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INVENTORY AND LAND SUITABILITY EVALUATION OF SELECTED SOILS OF NKWESI, IMO STATE, NIGERIA, FOR SUSTAINABLE PRODUCTION OF PINEAPPLE, CASSAVA AND SWEET POTATOES

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ABSTRACT

The study was conducted to inventorize a 54.81 ha farmland at Nkwesi community, Oguta LGA of Imo State, Southeast, Nigeria and evaluate its suitability for sustainable cultivation of pineapple, cassava and potatoes. A flexible grid soil survey method was adopted, and two soil mapping units (NKWE I and II) were delineated with four representative profile pits excavated. The pedons were described in situ for their morphological attributes, and samples collected from the pedogenetic horizons were analyzed for physical and chemical properties. Results showed very deep (> 130 cm), ranging from well-drained (NKWE I) to poorly drained (NKWE II). Textural class ranged from sand and loamy sand surface underlain by sandy loam and clay loam subsoil. The units were moderate to slightly acidic (4.7 – 5.50), moderately high organic carbon (1.38-2.11%), moderate to high (11.50 – 35.70 mg/kg) available P, very low exchangeable K (0.10-0.17 cmol/kg), very low ECEC (4.64 – 6.97 cmolkg-1) and eutric, (78.00-

94.00%) base saturation. Two soil classes were identified: Arenic Kandiustepts (NKWE I) and Arenic Kandiudepts (NKWE II) (USDA) correlated as Arenosols (WRB). Suitability assessment of the farmland classified NKWE I moderate (S2f) and NKWE II marginal (S3wf) for pineapple, cassava and potato cultivation. Identified constraints were low fertility and poor drainage (NKWE II). The optimum performance of the test crops in the area can be enhanced through adequate drainage (NKWE II), liming, organic manuring and efficient use of mineral fertilizers.
Keywords: Interpretation, Soil inventory, Sustainable crop production.

INTRODUCTION

Lack of adequate knowledge of our soils, their potentialities and limitations for various uses has contributed to persistent food insecurity in Nigeria today. Soil surveys have been reported as a veritable tool to gather reliable information about the soil and environmental factors that will help them make judicious decisions about sustainable soil management or land use (Esu, 2004; Lekwa *et al.*, 2004). Soil survey involves a combination of field and laboratory activities intended to identify soil's basic morphological, physical and chemical properties (soil characterization) and establish the distribution of those soils at specific map scales (classification and mapping).

It is pertinent that if the potential of agricultural land should be maximized, land use should not be based primarily on the needs and demands of the users but also on the suitability of such land for the intended use in order to derive maximum benefit and achieve environmental sustainability. Land evaluation is the first step in agricultural planning for sustainable crop production because it will guide decisions on land utilization so that resources are optimally used, resulting in sustainable environmental management (Fasina *et al*., 2015).

Different soils have varying nutrient capabilities, depending on the amount of total nutrient reserves, mobilization and accessibility of the chemically available nutrients to plant roots. Consequently, if the soil is not managed well, crop yield declines over time, accompanied by environmental degradation (Akinrinde and Obigbesan, 2000; Akamigbo, 2010). It is, therefore, important that before an agricultural project is established, mainly where intensive crop production is involved, the soil must be fully characterized through soil testing. Soil characterization will establish the various soil types present in the area and the levels of the different plant nutrients in the soil.

Crops require a wide range of nutrients (N, P, K, Ca, Mg, etc) and in appropriate amounts for optimum growth and yield (Chude *et al*., 2011). Each nutrient element is present in the soil to a certain level. The knowledge of the amounts of the nutrient elements that are required to be added, in the form of fertilizer, to the soil to enable the planted crop or crops to yield optimally is established through soil testing. If the right type and amount of fertilizer are not applied, the expected yield increase will not be obtained, and the return on investment may not be encouraging.

Therefore, understanding the characteristics of soils in an area is crucial for the productive and sustainable management of such soils to better the inhabitants' lives (Oluwatosin *et al*., 2006). Interpretation of soil survey reports (evaluation), as reported by Esu (2004), is a very handy tool for assessing the potential of land for specific purposes and the soils' responses to manipulative management for sustained agricultural production. The correct interpretation of soil and its environment is the basis for rational and sustainable land use for crop production.

In Nigeria, various food and cash crops have contributed largely to the national food basket, among which are pineapple, cassava, and potatoes. Nigeria is ranked 7th in the world in pineapple production and the leading producer in Africa, with an area of 199,891 ha under production and an average yield of 83 t/ha (FAO, 2019).

Similarly, sweet potato and cassava are essential to root crops in tropical and sub-tropical countries like China, India, Japan, Thailand, Nigeria, etc. Among the root and tuber crops grown in the world, sweet potato ranks second after cassava Ravindran *et al*. (2010)

Despite the significant role these crops have played, particularly as raw materials for agro-based industries, little or no organized research has attempted to assess the suitability of soils for sustainable production compared to other contemporary foreign exchange-earning crops (cocoa, oil palm, cashew, and rubber). However, this research presents a potential avenue for improving their productivity through soil suitability assessment, offering hope for the future of the agricultural sector. Therefore, the research work was carried out to inventorize and assess land suitability of selected soils in the community for sustainable production of pineapple, cassava and potatoes.

MATERIALS AND METHODS

Study Area

The research was carried out in the Nkwesi community, located between latitudes 5˚39'10"-5˚39'50" N and longitudes 6˚48'40"-6˚49'25" E, in the Oguta Local Government Area of Imo State, South-eastern Nigeria (Fig. 1). Nkwesi is about 42.7 km from Owerri, the capital of Imo State.

The area has an annual rainfall of 2,500 and 3000 mm distributed over seven months in the rainy season. Annual air temperatures range between 21oC and 31o, with a relative humidity of 64-80 % (NIMET, 2020). The original vegetation of the project site was typical equatorial rainforest. However, a greater percentage of the land is under a cassava-based cropping system, including sole cassava, cassava/maize intercrop and cassava/maize/melon intercrop with few stands of oil palm (*Elaeis guineensis*). The general land use pattern of cultivation in the area is subsistence in characteristics with a bush fallow system of regenerating the soil. Mixed cropping is a common practice. Presently, the study site was under a cassava-based cropping system, and a few stands of rubber trees and bush fallow in the northeastern and southern parts of the farm. The soils of the study area were developed from the Coastal Plain Sands (Benin formation) of the Oligocene Miocene era (Ojanuga *et al.*, 1981; Lekwa, 2002).

Field Work

The study site was reconnoitred to obtain relevant information by physically observing different physiographic features. A perimeter survey of the land area, measuring about 54.49 hectares was traversed at 100 m thereafter geo-referenced using Global Positioning System (GPS) receiver. Soils were examined using auger borings at points where soil changes occurred due to slope, soil colour, vegetation, geology and human influences. At each observation point, soil examination was done at a depth of 50 cm. Soils were examined for texture, colour, consistency, red-oximorphic features, root or water-restrictive layers, and coarse fragment inclusions. Based on the variability of these parameters, two mapping units (NKWE 1 and NKWE 2) were identified and delineated. To describe the mapping units, soil profile pits were located and dug at modal points. Based on the size of the units, one modal pit was established in unit NKWE 1 (5.01 ha), while mapping unit NKWE 2 (49.48 ha) had three profile pits.

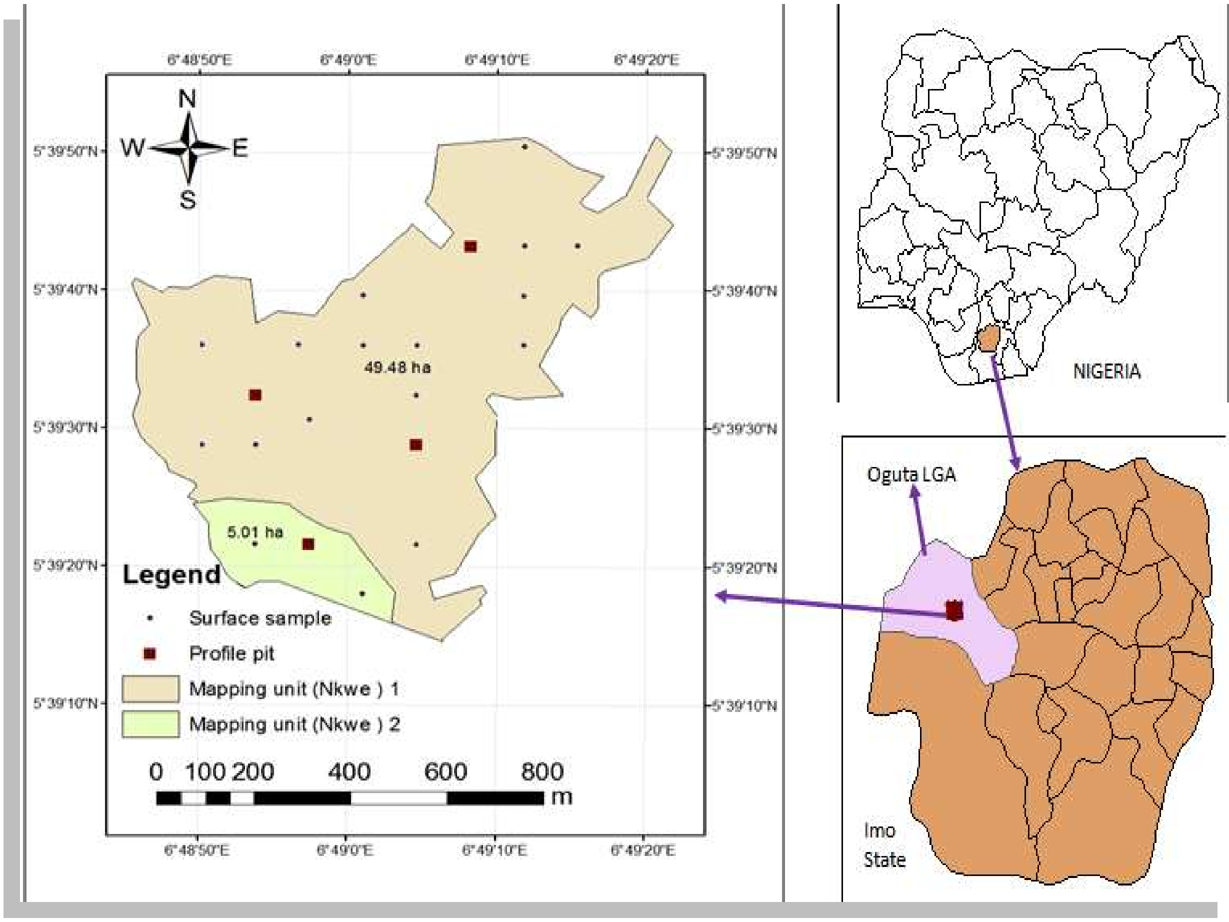

Fig. 1: Map of the Study Site Showing Sample Points

The profile pits were described following the USDA guidelines for soil profile descriptions (FAO 2006). Samples were collected according to the occurrence of identified master and subordinate horizons for detailed laboratory analysis. Surface (0-30 cm) soil samples were also obtained with an auger from soil sampling points across the whole farm to determine the soil fertility status of the farmland. The profile pits and surface soil sampling points were geo-positioned.

Soil Analysis and Data Interpretation

The soil samples were air-dried and ground to pass through a 2 mm sieve. For the determination of total N and organic carbon (OC), a 0.5 mm sieve was used. Analyses of the physicochemical properties followed standard laboratory procedures described by Udo *et al*. (2009). Particle-size distribution and bulk density were determined by Bouyocous hydrometer analysis and core methods, respectively. Soil pH was measured using a 1:2.5 soil-to-water ratio, whereas organic carbon (OC) was determined by the wet digestion method (Walkley and Black method). The

Kjeldahl wet digestion and distillation method and available P by the modified Olsen method determined total N. Exchangeable bases were extracted by saturating the soil with neutral 1N NH4OAc: Na+ and K+ displaced by NH 4+ were determined by a flame photometer.

In contrast, Ca2+ and Mg2+ were determined using the Ethylene Diamine Tetra-Acetic acid (EDTA) titration method. Exchangeable acidity was extracted with 1N KCl and estimated in the extract by titration (Udo *et al*., 2009). The effective cation exchange capacity (ECEC) was determined by summation of all exchangeable cations, including exchangeable acidity (Al3+ and H+), and finally, the base saturation (BS) Percentage was determined using the relationship.

$$BS\ (\%) = \frac{\sum Exchageable\ Bases}{\sum Exchageable\ Bases + \sum Exchangeable\ Acidity} \times 100$$ …………………… Equation 1

Data were interpreted based on (Chude, *et al*. 2011; Sasseville, 2013 and Hazelton and Murphy, 2016) ratings for soil data interpretation.

Soil Classification

Based on the morphological, physical, and chemical properties obtained, the soils were classified according to the USDA Soil Taxonomy System (Soil Survey Staff, 2014) and correlated with the World Reference Base for soil resources (WRB, 2014).

Suitability Classification of the Soils for Cassava, Sweet Potatoes and Pineapple.

Evaluating the project site for the suitability of the recommended agricultural enterprises will make it possible to identify soil characteristics that require intervention for optimum productivity. The land qualities of the project site were matched with standard land qualities for assessing the suitability of the mapping units for cassava, sweet potatoes and pineapple production based on the guidelines of FAO (2016). The parametric square root method was used to compute the index of productivity (IP) of the soil for the cultivation of the test crops:

$$IP = A\ x \sqrt{\frac{B}{100}}\ x\ \frac{C}{100}\ x\ \frac{D}{100}\ x\ \frac{E}{100}\ x\ \frac{F}{100}$$ ……………………………………... Equation 2

where: A is the overall lowest characteristic rating, and B, C…, and F are the lowest characteristics rating for each land quality group, such as climate (c), topography (t), soil physical properties (s), wetness (w), and chemical fertility (f). Only one member in each group was used because strong correlations exist among members of the same land quality group (Ogunkunle, 1993). The potential index of productivity (IPp) was calculated without considering N, P and K in the fertility (f) group because they can easily be changed. In contrast, the current (actual) index of productivity (IPc) considered N, P and K as parts of the 'f' group. Suitability classes such as high (S1), moderate (S2), marginal (S3) and none (N) are equivalent to IP values of 100-75 %, 74-50 %, 49-25 %, and 24-0 %, respectively.

RESULTS AND DISCUSSION

Morphological and Physical Characteristics

Selected morphological and physical properties across the mapping units in the study site are presented in Table 1.

Table 1: Land use Requirements for Sweet Potato Cultivation

Land qualities	Land characteristics	Units	S1 100-95 %	S2 94-85 %	S3 84-40 %	N1 39-20 %
Climate (c)						
Water Availability	Mean annual Rainfall	(mm)	1600-1100	1100-900	900-500	<500
Temperature regime	Mean annual Temp.	(^{O}C)	21-30	>18<21	>12	<12
Wetness (w)						
Oxygen Availability	Soil drainage		Well drained	Moderately drained	Poorly drained	Very poorly drained
Fertility (f)						
Nutrient Availability	Total N	(%)	>0.12	0.1-0.12	<0.1	-
	Avail P	(mgkg^{-1})	>25	6-25.	<6	-
	Exch. K	(cmol/kg)	>0.6	0.3-0.6	<0.3	-
	pH		5.5-6.8	6.8-7.8/ 5.0-5.4	>7.8 <5.0	-
	Organic C (0-15) cm	>1.5	1.0-1.5	<0.4-1.0	<0.4	
Nutrient retention	**CEC**	(cmol/kg)	>16	3-16	<3	-
	Base saturation	(%)	>35	20-35	<20	-
Soil physical characteristics (s)						
	Soil texture		L, SL	LS, CL	S, SCL	C
Rooting Condition	Soil depth	(cm)	>100	100-75	75-50	<50
Topography (t)	Slope	(%)	0-5	5-12	12-20	>20

(Modified from Sys *et al.,* 1991)

Key: S_1 = highly suitable, S_2 = moderately suitable, S_3 = marginally suitable, N_1 = currently not suitable, C = Clay, CL= clay loam, L = loam, SiC = silty clay, LS = loamy sand, SL= sandy loam, SCL = sandy clay loam, S = sand, SC = sandy clay.

Variations were observed in the colour of the horizons across the mapping units. For instance, soils mapping NKWE 1 were characterized by a reddish black hue in the epipedons (2.5 YR 2.5/2), while the endopedons varied between reddish brown to red (Table 1). However, the epipedons of soils of mapping NKWE 2 were very dark grayish brown (10 YR 3/1), while the endopedons varied between brown to very pale brown. According to Wakene (2001), soil colour is a function of pH, redox reaction and organic matter; consequently, a change in soil colour may signify differences in soil mineral type quantity and degree of weathering. Nuga *et al.* (2006) reported that the variation in soil colour matrix could be attributed to the sequence of drainage conditions and physiographic position. The grey colour observed in NKWE 2 could be attributed to the poor drainage condition of the unit (Lawal *et al.*, 2013).

Table 2: Land Use Requirement for Cassava

Land Quality and characteristics	S1(100-95)	S2(94-85)	S3(84– 40)	N1(39–20)	N2(19-0)
Climate (c)					
Mean annual rainfall (mm)	1500-1100	1100 - 900	900 – 500	< 500	any
Mean annual temperature (^0C)	18 - 30	16 – 18/ 30- 35	< 12 or > 35	any	any
Topography (t) *Slope (%)*	0 -5	5 – 12	12 – 20	>20	> 30
Wetness (w) Drainage	Well drained	Imperfectly drained	Poorly drained	Very poorly drained	Very poorly drained
Soil physical characteristics (s)					
Texture and Structure	L, SC, CL	LS,SL,SCL, SiCL	S, SiC	C	any
Soil depth (cm)	> 100	100 - 75	75 – 50	< 50	< 20
Fertility (f)					
CEC (cmolkg^{-1} clay)	>16	16 - 3	< 3	any	-
Base saturation (%)	>35	35 - 20	< 20	any	-
Organic carbon (%), 0-15cm	> 2	1.2 -2.0	2.0-0.8	<0.8	-
pH	6.1 – 7.3	7.4-7.8 or 5.1-6.0	>8.4 or <3	any	-
Total Nitrogen (%)	>0.2	0.2 – 0.1	<0.1	any	-
Exch. K cmolkg^{-1})	>0.6	0.3-0.6	<0.3	-	-
Available P (mgkg^{-1})	>25	25 - 6	< 6	Any	-
Exchangeable K (cmolkg^{-1})	>0.6	0.6 – 0.3	< 0.3	any	-

Key: C-Clay, CL=Clay Loam, L=Loam, SiCL= Silty Clay Loam, SL= Sandy Loam, SCL = Sand Clay Loam, SC= Sandy Clay, LS=Loamy Sand.
Source: (Sys *et al.*, 1991; Mongkosalwat *et al.*, 1997).

Table 3: Land Use Requirement for Pineapple

Land Quality and characteristics	S1(100-95)	S2(94-85)	S3(84- 40)	N1(39-20)	N2(19-0)
Climate (c)					
Mean annual rainfall (mm)	1200-1100	1100 - 800	800 – 600	6< 500	any
Mean annual temperature (^0C)	22 - 26	26 – 20	30 – 35	>35	any
Topography (t) *Slope (%)*	0-8	8- 16	16– 30	30-50	> 50
Wetness (w) Drainage	Well drained	Imperfectly drained	Poor and aeric	Poor but drainable	Poor not drainable
Soil physical characteristics (s)					
Texture and Structure	L, SL, SCL	LS, SiL, Si, SC	S, SiC	C	any
Soil depth (cm)	> 60	40 - 60	20 – 40	< 20	< 20
Fertility (f)					
CEC (cmolkg^{-1} clay)	>16	16 - 3	< 3	Any	-
Base saturation (%)	>35	35 - 20	< 20	Any	-
Organic carbon (%), 0-15cm	> 2	1.2 -2.0	0.8-1.2	<0.8	-
pH (H_2O)	5.0 – 6.5	4.5-5.0 or 6.5-7.0	7-7.8 or 4.0-4.5	<4.0/>7.8	-
Total Nitrogen (%)	>0.2	0.2 – 0.1	<0.1	Any	-
Exch. K cmolkg^{-1})	>0.6	0.3-0.6	<0.3	-	-
Available P (mgkg^{-1})	>25	25 - 6	< 6	Any	-
Exchangeable K (cmolkg^{-1})	>0.6	0.6 – 0.3	< 0.3	Any	-

Key: C-Clay, CL=Clay Loam, L=Loam, SiCL= Silty Clay Loam, SL= Sandy Loam, SCL = Sand Clay Loam, SC= Sandy Clay, LS=Loamy Sand.
Source: (Sys *et al.*, 1991; Mongkosalwat *et al*., 1997).

The structure of the soils of the project land ranged from granular in the surface horizons to weak, fine to medium angular blocky in the sub-surface horizons. Many moderate to fine plant roots were observed on the surface soils, which decreased down the profile. The soils of NKWE 1 were well-drained, while the soils of NKWE2 were imperfectly drained. Soils of NKWE 1 will not be susceptible to water logging because of the expected high infiltration rate. However, NKWE 2 was imperfectly drained, and with a low infiltration rate, water logging may occur.
The moist consistency of the surface soil remained friable, whereas the subsurface soils exhibited firm and non-sticky/non-plastic consistency under moist and wet conditions, respectively. The overall consistency showed that the soils would be workable at appropriate

moisture content. Therefore, soil conservation practices must be part of soil management practices on the farm.

Sand separate is the predominant size fraction in the soils of the project site, accounting for over eighty percent (> 80 %) in the surface soils and more than seventy percent (> 70 %) in the subsoils. The textural class ranges from sand to loamy sand in the surface soils and from loamy sand to sandy clay loam in the subsoils.

Soil texture affects the soil's physical and chemical properties, including infiltration and water retention, soil aeration, microbial activities, tillage and irrigation practices (Chude *et al*., 2011). Sandy soils have low water and nutrient-holding capacity. Soil texture is one of the inherent physical properties of soil that are less affected by management. However, Wakene (2001) has suggested that management systems may contribute indirectly to changes in particle size distribution, particularly in the surface horizons, as a result of clay removal through sheet erosion and mixing up of soils of the surface and subsurface horizons during mechanical tillage activities.

Chemical Characteristics

The soils of the farmland fall within the very strongly (4.6 – 4.9) to firmly (5.3 – 5.5) acid class (Chude *et al*., 2011), with pH (H2O) values ranging from 4.6 to 5.5 (Table 2). The acid nature of the soil can be adduced to a high rate of leaching of bases consequent upon high sand fractions in the area (Amusan *et al*., 2006). Chude *et al*. (2011) and Sasseville (2013) established a pH range of 5.5 - 7.0 (slightly acid to neutral reaction) as optimal for the overall satisfactory availability of plant nutrients. Consequently, the pH range of the farmland is not ideal for most crops to thrive well as most nutrient elements, especially phosphorus, will be fixed and, thus, will not be readily available for absorption by plant roots. Therefore, the sustainable productivity of the farmland is anchored on adequate liming to reduce the acid effects and ensure adequate availability of soil nutrients to crops.

The farmland's surface soil organic carbon content ranged from 1.38 to 2.39 % and decreased with soil depth. The surface soil organic carbon is considered moderate to high based on the soil nutrient interpretation of Chude *et al*. (2011) and Hazelton and Murphy (2016). However, the generally low organic carbon in the sub-surface horizons may be adduced to the fact that the surface horizons are where organic materials decompose and humidify. The nitrogen content of the soils of the project site was low; therefore, crop production on the project farm

Table 4: Morphological and Physical Properties of Nkwesi Farmland

Pedon	Horizon	Depth (cm)	Colour (moist)	Structure	Consistence moist	Consistence wet	Sand (%)	Silt (%)	Clay (%)	Texture
				NKWE 1						
	Ap	0 – 14	2.5 YR 2.5/1 (RB)	W, m, sbk	Friable	ns	86.80	3.00	10.20	LS
	AB	14 – 29	2.5 YR 3/2 (DR)	W, m, sbk	Friable	ns	86.80	3.00	10.20	LS
1	B1	29 – 53	2.5Y 3/4 (DRB)	W, m, sbk	Friable	ns	81.80	3.00	15.20	SL
	B2	53 – 99	2.5 YR 4/4 (RBr)	M, m, abk	Firm	ns	78.80	3.00	18.20	SL
	Bt	99 -189	2.5 YR 3/6 (DR)	M, m, abk	Firm	ss	77.80	2.00	20.20	SCL
				NKWE 1						
	Ap	0 – 18	2.5 YR 2.5/1 (RB)	M, m, abk	Friable	ns	82.80	5.00	12.20	LS
2	BA	18 – 40	2.5 YR 4/4 (RBr)	W, m, abk	Friable	ns	79.80	2.00	18.20	SL
	Bt1	40 – 82	2.5 YR 4/6 (DRB)	W, m, abk	Firm	ss	75.80	2.00	22.20	SCL
	Bt2	82 – 187	2.5 YR 4/8 (RBr)	S, f, abk	Firm	ss	73.80	2.00	24.20	SCL
				NKWE 1						
	Ap	0 – 13	2.5 YR 2.5/1 (RB)	W, m, gr	Friable	ns	89.80	3.00	7.20	S
3	AB	13 – 35	2.5 YR 4/4 (RBr)	W, c, abk	Friable	ns	83.80	2.00	14.20	LS
	BA	35 – 75	2.5 YR 5/3 (RBr)	W, c, abk	Friable	ns	79.80	4.00	16.20	SL
	B1	75 – 130	2.5 YR 4/6 (RBr)	W, c, sbk	Friable	ns	79.80	4.00	16.20	SL
	B2	130 – 200	2.5 YR 4/8 (R)	W, c, abk	Firm	ss	79.80	3.00	17.20	SL
				NKWE 2						
	Ap	0 – 18	10 YR 3/2 (DGB)	W, m, gr	Friable	ns	86.80	4.00	9.20	LS
4	BA	18 – 49	10 YR 5/3 (Br)	M, f, abk	Friable	ns	79.80	2.00	18.20	SL
	Bt1	49 – 86	10 YR 7/4 (PBr)	W, m, abk	Firm	ss	75.80	3.00	21.20	SCL
	Bt2	86-138	10 YR 7/3 (PBr)	W, M, SBK	Firm	ss	75.80	4.00	20.20	SCL

Key: Colour: RB = Reddish black, DR = Dusk red, DRB = Dark reddish brown, RBr = Reddish brown, R = Red, DGB = Dark grayish brown, Br = Brown, PBr = Pale brown, would require the application of nitrogen in the form of inorganic fertilizer or organic manure. The soils' available phosphorous content varied from 11.5 - 41.0 mgkg-1, having irregular distribution across the depths. The available P values are considered moderate, within the range recommended for most commonly cultivated crops (Enwezor *et al.*, 1989).

Chemical Characteristics

The soils of the farmland fall within the very strongly (4.6 – 4.9) to firmly (5.3 – 5.5) acid class (Chude *et al*., 2011), with pH (H2O) values ranging from 4.6 to 5.5 (Table 2). The acid nature of the soil can be adduced to a high rate of leaching of bases consequent upon high sand fractions in the area (Amusan *et al*., 2006). Chude *et al*. (2011) and Sasseville (2013) established a pH range of 5.5 - 7.0 (slightly acid to neutral reaction) as optimal for the overall satisfactory availability of plant nutrients. Consequently, the pH range of the farmland is not ideal for most crops to thrive well as most nutrient elements, especially phosphorus, will be fixed and, thus, will not be readily available for absorption by plant roots. Therefore, the sustainable productivity of the farmland is anchored on adequate liming to reduce the acid effects and ensure adequate availability of soil nutrients to crops.

The farmland's surface soil organic carbon content ranged from 1.38 to 2.39 % and decreased with soil depth. The surface soil organic carbon is considered moderate to high based on the soil nutrient interpretation of Chude *et al*. (2011) and Hazelton and Murphy (2016). However, the generally low organic carbon in the sub-surface horizons may be adduced to the fact that the surface horizons are where organic materials decompose and humidify. The nitrogen content of the soils of the project site was low; therefore, crop production on the project farm would require the application of nitrogen in the form of inorganic fertilizer or organic manure. The soils' available phosphorous content varied from 11.5 - 41.0 mgkg-1, having irregular distribution across the depths. The available P values are considered moderate, within the range recommended for most commonly cultivated crops (Enwezor *et al.*, 1989).

Generally, there was a low accumulation of bases in the horizons of the soil. The low level of bases in these soils could suggest that leaching is a marked pedogenic process resulting from the area's high sand proportion (Amusan *et al.*, 2006). The effective cations exchange capacity (ECEC) was generally low (< 7.0 cmolkg-1). The low ECEC could be attributed to the type of clay (such as 1:1 clay mineral, e.g. kaolinite). This was observed by Nnaji *et al*. (2002), who found that low CEC of soil is because of clay type content, high rainfall intensity, and previous land use. Base saturation was high and reflected the concentration of basic cations at the exchange complex site.

Table 5: Chemical Properties of the Soils of the Study site

Horizon	Depth (cm)	pH	Avail P	Total N	Org C	Ca	Mg	K	Na	EA		ECEC	BS %
			$mgkg^{-1}$			………..	$cmolkg^{-1}$	…………………					
		NKWE 1 (Pedon 1)											
Ap	0 – 14	5.30	32.0	0.14	1.38	4.00	1.60	0.16	0.12	0.40	0.12	6.29	94.00
AB	14 – 29	4.70	26.3	0.13	1.06	3.20	1.60	0.18	0.16	1.04	0.40	6.18	83.00
B1	29 – 53	4.80	20.1	0.08	0.40	2.80	0.80	0.18	0.12	1.12	0.32	5.03	78.00
B2	53 – 99	4.70	16.5	0.08	0.25	3.60	1.60	0.16	0.10	1.20	0.40	6.67	82.00
Bt	99 -200	4.80	18.2	0.07	0.18	3.20	1.20	0.16	0.10	0.96	0.48	5.63	83.00
		NKWE 1 (Pedon 2)											
Ap	0 – 18	5.40	21.0	0.08	1.66	3.60	1.60	0.19	0.08	0.80	0.40	6.26	87.00
BA	18 – 40	4.70	12.5	0.03	0.69	2.80	1.20	0.18	0.09	0.72	0.32	4.98	86.00
Bt1	40 – 82	4.80	14.0	0.06	0.47	3.60	1.20	0.15	0.09	0.80	0.32	5.84	86.00
Bt2	82 – 187	4.80	11.5	0.04	0.36	2.40	1.60	0.16	0.07	0.88	0.40	5.11	83.00
		NKWE 1 (Pedon 3)											
Ap	0 – 13	5.50	35.7	0.17	2.11	4.60	1.20	0.13	0.16	0.04	0.35	6.13	89.00
AB	13 – 35	4.90	17.1	0.08	0.73	3.20	0.80	0.14	0.12	0.40	0.16	4.66	91.00
BA	35 – 75	5.00	19.6	0.08	0.73	2.80	1.20	0.14	0.13	0.80	0.48	5.07	84.00
B1	75 – 130	4.70	15.6	0.06	0.22	4.00	1.00	0.13	0.10	0.88	0.24	6.11	88.00
B2	130 - 200	4.80	15.9	0.06	0.15	2.00	1.60	0.12	0.12	0.80	0.40	4.64	83.00
		NKWE 2 (Pedon 4)											
Ap	0 – 18	5.40	41.0	0.18	2.39	4.40	1.00	0.16	0.17	0.64	0.32	6.38	91.00
BA	18 – 49	4.60	18.5	0.08	1.06	3.60	1.60	0.15	0.10	1.52	0.48	6.97	78.00
Bt1	49 – 86	4.70	15.4	0.07	0.58	3.20	0.80	0.17	0.11	1.44	0.48	5.73	75.00
Bt2	86-138	4.90	19.8	0.08	0.33	2.40	1.20	0.17	0.10	1.28	0.48	5.16	75.00

Note: LS = Loamy sand, SL = Sandy loam, S = Sand, SCL = Sandy clay loam

Classification of Soils of the study site

The soils across the study area represented by mapping units NKWE 1 (comprising pedons 1-3) and NKWE 2 (pedon 4) were classified (Soil et al., 2014) and correlated (WRB, 2014). All the pedons showed poor pedogenic horizon development, as evidenced by a slight increase in clay fraction down the profile. This classifies it into soil order inceptisols.
The prevalent ustic soil moisture regime (soils, dry for more than 90 cumulative days but less than 180) of the area has placed NKWE 1 into the sub-order Ustepts. In contrast, mapping unit NKWE 2 classified the udic soil moisture as Udepts.

Kandic horizons were established in NKWE 1 and 2 due to the following requirements observed: coarser-textured surface horizons over vertically continuous subsurface horizons; CECs within subsurface B horizons that are less than 12 cmol kg-1clay and a regular decrease in organic carbon content with increasing depth (Soil Survey Staff, 2014). Therefore, the soils were placed into the great group Kandiustepts and Kandiudepts for NKWE 1 and NKWE 2, respectively. However, high sand fraction across the site placed the soils into the great group Arenic Kandiustepts and Arenic Kandiudepts for NKWE 1 and NKWE 2, respectively (USDA) (Soil Survey Staff, 2014). They were correlated as Arenosols in the World Reference Base (WRB, 2014).

Land Suitability Evaluation

Land suitability evaluation of Nkwesi farmland for the cultivation of sweet potatoes, cassava, and pineapple using the parametric method was determined. Results of matching agronomic requirements (Tables 1 - 3) for production of the test crops with land characteristics (Tables 4 and 5) are shown in aggregate suitability class score (Table 7). The climate was not a constraint to the production of the crops in the farmland and environs because there were more than five months of steady rainfall. Consequently, these crops would do best when planting and developmental stages are programmed to fall within the rainy months of the year. Topography (slope gradient) of the entire mapping units, < 5 %, was highly suitable for optimal production of the selected crops (Sys *et al.*, 1991) and, therefore, would not pose any limitation to the optimal performance of the crops on the farmland and its environs. Similarly, soil depth in the study area was greater than 100 cm and is considered adequate for sustainable crop production (FAO, 2016).

Regarding soil wetness (drainage), NKWE 1 had good drainage, while NKWE 2 had poor drainage. Therefore, poor drainage in NKWE 2 is considered a limiting factor to the optimal unit performance for the selected crops. The entire farmland was strongly acidic and deficient in nitrogen and exchangeable potassium. These limitations limit the optimal performance of the soils for the production of the selected crops.

The aggregate assessment of the study site (Table 6) has shown that NKWE 1 is potentially highly suitable (S1) for all the test crops, but its current optimal performance is constrained by fertility (f), thus placing the unit as moderately suitable (S2f) for the cultivation of the crops. However, the productivity of NKWE 2 is constrained by fertility (f) and poor drainage (w); thus, it is currently marginally suitable (S3fw) for the cultivation of sweet potatoes, cassava and pineapple. Soil fertility status, especially pH, nitrogen, exchangeable potassium, and poor drainage conditions, have been found to limit the potential of soils for optimal crop production.

Table 6: Aggregate Suitability Scores of the Mapping Units for the Cultivation of the Test Crops

	NKWE 1			NKWE 2
Test crop	**Pedon 1**	**Pedon 2**	**Pedon 3**	**Pedon 4**
Sweet potatoes				
Potential	S1	S1	S1	S2
Actual	S2	S2	S2	S3
Limitation	*F*	*F*	*F*	*w,f*
Cassava				
Potential	S1	S1	S1	S2
Actual	S2	S2	S2	S3
Limitation	*F*	*F*	*F*	*w,f*
Pineapple				
Potential	S1	S1	S1	S2
Actual	S2	S2	S2	S3
Limitation	*F*	*F*	*F*	*Wf*

Aggregate suitability class scores: S1 =75-100; S2=50-74; S3=25-49; N1=15-24; N2=0-14

Note: f = fertility, w = wetness (drainage)

Soil Fertility Assessment the Top Soil (0-15 cm depth) of the Study Site

The pH (water) ranged from 4.80 to 5.10, indicative of very strong acid conditions and varied minimally (CV <15 %) across the site (Table 7). The acid nature of the soil could be adduced to the leaching of exchangeable bases encouraged by the high sand fraction (Nkwopara *et al.*, 2019). This high sand fraction, a characteristic of the soil in the area, contributes to the low exchangeable bases. Total nitrogen values (Fig. 5) were low (< 0.15 %), covering about 75 % of the study site, while the remaining 25 % of the site was moderate (0.15 – 0.18). The larger portion of the study site under the influence of nitrogen deficits may be attributed to volatilization, especially under high-temperature regimes, denitrification processes and massive crop removal without replenishment common in the area.

Organic carbon contents ranged from 1.20 – 2.00 %, indicating moderately low to high, and varied moderately (CV>15<35) across the site. The few portions of the site that recorded high organic carbon were attributed to higher vegetal cover on the soil surface. The generally low value of organic carbon contents in the soil could be attributed to the high rate of decomposition and mineralization of organic matter consequent upon the prevalent high temperature, low vegetal cover, and poor soil management, sometimes by burning of crop residues, intense cultivation and seasonal bush burning, which is a common practice in the area. Therefore, it is imperative for the farmers in the area to adopt cultural practices such as minimum tillage operation, mulching, organic manuring, etc., that will encourage the return and incorporation of plant/crop residues into the soil to increase the level of soil organic matter. This proactive approach can significantly improve soil fertility and crop productivity, empowering farmers to take control of their land's health.

The exchangeable bases (Ca2+, Mg2+, Na+ and K+) were generally low and significantly varied across the site (Table 7). These low values of exchangeable bases in the study area are a cause for concern as they may be connected to the poor colloidal behaviour of the soils. Sands have a lower surface area and are more physically and chemically inactive than clay (Hazelton and Murphy, 2015; Osodeke et *al.* (2005). This could significantly impact the soil's productivity and the sustainability of agricultural practices in the area.

CONCLUSION AND RECOMMENDATIONS

The study inventoried and classified selected soils of Nkwesi, Oguta LGA of Imo State and assessed the soil's potential for sustainable sweet potatoes, cassava and pineapple production.

The finding revealed high sand fraction, high acidity and low exchangeable bases. Arenic Kandiustepts and Arenic Kandiudepts (USDA) correlating to Arenosols (World Reference Base) soil types were identified. Since the soils are highly acidic, low in fertility and with high sand fractions, the judicious use of lime, the full complements of organic manure, and the split application of fertilizers are recommended. Suitability assessment revealed two classes (moderate and marginal). NKWE 1 was moderately suitable (S2) for cultivating sweet potatoes, cassava and pineapple, while NKWE 2 was marginally suitable for the crops. The optimal productivity of the soil's farmland for the test crops was constrained by the poorly drained condition of NKWE 1 and the overall low fertility status of the soils of the farmland. Adequate drainage, liming, incorporation of organic manure, and application of appropriate fertilizers are needed to enhance the optimal productivity of the land for the test crops.

Table 7: Fertility Status of the Top Soil (0-15 cm depth) of the Study Site for Crop Production

Sample point	Particle size distribution (%) Sand	Silt	Clay	Textural class	pH	Avail P mg/kg	Total N %	Org C	Ca …………. cmol/kg	Mg	K	Na ……………	EA	ECEC	BS
1	86.80	3.20	10.00	Loamy sand	4.90	28.00	0.15	1.80	2.30	1.00	0.18	0.68	1.00	5.96	70.00
2	86.00	4.00	10.00	Loamy sand	5.00	30.20	0.18	2.00	2.40	1.20	0.20	0.18	0.60	4.58	87.00
3	84.00	4.80	11.20	Loamy sand	4.90	32.00	0.18	2.00	2.00	1.06	0.16	0.16	1.20	4.58	74.00
4	82.80	5.00	12.20	Loamy sand	5.00	25.80	0.10	2.00	2.20	1.00	0.18	0.42	1.00	4.80	79.00
5	86.00	4.00	10.00	Loamy sand	5.00	26.20	0.12	1.60	1.80	1.60	0.20	0.40	0.90	4.96	82.00
6	85.80	3.00	11.20	Loamy sand	5.00	30.20	0.12	1.40	1.00	1.80	0.22	0.50	0.90	5.42	83.00
7	86.00	4.00	10.00	Loamy sand	5.00	30.80	0.12	1.42	2.00	1.60	0.22	0.20	1.00	5.00	80.00
8	86.80	4.00	9.20	Loamy sand	4.90	25.20	0.11	1.56	3.60	1.20	0.15	0.11	0.64	5.70	89.00
9	86.00	4.00	10.00	Loamy sand	5.10	28.00	0.11	1.40	2.60	0.80	0.12	0.12	0.52	4.16	88.00
10	84.00	5.00	11.00	Loamy sand	5.00	25.20	0.09	1.20	3.20	1.16	0.16	0.08	0.50	5.54	91.00
11	86.00	4.00	10.00	Loamy sand	5.00	25.20	0.09	1.25	3.00	1.40	0.10	0.11	0.50	5.11	90.00
12	85.00	4.00	11.00	Loamy sand	5.00	20.00	0.12	1.20	4.00	1.20	0.10	0.11	0.40	5.81	93.00
13	86.20	3.80	10.00	Loamy sand	5.00	20.00	0.15	1.20	4..20	1.20	0.08	0.12	0.40	5.96	93.00
14	86.80	5.00	8.20	Sand	5.00	22.50	0.10	1.83	3.60	2.00	0.14	0.16	0.08	5.97	99.00
15	84.00	6.00	10.00	Loamy sand	4.90	23.50	0.15	1.50	2.40	2.00	0.14	0.14	0.50	5.18	90.00
16	86.50	5.00	8.50	Sand	4.80	24.00	0.17	1.80	3.80	2.00	0.12	0.12	0.60	6.64	91.00
17	87.20	6.00	6.80	Sand	5.00	24.80	0.11	1.60	3.60	2.40	0.16	0.16	0.60	7.06	92.00
18	84.20	4.00	11.80	Loamy sand	5.00	25.00	0.15	1.50	3.60	2.40	0.16	0.16	0.42	6.74	94.00
19	85.00	4.00	11.00	Loamy sand	5.00	22.00	0.12	1.80	4.60	2.00	0.16	0.18	0.42	7.32	94.00
20	87.00	5.00	8.00	Sand	4.90	20.00	0.12	2.00	4.80	2.00	0.08	0.14	0.60	7.62	92.00
MEAN	**85.61**	**4.39**	**10.01**		**4.97**	**25.43**	**0.13**	**1.60**	**2.97**	**1.55**	**0.15**	**0.21**	**0.64**	**5.71**	**87.55**
STDEV	**1.24**	**0.80**	**1.34**		**0.07**	**3.60**	**0.05**	**0.29**	**1.01**	**0.49**	**0.04**	**0.16**	**0.28**	**0.97**	**7.34**
CV	**1.44**	**18.31**	**13.44**		**1.32**	**14.17**	**34.91**	**17.81**	**33.96**	**31.71**	**27.86**	**74.64**	**43.12**	**16.96**	**8.39**

Key: CV < 15= low variability (LV), CV ≥15≤35=moderate variability (MV), CV>35= high variability (HV).

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