SOIL SUSTAINABILITY AND PRODUCTIVITY ASSESSMENTS FOR KEY CROPS CULTIVATION ON BASEMENT COMPLEX AT ABEOKUTA, NIGERIA

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Abstract

This study investigates the land suitability, crop productivity, and degradation status of soils developed from basement complex formations in Abeokuta, Ogun State, Nigeria. Target crops include cashew, cocoa, cassava, yam, and maize, which are assessed against land and climatic variables such as soil texture, nutrient content, slope, rainfall, and temperature. Twelve sites were evaluated for the soil physical and chemical properties, productivity potential, and degradation indicators. Findings revealed that while the soils are predominantly sandy loam and loamy sand with neutral pH and adequate phosphorus and potassium, they are constrained by low nitrogen, organic carbon, and cation exchange capacity (CEC). Suitability mapping and degradation classification highlighted spatial variability in crop performance and soil health. The results highlight the need for integrated soil fertility and conservation strategies to optimize agricultural productivity in basement complex terrains.

Keywords: Land suitability; crop productivity; degradation status; integrated soil fertility; basement complex

Introduction

Soil is a vital resource for farming, the environment, and economic growth (Lal, 2023). To support sustainable land use in tropical areas, we must understand soil traits, climate effects, and crop requirements. In Nigeria's sub-humid tropical region, basement complex soils are crucial for food production. However, they are degrading due to unsustainable practices, deforestation, and poor management (Wang *et al*., 2023; Ojo *et al*., 2018). These predominantly ferruginous and lateritic soils are low in fertility and prone to erosion and organic matter loss (Redmond and Valentine, 2012). Precambrian crystalline rocks in the basement complex of Abeokuta, Ogun State, and influence soil development and fertility (Adelana and MacDonald, 2008). Upon these rocks, crops like cashew, cocoa, cassava, yam, and maize are widely cultivated (Adesodun *et al*., 2020). Each crop has unique soil and climate needs. Their success relies on evaluating land suitability, soil fertility, and degradation risks (FAO, 2021; Eswaran *et al*., 2019). As land use increases without proper nutrient management, degradation has accelerated, especially in sandy and shallow soils (Lal, 2022).

These soils have varying weathering, minerals, and nutrients, making their assessment crucial for sustainable farming (Adeyemi and Abegunde, 2017). Rising population and farming pressures have worsened soil degradation in Abeokuta and nearby areas, reducing productivity and causing environmental challenges (Akinbola and Adediran, 2019). Despite their significance, researchers have conducted limited studies on soil fertility and degradation. This gap hinders the development of effective soil conservation strategies (Schmidt *et al*., 2018). Evaluating soil suitability and degradation is essential for land-use planning, fertilizer application, and improving soil health for sustainable farming (Tedersoo *et al*., 2015). Moreover, with food demand increasing in Nigeria, understanding soil properties is vital for enhancing productivity and minimizing land degradation (Zhang *et al*., 2021).

Agricultural productivity in Nigeria relies on healthy soil. Poor management, deforestation, and improper fertilizer use significantly contribute to the worsening degradation. Evaluating soil suitability and degradation can provide valuable data for policymaking, improving land-use practices, and better fertilizer management. Soils from the basement complex in Nigeria's sub-humid tropics suffer from degradation due to continuous farming, erosion, and nutrient loss. Few studies have examined their suitability for various crops and degradation patterns. Without action, declining soil fertility will threaten food security and economic stability. We need a thorough evaluation of soil suitability and degradation to boost land productivity and ensure sustainable management.

Soils from the basement complex in Southwest Nigeria show varied degradation levels that affect agricultural suitability. These soil properties and degradation trends significantly impact crop productivity and nutrient availability. Where specific management practices can enhance land suitability and mitigate degradation effects. This study will focus on assessing land suitability for key staple and cash crops based on soil characteristics. Thus, this research will provide important insights into the suitability and degradation of basement complex soils in soil quality and enhance agricultural sustainability in Nigeria.

Materials and Methods

Study Area

The research was conducted on a 6-hectare plot located in Alabata, Odeda Local Government Area, Ogun State, Nigeria. Geographically, the site lies between latitude 7°17′33″ N to 7°17′34″ N and longitude 3°29′40″ E to 3°29′35″ E. The region falls within the humid tropical climate zone, receiving approximately 1,115 mm of mean annual rainfall with a bimodal distribution and three to five dry months per year. Air temperatures range from 25 to 28 °C, while soil temperatures at 5 cm depth are higher, around 34 – 35 °C, tapering off with depth but remaining above 30 °C down to 50 cm. Relative humidity peaks in July–September (86 – 88 %) and declines to 66 – 68 % in January–February (Guimarães *et al*., 2025; Basil *et al*., 2023; Nimet, 2023). The landscape is nearly level and underlain by crystalline basement complex geology, producing coarse-grained soils. Lithologic variation is substantial, ranging from pegmatite to schist and from acid-quartzite to amphibole-rich basic rocks (Azadi *et al*., 2023; D'Hoore, 1964; Smyth and Montgomery, 1962). The vegetation is characterized as secondary forest, heavily impacted by human activity; most trees had been harvested mainly for charcoal leaving woody shrubs and non-commercial species such as *Daniella Oliveri* dominant in the ecosystem.

Field Survey and Soil Sampling

A random sampling design was used to ensure representative soil data across the site. Soil samples were collected using an auger at 20 cm depth intervals from the surface to 100 cm, barring any obstructions. Observations at each sampling location included soil color, mottling, texture, stoniness, concretions, structure, effective depth, and depth limitations. Two composite depth layers were defined: Topsoil: 0–20 cm and Subsoil: >20–50 cm (Table **1**).

Field assessments were conducted at twelve locations in Abeokuta with the soils derived from basement complex. A total of 24 samples were collected (12 from topsoil and 12 from subsoil) from soils developed on a basement complex in Abeokuta, Ogun State as shown in Figure **1**, properly labeled, sealed, and transported to the laboratory. These were analyzed for pH, organic carbon, total nitrogen, available phosphorus, exchangeable cations, base saturation, and texture using standard laboratory protocols (Walkley and Black, 1934; Nelson and Sommers, 1982). Slope, drainage, and climate variables (rainfall and temperature) were also recorded. Suitability was evaluated using FAO (1976) guidelines, while degradation status was assessed using nutrient decline indicators and fertility classes (Lal, 2022).

This approach aligns standard soil survey protocols that emphasize comprehensive site description and stratified depth sampling for accurate characterization (Wikipedia, 2025).

Table 1: Physical Properties of the soil

Sample no	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
1	0 - 20	69.3	28.2	2.5	Sandy loam
	20 - 50	67.5	30.2	2.3	Sandy loam
2	0 - 20	77.2	21.7	1.1	Loamy sand
	20 - 50	72.1	26.3	1.6	Loamy sand
3	0 - 20	75.8	22.2	2.0	Loamy sand
	20 - 50	73.5	25.2	1.3	loamy sand
4	0 - 20	65.4	31.8	2.8	Sandy loam
	20 - 50	68.9	28.8	2.3	Sandy loam
5	0 - 20	70.3	27.9	1.8	Sandy loam
	20 - 50	70.0	28.5	1.5	Sandy loam
6	0 - 20	67.4	30.5	2.1	Sandy loam
	20 > 50	76.9	21.9	1.2	Loamy sand
7	0 - 20	70.8	27.2	2.0	Sandy loam
	20 > 50	73.6	22.8	3.6	Sandy loam
8	0 - 20	71.2	27.2	1.6	Sandy loam
	20 > 50	78.1	20.9	1.0	Loamy sand
9	0 - 20	74.8	23.7	1.5	Loamy sand
	20 - 50	75.4	22.8	1.8	Loamy sand
10	0 - 20	76.8	22.0	1.2	Loamy sand
	20 - 50	78.1	19.1	2.8	Loamy sand
11	0 - 20	64.5	32.7	2.8	Sandy loam
	20 - 50	68.2	29.2	2.6	Sandy loam
12	0 - 20	64.2	32.7	3.1	Sandy loam
	20 > 50	66.2	31.4	2.4	Sandy loam

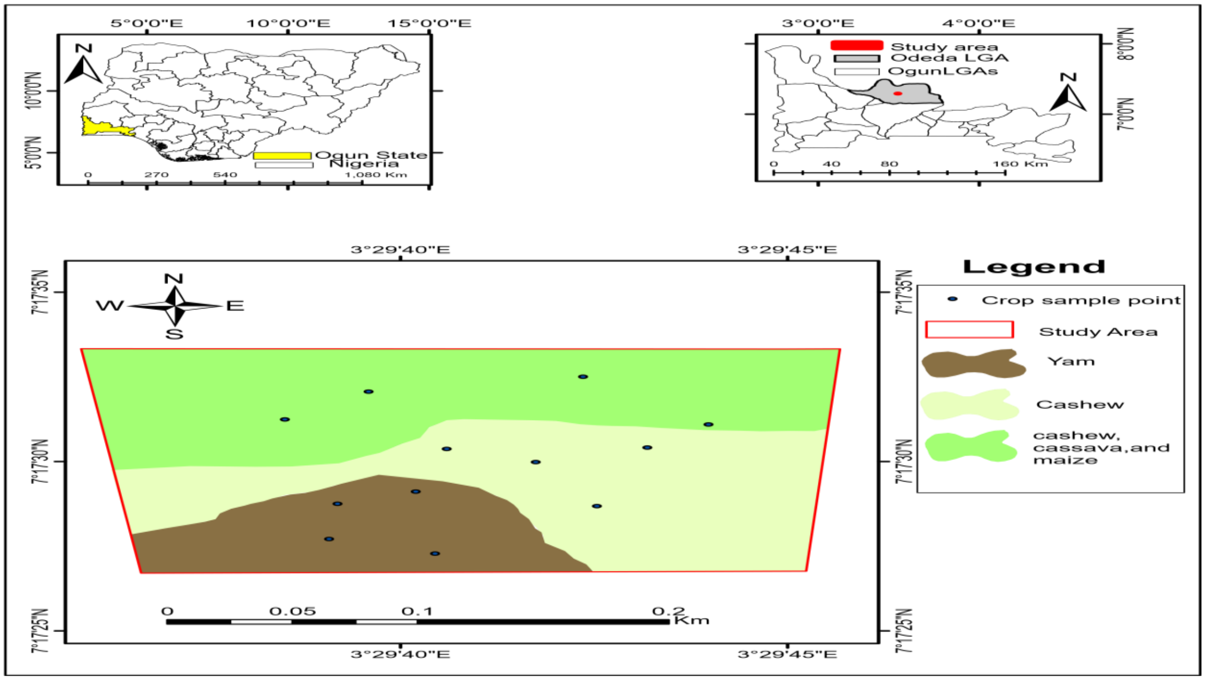
Laboratory Analysis

Upon arrival, samples were air-dried, crushed, and sieved (2 mm). Organic matter samples were ground further to fine powder. The following analyses were performed:

Organic Carbon – determined by the Walkley–Black method (Walkley and Black, 1934).

Soil pH – measured in water using a glass-electrode pH meter (McLean, 1965).

Exchangeable Cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) – extracted with 1 M NH_4OAc (pH 7.0); Na^+ and K^+ quantified via



flame photometry, while Ca^{2+} and Mg^{2+} were measured using atomic absorption spectrometry (Sparks, 1965).

Exchangeable Acidity – determined via KCl extraction (McLean, 1965).

Effective Cation Exchange Capacity (ECEC) – calculated as the sum of all exchangeable cations.

Available Phosphorus – extracted using the Bray-1 method, followed by molybdenum blue colorimetry with spectrophotometric reading.

Figure 1: Study Area map showing distribution of crops for soil collection at Alabata, Odeda LGA, Ogun State

Total Nitrogen – assessed via macro-Kjeldahl digestion (Jackson, 1962).

Particle Size Distribution – determined using the hydrometer (Bouyoucos) method, with Calgon as the dispersing agent (Bouyoucos, 1951).

These methods represent widely accepted, standard procedures in soil science, ensuring reliable physical and chemical characterization of the soil samples (Golabi *et al*., 2005).

Land Suitability Evaluation

The Parametric Square Root Method was applied to evaluate the soil's land suitability. The Index of Productivity (IP) was calculated as:

$$IP = A \times \sqrt{\left(\underset{c}{\frac{B}{100}} \times \underset{t}{\frac{C}{100}} \times \underset{w}{\frac{D}{100}} \times \underset{s}{\frac{E}{100}} \times \underset{f}{\frac{F}{100}}\right)}$$

Where:

IP = Index of productivity

A = Overall fertility-limiting factor

B, C, D, E, and F = Ratings for the most limiting variables in each land quality group: climate (c), topography (t), wetness (w), soil physical properties (s), and fertility (f).

Only the single most limiting parameter per group was used to avoid redundancy due to correlations (e.g., texture versus structure). This method is consistent with both FAO approaches and recent parametric land evaluation frameworks (Van Ranst *et al*., 2000).

Land Degradation Assessment

To assess land degradation levels, we employed the FAO (1979) Direct Approach, as well as the methodology described by Snakin *et al*. (1996). Each pedon was evaluated against predefined soil degradation indicators, and classified into degradation categories based on physical, chemical, and biological parameters across different land use types. This allowed for a broad classification of degradation severity, highlighting critical areas for soil restoration and conservation.

Results

Result of Physical Properties of soil

Sufficient rooting depth, especially > 50 cm, supports good water and nutrient availability in most location sampled distinguishes between topsoil (0 – 20 cm) and subsoil (20 – 50 or > 50 cm). Moderate silt levels were observed in the location sampled; especially higher in sampled locations 11 and 12 (as seen in Table.**1**). Clay Content was very low across all sampled locations, especially found highest in location 7 sub-soils. The loamy sand were found in approximately 50 % of lower horizons, where dominated by sand with small silt/clay. While the sandy loam are more balanced in sand and silt, with slightly better nutrient and water retention than the loamy sand. The soils are generally well-drained, but require amendments to improve fertility.

Result of Chemical Properties for the top soil

All samples are within the neutral to slightly alkaline range (Table **2**). Presence of moderately adequate nitrogen levels, moderately low organic carbon with high P levels was also observed. Exchangeable acidity was low. Na was low (favorable), K and Mg were adequate, and Ca was low as while. Low ECEC, typical of sandy soils with low OM.

Moderate to high BS, indicating good nutrient saturation. CEC of Clay indicates low nutrient-holding capacity due to poor clay contribution.

Result of Chemical Properties for the sub-soil

The sub-soils are neutral to slightly alkaline (Table **3**). Nitrogen content and OM were low to moderate, slightly lower than in the topsoil. The organic carbon is slightly lower than topsoil OC levels. Low ECEC which is in consistent with sandy soils and low OM.

Indicators of Chemical and Biological Degradation

Chemical and biological degradation refers to the decline in soil fertility and biological activity due to loss of nutrients, organic matter, and base-forming cations (Table 4). Nitrogen is vital for plant growth and chlorophyll synthesis. Decreasing levels indicate loss of fertility due to erosion, leaching, or organic matter decline. Phosphorus is critical for root development and energy transfer. It is easily fixed in tropical soils, especially under low pH conditions, reducing its bioavailability (Sanchez et al., 1997). Potassium regulates water use and enhances crop resilience to stress. Losses due to leaching are common in sandy or heavily cropped soils. Low base saturation (< 20 – 35 %) implies depletion of calcium, magnesium, potassium, and sodium, indicators of degradation. High base saturation (> 50 %) reflects good fertility. Decline indicates soil exhaustion due to overuse, erosion, and biomass export.

Table 2: Chemical Properties of the top soil

Sample no	Depth	pH	N (%)	O.C (%)	O.M (%)	P (mg/kg)	Ex. A	Na	K	Ca cmol/kg	Mg	ECEC	BS (%)	CEC clay
1	0 - 20	7.24	0.24	1.01	1.75	21.97	0.80	0.33	0.53	0.31	0.35	1.79	65.55	0.37
2	0 - 20	7.15	0.21	0.94	1.62	25.78	1.00	0.32	0.52	0.31	0.35	1.97	59.97	-1.02
3	0 - 20	7.09	0.21	0.93	1.61	23.76	0.60	0.32	0.51	0.30	0.34	1.56	71.01	-0.08
4	0 - 20	7.22	0.25	1.04	1.78	24.56	1.20	0.33	0.56	0.32	0.37	2.22	56.91	0.93
5	0 - 20	7.03	0.21	0.94	1.62	24.19	0.60	0.33	0.52	0.31	0.34	1.58	71.47	-0.25
6	0 - 20	7.16	0.24	1.01	1.73	22.16	0.60	0.35	0.57	0.32	0.37	1.64	72.81	-0.04
7	0 - 20	7.15	0.18	0.85	1.46	22.63	0.60	0.31	0.47	0.27	0.32	1.50	69.60	0.02
8	0 - 20	7.07	0.21	0.92	1.58	24.92	0.40	0.33	0.54	0.31	0.35	1.39	79.30	-0.61
9	0 - 20	7.05	0.22	0.96	1.65	24.06	0.40	0.34	0.56	0.33	0.38	1.45	80.07	-0.78
10	0 - 20	7.07	0.19	0.86	1.49	26.11	0.60	0.31	0.49	0.30	0.33	1.55	70.56	-0.97
11	0 - 20	7.13	0.23	1.00	1.72	26.45	0.40	0.34	0.56	0.33	0.39	1.46	80.20	0.21
12	0 - 20	7.26	0.23	0.99	1.71	28.52	1.20	0.34	0.57	0.33	0.38	2.25	57.48	1.13
Mean		7.14	0.22	0.95	1.64	24.59	0.70	0.33	0.54	0.31	0.36	1.70	69.58	-0.09

Ex. A: exchangeable acidity, BS: base saturation

Table 3: Chemical Properties of the sub-soil

Sample no	Depth (cm)	pH	N (%)	O.C (%)	O.M (%)	P (mg/kg)	Ex. A	Na	K	Ca cmol/kg	Mg	ECEC	BS (%)	CEC clay
1	20 - 50	7.17	0.22	0.96	1.66	16.88	0.60	0.31	0.49	0.29	0.33	1.53	70.34	0.07
2	20 - 50	7.11	0.20	0.91	1.56	16.53	0.40	0.30	0.49	0.28	0.32	1.31	77.70	-0.68
3	20 - 50	7.17	0.20	0.91	1.57	17.63	0.40	0.31	0.50	0.30	0.33	1.33	78.21	-1.12
4	20 - 50	7.08	0.22	0.97	1.67	18.83	0.60	0.32	0.53	0.31	0.38	1.61	71.90	0.13
5	20 - 50	7.24	0.20	0.89	1.54	16.32	0.80	0.31	0.51	0.30	0.32	1.74	64.40	-0.35
6	20 >50	7.11	0.21	0.94	1.62	16.92	0.60	0.32	0.52	0.31	0.35	1.59	71.54	-1.16
7	20 >50	7.33	0.17	0.83	1.47	16.02	1.00	0.30	0.47	0.27	0.31	1.88	57.32	1.08
8	20 >50	7.25	0.18	0.85	1.46	17.86	0.80	0.31	0.51	0.30	0.33	1.74	64.44	-1.22
9	20 - 50	7.28	0.20	0.91	1.57	17.35	0.80	0.33	0.53	0.31	0.36	1.80	65.71	0.03
10	20 - 50	7.23	0.17	0.82	1.41	18.03	1.20	0.30	0.46	0.26	0.32	2.08	52.68	1.06
11	20 - 50	6.94	0.19	0.87	1.51	18.22	0.40	0.32	0.53	0.32	0.34	1.38	79.01	0.20
12	20 >50	6.96	0.22	0.97	1.68	18.94	0.60	0.33	0.56	0.32	0.36	1.60	72.22	0.18
Mean		7.16	0.20	0.90	1.56	17.46	0.68	0.31	0.51	0.30	0.34	1.63	68.79	-0.15

Ex. A: exchangeable acidity, BS: base saturation

Table 4: Scores for Chemical and Biological degradation of the study area

Sample	Depth	B. saturation	N	P	K	O.M
1	0-20	4	1	1	1	3
	20-40	4	1	1	1	3
2	0-20	4	1	1	1	3
	20-40	4	1	1	1	3
3	0-20	4	1	1	1	3
	20-40	4	1	1	1	3
4	0-20	4	1	1	1	3
	20-40	4	1	1	1	3
5	0-20	4	1	1	1	3
	20-40	4	1	1	1	3
6	0-20	4	1	1	1	3
	20-40	4	1	1	1	3
7	0-20	4	1	1	1	3
	20-40	4	1	1	1	3
8	0-20	4	1	1	1	3
	20-40	4	1	1	1	3
9	0-20	4	1	1	1	3
	20-40	4	1	1	1	3
10	0-20	4	1	1	1	3
	20-40	4	1	1	1	3
11	0-20	4	1	1	1	3
	20-40	4	1	1	1	3
12	0-20	4	1	1	1	3
	20-40	4	1	1	1	3

Where 1= none to slight degraded soil; 2= moderately degraded soils; 3= highly degraded soils; 4= Very highly degraded soil

Result of Land and Soil Requirements for Cashew Suitability

The suitable evaluation (Table **5**) was prepared for cashew suitability by matching the summary of the land characteristics with the land/climatic characteristics of the crop determined. Cashew (*Anacardium occidentale* L.) thrives in tropical climates, favoring well-distributed rainfall between 1000–2000 mm annually. The highly suitable (S_1) class indicates optimal suitability with rainfall between 987–2247 mm, mean annual temperatures above 25 °C, and relative humidity over 75 %. In contrast, not suitable class (N), with rainfall below 601 mm and mean temperatures of 16 – 18 °C, is unsuitable due to water stress and limited photosynthetic efficiency. Cashew grows best in gently sloping terrains (< 12 %), which facilitate root penetration and mechanization. Land in the S_1 class (< 12 % slope) is optimal for cashew due to minimal erosion risk. Cashew is moderately drought-tolerant but sensitive to waterlogging. S_1 and moderately suitable (S_2) classes have good to moderately well-drained soils, reducing flooding risk. Avoidance of flood-prone or water-retentive soils is essential for sustainable productivity. S_1 and S_2 classes possess such textures with blocky structures and depths exceeding 40 cm, providing ample root zone. Marginally

Table 5: Land and Soil Requirements for Cashew

Land Qualities	100 - 86 **S_1**	85 - 61 **S_2**	60 - 41 **S_3**	≤40 **N**
Climatic (c)				
Annual rainfall(mm)	987 – 2247	827 - 987; 2247-3197	601 - 8273 197- 4926	< 601
Length of growing season (months)				
Mean Annual temp (°C)	> 25	20 - 25	18 - 20	16 - 18
Relative humidity (%)	> 75	65 - 70	62 - 65	60 - 62
Topography (t)				
Slope (%)	< 12	12 - 23	23 - 77	> 77
Wetness (w):				
Flooding				
Drainage	Good somewhat poorly drained	Mod. Well drained	Mod. Well drained	Poor aeric drained
Soil physical properties (s):				
Texture	CL, SCL, L	CL, SCL, L	SLC	SCL, Lfs
Structure	Blocky	Blocky		
Soil Depth (cm)	> 40	21 - 40	7 - 21	< 7
Fertility (f):				
CEC (cmol/kg clay)	> 12.4	8.5 - 12.4	2.6 - 8.5	< 2.6
Base saturation (%)	> 66	< 66		
Organic matter (% C) (0 – 15 cm)	> 0.8	0.5 - 0.8	0.1 - 0.5	< 0.1

Suitable (S_3) and N classes with shallow soils (< 21 cm) and coarse textures limit nutrient uptake and anchorage. There were high cation exchange capacity (CEC > 12.4 cmol/kg) and base saturation (> 66 %) in S_1 support nutrient retention essential for cashew nutrition. Organic matter content > 0.8 % enhances soil microbial activity and water retention.

Result of Climatic and Land suitability requirement for Cocoa

The suitable evaluation (Table **6**) was prepared for cocoa suitability by matching the summary of the land characteristics with the land/climatic characteristics of the crop determined. Inadequate or excessive rainfall reduces yield and increases disease incidence, unlike with the annual rainfall which was highly suitable (between S_{11} and S_{12}) and having optimal rainfall in supports of cocoa's high water demand without causing waterlogging. Slightly dry or overly wet occurrence was observed in the moderately suitable (S_2) rainfall on the current status which may require drainage or supplemental irrigation.

Table 6: Climatic and Land suitability requirement for Cocoa

Land, Soil and Climatic Characteristics	S_1	S_2	S_3	N_1	N_2
Climate (C)					
Annual Rainfall (mm)	1400 – 2500	1400 – 1600 2500 – 3500	1200 – 1400 3500 – 4500	< 1200	-
Mean annual temperature (O°C)	23 - 32	32 – 35	35 – 38	> 38	-
Length of Dry season (Months)	< 2	< 3	< 4	> 4	-
Relative humidity (driest month)	40 – 65	65 – 75	375 – 85	> 85	-
Topography (T)					
Slope (%)	< 8	< 16	< 30	-	-
Wetness (W)					
Flooding	Fo	Fo	F1	F1	Any
Drainage	WD	MD	ID	PD	VPD
Soil Physical Properties (S)					
Texture/Structure	C^- 60s to SC	C^+ 60s to SCL	C^+ 60s to LF S	C^+ 60s to LF S	CM to CS
Coarse fragment (%)	< 15	< 35	< 55	> 55	-
Soil depth (cm)	> 150	> 100	> 50	< 50	-
Fertility Characteristics (F)					
Apparent CEC (Cmol/kg)	> 16	< 16	-	-	-
Base Saturation	> 35	> 20	Any	Any	-
Organic matter (% OC 0 – 15 cm)	> 1.5	> 0.8	< 0.8	-	-
pH in distilled water	6.0 – 7.0	7.0 - 7.6	< 5.5	-	-

Symbols used for soil texture and structures are defined as follows: CM: massive clay, CS: structure clay, SC; sandy clay, SCL: sandy clay loam, LF:

Deficit in rainfall may lead to drought stress due to marginal (S_3) characters observed in current status of cocoa. Insufficient occurred (between N_1 and N_2) for sustained cocoa growth due to extremes in rainfall beyond upper/lower thresholds which hinder productivity. Temperatures (mean annual temperature °C) beyond the optimal range affect physiology and reduce productivity, as observed with the highly suitable (S_1) which was ideal for photosynthesis and pod development. While moderately suitable (S_2) mean temperature was slightly hot which may reduce pollination and increase evapotranspiration. The marginal (S_3) mean temperature was high in stress which impacts flowering and bean quality of cocoa. Heat stress likely fatal occurred with the unsuitable (N_1) mean temperature in current status. Longer dry seasons (in months) led to moisture stress and yield loss, unlike in suitable (S_1 - S_3) having < 4 months been acceptable, but < 2 months been optimal in current status of cocoa. Extended dryness hampers flowering and pod filling of cocoa with unsuitable (N_1) period of > 4 months. High relative humidity (RH) increases disease prevalence and low RH may cause desiccation as the RH was observed highly suitable (S_1) with ideal balance for cocoa's microclimate. And still acceptable but may increase fungal disease risk during moderate/marginal suitable (between S_2 and S_3) RH of 65 – 85 %. High humidity favors black pod disease when unsuitable (N_1) RH > 85 %.

Slope affects erosion risk, water runoff, and mechanization feasibility as the topography implications was highly suitable (between S_{11} and S_{12}) which makes easy mechanization due to less erosion risk (with < 8 % slope). While moderately suitable (S_2) has slightly sloppy landscape of manageable erosion risk where moderate management are needed. The marginal (S_3) features of current soil status with < 30 % slope are prone to erosion where restrict cultivation or the use terraces are required. And the unsuitable (between N_1 and N_2) features indicate not suitable with > 30 % slope are typically unsuitable due to severe erosion risk. However, the wetness implications of highly suitable (between S_1 and S_2) were observed ideal for cocoa development. The marginal (S_3) and the fairly unsuitable (N_1) were seasonal with reduced oxygen accessibility that affects root health. Any flooding condition beyond seasonal unsuitable (N_2) had severe root damage and poor health of cocoa. Poor drainage increases root rot and fungal diseases, unlike the drainage implications discovered with highly suitable (S_1) that was well-drained which ensures root aeration. The acceptability of moderately suitable (S_2) drained current status may need drainage enhancement. While the marginal (S_3) imperfectly drained reduces productivity of cocoa. The poor/very poor unsuitable (between N_1 and N_2) status may be due to waterlogging and disease in the development of cocoa.

Soil texture, depth, and structure affect root expansion, moisture retention, and nutrient cycling. Improve poor soils through organic amendments, deep tillage, or raised beds, as the soil physical properties implications in texture/structures were highly suitable (between S_1 and S_2) with loamy texture of moderate clay content which is ideal for cocoa production. While the marginal (S_3) was sand with poor water-holding capacity. The poor and unsuitable (between N_1 and N_2) drainage or nutrient leaching status arises due to the presence of massive clay or coarse sand. Coarse Fragments (%) with < 15 % were highly suitable

(S_1) as fewer obstacles to root penetration were identified. Meanwhile, the fairly marginal suitability (between S_2 and S_3) status with < 55 % may reduce effective root zone. And the unsuitable (N_1) status with > 55 % restricts root growth, and reduces fertility. Soil Depth (cm) with > 150 cm was highly suitable (S_1) having deep rooting potential. Meanwhile, the moderate and marginal suitability (S_2 and S_3) status had restricted rooting. And the unsuitable (N_1) status with < 50 cm has severely limits plant stability and nutrient uptake.

Fertile soils with balanced pH and good CEC are essential for cocoa's nutrient-demanding nature. The apparent CEC derived from highly suitable (S_1) had high nutrient retention capacity. And the marginal suitability (S_3) and the unsuitable (N_2) status were likely too low for sustained fertility. Base Saturation (%) was highly suitable (S_1) which indicate available exchangeable bases. And the marginal suitability (S_3) was accepted but less ideal. Organic Matter had highly suitable (S_1) that maintains soil structure and nutrient supply. And the marginal suitability (S_3) had low fertility status. The pH (in distilled water) was found near neutral, from highly suitable (S_1) current status that is ideal for cocoa production. And marginally suitable (S_3) in acidic status that may cause aluminum toxicity.

Result of Land and Soil Requirements for Cassava Suitability

Cassava thrives in warm and humid environments. The optimal temperature ranges between 22 °C and 26 °C (S_{11} and S_{12}). Classes S_2 and S_3 experience sub-optimal conditions, while N_1 and N_2 face critical limitations in rainfall (< 500 mm) and high temperature (>35 °C). Ideal slope for cassava cultivation is between 0 – 12 % (S_{11} and S_{12}), which supports mechanization and reduces erosion risks. S_2 and S_3 (slopes 12–30 %) pose moderate to high erosion risks, requiring conservation practices like contour farming. Cassava is moderately tolerant to water stress but susceptible to waterlogging. Well-drained soils in S_{11} and S_{12} provide ideal aeration and root development. Classes S_3 to N_2 are associated with poor or very poor drainage and periodic flooding (F_1). Soil depth > 75 cm (S_{11}) supports optimal root expansion. Soils in S_3 and N_2 with shallow depths (< 40 cm) limit root development and moisture retention. Fine-textured soils (Cm, Si) in N_2 hinder drainage and aeration. Cassava tolerates a range of soil pH (5.0 – 6.5) but performs best in slightly acidic soils (5.5–6.0). Organic carbon > 20 g/kg and CEC >2 4 cmol/kg enhance nutrient availability (S_{11}). Fertility drops drastically in S_3 to N_2 with low organic carbon (<8 g/kg), low CEC (<15 cmol/kg), and poor base saturation (< 20 %) as observed in Table **7**.

Result of Land and Soil Requirements for Maize Suitability

The suitable evaluation (Table **8**) was prepared for maize suitability by matching the summary of the land characteristics with the land/climatic characteristics of the crop determined. The evaluations show that the current status of the land and soil requirements was highly suitable (between S_{11} and S_{12}) with the characteristics that align with maize's optimal climate needs requirements. While moderately suitable (S_2) characteristics of the current status indicated longer season that compensates for low rainfall. The marginal (S_3) characteristics observed in current status of the soil had risk of drought stress due to temperature and rainfall limitations. The unsuitable (between N_1 and N_2) characteristics had extreme climatic limitations such as low rainfall, low temps, and high RH.

Moreso, the topography implications was highly suitable (between S_{11} and S_{12}) and ideal for mechanization and erosion control. While moderately suitable (S_2) having slightly sloppy landscape of manageable erosion risk. The marginal (S_3) features of current soil status had risk of runoff (increased) and soil erosion. And the unsuitable (between N_1 and N_2) features indicate not suitable due to high erosion, and machinery challenges i.e. too steep for maize cultivation. However, the wetness and drainage implications were highly suitable (between S_{11} and S_{12}) which was optimal for maize root development. There may be the risk of germination delays and possible root diseases of maize due to moderately suitable (S_2) characters of possess somewhat poorly drained current soil position. And those with marginal (S_3) characters had poor drainage with waterlogging risks. The unsuitable (between N_1 and N_2) characters of current soil status had very poor drainage with high probability of root rot, not suitable for cultivation.

Nevertheless, the soil physical properties implications were highly suitable (between S_{11} and S_{12}) with > 75 cm soil depth of loamy soils ideal for rooting and water retention. While moderately suitable (S_2) soil properties had moderate rooting depth of light texture which may need frequent watering. The marginal (S_3) properties had shallow soil that limits root growth with low water retention. And the unsuitable (between N_1 and N_2) properties of current soil status had very poor soil structure that restricts maize development.

Furthermore, the soil fertility properties implications were highly suitable (between S_{11} and S_{12}) with excellent nutrient availability of high potential with fertilization. The response to fertilization (nutrient inputs) for the current soil status was moderately suitable (S_2). The marginal (S_3) properties were input dependent in maintaining marginal fertility. And the unsuitable (between N_1 and N_2) properties of current soil status had very low fertility, unsuitable for maize.

Result of Land Quality Parameters for Yam Suitability

The suitable evaluation (Table **9**) was prepared for maize suitability by matching the summary of the land characteristics with the land/climatic characteristics of the crop determined. Yam requires warm, moist climates with well-distributed rainfall. The S_{11} class, with rainfall > 800 mm and temperatures between 25 – 30 °C, is optimal for yam growth. S_2 (600 – 800 mm and 20 –25 °C) and S_3 (500–600 mm and 20 °C) are moderately suitable. N class (< 500 mm) lacks adequate moisture for optimal growth. It thrives on gentle slopes due to its sensitivity to waterlogging and erosion. S_{11} with 0 – 4 % slope is ideal. S_2 (4 – 8 %) and S_3 (8 – 18 %) are manageable with conservation practices. N (> 16 %) may lead to erosion and poor root anchorage. Yams require well-drained soils. S_{11} and S_2 with FO (no flooding) and well to moderately drained soils are suitable. S_3 (imperfect drainage) poses risk of root rot. N (poor drainage, frequent flooding) is unsuitable. Deep, loamy to sandy loam soils (S_{11}) provide

Table 7: Climatic and Land suitability requirement for Cassava

Land qualities and Land characteristics	S_{11} (96 – 100)	S_{12} (86 – 95)	S_2 (61 – 85)	S_3 (41 – 60)	N_1 (21 - 40)	N_2 (0 – 20)
Climate (c)						
Annual rainfall	1200 – 1400	1500 - 1200	1100 – 900	900 – 500		< 500
Mean annual temp (°c)	22 - 24	24 - 26	26 - 30	30 - 35		> 35
Relative humidity (%)	60 – 80	50 – 60	40 – 50	30 – 40		< 30
Wetness(w)						
Flooding	FO	FO	-	-	F1	
Drainage	WD	Well Drained	Moderately Drained	Poorly Drained	Very poorly drained	
Soil physical prop (s)						
Soil depth	> 75	60 - 75	40 - 60	20 - 40	-	< 20
Texture	SCL, L	SL, SiL, Si, SC	LS, LFS, Co, SiC			Cm, Si
Fertility (f)						
Soil pH	5.4 - 5.7 &	5.0 - 5.4 & 6.0 -	4.3 - 5.0 & 6.5 - 7.0	4.0 - 4.3 & 7.0 -	-	> 7.8
Organic carbon (g/kg)	5.7 - 6.0	6.5	8 - 12	7.8	-	
CEC	> 20	12 - 20	15 - 16	< 8	-	
Base saturation (%)	> 24	16 - 24	20 - 35	< 15	-	
	> 50	35 - 50		< 20		
Topography (t)						
Slope (%)	0.0 -5	5 - 12	12 - 120	12 - 30		> 20

Symbols used for soil texture, structures and flooding is defined as follows: Cm: massive clay, Si: silt, SiL: silty loam, SC; sandy clay, L; loam, SCL: sandy clay loam, SL: sandy loam, LFS: loamy fine sand, LS: loamy sand, Co: coarse sand.

Table 8: Land and Soil Requirements for Maize

Land Qualities	100 - 96 S_{11}	95 - 86 S_{12}	85 - 61 S_2	60 - 41 S_3	40 - 26 N_1	≤ 25 N_2
Climatic (c)						
Annual rainfall (mm)	850 - 1250	850 - 750	750 - 600	600 - 500	550 - 500	> 500
		1250 - 1600	1600 - 1800	> 1800		
Length of growing season (days)	150 - 220	220 - 270	270 - 325	325 - 335	335 - 245	> 345
		130 - 150	110 - 130	90 - 110	90 - 100	< 90
Mean Annual temp (°C)	22 - 26	22 - 18	18 - 16	16 - 14	14	< 14
		26 - 32	32$^+$			
Relative humidity Developmental stage (%)	50 - 80	50 - 42	42 - 36	36 - 32	32 - 30	< 30
Topography (t) Slope (%)	0 - 2	2 - 4	4 - 8	8 - 16	30 - 50	> 16
		4 - 8	8 - 16	16 - 30		> 50^a
Wetness (w)		Moderate	Somewhat poorly drained	Poor	Poor	Poor and very poor
Drainage	Good somewhat poorly drained	Moderate	Good	Aeric	Drainage	Poor not drainable
Soil physical properties (s):						
Texture	Cs, SiCs Co, CL	Cs, SC, L, SCL	SL Lfs, LS	LCS, Fs	Cm, CL	Cm, CS
Soil Depth (cm)	<100	75-100	50 - 75	30 - 50	20 - 30	< 20
Fertility (f):						
CEC (cmol/kg clay)	> 24	16 - 24	< 16 (*)	< 16	< 10	< 10
Base saturation (%)	> 50	35 - 50	20 - 35	15 - 20	< 15	< 15
Organic matter (% C)	> 2	1.2 - 2	1.0 - 1.2	0.8 - 1.0	0.6 - 0.8	< 0.6
(0-15 cm)	> 1.5	0.8 - 1.2	0.6 - 0.8	0.5 - 0.6	< 0.5	< 0.5
	> 0.8	0.6 - 0.8	0.5 - 0.6	0.4 - 0.5	< 0.4	< 0.4

Symbols used for soil texture and structures are defined as follows: Co: coarse sand, Cs: structure clay, Cm: massive clay, SiCs: silty clay; blocky clay, CL: clay loam, SC; sandy clay, L; loam, SCL: sandy clay loam, SL: sandy loam, Lfs: loamy fine sand, LS: loamy sand, LCS: loam coarse sand, Fs: fine sand.

Table 9: Land requirement of suitability classes for Yam

Land qualities and Land characteristics	S_{11} (100 – 95)	S_2 (94 – 85)	S_3 (84 – 40)	N (39 – 20)
Climate (c)				
Annual rainfall Mean	> 800	600 - 800	500 – 600	< 500
annual temp(°c)	25 - 30	20 - 25	20	20 - 30
Wetness(w)				
Flooding	FO	FO	-	F1
Drainage	WD	MODERATE	IMPERFECT	POOR
Soil physical prop (s)				
Soil depth				-
Texture	> 70	50 - 70	35 - 50	< 35
	SL, L, SCL	SiC, SiCL	LS, LCS, Fs	CS, S
	SiL, SCL	CL, SC		
Fertility (f)				
Soil pH	6.1 - 7.5	5.6 - 6.0	45 - 5.5	7.6 - 9.0, > 9.0, < 4.5
CEC clay (Cmol/kg)	> 40	40 - 16	16 -12	< 12
Base saturation (%)	> 35	35 - 20	20	< 20
Total N (%)	> 0.20	0.20 - 0.15	0.10 - 0.15	< 10
Exchangeable K	> 0.6	0.3 - 0.6	0.3 - 0.2	< 0.2
Topography (t)				
Slope (%)	0 - 4	4 - 8	8 - 18	> 16

Symbols used for soil texture and structures are defined as follows: Cs: structure clay, SiC: silty clay, SiCL: silty clay loam, CL: clay loam, SiCL: silt clay loam, SiL: silty loam, SC; sandy clay, L; loam, SCL: sandy clay loam, SL: sandy loam, LS: loamy sand, LCS: loam coarse sand, Fs: fine sand, S: sand.

the best physical environment for yam. S_2 has moderately suitable textures like silty clay and silty clay loam. S_3 includes sandy and coarse soils which limit root development. N class soils are very coarse and shallow.

Optimal yam growth requires pH 6.1 – 7.5 (S_{11}), high CEC (> 40 cmol/kg), good base saturation (> 35 %), and high total N and K. S_2 is moderately suitable. S_3 has poor fertility. N class soils are too acidic/alkaline with very low fertility.

DISCUSSION

Suitability depends on crop rooting depth and water needs. The shallow soils limit deep-rooted crops and moisture storage during dry spells. Presence of high sand implies good drainage but poor water/nutrient retention. This is prone to erosion and leaching, especially under heavy rainfall. High silt with low clay presence may still result in unstable aggregates prone to crusting, which contributes to better structure and nutrient-holding capacity than sand alone. Low CEC has limited ability to hold nutrients which indicates light-textured soils, often requiring frequent fertilizer applications.

Neutral pH is optimal for nutrient availability and microbial activity, as Brady and Weil (2016) note that pH 6.5–7.5 is optimal for most crop growth. No substantial aluminum or H^+ toxicity risk as low exchangeable acidity is favorable for most crops (Brady and Weil, 2016). Tisdale *et al*. (2002) note the importance of balanced Ca:Mg:K for nutrient uptake. Na was within safe limits having no salinity issue. Clay CEC usually > 10 cmol/kg; lower values may signal sandy/low-activity clays (Lal, 2015).

The sub-soils are ideal for nutrient availability and root zone stability; albeit no issues with acidity toxicity as Brady and Weil (2016) emphasize that pH 6.5 – 7.5 is ideal for most crops. However, Havlin *et al*. (2014) note subsoil N tends to be naturally lower but is still essential for deep-rooted crops development. According to Lal (2015), subsoil OC is critical for long-term C storage and root health.

Soil nitrogen deficiency is a major constraint in Sub-Saharan Africa and is often tied to organic matter decline (Palm *et al*., 2001). Low phosphorus availability is a major fertility problem in weathered tropical soils (Sanchez *et al*., 1997). Potassium is often overlooked but plays a critical role in plant health and yield (Mengel and Kirkby, 2001). Declining base saturation is a key marker of soil acidification and degradation (Van Breemen and Buurman, 2002). Soil organic carbon is a primary indicator of biological health and resilience (Lal, 2004).

Cashew prefers loamy or sandy loam soils that ensure good aeration and water infiltration that can decrease performance (Olaniyi *et al*., 2022). These conditions support vigorous vegetative growth, flowering, and fruit setting of cashew (Omomowo *et al*., 2023). Slopes > 23 % increase erosion risks and reduce soil retention capacity, adversely impacting yield potential (Aduloju and Etejere, 2020). Poorly drained (aeric) soils restrict oxygen availability to roots, causing physiological stress (FAO, 2021). There is decline in fertility indices, while severely nutrient-deficient persists therefore amendments like compost or biochar are required in marginal soils (Ayodele *et al*., 2021).

Adequate rainfall (1500 – 2500 mm) is vital for cocoa growth and pod development (Aikpokpodion *et al*., 2010; Wood and Lass, 2001), as inadequate or excessive rainfall reduces yield and increases disease incidence. Temperatures beyond the optimal range affect physiology and reduce productivity of cocoa growth and pod development (Anim-Kwapong and Frimpong, 2004). Cocoa is highly sensitive to prolonged dry periods (Obiri *et al*., 2007) as longer dry seasons lead to moisture stress and yield loss. For instance, high RH favors *Phytophthora palmivora* resulting from improvement in air circulation and applying fungicides during peak humidity (Opoku *et* *al*., 2000). Cocoa thrives in deep, well-drained loamy soils (Hartemink, 2005). Optimal cocoa sites are found on gently sloping or flat where terracing and contour farming were used on steeper lands (Asare, 2005). Cocoa roots need aerated conditions, as it is sensitive to waterlogging (Ahenkorah *et al*., 1987). Fertility is a major determinant of cocoa yield (Anim-Kwapong and Frimpong, 2004).

A sub-optimal condition, critical limitations in rainfall and high temperature, makes them unsuitable for cassava production (CIAT, 2002). Relative humidity above 60 % and rainfall between 1200 – 1500 mm are suitable for cassava growth, ensuring efficient photosynthesis and reduced water stress (El-Sharkawy, 2006). Slopes > 30 % are unsuitable for cassava due to mechanization difficulty and erosion hazards (Howeler, 2014). Associated poor or very poor drainage and periodic flooding leads to root rot and yield loss (Alves, 2002). Also, preferred soil textures include sandy clay loam (SCL) and loam (L) (Howeler, 2014).

The unsuitable zones of current soil status likely suffer drought stress and poor pollination due to temperature inhibition. This makes maize highly sensitive, as the ideal temperatures range from 18 – 27 °C and rainfall between 500 – 1200 mm (FAO, 2021). The high erosion rates in unsuitable zones reduce nutrient retention (Kebede *et al*., 2022) which makes maize roots poorly in steep slopes due to shallow soil anchorage and water runoff. Maize cultivation requires well-drained soils to avoid hypoxic stress. A poorly drained area is prone to Fusarium and Pythium infections (Chandler *et al.*, 2021). Sandy or massive clay soils restrict root elongation and water movement, as maize performs best in deep, and well-aerated loamy soils with good structure (Zhao *et al*., 2020). Presence of high CEC and organic matter enhance nutrient retention (Behera *et al*., 2023), but the soils in the unsuitable zones of current soil status are severely nutrient-deficient.

Yams need consistent water for tuber formation. Lower rainfall levels or inconsistent temperatures can hinder yield (Oke and Bolarinwa, 2021). Steep slopes increase risk of erosion, affecting tuber development and yield (Udoh *et al*., 2020). Poor drainage leads to waterlogging, impeding root respiration and tuber development (Asadu and Oti, 2022). Soil depth and texture affect tuber expansion and nutrient availability (IITA, 2021). Poor fertility leads to reduced tuber size and increased vulnerability to pests and diseases (Ayeni and Adeleye, 2023).

CONCLUSION

The suitability evaluation and degradation assessment of basement complex-derived soils in Abeokuta, Nigeria, reveal predominantly sandy loam and loamy sand textures with neutral pH but low organic matter, nitrogen, and cation exchange capacity. While these soils exhibit good drainage, their low fertility and poor nutrient retention necessitate integrated management through organic matter enrichment, erosion control, and targeted nutrient supplementation; particularly nitrogen, calcium, and micronutrients.

Land classification shows variable crop suitability. Cashew and cocoa require deep, fertile, well-drained soils, with cocoa benefiting additionally from mulching, water harvesting, and agroforestry in suboptimal zones. Cassava and maize can be grown successfully on moderately suitable lands using contour farming, cover cropping, and organic fertilization, while marginal zones require drainage improvement and nutrient rehabilitation. Yam cultivation demands soil depth and drainage; in less suitable zones, raised beds, lime, and green manures are essential.

Sustaining productivity across these soils hinges on informed land use planning, soil restoration in degraded areas, and climate-smart practices adapted to local topography and crop needs.

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