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Land Suitability Evaluation of Selected Soils for Oil Palm Cultivation for Food Security in Akwa Ibom State, Nigeria

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Abstract
Lack of pedological information to guide plantation establishment and management has been a mitigating factor to optimum oil palm production. A land suitability evaluation was carried out on selected soils for their suitability for oil palm cultivation in Akwa Ibom State. Based on parent material, topography and drainage, four soil units were selected for the study. At representative locations, a total of fifteen (15) profile pits were dug in each soil units and described based on FAO (2006) guidelines for profile description. Soil samples were collected based on genetic horizons for laboratory analysis. The four soil units are thus represented – Onna (Beach ridge sands), Ini (River Alluvium), Uyo (Coastal plain sand) and Ibiono Ibom (Sandstone/Shale). Results from the study revealed that climate, soil physical characteristics, topography and wetness were not constraints to oil palm cultivation. Fertility (low CEC) was detected as a major constraint in Onna and Uyo Soil Units and was currently not suitable (N1). Based on the suitability classes of these soil units derived from dissimilar parent materials. Appropriate site-specific soil fertility management approach is required to boost oil palm yields especially with special regards to low CEC improvement through organic manure (poultry, goat and cow dung), compost, vermicompost, crop residues, biomass and biochar should be incorporated into soils, regular soil tests should be conducted as well as suitability evaluation to ascertain the productivity status of soils for oil palm cultivation for food security and the environment.

Key words: *Food security, land suitability evaluation, oil palm*

INTRODUCTION

In recent years, food insecurity has risen in Sub-Saharan Africa predominantly due to rapid population growth, low agricultural productivity and economic down turns (Wudil *et al*., 2022). Globally, population is expected to approximately reach 10 billion by 2050, much of this growth is anticipated in the Sub-Saharan African (SSA) Countries, such as Nigeria, the Democratic Republic of Congo, Ethiopia, Tanzania and Uganda (UNDESAPD, 2022). Food insecurity has enormously impacted negatively on Nigeria, where 25 % of her population is already food insecure (Nkwonta *et al*., 2023). This is as a result of land degradation and low soil quality (Ndubuisi and Kelechi, 2021) and other factors which have contributed to the crises, and include income inequalities, poor soil health and more recently, climate change and conflict/war (UNICEF, 2022; Moyer *et al*. 2023). Land degradation is a great threat to food insecurity in Africa and to curb this menace, soils need to be evaluated and assessed for their quality to be sustained, sustainable agriculture and the environment. Land suitability evaluation is one of the key processes of the land use planning (Shakya *et al*., 2019) and is prerequisite to achieving optimum utilization of the available land resources (Everest *et al*., 2021) as well as can establish strategies to increase agricultural productivity (Ustaoglu, 2022).

Oil palm (*Elaeis guineensis* jacq.), an economically important crop is generally believed to have evolved from the tropical rain forest of West Africa (FAO, 2002, Paterson and Lima, 2018; Kome, 2022) and noted as one of the largest perennial crops (Murphy *et al*., 2021). The specie, *guineensis* portrays the name of the area where it was first discovered and not the country now known as Guinea (Abubakar *et al.*, 2022; 2022a; 2022b). It has become the world's most important oil crop, contributing nearly 30% of the world's edible vegetable oil requirements (Hansen *et al*., 2015; Rhebergen *et al*., 2016) with the largest global demand which resulted in a rapid expansion of its cultivation. Consequently upon the dwindling availability of suitable land posed by expansion as expected, however shifts to Sub-Saharan Africa (SSA), where large area with agricultural potential is available (Laurance *et al*., 2014; Rhebergen *et al*., 2016). As the population grows in West Africa and in Nigeria at large, the consumption of oil palm and derived products is expected to increase (Ofosu-Budu and Sarpong, 2013; Rhebergen *et al*., 2016). With almost zero level of waste, the crop is totally useful. Its importance cannot be overlooked as it is an international commodity used for food (Kome, 2022), pizza dough, instant noodles, ice cream, margarine, chocolate, cookies, packaged breads, frying foods, biscuits, snacks food, bakery products; pharmaceuticals; fresh palm wine, spirits and alcohol (Ofem *et al*., 2022), cosmetics, lipsticks, shampoo, soaps, detergents, candles, supermarkets goods, (Abubakar *et al*., 2022); the fibrous stems is a source of fuel and manure, fronds are important roofing materials; its kernel shell and stalk and empty bunches are sources of fuel, mulching materials and manure (Ofem *et al.,* 2016; Okolo *et al*., 2019; Ofem *et al*., 2022); acts as a major source of income and provides employment for millions of workers (Ofosu-Budu and Sarpong, 2013; Rhebergen *et al*., 2016). It is economically the most efficient of all oil crops because of its ease of establishment, low cost and high output (Dislich *et al*., 2017; Abubakar *et al*., 2022) as well as requires little skills for cultivation and processing and can be cultivated by rural farmers with little supervision (Ofem *et al*., 2022). One of the problems mitigating against optimum oil palm production is lack of detailed pedological information to guide plantation establishment and management (Kome *et al*., 2020). However, relationships between oil palm yields and soil nutrients have been established. The key to successful and sustainable oil palm production has been pointed to be soil fertility management; while soil fertility has been a major constraint to sustainable oil palm production in Nigeria (Obi and Udoh, 2012; Kome *et al*., 2020). This study was designed to determine the constraints to palm oil cultivation based on the analysis of land characteristics that limit productivity for food security in the study area.

MATERIALS AND METHODS

Description of the Study Area

The study area lies between latitudes 4° 33" and 5° 33" North and Longitudes 7° 35" and 8° 25" East bounded by Rivers State, Cross River State, Abia and Gulf of Guinea on the East, West, North and South respectively (AKSG, 2023). The study area cuts across four (4) Soil Units overlain with Beach Ridge Sand, River Alluvium, Coastal Plain Sand and Sandstone/Shale parent materials in Akwa Ibom State. The sites overlain with beach ridge sand were (Ikot Abasi, Onna and Eket – Onna Soil Unit), river alluvium (Uruan, Ini, Ini and Ini- Ini Soil Unit), coastal plain sand (Nsit Atai, Uruan, Uyo and Ibesikpo/Asutan – Uyo Soil Unit) and sandstone/shale (Itu, Ibiono Ibom, Ini and Ini – Ibiono Ibom Soil Unit). Originally, this region belonged to the humid tropical forest zone of southern Nigeria. The natural vegetation of this kind resulted from the interaction of climate, humidity, rainfall and soil (Adepoju *et al*., 2019). The forest cover has largely been removed, modified and/or converted in line with the needs, aspirations and socio-economic realities of the inhabitants. On the land use pattern, there is a clear orientation towards arable crop production as the main agricultural enterprise across the entire State (Adepoju *et al*., 2019). The wet season is from March to October interrupted by the "little dry season" in August usually referred to as "August break". According to Ekanem (2010), the little dry season is as a result of the invasion of tropical maritime wind which does not allow the rise of moist air. The dry season lasts from November through February with the annual rainfall that varies from 3000 mm along the coast to about 2250 mm at the extreme north. The temperature varies from 23° C to 31° C. The mean daily maximum temperature is about 27° C all through the year. The highest temperatures are recorded between February and April but they do not usually exceed 37° C. The variation in temperature within the State is not much but the coastal regions experience lower temperatures generally because of the moderating effects of the ocean. The mean minimum temperatures decrease from the coastal areas towards the interior of the State. Generally, the mean annual temperature is above 23° C and does not exceed 29° C. The mean annual Relative Humidity of 75-80 % (Udoh *et al*., 2013), decreases steadily from the coast towards the interior reflecting the effects of the maritime (Ekanem, 2010).

Field Sampling

Profile pits will be sunk in the study area and in each profile pit, soil description will be carried out in accordance with the FAO (2006) guidelines for soil profile description. Based on genetic horizons that will be identified, soil samples and core samples will be collected for bulk density and saturated hydraulic conductivity determinations using core rings in the laboratory.

Laboratory Analysis

The samples were air-dried under laboratory condition, gently crushed with mortar and pestle and passed through a 2 mm mesh sieve. In accordance to standard laboratory procedures, the soil samples were subjected for laboratory analyses as described by Udo *et al*. (2009).

Soil Classification

Based on the field and laboratory data, the soils in the different soil units studied were classified to Sub-Group level according to the USDA Soil Taxonomy (Soil Survey Staff, 2010) and correlated with the FAO/UNESCO Legend World Reference Base (FAO/UNESCO, 2006).

Soil Quality Index (SQI)

Principal component analysis (PCA) was executed to select minimum dataset (MDS) for the calculation of soil quality (Yu *et al*., 2018). Expert opinion was also applied to bring in important soil properties with direct effect on crop production and other ecosystem functions that could be omitted by principal component analysis as well as indicator transformation and scoring function were also applied (Maulood and Darwesh, 2020; Bandypadhyay and Maiti, 2021; Akpan, 2022).

Land Suitability Evaluation

The square-root method of Khiddir (1986) model was used to evaluate the suitability of the soil series for coconut cultivation. Land/soil characteristics were grouped into climate, wetness, fertility, soil physical properties and topography. Each land characteristics was matched with the agronomic requirements of coconut. Based on the extent to which the land characteristic met the requirements of the crop, scores were allocated and minimum score in each of the selected group were integrated (aggregated) using $I = R_{min} \times \sqrt{\frac{A}{100} \times \frac{B}{100} \times \frac{C}{100} \times \frac{D}{100} \ldots \ldots \ldots n}$; I: suitability index; R_{min}: overall minimum score; while, A, B, C, D = Minimum score in each group.

Table 1: Mean of selected soil indicators (MDS), scoring and soil quality index for Ap-horizons

Soil Indicator	**Onna Soil Unit**			**Ini Soil Unit**			**Uyo Soil Unit**			**Ibiono Ibom Soil Unit**		
	Mean	**Liebig score**	**Glover score**	**Mean**	**Liebig score**	**Glover score**	**Mean**	**Liebig score**	**Glover score**	**Mean**	**Liebig score**	**Glover score**
Sand (%)	92.29	0.97	-91.29	83.67	0.88	-82.67	84.18	0.89	-83.18	95.08	1	-94.08
Silt (%)	2.83	0.33	0.094	8.57	1	0.29	5.28	0.62	0.18	0.93	0.11	0.031
Clay (%)	4.94	0.47	0.16	7.76	0.74	0.26	10.54	1	0.35	3.87	0.37	0.13
BD (g/cm^{-3})	1.55	0.66	0.31	1.57	0.65	0.68	1.53	0.67	0.34	1.02	1	0.98
TP (%)	41.64	0.78	3.55	47.51	0.68	4.08	32.51	1	2.73	61.61	0.53	5.34
Ph	4.90	0.88	0.69	5.60	1	0.89	5.20	0.93	0.77	4.85	0.87	0.67
EC (dSm^{-1})	0.087	0.25	0.99	0.35	1	0.94	0.19	0.54	0.97	0.06	0.17	0.99
OM (%)	2.13	0.42	0.67	5.04	1	1.78	2.72	0.54	0.89	3.37	0.67	1.14
Total N (%)	0.053	0.053	0.053	0.13	0.13	0.13	0.07	0.07	0.07	0.09	0.09	0.09
Av. P (mgkg^{-1})	7.55	1.33	7.37	23.42	0.41	1.20	56.61	1	3.15	8.45	0.15	0.32
Ca (cmol/kg)	1.37	0.15	1.37	8.95	1	8.95	2.00	0.22	2.00	8.80	0.98	8.80
Mg (cmol/kg)	1.62	0.41	0.17	3.93	1	0.47	2.35	0.60	0.27	2.93	0.75	0,34
K (cmol/kg)	0.037	0.19	-0.074	0.19	1	-0.0055	0.03	0.16	-0.0944	0.13	0.68	-0.00388
ECEC (cmol/kg)	6.48	0.35	0.014	18.65	1	0.37	7.81	0.42	7.63	14.29	0.77	14.11
BS (%)	69.02	0.80	68.73	71.11	0.83	0.73	63.71	0.74	0.62	85.87	1	0.94
SQI		**0.5362**	**-0.4795**		**0.82**	**-4.127**		**0.63**	**-4.2203**		**0.61**	**-4.3245**

Source: Field data (2022)

Table 2: Mean of selected soil indicators (MDS), scoring and soil quality index for B-horizons

Soil Indicator	Onna Soil Unit			Ini Soil Unit			Uyo Soil Unit			Ibiono Ibom Soil Unit		
	Mean	Liebig score	Glover score	Mean	Liebig score	Glover score	Mean	Liebig score	Glover score	Mean	Liebig score	Glover score
Sand (%)	89.56	1	-88.56	72.17	0.81	-71.17	77.68	0.87	-76.68	89.16	1	-88.16
Silt (%)	2.51	0.29	0.084	8.57	1	0.29	5.78	0.67	0.19	2.05	0.24	0.068
Clay (%)	7.93	0.41	0.26	19.26	1	0.64	16.54	0.86	0.55	8.80	0.46	0.29
BD (g/cm^{-3})	1.62	0.80	0.23	1.83	0.71	0.42	1.30	1	0.95	1.45	0.90	0.8
TP (%)	38.75	1	3.29	43.32	0.89	3.70	42.53	0.91	42.35	45.19	0.86	45.01
pH	4.90	0.88	0.69	5.58	1	0.88	5.225	0.94	0.78	4.63	0.83	0.61
EC (dSm^{-1})	0.073	0.33	0.88	0.22	1	0.96	0.135	0.61	0.98	0.03	0.14	1.0
OM (%)	1.79	0.48	0.53	3.73	1	1.28	1.8225	0.49	0.55	2.01	0.54	0.62
Total N (%)	0.47	0.47	0.47	0.10	0.10	0.10	0.05	0.05	0.05	0.05	0.05	0.05
Av. P ($mgkg^{-1}$)	3.93	0.10	0.05	19.73	0.49	0.98	40.17	1	2.18	6.08	0.15	0.18
Ca (cmol/kg)	0.90	011	0.90	6.75	0.85	6.75	1.80	0.23	1.80	7.90	1	7.90
Mg (cmol/kg)	1.63	0.51	0.17	3.20	1	0.38	2.36	0.74	0.27	2.63	0.82	0.30
K (cmol/kg)	0.043	0.39	-0.07	0.11	1	-0.05	0.043	0.39	-0.0872	0.06	0.55	-0.0511
ECEC (cmol/kg)	6.80	0.46	6.62	14.84	1	0.26	8.08	0.54	0.061	11.65	0.79	0.17
BS (%)	51.88	1	51.59	67.48	1.30	0.68	52.47	0.91	0.46	91.00	1.75	1.01
SQI		**0.55**	**-1.5244**		**0.88**	**-3.5933**		**0.68**	**-1.7064**		**0.67**	**-2.0135**

Source: Field data (2022)

Table 3: Land quality and factor rating for oil palm (*Elaeis guineensis*) cultivation

Land Quality	Characteristics	Unit	S1 (100) 1	S2 (85) 2	S3 (60) 3	N1 (40) 4
Climate (C):	Annual rainfall	Mm	1700-2500	1450-1700	1250-1450	1000-1250
	Annual Temperature	º C	25-28	22-25 28-32	20-22 32-35	>35
	Length of dry season	Months	<2	2-3	3-4	>4
Soil Physical Properties (s):						
	Texture	Surface	Fine-medium	Medium-slightly coarse	Coarse	Very coarse
	Soil depth	Cm	>100	75-100	50-75	54-50
	Coarse material	%	<15	15-35	35-55	>55
	Surface stoniness (0-10 cm)	Vol. %	<5	5-15	15-40	40-45
	Rock outcrops	%	<5	5-15	15-25	25-30
Wetness (w)						
	Drainage		Moderate	Moderately-poor	Poor-mod. Rapid	Very poor-Rapid
	Flooding		Fo	F1	F2	>F2
Fertility (f)						
	CEC	$cmolkg^{-1}$	>16	12-16	8-12	5-8
	Base sat.	%	>20	15-19	10-14	<10
	Org. C (0-15 cm)	%	>0.8	0.5-0.8	0.3-0.5	<0.3
	pH	H_2O	5-6.5	4.2-5 6.5-7.0	<4.2 >7.0	<4
	Mg:K	$cmolkg^{-1}$	>3.50	2.00-3.50	1.00-2.00	-
Salinity (n)						
	EC		-	-	-	-
Topography (t)						
	Slope	%	<8	8-15	16-30	>30
	Erosion hazard		Very low	Low-moderate	Severe	Very severe

Source: FAO (1976) modified by Sys (1993)

Key = S1: highly suitable, S2: moderately suitable, S3: marginally suitable, N1: currently not suitable; Fo = without flooding, F1= mild, F2 = moderate, F3 = somewhat heavy, F4 = very heavy

Table 4: Suitability class score of the Soil Units for Oil Palm (*Elaeis guinensis*) cultivation

Land Quality	Characteristics	Unit	Onna Soil Unit	Ini Soil Unit	Uyo Soil Unit	Ibiono Ibom Soil Unit
Climate (C):	Annual rainfall	Mm	S1 (100)	S1 (100)	S1 (100)	S1 (100)
	Annual Temperature	º C	S1 (100)	S1 (100)	S1 (100)	S1 (100)
	Length of dry season	Months	S3 (60)	S3 (60)	S3 (60)	S3 (60)
Soil Physical Properties (s):						
	Texture	Surface	S3 (60)	S3 (60)	S3 (60)	S3 (60)
	Soil depth	Cm	S1 (100)	S1 (100)	S1 (100)	S1 (100)
	Coarse material	%	S1 (100)	S1 (100)	S1 (100)	S1 (100)
	Surface stoniness (0-10 cm)	Vol. %	S1 (100)	S1 (100)	S1 (100)	S1 (100)
	Rock outcrops	%	S1 (100)	S1 (100)	S1 (100)	S1 (100)
Wetness (w)						
	Drainage		S1 (100)	S3 (60)	S1 (100)	S1 (100)
	Flooding		S1 (100)	S3 (60)	S1 (100)	S1 (100)
Fertility (f)						
	CEC		N1 (40)	S1 (100)	N1 (40)	S2 (85)
	Base sat.	%	S1 (100)	S1 (100)	S1 (100)	S1 (100)
	Org. C (0-15 cm)	%	S1 (100)	S1 (100)	S1 (100)	S1 (100)
	pH	H_2O	S2 (85)	S1 (100)	S1 (100)	S2 (85)
	Mg:K		S1 (100)	S1 (100)	S1 (100)	S1 (100)
Salinity (n)						
	EC		-	-	-	-
Topography (t)	Slope	%	S1 (100)	S1 (100)	S1 (100)	S1 (100)
Productivity Index						
Non-parametric Method						
Current (Actual) Productivity			**N1 (40) f**	**S3 (60) csw**	**N1 (40) f**	**S3 (60) cs**
Potential Productivity			**N1 (40) f**	**S3 (60) csw**	**N1 (40) f**	**S3 (60) cs**
Parametric Method						
Current (Actual) Productivity			**N1 (15.18)**	**S3 (27.89)**	**N1(15.18)**	**S3 (33.19)**

Potential Productivity	**N1 (15.18)**	**S3 (27.89)**	**N1(15.18)**	**S3 (33.19)**

Source: Field data (2022)

RESULTS AND DISCUSSION

Procedure for data analysis

Descriptive statistics such as mean and standard deviation were employed to analyze the data.

Morphological, physical and chemical characteristics of soils

The morphological, physical and chemical properties of the soil profiles are presented as follows. Colour varied in all the Soil Units. In Onna Soil Unit, the colour ranged from dark brown (7.5YR 3/2) to brown (7.5YR 4/2) in the Ap horizon, while the B horizon ranged from reddish yellow (7.5YR 4/6), light brown (7.5YR 6/3) to reddish brown (7.5YR 6/8). In Ini Soil Unit, soil colour ranged from dark brown (7.5YR 3/3), dark red (7.5YR 4/1) to brown (7.5YR 4/3) in the Ap horizon; while at the B horizon, soil colour varied from very dark gray (7.5YR 3/1), gray (7.5YR 5/1), pinkish gray (5YR 6/4) to light reddish brown (5YR 6/4). In Uyo Soil Unit, soil colour ranged from brown (10YR 4/3), brown (7.5YR 4/3) to dark brown (7.5YR 3/2) in the Ap horizon; while it ranged from brown (7.5YR 4/4), strong brown (7.5YR 4/6) to strong brown (7.5YR 5/6) in the B horizon. In Ibiono Ibom Soil unit, the colour of soils ranged from black (7.5YR 2.5/1), dark brown (7.5YR 3/3) to brown (7.5YR 4/3) in the Ap horizon; whereas soil colour varied from red (2.5YR 4/8), dark brown (7.5YR 3/2), dark gray (7.5YR 4/1) to strong brown (7.5 YR 5/6) in the B horizon. Variations in morphological properties could be attributed to the drainage pattern of these sites. This was in agreement with the submission of Pretorius *et al*. (2017) and also Zhang *et al*. (2021) that soil colour is determined by mineral composition, elemental concentration, organic matter and moisture content. The consistency ranged from friable to firm. Generally, the particle size distribution of sand, silt and clay varied from profile to profile. Very high sand contents were recorded across profiles studied. In Onna Soil Unit, sand fraction ranged from 89.32 to 93.33 % (mean 92.29 %) in the Ap horizon and 83.32 to 93.68 % (mean 89.56 %) in the B horizon. The clay fraction ranged from 4.74 to 5.04 % (mean 4.94 %) in the Ap horizon and 5.04 to10.74 % (mean 7.93 %) in the B horizon. The silt fraction ranged from 1.28 to 5.94 % (mean 2.83 %) in the Ap horizon and 0.32 to 5.94 % (mean 2.51 %) in the B horizon. There was no significant difference ($p < 0.05$) recorded between the Ap and the B horizons in all particle size distribution analyzed. In Ini Soil Unit, sand fraction ranged from 73.00 to 89.00 % (mean 83.67 %) in the Ap horizon and 67.00 to 81.68 % (mean 72.17 %) in the B horizon. The clay fraction ranged from 6.00 to 10.00 % (mean 7.76 %) in the Ap horizon and 13.04 to 26.00 % (mean 19.26 %) in the B horizon, while silt fraction ranged from 5.00 to 17.00 % (mean 8.57 %) in the Ap horizon and 5.28 to 11.00 % (mean 8.57 %) in the B horizon. There was no significant difference ($p < 0.05$) recorded between the Ap and B horizons amongst the particle size fraction. In Uyo Soil Unit, sand fraction ranged from 79.68 to 89.68 % (mean 84.18 %) in the Ap horizon and 73.68 to 81.68 % (mean 77.68 %) in the B horizon. The clay fraction ranged from 7.04 to 17.04 % (mean 10.54 %) in the Ap horizon and 11.04 to19.04 % (mean 16.54 %) in the B horizon. The silt fraction ranged from 3.28 to 9.28 % (mean 5.28 %) in the Ap horizon and 3.28 to 7.28 % (mean 5.78 %) in the B horizon. There was no significant difference ($p < 0.05$) recorded between the Ap and B horizons of all fractions determined. In Ibiono Ibom Soil Unit, sand fraction ranged from 94.44 to

95.44 % (mean 95.08 %) in the Ap horizon and 83.20 to 95.44 % (mean 89.16 %) in the B horizon. The clay fraction ranged from 2.70 to 4.68 % (mean 3.87 %) in the Ap horizon and 4.56 to14.80 % (mean 8.80 %) in the B horizon. The silt fraction ranged from 0.00 to 2.18 % (mean 0.93 %) in the Ap horizon and 0.00 to 4.00 % (mean 2.05 %) in the B horizon. There was no significant difference ($p < 0.05$) established between the Ap and B horizons of all the soil fractions. The high percentage sand in all Soil Units studied is a good indication of the observable high infiltration rate (Osinuga *et al*., 2020).

The pH indicated that soils were very strongly acid (4.5-5.0) in Onna and Ibion Ibom Soil Units, while Ini and Uyo Soil units were strongly acid (5.1-6.0) (Enwezor *et al*., 1989) and showed no significant difference ($p < 0.05$) in soil pH between the Ap and B horizons. The mean values of electrical conductivity in the different Soil Units studied indicated that the soils were salt free or non-saline. Organic matter varied across the sites studied. It ranged from moderate (1.72-2.6 %) in Onna, Uyo and Ibiono Ibom Soil Units in the B horizon to high (2.6-3.4 %) (Enwezor *et al*., 1989) in Ini and Ibiono Ibom Soil Units in Ap horizon. Total nitrogen was low (< 0.15 %) in all the Soil Units studied, while, there was no significant difference ($p < 0.05$) in total N between the Ap and B horizon in all the sites. Available P was rated low (<10 $mgkg^{-1}$) in Onna and Ibiono Ibom Soil Units and high (> 20 $mgkg^{-1}$) (Esu, 1991) in Ini and Uyo Soil Units (medium in B horizon). There was no significant difference ($p < 0.05$) in the available P between the Ap and B horizon in all sites studied. Exchangeable bases were as follows: Ca was low (2-5 $cmolkg^{-1}$) in Onna Soil Unit, moderate (5-10 $cmolkg^{-1}$) in Ini and Ibiono Ibom Soil Units, very low (< 2 $cmolkg^{-1}$) in Uyo Soil Unit. Mg contents was moderate (1 -3 $cmolkg^{-1}$) in Onna, Uyo and Ibiono Ibom Soil Units, high (3-8 $cmolkg^{-1}$) (Enwezor *et al*., 1989) in Ini Soil Unit as well as no significant difference ($p < 0.05$) was recorded in exchangeable Mg between the Ap and B horizon across the entire study area. Exchangeable K contents were very low (0.2 $cmolkg^{-1}$) (Enwezor *et al*., 1989) across the Soil Units and these soils portrayed no significant difference ($p < 0.05$) in exchangeable K between the Ap and B horizons studied. Exchangeable Na was high (0.7-2 $cmolkg^{-1}$) in Onna Soil Unit basically the Ap horizon and low B horizon, moderate (0.3-0.7 $cmolkg^{-1}$) (Enwezor *et al*., 1989) in Ini, Uyo and Ibiono Ibom Soil Units. However, there was no significant difference ($p < 0.05$) in exchangeable bases across the entire study area. Base Saturation mean values were generally rated from moderate (40-60 %) to very high (90-100 %) across the Soil Units and therefore indicated that these soils did not show significant difference ($p < 0.05$). The high base saturation in the different Soil Units studied could be attributed to low ECEC where the little bases saturate all the exchange sites (Landon, 1991). The ratings of these soils indicated that they are fertile and potentially productive soils. This is in agreement with the submissions of Landon (1991) that soils having greater than 60 % base saturation are rated as fertile and productive soils. The very high base saturation could be attributed to low ECEC where the little bases saturate all the exchange sites (Landon, 1991). The Exchangeable acidity of these soils though rated medium and low at the Ap and B horizon brings about the very high ratings for these soils according to Landon (1991). While, Lawal *et al*. (2014) asserted that the high base saturation in the soils studied reflect the dominance of non-acid cations on exchange sites.

Soil Classification

In Onna Soil Unit, pedons 1 and 3 were classified as Typic and Arenic Paleudult (Acrisols), while pedon 2 was Typic Dystrudept (Dystric Acrisol); Ini Soil Unit, had all four pedons classified as Typic Epiaquults (Gleyic Canbisols); Uyo Soil Unit, had pedon 2 classified as Typic Hapludult (Haplic Acrisol), while pedons 1, 3 and 4 were Typic Paleudults (Acrisols), while Ibiono Ibom Soil Unit had pedon 1 as Arenic Hapludult (Haplic Acrisol), pedon 2 Arenic Eutrudept (Eutric Acrisol), while pedons 3 and 4 were Typic Paleudults (Acrisols).

Soil Quality Index of the Selected Study Area

For the Ap horizons, the average SQI values computed using Liebig scoring function as indicated in Table 1, shows that soils from Ini Soil Unit had Grade I which indicated a very high SQI value (0.82), followed by Uyo Soil Unit (0.63) and Ibiono Ibom Soil Unit (0.61) which signified that these soils are most suitable for crop growth, while a high grade SQI was recorded for Onna Soil Unit (0.53), this however showed that soils in the study site are suitable for crop growth using Liebig scoring function. While in the B-horizon, the SQI values followed the same trend as observed in the Ap horizon, thus indicated that soils of Ini Soil Unit had a very high grade SQI value (0.88), followed by Uyo Soil Unit (0.68) and Ibiono Ibom Soil Unit (0.67) which shows that the soils are most suitable for crop growth; while a high grade SQI was recorded at Onna Soil Unit (0.55) which portrayed that soils in the study area are suitable for crop growth as represented in Table 3, when Liebig scoring function was employed. With the use of Glover scoring function, soils in the entire study site had very low SQI values as recorded for both Ap and B-horizons indicating that they have most severe limitations (Li *et al*., 2018).

Land Suitability Evaluation for Oil Palm (E*laeis guinensis*) Cultivation

Characteristics in comparison with values in Table 3 as modified from Sys (1993), gave rise to the actual suitability classes and scores in Table 4. Also, aggregate suitability scores for each of the Soil Units were calculated and presented in Table 4.

Climate

Temperature and rainfall were optimum for the cultivation of oil palm, with rating of S1 which is highly suitable. This result indicated that climate was not a limiting factor for oil palm cultivation.

Topography

In all the Soil Units studied, topography was highly suitable (S1) for oil palm cultivation.

Wetness

Wetness land quality was represented by drainage and flooding. Soils in Onna, Uyo and Ibiono Ibom Units were well-drained and rated highly suitable (S1) with no limitations, while Ini Soil Unit was poorly-drained, and rated marginally suitable (S3) with flooding as slight limitation which is no longer than 1 to 2 months. However, soils in the study area had no limitations in flooding and drainage level for the cultivation of oil palm.

Potential Soil Fertility

All the Soil Units were optimum in CEC and were rated highly suitable (S1) in Ini and Ibiono Ibom Soil Units, Uyo Soil Unit was rated moderately suitable (S2) and marginally suitable (S3) in Onna Soil Unit. Exchangeable K for all the Soil Units studied was not optimum and was rated currently not suitable (N1) for the cultivation of oil palm. This is a serious limitation for the cultivation of oil palm. This could be attributed to the loss of K in soils which in turn may cause severe loss in oil palm yield (Ogunkunle, 1993).

Current Soil Fertility

Currently in all the Soil Units, base saturation was optimum with a rating of S1 (highly suitable). Cation Exchange Capacity was rated currently not suitable (N1) (15.18) for Onna and Uyo Soil Units, while Ini and Ibiono ibom Soil Units were marginally suitable (S3) (27.89) and (S3) (33.19). For most of the soils in the study area, organic matter was adequate for the cultivation of oil palm with a suitability score of S1 for all the Soil Units studied. Organic matter did not constitute a limitation for the cultivation of oil. These soils can be improved by applying appropriate fertilizer technology to improve the soil fertility deficiency. Olaleye (1998) and Ahukaemere (2018) reported that poorly textured soils, properly supplied with fertilizer (nutrient) produced superior crop yield. While Babalola *et al*. (2011) and Ahukaemere (2018) submitted that the negative influence of texture could be overcome by proper fertilizer application provided soil moisture is adequate. The low level of CEC in Onna and Uyo Soil Units can be improved through the application of biochar, compost, combination of biochar with compost, organic matter such as permanent pasture, regular slashing, green manure crops, leaving crop stubbles to rot, rotating crops or pasture, addition of mulch and manure as well as liming acid soils (Daghighi, 2022; Šimanský *et al*., 2022). From the results, though soil texture was not a severe limitation that could limit oil palm production in the sites investigated. Conversely, since soil texture is considered to be an inherent property and changing it is not a feasible option for soil management, while other management practices such as conservational tillage and manure application that enhance the physical and fertility conditions of the soils should be adopted to raise the soil texture from marginally suitable (S3) to moderately suitable (S2) status.

CONCLUSION

In the light of the above, results obtained using the parametric square-root method of Khiddir (1986) indicated that Onna and Uyo Soil Units were currently not suitable (N1) whilst Ini and Ibiono Ibom were marginally suitable (S3) with fertility (Cation Exchange Capacity) and climate, soil physical properties and wetness as major constraints respectively for oil palm cultivation. Consequently, soil texture being considered to be an inherent property and changing it is an unfeasible option for soil management, other management practices such as conservational tillage and manure (compost) and biochar application that enhance the physical and fertility conditions of the soils should be adopted to raise the soil texture from marginally suitable (S3) to moderately suitable (S2) status. While, low CEC can be improved by the application of biochar, compost, organic matter such as permanent pasture, regular slashing, green manure crops, leaving crop stubbles to rot, rotating crops or pasture, addition of mulch and manure as well as liming acid soils. In the light of the fore-going, for the attainment of food security, agricultural and environmental sustainability, it is highly recommended that periodic soil tests and soil quality assessments should be employed to identify the conditions of our soil resources to facilitate efficient management.

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