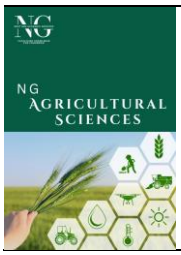

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Evaluation of Land Constraints to Yam (*Dioscorea rotundata*) Production in Wukari Area, Northeastern Nigeria

Donald Nweze Osujieke, Yasin Agono Awwal*, Hussaini Okpanachi Muhammad

Department of Soil Science and Land Resources Management, Federal University Wukari, Taraba State, Nigeria

*Corresponding author email ID: awwalyasin@fuwukari.edu.ng

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ABSTRACT

This study evaluated land constraints affecting yam (*Dioscorea rotundata*) production in the Wukari area, northeastern Nigeria, with emphasis on identifying key soil and land factors limiting productivity. Three representative soil profile pits were excavated in major yam-growing locations and assessed using field characterisation and laboratory analyses within the Land Suitability Evaluation framework. The soils were deep (108–118 cm), well drained, and located on nearly level terrain (0–2% slope), indicating generally favourable physical conditions for yam cultivation. However, soil fertility indicators were low, with organic matter (0.5–1.9 g kg^{-1}), total nitrogen (0.09–0.11 g kg^{-1}), available phosphorus (0.74–2.57 mg kg^{-1}), and cation exchange capacity (3.72–4.92 cmol kg^{-1}) consistently below optimal levels. Soil texture ranged from loamy sand to sand, further limiting nutrient and moisture retention. Actual land suitability indices ranged from 33.54 to 43.30 (marginally suitable to currently not suitable), while potential suitability improved to 86.05 (highly suitable) under improved fertility scenarios. The major constraints were identified as low available phosphorus, low nitrogen, low organic matter content, low cation exchange capacity, and coarse soil texture. These limitations collectively reduce nutrient availability, nutrient retention, and tuber development efficiency in yam systems. The study concludes that declining yam productivity in the area is primarily driven by soil fertility depletion rather than physical land limitations. Targeted soil fertility management, particularly phosphorus supplementation, organic matter enhancement, and balanced nutrient application, is essential for sustainable yam production in the region.

1. INTRODUCTION

Yam (*Dioscorea rotundata*) is one of the most important food and cash crops cultivated in tropical regions, particularly in West Africa, where it contributes significantly to food security, rural income generation, and socio-economic stability (Obidiegwu et al., 2026). According to Agricultural production statistics (FAO Knowledge Repository, 2025), Nigeria is the world's largest producer of yam, accounting for approximately 65–70% of global production, with its cultivation serving as a major livelihood activity among smallholder farmers across the Guinea Savanna and derived savanna agroecological zones. Beyond its dietary importance as a major carbohydrate source, yam also has cultural and economic significance in many Nigerian communities, where it is widely consumed, traded, and used in traditional ceremonies and social activities (Anugwo et al., 2025). Consequently, sustained yam production is essential not only for household food supply but

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also for national agricultural development and rural economic resilience.

The productivity of yams is strongly influenced by the suitability of the land on which they are cultivated. Numerous studies have shown that optimal yam growth and tuber development require deep, well-drained, friable soils with favourable physical conditions for root penetration and tuber expansion, adequate nutrient availability, and moderate topography that minimises erosion and waterlogging risks (Carsky et al., 2010; Mondo et al., 2024). Soil properties such as texture, depth, structure, organic matter content, pH, and nutrient status are particularly important determinants of yam performance, while drainage conditions and slope influence moisture availability and field accessibility (Ukabiala et al., 2025). Hence, variations in soil and terrain characteristics can result in substantial differences in yam productivity even within the same agroecological zone. Therefore, assessing the extent to which these land qualities meet crop requirements is fundamental for identifying production constraints and ensuring the sustainability of yam-based farming systems.

Land Suitability Evaluation (LSE) provides a structured framework for assessing the suitability of land for specific uses by systematically matching land characteristics with the requirements of a given crop or land-use type (FAO, 1976; FAO, 2007). It has been widely applied across diverse agroecological contexts and cropping systems, including maize, rice, cassava, wheat, oil palm, and yam, and serves as a key tool for land-use planning, agricultural intensification, and sustainable resource management (Fatihu et al., 2020; Awwal, 2021; Gani & Awwal, 2026). The framework enables the integration of soil information, topography, drainage, climate, and related environmental factors to identify land potentials for specific crop production. Its broad applicability across environments has made it one of the most widely adopted approaches in agricultural land assessment (Osujieke et al., 2025). Beyond classifying suitability, LSE also supports the diagnosis of specific biophysical constraints affecting crop performance, thereby informing targeted management strategies to improve productivity and maintain long-term land quality.

Wukari, located in the northeastern Guinea Savanna of Nigeria, is an important agricultural area where yam cultivation forms a key component of local farming systems (Awwal et al., 2026). However, production is increasingly occurring under conditions of continuous cultivation, shortened fallow periods, and rising pressure on available arable land. Farmers have reported declining tuber yields and reduced field performance, indicating possible land-related constraints to production. The area also exhibits marked variability in topography, drainage, and soil properties, suggesting that these constraints may vary across the landscape. Despite these conditions, the specific nature and distribution of land limitations affecting yam production in Wukari remain insufficiently documented.

Although land suitability studies have been conducted for various crops in Nigeria and elsewhere, most studies, such as Carsky et al. (2010) and Igbawua et al. (2022), emphasised general suitability classification at large scales with limited attention to specific land qualities responsible for observed constraints under local conditions. Thus, detailed information on the dominant soil and terrain factors limiting yam production in Wukari is still lacking. Addressing this gap is essential for improving land-use planning, guiding soil management interventions, and enhancing the sustainability of yam production systems in the area. This study, therefore, assessed the suitability of selected lands for yam (*Dioscorea rotundata*) production in Wukari using the FAO land evaluation framework. It first characterised key land quality indicators across representative yam cultivation sites, then evaluated their suitability for yam production, and finally identified the principal land constraints limiting optimal yam performance in the area.

2. MATERIALS AND METHODS

2.1 Study area

The study was conducted in the Wukari area of Taraba State, northeastern Nigeria. The area lies approximately between latitudes 7.84°N and 7.89°N and longitudes 9.76°E and 9.81°E (Figure 1). The landscape is generally characterised by gently undulating plains with elevations ranging from about 162 to 198 m above sea level. Surface drainage in the area is controlled by minor tributaries and seasonal streams that discharge into the Donga and Benue River systems (Gabriel et al., 2018). The relatively low relief and seasonal hydrological conditions influence soil drainage, erosion patterns, and moisture availability, which are important factors affecting yam production.

The climate of the area is tropical sub-humid, characterised by distinct wet and dry seasons. Rainfall is concentrated between April and October, while the dry season extends from November to March. Climatic data obtained from the NASA POWER Project for the period 2000–2025 indicate a mean annual rainfall of approximately 1130 mm (Figure 2).

The area records a mean annual temperature of 26.9°C, with minimum and maximum temperatures of 19.6°C and 34.4°C, respectively.

Geologically, the area lies within the southern section of the Benue Trough and is underlain predominantly by sedimentary rocks, mainly sandstone and shale (Awwal & David, 2024). The weathering of these parent materials has contributed to the development of soils with varying physical and chemical characteristics across the landscape. Such variations are important in determining rooting conditions, nutrient availability, drainage characteristics, and other land qualities relevant to yam cultivation.

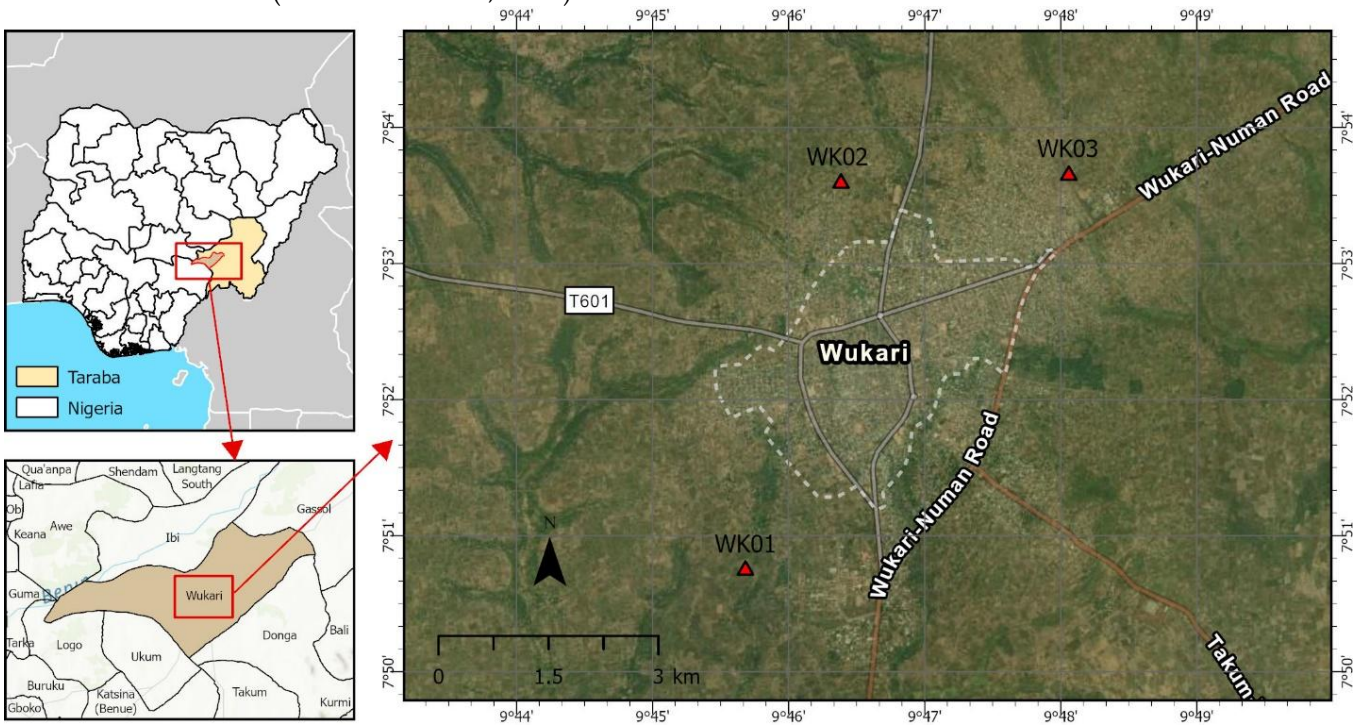

Figure 1. Map of Study Area showing Study Location and Profile Pits Location (WK01 – 03)

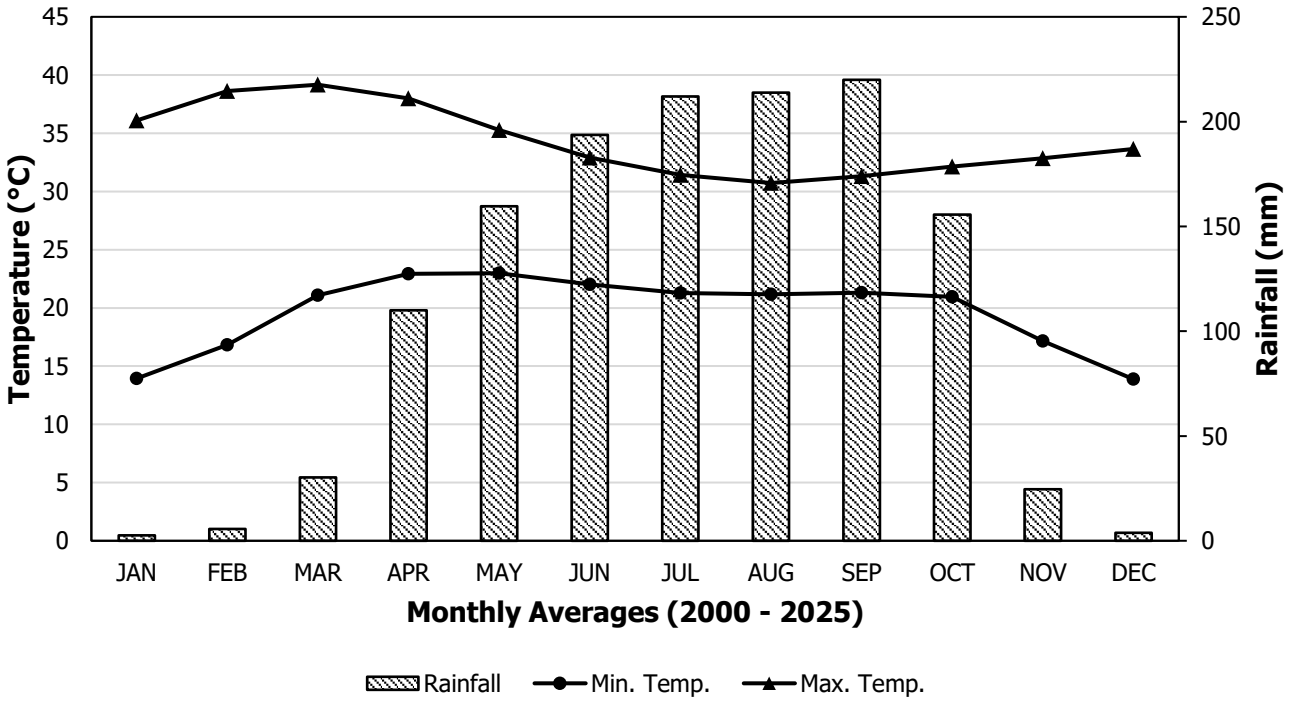

Figure 2. Climatic Data of the Study Area showing Monthly spread of Rainfall, Minimum and Maximum Temperatures from 2000 - 2025

2.2 *Field Study and Soil Sampling*

A reconnaissance survey was conducted to identify representative locations used for yam cultivation within the study area. The survey involved preliminary field observations of variations in topography, drainage conditions, surface characteristics, and cropping intensity across major yam-producing areas in Wukari. Based on these observations, three representative yam farms were purposively selected to capture the dominant land conditions under which yam is cultivated within the study area (Figure 1). The use of three pedons was considered adequate for capturing the inherent variation of yam farms in this study area, since the investigation focused primarily on the detailed characterisation of representative land units to identify dominant land constraints affecting yam cultivation rather than extensive soil mapping or spatial variability assessment. The profile pits were subsequently excavated and morphologically described in the field following the USDA soil survey procedures (Soil Survey Staff, 2017). Site characteristics, including slope, drainage condition, surface stoniness, erosion evidence, effective soil depth, and landscape position, were observed because of their relevance to yam production. Soil samples were collected, air-dried, crushed, and passed through a 2 mm sieve prior to analysis.

Table 1: Land Requirements for Yam (*Dioscorea rotundata*) Production (Modified from Ogbu *et al.* [2022])

Factors	Land Characteristics	S1	S2	S3	N1	N2
A.	**Climate (c)**					
	MAP (mm)	1000 –1800	750–1000	600–750	500–600	<500
	MAT (°C)	25–35	20–25 35–38	15–20	10–15	<10
B.	**Topography (t)**					
	Slope (%)	0–4	4–8	8–16	16–30	>30
C.	**Wetness (w)**					
	Drainage condition	WD	MD	ID	PD	VPD
D.	**Soil physical properties (s)**					
	Texture	L, SCL	SL	SC, CL, S	C	
	Soil depth (cm)	>100	75–100	50–75	25–50	<25
	Surface stoniness (%)	<5	5–15	15–35	35–60	>60
E.	**Soil fertility characteristics (f)**					
	Soil pH	5.5–7.0	5.0–5.5 7.0–7.5	4.5–5.0	4.0–4.5	<4.0
	TN (g kg^{-1})	>0.20	0.15–0.20	0.10–0.15	0.05–0.10	<0.05
	Av. P (mg kg^{-1})	>25	10–25	5–10	2–5	<2
F.	**Nutrient retention capacity (n)**					
	OC (g kg^{-1})	>1.5	0.8–1.5	0.5–0.8	0.2–0.5	<0.2
	Ex. K (cmol kg^{-1})	>0.30	0.20–0.30	0.10–0.20	0.05–0.10	<0.05
	CEC (cmol kg^{-1})	>16	10–16	5–10	2–5	<2
G.	**Salinity (z)**					
	EC (dS m^{-1})	<2	2–4	4–6	6–8	>8

Note: MAP = mean annual precipitation; MAT = mean annual temperature; WD = well drained, MD = moderately drained; ID = imperfectly drained; PD = poorly drained; VPD = very poorly drained; L = loam; SCL = sandy clay loam; SL = sandy loam; SC = sandy clay; CL – clay loam; S = sandy; C = clay; TN = total nitrogen; Av. P = available phosphorus; OC = organic carbon; ex. K = exchangeable potassium; CEC = cation exchange capacity; EC = electrical conductivity. Suitability ranges: S1 = highly suitability; S2 = moderately suitable; S3 = marginally suitable; N1 = currently not suitable; N2 = permanently not suitable.

2.3 *Laboratory Analysis*

Particle size distribution was determined using the hydrometer method (Bouyoucos, 1962). Soil pH was measured potentiometrically in a soil–water suspension (1:2.5) following standard procedures (Thomas, 1996). Organic matter content was estimated from organic carbon determined by the Walkley and Black wet oxidation method (Walkley & Black, 1934). Total nitrogen was determined using the Kjeldahl digestion method (Bremner, 1996). Available phosphorus was extracted using the Bray-1 method and determined colourimetrically (Bray & Kurtz, 1945). Exchangeable potassium was extracted using

neutral ammonium acetate as described by Chapman (1965). Cation exchange capacity (CEC) was determined using the ammonium acetate (1 M NH4OAc, pH 7.0) saturation method following Sumner and Miller (1996), and base saturation was computed as the percentage ratio of total exchangeable bases to CEC.

2.4 Suitability Evaluation for Yam Production

The suitability of the land for yam production was evaluated using the FAO LSE approach by matching observed land and soil characteristics with the ecological requirements of yam cultivation (Table 1). The assessment was based on key land qualities, including climate (c), topography (t), wetness (w), soil physical properties (s), soil fertility characteristics (f), nutrient retention capacity (n), and salinity (x). Each land quality was rated and combined to reflect its overall influence on crop performance, with particular emphasis on the most limiting factors governing yam development. The parametric suitability was further quantified using the square-root method, expressed as:

$$IP = A \times \sqrt{\prod_{i=1}^{n} \frac{N_i}{100}}$$

where IP is the suitability index, A is the rating of the most critical factor (i.e., climate), while Ni represents the ratings of other land characteristics (Awwal & Maniyunda, 2023). The resulting suitability indices (IP) were interpreted using standard classification limits, where S1 (highly suitable): >75, S2 (moderately suitable): 50–75, S3 (marginally suitable): 25–50, N1 (currently not suitable): 10–25, and N2 (permanently not suitable): <15. This classification was used to determine the actual and potential suitability status of each pedon based on both measured land conditions and projected improvements under improved management scenarios.

3. RESULTS

3.1 Land Characteristics of the Studied Sites

The land characteristics of the soils used for yam production in Wukari area are presented in Table 2. The evaluated land qualities included climatic conditions, topography, wetness characteristics, soil physical properties, soil fertility parameters, nutrient retention properties, and salinity indicators.

3.2 Climate and Topographic Characteristics

The study area recorded a mean annual rainfall of 1,130 mm and a mean annual temperature of 26.9 °C across all pedons between 2000 and 2025. The uniformity of climatic conditions across the sites reflects the relatively close spatial distribution of the profile locations within the same agroecological environment. The rainfall observed in the area falls within the range generally reported for the Southern Guinea Savannah zone of northeastern Nigeria, where annual rainfall commonly ranges from 1,000 to 1,300 mm (Awwal, 2021). Similar rainfall conditions have been reported for adjoining agricultural areas within the Benue Trough and southern Taraba region by previous workers studying crop production environments in the Guinea Savannah zone (Gabriel et al., 2018; Ogbu et al., 2022).

The observed temperature regime also aligns with findings from previous studies in northeastern Nigeria, where mean annual temperatures of 26-28 °C have been commonly reported (Awwal & David, 2024). The relatively high temperatures are attributable to the region's tropical continental climate, characterised by prolonged dry seasons and high solar radiation. Such climatic conditions influence evapotranspiration rates, organic matter decomposition, nutrient cycling, and soil moisture dynamics within cultivated lands (Taylor et al., 2021; Awwal et al., 2025a).

Slope values across the pedons ranged between 0 and 2%, indicating nearly level to gently sloping terrain. This confirms the generally undulating but low-relief nature of the Wukari landscape earlier reported for the Benue Valley region (Awwal et al., 2026). Low slope gradients in agricultural lands are often associated with reduced runoff velocity and relatively lower susceptibility to severe erosion compared with strongly sloping terrains (Osujieke et al., 2020). The uniformity of slope across the pedons suggests that topographic variation may not be a major source of spatial variability among the studied sites.

3.3 Wetness and Soil Physical Characteristics

From Table 2, all three pedons were classified as well drained, attributed to the relatively sandy nature of the surface horizons and the gently sloping landscape, which encourages infiltration and internal drainage. Similar drainage conditions have been reported for savannah soils derived from sandstone materials in northeastern Nigeria (Ekebuike et al., 2024). Good drainage conditions are also common in soils developed under prolonged seasonal wetting

and drying cycles characteristic of the Guinea Savannah environment.

Surface texture varied between loamy sand (LS) in Pedons WK01 and WK02 and sand (S) in Pedon WK03. The predominance of coarse-textured surface soils suggest significant influence of sandy parent materials, likely derived from sandstone formations associated with the Benue Trough geology (Awwal et al., 2026). The sandy nature of the soils may also reflect intensive weathering and eluviation processes common in tropical environments with alternating wet and dry seasons. Similar coarse-textured soils have been widely reported in many cultivated savannah soils of Nigeria, particularly within sedimentary formations (Ogbu et al., 2022).

Table 2: Land Characteristics Used for Suitability Evaluation of Yam (*Dioscorea rotundata*) Production in Wukari Area, Northeastern Nigeria

Factors	Land Characteristics	Unit	WK01	WK02	WK03
A.	**Climate (c)**				
	Annual rainfall	mm	1130	1130	1130
	Mean annual temperature	°C	26.9	26.9	26.9
B.	**Topography (t)**				
	Slope	%	0-2	0-2	0-2
C.	**Wetness (w)**				
	Drainage condition	Class	WD	WD	WD
D.	**Soil physical characteristics (s)**				
	Surface texture	Class	LS	LS	S
	Effective soil depth	cm	118	108	118
	Surface stoniness/gravelliness	%	<2	<2	<2
E.	**Soil fertility characteristics (f)**				
	Soil pH	–	5.5	5.85	5.23
	Organic matter	g kg^{-1}	1.9	0.5	1.26
	Total nitrogen	g kg^{-1}	0.11	0.09	0.1
	Available phosphorus	mg kg^{-1}	2.57	0.74	1.84
F.	**Nutrient retention characteristics (n)**				
	Cation exchange capacity (CEC)	cmol kg^{-1}	4.92	3.72	3.91
	Base saturation	%	79.2	58.8	60.6
	Exchangeable potassium	cmol kg^{-1}	1.12	0.91	1.01
G.	**Salinity (z)**				
	Electrical conductivity (EC)	dS m^{-1}	0.1	0.11	0.1

Note: WK01 – 03 = profile pits location; drainage class: WD – well drained

The effective soil depth ranged from 108 cm in WK02 to 118 cm in WK01 and WK03, indicating generally deep soils across the study sites. Deep soils are characteristic of stable landscapes with prolonged pedogenic development and limited exposure of lithic or restrictive layers near the surface (Gani & Usman, 2024). Surface stone and gravel content were generally low (<2%) across the pedons. The low gravel content suggests minimal exposure of coarse fragments at the soil surface and may indicate relatively stable geomorphic conditions with limited erosion-induced lag deposits. Similar observations have been made in cultivated savannah soils developed on fine to medium-textured sedimentary materials (Gani & Awwal, 2025).

3.4 Soil Fertility Characteristics

The soil pH values ranged from 5.23 in WK03 to 5.85 in WK02, indicating slightly acidic soil conditions. The observed pH values are consistent with the moderately acidic nature of many tropical savannah soils subjected to prolonged leaching under seasonal rainfall conditions. Similar pH ranges have been reported in cultivated soils within Taraba State and other parts of the Guinea Savannah ecological zone (Ogbu et al., 2022; Waizah & Gani, 2025). The acidity observed in the soils may be linked to continuous cropping, leaching of basic cations, organic matter decomposition, and prolonged weathering of parent materials.

Organic matter content varied considerably among the pedons, ranging from 0.50 g kg^{-1} in WK02 to 1.90 g kg^{-1} in WK01. The relatively higher OM content in WK01 may be associated with greater accumulation of plant residues, reduced disturbance, or localised differences in vegetation cover and management practices (Sun et al., 2024). In contrast, the lower values in WK02 suggest rapid

mineralisation and possible depletion, driven by continuous cultivation and biomass removal (Awwal et al., 2025b). The generally low to moderate organic matter levels observed across the sites agree with findings from many tropical cultivated soils, where high temperatures accelerate decomposition rates and reduce long-term organic matter accumulation.

Total nitrogen values ranged between 0.09 and 0.11 g kg^{-1}, indicating generally low nitrogen status across the study area. The low nitrogen levels are consistent with the observed OM content since soil organic matter constitutes the principal reservoir of nitrogen in tropical soils (Awwal et al., 2025a). Available phosphorus values were also low across the pedons, ranging from 0.74 to 2.57 mg kg^{-1}. These values are lower than the commonly recommended critical phosphorus levels for many tropical agricultural soils. The low phosphorus status may be associated with fixation by iron and aluminium oxides, nutrient depletion resulting from continuous cultivation, and limited fertiliser application (Singh et al., 2025).

3.5 Nutrient Retention Characteristics and Salinity

Cation exchange capacity values ranged from 3.72 to 4.92 cmol kg^{-1}, indicating generally low nutrient retention capacity. The low CEC values are likely related to the dominance of sandy particles and relatively low OM content within the soils. Coarse-textured soils typically possess lower surface area and fewer exchange sites for retaining nutrient cations (Ferré & Warrick, 2005). Base saturation values ranged from 58.8% in WK02 to 79.2% in WK01. These moderate to high base saturation values suggest appreciable presence of exchangeable basic cations despite the relatively low CEC of the soils (Awwal & David, 2024). The observed values may indicate partial replenishment of bases through weathering processes or seasonal nutrient cycling within cultivated systems.

Exchangeable potassium values ranged between 0.91 and 1.12 cmol kg^{-1}, indicating moderate potassium levels across the pedons. This may be associated with mineral weathering and recycling of crop residues within cultivated fields (Javan et al., 2025). Electrical conductivity values were uniformly low, ranging from 0.10 to 0.11 dS m-1. These values indicate non-saline soil conditions across the study sites, as expected under humid to sub-humid tropical conditions where seasonal rainfall promotes leaching of soluble salts from the soil profile (Awwal, 2021).

3.6 Suitability Evaluation of the Studied Sites for Yam Production

The suitability ratings of the evaluated land qualities for yam production are presented in Table 3. The results revealed variations in suitability levels among the pedons, mainly due to differences in soil physical and fertility characteristics, while climatic, topographic, drainage, and salinity conditions remained generally favourable across the study area. Climatic factors, including annual rainfall and mean annual temperature, were rated as highly suitable (S1) across all the pedons. Similarly, slope and drainage conditions were also highly suitable. This finding suggests that the principal limitations to yam production in Wukari are not associated with the prevailing climatic environment but rather with soil-related factors that directly influence nutrient availability, nutrient retention, and tuber development. Similar observations have been reported in yam-growing areas of the Guinea Savannah, where soil fertility decline rather than climate was identified as the dominant constraint to sustainable yam production (Carsky et al., 2010; Ogbu et al., 2022).

The nearly level terrain and well-drained soils indicate relatively stable landscape conditions with minimal topographic constraints. Electrical conductivity values were equally rated as highly suitable, indicating the absence of salinity-related limitations within the study area. These favourable climatic and landscape conditions provide a suitable environment for yam establishment, tuber initiation, and tuber enlargement. Yam is particularly sensitive to waterlogging and excessive slope-induced erosion (Igbawua et al., 2022); therefore, the observed drainage and topographic conditions constitute important advantages for yam cultivation in the study area.

Variations in suitability were also observed in some soil physical characteristics. Surface texture in Pedons WK01 and WK02 was rated moderately suitable (S2) due to the loamy sand texture, while Pedon WK03 was rated marginally suitable (S3) because of its sandy texture. Effective soil depth and surface stoniness were highly suitable (S1) across all pedons, reflecting the deep and relatively stone-free nature of the soils. Deep, stone-free soils are generally regarded as highly favourable for yams because they permit unrestricted tuber penetration and enlargement. However, the predominance of sandy and loamy sand textures may reduce soil moisture and nutrient retention, thereby limiting the soil's capacity to sustain yam growth throughout the cropping season. Similar textural limitations have

been reported in other yam-producing areas developed on sandstone-derived parent materials, where nutrient leaching and seasonal moisture deficits constrained crop performance despite otherwise favourable physical conditions (Ogbu et al., 2022; Ukabiala et al., 2025).

The fertility characteristics showed greater variability among the pedons. Soil pH was highly suitable in WK01 and WK02, while WK03 was moderately suitable. Organic matter content ranged from highly suitable in WK01 to marginally suitable in WK02. Total nitrogen was rated marginally suitable in WK01 and WK03 but currently not suitable (N1) in WK02. Available phosphorus was among the poorest-rated fertility parameters, with WK01 currently rated not suitable (N1), while WK02 and WK03 were permanently rated not suitable (N2). Nutrient retention characteristics also showed considerable limitations. Cation exchange capacity was rated as currently not suitable (N1) across all pedons, indicating generally low nutrient retention potential in the soils. Base saturation ranged from highly suitable in WK01 to moderately suitable in WK02 and WK03, while exchangeable potassium remained highly suitable across all sites.

Table 3. Matching of Land Characteristics with Yam Requirements and Suitability Ratings for Wukari Area

Factors	Land Characteristics	Rating	Rating	Rating
A.	**Climate (c)**			
	Annual rainfall	S1 (100)	S1 (100)	S1 (100)
	Mean annual temperature	S1 (100)	S1 (100)	S1 (100)
B.	**Topography (t)**			
	Slope	S1 (100)	S1 (100)	S1 (100)
C.	**Wetness (w)**			
	Drainage condition	S1 (100)	S1 (100)	S1 (100)
D.	**Soil physical characteristics (s)**			
	Surface texture	S2 (75)	S2 (75)	S3 (50)
	Effective soil depth	S1 (100)	S1 (100)	S1 (100)
	Surface stoniness/gravelliness	S1 (100)	S1 (100)	S1 (100)
E.	**Soil fertility characteristics (f)**			
	Soil pH (H_2O)	S1 (100)	S1 (100)	S2 (75)
	Organic matter	S1 (100)	S3 (50)	S2 (75)
	Total nitrogen	S3 (50)	N1 (25)	S3 (50)
	Available phosphorus	N1 (25)	N2 (15)	N2 (15)
F.	**Nutrient retention characteristics (n)**			
	CEC	N1 (25)	N1 (25)	N1 (25)
	Base saturation	S1 (100)	S2 (75)	S2 (75)
	Exchangeable potassium	S1 (100)	S1 (100)	S1 (100)
G.	**Salinity (z)**			
	Electrical conductivity	S1 (100)	S1 (100)	S1 (100)
IP (Actual Suitability)		43.3	33.54	33.54
Actual Class		S3 - sfn	N1 - sfn	N1 - sfn
IP (Potential Suitability)		86.05	86.05	86.05
Potential Class		S1	S1	S1

Note: Suitability ranges: S1 = highly suitability; S2 = moderately suitable; S3 = marginally suitable; N1 = currently not suitable; N2 = permanently not suitable.

The actual parametric suitability index (IP) values ranged from 33.54 to 43.30, indicating levels of currently not suitable (N1) to marginal suitability (S3) among the pedons. However, potential suitability indices increased substantially to S1 (86.05) across the pedons following the assumed improvement of manageable fertility-related constraints. The increase in potential suitability suggests that some of the identified limitations can be improved through appropriate soil management practices, indicating considerable potential to increase yam productivity in Wukari if appropriate soil fertility restoration measures are implemented.

4. DISCUSSION

The results indicate that the major land constraints affecting yam production in the Wukari area are predominantly related to soil fertility and nutrient retention characteristics rather than climatic or topographic conditions. Among the identified constraints, low available phosphorus, low cation

exchange capacity, low total nitrogen, low organic matter content, and coarse soil texture were the most prominent.

Available phosphorus emerged as one of the most severe constraints across the pedons. The low phosphorus values recorded in the soils may be attributed to intense weathering, phosphorus fixation by iron and aluminium oxides, continuous cultivation, and inadequate replenishment of fertiliser. In yam production systems, phosphorus plays a critical physiological role in early root development, energy transfer (ATP formation), and tuber initiation and bulking. Adequate phosphorus supply enhances early vine establishment and promotes strong root systems that support efficient carbohydrate translocation into developing tubers (Emerald et al., 2026). Therefore, the low phosphorus status observed in the study area may directly translate into poor tuber initiation, delayed tuber bulking, reduced tuber size, and overall low yield and market quality of yam. Similar phosphorus deficiencies have been widely reported in tropical savannah soils of Nigeria, where prolonged cultivation and nutrient mining reduce phosphorus availability (Ogbu et al., 2022).

Low CEC was another major limitation identified across all the pedons. The uniformly low CEC values indicate poor nutrient retention capacity within the soils, largely associated with sandy textures and low organic matter content. This agrees with findings by Alghamdi et al. (2024) and Ferré & Warrick (2005), who reported that sandy soils with limited clay and organic colloids exhibit weak nutrient-holding capacity. For yam cultivation, low CEC has important implications because yam is a long-duration crop that requires sustained nutrient availability throughout its growth cycle. In soils with low CEC, applied nutrients such as potassium and nitrogen are readily lost through leaching, leading to temporal nutrient deficiencies during critical stages of tuber formation and bulking. This contributes to poor nutrient-use efficiency and unstable yield performance, particularly under high rainfall conditions such as those in the Guinea Savannah zone (Yoni et al., 2024; Ukabiala et al., 2025).

Low total nitrogen also constituted an important fertility limitation in the study area, particularly in unit WK02, where the parameter was rated as currently unsuitable. The low N status may be linked to continuous cultivation, rapid mineralisation of organic residues under high tropical temperatures, and insufficient incorporation of organic materials into the soils. Nitrogen is essential in yam production for promoting vegetative growth, leaf area expansion, and photosynthetic activity, which ultimately determines the amount of assimilates available for tuber development (Carsky et al., 2010). Insufficient nitrogen reduces canopy development and limits carbohydrate production, thereby directly restricting tuber bulking and final yield. The observed low nitrogen levels, therefore, provide a plausible explanation for the reduced yam productivity reported in parts of the study area under continuous cultivation systems. Nitrogen depletion has been identified as a common problem in intensively cultivated tropical soils, where nutrient removal through crop harvest is not adequately compensated for by fertilisation or residue recycling (Ṭopa et al., 2025).

Organic matter content varied considerably among the pedons and represented another important limitation, particularly in WK02. In yam-based systems, OM is fundamental because it improves soil structure, enhances moisture retention, and provides a slow-release source of nutrients required throughout the long yam growth cycle. Its decline reduces soil friability, increases drought-stress sensitivity, and limits nutrient-buffering capacity, all of which negatively affect tuber enlargement and yield stability (Kumar et al., 2024). The low OM status observed in the study area therefore represents a key constraint to sustainable yam production under continuous land use.

Coarse soil texture also represented a notable physical constraint within the study area. The predominance of loamy sand and sandy textures suggests limited capacity for water and nutrient retention. Sandy soils are generally characterised by high infiltration rates and low nutrient-holding capacity, which may increase susceptibility to nutrient leaching under seasonal rainfall (Alghamdi et al., 2024). Yam requires a loose but moisture-retentive soil environment for tuber expansion, excessively sandy textures may lead to rapid drainage and reduced soil moisture availability during dry spells, thereby restricting tuber bulking and increasing tuber deformation and yield variability (Carsky et al., 2010).

Despite the identified fertility and textural limitations, some land qualities remained favourable across the pedons. The deep soil profiles, good drainage conditions, low surface stoniness, favourable climatic conditions, moderate to high base saturation, and low salinity levels indicate that the major constraints within the study area are largely manageable rather than irreversible. The substantial increase observed between actual and potential suitability indices further supports the possibility of improving land productivity through appropriate soil

fertility management and sustainable land-use practices (Osujieke et al., 2025).

The declining yam performance in the Wukari area may be strongly associated with progressive fertility depletion and reduced nutrient retention capacity resulting from continuous cultivation and inadequate soil management practices. The results, therefore, highlight the need for integrated soil fertility management strategies to improve nutrient availability, enhance soil organic matter content, and increase soil nutrient retention capacity for sustained agricultural productivity.

5. CONCLUSIONS

This study evaluated the land characteristics and constraints influencing yam production in Wukari, northeastern Nigeria, and found that the area generally offers favourable conditions for yam cultivation, including a suitable climate, gentle topography, good drainage, deep soils, and low salinity. Nevertheless, variations in soil properties among pedons resulted in differing levels of land performance within the same agroecological environment. The major limitations identified were low available phosphorus, low cation exchange capacity, reduced organic matter and total nitrogen contents, and coarse soil texture, which collectively restrict nutrient availability and retention and are largely associated with continuous cultivation and sandy parent materials. The observed improvement between actual and potential suitability indices indicates that these constraints are largely manageable. Therefore, enhancing yam productivity in the area requires integrated soil fertility management practices, including the application of phosphorus-based and balanced nitrogen fertilisers, incorporation of organic amendments such as manure, compost, and crop residues to improve soil fertility and nutrient retention, and the adoption of mulching and residue retention practices to conserve moisture and enhance soil structural stability.

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