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Land suitability evaluation for arable and tree crop in Kulani, Balanga Local Government Area of Gombe State, Nigeria

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Abstract:
Land suitability evaluation is a critical tool for achieving sustainable agriculture and meeting global food security targets. This study assesses the suitability of Kulani soils of Balanga Local Government Area, Gombe State, Nigeria, for both arable crops (maize, rice, sorghum, cassava) and tree crops (citrus, mango). Kulani's steep slopes and limited arable land, combined with an annual population growth of 2.8% over the past decade, intensify pressure on finite agricultural resources. A survey of four plots (UP1, UP2 in upland and WT1, WT2 in wetland), from which twelve composite soil samples were collected and analyzed for physical and chemical properties. Qualitative and quantitative land evaluation methods classified land qualities: climate, soil physical and chemical properties, wetness, nutrient availability, and salinity into suitability classes (S1–S3, N). Results showed that upland soils ranged from sandy loam to sandy clay loam, while wetland soils ranged from loamy sand to sandy loam. Soils were generally acidic with low to moderate OC and TN levels but high base saturation and ECEC values. Results indicate that soil fertility is the primary limiting factor across all plots and crops, with upland soils exhibiting strong acidity and lower organic carbon, and wetland soils showing higher nutrient contents but imperfect drainage. Under current conditions, most plots are marginally suitable (S3) to not suitable (N) for maize, rice, sorghum, citrus, and mango, while cassava demonstrates moderate suitability (S2) in three plots. Potential suitability (with amendments) improves to predominantly S2, particularly for arable crops with targeted organic amendments and fertilizer applications. Recommendations include site-specific application of organic matter, balanced NPK fertilization, pH correction (lime), conservation tillage, and water management practices. This research provides a decision-support framework to guide farmers in optimizing crop selection, enhancing productivity, and mitigating land degradation in Kulani.

Keyword: *Land evaluation, Suitability, Soil quality, Agriculture crop, Kulani*

1. Introduction

Sustainable agriculture is a long-term objective focused on assessing environmental challenges and constraints that influence the suitability, economic viability, and ecological sustainability of agricultural production. Among its most powerful tools is land suitability analysis for crop production, which underpins efforts to achieve the United Nations Sustainable Development Goals on food security (Akpoti *et al*., 2019). The primary determinants of site suitability include soil characteristics, climate, water resources, landscape structure, and native biophysical conditions. Nigerian soils hold substantial agricultural potential, but development is hampered by limited land-resource data and management. To address this, land evaluation uses scientific procedures to assess both the potentials and constraints of a given tract for agricultural use (Amirshenava and Osanloo, 2021), thereby guiding corrective measures to ameliorate soil limitations before or during the cropping cycle. Land suitability analysis identifies optimal land uses and recommends management practices to enhance sustainability (Wang, *et al*., 2017).

Population growth places increasing pressure on agricultural systems worldwide. The global population is projected to reach nearly 10 billion by 2050, intensifying the demand for food and raising concerns about land scarcity. In Sub-Saharan Africa, where population growth rates remain highest, per-capita arable land is rapidly declining, making efficient land use planning ever more critical (Jayne et al., 2019). Crop suitability assessments must therefore account not only for agro-climatic and soil factors but also for socio-economic drivers, such as market access, labor availability, and dietary shifts toward higher-value crop. Crop suitability research has demonstrated that matching specific varieties and management practices to local agro-ecological niches can markedly increase yields without additional land expansion. For example, site-specific selection of drought-tolerant maize hybrids in East Africa reduced yield gaps by up to 30% under water-limited conditions (Marenya and Barrett, 2009). Similarly, integrating leguminous cover crops into cereal rotations improves soil nitrogen status and reduces dependency on chemical fertilizers, thereby enhancing both productivity and environmental health (Snapp et al., 2010). Integrating soil, water, climate, crop, livestock, and human factors is essential for planning land use that improves productivity and supports commercialization. Such evaluations deliver actionable recommendations for planners and decision makers, specifying which crops to cultivate in a given locale and the necessary management interventions.

Kulani's study area is characterized by highland terrain with steep slopes, constraining arable land availability. The region has experienced steady population growth estimated at 2.8% annually over the past decade exacerbating competition for limited farmland and heightening the risk of soil erosion on marginal lands (National Bureau of Statistics, 2023). This demographic pressure underscores the need for precise land suitability evaluations that can identify both the highest-value uses for each land parcel and the appropriate conservation measures to maintain long-term productivity. This research aims to evaluate Kulani soils' suitability for selected arable crops (maize, rice, sorghum, cassava) and tree crops (citrus, mango), with the goal of maximizing yield potential while mitigating land degradation.

2. Materials and methods

2.1 Study area

The study area is Kulani in Balanga Local Government Area of Gombe State where the dam and irrigation scheme are located (Figure 1). The area lies between latitude 09^0 32' to 10^0 04' N and longitude 11^0 20' E to 11^0 52' E of the Green Wich Meridian. It is bordered by Reme and Balanga to the south, Tula-lafiya in the west, Gelengu to the east and Swa District to the north. The Balanga dam was built in the 1980's on River Balanga to provide water for Irrigation practice. The geology of the area is characterized by older basalt, sandstones, siltstone, shale, and fluvisols (Ikusemoran et al., 2018). The major and most important river that drains the area is River Balanga. The climate has two distinct seasons, the dry season (November–March) and the rainy season (April–October) with an average rainfall of 850mm. The mean annual temperature is about 32˚C, while the vegetation of the area is that of savanna woodland comprising scattered shrubs and trees such as *Butyrospermum, paradoxum, Tamarin indica, Parkiabiglibosa, Aflexia Africana,* and grasses (Ikusemoran *et al*., 2018). The major crops grown include rice, maize, cowpea and vegetables.

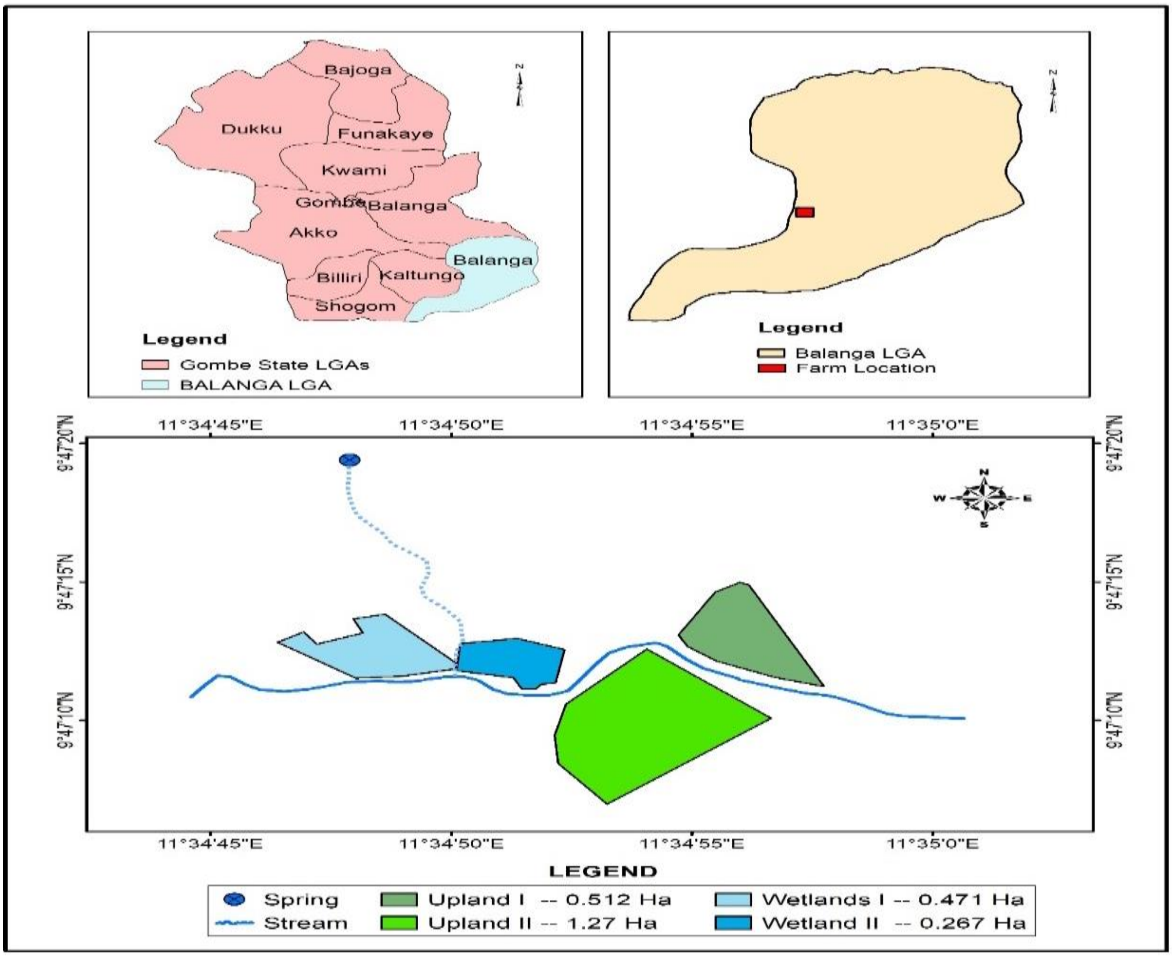

Figure 1: Kulani the Study area

2.2 Field work

A Reconnaissance field survey was undertaken to identify the various land uses and ground truthing of road network identified in the Satellite images to validate the interpretation of images. Satellite imageries and digital elevation model (DEM) was used to delineate and map different soil types in the study area and other relevant geographic phenomena. A detailed soil survey was then conducted in the study area at a scale of 1:25,000. There are four plots in the study area, two were located on upland (UP1 and UP2) and two on low land (WT1 ad WT2). Twelve (12) soil samples were collected from each plot, making a total of forty-eight (48) and composite into twelve (12) for the four plots. The soils were transported to the laboratory for analysis.

2.3 Laboratory Analysis

The analysis was carried out at Department of Soil Science Laboratory, Ahmadu Bello University Zaria from June 2024 – July 2024. The soil sample were then air-dried, grounded, and sieved through a 2 mm sieve, after which less than 2 mm fractions were used for laboratory analysis using Agbenin (1995) procedure. Particle size distribution was determined by the hydrometer method. Soil pH was measured in water and 0.01M $CaCl_2$ (1:2.5 w/v) using glass electrode pH meter. Organic carbon (O.C.) was determined by the dichromate wet oxidation method of Walkley and Black. Total nitrogen (T.N.) was determined by micro Kjeldahl method. Available phosphorus (Avail. P.) was determined using Bray 1 method. Exchangeable bases (calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na) in the soil were determined using the ammonium acetate extract. Sodium and potassium in the extract were determined using flame photometer, while calcium and magnesium were determined using atomic absorption spectrometer.

2.4 Qualitative land suitability evaluation for the crops and plantations

Qualitative or Non-parametric method of land suitability evaluation for maize and rice was carried out using the FAO method (FAO, 1983) (Table 1). Key environmental factors considered in the evaluation were climate (annual rainfall, temperature), topography (slope) and soils. The identified soil units were placed in suitability classes by matching their characteristics with requirements of the test crop. The most limiting characteristic dictate overall suitability for each soil unit using limiting condition procedure. The suitability of each factor for respective soil unit was classified as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) or not suitable (N).

2.5 Quantitative land suitability evaluation for the crops and plantations

In quantitative (parametric) method of land evaluation, each limiting characteristic was rated as follows: S1 (95), S2 (85), S3 (60), N (40). The index of productivity for each soil mapping units was calculated using Ogunkunle (1993) modified equations 1:

$$IP = A \times \sqrt{(\frac{B}{100} \times \frac{C}{100} \times \frac{D}{100} \times \frac{E}{100} \times \frac{F}{100})} \qquad (1)$$

Where A= overall lowest characteristic rating of all land quality groups (Nutrient availability), B, C, D, and E are lowest characteristic ratings for their respective land quality group. The land characteristic was grouped into the following land qualities; climate (c), soil physical property (s), wetness (w), Nutrient availability (f) and Salinity (n). The suitability classification was done separately for each soil unit identified in the study area.

2.6 Productivity index was calculated using the following methods

Potential Index of Productivity (IPp)**:** In computing the IPp, properties that are not easily altered like cation exchange capacity, base saturation, pH and organic matter were used as part of the fertility (f) group while the easily altered chemical properties like exchangeable K, Ca, available P, and total N were not part of the calculation.

Current Index of Productivity (IPc):In this case, both the easily altered chemical properties like exchangeable K, Ca, available P and total N as well as those used for IPp were used for the calculation of the IPc.

3. Result and Discussion

3.1 Land evaluation analysis for the crops and plantations

A summary of land qualities/characteristics of the study area is shown in Table 1. The requirements for maize and rice were presented in Table 2.

The requirements for cassava and sorghum are shown in Table 3 while the requirements for citrus and mango in Table 4 using the suitability ratings.

The assessment ratings resulting from matching of land qualities with crop requirement was presented in Table 5and 7 respectively.

3.2 Land suitability evaluation for maize cultivation

All the four plots were influenced by soil fertility as either marginally suitable (S3) or currently not suitable (N2). Other land qualities that limit the suitability of plots for Maize production are wetness (w) and rooting condition (r). Land qualities that were rated as highly suitable for rice for most of the study area include climate (rainfall and temperature) (c), salinity hazard (n) and erosion hazard (e) (Table 5). The parametric evaluation of the land suitability for maize indicated 100 % of the plots (UP1, UP2, WT1 and WT2) were moderately suitable (S2) (potentially) and none was highly suitable (S1) currently. All the plots were marginally suitable (S3) under qualitative evaluation Soil fertility (f) was the most critical factor evaluated to limits Maize cultivation in the study areas. To upgrade the currents suitability of the plots from N2 and S3 to S2/S1 for maize production, fertilizer application, organic matter sourced from crop residue and farmyard manure will be required to improve nutrient availability, increase CEC, water retention, aggregate stability, improve drainage condition (Odunze, 2017).

Table 1: Summary of soil quality used for suitability evaluation in Kulani, Balanga LGA

Land Characteristic	UP1	UP2	WT1	WT2
Climate				
Mean Annual rainfall (mm)	970	970	970	970
Temperature (°C)	28	28	28	28
Land/soil physical property				
Slope (%)	0-3	0-3	0-2	0-2
Soil Depth (cm)	>50	>100	>120	>120
Soil Texture	SCL	SL	LS/SL	SL
Drainage	Well Drained	Moderately Drained	Imperfect drained	Imperfect drained
Nutrient availability (top soil)				
pH (H_2O)	5.59	4.99	5.16	5.20
Organic Carbon ($mgkg^{-1}$)	5.20	9.20	5.10	6.70
Total Nitrogen (%)	1.40	1.00	2.00	2.20
Available P ($mgkg^{-1}$)	12.7	15.7	27.8	10.2
Exchangeable K ($mgkg^{-1}$)	8.85	12.80	13.12	13.00
ECEC ($cmol(+)kg^{-1}$)	18.83	22.00	24.37	23.97
Base Saturation (%)	95.00	96.00	98.00	97.00
Salinity and Sodicity				
Salinity EC (ds/m)	0.009	0.011	0.010	0.011
Sodicity ESP (%)	11.70	8.92	8.85	7.09

3.3 Land suitability evaluation for rice cultivation

All the four plots were influenced by soil fertility as either marginally suitable (S3) or currently not suitable (N2). Other land qualities that limit the suitability of plots for rice production are wetness (w), erosion hazard (e), texture (s) and rooting condition (r). Land qualities that were rated as highly suitable for rice for most of the study area include climate (rainfall and temperature) (c) and salinity hazard (n) (Table 5). The parametric evaluation of the land suitability for rice indicated 100 % of the plots (UP1, UP2, WT1 and WT2) were marginally suitable (S3) (potentially) and none was highly suitable (S1) currently. All the plots were marginally suitable (S3) under qualitative evaluation Soil fertility (f) was the most critical factor evaluated to limits rice cultivation in the study areas. To upgrade the currents suitability of the plots from N2 and S3 to S2/S1 for rice production, fertilizer application, organic matter sourced from crop residue and farmyard manure will be required to improve nutrient availability, increase CEC and water retention (Abagyeh, *et al*., 2016).

3.4 Land suitability evaluation for cassava

All the four plots were influenced by soil fertility as marginally suitable (S3) to moderately suitable (S2) for cassava production. Land qualities that limit the suitability of plots for cassava production is rooting condition (r) in plot UP1. All the land qualities were rated as highly to moderately suitable for cassava production except soil depth (Table 6). The parametric evaluation of the land suitability for cassava indicated 75 % of the plots (UP2, WT1 and WT2) were moderately suitable (S2) while 25% of the plots (UP1) was marginally suitable (S3) (currently and potentially) and none was highly suitable (S1) currently. Soil quality evaluation also reveals similar result with that of quantitative evaluation. Soil depth (s) was the most critical factor evaluated to limits cassava cultivation in the study areas. To upgrade the currents suitability of the plots from S3/S2 to S1 for cassava production, organic matter sourced from crop residue and farmyard manure will be required to improve nutrient availability, increase CEC of the soils (Odunze, 2017). Plot UP1 with shallow depth could be used for short rooted crops.

3.5 Land Suitability Evaluation for Sorghum

All the four plots were influenced by soil fertility as marginally suitable (S3) for sorghum production. Land qualities that limit the suitability of plots for sorghum production is rooting condition (r) in plot UP1, soil texture, pH and available P. All the land qualities were rated as marginally suitable (S3) for sorghum (Table 6). The parametric evaluation of the land suitability for sorghum indicated 100 % of the plots (UP1, UP2, WT1 and WT2) were marginally suitable (S3) (currently) and moderately suitable (S2) potentially except UP1 which was still marginally suitable (S3). Soil quality evaluation also reveal similar result with that of current quantitative evaluation. Soil depth, soil texture, pH and available P were the most critical factor evaluated to limits sorghum cultivation in the study areas. To upgrade the currents suitability of the plots from S3 to S2/S1 for sorghum production, organic matter sourced from crop residue and farmyard manure will be required to improve nutrient availability of the soils and liming will be also be required to improve the soil pH (Abagyeh*et al*., 2016).

3.6 Land Suitability Evaluation for Citrus

All the four plots were influenced by soil fertility as either marginally suitable (S3) or currently not suitable (N2). Other land qualities that limit the suitability of plots for citrus production are rooting condition (r), soil pH, organic carbon and available P. Land qualities that were rated as highly to moderately suitable for citrus for most of the study area include climate (rainfall and temperature), salinity hazard and erosion hazard, soil texture, drainage, total nitrogen, and available P. (Table 7). The parametric evaluation of the land suitability for citrus indicated 100 % of the plots (UP1, UP2, WT1 and WT2) were marginally suitable (S3) both potentially and currently except UP1 that was none suitable (N2) (currently).

Table 2: Factor Suitability Rating for Maize and Rice

	Maize				Rice			
Land Characteristic	**S1**	**S2**	**S3**	**N**	**S1**	**S2**	**S3**	**N**
diagnostic factor	95–85	85 – 60	60 – 40	<40	95 – 85	85 – 60	60 – 40	<40
Climate								
Rainfall (mm)	>800,	700 – 800	600 – 700	<600	800-1200	700 – 800	600 – 700	<600
Temperature (^oC)	24-30	20 - 24, 30-32	15 - 20, 32-35	<15, >35	24 – 28	22 - 24, 30-32	18 - 22, 32-35	<18, >35
Land/soil physical property								
Slope (%)	0 – 2	4 – 8	8 – 16	>16	0 – 1	1 – 2	2 – 4	>4
Soil depth (cm)	>120	75 - 120	30 – 75	<30	>75	50 - 75	25 – 50	<25
Soil Texture	CL, L	SL, LS	LCS	CS	C, SiC, CL	SC, SiC, SiL	SL, L, SCL	S, LS
Volume of coarse fragment	< 5	5 – 25	46 – 70	> 70	< 15	<35	<55	<55
Drainage	Well	Moderately	Imperfect	very poor	Well	Moderately Well	Imperfect	Poor, very poor
Nutrient availability (top soil)								
pH	6-6.5	5.5-6.0, 6.5-7	5- 5.5, 7-8.2	<5, >8.2	5.0 -6.0	6.0 - 7.0	7.0 - 8.0	> 8
Organic Carbon (gkg^{-1})	> 20	10 – 20	5 – 10	< 5.0	> 20	10 - 20	5 - 10	< 5.0
Total Nitrogen (gkg^{-1})	8 – 4	4 – 2	< 2	Any	> 2.0	1.0 - 2.0	0.5-1.0	<0.5
Available P ($mgkg^{-1}$)	> 40	10 - 40	3 – 10	< 3	> 40	20 – 40	10 - 20	<10
Exchangeable K ($mgkg^{-1}$)	3 - 5	2 – 3	1 – 2	< 1	> 0.2	0.1- 0.2	< 0.1	< 0.1
CEC ($cmol(+)kg^{-1}$)	> 25	13 – 25	6 – 12	< 6	> 25	13 – 25	6 – 12	< 6
Base Saturation (%)	> 80	40 – 80	20 – 40	< 20	> 75	50 – 75	30 – 50	< 30
Salinity and Sodicity								
Salinity EC (ds/m)	< 1	1 – 2	2-4	>4	< 3	3 – 6	6 – 10	>10
Sodicity ESP (%)	< 10	10 - 15	>15	-	< 15	15- 40	40– 50	>50

Adopted FAO (1983) Key: CL=clay loam, L=loam, SL=sandy loam, LS= loam sand, LCS=loam clay sand, CS=clay sand

Table 3: Factor Ratings of Land Use Requirements for Cassava and Sorghum Suitability

		Cassava				**Sorghum**			
Land qualities/ Characteristics	**Unit**	**S1 (100)**	**S2 (85)**	**S3 (60)**	**N (40)**	**S1 (100)**	**S2 (85)**	**S3 (60)**	**N (40)**
Climate (c)/Physical Properties									
Annual rainfall	mm	1100 - 1500	900-1100, 1500- 2500	500- 900, 2500-4000	<850, >4000	650 – 850	550 - 650	450 - 550	< 450
Mean Temperature	oC	24 - 30	18-24	12 – 18	<12	26 – 30	24 - 25, 31 - 34	20-23, 35-40	<20, >40
Erosion hazard (e)	%	0 - 5	5 – 12	12 – 20	> 20	2 – 3	3 – 8	8 - 15	>15
Effective soil depth	Cm	>100	75 – 100	50 – 75	< 50	100 - 75	50 - 75	30 - 50	<30
Soil texture		L, SL, SiL, CL	LS, SCL, SiCL, SC	S, SiC, C	cS, cC, G	C, CL, SiCl, SC	L, SiC, SiL	SL, LS	S, fragmental skeletal
Drainage		well,	imperfectly, moderately	Poorly	v. poorly, excessively	Well to moderate	Imperfectly	Poor and excessive	Very poor.
Nutrient availability									
soil pH		5.5 – 7	4.5 – 5.4, 7.0 - 8.5	4-4.5, 8.5-9	<4.0, >9.0	6.0 -8.0	5.5-5.9, 8.1–8.5	<5.5, 8.6 – 9.0	> 9.0
OC	(gkg-1)	20 - 12	12 – 8	8 – 4	< 4	20 – 40	10 – 20	5.0 - 10	> 0.5
ECEC	(cmolkg-1)	>18	12 18	6 – 12	< 6	30 - 20	20 – 10	10 - 5	< 5
Avail. P	(gkg-1)	>25	6 25	< 6	Any	80 -50	50 – 35	35 - 20	< 20
Exch K	(cmolkg-1)	> 6	3 6	< 3	Any	-	-	-	-
Salinity EC	(ds/m)	< 3	4 – 8	8 – 12	12 – 16	2 – 4	4 – 8	8 - 10	> 10
Sodicity ESP	%	5 – 8	8 10	10 15	> 15	5 – 8	8 – 10	10 - 15	> 15

Source: NBSS and LUP (1994)
SL: sandy loam, LS: loamy sand, SCL: sandy clay loam, L: loam, C: clay, gSL: gravelly sandy loam, CL: clay loam,
SiL: silt loam, SC: sandy clay, SiC: silty clay, S: sand, C: clay, cS: coarse sand, cC: cracking clay, G: gravels.

Table 4: Factor Suitability Rating for Citrus and Mango

	Citrus				Mango			
Land Characteristic / diagnostic factor	**S1 (100)**	**S2 (85)**	**S3 (60)**	**N (40)**	**S1 (100)**	**S2 (85)**	**S3 (60)**	**N (40)**
Climate								
Rainfall (mm)	1200-1800	1000 – 1200	800 – 1000	< 800	1200-1800	1000 – 1200	800 – 1000	< 800
Temperature (oC)	28 – 30	24 - 27, 31-35	20 - 23, 36-40	<20, >40	28 - 32	24 - 27, 33-35	36-40	20 - 24
Land/soil physical property								
Slope (%)	< 3	3 – 5	5 – 10	> 10	< 3	3 – 5	5 – 10	> 10
Soil depth (cm)	>150	100 - 150	50 – 100	< 50	>200	125 - 200	75 – 125	< 75
Soil Texture	L, LS	SL, SiL	Sl, CL	S, C	SC, L, SiL, CL	Sl, SC, SiC, L, C	C	S, LS
Drainage	Well	Moderately, Imperfect	poorly	very poor	Well	Moderately, Imperfect	Poorly	very poor
Nutrient availability (top soil)								
pH	6.5- 7.5	5.5 - 6.4, 7.6 - 8.0	4.0 - 5.4, 8.1 - 8.5	< 4.0 > 8.5	5.5 - 7.5	5.0 - 5.4, 7.6 - 8.5	8.6 -9.0, 4.0 - 4.9	< 4.0 > 9.0
Organic Carbon (gkg-1)	> 25	10 25	5 10	< 5.0	> 25	10 25	5 10	< 5.0
Total Nitrogen (gkg-1)	> 2.0	1.0 - 2.0	0.5-1.0	<0.5	> 2.0	1.0 - 2.0	0.5-1.0	<0.5
Available P (mgkg-1)	> 15	6 – 15	< 6	any	> 15	6 – 15	< 6	any
Exchangeable K (mgkg-1)	> 15	10 – 15	5 - 10	< 5.0	> 15	10 - 15	5 – 10	< 5.0
Salinity and Sodicity								
Salinity EC (ds/m)	< 3.0	3.0 – 6.0	6.0 – 10	>10	<1.0	< 2.0	2.0 – 3.0	> 3
Sodicity ESP (%)	< 15	15- 40	40– 50	>50	< 5.0	< 10	10 – 15	> 15

Table 5: Matching land use requirement with soil quality

	Maize				Rice			
Land Characteristic	**UP1**	**UP2**	**WT1**	**WT2**	**UP1**	**UP2**	**WT1**	**WT2**
Climate								
Mean Annual rainfall (c)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Temperature (c)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Land/soil physical property								
Slope (e)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S3 (60)	S3 (60)	S2 (85)	S2 (85)
Soil Depth (r)	S3 (60)	S2 (85)	S1 (95)	S1 (95)	S3 (60)	S2 (85)	S1 (95)	S1 (95)
Soil Texture (s)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S3 (60)	S3 (60)	S3 (60)	S3 (60)
Drainage (w)	S1 (95)	S2 (85)	S3 (60)	S3 (60)	S1 (95)	S2 (85)	S2 (85)	S2 (85)
Nutrient availability (f)								
pH (H_2O)	S2 (85)	S3 (60)	S3 (60)	S3 (60)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Organic Carbon	S3 (60)	S3 (60)	S3 (60)	S3 (60)	S3 (60)	S3 (60)	S3 (60)	S3 (60)
Total Nitrogen	S3 (60)	S3 (60)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S1 (95)	S1 (95)
Available P	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S3 (60)	S3 (60)	S2 (85)	S3 (60)
Exchangeable K	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
ECEC	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)
Base Saturation (%)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Salinity and Sodicity (n)								
Salinity EC	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Sodicity ESP	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Qualitative	S3fr	S3f	S3fw	S3fw	S3fers	S3fes	S3fs	S3fs
Quantitative (Current)	N2(21)	N2(20)	N2(21)	N2(21)	N2(15)	N2(17)	S3(27)	N2(22)
Quantitative (Potential)	S2(50)	S2(67)	S2(50)	S2(50)	S3(33)	S3(38)	S2(56)	S2(56)

Table 6: Matching land use requirement with soil quality

Land Characteristic	Cassava				Sorghum			
	UP1	**UP2**	**WT1**	**WT2**	**UP1**	**UP2**	**WT1**	**WT2**
Climate (c)								
Mean Annual rainfall	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Temperature	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Land/soil physical property (s)								
Slope	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Soil Depth	S3 (60)	S1 (95)	S1 (95)	S1 (95)	S3(60)	S1 (95)	S1 (95)	S1 (95)
Soil Texture	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S3(60)	S3(60)	S3(60)	S3(60)
Drainage	S1 (95)	S2 (85)	S2 (85)	S2 (85)	S1 (95)	S1 (95)	S2 (85)	S2 (85)
Nutrient availability (f)								
pH (H_2O)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S2 (85)	S3(60)	S3(60)	S3(60)
Available P	S2 (85)	S1 (95)	S1 (95)	S2 (85)	S3(60)	S3(60)	S3(60)	S3(60)
CEC	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S2 (85)	S1 (95)	S1 (95)	S1 (95)
Salinity and Sodicity (n)								
Salinity EC	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Sodicity ESP	S2 (85)	S1 (95)	S1 (95)	S1 (95)	S2 (85)	S1 (95)	S1 (95)	S1 (95)
Qualitative	S3fs	S2s	S2s	S2fs	S3fs	S3fs	S3fs	S3fs
Quantitative (Current)	S3(37)	S2(59)	S2(59)	S2(56)	S3(25)	S3(29)	S3(28)	S3(28)
Quantitative (Potential)	S3(47)	S2(67)	S2(67)	S2(67)	S3(42)	S2(53)	S2(50)	S2(50)

All the plots were marginally suitable (S3) under qualitative evaluation similar to quantitative evaluation result. Soil fertility (f) was the most critical factor evaluated to limits citrus plantation in the study areas. To upgrade the currents suitability of the plots from N2 and S3 to S2/S1 citrus production, fertilizer application, organic matter sourced from crop residue and farmyard manure will be required to improve nutrient availability, increase CEC and water retention (Abagyeh*et al*., 2016).

3.7 Land suitability evaluation for mango

All the four plots were influenced by soil fertility as either marginally suitable (S3) or currently not suitable (N2). Other land qualities that limit the suitability of plots for mango production are rooting condition (r), organic carbon and Exchangeable K. Land qualities that were rated as highly to moderately suitable for mango for most of the study area include climate (rainfall and temperature), salinity hazard and erosion hazard, soil texture, drainage, total nitrogen, and available P. (Table 7). The parametric evaluation of the land suitability for citrus indicated 100 % of the plots (UP1, UP2, WT1 and WT2) were marginally suitable (S3) both potentially and currently except UP1 that was none suitable (N2) (currently). All the plots were marginally suitable (S3) under qualitative evaluation similar to quantitative evaluation result. Soil fertility (f) was the most critical factor evaluated to limits citrus plantation in the study areas. To upgrade the currents suitability of the plots from N2 and S3 to S2/S1 mango production, fertilizer application, organic matter sourced from crop residue and farmyard manure will be required to improve nutrient availability, increase CEC and water retention (Odunze, 2017). The results corroborate the findings of Udoh et al. (2011), which reported that suitability of alluvial soils in Southeastern Nigeria varied between S3 and N1 classes for rice cultivation.

Table 7: Matching Land use Requirement with soil Quality

Land Characteristic	Citrus				Mango			
	UP1	UP2	WT1	WT2	UP1	UP2	WT1	WT2
Climate (c)								
Mean Annual Rainfall	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)
Temperature	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Land/soil physical property (s)								
Slope	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Soil Depth	S3(60)	S2 (85)	S2 (85)	S2 (85)	S3(60)	S3(60)	S2 (85)	S2 (85)
Soil Texture	S2(85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)	S2 (85)
Drainage	S1 (95)	S2(85)	S2 (85)	S2(85)	S1 (95)	S2 (85)	S2 (85)	S2 (85)
Nutrient availability (f)								
pH (H_2O)	S2(85)	S3(60)	S3(60)	S3(60)	S1 (95)	S2 (85)	S2 (85)	S2 (85)
Organic Carbon	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)	S3(60)
Total Nitrogen	S2(85)	S2(85)	S1 (95)	S1 (95)	S2(85)	S2(85)	S1 (95)	S1 (95)
Available P	S2(85)	S1 (95)	S1 (95)	S2(85)	S2(85)	S1 (95)	S1 (95)	S2(85)
Exchangeable K	S3(60)	S2 (85)	S2 (85)	S2 (85)	S3(60)	S2 (85)	S2 (85)	S2 (85)
Salinity and Sodicity (n)								
Salinity EC	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Sodicity ESP	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S2(85)	S1 (95)	S1 (95)	S1 (95)
Qualitative	S3fs	S3f	S3f	S3f	S3fs	S3fs	S3f	S3f
Quantitative (Current)	N2(21)	S3(25)	S3(27)	S3(25)	N2(21)	S3(25)	S3(32)	S3(30)
Quant. (Potential)	S3(29)	S3(37)	S3(39)	S3(37)	S3(47)	S3(45)	S2(63)	S2(63)

Across all crops, soil fertility was the dominant limiting factor, aligning with findings by Udoh et al. (2011), Jimoh et al. (2016), and Maniyunda and Ya'u (2023). Consistent with earlier studies, soil chemical properties critically influence land suitability for crop production in Nigeria's alluvial and wetland soils. Effective use of organic matter and fertilizers (especially NPK) is key to upgrading suitability ratings across all plots and crops evaluated.

4. Conclusion

The land suitability evaluation indicates that soil fertility is a predominant limiting factor across all crops and plots. Plot UP1 consistently shows the most constraints due to shallow soil depth and poor rooting conditions. To enhance crop productivity, an integrated approach involving organic amendments, conservation practices, soil nutrient balancing, and modern irrigation techniques is essential. These practices are supported by recent research findings and align with sustainable land management goals.

Recommendations

Site-Specific Crop Planning: UP1: Shallow soils – prioritize shallow-rooted or fast-maturing crops. WT1 and WT2: More suitable for long-term crops like mango, citrus, and cassava with minimal soil amendment.

a. Apply lime or dolomite to raise pH levels and enhance nutrient availability
b. Employ integrated nutrient management strategies combining organic and inorganic fertilizers to enhance nutrient availability, soil CEC, and moisture retention and also using leguminous cover crops to increase soil nitrogen and microbial biomass.
c. Use phosphate-solubilizing microorganisms to improve phosphorus availability.
d. Adopt conservation tillage to improve rooting conditions and reduce compaction and practices such as cover cropping and reduced tillage for better soil health.
e. Use climate-smart rice varieties adapted to low-nutrient soils and erratic rainfall
f. Employ ridge planting and mulching to optimize root development and moisture conservation.
g. Intercrop with legumes to improve soil structure and minimize nutrient depletion.

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