LAND/SOIL CHARACTERISTICS OF THE SITES, PEDONS 1-8

Land characteristics	Igoba 1	Saasa 2	Airport 3	Oda 4	Imafo-Ilado 5	Iju 6	Ogbese 7	Eleyowo 8
Climate (c)								
Annual rainfall (mm)	1100-1500	1100-1500	1100-1500	1100-1500	1100-1500	1100-1500	1100-1500	1100-1500
Relative humidity (%)	70 – 85	70 - 85	70 - 85	70 - 85	70 - 85	70 - 85	70 - 85	70 - 85
Temperature (°C)	26-35	26-35	26-35	26-35	26-35	26-35	26-35	26-35
Topography (t)								
Slope (%)	2.00	2.00	2.00	> 2	2.00	2.00	3.00	2.00
Wetness (w)								
Drainage	Well drained	Well drained	Well drained	Well drained	Well drained	Poorly drained	Well drained	Well drained
Soil physical characteristic (S)								
Sand (g kg^{-1})	59.00	54.00	52.00	62.00	47.00	59.00	57.00	47.00
Silt (g kg^{-1})	18.00	16.00	17.00	19.00	13.00	18.00	18.00	23.00
Clay (g kg^{-1})	23.00	30.00	31.00	19.00	40.00	23.00	25.00	30.00
Texture	SCL	SCL	SCL	SL	SC	SCL	SCL	CL
Soil depth (cm)	120.00	150.00	70.00	150.00	150.00	120.00	100.00	120.00
Soil fertility (f)								
ECEC (cmol + kg^{-1})	6.54	14.85	9.83	5.57	6.01	5.79	6.96	6.93
BS (%)	39.93	58.02	48.97	59.88	45.00	37.92	46.86	45.64
OC (g kg-1)	1.96	2.06	0.55	1.44	1.32	0.93	2.38	1.67
pH	6.17	5.79	6.15	6.69	6.71	6.46	5.64	6.51
Total nitrogen (g kg^{-1})	1.09	0.57	0.48	0.90	0.76	0.51	2.17	1.28
Av. Phosphorus (mg kg^{-1})	1.12	1.10	0.80	1.22	0.04	1.47	2.07	1.14
Calcium (cmol + kg^{-1})	1.56	2.96	2.21	2.00	1.17	1.06	1.57	1.57
Mg (cmol + kg^{-1})	0.58	0.51	1.80	1.52	1.35	0.41	0.67	0.52
Potassium (cmol + kg^{-1})	0.26	0.57	0.41	0.32	0.18	0.59	0.54	0.57

SL = Sandy loam, LS = Loamy sand, C = Clay, ESP = Exchangeable sodium percentage.

TABLE II
LAND/SOIL CHARACTERISTICS OF THE SITES, PEDONS 9-16

Land characteristics	Aladura 9	Alagbado 10	Adofure 11	Olokuta 12	FECA 13	Seebi 14	FUTA 15	Ijoka-Olope 16
Climate (c)								
Annual rainfall (mm)	1100-1500	1100-1500	1100-1500	1100-1500	1100-1500	1100-1500	1100-1500	1100-1500
Relative humidity (%)	70 – 85	70 – 85	70 - 85	70 – 85	70 – 85	70 – 85	70 – 85	70 – 85
Temperature (ºC)	26-35	26-35	26-35	26-35	26-35	26-35	26-35	26-35
Topography (t)								
Slope (%)	2.00	5.00	2.00	> 7	2.00	> 5	2.00	2.00
Wetness (w)								
Drainage	Well drained	Well drained	Well drained	Well drained	Well drained	Poorly drained	Well drained	Well drained
Soil physical characteristic (S)								
Sand (%)	56.00	57.00	51.00	69.00	55.00	58.00	65.00	55.00
Silt (g %)	18.00	21.00	14.00	11.00	25.00	10.00	16.00	25.00
Clay (%)	26.00	22.00	35.00	20.00	20.00	32.00	19.00	20.00
Texture	SCL	SCL	SC	SL	SCL	SCL	SL	SL
Soil depth (cm)	120.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00
Soil Fertility (f)								
ECEC (cmol+kg^{-1})	7.73	6.38	14.62	9.28	10.92	10.15	8.25	6.82
BS (%)	40.41	65.99	42.26	56.85	76.38	53.35	56.45	59.85
OC (g kg^{-1})	1.09	1.34	1.98	1.56	2.76	0.93	1.14	1.19
pH	6.17	5.69	5.57	4.94	5.51	5.52	5.56	5.26
Total nitrogen (g kg^{-1})	1.26	0.39	1.37	0.78	1.39	0.23	0.75	0.39
Av. Phosphorus (mg kg^{-1})	1.49	0.56	0.05	0.05	0.39	0.37	0.07	0.52
Calcium (cmol$_+$kg^{-1})	1.34	2.17	2.49	1.50	2.44	1.48	1.23	1.69
Mg (cmol$_+$kg^{-1})	0.82	1.39	1.56	2.48	3.48	2.53	1.93	1.44
Potassium (cmol$_+$kg^{-1})	0.62	0.53	1.21	0.71	1.27	0.58	0.97	0.51

SL = Sandy loam, LS = Loamy sand, C = Clay, ESP = Exchangeable sodium percentage.

Pedon 7 contained a higher total nitrogen than other sites and the value corresponds to the soil organic matter content. The available phosphorus was generally low compared to the critical value of 10 mg kg^{-1} [15]. Nigerian soils have been reported to be phosphorus deficient due to the high P-fixing capacity of these soils [21]. The low levels of available phosphorus in the soils can be attributed to the kaolinitic clay type observed as a low activity (low CEC) clay in the soils of the study areas, which binds more available phosphorus than other clays. Another factor for low available P in soils could be attributed to the fixation of phosphorus to iron (Fe) in soils [28]. The biological fixation of phosphorus in microbe's bodies is also a contributing factor with a high organic matter content and high carbon to phosphorus ratio. All these lead to a slow release of phosphorus through the soil. Calcium (Ca^{+2}) and magnesium (Mg^{+2}) in Nigerian soils are between 2.00 and 1.2 cmol kg^{-1}, respectively. Exchangeable calcium (Ca^{+2}) and magnesium (Mg^{+2}) levels for the study area were rated as low to moderate in all pedons. The potassium K^{+} of the studied areas was claimed to be moderate in all pedons when compared to the critical values of 2.00 cmol kg^{-1}.

TABLE III
LAND USE REQUIREMENTS FOR OIL PALM

Land Quality and characteristics	Highly Suitable SI (100 - 95%)	Moderately Suitable S2 (94 - 85%)	Marginal Suitable S3 (84 - 40%)	Unsuitable N1 (39 - 20%)	Highly Unsuitable N2 (19- 0%)
Climate (c):					
Annual rainfall (mm)	> 2000	1450 - 1700	1250 - 1450	≤ 1250	≤ 1250
Mean annual temperature (°C)	25 - 35	22 - 25	20- 22	18 - 20	≤ 18
Topography (t):					
Slope (%)	0 – 4	04-Aug	Aug-16	16 - 30	> 30
Wetness (w):					
Drainage	Imperfect	Moderate	Moderate	Poor, drainable	V/poor, not drainable
Soil Physical Properties (s):					
Texture	CL, SCL, L	SC, SCL	SL	LS	C, S
Coarse fragments (l%), 0-10cm	03-10	10-15	15 - 35	35 - 55	> 35
Depth (cm)	> 100	90 - 100	50 - 90	25 - 50	≤ 25
Fertility (f):					
CEC (cmolkg^{-1})	> 10	8 – 10	6 – 8	≤ 6	-
Base saturation (%)	> 35	20 - 35	≤ 20	-	-
pH	5.5 – 6.0	6 – 6.5	6.5 - 7	≤ 5.0, > 7.0	≤ 4.0, > 7.0
OC (%), 0-15 cm	> 1.2	1.2 - 0.8	≤ 0.8	-	-
Exch. K (cmolkg^{-1})	> 1.5	1.2 - 1.5	1.2 - 0.5	≤ 0.5	≤ 0.2

CL, clay loam; SCL, sandy clay loam; L, loam; LS, loamy sand; C, clay; SC, sandy clay. Source: Modified from [29].

TABLE IV
SUITABILITY CLASS SCORES OF THE SOILS FOR OIL PALM CULTIVATION, PEDONS 1-8

Land Quality		Igoba 1	Saasa 2	Airport 3	Oda 4	Imafo-Ilado 5	Iju 6	Ogbese 7	Eleyowo 8
Climate (c)	Mean annual rainfall (mm)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
	Mean. Annual temperature (°C)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Topography (t)	Slope (%)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Wetness (w)	Drainage	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Soil physical characteristics (s)	Texture	S1(100)	S1(100)	S1(100)	S3(60)	S2(85)	S1(100)	S1(100)	S1(100)
	Soil depth (cm)	S1(100)	S1(100)	S3(60)	S1(100)	S1(100)	S1(100)	S2(94)	S1(100)
Fertility (f)	CEC (cmol kg^{-1} clay)	S3(60)	S1(100)	S2(85)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
	Base saturation (%)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	pH	S2(85)	S1(100)	S2(85)	S3(60)	S3(60)	S2(85)	S1(100)	S2(85)
	OC (%)	S1(100)	S1(100)	S3(60)	S1(100)	S1(100)	S2(85)	S1(100)	S1(100)
	Exchangeable K (cmol kg^{-1})	N1(30)	S3(60)	N1(30)	N1(30)	N1(30)	S3(60)	S3(60)	S3(60)
Aggregate suitability	Potential	S2(55)	S1(85)	S3(43)	S3(43)	S2(51)	S2(55)	S2(54)	S2(55)
	Actual (Current)	S3(28)	S2(55)	S3(28)	N1(21)	S3(26)	S2(55)	S2(54)	S2(55)
	Major limiting factors	F	F	SF	SF	SF	F	F	F

Aggregate suitability class scores: S1 = 75-100; S2 = 50-74; S3 = 25-49; N1 = 15-24; N2 = 0-14. S1- Highly Suitable, S2- Moderately Suitable, S3- Marginally Suitable, N1- Currently Not Suitable, N2- Permanently Not Suitable.

IV. LAND SUITABILITY EVALUATION

The suitability of oil palm, cocoa and cashew, which are common and currently cultivated crops in the study area, was evaluated by matching the area's soil properties with the agronomic requirements of the test crops [24]. The land use requirements for Oil palm production are shown in Table III. The sites have been carefully evaluated for land qualities (Tables I and II) and the soil suitability rating for oil palm cultivation is shown in Tables IV and V. Climate, topography and wetness indicate that all sites were highly suitable for oil palm production when compared to oil palm land use requirements (Table III), with the exception of mean annual precipitation under the moderately suitable climate. The results proved that the areas are highly suitable for growing oil palm. At pedons 4, 5, 12, 15, and 16 the soil texture was sandy clay loam. The soil type clay loam is the best soil type for oil palm agriculture according to [4]. Imafo-Ilado (Pedon 5) and Adofure (Pedon 11) areas were highly suitable. All pedons have great soil depth, with the exception of FECA (Pedon 13) and the airport area (Pedon 3), which have marginal soil depth.

TABLE V
SUITABILITY CLASS SCORES OF THE SOILS FOR OIL PALM CULTIVATION, PEDONS 9-16

Land Quality		Aladura 9	Alagbado 10	Adofure 11	Olokuta 12	FECA 13	Seebi 14	FUTA 15	Ijoka-Olope 16
Climate (c)	Mean annual rainfall (mm)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
	Mean. Annual temperature (°C)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Topography (t)	Slope (%)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Wetness (w)	Drainage	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Soil physical characteristics (s)	Texture	S1(100)	S1(100)	S2(85)	S3(60)	S1(100)	S1(100)	S3(60)	S3(60)
	Soil depth (cm)	S1(100)	S1(100)	S1(100)	S1(100)	S3(60)	S1(100)	S1(100)	S1(100)
Fertility (f)	CEC (cmol kg^{-1} clay)	S3(60)	S3(60)	S1(100)	S2(85)	S1(100)	S1(100)	S2(85)	S3(60)
	Base saturation (%)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	pH	S2(85)	S1(100)	S1(100)	N1(30)	S1(100)	S1(100)	S1(100)	S1(100)
	OC (%)	S2(85)	S1(100)	S1(100)	S1(100)	S1(100)	S2(85)	S2(85)	S2(85)
	Exchangeable K (cmol kg^{-1})	S3(60)	N1(30)	S2(85)	S3(60)	S2(85)	N1(30)	S3(60)	N1(30)
Aggregate suitability	Potential	S2(55)	S2(55)	S3(32)	S2(51)	S2(55)	S1(78)	S2(51)	S3(43)
	Actual (Current)	S2(55)	S3(28)	S3(36)	N1(21)	S1(51)	S3(28)	S3(43)	N1(21)
	Major limiting factors	F	F	SF	SF	SF	F	SF	SF

Aggregate suitability class scores: S1 = 75-100; S2 = 50-74; S3 = 25-49; N1 = 15-24; N2 = 0-14. S1- Highly Suitable, S2- Moderately Suitable, S3- Marginally Suitable, N1- Currently Not Suitable, N2- Permanently Not Suitable.

TABLE VI
LAND USE REQUIREMENTS FOR COCOA

Land Quality and characteristics	Highly Suitable SI (100 - 95%)	Moderately Suitable S2 (94 - 85%)	Marginal Suitable S3 (84 - 40%)	Unsuitable N1 (39 - 20%)	Highly Unsuitable N2 (19- 0%)
Climate (c):					
Annual rainfall (mm)	1600 - 2500	1400 - 1600	1250 - 1450	≤ 1250	≤ 1250
Mean annual temp. (°C)	23 - 32	22/35	22/38	18 - 20	≤ 18
Length of dry season (month)	≤ 2	2 – 3	3 – 4	-	-
Topography (t):					
Slope (%)	≤ 8	≤ 16	≤ 30	> 30	> 30
Wetness (w): Drainage	Well	Moderate	Imperfect	Poor	Very poor
Soil Physical Properties (s):					
Texture	CL, SC	SC, SCL	SL	LS	S
Coarse fragments (l%), 0-10cm	≤ 15	15 - 35	35 - 55	> 55	-
Depth (cm)	> 150	> 100	50 - 90	25 - 50	≤ 25
Fertility (f):					
CEC ($cmolkg^{-1}$)	> 16	10 - 16	6 - 8	≤ 6	-
Base saturation (%)	> 35	20 - 35	≤ 20	-	-
pH	6.0 – 7.5	5.5/8.0	4.0 - 5.0	≤ 4.0, > 7.0	≤ 4.0, > 7.0
OC (%), 0-15 cm	> 1.5	1.5 - 0.8	≤ 0.8	-	-
Exch. K ($cmolkg^{-1}$)	> 1.5	1.2 - 1.5	1.2 - 0.5	≤ 0.5	≤ 0.2

Source: Modified from [29]

Fertility characteristics were the main limiting factors for oil palm cultivation at this site, with the exception of base saturation, which is very suitable at all sites. The level of the exchangeable K in Igoba, Airport, Oda, Imafo-Ilado, Alagbado, Seebi and Ijoka-Olope (pedons 1, 3, 4, 5, 10, 14 and 16, respectively), indicates that the aptitude class is N1, which means the sites are not currently suitable for oil palm cultivation, but pedons 11 and 13 are moderately suitable while other sites have limited suitability. None of the sites were shown to be suitable for oil palm when CEC and pH land qualities were matched to land needs, the CEC and pH of all sites ranged from very suitable to moderately suitable to slightly suitable for growing oil palm at all locations.

A. Suitability of the Sites for Cocoa Cultivation

All sites were rated as highly suitable (S1) for cocoa production when the cocoa land use requirements (Table VI) were compared to the study area land qualities (Tables I and II). This result indicates that in terms of climate, the annual rainfall was moderately suitable, annual temperatures were highly suitable and months of dry season are marginally suitable for all the study sites. For soil physical characteristics, the result showed that the depth of all soils was highly suitable.

TABLE VII
SUITABILITY CLASS SCORES OF THE SOILS FOR COCOA CULTIVATION, PEDONS 1 - 8

Land Quality		Igoba 1	Saasa 2	Airport 3	Oda 4	Imafo-Ilado 5	Iju 6	Ogbese 7	Eleyowo 8
Climate (c)	Mean annual rainfall (mm)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
	Mean annual temperature (°C)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	Length of dry season (month)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
Topography (t)	Slope (%)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Wetness (w)	Drainage	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Soil physical characteristics (s)	Texture	S2(85)	S2(85)	S1(100)	S3(60)	S3(60)	S2(85)	S3(60)	S3(60)
	Soil depth (cm)	S2(85)	S1(100)	S3(60)	S1(100)	S1(100)	S2(85)	S2(85)	S2(85)
Fertility (f)	CEC (cmol^{-1} clay)	S3(60)	S2(85)	S2(85)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
	Base saturation (%)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	pH	S1(100)	S2(85)	S1(100)	S1(100)	S1(100)	S2(94)	S2(85)	S1(100)
	OC (%) (0 – 15 cm)	S1(100)	S1(100)	S3(60)	S2(85)	S2(85)	S2(85)	S1(100)	S1(100)
	Exchangeable K (cmol^{-1})	N1 (30)	S3(60)	N1(30)	N1(30)	N1(30)	S3(60)	S3(60)	S3(60)
Aggregate suitability	Potential	S3(43)	S2(51)	S3(36)	S3(36)	S3(36)	S3(43)	S3(36)	S3(36)
	Actual (Current)	S3(26)	S3(43)	N1(18)	N1(18)	N1(18)	S3(43)	S3(36)	S3(36)
	Major limiting factors	CSF	CSF	CSF	CSF	CSF	CSF	CSF	CSF

Aggregate suitability class scores: S1 = 75-100; S2 = 50-74; S3 = 25-49; N1 = 15-24; N2 = 0-14. S1- Highly Suitable, S2- Moderately Suitable, S3- Marginally Suitable, N1- Currently Not Suitable, N2- Permanently Not Suitable.

TABLE VIII
SUITABILITY CLASS SCORES OF THE SOILS FOR COCOA CULTIVATION, PEDONS 9 - 16

Land Quality		Aladura 9	Alagbado 10	Adofure 11	Olokuta 12	FECA 13	Seebi 14	FUTA 15	Ijoka-Olope 16
Climate (c)	Mean annual rainfall (mm)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
	Mean annual temperature (°C)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	Length of dry season (month)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
Topography (t)	Slope (%)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Wetness (w)	Drainage	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S2(85)	S1(100)	S1(100)
Soil physical characteristics (s)	Texture	S2(85)	S2(85)	S1(100)	S3(60)	S2(85)	S2(85)	S3(60)	S3(60)
	Soil depth (cm)	S2(85)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Fertility (f)	CEC (cmol^{-1} clay)	S3(60)	S3(60)	S2(85)	S2(85)	S2(85)	S2(85)	S3(60)	S3(60)
	Base saturation (%)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	pH	S1(100)	S2(85)	S2(85)	S2(85)	S3(60)	S3(60)	S3(60)	S2(85)
	OC (%) (0 – 15 cm)	S2(85)	S2(85)	S1(100)	S1(100)	S1(100)	S2(85)	S2(85)	S2(85)
	Exchangeable K (cmol^{-1})	S3(60)	N1(30)	S2(85)	S3(60)	S2(85)	N1(30)	S3(60)	N1(30)
Aggregate suitability	Potential	S3(43)	S3(43)	S2(55)	S3(43)	S2(51)	S3(47)	S3(36)	S3(36)
	Actual (Current)	S3(43)	N1(21)	S2(55)	S3(36)	S3(43)	N1(20)	S3(36)	N1(18)
	Major limiting factors	CSF	CSF	CSF	CSF	CSF	CSF	CSF	CSF

Aggregate suitability class scores: S1 = 75-100; S2 = 50-74; S3 = 25-49; N1 = 15-24; N2 = 0-14. S1- Highly Suitable, S2- Moderately Suitable, S3- Marginally Suitable, N1- Currently Not Suitable, N2- Permanently Not Suitable

B. Suitability of the Sites for Oil Palm Cultivation

The texture is currently highly suitable at Airport and Adofure, (pedons 3, 11) for oil palm but moderately suitable at Igoba, Saasa, Iju, Aladura, Alagbado, FECA and Seebi (pedons 1, 2, 6, 9, 10, 13 and 15) while others sites are marginally suitable. The primary limiting factor was fertility. The base saturation was highly suitable for all the pedons but the CEC were moderately suitable at Saasa, Airport, Olokuta, FECA, and Seebi (pedons 2, 3, 12, 13, and 14) while the other pedons are marginally suitable. The value of pH, when matched with the land requirement, indicated that only pedons 1, 3, 4, 5, 8 and 9 were highly suitable while pedons 2, 6, 7, 10, 11, 12 and 16 are moderately suitable and pedons 13, 14 and 15 are marginally suitable, OC is highly suitable at pedons 1, 2, 7, 8, 11, 12 and 13, while pedons 4, 5, 6, 9, 10, 14, 15 and 16 were moderately suitable and only pedon 3 falls into the marginally suitable class. The exchangeable K for pedons 1, 3, 4, 5, 10, 14 and 16 were reported to be not suitable for cocoa cultivation while potassium for other pedons was said to be marginally suitable. All the sites were highly suitable (S1) for cashew cultivation when land-use requirements (Table IX) were matched with the land qualities of the study area (Tables I and II). The suitability class scores of the soils for cashew cultivation (Tables X and XI) are similar to that of cocoa, the climate; mean annual rainfall and annual temperature were highly suitable and the length of the dry season are moderately suitable for all the study sites. For soil physical characteristics, the result showed that the depth of all soils was highly suitable for the cultivation of cashew. The texture is currently moderately suitable at pedons 4, 5, 11, 12, 15 and 16) while the other pedons fall into the highly suitable category. The base saturation is moderately suitable for all the pedons but the CEC were highly suitable at Igoba (pedon 2) but pedons 3, 11, 12, 13 and 14 were moderately suitable while the other pedons are marginally suitable for cashew cultivation.

TABLE IX
LAND USE REQUIREMENTS FOR CASHEW

Land quality/Land Characteristics	Very Suitable S1	Moderately Suitable S2	Marginal Suitable S3	Unsuitable N
Temperature				
Elevation	≤ 196	196-324	324-456	> 456
Water availability				
Rainfall (mm)	987-2247	827-987/2247-3.197	601-827/337-4926	≤ 601
Dry month (number)	05-10	4-5.0/10-11	≤ 4	> 4.926
Wet month (number)	1-3	≤ 3-5	10-11	> 11
Rooting media			5.0-8.0	> 8
Texture	Clay loam, sandy clay loam, loam	sandy clay, sandy loam	Clay, Silt Clay, Silty Clay Loam	Heavy Clay, silt, loam sand, sand
Effective depth (cm)	> 40	21-40	44378.00	≤ 7
Nutrient Retention		8.5-12.4	2.6-8.5	≤ 2.6
CEC (cmol/kg)	12.4	5.1-5.4/6.4-6.9	4.6-51	≤ 4.6
pH	5.4-6.4	6.4-6.9	6.9-7.7	> 7.7
OC	> 0.8	0.5-0.8	0.1-0.5	≤ 0.1
Base Saturation (%)	> 66	≤ 66		
Available Nutrients				
Total N	> 0.07	0.05-0.07	0.03-0.05	≤ 0.03
Available P (ppm)	> 40	11-40	1.0-11.0	≤ 1
Exchangeable K (cmol/kg)	> 0.37	0.27-0.37	0.10-0.27	≤ 0.10
Slope (%)	12	12.0-23	23-77	> 77
Surface Rock (%)	15	15-29	29-76	> 76

Aggregate suitability class scores: S1 = 75-100; S2 = 50-74; S3 = 25-49; N1 = 15-24; N2 = 0-14. S1- Highly Suitable, S2- Moderately Suitable, S3- Marginally Suitable, N1- Currently Not Suitable, N2- Permanently Not Suitable

TABLE X
SUITABILITY CLASS SCORES OF THE SOILS FOR CASHEW CULTIVATION, PEDONS 1-8

Land Quality		Iju 1	Igoba 2	Eleyowo 3	Ogbese 4	Aladura 5	Saasa 6	Airport 7	FECA 8
Climate (c)	Mean annual rainfall (mm)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	Mean annual temperature (°C)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	Length of dry season (month)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
Topography (t)	Slope (%)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Wetness (w)	Drainage	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Soil physical characteristics (s)	Texture	S1(100)	S1(100)	S1(100)	S2(85)	S2(85)	S1(100)	S1(100)	S1(100)
	Soil depth (cm)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Fertility (f)	CEC (cmol kg^{-1})	S3(60)	S1(100)	S2(85)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
	Base saturation (%)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
	pH	S1(100)	S1(100)	S1(100)	S2(85)	S2(85)	S2(85)	S1(100)	S2(85)
	OC (%) (0-15 cm)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	Available P (mg kg^{-1})	S3(60)	S3(60)	N1(30)	S3(60)	N1(30)	S3(60)	S3(60)	S3(60)
	Total N (g kg^{-1})	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	Exchangeable K (cmol kg^{-1})	S3(60)	S1(100)	S1(100)	S2(85)	S3(60)	S1(100)	S1(100)	S1(100)
Aggregate suitability	Potential	S2(55)	S1(78)	S1(78)	S2(51)	S1(51)	S2(55)	S2(55)	S2(55)
	Actual (Current)	S2(55)	S2(55)	S3(28)	S2(51)	S3(26)	S2(55)	S2(55)	S2(55)
	Major limiting factors	F	F	F	F	F	F	F	F

Aggregate suitability class scores: S1 = 75-100; S2 = 50-74; S3 = 25-49; N1 = 15-24; N2 = 0-14. S1- Highly Suitable, S2- Moderately Suitable, S3- Marginally Suitable, N1- Currently Not Suitable, N2- Permanently Not Suitable.

C. Suitability of the Sites for Cashew Cultivation

The pH values indicated that only pedons 4, 5, 6, 8 and 16 were moderately suitable, the pH of only pedon 12 (Adofure) falls into the marginally suitable class while other pedons were highly suitable for cashew cultivation, OC and total nitrogen were highly suitable at all the pedons. The available P is highly suitable only at pedon 9 (Imafo-Ilado) and marginally suitable at pedons 1, 2, 4, 6, 7 and 8 while other pedons are not suitable. The exchangeable K at pedons 1, 4 and 10 were reported to be moderately suitable for cocoa cultivation while pedons 1, 5 and

9 were marginally suitable and the other pedons were highly suitable for cashew cultivation.

TABLE XI
SUITABILITY CLASS SCORES OF THE SOILS FOR CASHEW CULTIVATION, PEDONS 9-16

Land Quality		Imafo-Ilado 9	Oda 10	Alagbado 11	Adofure 12	Olokuta 13	Seebi 14	FUTA 15	Ijoka-Olope 16
Climate (c)	Mean annual rainfall (mm)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	Mean annual temperature (°C)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	Length of dry season (month)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
Topography (t)	Slope (%)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Wetness (w)	Drainage	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Soil physical characteristics (s)	Texture	S1(100)	S1(100)	S2(85)	S2(85)	S1(100)	S1(100)	S2(85)	S2(85)
	Soil depth (cm)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
Fertility (f)	CEC (cmol kg^{-1})	S3(60)	S3(60)	S2(85)	S2(85)	S2(85)	S2(85)	S3(60)	S3(60)
	Base saturation (%)	S2(85)	S2(85)	S2(85)	S2(85)	S1(100)	S2(85)	S2(85)	S2(85)
	pH	S1(100)	S1(100)	S1(100)	S3(60)	S1(100)	S1(100)	S1(100)	S2(85)
	OC (%) (0-15 cm)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	Available P (mg kg^{-1})	S1(100)	N1(30)	N1(30)	N1(30)	N1(30)	N1(30)	N1(30)	N1(30)
	Total N (g kg^{-1})	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)	S1(100)
	Exchangeable K (cmol kg^{-1})	S3(60)	S2(85)	S1(100)	S1(100)	S2(85)	S1(100)	S1(100)	S1(100)
Aggregate suitability	Potential	S2(55)	S2(55)	S2(72)	S2(72)	S1(78)	S1(78)	S2(51)	S2(51)
	Actual (Current)	S2(55)	S3(28)	S3(26)	S3(26)	S3(28)	S3(28)	S3(26)	S3(26)
	Major limiting factors	F	F	F	F	F	F	F	F

Aggregate suitability class scores: S1 = 75-100; S2 = 50-74; S3 = 25-49; N1 = 15-24; N2 = 0-14. S1- Highly Suitable, S2- Moderately Suitable, S3- Marginally Suitable, N1- Currently Not Suitable, N2- Permanently Not Suitable.

D. Aggregate Suitability Rating

The soil suitability assessment for oil palm is presented in Table III. The result shows that maybe only pedons 2 (Saasa) and 14 (Seebi) are very suitable for oil palm production (S1), while pedons 3 (Airport), 4 (Oda), 11 (Adofure) and 16 (Ijoka-Olope) are conditionally suitable (S3) and all other pedons fall into the category moderately suitable (S2). Currently, the aggregate suitability assessment has shown that pedons 4, 12 and 16 (Oda, Olokuta and Ijoka-Olope) are each not suitable (N1), but pedons 2, 6, 7, 8 and 9 (Saasa, Iju, Ogbese, Eleyowo, and Aladura) are moderately suitable (S2), while other pedons are conditionally suitable (S3). The main limitations identified are low fertility status, particularly exchangeable potassium and pH in some locations of the study area, and according to [25] soil pH can have a significant impact on plant growth efficiency and bioavailability of plant nutrients. The assessment of suitability for cocoa cultivation showed that none of the study areas are both potentially and currently very suitable. Currently, pedons 3, 4, 5, 10, 14 and 16 (Airport, Oda, Imafo-Ilado, Alagbado, Seebi and Ijoka-Olope) are each not suitable for cocoa cultivation, while others are conditionally suitable (S3). But possibly only pedons 2, 11 and 13 (Saasa, Adofure and FECA) are each moderately suitable (S2), while other pedons are all marginally suitable (S3) for cocoa cultivation. Dry season length, soil fertility and soil composition are the major constraints on cocoa cultivation in the study areas. However, the texture of the soil can be regulated through the incorporation of crop residues and organic matter, especially fertilizer, as it helps bind the soil together, thereby improving its water-holding capacity and nutrient retention. As reported by [26] poorly structured soils provided with sufficient fertilizer (nutrients) produce superior crop yield [27], application of adequate moisture, to poor textured soil could be overcome by appropriate fertilizer application.

V. CONCLUSIONS

None of the pedons was deemed unsuitable (N1) in the overall suitability assessment in either the current or potential categories, indicating that the research sites offer a considerable deal of potential for cashew cultivation. Potentially, most of the study areas were found to be moderately suitable (S2), while only pedons 2, 3, 13 and 14 (Igoba, Eleyowo, Olokuta and Seebi) were each very suitable (S1) for cashew cultivation. But, pedons 1, 2, 4, 6, 7, 8 and 9 (Iju, Igoba, Ogbese, Saasa, Airport, FECA and Imafo-Ilado) are all moderately suitable (S2), while other pedons are marginally in the class fall matching category. The biggest limiting factor is soil fertility, especially the available phosphorus. The low levels of available phosphorus in the soils can be attributed to the kaolinitic clay type observed as a low activity (low CEC) clay in the soils of the study areas, which binds more available phosphorus than other clays. Another factor for low available P in soils could be attributed to the fixation of phosphorus to iron (Fe) in soils [28]. The biological fixation of phosphorus in microbe's bodies is also a contributing factor with a high organic matter content and high carbon to phosphorus ratio. All this leads to a slow release of phosphorus through the soil. According to the results, in general, soil fertility and soil texture were the most limiting factors for tree crop production at the studied sites. However, because the texture of the soil cannot be easily altered, it is important to employ management practices such as conservation tillage and fertilization that improve the soil's physical and fertile conditions. The incorporation of organic fertilizer and legumes into the site's cultivation pattern is suggested.

VI. Significance Statement

This study presents that the allocation of land for which they are intended to use is limited by fertility, environment and climatic factors; such land can be beneficial in achieving optimum utilization if the limitations are known and ameliorated for optimal crop production.

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