Land Suitability Evaluation of Soils of Bayelsa State for Oil Palm Production

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ABSTRACT

Selected soils of Bayelsa State were evaluated for oil palm production using FAO land suitability classification. Eight pedons were sunk on each the three geomorphic features found in Bayelsa State. A total of twenty-four pedon were investigated and soil samples were taken to the laboratory for routine analysis. The average of the results from each geomorphic unit was calculated. Results of the physicochemical properties of soil showed that soils of Mangrove Swamp Deposits (MSD) and Sombreiro Warri Deposit (SWD) were characterized by sandy texture while the texture of soils of Recent and Sub-recent Alluvial Deposits (RSA) were loamy sand. Soil pH ranged from strongly (3.9) to moderately (6.2) acidic. Organic matter reduces down the profile. Effective cation exchangeable capacity (E.C.E.C.) ranged from 3.34-7.28cmol/kg while base Saturation ranged from 33 – 48.6%. From the land suitability results, rainfall and temperature were highly suitable while relative humidity was moderately suitable for oil palm production. The texture was marginally suitable in RSA while it was not suitable in MSD and SWD. For soil fertility characteristics, the major limitation affecting oil palm production was the C.E.C. which placed these soils in suitability class N1 (Not Suitable). Organic matter was another serious constrain to oil palm cultivation in RSA.

Keywords: Oil Palm, Land evaluation, Soil fertility, Land suitability.

INTRODUCTION

There is need to make adequate strategic plans in order to sustain food production for the growing population in Bayelsa State (Okorocha *et al*, 2023). The major problem of agricultural development in this area is poor knowledge of the suitability of the soils to support arable crop production. Land evaluation match the land use to the land qualities and this is a sure way to minimize the risk of farming (Udoh *et al*., 2011). The Food and Agricultural Organization (FAO) framework for land evaluation (FAO, 1976) is capable of identifying the most limiting land qualities which will provide a good ground for educating the farmers on the best management practices that will give the optimum food production in their region.

Oil palm is a major crop in international trade that is capable of boosting the economy of a State. It is a major crop that had contributed extensively to the external earning of the country in the past (Ajiboye et al., 2015). Oil palm can live for so many years and every part of it is useful to man (Okolo et al., 2019). However, there is less information on land quality of the soils of Bayelsa State which will expose the agronomic capability of the study area. Bayelsa State has been over dependent on crude oil activities commonly known as black gold to the utter neglect of agriculture over the years. This is because most studies on soils of Bayelsa state have been concentrated on oil and gas deposits; as a result, information on soils for land evaluation purposes for crop production is scanty in Bayelsa State. With the increase in depletion of soil nutrients in most soils of upland and the need to study other soil types for agricultural productivity, there is need to effectively harness the underutilized wetland soils of Bayelsa for effective agricultural activities.

The aim of this study is to evaluate the suitability and limitation of soils of Bayelsa State for the optimum and sustainable production of oil palm with the view of establishment of intensive production of this crop in this region.

MATERIALS AND METHODS

Description of the Study Sites

The study was conducted in Bayelsa State in the Niger Delta, Nigeria (Figure 1). The state lies within Latitudes 4° 30'to 4° 39`00'' North and longitude 6° 11'to 6° 16`00" East. Soils of the study sites are derived from geologic materials of Fluvial and alluvial materials which are recent and sub- recent deposits of alluvium incorporated with humus (Ayolagha, 2001). The climate is tropical and Köppen-Geiger climate classification is Af. The average annual temperature is 26.0 °C | 78.9 °F (in) while the precipitation is about 2909 mm | 114.5 inch annually and it is within the equatorial rainforest region.

Field Study

The geology map aided the selection of sampling sites using target sampling techniques. Eight profiles were established on each of the three parent materials namely Sombreiro/Warri Deltaic Deposits (SWD), Mangrove Swamp Deposits (MSD), and Recent and Sub Recent Alluvium (RSA). A total of 24 profile pits was dug, delineated and described according to FAO (2006) guideline. The samples collected were taken to the laboratory for standard routine analysis.

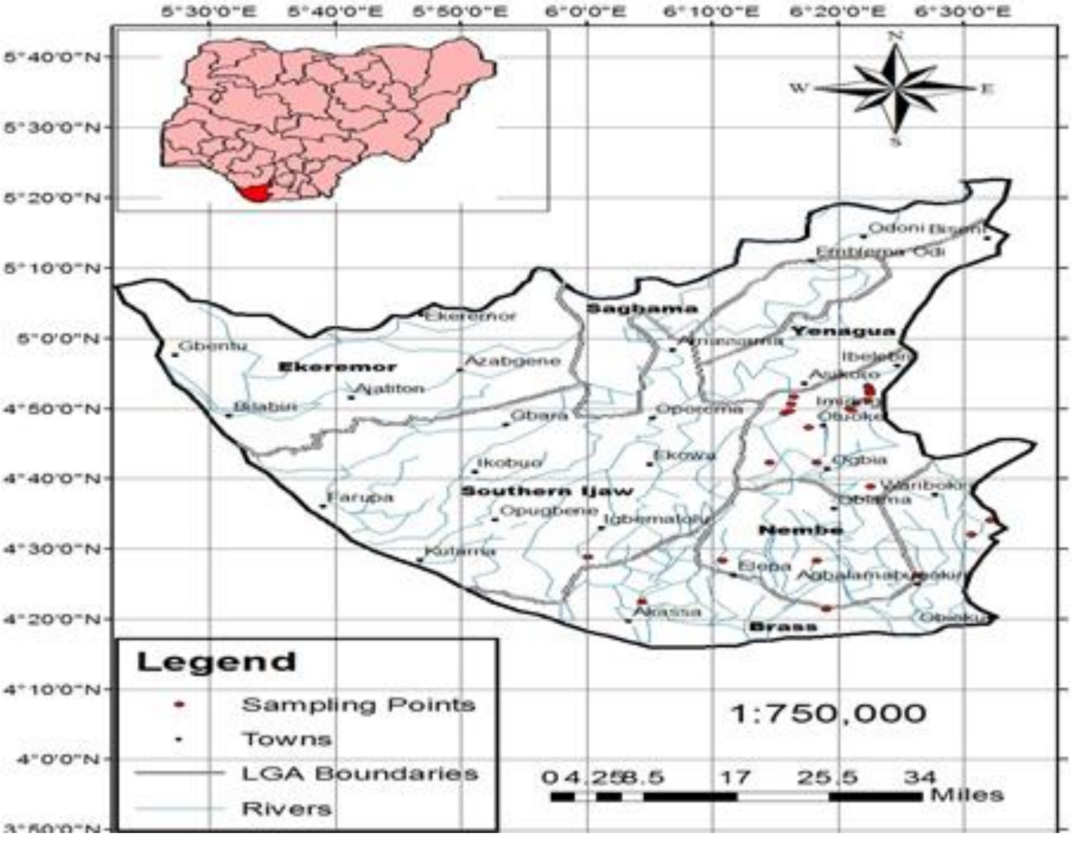

Figure 1: Location map of Bayelsa state

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Soil Analysis

Soil samples collected from the field were air dried, pulverized and sieve with 2 mm sieve. Some physical and chemical properties were analysed from the processed soil following procedures outlined by Van Reeuwijk (2002). Hydrometer method was used for particle size analysis. pH meter was used to determine the pH of 1:2.5 water suspension of the soil sample. Nelson and Sommer method was used to determine the organic carbon content. Bray No. 11 was used to determine available Phosphorus. Total Nitrogen was determined by micro-Kjeldahl digestion method. Neutral ammonium acetate (NH4OAc of pH 7) was used to extract exchangeable bases. Titration with ethylene diamine tetra-acetic acid (EDTA) was used to determine calcium and magnesium while flame photometer was used to determine sodium and potassium.

Land Evaluation and Data Analysis

Means of the data generated from the laboratory results were used to evaluate the soils base on Storie method (Storie 1978). The conventional land evaluation techniques as described by FAO (1976) and modified by Sys, (1985; 1991) were used (Table 1). The environmental factors considered in the evaluation include, climate (annual rainfall relative humidity and temperature), topography (slope and erosion hazard) and soils. The bases for soil evaluation include soil texture, soil depth, coarse material, drainage. Soil fertility factors considered include total nitrogen, organic matter, cation exchange capacity, base saturation, pH (H_2O) and organic carbon (Table 1). The most limiting factor determines the overall suitability for each soil. The soil units classified as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and currently not suitable (N1) base on the limiting factors.

Table 1: Land requirements for the production of Oil palm (*Elaeis guinensis*)

Land requirements/Land characteristics		Land Suitability Class		
	S1	S2	S3	N1
Climate (c):				
Annual rainfall (mm)	1700 – 2500	1450 – 1700	1300 – 1450	1300-1250
Relative humidity (%)	>75	65-75	62-65	60-62
Temperature (^{O}C)	>22	20-22	18-20	<16
Topography (t):				
Slope (%)	<8	8 – 16	16 – 30	>30
Erosion hazard(eh)	Very low	Low –moderate	Severe	Very Severe
Wetness (w):				
Drainage	Well drained	Moderately drained	poorly drained	Poorly drained
Soil Physical Characteristics (s):				
Texture (surface)	CL,L	SCL	LS, SL	Any
Soil depth (cm)	>125	75 – 100	50-75	< 50
Coarse material (%)	<15	15 – 35	35 – 55	>55
Fertility (f):				
Total Nitrogen (g/kg)	>1.5	1.0-1.5	0.5-1.0	< 0.5
Organic matter(g/kg)	>8.0	5.0-8.0	3.0 – 5.0	< 3
Cation exchange capacity (cmol/kg)	>16	12–16	8 – 12	5 – 8
Base saturation (%)	>20	15- 19	10 – 14	<10
pH H_20	6.0-7.0	5.0 – 7	4.0-5.0	< 4
Organic carbon (%), 0-15cm	> 0.8	0.5 – 0.8	0.3 – 0.5	< 0.3

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Source: FAO (1976) modified by Sys, (1985). CL = Clay loam, SL = Sandy loam, LS = Loamy sand, SCL = Sandy clay loam.

RESULTS AND DISCUSSION

Physicochemical properties of the soils studied

The mean result of the physicochemical Properties was shown in Table 2. Sand varied from 880 – 940 g/kg, 930 -970 g/kg and 820 -890 g/kg in soils underlain by Mangrove Swamp Deposits (MSD), Sombreiro Warri Deposit (SWD) and Recent and Subrecent Alluvial Deposits (RSA) respectively, implying that sand particle was greater in MSD than others. According to the rating of Wielding *et al*. (1994) which stated coefficient of variability (CV) of ?15%, >15?35% and >35% as low, moderate and high respectively, sand content of all the soils were homogenously distributed since they had CV ?15%. Sand was also shown to increase slightly with depth in MSD and RSA while it was a decrease with depth in SWD.

Table 2: Physicochemical Properties of the Soils Studied

Depth (cm)	Sand (g/kg)	Clay (g/kg)	Texture	pH (H_20)	OC (g/kg)	OM (g/kg)	TN (g/kg)	TEB (cmol/kg)	ECEC (cmol/kg)	Bsat (%)
				MANGROVE SWAMP DEPOSITS (MSD)						
0-8	890	30	sand	3.9	51	87.9	3.55	3.46	6.02	48.6
28-Aug	880	50	sand	4	50	86.2	3.62	3.4	6.22	48
28-56	980	50	sand	5.5	28	48.2	3.58	3.73	5.69	41.4
56-90	930	20	sand	6	8	13.7	2.21	3.42	5.54	37.6
90-130	940	10	sand	6.2	2	3.4	0.7	3.7	5.55	43.2
CV	4.4	55.9		21.5	82.2	82.3	46.9	4.5	5.2	32.5
				SOMBREIRO WARRI DEPOSIT (SWD)						
0-20	970	10	sand	4.6	14.8	25.51	1.59	2.68	6.04	33
20-43	940	40	sand	4.5	12.6	21.72	1.22	2.96	7.05	36
43-80	930	40	sand	4.8	13.8	22.06	1.26	3.22	7.28	40
80-110	930	50	sand	4.7	11.3	19.48	1.11	2.74	6.34	40
110-220	960	10	sand	4.2	5.1	8.79	0.45	2.62	6.94	40
CV	1.9	62.4		5	33.2	32.7	37.1	8.7	7.7	8.4
		RECENT AND SUBRECENT ALLUVIAL DEPOSITS (RSA)								
0-25	860	40	LS	6	10.2	17.5	0.9	2.16	4.16	42.2
25-80	820	40	LS	5.8	10.8	18.6	0.8	2.37	4.17	40.6
80-110	870	30	LS	5.9	0.6	1	0.1	1.43	2.23	34
110-130	890	30	sand	5.5	0.7	1	0.1	1.61	2.81	35.3
CV	3.4	16.5		3.7	102.1	103.5	91.6	23.5	29.3	10.5

OC-organic carbon, OM-organic matter, TN- total nitrogen, TEB- total exchangeable bases, ECEC-effective exchangeable bases, Bsat- base saturation, LS- loamy sand, CV- coefficient of variation

On the other hand, clay fractions varied from 10- 50 g/kg, 10- 50 g/kg and 30-40g/kg in MSD, SWD and RSA respectively with coefficient variation down the profile being high in MSD and SWD, moderate in RSA. Distribution pattern of clay with depth was irregular in MSD and SWD while it decreased down the profile in RSA. This is in agreement with the observations made by Idoga, (2002) and Ugwu *et al*, (2001) where they asserted that clay content generally increases with depth due to some pedogenic processes such as lessivage, eluviations, and illuviation as well as the contribution of the underlying geology through weathering. Also, soils of MSD and SWD were sand textured while RSA was dominated by loamy sand texture. According to Abagyeh *et al*., (2016), sandy loam texture is sub-optimum for most crop cultivation. All the soils were generally acidic (pH< 7). The coefficient of variation (CV) was low in RSA (3.7%) and SWD (5.0%) and moderate variation (21.5%) in MSD. Variation of pH in the soils was irregular with depth with a range of 3.9-6.2, 4.2-4.8 and 5.5-6.0 in Mangrove Swamp Deposits (MSD), Sombreiro – Warri Deltaic Deposits (SWD) and Recent and Subrecent Alluvial Deposits (RSA) respectively, indicating that soils of SWD were more acidic than others. According to James (2010), this range of pH recorded indicated a moderate acid reaction. According to FAO (1998), moderately acidic soils may be deficient in phosphorus, calcium, magnesium and molybdenum. Effectively, pH plays an important role in the biological activity of the soil and the availability of mineral nitrogen to plants, thus reflecting a synthetic indicator of the chemical fertility of the soil (Isitekhale, 2014; Diallo *et al*., 2015). The pH of the soil can influence the efficiency of plant growth in the soil as well as the bioavailability of crop nutrients, the activity of microorganisms, and is related to toxiurban risk (Diallo *et al*., 2015).

Organic carbon (OC) and organic matter (OM) contents of the soils were shown to decrease with depth in all soil pedons and with degree of variation being high (CV>35%) in MSD and SWD, and moderate (CV>15?35%) in RSA. OC ranged from 2- 51 g/kg, 5.1-14.8 g/kg, and 0.6 – 10.8 g/kg while OM ranged from 3.4 – 87.9 g/kg, 8.79 – 25.51 g/kg and 1.0 – 18.6 g/kg in MSD, SWD and RSA respectively. According to the ratings of FAO (2004), values recorded for OC and OM is very high in MSD and SWD and low in and RSA. The low organic carbon content of RSA may be due to continuous cropping, bush burning, high erosive rate, grazing and poor management of the soils as attributed by Ogbu *et al*. (2019). Total nitrogen followed similar pattern with OC and OM with highest value of 3.55 g/kg recorded at the top soil of MSD followed by SWD (1.59g/kg) and least value was found in RSA (0.9g/kg). It was also shown that total nitrogen (TN) was widely distributed (CV>35%) down the profile in all the soils (Table 2). Following the rating by Landon (1991), soils of RSA and SWD were low in TN content while MSD was moderate. This implication of this results is that crops grown in the soils are likely to require N-application. TEB was higher in epipedon and showed low variation down the profile in soils of MSD and SWD. Its distribution ranged from 3.4-3.73 cmol/kg, 2.62-3.22 cmol/kg and 1.43-2.37 cmol/kg in MSD, SWD and RSA respectively. The low exchangeable bases of these soils may be due to the underlying materials, intensity of weathering, leaching, low activity clay, very low organic matter content and the lateral translocation of bases (Krasilinikoff et al., 2003). Similar to TEB, variation of effective cation exchange capacity (ECEC) of the soils down the profile was low in MSD and SWD while RSA showed moderate variation. Effective cation exchange capacity (ECEC) decreased irregularly with depth. Highest value (7.28 cmol/kg) was recorded in soils of SWD. The relatively low values of effective cation exchange capacity (ECEC) could be attributed to the low activity clay characteristics of 1:1 clay minerals, probably dominated by Kaolinite (Adesemuyi, 2014). Percentage base saturation (BS) ranged from 37.6- 48.6%, 33-40% and 34-42.2% in MSD, SWD and RSA respectively, implying that basic cations were more saturated in soils of MSD than others. BS also showed low variation down the profile in soils of SWD (8.4%) and RSA (10.5%) and moderate variation (CV=32.5%) in soils of MSD. However, the soils were generally low in base saturation (> 50 %) indicating that the exchange sites of the complexes (clay and humus) were less dominated by basic cations (Abagyeh *et al*., 2016).

Land Suitability Evaluation for Oil palm production

Land suitability evaluation is the process of assessing the suitability of land for specific kinds of use (Ufot, 2012, Brady and Weil, 2014). Suitability of the soils for oil palm production in the study area was evaluated (Table 3). Climatic and topographic characteristics of the study area as well as results of selected physicochemical properties of the studied soils (Table 1) were marched against FAO (1976, 1983 and 1985)

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recommendations to obtain the suitability of the soils for oil palm production. According to Table 3, mean annual rainfall, temperature and slope were highly suitable (S1) while relative humidity and erosion hazard were moderately suitable (S2) in all locations. However, flooding and drainage were highly suitable (S1) for oil palm production in all the soils exception being Sub-Recent Alluvial Deposits (RSA) that showed moderate suitability. Under soil physical characteristics, soil texture was presently non-suitable (N1) in soils of MSD and SWD while it was marginally suitable (S2) RSA. In all the soils, soil depth was highly suitable. Based on soil fertility, total N concentration was marginally suitable in MSD and RSA and moderately suitable (S2) for soils of SWD. Organic matter was highly suitable in MSD, moderate suitable in SWD and presently non-suitable in RSA. According to Yimer *et al*. (2007), inappropriate farming practices can seriously degrade soils and can significantly lower concentrations of organic matter and total nitrogen in soil. While cation exchange capacity in all soils was presently non-suitable (N1), base saturation was highly suitable for oil palm production.

Table 3: Land suitability assessment for Oil palm (*Elaeis guinensis*) production in the mangrove swamp deposits

Land requirements/Land characteristics	Land Suitability Class		
	MSD	SWD	RSA
Climate (c):			
Annual rainfall (mm)	S1	S1	S1
Relative humidity (%)	S2	S2	S2
Temperature (^{O}C)	S1	S1	S1
Topography (t):			
Slope (%)	S1	S1	S1
Erosion hazard(eh)	S2	S2	S2
Wetness (w)*:			
Flooding	S1	S1	S2
Drainage	S1	S1	S2
Soil Physical Characteristics (s):			
Texture (surface)	N1	N1	S3
Soil depth (cm)	S1	S1	S1
Coarse material (%)	S2	S2	S2
Fertility (f):			
Total N (g kg-1)	S3	S2	S3
Organic matter(g kg-1)	S1	S2	N1
Cation exchange capacity (cmol-kg-1)	N1	N1	N1
Base saturation (%)	S1	S1	S1
pH (H_20)	S2	S3	S2
Overall suitability	N1 (s, f)	N1 (s, f)	N1 (f)

Soil pH (H_20) was shown to be moderately suitable in soils of both MSD and RSA whereas suitability was marginal in SWD. The overall suitability of the soils was rated presently non-suitable (N1) for oil palm production with limitation in soil physical characteristics and fertility. This confirm results of Oluwatosin (2005) who reported that low fertility, erosion hazard and drainage are factors limiting productivity of savannah soil for crop production. Similarly, Ajiboye and Olaniyan (2016) reported that oil palm production was actually not suitable in all the pedons sampled in Cross River State

CONCLUSIONS

It could be concluded from the findings of this study that soil physicochemical properties varied across the soils studied. Soil properties that support crop production were higher at the epipedon than subsoils. The climate, topography and wetness were suitable however, texture, one of the soil physical characteristics and poor soil fertility made the soils of Bayelsa presently not suitable for oil palm production.

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