NIGERIAN AGRICULTURAL JOURNAL
ISSN: 0300-368X
Volume 51 Number 2, August 2020 Pg. 476-486
Available online at: http://www.ajol.info/index.php/naj

CHARACTERIZATION AND LAND SUITABILITY ASSESSMENT FOR PINEAPPLE (*Ananas comosus*) PRODUCTION IN BASEMENT COMPLEX SOILS OF SOUTH-WEST, NIGERIA

[1,2]Osinuga, O.A., [1]Oyegoke, C.O. and [2]Jaiyeola, M.A.

[1]Department of Soil Science and Land Management,
Federal University of Agriculture, Abeokuta, Nigeria
[2]Directorate of University Farms, Federal University of Agriculture, Abeokuta, Nigeria
Corresponding Authors' email:olufemi500@yahoo.com; osinugaoa@funaab.edu.ng

Abstract

To end persistent and widespread hunger and malnutrition by 2030, more lands need to be open for inclusive and sustainable food production. Detailed survey of soils derived from basement complex in Abeokuta, South-West Nigeria were carried out using the free traverse method. The soils were characterized, classified, and evaluated for pineapple production using both the non-parametric and parametric methods of suitability assessment. The delineated five mapping units classified as Alfisols and Inceptisols were well drained with loamy sand to sandy loam surface horizons overlying sandy loam to sandy clay loam subsurface horizons. The soils were moderate in bulk density (1.12 – 1.54g/cm^3), low saturated hydraulic conductivity (0.96 – 4.01cm/hr), moderate to slightly acid pH (5.38 – 6.81), low to moderate OC (3.90 – 23.11mg/kg), low CEC (4.01– 8.61cmol/kg), high base saturation (84.04 – 91.69%), and low ESP (5.85 – 9.21%). When assessed by the non-parametric method, potentially, all the mappings units were moderately suitable (S2) for pineapple production. But currently, they were marginally suitable (S3). From the computed values of the current productivity index (40.3 – 46.9) using the parametric method, all the mapping units were marginally suitable (S3) for pineapple production. However, the values of the potential productivity index (63.1 – 76.4) revealed that all the mapping units will be moderately suitable (S2) for production. The limiting factors identified include; low soil fertility, especially CEC, and soil physical characteristics in terms of texture. With the adequate application of appropriate fertilizers and suitable soil management, the productivity of the land will be optimally enhanced for pineapple yield and quality.

Keywords: Basement complex, Characterization, Land suitability, Pineapple, and Soil fertility

Introduction

Characterization, classification, and land suitability analysis are fundamental to land potential for agricultural purposes and management decisions, planning, and utilization, providing a link between resource assessment and the decision-making process. It concerns the selection of suitable land based on clearly defined objectives such as cropping, irrigation, or other management alternatives that are physically practicable, financially feasible, and economically viable (FAO, 1985; 2007; Anaya-Romero, 2015). Operationally, land suitability assessment describes a procedure of land appraisal with a specific land use objective in mind (FAO, 1976). Land suitability status is based on intrinsic properties of soils (parent materials, soil texture, and depth), and characteristics that can be altered by human management (drainage, salinity, nutrient concentration, and vegetation cover) (FAO, 1985; 1993). It has been projected that the current world population of 7.7 billion will rise to 9.8 billion by 2050 (UN, 2019). Climate change, demographic developments, and changing consumption patterns are expected to induce pressure on land, thereby increasing the risk of food insecurity, especially in developing countries (FAO, 2011). The second Sustainable Development Goal (SDG) was proposed to end all forms of hunger and malnutrition by 2030. To date, millions of people still suffer from undernourishment (UN, 2017). These goals can only be achieved if growth in agricultural production exceeds population growth through a sustainable intensification of existing agricultural land (FAO, 2011). Meanwhile, land resources are pivotal to agricultural production and inseparably connected with food security (FAO, 2011).

Pineapple [*Ananas comosus* (L.) Merr.] is a perennial monocotyledon crop grown for its fruits which are well-appreciated globally for its exceptional juiciness and inviting flavor (Hossain, 2016), and is cultivated mostly in the tropical and subtropical regions of the world for local consumption and export (Dhar *et al*., 2008). It can be used as a supplementary nutritional fruit for good health, with an excellent source of fiber, micronutrients, vitamins, and minerals (Joy, 2010; Afu *et al*., 2017). In Nigeria, various food and cash crops have contributed largely to the national food basket among which is pineapple. Nigeria is ranked 7th in the list of world pineapple production and the leading producer in Africa with an area of 199,891ha under production, and an average yield of 83tha^{-1}(FAO, 2019). Despite the significant role pineapple has played particularly as raw material for agro-based fruit processing and canning industries, little or no organized research has attempted to assess the suitability of soils for pineapple production when compared to other contemporary foreign exchange earning crops (cocoa, oil palm, cashew, and rubber). Most studies on this crop are designed towards agronomic problems like inducement for early flowering and regular fruit supply, and rapid multiplication techniques of propagules aimed at solving the problem of high seed rate (Afu *et al*., 2017). However, efforts can be made toward improving pineapple productivity through soil suitability assessment.

For specific sustainable land use, what is required is a synthesis of the complex relationships between different attributes of land such as; soil properties, land cover, topography, and climate, which themselves are dynamically variable. Land suitability assessment is therefore conventionally evaluated by matching requirements of biophysical/ecological, socio-economic and political factors for the particular application with characteristics and qualities of land components (FAO, 1985; Sys *et al*., 1993). Given the importance of the agricultural sector in Nigeria, there is a strong need for assessment of the agricultural potential of the existing soils. This is especially important in an area extremely vulnerable to land degradation and where soil productivity is important for food security. The main objectives of the study were: (i) characterization and classification of the soils, (ii) climate and soil suitability assessment in relation to pineapple production, and (iii) recommend appropriate soil and nutrient management practices to mitigate soil fertility constraints.

Materials and Methods

Study Area

The study was conducted in a proposed site for pineapple orchard of the Directorate of University Farms (DUFARMS), Federal University of Agriculture, Abeokuta. The proposed site covers an area of about 15 hectares. The University lies between Latitude $7^0 12'$N and $7^0 19'$N, Longitude $3^0 20'$E and $3^0 28'$E and is located within the forest-savanna transition zone. The site is underlain by crystalline basement complex rocks producing very coarse grains with modification of colluvial and colluvial/alluvial sediments at the bottom of the valleys. The rocks show considerable variation in grain size and mineral composition, ranging from very coarse-grained pegmatite to fine-grained schist, and from acid quartzite to underlying rocks consisting mainly of amphiboles (Smyth and Montgomery, 1962). The farm is located in a Coastal hinterland plain that is characterized by gently undulating plains at an average altitude range of 140-170m, and average relief intensity of 40m. The average slope gradient is nearly flat to gently undulate (0 to 3% slope). Most valleys are U-shaped with narrow incisions forming seasonal water passages. The study area enjoys the hot and humid tropic climate like the rest of South-West Nigeria. The area is noted for two distinct seasons of rainy and dry periods in a year, which are primarily controlled by two major air masses or wind currents. The southwest trade wind dominated the area bringing about rainy season between April and November, while the Northeast trade wind has greater influence between December and March, imposing dryness in the area. The period of cold, dryness, and dust in December/January is often referred to as Harmattan. Climate data comprising total rainfall amount, air temperature, soil temperature, relative humidity, and length of dry season were collected from the FUNAAB Meteorological station. The area has an annual rainfall of 1,000-1,500 mm (increasing trend), air temperature of 26-32^{0}C (decreasing trend) (Figures 1 and 2).

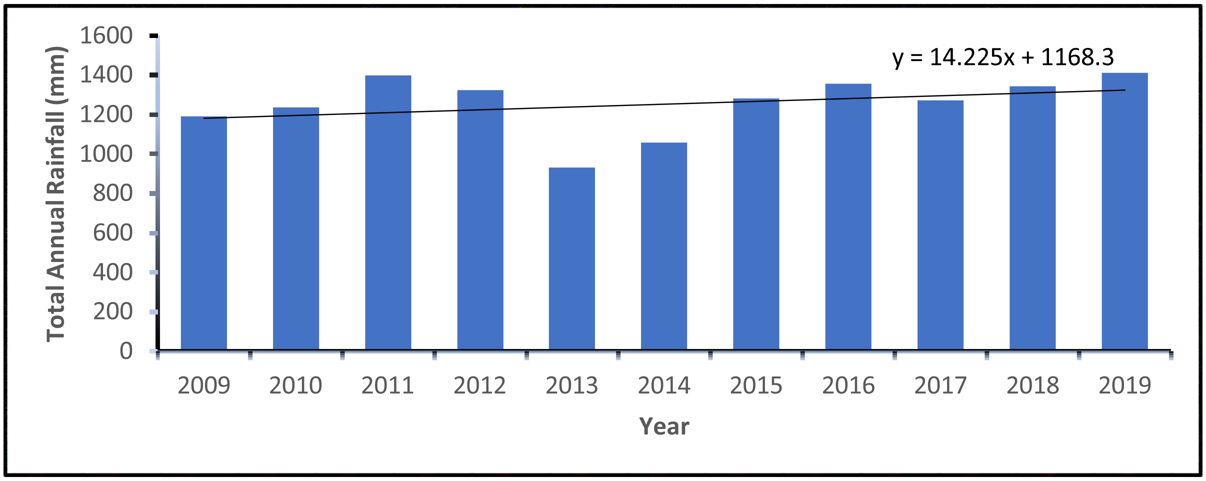

Figure 1: Total Annual Rainfall of the Study Area
Source: FUNAAB Meteorological Station.

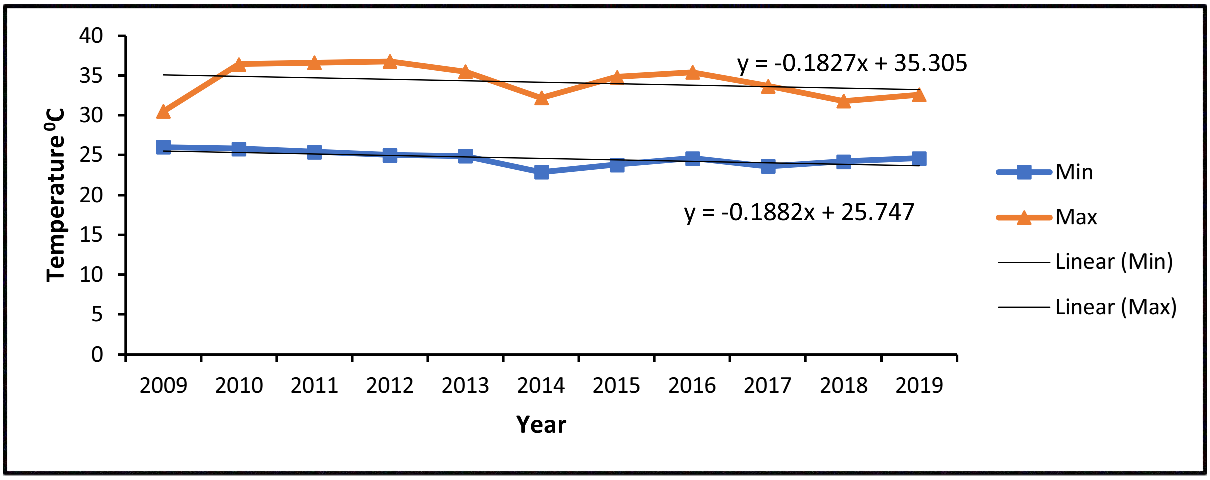

Figure 2: Air Temperature of the Study Area
Source: FUNAAB Meteorological Station

The original tropical forest-savanna vegetation is still available in some parts of the University. The present vegetation in the farm is secondary and tertiary bush land and bush thicket. Most of the original vegetation was cleared for plantation crops (Cashew, Oil palm, Arboretum), arable crops (maize, cassava, yam, leafy and fruit vegetables) and buildings of various kinds. The area is presently used for extensive grazing. The fringes along the river banks were cultivated with plantain and banana, and nursery for pawpaw.

Pedological Studies

Soils of the study area of about 15 hectares were studied by a free traverse technique. Topographic features (valleys and ridges) were used as a reference for locating soil observation sites using an auger. Auger observations were made at increments of 20cm to record soil morphological characteristics to a depth of 120cm on an impervious layer. Soil characteristics investigated were: depth, drainage, colour, texture, structure, consistence and root distribution. Based on similarities and differences observed from the auger samples, the area was delineated into five mapping units for a more detailed study. One modal profile pit was dug in each of the mapping units. The pits were described according to guidelines for soil description (FAO, 2006). Bulk and composite soil samples for analysis were collected from natural horizons identified in these pits, and were air-dried at room temperature for laboratory analysis. Garmin GPSmap 62s was used to record the geographical location (coordinates) of all auger points and pits sites.

Laboratory Analysis

The air-dried soil samples were crushed gently and passed through a 2mm sieve to separate gravel from fine earth fraction. The fine earth fraction (<2mm) was subjected to routine soil analysis. Particle size fraction analysis was determined by the mechanical analysis technique of Bouyocous (1951) modified by Gee and Bauder (1986), using sodium hexametaphosphate as a dispersant. Soil pH was measured potentiometrically in a soil water suspension (mixed at a ratio of 1:1 soil: water), using glass electrode pH meter, following the procedure described by Udo *et al.* (2009). Organic carbon (OC) was determined by the dichromate wet oxidation method of Walkley and Black as outlined in Nelson and Sommers (1996). Total nitrogen (N) was determined by micro-Kjeldahl digestion method. Available phosphorus (P) was extracted by Bray-1 method, and the colour was developed in soil extract using the ascorbic acid blue method (Murphy and Riley, 1962). Exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) were extracted by saturating the soil with neutral 1M NH_4OAc (Thomas, 1982). Ca and Mg in the extract was determined using atomic absorption spectrophotometer (AAS), while Na and K were determined by flame photometry. Exchangeable acidity was determined by extracting the soil with 0.17KC1 solution and titrating the aliquot of the extract with IN NaOH, following the procedure outlined by Udo *et al.* (2009). Cation exchange capacity (CEC) was determined by saturating the soil with a normal neutral ammonium acetate solution. Base saturation was calculated as the ratio of sum of total exchangeable bases to NH_40Ac cation exchange capacity, expressed as a percentage (Page *et al.*, 1982).

Soil Classification Procedure

Data obtained from the field and laboratory analyses were used to classify the soil into its appropriate local series using the Smyth and Montgomery (1962) method. The local classification was correlated with the USDA Soil Taxonomy (Soil Survey Staff, 2014) and FAO/IUSS World Reference Base system of classification (FAO-UNESCO, 2015).

Land Evaluation Procedure

The method of land evaluation employed in this study was the one developed by Sys *et al.* (1993) for tropical soils and crops. Site characteristics such as climate (c), topography (t), soil physical characteristics (s), wetness (w), chemical fertility (f), and salinity and alkalinity (n), were matched with identified individual requirements known to exert significant influences on crop yield. The suitability of the soils was evaluated using both the conventional (non-parametric) (FAO, 1976) and the parametric method (Ogunkunle, 1993). For the non-parametric evaluation, mapping units were first placed in suitability classes by matching their land qualities and soil properties (Tables 1 and 2) with the specification for pineapple cultivation (Table 4). Aggregate suitability class for each mapping unit as indicated by the most limiting site characteristics was determined at the actual and potential levels of suitability for pineapple. The actual refers to the suitability of pineapple to soil and/or site characteristics in its present condition without any improvement on the land. The potential is suitability for the desired use in the future after substantial improvement must have been made on the modifiable properties of the land. The final (aggregate) suitability classes were determined by the number and intensity of the limitation(s), and the most unfavorable quality determined the suitability classification. Suitability classes SI (highly suitable), S2 (moderately suitable), S3 (marginally suitable), and N (not suitable) were established. For the parametric method, scores were given to the characteristic of each mapping unit and suitability calculated as an index of productivity following square root method as stated thus:

$$\mathrm{IP} = \mathrm{A} \times \sqrt{\frac{\mathrm{B}}{100} \times \frac{\mathrm{C}}{100} \times \frac{\mathrm{D}}{100} \times \frac{E}{100} \times \frac{F}{100}}$$

Only one member in each group was used for calculation purposes, because there are usually strong correlations among members of the same group (e.g. texture and structure in's' group). For the actual (current) productivity index, all the lowest characteristic ratings for each land quality group were substituted into the index of productivity equation. However, in the case of the potential productivity index, it was assumed that the corrective fertility measure would no longer have fertility constraints. Therefore, other qualities, except for fertility (f), were used to calculate the potential productivity index. The index of productivity was then interpreted into suitability classes as follows: IP values of 100-75% equivalent to SI (highly suitable), 74-50% equivalent to S2 (moderately suitable), 49-25% equivalent to S3 (marginally suitable), and 24-0% equivalent to N (not suitable).

Results and Discussion

Site Characteristics

Some important morphological, physical, and chemical properties of soils of the mapping units are presented in Tables 1 and 2. The soils were generally deep (>100cm), except for the mapping unit D which had a high-water table. The studied mapping units were undulating with the degree of slope between 2-5% gradient. They were well-drained to moderately well-drained and exhibited no sign of flooding. The profile samples indicated that the area had different texture ranging from loamy sand to sandy clay loam, with medium to coarse texture dominating. The soil colours differ from one mapping unit to another with surface horizons colour ranging from dark gray (7.5YR 4/1) to light brownish gray (10YR 6/2), and the subsoil horizons between reddish-brown(2.5YR5/4) to light yellowish-brown (10YR6/4). Variations in soil colours indicate differences in soil moisture and drainage conditions as influenced by topography (Buol *et al*., 1989; Udoh *et al*., 2013). The soil's structures were mostly subangular blocky with weak to strong grade and fine to coarse classes. The topsoils had fine, medium, or coarse granular or crumb structure, while the subsoils had a medium sub-angular blocky structure (Table 1). The blocky structures (angular and sub-angular blocky) especially in the subsoils, were due to the presence of higher clay fractions (Sharma *et al*., 2004). All the mapping units were dominated by sand fraction (606-836g/kg), while that of the silt fraction range from 44 to 114g/kg, and clay fraction from 90 to 350g/kg. The soil had loamy sand texture at the surface horizons, except for mapping units C and D, which had sandy loam, and sandy clay loam respectively. The texture of the soil at the sub-surface horizons range from sandy loam to sandy clay loam. The bulk density increased with increasing depth. The presence of organic matter influenced aggregation reducing bulk density, and overhead weight at lower depths. This was attributed to surface layers which were because of the overhead weight of surface horizons (Singh *et al*., 2013). Many variations in hydraulic conductivity were observed, from low (0.96cm/hr) to moderate (4.01cm/hr), across the mapping units (Table 1). The decrease in hydraulic conductivity may be due to an increase in clay content.

Table 1: Morphological and Physical Properties of the Mapping Units

Horizon Designation	Depth (cm)	Colour (Moist)	Structure	Drainage	Mottle Concretions	Gravel	Sand	Silt	Clay	Texture	BD g/cm^3	SHC cm/hr
						…………….g/kg…………						
Mapping Unit A												
Ap	0-25	10YR5/2	1, m, sab	wd	n	17	826	74	100	LS	1.23	3.41
Bt1	25-62	10YR5/3	2, m, sab	wd	n	22	786	74	140	SL	1.28	2.34
Bt2	62-124	10YR5/6	2, m, sab	wd	n	26	626	84	290	SCL	1.52	1.87
Bc	124-170	10YR6/4	1, c, sab	wd	m, Fe-Mn	63	726	74	190	SL	1.44	2.11
Mapping Unit B												
Ap	0-27	10YR6/2	1, m, cr	wd	n	16	836	74	90	LS	1.18	2.94
AB	27-68	2.5YR3/4	2, m, sab	wd	n	25	796	74	130	SL	1.31	3.07
Bt1	68-109	2.5YR5/3	1, m, sab	wd	n	20	726	64	200	SL	1.40	2.54
Br	109-156	2.5YR6/4	1, c, sab	wd	n	93	696	114	190	SCL	1.25	2.38
Mapping Unit C												
Ap	0-42	10YR5/2	2, f, cr	wd	n	12	816	64	120	SL	1.12	4.01
Bt1	42-74	10YR5/4	2, m, sab	wd	n	18	736	74	190	SL	1.27	2.64
Bt2	74-103	10YR6/3	2, m, sab	wd	N	14	716	64	230	SCL	1.39	2.03
Bc	103-168	10YR6/4	1, c, sab	wd	vm, Fe-Mn	32	736	94	170	SL	1.33	0.96
Mapping Unit D												
Ap	0-36	7.5YR4/1	2, f, sab	md	n	23	636	84	280	SCL	1.28	3.67
Bc	36-84	7.5YR6/3	3, m, sab	md	m, Fe-Mn	14	666	94	240	SCL	1.30	2.33
Mapping Unit E												
A	0-34	7.5YR4/2	1, f, sab	wd	n	10	816	84	100	LS	1.17	3.62
AB	34-61	7.5YR4/6	2, m, sab	wd	n	22	796	64	140	SL	1.22	2.07
Bt1	61-98	7.5YR5/6	3, m, sab	wd	n	19	736	54	210	SCL	1.35	1.98
Bt2	98-134	7.5YR6/4	3, c, sab	wd	N	17	606	44	350	SCL	1.54	1.54

Structure:1 = weak, 2 = moderate, 3 = strong,f = fine, m = medium, c = coarse, cr = crumb, sab = subangular blocky. Concretions: m = many, vm = very many, Fe-Mn = Iron and Manganese. Drainage: wd = well drained,md = moderately drained. Texture: LS = Loamy Sand, SL = Sandy Loam, SCL = Sandy Clay Loam. BD = Bulk Density; SHC = Saturated Hydraulic Conductivity

Table 2: Chemical Properties of the Mapping Units

Horizon Designation	Depth (cm)	pH (H_2O)	EC dS/m	OC	TN	Avail-P	Na^+	K^+	Ca^{2+}	Mg^{2+}	SBC	$Al^{3+} + H^+$	CEC	BS %	ESP %
				…….$mgkg^{-1}$………			…………………….. $cmolkg^{-1}$………………………..								
Mapping Unit A															
Ap	0-25	6.51	0.63	17.16	2.26	12.52	0.59	0.53	3.36	2.41	6.62	0.13	7.24	91.06	8.12
Bt1	25-62	6.34	0.57	9.42	1.61	10.08	0.44	0.32	2.46	1.67	4.89	0.10	5.38	90.89	9.00
Bt2	62-124	5.38	0.12	4.71	0.84	8.44	0.33	0.29	1.85	1.22	3.69	0.08	4.36	84.63	9.21
Bc	124-170	5.80	0.31	3.90	0.78	5.93	0.31	0.22	1.66	1.18	3.37	0.09	4.01	84.04	9.20
Mapping Unit B															
Ap	0-27	6.63	0.29	11.52	1.92	13.46	0.51	0.39	3.07	1.92	5.89	0.10	6.73	87.52	7.58
AB	27-68	6.44	0.08	9.34	1.27	11.19	0.45	0.38	2.93	1.76	5.52	0.08	6.04	91.69	8.15
Bt	68-109	6.28	0.44	8.17	1.91	10.85	0.38	0.33	2.48	1.44	4.63	0.11	5.19	89.21	8.21
Br	109-156	6.05	0.25	5.03	0.95	7.62	0.33	0.21	1.95	1.19	3.68	0.07	4.27	86.18	8.97
Mapping Unit C															
Ap	0-42	6.47	0.18	10.81	1.60	11.21	0.43	0.36	3.13	1.26	5.18	0.09	6.14	84.36	8.30
Bt1	42-74	6.29	0.10	10.25	1.12	9.65	0.39	0.32	2.56	1.49	4.76	0.12	5.28	90.15	8.19
Bt2	74-103	6.16	0.18	8.80	1.06	7.27	0.37	0.29	2.59	1.07	4.32	0.10	4.76	90.76	8.56
Bc	103-168	5.82	0.07	4.91	0.73	4.88	0.31	0.22	2.04	1.12	3.69	0.08	4.05	91.11	8.40
Mapping Unit D															
Ap	0-36	6.81	0.83	23.11	10.41	14.29	0.43	0.40	4.15	2.37	7.35	0.07	8.61	85.37	5.85
Bc	36-84	6.48	0.69	10.93	1.79	10.85	0.36	0.28	2.99	1.70	5.33	0.09	6.12	87.09	6.75
Mapping Unit E															
A	0-34	6.73	0.75	17.40	2.11	13.64	0.50	0.43	3.72	2.56	7.21	0.11	8.34	86.45	6.93
AB	34-61	6.52	0.66	9.89	1.44	11.87	0.42	0.29	2.57	2.44	5.72	0.09	6.46	88.54	7.34
Bt1	61-98	6.36	0.41	6.76	0.85	8.16	0.41	0.21	2.80	1.93	5.35	0.10	6.09	87.85	7.66
Bt2	98-134	6.21	0.19	5.24	0.63	5.96	0.32	0.19	2.00	1.27	3.78	0.08	4.38	86.30	8.47

EC = Electrical Conductivity; OC = Organic Carbon; TN = Total Nitrogen; Avail. P = Available Phosphorus; SBC = Sum of Basic Cations; BS = Base Saturation; ESP = Exchangeable Sodium Percentage

The soil pH ranged from 5.38 to 6.81 with the surface horizon of mapping unit D having the highest pH(6.81), and the subsurface horizon of mapping unit A with the lowest pH (5.38). The pH decreased regularly down the profile in all the mapping units, except for mapping unit A with an irregular decrease in pH with depth. The soil pH recorded were within the tolerant acidic range of 4.5-6.9 for the growth and performance of pineapple (Sys *et al*., 1993). Soil pH is a "master determinant" and it regulates almost all biological and chemical reactions in soils (Tan, 2011). All the mapping units showed very low to low electrical conductivity, with values ranging from 0.07 to 0.83 ds/m, interpreting the non-saline nature of the soil (<2 ds/m). The low electrical conductivity may be due to free drainage conditions which favoured the leaching of released bases with percolating water (Table 2). Organic carbon ranged from 3.90 to 23.11mg/kg with the surface horizons having high contents in all the mapping units. The low values of organic matter would encourage rapid leaching of cations into the sub-soils from the surface (Afu *et al*., 2017). The mapping units studied were characterized by high temperature, and relative humidity conditions that favour rapid decomposition and mineralization of organic matter. Therefore, organic matter content has to be substantially increased through effective crop residue management. Likewise, the values of total N content were low to moderate (0.06-1.04%), and are not surprising, as light-textured soils of the tropics are naturally endowed with a low level of native nitrogen due to high level of leaching as a result of high rainfall amounts (Amalu and Isong, 2015). The available phosphorus ranged from low to moderate (4.88-14.29mg/kg) and decreased with depth in all the mapping units. The level of phosphorus content may be in connection with the soil acidity. The surface soils recording higher P may be attributed to the confinement of crop cultivation to the rhizosphere and supplementation of depleted phosphorus with manures and phosphorus-rich fertilizers (Uzoho and Oti, 2004).The exchangeable cations in all the mapping units were generally low with Na ranges from 0.31-0.59cmol/kg, K from 0.19-0.53cmol/kg, Ca from 1.66-4.15cmol/kg, and Mg from 1.07-2.56cmol/kg (Table 2). The dominance of exchangeable cations followed the order; $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$. The same order was reported by Osinuga and Oyegoke (2017). Exchange acidity value was also low (0.07-0.13cmol/kg) indicating that acidity will not affect pineapple production. The CEC of the mapping units ranged from 4.01 to 8.61cmol/kg soil, and decreased with an increase in depth in all the profile pits which is attributed to low activity clays at lower depths. The low to moderate CEC in these mapping units was due to the mixed type of kaolinitic, illitic, and other clay types (Singh *et al*., 2013). The percent base saturation (BS) and exchangeable sodium percentage (ESP) ranged from 84.04 to 91.69% and 5.85 to 9.21% respectively.

Soil Classification

The classification of the five mapping units representing the area of study is shown in Table 3. The mapping units were classified into order, suborder, great group, and subgroup, based on the diagnostic horizons, the properties of the soils that reflect the nature of the soil environment, and the dominant pedogenic processes that are responsible for the soil formation (Ajiboye and Ogunwale, 2010). Generally, the results of the field study and laboratory analyses showed that all the soils were relatively old, and have argillic or kandic horizons. However, based on the profile development, soils in the area could be placed in the Alfisols soil order, except for mapping unit D. Moderate weathering was placed in the order Inceptisols (Soil Survey Staff, 2014), which correlate with Lixisols and Cambisols, each (FAO/UNESCO, 2015). The difference between the mean maximum and minimum annual soil temperature is more than 5°C which qualifies for an iso-hyperthermic temperature regime. The partial leaching (summer monsoon) udic soil moisture regime was the criteria to place the soils under udalfs and udepts sub-order. At the great group level, mapping units A, C and E are classified as Kandiudalfs based on the presence of kandic horizons, while mapping unit B is Rhodudalfs due to their reddish colour. On the other hand, mapping unit D is classified as Eutrudepts with base saturation greater than 60% in the subsurface horizons, while at sub-group is placed as Oxyaquic Eutrudepts as it was saturated with water for more than 20 days in a normal year.

Table 3: Taxonomic Classification of Soils of the Study Area

Mapping Units	Soil Survey Staff (2014)	FAO/UNESCO (2015)	Local Series Name
A	Plinthic Kandiudalfs	Plinthic Lixisols	Iwo Series
B	Typic Rhodudalfs	Rhodic Lixisols	Egbeda Series
C	Plinthic Kandiudalfs	Plinthic Lixisols	Iwo Series
D	Oxyaquic Eutrudepts	Gleyic Regosols	Jago Series
E	Arenic Kandiudalfs	Arenic Lixisols	Apomu Series

Land Suitability Evaluation

The actual and the potential of climatic/land characteristics (climate, topography, wetness, soil physical characteristics, fertility, and salinity/alkalinity) in determining the suitability of the five mapping units studied for the cultivation of pineapple was evaluated using the conventional (non-parametric), and parametric methods (Table 4). Results of matching land requirements for pineapple production with land characteristics/qualities are shown. The climatic parameters considered were annual rainfall, mean annual temperature, and relative humidity. The class score (rating) of the five mapping units in the study area (Table 5), showed that the area is climatically suitable for pineapple, being optimal (100% suitable) in terms of annual rainfall and relative humidity, and sub-optimal (85% suitable), in terms of mean air temperature. This is an indication that temperature might possess a slight constraint to pineapple production. The topography (slope gradient) of four mapping units (B, C, D, and E) were optimal, while one mapping unit (A) was nearly optimal (95% suitable) for pineapple production because it had slope gradient > 4% (Sys *et al.*, 1993). In terms of soil wetness (drainage and flooding), the entire mapping units were optimally suitable for pineapple production (Table 5). This shows that topography and wetness have no limitations to the production of pineapple in the study area. Soil depth is one of the physical characteristics that are very important for land evaluation. Depth was optimal (100%) in the entire mapping units studied. Soil texture and structure were sub-optimal in mapping units A, C, and E, whereas, it was nearly optimal and optimal in mapping units B and D respectively. The coarse fragments were sub-optimal (80-85%). The soil texture and coarse fragments in all the mapping units except for mapping unit D, was nearly optimal (95% suitable)-the most limiting of the soil physical characteristics. Soil texture for optimum pineapple performance is said to be sandy clay loam or loam (Sys *et al*., 1993), but the dominant texture for the study area was loamy sand and sandy loam (Table 5). This has scored the area only moderately suitable for pineapple cultivation, and constitutes a slight constraint to pineapple production.

Table 4: Climatic and Land Requirements for Suitability Evaluation of Pineapple

Climatic and Land Characteristics	**S11 96-100**	**S12 86-95**	**S2 61-85**	**S3 41-60**	**N1 21-40**	**N2 0-20**
Climate (c)						
Annual Rainfall (mm)	1200-1400	1000-1200	800-1000	600-800	-	< 600
Mean Annual Temp. (^{0}C)	22-24	24-26	26-30	30-35	-	> 35
Relative Humidity (%)	60-80	50-60	40-50	30-40	-	< 30
Topography (t)						
Slope (%)	0-4	4-8	8-16	16-30	30-50	>50
Wetness (w)						
Flooding	F0	F0	-	-	-	F1
Drainage	wd	md	id	p,a	pbd	Pnd
Soil Physical Properties (s)						
Soil Depth (cm)	> 75	60-75	40-60	20-40	-	< 20
Surface Texture	SCL, L	SL, SiL, Si, SC	LS, Lfs, Co, SiC	C><60v C>60s	Fs	Cm, SiCm
CoarseFragments (%)	0-3	3-15	15-35	35-55	-	> 55
Chemical Fertility (f)						
pH (H$_2$0)	5.4-5.7 5.7-6.0	5.0-5.4 6.0-6.5	4.3-5.0 6.5-7.0	4.0-4.3 7.0-7.8	<4.0 -	- > 7.8
Organic Carbon (mg/kg)	> 20	12-20	8-12	< 8	-	-
CEC (cmol/kg)	> 24	16-24	15-16	< 15	-	-
Base Saturation (%)	>50	35-50	20-35	< 20	-	-
SBC (cmol/kg)	> 4	2.8-4.0	1.6-2.8	< 1.6	-	-
Salinity & Alkalinity (n)						
ECe (dS/m)	0-1	1-2	2-3	3-4	-	> 4
ESP (%)	0-5	5-10	10-15	15-20	-	-

F0 = No flooding; F1 = 1-2 flooding months; wd = well drained, md = moderately drained; id = imperfectly drained; p,a = poor and aeric; pbd = poor but drainable; pnd = poor not drainable.
Source:Modified from Sys *et al.* (1993).

Table 5: Suitability Evaluation of the Soils for Pineapple Production

Climatic/Land Characteristics	Mapping Unit A	Mapping Unit B	Mapping Unit C	Mapping Unit D	Mapping Unit E
Climate (c)					
Annual Rainfall (mm)	S11(100)	S11(100)	S11(100)	S11(100)	S11(100)
Mean Annual Temperature (^{0}C)	S2(85)	S2(85)	S2(85)	S2(85)	S2(85)
Relative Humidity (%)	S11(100)	S11(100)	S11(100)	S11(100)	S11(100)
Topography (t)					
Slope Gradient (%)	S12(95)	S11(100)	S11(100)	S11(100)	S11(100)
Wetness (w)					
Drainage	S11(100)	S11(100)	S11(100)	S11(100)	S11(100)
Flooding	S11(100)	S11(100)	S11(100)	S11(100)	S11(100)
Soil Physical Properties (s)					
Soil Depth (cm)	S11(100)	S11(100)	S11(100)	S11(100)	S11(100)
Surface Texture	S2(85)	S12(95)	S2(85)	S11(100)	S2(85)
Coarse Fragments at 0-20 cm (%)	S2(85)	S2(85)	S12(95)	S2(80)	S12(95)
Chemical Fertility (f)					
pH in distilled water	S2(85)	S2(65)	S12(95)	S2(85)	S2(75)
Organic Carbon (%)	S12(95)	S2(85)	S2(75)	S11(100)	S12(95)
CEC (cmol/kg)	S3(50)	S3(50)	S3(50)	S3(60)	S3(55)
Base Saturation (%)	S11(100)	S11(100)	S11(100)	S11(100)	S11(100)
SBC (cmol/kg)	S11(100)	S11(100)	S11(100)	S11(100)	S11(100)
Salinity & Alkalinity (n)					
ECe (dS/m)	S11(100)	S11(100)	S11(100)	S11(100)	S11(100)
ESP (%)	S12(95)	S12(90)	S12(95)	S12(90)	S12(90)
Aggregate Suitability					
Actual (Parametric)	**S3(40.4)**	**S3(40.3)**	**S3(41.4)**	**S3(46.9)**	**S3(44.4)**
Actual (Non-Parametric)	**S3f**	**S3f**	**S3f**	**S3f**	**S3f**
Potential (Parametric)	**S2(63.1)**	**S2(74.3)**	**S1(76.4)**	**S2(70.0)**	**S2(74.3)**
Potential (Non-Parametric)	**S2f**	**S2f**	**S2f**	**S2sf**	**S2f**

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

Soil fertility is another serious constraint limiting crop production in the tropics. The soil pH was sub-optimal (65-85%) in the mapping units, except for mapping unit C, which was nearly optimal (95% suitable). The organic carbon also follows the same trend as soil pH with the exception of mapping unit D that was optimal (100% suitable) for pineapple cultivation. The cation exchange capacity (CEC) was grossly inadequate (50-60% suitable), thereby rendering the area only marginally suitable for pineapple production. The result showed that CEC can constitute a major constraint to pineapple production. The percent base saturation (BS%), and the sum of basic cations (SBC) revealed that all the mapping units were rated optimal (100% suitable). In the same vein, in terms of salinity/alkalinity (EC and ESP), the entire area was rated optimal (100% suitable) for pineapple production.

Aggregate Suitability for Pineapple Production

Table 5 also showed a summary of the suitability aggregate scores and suitability classifications under the potential and actual (current) evaluation by the parametric and non-parametric methods, for all the five mapping units identified in the study area for pineapple production. The aggregate suitability classes S1 (highly suitable), S2 (moderately suitable), S3 (marginally suitable), N1 (currently not suitable) and N2 (permanently not suitable), are equivalents of suitability class scores (ratings) 100-75, 74-50, 49-25, 24-15, 14-0, respectively. According to the parametric method, potentially, all the mapping units in the study area were classified as moderately suitable (S2) for pineapple production. However, all the mapping units were classified as marginally suitable (S3) for pineapple production. By the non-parametric evaluation, the area is shown to be of the same advantage to pineapple cultivation with the parametric method. Potentially, all the mapping units were classified as moderately suitable (S2) for pineapple production due to the slight severity of soil physical characteristic (s) and fertility (f) limitations. However, all the mapping units were classified as marginally suitable (S3) for pineapple production because of the severity of soil physical characteristic (s) and fertility (f) limitations. Thus, the fertility status of these mapping units need amendments in order to improve the productive capacity of the mapping units into those that are highly suitable for pineapple production.

Conclusion

The result of the study shows that in spite of the optimal or near optimal climatic features (annual rainfall, air temperature, and relative humidity), topography, soil wetness, depth, and base saturation, there is no highly suitable (S1) land for pineapple production in the entire mapping units. The soils are mostly moderately (S2) to marginally (S3) suitable for pineapple by both parametric and non-parametric methods. The major limitation to pineapple production in the area is chemical fertility-particularly CEC. A moderate limitation was observed by texture, soil pH and organic carbon. To raise the productivity of the land to optimum for pineapple production, management techniques to be adopted should enhance the nutrient and moisture holding capacity of the soil. Fertilizers with a substantial amount of CaO and MgO in addition to NPK will be of great advantage to pineapple production. Organic manure and crop residues could also enhance land productivity. To avoid yield reduction popping up from incidence of pests and diseases, as a result of excessive rainfall during the growing season, appropriate drainage facilities should be put in place to take care of the excessive moisture and check the rising water table, particularly in mapping unit D, while provision of irrigation facilities would make dry season farming possible in other mapping units. This would ensure optimum land productivity as a result of high insolation, relatively dry environment, and thence a favourable ecology for pineapple production.

References

Afu, S. M., Amalu, U. C. and Isong, I. A. (2017). Fertility Status and Suitability Assessment of Soils Supporting Production of Pineapple (Ananas comosus) in Cross River State. *Nigerian Journal of Soil and Environmental Research*, 15:197-192.

Ajiboye, G. A. and Ogunwale, J. A. (2010). Characteristics and Classification of Soils Developed over Talc at Ejiba, Kogi State. *Nigeria. Nigerian Journal of Soil Science*, 20:1-14.

Amalu, U. C. and Isong, I. A. (2015). Land Capability and Soil Suitability of some Acid Sand Soil Supporting Oil Palm (*Elaeis guinensis* Jacq) trees in Calabar, Nigeria. *Nigerian Journal of Soil Science*, 25:92 -109.

Anaya-Romero, M., Abd-Elmabod, S.K., Muñoz-Rojas, M., Castellano, G., Ceacero, C.J., Alvarez, S., Méndez, M. and De la Rosa, D. (2015). Evaluating Soil Threats under Climate Change Scenarios in the Andalusia Region Southern Spain. *Land Degradation and Development,* 26:441–449.

Bouyoucos, G.H. (1951) A Recalibration of the Hydrometer for Making Mechanical Analysis of Soils. *Agronomy Journal,* 43: 434-438.

Buol, S.W., Hole, F. D. and McGracken, R. J. (1989). Soil Genesis and Classification. 3rd ed., Ames: Iowa State University Press. Pp. 446.

Dhar, M., Rahman, S. M. and Sayem, S. M. (2008). Maturity and Post-Harvest Study of Pineapple with Quality and Shelf Life under Red Soil. *International Journal of Sustainable Crop Production*, 3(2): 69-75.

FAO (1976). Food and Agriculture Organization. A Frame Work for Land Evaluation. FAO Soils Bulletin 32, Rome, Italy. Pp. 72.

FAO (1985). Food and Agriculture Organization. Guidelines: Land Evaluation for Irrigated Agriculture; Soils Bulletin 55, FAO, Rome, Italy. Pp. 290.

FAO (1993). Food and Agriculture Organization. Guidelines for Land-Use Planning; FAO Development Series 1, FAO, Rome, Italy. Pp. 96.

FAO (2007). Food and Agriculture Organization. Land Evaluation: Towards a Revised Framework; Land and Water Discussion Paper 6, FAO, Rome, Italy. Pp. 107.

FAO (2011). Food and Agriculture Organization. The State of the World's Land and Water Resources for Food and Agriculture. Managing Systems at Risk; Food and Agriculture Organization of the United Nations and Earthscan: Abingdon, UK. ISBN 978-1-84971-326-9.

FAO-UNESCO (2015). Food and Agriculture Organization- United Nations Educational, Scientific and Cultural Organization. World Reference Base for Soil Resources 2014. International soil classification system for naming soils and creating legends for soil maps. FAO, Rome. Pp.203.

FAO (2019). Food and Agriculture Organization. Crop Information: Pineapple. http://www.fao.org/(Accessed on May 25, 2020).

Gee, G.W. and Bauder, J.W. (1986). Particle size analysis. In: Methods of soil analysis, Part 1, (A. Klute, Ed.), American Society of Agronomy: Madison, WI., 9:91-100.

Hossain, M.F. (2016). World Pineapple Production: An Overview. *African Journal of Food, Agriculture, Environment and Development*, 16(4): 11443-11456.

Joy, P. P. (2010). Benefits and Uses of Pineapple. Pineapple Research Station (Kerala Agricultural University), Vazhakulam -686 670, Muvattupuzha, Ernakulam District, Kerala, India.

Murphy, J. and Riley, J.P. (1962). A Modified Single Solution Method for the Determination of Phosphate in Natural Waters. *Anal Chemical Acta.*, 27: 31-36.

Nelson, D.W. and Sommers, L.E. (1996). Total Carbon, Organic Carbon and Organic Matter. In D.L. Sparks (Eds.) Methods of Soil Analysis. Part 3. Chemical methods. SSSA Book Ser. 5. SSSA, Madison, WI. Pp. 961-1010.

Ogunkunle, A.O. (1993). Soil in Land Suitability Evaluation: An Example with Oil Palm in Nigeria. Soil Use and Management, 9(1): 35-40.

Osinuga, O.A. and Oyegoke, C.O. (2017). Impact of Land Use and Agrochemicals on Quality Potential of Wetland Soils of Odeda Farm Institute, Eweje, Ogun State, Nigeria. *Agriculture, Forestry and Fisheries*, 6(3): 82-88.

Page, A.L., Miller, R.H. and Keeney, D.R. (1982).

Methods of Soil Analysis (Eds) Agronomy 9, part 2, ASA, Madison Wisconsin.

Sharma, S.S., Totawat, K.L. and Shyampura, R.L. (2004). Characterization and Classification of Salt-Affected Soils of Southern Rajasthan. *Journal of Indian Society of Soil Science*, 52: 209-213.

Singh, T.B., Devi K.D., Kumar Y.B., Bishworjit, N., Singh L.N.K. and Singh, A.H. (2013). Characterization and Evaluation for Crop Suitability in Lateritic Soils. *African Journal of Agricultural Research*,8 (37): 4628-463.

Smyth, A.J. and Montgomery, R.F. (1962). Soils and Land Use in Central Western Nigeria. Government Printer, Ibadan, Western Nigeria. Pp. 264.

Soil Survey Staff. (2014). Keys to Soil Taxonomy. 12th ed., United State Development of Agriculture: Natural Resources Conservation Service. Pp. 372.

Sys, C. Van Ranst, E. and Debaveye, J. (1993). Land Evaluation. Part 3: Crop Requirements; Agricultural Publications, General Administration of Development Cooperation: Belgium, Brussels. Pp. 199.

Tan, K.H. (2011). Principles of Soil Chemistry. 4th ed., CRC Press, Taylor and Francis Group. Pp. 476.

Thomas, G.W. (1982). Exchangeable Cations. In Page, A. L., Miller, A. & Keeney, D. R. (eds.). Methods of Soil Analysis Part 2. Agronomy Monograph 9 (2nd ed.), ASA and SSSA, Madison, Wiscosin, USA. Pp 159 -165.

Udo, E. J., Ibia, T. O. Ogunwale, J.A. Ano,A.O. and Esu,I.E. (2009). Manual of Soil, Plant and Water Analysis. Lagos, Nigeria: Sibon Books Ltd. Pp. 183.

Udoh, B.T., Esu, I.E., Ibia, T.O. Onweremadu, E.U. and Unyienyin, S. E. (2013). Agricultural Potential of the Beach Ridge Soils of the Niger Delta Nigeria. *Malaysian Journal of Soil Science*, 17: 17-39.

UN (2017). United Nations, Department for Economic and Social. Sustainable Development Goals Report (2017). United Nations, Department for Economic and Social: New York, NY, USA; ISBN 978-92-1-101368-9.

UN (2019). United Nations, Department of Economic and Social Affairs, Population Division. (2019). World Population Prospects 2019: Data Booklet (ST/ESA/SER.A/424).

Uzoho, B.U. and Oti, N.N. (2004). Phosphorus Adsorption Characteristics of Selected Southeastern Nigeria Soils. In: Proceeding of the 29th Annual conference of the Soil Science Society of Nigeria. Pp. 121-131.