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Original Research

Land Suitability Assessment for Rainfed Cassava (*Manihot esculenta Crantz*) Production in Farm Settlement (Papa Abede), Ogbomoso, Oyo State, Nigeria

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Abstract

Reliable land suitability information strengthens site-specific management decisions for cassava (*Manihot spp*.), a crop of major economic and food-security importance in Nigeria, yet such site-level assessment has received little attention in the derived savanna zone around Ogbomoso. This study assessed the suitability of soils for rainfed cassava production in twelve soil observation points at Farm Settlement (Papa Abede), Ogbomoso, Oyo State, Nigeria. Surface soil samples were collected at a depth of 0-30 cm using the rigid grid method along transverses cut at 100 m intervals, and analysed for physical and chemical properties following standard laboratory procedures; soil morphology (profile depth and drainage) was additionally assessed from representative profile pits described using standard soil survey procedures. The soils were sandy loam in texture, with sand, silt and clay contents averaging 78.3%, 11.2% and 10.5% respectively. Soil pH (H_2O) ranged from 5.04 to 6.12 (slightly to moderately acidic). Organic carbon (1.35-3.76%) and total nitrogen (0.18-0.49%) were generally low, while available phosphorus (0.08-14.76 mg/kg) and exchangeable potassium (0.04-0.21 cmol/kg) were also low at several soil observation points. A significant positive correlation was found between organic carbon and available phosphorus ($r = 0.68$, $p = 0.015$), suggesting organic matter management as a practical lever for improving both properties. Using the FAO parametric land-matching system with the square-root method for combining individual land quality ratings, climate, slope and pH were rated highly suitable (S1) with no limitation across all soil observation points, while total nitrogen, though generally low, is not part of the cassava-specific suitability criteria and available phosphorus and exchangeable potassium showed very severe, permanent-class limitations (N2) at about half of the soil observation points; profile depth was found to be adequate (S1) at representative sampling points, while drainage was seasonally poor (S3) at these points. Overall suitability, by observation point, ranged from marginally suitable, S3dk (Lu2, Lu7, Lu9, Lu11, Lu12), through currently not suitable but correctable, N1dk/N1dp (Lu1, Lu6, Lu8, Lu10), to not suitable, N2pk (Lu3, Lu4, Lu5), driven mainly by drainage, phosphorus and potassium rather than nitrogen. The findings indicate that the soils of Papa Abede farm settlement are currently constrained mainly by nutrient status and drainage rather than physical land qualities overall, and can become suitable for cassava cultivation with targeted phosphorus and potassium management together with drainage improvement, guided by the site-specific variability identified in this study.

1. Introduction

Land suitability analysis is a prerequisite to achieving optimum utilization of the available land resources for sustainable agricultural production. Hence, comprehensive, reliable and timely information on agricultural resources is necessary for Nigeria, where agricultural potential is being pressurized by high population growth and environmental hazards like drought and soil erosion (Kefas and Zemba, 2016). However, Nigerian soils have a substantial agricultural potential, but a fundamental constraint to its development is the unreliable acquisition and management of agricultural land data (Joshua *et al*., 2013). In addition, the use of land is not only determined by the user but also by the land suitability, which is governed by different land attributes such as soil physicochemical properties, topography, hydrology and underlying geology (FAO, 1993). These attributes can limit the extent of land available for various purposes, and in

Nigeria, the productivity of soil has been decreasing because lands are utilized at the expense of their suitability, thereby resulting in land degradation (Senjobi, 2007). Several studies have evaluated land suitability for cassava production in different parts of Nigeria (Kefas and Zemba, 2016; Ofem *et al*., 2023; Umeugokwe *et al*., 2025), but there is limited site-specific information on the soils of farm settlements such as Papa Abede, Ogbomoso, and this constrains evidence-based fertilizer recommendations and sustainable land-use planning at the local level.

Cassava (*Manihot esculenta Crantz*) is an important crop in Nigeria, playing a dominant role in the rural economy of the southern agro-ecological zones and increasingly gaining importance in other parts of the country (FAO, 2018; FAOSTAT, 2019). Despite Nigeria's position as the world's largest producer, very little attention has been given to the proper soil and nutrient requirements of the crop, partly because of the ease with which it grows and its traditional position as the last crop before land is left to fallow. Continuous cassava cultivation without adequate soil management leads to nutrient depletion, especially of potassium and nitrogen, and increases the susceptibility of the land to erosion (Ande *et al*., 2008). An effective land evaluation, using a system such as the FAO Land Suitability Evaluation framework, which considers land qualities such as nutrient availability, nutrient retention capacity, rooting conditions, oxygen availability, salinity, toxicity and workability, is therefore necessary to guide cassava production (Awwal and David, 2024).

In view of the persistently low cassava yields in Nigeria relative to its production potential, and the lack of site-specific soil information for many farm settlements, this study was carried out to examine the physicochemical characteristics of soils at Farm Settlement (Papa Abede), Ogbomoso, and to evaluate their suitability for cassava cultivation. The specific objectives were to (i) examine the soil characteristics of the study area and their implications for cassava production, and (ii) determine the potential and limitations of the soils for cassava production following the FAO land suitability classification system.

We hypothesized that despite generally favourable climatic conditions, soil chemical and wetness constraints, particularly available phosphorus, exchangeable potassium and drainage, would limit the suitability of some soil observation points for cassava production.

2. Materials and Methods

2.1 Study Area

The study was conducted at Farm Settlement (Papa Abede), Ogbomoso South Local Government Area, Oyo State, Nigeria, situated approximately between latitudes 8.102° and 8.114°N and longitudes 4.247° and 4.264°E, within the derived savanna zone of southwestern Nigeria. The farm settlement covers a total area of approximately 249 ha. The twelve soil observation points were established across this area on a rigid grid at 100 m intervals; given the reconnaissance-level sampling density, an area-weighted distribution per observation point was not calculated, and suitability results are therefore interpreted as point-based rather than as a formal soil map. The area experiences a bimodal rainfall pattern, with peaks in June-July and September-October, a mean annual rainfall of about 1200 mm (range 786.2-1513 mm), and a mean annual temperature of approximately 26°C, with the dry (Harmattan) season lasting from November to February (Nigerian Meteorological Agency, 2023). The vegetation is derived/southern guinea savanna, dominated by arable crops (principally cassava and maize) under both mixed- and mono-cropping systems, with scattered stands of cashew (*Anacardium occidentale*), mango (*Mangifera indica*) and teak (*Tectona grandis*).

2.2 Soil Sampling and Laboratory Analysis

Twelve soil observation points, labelled Lu1-Lu12, were established across the farm settlement using the rigid grid sampling method: transverses were cut across the land at 100 m intervals to lay out the grid, and one surface soil sample (0-30 cm depth) was collected at each grid intersection using a soil auger. These twelve points are grid-based soil observation points rather than delineated land-mapping units with defined boundaries; formal land-unit delineation based on landform, slope or soil-pattern criteria was not carried out, and this is acknowledged as a limitation of the suitability matching approach (Section 4.2). In addition, three profile pits were excavated at separate representative points within the farm settlement to characterize soil morphology, following standard soil description procedures; profile thickness, drainage class and depth to water table were recorded on soil description cards for each pit. These three pits are not co-located with the twelve grid observation points; depth and drainage are therefore reported as representative, site-level values for the farm settlement as a whole rather than as point-specific data, and this is also acknowledged as a limitation (Section 4.2). Surface soil samples were air-dried, gently crushed and sieved (2 mm) to separate fine earth from gravel, and the fine fraction was used for laboratory analysis. Particle size distribution was determined by the hydrometer method (Bouyoucos, 1962); soil pH was measured potentiometrically in 1:1 soil-to-distilled water and 1:1 soil-to-0.01 M KCl suspensions. Exchangeable bases (Ca, Mg, K, Na) were extracted with 1 N NH_4OAc; K and Na were determined by flame photometry, while Ca and Mg were determined by atomic absorption spectrophotometry. Flame photometric determination of Ca, sometimes used as a faster screening method where atomic absorption capacity is limited, was cross-checked against a subset of atomic absorption readings and found comparable; this is noted for transparency given that atomic absorption spectrophotometry is the more common method for Ca in current practice. Exchangeable acidity (Al^{3+} + H^+) was determined by 1 N KCl extraction and titration (McLean, 1965), and effective cation exchange capacity (ECEC) was calculated as the sum of total exchangeable bases and exchangeable acidity. Organic carbon was determined by the Walkley-Black wet oxidation method (Walkley and Black, 1934) and organic matter estimated using a conversion factor of 1.72. Available phosphorus was determined by the Bray P-1 method (Bray and Kurtz, 1945), total nitrogen by the micro-Kjeldhal method (Bremner, 1996), and micronutrients (Fe, Mn, Cu, Zn) by 0.1 N HCl extraction followed by atomic absorption spectrophotometry (IITA, 1979). Micronutrients were determined to provide a broader characterization of soil fertility status and to screen for potential deficiency, even though they were not used as matching criteria in the cassava suitability evaluation (Table 1).

2.3 Land Suitability Classification

Soil observation points were classified according to USDA Soil Taxonomy (Soil Survey Staff, 2014), the most recent edition available to the author at the time of the field survey; the classification was correlated separately with the FAO World Reference Base legend (IUSS Working Group WRB, 2022) for international comparability, and the two systems are reported independently rather than combined, since they represent distinct classification schemes. Soil suitability for cassava production was evaluated using the FAO parametric land-matching system, in which measured land qualities and characteristics (climate, topography, wetness, and soil physical and chemical properties) were compared against critical crop-specific requirement classes (Table 1) modified from Sys *et al.* (1993), FAO (2007) and Adekiya *et al.* (2022). Each land quality was rated on a 100-point scale and classified as S1 (highly suitable, 96-100; or slightly limited, 86-95), S2 (moderately suitable, 61-85), S3 (marginally suitable, 41-60), N1 (currently not suitable but correctable, 21-40) or N2 (permanently not suitable, 0-20). The soil fertility land quality group followed the cassava-specific criteria of Sys *et al.* (1993), namely organic matter, available phosphorus and exchangeable potassium; total nitrogen, while measured and reported descriptively (Table 3), is not part of this crop-specific criterion set and was therefore not scored as a separate suitability rating. The overall suitability index for each soil observation point was calculated from the individual land quality ratings using the square-root method (Sys *et al.*, 1993): overall index = $\sqrt{(R1 \times R2)}$, where R1 and R2 are the lowest and second-lowest individual ratings for that land unit, respectively.

2.4 Statistical Analysis

Descriptive statistics (mean, range) and the coefficient of variation (CV) were calculated for the measured soil properties to assess the degree of spatial variability among the twelve soil observation points, informing whether site-specific or blanket fertility management would be more appropriate for the study area. Pearson correlation analysis was additionally carried out among the measured soil chemical properties to explore relationships that could support integrated fertility management recommendations, complementing rather than substituting for the land suitability ratings; given the small sample size (n = 12), correlation results are treated as preliminary and are reported separately from the suitability evaluation (Section 3.5).

Table 1. Soil requirement/critical levels used for suitability evaluation of cassava (modified from Sys *et al.*, 1993; FAO, 2007; Adekiya *et al.*, 2022; Howeler, 1996)

Land quality	$S1_1$ (96-100)	$S1_2$ (86-95)	S2 (61-85)	S3 (41-60)	N1 (21-40)	N2 (0-20)
Annual rainfall (mm)	>1000	900-1000	800-900	600-800	500-600	<500
Mean annual temp (°C)	>25	22-25	20-22	18-20	16-18	<16
Slope gradient (%)	<2	3-4	5-6	7-8	9-10	>10
Drainage	WD	WD	MD	ID	PD	VPD
Surface texture	Loam, silt loam	Silty clay loam	Sandy loam, clay loam, sandy clay loam	Loamy sand, silty clay	Sand	Clay, heavy clay
Soil depth (cm)	>75	70-65	65-50	50-35	35-30	<30
pH (H_2O)	5.5-6.5	5.0-5.5	4.5-5.0	4.0-4.5	<4.0	<4.0
Organic matter (%)	>2.0	2.0-1.5	1.2-1.5	1.0-1.5	0.5-1.0	<0.5
Available P (mg/kg)	>20	15-20	8-15	5-8	3-5	<3
Exchangeable K (cmol/kg)	>0.5	0.3-0.5	0.2-0.3	0.15-0.2	0.1-0.15	<0.1

Note: S1(96-100) = No limitation; S1(86-95) = slight limitation; S2(61-85) = moderate limitation; S3(41-60) = severe limitation; N1(21-40) = very severe limitation that can be corrected; N2(0-20) = very severe limitation that cannot be corrected. WD = Well Drained; MD = Moderately Drained; ID = Imperfectly Drained; PD = Poorly Drained; VPD = Very Poorly Drained. Source: modified from Sys *et al.* (1993), FAO (2007), Adekiya *et al.* (2022) and Howeler (1996). Surface texture is rated by class membership rather than a continuous numeric range, following the textural suitability grouping of Sys *et al.* (1993); all soils in this study were classified as sandy loam, corresponding to an S2 (moderate limitation) rating. The exchangeable potassium boundary between S3 and N1 follows the cassava-specific critical level of 0.15 cmol/kg reported by Howeler (1996), as cited in Ande (2011).

3. Results and Discussion

3.1 Particle Size Distribution

Table 2 shows the particle size distribution of the soils in the study area. Sand was the dominant fraction across all soil observation points, ranging from 76% to 80% (mean 78.3%), followed by silt (10-12%; mean 11.2%) and clay (8-14%; mean 10.5%). This gave a uniform sandy loam texture throughout the sampled soils. This texture, which might be influenced by the parent material and the effect of cultivation and fertilization over time, suggests that the soils have a moderate inherent fertility potential and should allow for good root penetration, which is important for cassava tuber development. This matters practically for cassava because the crop is sensitive to waterlogging, so the free-draining, well-aerated nature of sandy loam soils supports the unrestricted root and tuber expansion the crop needs.

Table 2. Particle size distribution of soils in the study area

Observation point	Sand (%)	Silt (%)	Clay (%)	Textural class
Lu1	80	10	10	SL
Lu2	78	12	10	SL
Lu3	79	12	9	SL
Lu4	78	10	12	SL
Lu5	80	12	8	SL
Lu6	79	12	9	SL
Lu7	78	11	11	SL
Lu8	78	12	10	SL
Lu9	78	11	11	SL
Lu10	76	10	14	SL
Lu11	80	10	10	SL
Lu12	76	12	12	SL
Mean	78.3	11.2	10.5	-

3.2 Chemical Properties

The chemical properties of the soils are shown in Table 3. Soil pH (H_2O) ranged from 5.04 to 6.12, indicating that the soils are slightly to moderately acidic. This range falls within what cassava can tolerate, since the crop is known to perform fairly well even on marginal, acid soils (El-Sharkawy, 2004), although pH values above 7.8 or strongly acidic conditions would limit its growth (Howeler, 2002). Organic carbon (1.35-3.76%) and total nitrogen (0.18-0.49%) were generally low across the study area, which may be due to limited organic matter input or accelerated mineralization (Brady *et al.*, 2016), and this points to a need for organic or inorganic nitrogen amendment. Available phosphorus was also low overall (0.08-14.76 mg/kg) relative to the critical Bray-1 level of approximately 7 mg P/kg reported for cassava production on tropical soils (Aliyu *et al.*, 2019), except at Lu8, where the value exceeded this threshold, while exchangeable acidity remained low (below 1.05 cmol/kg) in all the soil observation points, suggesting minimal risk of aluminium toxicity and generally favourable conditions for root development. The generally low phosphorus levels observed are consistent with fixation of phosphate by Fe and Al oxides under acidic conditions, a mechanism further supported by the organic carbon-phosphorus relationship reported in Section 3.5.

Table 4 shows the exchangeable bases and micronutrients of the soils. Exchangeable calcium (1.69-3.29 cmol/kg) and magnesium (0.18-3.29 cmol/kg) were low to moderate, while exchangeable potassium (0.04-0.21 cmol/kg) and sodium (0.02-0.09 cmol/kg) were low throughout the study area. This indicates a general need for potassium fertilization, which agrees with the known heavy potassium demand of cassava during root bulking (Nassar and Ortiz, 2006). The micronutrient levels (Mn 61-96 mg/kg; Fe 109-175 mg/kg; Cu 1.03-1.84 mg/kg; Zn 1.84-2.60 mg/kg) were comparatively high across the sampled soils, indicating a reasonable level of micronutrient fertility that is not likely to constrain cassava production. This is agronomically important because cassava draws heavily on soil potassium during the tuber-bulking stage, so a shortfall at this point in the growth cycle can directly limit root yield.

3.3 Variability of Soil Chemical Properties

The coefficient of variation (CV) analysis in Table 5 showed that pH, manganese and zinc were the least variable of the

Table 3. Chemical properties of soils in the study area

Observation point	pH (H_2O)	OC (%)	TN (%)	Avail. P (mg/kg)	Exch. Acidity (cmol/kg)
Lu1	5.14	1.353	0.25	2	0.58
Lu2	5.36	1.914	0.28	2.2	0.65
Lu3	5.07	2.145	0.22	0.6	0.8
Lu4	5.31	1.683	0.6	0.8	0.75
Lu5	5.4	3.201	0.42	0.64	0.65
Lu6	5.2	1.98	0.26	2.88	1
Lu7	5.54	1.848	0.24	2	1.05
Lu8	5.47	3.762	0.49	14.76	0.95
Lu9	5.04	2.838	0.37	3.52	1
Lu10	5.58	1.353	0.18	0.08	0.55
Lu11	6.12	2.376	0.22	3.56	0.75
Lu12	5.58	2.343	0.31	1.28	0.7
Mean	5.4	2.233	0.32	2.86	0.79
S.D.	0.2855	0.698	0.1285	4.72	0.2168

Table 4. Exchangeable cations and micronutrients of soils in the study area

Observation point	Ca (cmol/kg)	Mg (cmol/kg)	K (cmol/kg)	Na (cmol/kg)	Mn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
Lu1	1.69	0.27	0.07	0.05	76	175	1.22	2.6
Lu2	1.75	0.41	0.11	0.07	73	126	1.09	2.57
Lu3	1.96	0.36	0.09	0.04	81	131	1.36	2.12
Lu4	1.83	0.3	0.06	0.03	96	117	1.14	2.33
Lu5	3.29	3.29	0.07	0.04	80	110	1.11	2.1
Lu6	2.48	1.06	0.04	0.04	77	109	1.23	1.84
Lu7	2.5	1.21	0.16	0.09	79	127	1.16	2.11
Lu8	2.09	0.35	0.06	0.03	61	114	1.84	2.16
Lu9	3.03	0.91	0.12	0.08	77	109	1.32	2.09
Lu10	2.31	0.5	0.21	0.07	91	126	1.27	2.59
Lu11	1.74	0.29	0.1	0.08	86	110	1.03	2.13
Lu12	1.74	0.18	0.13	0.08	82	151	1.09	2.37
Mean	2.2	0.76	0.1	0.06	80	125	1.24	2.25
S.D.	0.51	0.83	0.05	0.02	8.48	19.07	0.21	0.23

properties tested (CV 5.3-10.6%), while organic carbon, exchangeable acidity, calcium, iron, sodium and copper showed moderate variability (CV 15.3-33.3%). Total nitrogen (CV 40.2%), exchangeable potassium (CV 50.0%) and magnesium (CV 109.2%) were highly variable across the soil observation points, and available phosphorus was the most variable property measured (CV 165.0%), reflecting the sharp contrast between the elevated value at Lu8 (14.76 mg/kg) and the low values recorded elsewhere (as low as 0.08 mg/kg). This variability, especially in nitrogen, phosphorus and potassium status, shows that site-specific rather than blanket fertilizer recommendations would be more appropriate for the study area.

Table 5. Coefficient of variation (CV%) classes for selected chemical properties

Property	Mean	S.D.	CV (%)	Variability class
pH (H_2O)	5.40	0.29	5.3	Slightly variable
Organic carbon (%)	2.23	0.70	31.3	Moderately variable
Total nitrogen (%)	0.32	0.13	40.2	Highly variable
Av. P (mg/kg)	2.86	4.72	165.0	Highly variable
Exchangeable acidity (cmol/kg)	0.79	0.22	27.4	Moderately variable
Calcium (cmol/kg)	2.20	0.51	23.2	Moderately variable
Magnesium (cmol/kg)	0.76	0.83	109.2	Highly variable
Exchangeable K (cmol/kg)	0.10	0.05	50.0	Highly variable
Sodium (cmol/kg)	0.06	0.02	33.3	Moderately variable
Manganese (mg/kg)	80	8.48	10.6	Slightly variable
Iron (mg/kg)	125	19.07	15.3	Moderately variable
Copper (mg/kg)	1.24	0.21	16.9	Moderately variable
Zinc (mg/kg)	2.25	0.23	10.2	Slightly variable

3.4 Land Suitability Evaluation for Cassava Production

The suitability evaluation, shown in Tables 6a and 6b, indicated that climate (rainfall, number of dry months, temperature, relative humidity), topography (slope gradient) and soil pH were all rated S1 (highly suitable, no limitation; 100%) across all twelve soil observation points, reflecting generally favourable macro-environmental conditions for cassava production in the study area. Soil depth, assessed at three representative profile pits, was rated S1 (highly suitable; 100%), while drainage at these points was rated S3 (severe limitation; 60%), reflecting seasonally poor drainage recorded on the soil description cards; as noted in Section 2.2, these two ratings are representative, site-level values rather than land-unit-specific measurements. Surface texture was rated S2 (moderately suitable; 85%) throughout because of the uniformly sandy loam texture. Total nitrogen was generally low (Table 3) but, following the cassava-specific criteria of Sys *et al.* (1993), is not part of the scored suitability criteria and is reported descriptively rather than as a rated land quality (Section 2.3). Organic matter ranged from S1 (100%, no limitation) at most soil observation points to S2 (85%, moderate limitation) in Lu1 and Lu10. Available phosphorus and exchangeable potassium showed the greatest variation among the soil observation points, ranging from S1 (highly suitable) in units such as Lu2, Lu8, Lu9 and Lu11, through S2/S3 (moderate to severe limitation), to N2 (very severe, uncorrectable limitation) at units such as Lu3, Lu4 and Lu5 for phosphorus, and at Lu1, Lu3, Lu4, Lu5, Lu6 and Lu8 for potassium. Because drainage was rated uniformly S3 (60%) at all twelve points, based on the three representative profile pits (Section 2.2) rather than on point-specific measurement, it entered the square-root aggregation (Section 2.3) as one of the two lowest ratings at nine of the twelve observation points, wherever the point-specific phosphorus or potassium status was not itself low enough to fall below drainage's rating; at Lu10, available phosphorus took this role instead of potassium. The differences in overall class among these nine points therefore reflect measured differences in potassium (or,

Table 6a. Suitability evaluation of soils for cassava production (Lu1-Lu6)

Land quality	Lu1	Lu2	Lu3	Lu4	Lu5	Lu6
Annual rainfall (mm)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
No. of dry months	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Mean annual temp (°C)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Relative humidity (%)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Slope gradient (%)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Drainage	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
Flooding	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Soil depth	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Surface texture	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
pH (H_2O)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Organic matter	S2(85)	$S1_2$(95)	$S1_1$(100)	$S1_2$(95)	$S1_1$(100)	$S1_2$(95)
Available P	$S1_2$(95)	$S1_1$(100)	N2(20)	N2(20)	N2(20)	$S1_1$(100)
Exchangeable K	N2(20)	N1(40)	N2(20)	N2(20)	N2(20)	N2(20)
Overall rating	N1dk(35)	S3dk(49)	N2pk(20)	N2pk(20)	N2pk(20)	N1dk(35)

Table 6b. Suitability evaluation of soils for cassava production (Lu7-Lu12)

Land quality	Lu7	Lu8	Lu9	Lu10	Lu11	Lu12
Annual rainfall (mm)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
No. of dry months	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Mean annual temp (°C)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Relative humidity (%)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Slope gradient (%)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Drainage	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
Flooding	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Soil depth	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Surface texture	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
pH (H_2O)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)	$S1_1$(100)
Organic matter	$S1_2$(95)	$S1_1$(100)	$S1_1$(100)	S2(85)	$S1_1$(100)	$S1_1$(100)
Available P	$S1_2$(95)	$S1_1$(100)	$S1_1$(100)	N2(20)	$S1_1$(100)	S2(85)
Exchangeable K	S3(60)	N2(20)	N1(40)	S2(85)	N1(40)	N1(40)
Overall rating	S3dk(60)	N1dk(35)	S3dk(49)	N1dp(35)	S3dk(49)	S3dk(49)

Note: $S1_1$ (96-100) = no limitation; $S1_2$ (86-95) = slight limitation; S2 (61-85) = moderate limitation; S3 (41-60) = severe limitation; N1 (21-40) = very severe limitation, correctable; N2 (0-20) = very severe limitation, not correctable. Overall rating subclass letters denote the specific land qualities combined in the square-root aggregation (Section 2.3): p = available phosphorus; k = exchangeable potassium; d = drainage. Total nitrogen was measured and is reported descriptively (Table 3) but was not included as a scored suitability criterion, as it is not part of the cassava-specific land quality set of Sys *et al.* (1993); see Section 2.3 for detail.

at Lu10, phosphorus) status between points, not measured differences in drainage itself, which was assessed only at the three representative locations. The severity of the potassium limitation distinguished two subgroups sharing the same drainage-potassium pairing: Lu1, Lu6 and Lu8, where a very severe potassium limitation (N2, 20%) combined with drainage (S3, 60%) to give an overall N1 rating, and Lu2, Lu7, Lu9, Lu11 and Lu12, where a less severe potassium limitation (S3, 60%) combined with drainage (also S3, 60%) to give an overall S3 rating. Lu10 shared the same overall N1 class as Lu1, Lu6 and Lu8 but through a different pairing, drainage with available phosphorus rather than potassium. Only Lu3, Lu4 and Lu5 fell outside this drainage-led pattern, limited instead by the compounding effect of available phosphorus and exchangeable potassium together, without drainage entering the two lowest ratings at these points.

This pattern, of a landscape with favourable climate and physical land qualities but suitability constrained primarily by seasonally poor drainage and chemical fertility, is a materially different outcome from land suitability studies that rely mainly on physical and environmental criteria. Kefas and Zemba (2016), for example, evaluated cassava suitability in southern Adamawa State using a multi-criteria GIS approach built on rainfall, temperature, relief and generalized soil data, and reported that roughly two-thirds of their study area was suitable without directly incorporating detailed soil chemical fertility into the matching criteria. The present study suggests that such physical-criteria-only approaches may overstate suitability in areas, like Papa Abede, where the broad physical land qualities they assess are genuinely favourable but drainage and underlying nutrient status are not; a site could appear physically suitable yet still require drainage and fertility correction before cassava production is viable, a distinction that a purely physical evaluation cannot capture. Conversely, the fertility- and wetness-driven pattern found here echoes Ahukaemere and Obasi (2018), who reported that soil fertility, specifically low organic carbon and total nitrogen, was the principal constraint on cassava, yam and maize suitability across two soil groups in Ebonyi State despite adequate physical conditions; while their specific limiting nutrient (nitrogen) differs from the drainage, phosphorus and potassium limitations identified here, the broader pattern is the same, that chemical and wetness constraints rather than physical land qualities are what most often separate suitable from unsuitable land in long-cultivated savanna and derived-savanna soils in Nigeria, rather than this being a feature unique to this study area. Because deficiencies of this kind are correctable through fertilization, organic matter amendment, drainage improvement and site-specific nutrient management, these findings point to a practical and achievable path to improving land suitability, rather than a permanent constraint (Fermont *et al.*, 2009; Howeler, 2002), and they reinforce the case made in Section 1 for site-specific fertility data as a basis for evidence-based fertilizer recommendations rather than blanket regional guidance.

3.5 Organic Carbon-Phosphorus Relationship and its Implication for Suitability Management

Because available phosphorus was identified in Section 3.4 as one of the main nutrient constraints on cassava suitability in this study area, correlation analysis was used to test whether phosphorus availability was linked to a manageable soil property. Organic carbon and available phosphorus showed a statistically significant positive correlation ($r = 0.68$, $p = 0.015$), suggesting that organic matter content is an important factor for phosphorus availability in these soils, possibly through the complexation of Fe and Al ions that would otherwise fix phosphorus into forms unavailable to the plant (Howeler, 2002).

Table 7. Pearson correlation coefficients among selected soil properties (n = 12)

Relationship	r	p-value	Significance (α = 0.05)
Organic carbon vs Total nitrogen	0.46	0.129	Not significant
pH vs Exchangeable acidity	-0.17	0.592	Not significant
Clay content vs Exchangeable Ca	-0.24	0.448	Not significant
Clay content vs Exchangeable Mg	-0.48	0.111	Not significant
Organic carbon vs Exchangeable Ca	0.42	0.173	Not significant
Organic carbon vs Available P	0.68	0.015	Significant

This directly supports the practical recommendation in Section 4.3: organic matter amendment offers a route to improving both organic carbon and available phosphorus simultaneously, addressing two of the constraints driving the N2 rating at Lu3, Lu4 and Lu5 and the N1 rating at Lu10, the four soil observation points where available phosphorus was itself one of the limiting land qualities (Tables 6a, 6b), rather than requiring separate management for each nutrient. The remaining relationships tested among soil properties (Table 7) were not statistically significant at this sample size (n = 12) and are reported in the correlation matrix for completeness rather than discussed individually, since they do not indicate additional manageable levers for suitability beyond the fertility management already identified in Section 3.4.

4. Conclusion and Recommendations

4.1 Conclusion

This study assessed the suitability of soils for rainfed cassava production at Farm Settlement (Papa Abede), Ogbomoso, Oyo State, across twelve soil observation points. The soils were uniformly sandy loam in texture, slightly to moderately acidic, and low in organic carbon and, in several units, available phosphorus and exchangeable potassium; total nitrogen was also generally low but was reported descriptively rather than scored as a suitability criterion, following the cassava-specific requirements of Sys *et al.* (1993). Climate, slope and pH were highly favourable throughout, and profile depth, assessed at representative profile pits, was adequate (S1), while drainage, assessed at three representative profile pits rather than at each observation point individually, was seasonally poor (S3). Using the FAO parametric method with the square-root approach for combining individual land quality ratings, overall suitability ranged from marginally suitable, S3 (Lu2, Lu7, Lu9, Lu11, Lu12), through currently not suitable but correctable, N1 (Lu1, Lu6, Lu8, Lu10), to not suitable, N2 (Lu3, Lu4, Lu5). The main limiting factors were seasonally poor drainage, rated uniformly across all points from the representative profile pits, together with available phosphorus or exchangeable potassium, whose measured severity varied by point and determined the difference between the S3, N1 and N2 classes, rather than physical soil properties overall. A significant positive correlation was found between organic carbon and available phosphorus ($r = 0.68$, $p = 0.015$), suggesting that organic matter management could improve both properties at once. These results indicate that, while currently limited by drainage and fertility status, the soils of Papa Abede farm settlement have the underlying physical potential to support cassava production, since these constraints are of a kind that can, in principle, be addressed through appropriate soil management; specific management recommendations are given in Section 4.3.

4.2 Study Limitations

This study is subject to some limitations that should be considered when interpreting the results. First, the sample size (twelve soil observation points, one surface sample per observation point) reflects a reconnaissance-level survey and did not allow for replicate sampling or inferential statistical testing beyond descriptive coefficients of variation; results should therefore be interpreted as indicative of general soil conditions in the study area rather than as spatially exhaustive. Second, soil morphological data (profile depth and drainage) were obtained from three representative profile pits excavated within the farm settlement rather than from each of the twelve soil observation points individually; depth and drainage ratings are therefore applied uniformly across soil observation points as representative, site-level values rather than spatially differentiated, pit-specific data, and the resulting suitability ratings for these two land qualities should be interpreted with appropriate caution. Third, while soil observation points were intended to be classified according to USDA Soil Taxonomy and correlated with the FAO World Reference Base legend (Section 2.3), horizon-level diagnostic data sufficient to support formal taxonomic classification were not obtained for all units; taxonomic classification results are therefore not reported here, and this is noted as a further limitation rather than presented as a completed classification. Future studies at this site should incorporate profile pits at each soil observation point, together with full horizon-level description and analysis, to refine both the depth/drainage assessment and the taxonomic classification.

4.3 Recommendations

Based on these findings, it is recommended that soil management for cassava production in the study area should focus on (i) drainage-improving practices such as ridging or mounding, given that seasonally poor drainage was documented at all representative profile pits and was the most consistent limiting factor identified; (ii) targeted phosphorus and potassium fertilization for soil observation points with very severe nutrient limitations, guided by the site-specific variability identified in this study; (iii) organic matter enrichment to improve organic carbon and phosphorus status simultaneously, given the positive correlation observed between organic carbon and available phosphorus; and (iv) routine nitrogen monitoring, since total nitrogen was also generally low across the study area even though it was not part of the formal suitability criteria applied here. Regular soil health monitoring is also recommended to track improvement in soil fertility and drainage status across successive cropping seasons.

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Conflict of Interest

The author declares no conflict of interest.

Data Availability Statement

All data generated and analysed during this study are included in this published article (Tables 2-4).

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